STABLE CARBON ISOTOPIC ASSESSMENT OF PREHISTORIC DIETS IN THE SOUTH-WESTERN CAPE, SOUTH AFRICA

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by

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ABSTRACT

This thesis consists of a stable carbon isotopic assessment of the diets of the Holocene human inhabitants of the south-western Cape, South Africa. Samples of the foods these people ate were collected from each of the four major physiographic zones in the area, and their $^{13}C/^{12}C$ ratios measured. A total of more than 200 such analyses enabled the estimation of the average $\delta^{13}C$ values of prehistoric human diets in each zone. This information is used to interpret $\delta^{13}C$ measurements on a series of archaeological human skeletons. The results are consistent with a model of prehistoric subsistence behaviour in which people living at the coast made intensive use of marine food resources throughout the Holocene, consuming such a large proportion of these foods that they must have spent much, if not all of their time at the coast. Inland skeletons reflect an almost entirely terrestrial diet. These results contradict hypotheses about seasonal population movements between the coast and the interior generated from excavated archaeological material. Considerable changes in many of our current views of the Late Stone Age of the south-western Cape will have to be made in order to accommodate these data.

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Animal samples came from the South African Museum, where

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CHAPTER 1

INTRODUCTION

This thesis consists of a stable carbon isotope assessment of Holocene human diets in the south-western Cape, South Africa, and tests various models of prehistoric subsistence derived from archaeological evidence. Such assessments have been attempted in a number of areas in recent years, including woodland North America (van der Merwe & Vogel, 1978), Denmark (Tauber, 1981), Venezuela (van der Merwe, Roosevelt & Vogel, 1981) and the east coast of Canada (Chisholm, Nelson & Schwarcz, 1982). Some preliminary work has also been done in South Africa (Silberbauer, 1976, 1979; Rawlinson, 1982). All these studies have, however, consisted mainly of isotopic analyses of human skeletons, constructing theoretical dietary carbon isotope ratios from first principles. Silberbauer and Rawlinson recognised that this limited the amount of information they could glean from the skeletal analyses, and recommended that future research concentrate on obtaining a more detailed picture of the $\delta^{13}C$ values of the actual plants and animals eaten. This, therefore, is the first explicitly ecological study of a prehistoric human foodweb.

The first step in the isotopic characterisation of this foodweb is the identification of the most important animal and vegetable components of the Holocene human diet in the south-western Cape. Ethnographic sources and the food-waste recovered from archaeological excavations provide much of this information. The list of organisms obtained in fact includes a fairly representative cross-section (in isotopic terms) of the fauna and flora of the area. A selection of the most important items was collected from each of the clearly-differentiated ecological zones of the research area, and the $^{13}C/^{12}C$ ratio measured. This information enables one to estimate the isotopic 'signature' of the average diet that would have been consumed by a person living in any one of these ecological zones. Since this 'signature' is incorporated into people's body tissues, it is preserved in archaeological skeletons. Stable carbon isotope analysis of these skeletons, combined with the information on diet described above, tells us the proportions of foods from each isotopically distinct area that the individual consumed during his lifetime. These proportions obviously reflect the amount of time spent in each zone, thus providing an independent test of hypotheses about seasonal movements of people generated from excavated archaeological material.

Almost all recent archaeological research in the south-western Cape has been conducted within the framework of a seasonal mobility hypothesis proposed by John Parkington (1972, 1976a, 1976b, 1977, 1979, 1980, 1981, 1983, in prep.).

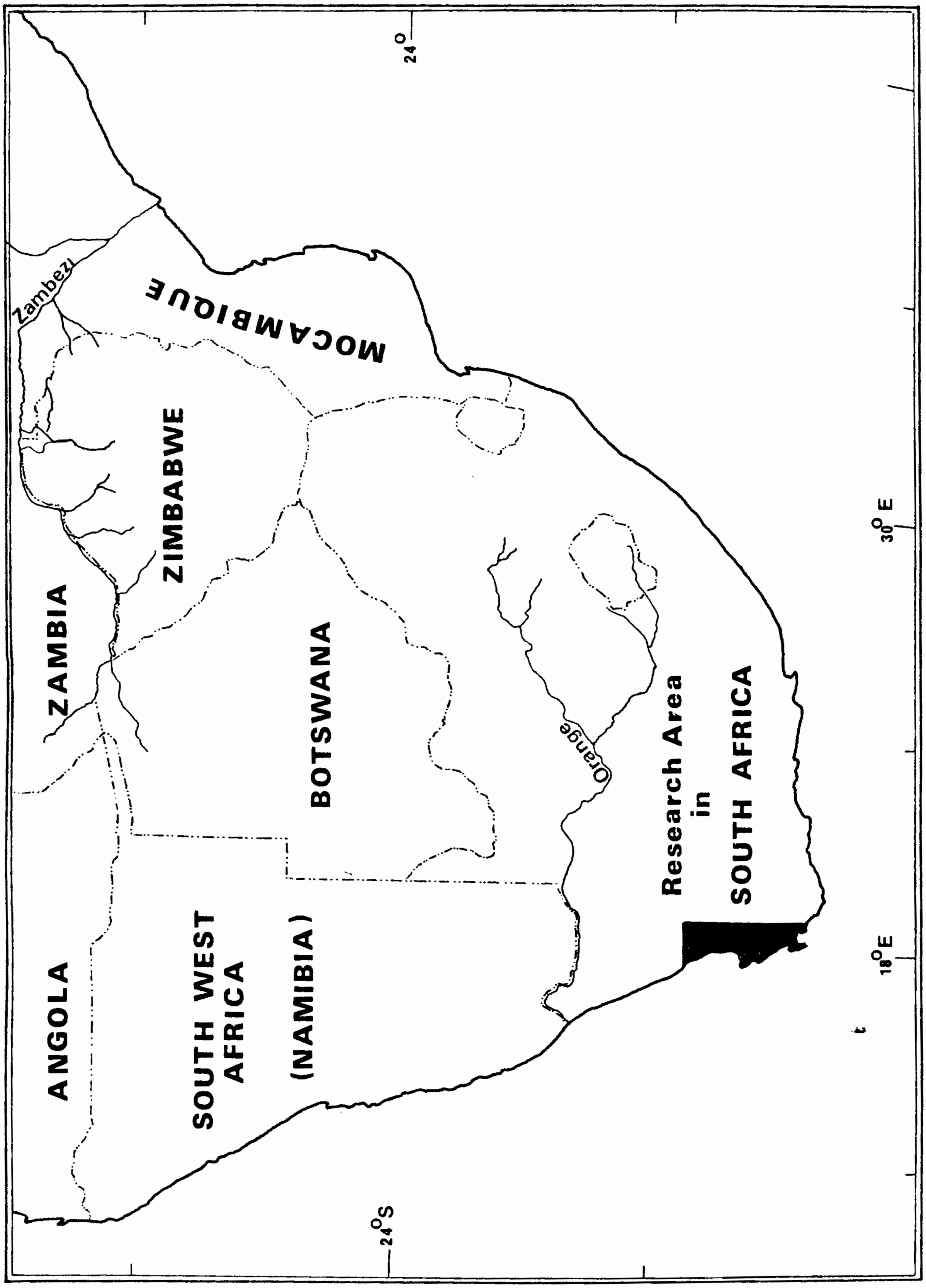
Parkington has postulated seasonal movement of Late Stone Age people between the coast and the interior, in a cycle designed to make maximum use of temporary peaks in seasonally fluctuating food sources, while avoiding troughs. There is some archaeological evidence for this, but it is difficult to prove or disprove conclusively. One of the great strengths of this hypothesis is that it has testable consequences and stable carbon isotope analysis is ideally suited to such testing. If people were engaging in a seasonal round incorporating both the coast and the river valleys of the inland mountains, then archaeological skeletons from these two areas should be the remains of the same population, and have similar isotopic ratios.

Quite apart from the testing of this extremely interesting hypothesis, a better understanding of the $\delta^{13}C$ values of the human foodweb and skeletal remains will provide a great deal of other information. Such measurements are direct reflections of the diets of prehistoric individuals. The biases inherent in more conventional dietary reconstructions, such as differential preservation of various kinds of food-waste, do not enter the picture. Moreover, small-scale dietary differences within one population (e.g. differences between the diets of men and women) can be studied. These are often difficult, if not impossible, to detect at the level of site-based reconstructions.

The $\delta^{13}C$ values of modern plants and animals that will be obtained will also serve as a base-line for palaeoenvironmental reconstructions. $\delta^{13}C$ measurements are climate-dependent, so that once we have a good idea of what the modern carbon isotope 'map' looks like, we will be able to detect deviations from this norm corresponding to palaeoclimatic shifts. It may be, for example, that there was a warmer period in the mid-Holocene caused by a slight poleward shift of the zonal circulation belts (Van Zinderen Bakker, 1978). Predictions of this kind are necessarily very general, and the present state of our palaeoenvironmental knowledge does not usually allow detailed reconstruction of the climates of small areas. These are influenced by regional topographic features, changes in wind velocities or the type and amount of precipitation, and a great deal more research is needed into local weather systems before past climates in most small areas can be accurately described (Parkington, in prep.). Future stable carbon isotope research can contribute to the solving of such problems. Isotopic ratios of the bones of territorial animals from well-dated archaeological sequences will reflect past climatic conditions near the site, while those of more wide-ranging animals will provide an integrated measure of the environment on a larger scale.

This thesis will therefore fulfil some short-term research objectives, and contribute to the solving of a number of longer-term ones. It fits squarely into a major programme of investigation into the Later Stone Age of the south-western Cape.

The rest of the thesis is divided into seven chapters. Chapter 2 is a discussion of the geography, geology, fauna and flora of the south-western Cape, and is meant as a background to the discussions of archaeology and isotope ecology which follow. Chapter 3 consists of a short account of what we know about the Later Stone Age of the area. Chapter 4 is a broad-based account of its edible plants and animals with comments drawn from both ethnographic and archaeological sources. Chapter 5 contains a discussion of stable isotope tracer techniques with specific reference to the south-western Cape. The various classes of plant and animal material to be analysed are mentioned, and the kinds of isotopic variation expected in each case examined. Chapter 6 is an account of the fieldwork and laboratory procedures, and of the results of the analyses. The isotopic signature of each ecological zone is defined, and in Chapter 7 this information is used to interpret $\delta^{13}C$ readings on archaeological human skeletons. Chapter 8 concludes the thesis with a discussion of the implications of the results for future archaeological research in the south-western Cape.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Orange
Research Area
in
SOUTH AFRICA

MAP I

CHAPTER 2

THE SOUTH-WESTERN CAPE

The research area is the south-western part of the Cape Province from the Cape Peninsula in the south to Lambert's Bay in the north, and from the Atlantic coastline in the west to the edge of the Karoo in the east (see Maps I and II). This chapter consists of a description of the area, its geography, climate, fauna and flora, concentrating upon those aspects of the ecology which would have been of importance to its prehistoric human inhabitants.

GEOGRAPHY AND CLIMATE

Several distinct physiographic zones can be distinguished; these tend to run from north to south and are (in order, from the coast) : the Sandveld, the Coastal Foreland, the mountains of the Cape Fold Belt and the Karoo. The differing geology and rainfall of these various regions mean that they support noticeably different vegetations, and hence provided different sets of resources to the prehistoric population.

Along the coast, the rainfall varies from about 600 mm/year at Cape Town to less than 200 mm/year at Eland's Bay.

The Fold Mountain Belt tends to be wetter, with the highest areas receiving more than 3 500 mm/year, but the Karoo, which lies in the rain-shadow of these mountains, is much drier (Weather Bureau, 1965). The whole of the research area is in the winter rainfall region of the south-western Cape, so that most of its rain falls between May and October, although there can be occasional short showers in other months. Snow may be found on the mountain tops in winter, but it is infrequent. Frosts are commoner, occurring on an average of about 40 days each winter in the mountains. Nearer the coast they are very rare, and seasonal variations in temperature are less pronounced (Weather Bureau, 1954).

GEOLOGY AND VEGETATION

The geology of the area is varied. The Fold Mountain Belt itself consists mainly of hard quartzitic rocks belonging to the Table Mountain Group. These weather slowly, and the soils as they are produced tend to erode away because of the steepness of the terrain. As a result, the mountain soils are shallow, stony, acid and rather poor in nutrients (Lambrechts, 1979). The vegetation they support is mountain fynbos, Acocks' vegetation type No. 69 (Acocks, 1953), one of the two major fynbos types. Fynbos is one of the six floral kingdoms of the world. It is characterised by a very high species diversity (more than 6 000 plant species have been recorded from the fynbos biome), and a lack of single-species dominance. Many plants have very restricted ranges, sometimes only a few hectares. Fynbos always contains ericoid shrubs : low, evergreen shrubs with hard, narrow rolled leaves, including heaths, Erica spp. Restioid herbs, too, are always present : reed-like, tufted evergreen plants with nearly leafless tubular stems; the family Restionaceae is particularly prominent and widespread. A third component, proteoid shrubs, is present in some habitats. These are medium to tall shrubs with fairly large leathery, often hairy leaves (Taylor, 1972). Fynbos is adapted to periodic fires, after which plants with underground bulbs, corms and rhizomes (chiefly members of the Iridaceae and Liliaceae) produce spectacular displays of flowers (Kruger, 1979a). The proteoid element does occur in mountain fynbos, where members of the Proteaceae and other families are some of the largest plants to be seen. Trees are rare in this vegetation type, although they do occur in valleys and ravines where the soil is often deeper. True mountain fynbos is poor in grasses for grazing animals, and in the geophytes whose corms were sought after by prehistoric people (Taylor, 1972), and so was probably not one of their preferred habitats.

Coastal fynbos (Acocks' vegetation type No. 47) occurs on fine-grained marine sands along the coast. The proteoid element is less important here than it is in mountain fynbos, but there are more grasses, many of them palatable and nutritious to grazing animals (Taylor, 1978). The other vegetation type which occurs on these sands on the coastal plain is strandveld (Acocks' vegetation type No. 34). This is a broad-leaved sclerophyllous woody shrubland characteristic of coastal sand-dunes, but it may be mixed with coastal fynbos. It includes a number of succulent or semi-succulent plants, and annuals and grasses are prominent in the spring (Acocks, 1953).

A large part of the coastal foreland has, by contrast, quite different geology and vegetation. The districts of Malmesbury, Morreesburg and Piketberg that are today important wheat-farming areas, have soils derived from shales, rather than quartzites and sandstones. These include a greater proportion of fine sand and silt than other western Cape soils, and are less acid and richer in nutrients, especially potassium (Lambrechts, 1979). Today, the rare uncultivated patches of these fertile soils are covered with coastal renosterveld (Acocks' veld type No. 46). *Elytropappus rhinocerotis* (renosterbos) is the dominant species, and although there are other narrow-sclerophyllous shrubs, ericoids and proteoids are rare. The species diversity is far lower than in fynbos communities, and annual herbs and grasses are much more common (Acocks, 1953).

The Coastal Plain : View from the Fold Belt Mountains towards the Atlantic Ocean just south of Clanwilliam

Typical scenery in the Fold Belt Mountains

The Karoo : View from the Fold Belt Mountains into the interior, showing flat-topped shale hills

On the eastern side of the Fold Belt, both geology and vegetation change abruptly as the quartzites and sandstones of which the mountains are composed, give way to the Ecca and Dwyka shales of the Karoo system. The vegetation type is Acocks' succulent karoo (type No. 31). This is the kind of karoo found in hot arid areas with winter or year-round rainfall of between 50 and 200 mm/year. It contains numerous succulent species as well as a great many geophytes and annuals (Acocks, 1953). In spring there is plenty of grass, and edible geophytes can be collected, but for the rest of the year animals have to browse on the small bushes or succulents.

THE LATE PREHISTORIC FLORA AND FAUNA

Those boundaries between and characteristics of vegetation types that are determined by geological substrate are unlikely to have changed in the last few tens of thousands of years. The ecology of the south-western Cape has, however, been considerably disturbed by recent human activity, particularly agriculture since *ca*. 1750 A.D., and stock-keeping since *ca*. 2000 B.P. The modern vegetation is widely considered to differ in a number of respects from that of two thousand years ago. Increased fire frequency and grazing pressure have probably reduced the amount of grass, and scrubby shrublands undergone a corresponding expansion (Levyns, 1927; Hendey, 1983). This is likely to be particularly true of the renosterveld, where the plants most common today (e.g. renosterbos) are known to be weedy, pioneer species that thrive in disturbed or recently-burned ground. The 'climax' vegetation of the shale-derived soils of the coastal foreland was probably rather grassier than modern renosterveld (Hendey, 1983; Moll, pers.comm.).

In other areas, recent changes in the vegetation are even more dramatic. Within living memory, the carrying capacity of parts of the Karoo that fall within the research area has decreased tremendously due to overgrazing and poor land management. Farms that, at the beginning of this century, provided good spring grazing, are today almost denuded of vegetation (Nieuwoudt, pers.comm.).

Factors such as these have had a profound effect on the indigenous fauna of the region. Although a number of small animals are still plentiful all over the research area, herds of large ungulates are extinct except in a few small game reserves. It is, however, possible to reconstruct the likely late prehistoric faunal communities from a knowledge of the vegetation, the records of early travellers and the remains found in archaeological excavations.

Common small animals include dassies or rock hyraxes (<u>Procavia capensis</u>), small buck such as steenbok (<u>Raphicerus</u>

campestris) and grysbok (Raphicerus melanotis) and grey duiker (Sylvicapra grimmia). The Cape hare (Lepus capensis) and dune mole rat (Bathyergus suillus) are widespread, as is the angulate tortoise (Chersina angulata). All these animals are found in all the vegetation types described above. They are common in the food waste excavated from archaeological sites, and are, indeed, still important in the diets of rural people today.

Larger grazing animals are likely to have been restricted to the grassier areas of the coastal plain or the Karoo. The coastal foreland with its rich pastures is known to have supported numbers of large animals : early travellers recorded elephant (Loxodonta africana), black rhinoceros (Diceros bicornis), hippopotamus (Hippopotamus amphibius), zebra (Equus burchelli), quagga (Equus quagga), eland (Taurotragus oryx) and hartebeest (Alcelaphus buselaphus) (Skead, 1980). These species were probably more common in the renosterveld (or its prehistoric equivalent) than in the less fertile coastal fynbos and strandveld, although this is, as yet, unproven.

The highest parts of the Fold Belt Mountains probably never supported many animals, for the reasons already mentioned, but the foothills and river valleys were rich hunting-grounds for indigenous people and early settlers alike. Seventeenth- and eighteenth-century records of animals encountered in the Olifants River Valley mention herds of elephant with several hundred animals (Thom, 1958).

The Karoo is likely to have supported herds of larger animals, possibly migratory herds which moved into the winter rainfall area in spring to take advantage of the new grass. There are historical records of this behaviour pattern in springbok (*Antidorcas marsupialis*) (Thunberg II, 1795). Early farmers in the area followed a similar schedule, moving between the mountains and the Karoo to make the most of temporary pastures (Borcherds, 1861).

The various vegetation types thus probably supported substantially different faunal communities. Variations in both the plant and animal food potential of the different physiographic zones of the south-western Cape mean that prehistoric people were exploiting a strongly-patterned environment offering a fluctuating food supply.

THE ATLANTIC COASTLINE

The last major ecological zone is the Atlantic shoreline, a coast well-known for its high plant and animal biomass. Here the combination of south-easterly winds, the Benguela current and the direction in which the earth spins deflect surface waters away from the coast so that deep, cold water has to rise up to replace it (Branch & Branch, 1981).

This water is rich in nutrients which support large populations of plankton. Plankton contributes, together with algae, to the lowest trophic level in a food-web which includes filter-feeding shellfish (such as mussels) and fish like anchovies and sardines, the prey of larger carnivorous fish. Mussels, limpets, fish, fish-eating birds, seals and crayfish provided a rich storehouse of food for prehistoric people. Shellfish are a predictable resource that prehistoric coast-dwellers may have used as a staple food, supplemented occasionally by the larger animals mentioned (H.J. Deacon, 1972, 1976, 1983; Parkington, 1972, 1976a, 1976b, 1980; Robertshaw, 1979a).

The relative importance of all the different food resources mentioned will be discussed in detail in Chapter 4. This information will then be integrated into a discussion of what is known about prehistoric diets in the south-western Cape as revealed by archaeological excavations.

CHAPTER 3

ARCHAEOLOGICAL RESEARCH INTO THE LATER STONE AGE OF THE SOUTH-WESTERN CAPE

Human occupation of the south-western Cape dates back at least as far as the Early Stone Age : there are a number of Acheulean and Middle Stone Age sites scattered throughout the region but they have received relatively little archaeological attention (Inskeep, 1978). The vast bulk of archaeological research has been directed towards the Later Stone Age, the last ten to twelve thousand years of prehistory. This work has recently been extensively reviewed by J. Deacon (1982), Parkington (in prep.) and Thackeray (1981). This short summary draws considerably on their syntheses.

The beginning of the Later Stone Age more or less correlates with the establishment of the present climatic regime as higher temperatures and the melting of the large Pleistocene ice sheets resulted in a rise in sea levels and an increase of 5 - 10 °C in global temperatures compared with the last glacial maximum (Butzer, 1973; H.J. Deacon, 1979; J. Deacon, 1982; Vogel, 1983). These events considerably changed the environment and way of life of prehistoric people at the Cape. During the cold Ice Age some thirty kilometres of presently submerged coastal shelf was above sea level, and was probably covered with a grassy vegetation supporting large migratory herds of grazing animals. These included a number of species and even genera that are now extinct, including a giant Cape horse (*Equus capensis*), a giant buffalo (*Pelorovis antiquus*) and a hartebeest (*Megalotragus priscus*), and some smaller animals such as a species of springbok (*Antidorcas australis*) (Klein, 1972, 1974, 1978, 1980). These animals were hunted and/or scavenged by bands of hunter-gatherers. One can deduce from ethnographic evidence that the best way for humans to hunt large herds of animals is to be organised in fairly big, mobile groups each operating in an extensive territory. This strategy enables the group to follow herds around, and makes the best use of large quantities of meat when they are obtained. Sites dating to this period are not nearly as numerous as Holocene sites, perhaps because the population density was lower and/or because more use was made of open areas where preservation is poor, rather than caves (H.J. Deacon, 1976).

As the climate became warmer, the sea level rose to more or less its present level, submerging the continental shelf. The rainfall probably increased. Palaeoecological information from a number of sites in the southern and western Cape seems to show that the vegetation became more bushy (H.J. Deacon, 1972, 1979; Avery, 1982; J. Deacon, 1982; Klein, 1983; Parkington, in prep.). There was a relatively sudden technological change reflected in archaeological sequences all over southern Africa. Within about a thousand years, at 12 000 - 11 000 B.P., new kinds of stone tool assemblages appeared. These had few formal tools, what there was being mostly medium to large scrapers (mean length > 20 mm). Irregular cores with more than one striking platform and large quadrilateral flakes were common, as were beautifully-fashioned bone tools and beads. The microlithic flaking techniques and tiny retouched pieces so characteristic of the later Holocene were very rare (J. Deacon, 1982). Food remains at coastal sites include marine fish, birds, shellfish and some terrestrial animals. Both coastal and inland sites contain the bones of some of the Pleistocene large grazers, but more use was starting to be made of the small bovids that were such an important food source later on. The fauna is therefore transitional between that of Pleistocene and the Holocene levels (H.J. Deacon, 1972, 1976; Klein, 1974, 1980). There do not seem to be a great many plant food remains. Interestingly, while this new lifestyle must represent an adaptation to changing climate, it post-dates by some 3 000 years the major climatic shift and vegetation changes, at least in the southern Cape (J. Deacon, 1982).

Gradually yet another kind of stone tool assemblage spread over southern Africa. The earliest dates for Holocene microlithic assemblages are around 10 000 B.P. in Zimbabwe, Namibia and the northern Cape. By 7 000 B.P. they appear in the extreme south of the Cape Province (J. Deacon, 1982). In some areas (such as the south-western Cape) microliths were still being made when the first European settlers arrived in the seventeenth century A.D. These small tools included scrapers (mean length in the mid-Holocene < 20 mm), adzes, segments, backed points and bladelets, borers and grooved and bored stones. Many of the formal tools and some unretouched flakes were hafted; a few mounted artefacts and a great many bearing traces of mastic have been found. There were also bone tools, tortoiseshell bowls, ostrich egg-shell beads and water containers, digging sticks, wooden pegs, bows and arrows and leather bags, sandals and clothes (J. Deacon, 1982).

We can see from skeletal remains that the people who made these tools were the ancestors of the modern Bushmen. Late Stone Age burials are not uncommon, both in caves and in the open, and frequently have associated beads, ornaments, tools, ochre and sometimes painted stones.

Food remains include animal bones : after 8 000 B.P. only those species that we recognise from historic times are found. Small, browsing antelope such as steenbok, duiker and rhebok, dassies and tortoises were the most frequently-eaten animals. Most sites contain plant food residues, particularly the tough, fibrous corm casings that surround the edible corms of a number of species of Iridaceae. Seeds, too, are common. People along the coast ate fish, shellfish, marine birds, seals and stranded whales (see Tables I - IV). We know from the records of early European travellers in South Africa that honey, caterpillars, locusts, termites, birds' eggs, lizards and snakes were also important (Sparrman, 1785; Thunberg, 1795; Barrow, 1801-4; Waterhouse, 1932), although many of these items leave no archaeologically identifiable residues.

There are a few features particular to sites of this time period in the south-western Cape which require mention. Eland's Bay Cave (excavated by John Parkington) and the nearby Tortoise Cave (excavated by Tim Robey) were unoccupied from 8 000 to 4 000 B.P. (Parkington, 1976a, 1981, in prep.; Robey, pers.comm.). This has been tentatively interpreted as the consequence of a temporary increase in aridity, making an already marginal area uninhabitable (as proposed for the interior of the subcontinent by J. Deacon (1974)), (Parkington, 1980, in prep.). Alternatively, it might be the result of a small rise in sea level. A 'mid-Holocene transgression' has been well documented by Flemming (1977) and if the shellfish-rich rocks near these sites had been permanently submerged, there might have been little reason for people to go to Eland's Bay (Parkington, in prep.). From about 4 000 to 2 000 B.P. these sites had a classic mid-Holocene backed blade and segment industry (Parkington, 1976a; Robey, pers.comm.). A great many of the large shell middens along this stretch of coast probably accumulated at this time, and the small, sandy deflation hollows in the sandveld were also occupied. These rather enigmatic sites are difficult to deal with, since they usually contain only surface stone tools with little or no stratified deposit or dateable organic material. Moreover, shifting sands continuously cover and re-expose sites, and may mix together artefacts that would be clearly separated in undisturbed sites with good stratigraphy. Nevertheless, Manhire (pers.comm.) feels that most of these were occupied between 4 000 - 2 000 B.P. and not earlier or later.

THE SEASONAL MOBILITY HYPOTHESIS

The framework for most of the recent archaeological research in the western Cape has been John Parkington's seasonal mobility hypothesis (Parkington, 1972, 1976a, 1980, 1981, 1983, in prep.). Models of this kind have been applied to prehistoric hunter-gatherer groups in various parts of the world for some time (see, for example, Higgs *et al.*, 1977). They generally involve the postulation of a pattern of seasonal transhumance designed to make the best use of the greatest possible range of food and non-food resources without overexploiting any one particular item. There are both material and non-material benefits from such a lifestyle : regular contacts with other bands are of social importance, allowing renewal of kinship ties and exchange of information about distant food resources. This may be essential to survival if any particular area is struck by an ecological disaster such as a drought. Nineteenth century ethnographic records from the southern Cape describe seasonal movements of the last bands of San between the coast and the mountains (H.J. Deacon, 1969, 1970, 1976). The western Cape, with its strong north-south environmental zonation and the differing resource potentials of the various zones, readily lends itself to the formulation of a seasonal mobility hypothesis.

The evidence for such seasonal mobility is based on excavations at two cave sites : De Hangen in the Fold Mountain Belt and Eland's Bay Cave at the coast (see Map IV). The food remains from De Hangen included a number of indicators of summer occupation, while many of those from Eland's Bay suggested winter occupation.

The deposits at De Hangen contained large numbers of dassie bones, of which many were those of immature animals. Dassies have a restricted breeding season, the young being born in late October or early November. As they grow, their deciduous teeth erupt and are in turn replaced by permanent teeth at very specific, well-defined ages. Of the dassie jaws at De Hangen, 45% were those of young animals with dentition such that they were most likely killed some time between October and May (54% were adults or adiagnostic individuals). There were also a large number of tortoises in this site (more tortoises than all the other animals put together), and tortoises are much more active and hence easier to collect in summer than in winter. A number of the wads of grass used as bedding contained plants with inflorescences, and the grasses in question flower in summer. Plant food remains included the seeds of summer fruits (*Nylandtia*, *Euclea*, *Olea* and *Rhus*), as well as large quantities of corm casings from *Iridaceae*. The starchy corms of these plants are at their largest - and most palatable - during the summer, when the plants are dormant. They are thought to have been eaten as a staple food, since they are a predictable resource that people could have relied on finding every day, or could have stored for periods. Hilary Deacon (1976) has suggested that prehistoric seasonal movements in the southern Cape were geared to the animal cycle of *Iridaceae*, especially *Watsonia*, and that people may have moved to the coast during the times when corms were unpalatable (see Chapter 4 for a discussion of the growth cycle of the *Iridaceae*). Parkington, too, has proposed (1972, 1976a) that a temporary lack of plant foods in the Fold Mountain Belt in the winter would have increased the attractiveness of the coast.

Eland's Bay Cave is situated on the Atlantic coastline about sixty kilometres from De Hangen. Like most coastal sites, this cave has few plant food remains. It is important to note that plants are preserved in the Holocene deposits, and a number of wads of bedding grass and fragments of seaweeds have been recovered (Parkington, 1980), but the Iridaceae corm casings so prominent at De Hangen are rare and fragmentary at Eland's Bay. A likely substitute staple food would have been shellfish, particularly the limpets and mussels common on the rocky outcrops below the cave. Vast quantities of the shells are found in the cave. These animals, too, are a dependable resource that could have provided the basis of the prehistoric coast-dwellers' menu (H.J. Deacon, 1972, 1976, 1983; Parkington, 1972, 1976a, 1976b, 1980; Robertshaw, 1979a). Shellfish would have been supplemented by the meat of coastal birds and seals, fish, crayfish and stranded whales. Seals have an extraordinarily restricted pupping season, the females in a given rookery giving birth during the same week each year and conceiving again the following week. The actual calendar week varies somewhat from north to south, but is generally in November. Measurements of the mandibles of juvenile seals can reveal their ages with considerable precision, and hence the time of year at which they died. The animals in the Eland's Bay Cave deposits are nearly all yearlings killed between July and October. This short time period seems to be confirmed by the analysis of seasonal growth rings on a small sample of adult male canines from the same site (Fletemeyer, 1977). There is some doubt as to exactly how prehistoric people obtained seals, since they tend to breed on offshore islands and rarely come on to the mainland unless sick or dying. Dead animals are washed ashore, particularly during winter storms. It is possible that there used to be a rookery near Eland's Bay and that the young seals were actively hunted. They are easier to catch than adults, and yearlings are in peak condition since they are suckled until the new black pups are born. It would therefore make sense for hunters to concentrate on yearling seals, but the pattern is less easy to explain if the animals were scavenged. There are, however, peaks and troughs in the seasons and ages at which seals die, and Parkington (1976a: 113) has noted that :

> "some rather uncontrolled personal observations along the Atlantic coast suggest that seals of all sizes may be washed ashore, but that black pup carcasses will be close to off-shore rookeries, and those of newly-weaned yearlings in rough winter seas may form a significant proportion of winter washups".

The incidence of black pups in the cave sample is very low, and there is no reason why they should not have been eaten if they were available (as at Nelson Bay Cave on the south coast). Hence the implication here is that there was no nearby rookery, and that the yearling seals were probably scavenged off the beaches.

A less reliable indicator of winter occupation may be the large number of black mussels in both cave and open sites at Eland's Bay. These can be harvested from the rocks all year round, but Parkington suggests that they would have been somewhat safer to eat in winter, due to the phenomenon of red tide. Sudden 'blooms' or population explosions of various red plankton species occur in these waters. They are more frequent in summer, since this is the season during which the south-easterly winds prevail, helping to deflect surface waters away from the coast so that deep, nutrient-rich water wells up to replace them (Branch & Branch, 1981). One of these organisms (*Gonyaulax catenella*) is toxic to man, and is concentrated by filter-feeding shellfish such as mussels, while grazing molluscs (e.g. limpets) are unaffected. *Gonyaulax catenella* does not kill the mussel, but eating even one contaminated mussel can kill a person. Shellfish may remain toxic for up to four months after a red tide (Grindley & Sapeika, 1969), so it is better to avoid using them as food for the entire season during which red tides are likely.

Several other factors may have increased the range of food resources available to hunter-gatherers at Eland's Bay during the winter. This is the season when female whales come close inshore to calve, and it seems probable that the whale mortality rate, and the number of carcasses washed ashore, would have increased at this time. The bones of several species of birds that are winter visitors to the nearby Verlore Vlei (e.g. flamingoes) have been found throughout the Holocene levels of the cave deposits. Winter is also the time when the vlei, swollen by winter rains, used to break through into the sea carrying with it organic material that would attract fish, especially the white steenbras (*Lithognathus lithognathus*). This is one of the commonest fish in the cave deposits.

There is thus a considerable amount of archaeological evidence for summer occupation at De Hangen and winter occupation at Eland's Bay Cave. This is supported by a number of accounts of summer meetings between early European travellers and 'Soaqua' or hunter-gatherers in or near the Olifants River Valley (tabulated in Parkington, 1976a, 1977). Some of these people advised Van Meerhoff in February 1661 to travel up the valley of the Olifants River, saying that lack of water made other routes impractical (in Parkington, 1977).

This, then, was the original form in which the seasonal mobility hypothesis was proposed. Parkington saw inland sites in the Fold Mountain Belt, particularly those in the Olifants River Valley, and coastal sites at Eland's Bay as different segments of one integrated subsistence economy. People moved between the various resource zones in such a way as to exploit peaks in animal, and particularly plant, resources, while avoiding troughs.

> "People will be attracted to areas because by comparison with others they offer a more secure subsistence base at particular times in the seasonal cycle. Moreover, although some areas may not fluctuate at all seasonally in terms of what they offer, their attraction may fluctuate simply because their competitors fluctuate and, therefore, *relatively* so do they"

(Parkington, 1977: 156). The Olifants River Valley, particularly, was seen as a focus of hunter-gatherer settlement, providing a life-giving source of water in the dry summer months (when, presumably, large numbers of people would congregate there). In wetter months, people could have moved out into the Sandveld or the Karoo to take advantage of temporary abundances of plant foods, and perhaps animals attracted by new grass. Tentative support for this hypothesis comes from the rock art of the Olifants River Valley, which seems to depict unusually large numbers of scenes involving group co-operation (Manhire *et al.*, 1983).

In recent papers, Parkington (1983, in prep.) has fitted his seasonal mobility hypothesis more securely into a chronological framework. He now expects that it will be found to apply, in the form outlined above, only to the period between 4 000 B.P. and 2 000 B.P. Prior to this, there was the hiatus in human occupation of Eland's Bay, and after 2 000 B.P. the system was probably seriously disrupted by the arrival of domesticated animals and pottery in the south-western Cape. It is not yet known whether these items were acquired from elsewhere by the already existing population, or whether they were brought by a separate group of people. The first European settlers distinguished the 'Khoi' or 'Hottentots', who were practising pastoralism, from the 'San' or 'Bushmen' who were hunter-gatherers, but the two ways of life were to some extent interchangeable : a pastoralist would hunt and gather to supplement his diet, and might be driven to do this full-time if his stock died or were stolen. Hunter-gatherers hunted other peoples' domestic animals, when they could, as though they were just another kind of game animal (Marks 1972). Nevertheless, the advent of this new way of life must have had a tremendous effect on the activities of hunter-gatherers : seventeenth century travellers tell of herds of thousands of sheep and cattle on the fertile low-lying grasslands of the western Cape. These herds must have driven many of the wild animals out of the best grazing lands. Hunter-gatherers probably took refuge in the more mountainous areas, as suggested for the south coast by Janette Deacon (1972), or along the coastline where the environment was less disrupted.

This pattern is confirmed by many small archaeological sites in the little rocky hills that dot the Sandveld. Most of these are small rock shelters that were not occupied prior to 2 000 B.P. The deposits they contain have wads of grass used as bedding, usually around the walls of the shelter. In the middle are the ashy remains of fires, a few marine shells, pottery, grindstones and wood-working adzes. The remains of plant foods suddenly become much more abundant. Many shelters have rock paintings. This is the kind of site found in the Folded Mountain Belt between 4 000 and 2 000 B.P., but after 2 000 B.P. the pattern spreads to these Sandveld hillocks (Manhire, pers.comm.). Although there must have been some occupation of the deflation hollows after 2 000 B.P., since some of them contain pottery (which might have been left there by herders), Parkington and Manhire see the main focus of hunter-gatherer settlement moving out of the Sandveld at this time. There also seems to have been much more intensive exploitation of shellfish at Eland's Bay in the post-2 000 B.P. period. Of 67 charted middens at Eland's Bay, only five are without (or have lower levels without) pottery. Very large middens situated right next to rocky outcrops tend to have some lenses appearing to pre-date the introduction of the pottery. After 2 000 B.P. middens are found not only in these optimal locations, but small sites are thickly scattered along the shore, strongly suggesting increased reliance on shellfish (Buchanan, pers.comm.). Thus patterns of site distribution seem to fit in with Parkington's proposals, although the difficulty of distinguishing hunter-gatherer sites from herder sites has not been overcome, and it is possible that some of the late shell middens could have been left by pastoralists rather than by hunter-gatherers (Hausman, 1980).

This was the situation at the Cape when the first European settlers arrived in the seventeenth century A.D. There had been periodic visits by ships en route to the East before this, and sailors had encountered and traded with some of the local inhabitants, but had probably not seriously disrupted their lives. Very soon after the establishment of the Colony of the Cape of Good Hope, trading and hunting parties were sent off into the interior, and the territory they opened up was rapidly appropriated by farmers. This led to a conflict of interests with the previous inhabitants, many of whom were killed and the remainder driven northwards so that by the end of the eighteenth century none were left in the research area.

CHAPTER 4

INDIGENOUS FOODS

This chapter is meant to provide a broad overview of the kinds of indigenous plant and animal foods available in the various resource zones of the south-western Cape. The picture will be a wider one than can be obtained from analysis of food-waste from archaeological excavations, because such food-waste is the product of two separate selection processes. The first is the choice of foods made by prehistoric people, and the second is the bias caused by differential preservation of the various kinds of remains in archaeological sites. Although the ecological (what was available) and archaeological (what was actually utilised) pictures will ultimately be integrated, it is important to appreciate both aspects before evaluating the significance of the food-waste patterning in archaeological sites.

Hunter-gatherers, even when living in such marginal environments as the Kalahari Desert, do not usually eat all the different kinds of food available to them. Ethnographic evidence indicates that there is a ranking of foods, with a few preferred species (of both plants and animals) providing the bulk of the diet, i.e. acting as staples. Other species may be eaten occasionally for variety, or may be intensively exploited when the preferred foods are difficult to get, as in times of drought. People thus carry around in their heads long checklists of potential foods, but may actually only ever consume a small fraction of them (Tanaka, 1976; Lee, 1978 & 1979). The south-western Cape is a much richer, more varied environment than the Kalahari, and so it seems likely that prehistoric hunter-gatherers in this area had a great deal of choice as to what they were going to eat. Lists of food-waste from archaeological sites certainly reflect considerable biases towards some plants and animals and away from others. Although this does relate, to some extent, to certain items being easier than others to obtain, there is likely also to be an element of conscious choice often overlooked in archaeological studies.

PLANT FOODS

This tendency towards ecological determinism is particularly noticeable in relation to plant foods. H.J. Deacon (1976) suggested that, in the southern Cape, people moved across the landscape in a seasonal cycle geared to the availability of *Iridaceae* corms, particularly those of the genus *Watsonia*. Parkington (1972, 1976a) has proposed that, in the western Cape too, this resource was an important influence on prehistoric behaviour, leading people to spend the summer months in the river valleys of the Folded Mountain Belt gathering corms as one of their staple foods, and the winter months on the coast. Here shellfish would provide an easily-collected substitute for plant foods at a time when the corms are unpalatable because they are putting up new shoots. At this stage the corms are pinkish, full of a very bitter resin, and unpleasant to eat. Just before the plant flowers, a new corm starts to be formed : this is white and good to eat. It goes on growing during the springtime when the plant is flowering, and is best gathered when at its maximum size just after the flowers have died off. The plant then undergoes a period of dormancy during the summer, and the corms can also be collected at this stage, until new growth begins again in autumn (Silberbauer, 1974; H.J. Deacon, 1976). Thus there are undoubted seasonal peaks and troughs in the availability of <u>Iridaceae</u> corms, and there are two strands of evidence supporting the idea that they were staple foods. These are firstly, ethnographic evidence from early travellers, and, secondly, the remains from archaeological sites. A number of early travellers recorded <u>Iridaceae</u> corms as articles of diet amongst the indigenous peoples of the Cape, including Kolbe who in 1685 wrote :

> "The Sisyrinchia, the Cape-Europeans call
> Onions (ajuine), Tho' they are nothing
> like Onions, either in shape or taste . .

> They had been better call'd Potatoes, for
> they are Roots that come somewhat near.
> When boil'd they eat much like chestnuts.
> They are very plentiful at the Cape in
> September and the Two or Three following
> months . . . their Roots differ in colour
> as well as size; some being white, others
> a dark red, and others (of which is the
> Sort from the Hills) of a black colour"

(in Smith, 1966: 24-25). Smith (1966) interprets this description as being of species of _Sparaxis_, _Watsonia_ and _Hexaglottis_ respectively. The old word "ajuin" gave rise, through "ajuintje" and "uientje" to "uintjie", a common name for a number of species of _Iridaceae_ still in widespread use today. Sparrman (1785), Thunberg (1795-96), Barrow (1801-04) and Lichtenstein (1812-15) all mentioned the importance of the "iris" to local people, and the first three authors also described its use as a seasonal indicator, the time of the year being expressed in relation to the flowering time of the "uintjies".

Almost without exception, archaeological sites in which plant remains are preserved contain corm tunics and corm bases of _Iridaceae_. Corm tunics can often be identified to genus level by the characteristic patterning of their interlocking ribs; the most important genera seem to be _Watsonia_ and _Babiana_ in the mountains, and _Moraea_ and _Gladiolus_ in the Sandveld (see Table V). This probably relates to the differing availability of these plants in the mountains and the Sandveld. All four genera are found in both environments, but *Watsonia* and *Babiana* prefer rocky ground whereas *Moraea* and *Gladiolus* do well in deep sandy soil.

The presence of large quantities of these plants in excavated samples is due in part to sheer good luck : their fibrous corm casings and corm bases tend to be well-preserved because they are so tough and dry. It is quite likely that there were other important plant foods that we do not know about because their remains have all decayed away. To take a quite arbitrary example, *Grielum humifusum*, a small creeping plant common in sandy areas of the west coast, has thick slimy roots that can easily be dug up (far more easily than most *Iridaceae*). These may be eaten raw, or dried and ground into a powder and used to make a porridge that tastes similar to oatmeal. This is still today a staple food of poor rural people in the Richtersveld, since the roots can be found all year round (Meterlerkamp & Sealy, 1983). It is also remarkably nutritious, with a kilojoule content similar to that of potatoes (Archer, 1983). *Grielum* is however a soft plant, the roots do not have any hard outer casing and it would be unlikely to leave any identifiable remains in archaeological sites.

This is merely meant to illustrate that it is quite possible that archaeologists have over-emphasised the role of

Iridaceae corms in prehistoric menus, at least in the south-western Cape. While they were undoubtedly important, and probably did attract foraging bands to areas where they were abundant, it may well be over-stating the case to suggest that their absence in any particular area or at any season imposed significant restraints on prehistoric occupation.

Table VI presents a list of the plants occurring in the research area that are known to be edible. Much of the information was extracted originally from Smith (1966), who, in the process of documenting the common names of South African plants, collated much of the existing literature on edible species. A great deal of it has since been confirmed by other authors (Mason, 1972; Le Roux & Schelpe, 1981; Kidd, 1983; Fox & Norwood Young, 1983), in conversations with botanists and farmers or by personal experiment. Although unlikely to be comprehensive, the list is surprisingly long - over 200 species altogether, compared with fewer than 30 species identified from archaeological sites. A combination of factors is responsible for this huge discrepancy : selection of favourite species by prehistoric collectors, poor preservation of soft plants in sites, and the relative paucity of excavated sites containing any plant material at all - most of the excavated sites in the research area are coastal sites, which are notoriously poor in plant remains. Other factors too influence the kinds (and quantities) of plant food refuse in sites, seeds posing some particularly difficult problems. Almost all the fruits and berries eaten by man are also favourite foods of baboons and birds, which may bring them into caves. It is quite likely that this sort of food, and others which do not require processing or cooking, were often eaten by humans away from areas we recognise as archaeological sites. They may have been consumed during gathering expeditions, or in the course of other day-to-day activities and one can seldom be certain that the excavated remains even of plants known to be edible are a reliable guide to their status as prehistoric human foods. It was therefore deemed prudent to consider a wider range of plants than those actually identified from an archaeological context in assessing the isotopic signature of this component of prehistoric diet.

A number of edible plants have common names that include the prefix Hottentots - or Bushmans/Boesmans. These include Hottentots' cherry (*Maurocenia frangularia*, which has a small red fruit), Hottentotsbrood (*Dioscorea elephantipes*, which has a large fleshy tuber), Hottentotskool (several species of *Trachyandra* whose unopened green flower buds can be eaten, although they do not bear much resemblance to 'kool' (cabbage)), Hottentotsamandel (*Brabejum stellatifolium*, whose almond-shaped nuts are edible once they have been leached in running water to get rid of the cyanide they contain, and many others. There are also a variety of names derived from Khoisan words such as kukumakranka, a general term for all the species of *Gethyllis*, lilies with very fragrant edible fruits; bietou, used for several members of the family *Asteraceae*, but particularly *Chrysanthemoides monilifera* which has juicy edible berries; kannip, *Hydnora africana*, a parasitic plant with a large fleshy edible fruit; and kambro, used for several kinds of *Aslepiadaceae* with large fleshy edible tubers, including *Pachypodium*, *Brachystelma* and, particularly, *Fockea*. The specific Latin name of the most common *Fockea* in the research area, *F. comaru*, is derived from the Khoisan name (Smith, 1966). These tantalising associations of Khoisan people with particular plants probably often reflect some real, if extinct, preoccupation with the species, particularly in the cases where the Khoisan word has survived.

The plants listed in Table VI would not all have been of equal importance in the diets of prehistoric people. Unfortunately, even rough estimates of their relative significance are almost impossible to make with the knowledge we have at present, and this study does not attempt any such assessment. Certain species are, however, abundant and widespread, while others are more particular about their habitat; the former probably made a greater total contribution to Khoisan diet than did the latter. Broadly speaking, storage organs such as corms and tubers and seeds are 'better' foods (in that they provide more kilojoules) than leaves, flowers or fruits, although these may contain important vitamins or be consumed as a source of water rather than of energy. The comments that follow are based largely on personal observations.

Of the plants listed in Table VI as having edible flowers or nectar, in only three cases are the actual flowers eaten. *Crassula alpestris*, a drylands species found in the Karoo, has a peppery flower-stalk eaten as a delicacy by children. The two plants in this category that might have been important foods in prehistory are *Aponogeton distyachos* (water-blommetjies) and *Trachyandra* spp. The young flowers of both these plants are used today as green vegetables, often as an ingredient in meat stews. They are widespread, but available for only a short time in spring or early summer. Considerable quantities can be collected when they are in season. Some nutritional data on *Trachyandra* is available; it has a surprisingly high protein content and kilojoule value (Archer, 1982). The other plants listed merely contain small amounts of sweet nectar which can be sucked out of the flowers.

In the group with edible leaves or stems, all the *Aslepiadaceae* and *Albuca* are important mainly as sources of water. The species of *Aslepiadaceae* mentioned are found mostly in the Karoo. They are available all year round, but some (e.g. *Hoodia* and *Caralluma*) can become very bitter after prolonged dry periods (Meterlerkamp & Sealy, 1983). *Albuca* is available only in the spring in the foothills of the mountains and on the coastal plain Flour can be made from the powdered bases of the stems of *Phragmites*, *Prionium* and *Typha* (Smith, 1966), all of which are common along rivers and streams everywhere in the south-western Cape, and can be found all year round. The leaves of *Hypertelis salsoloides* and *Oxalis* spp. are chewed raw or, in the case of *Oxalis*, cooked in stews. Other species mentioned have green leaves that can be used as vegetables.

Species with edible roots, corms or tubers vary widely in their distribution, availability and palatability. *Iridaceae* are plentiful and widespread but with strong seasonal fluctuations in availability and palatability. *Oxalis* spp. and *Grielum humifusum* are also common and widespread, and seem less subject to seasonal cycles. *Cyanella hyacinthoides* is abundant all over the research area today, and very noticeable when it flowers in spring, but since it flourishes on disturbed ground such as abandoned fields (Archer, 1982), it may have been less common in the past. It has large corms and is today still eaten as a staple in parts of Namaqualand (Archer, 1982). *Annesorhiza* and *Cyphia* are mainly Karoo and coastal plain genera; plants often occur in groups but are very difficult to recognise except when they put up stems and leaves in the spring. *Brachystelma* is today very rare indeed, but *Fockea comaru* is still quite common in the Karoo and well-known as an edible plant. It can be found all year round, as can *Dioscorea elephantipes*. The tubers of this plant, of which 700 lb. specimens have been recorded (Archibald, 1967), must have provided occasional feasts for prehistoric people, but they are slow-growing and require a fairly specific habitat (Bayer, pers.comm.), so were probably never a staple food. *Allium*, *Asparagus* and *Pelargonium* are all relatively widespread and consistently available, although *Allium* is more visible during its winter/spring growing season.

Fruits of the plants mentioned in Table VI probably made welcome occasional additions to the Khoisan diet. Most are available only seasonally, usually in late summer or autumn, although odd berries can be found on species such as *Colpoon compressum* during much of the year (Mason, 1972 and own observations). *Nylandtia spinosa* is a common Sandveld species valued for its sweet juicy berries rich in Vitamin C. *Rhus*, *Olea*, *Euclea* and *Carpabrotus* are very common all over the coastal plant and Folded Mountain Belt.

The plant food component of the Khoisan diet probably provided the bulk of the food eaten, with occasional meat from

Grysbok (Raphicerus melanotis) amongst typical Fynbos plants

<u>Cyanella</u> <u>hyacinthoides</u> showing corm casings
and edible white corms

successful hunts or, later, from domestic stock. This pattern is common to most hunting-and-gathering societies in middle latitudes (Lee, 1968), and is confirmed for South Africa by ethnographic accounts such as that of Ten Rhyne :

> "These (bulbs and roots) are dug up by the women, for it is the women who provide the food for the men; the men look after the huts and the herds or else are occupied in war"

(Schapera, 1933: 129). Kolbe also described how women collected plants :

> "Every morning, excepting when her husband goes a-hunting or fishing, which happens not very often, she goes out to collect certain roots . . . for the sustenance of the family"

(Kolbe, 1731: 160).

Small animals such as tortoises and dassies (rock-rabbits) were also gathered rather than hunted, and these are the most common animals identified from western Cape sites (see Table I). Like plants, they are relatively dependable resources that people could rely on to keep them going from day to day, supplemented by occasional larger animals. Parkington (1976a) tabulates nine references to Khoisan foods by early travellers at the Cape between the 1650's and 1820's. Of these, eight mention roots or plant food, five refer to insects, caterpillars or ants' eggs and five to big game, usually adding that it is only "occasionally taken". In addition, tortoises, dassies and honey are specifically mentioned.

ANIMAL FOODS - TERRESTRIAL ANIMALS

Tortoises are still very common in the western Cape, and are especially visible in spring and summer when they are most active. The vast majority are *Chersina angulata*, the angulate tortoise which occurs along the South African coast from East London to the mouth of the Orange River. Its preferred habitat is coastal sandveld, but it is found all over the research area except in the very high mountainous regions (Greig & Burdett, 1976). Average length is about 15 - 20 cm and each animal weighs up to five pounds (Loveridge & Williams, 1957) (males are slightly smaller than females). Although they are now a protected species, many people still consider the meat a delicacy.

Small numbers of other tortoises also occur in the western Cape : the northern part of the research area is the southern limit of the distribution of *Homopus signatus*, the padlopertjie. This is a small flat tortoise; it would provide much less meat than *C. angulata* and is in any case uncommon. *Psammobates geometricus*, the geometric tortoise, is endemic to the south-western Cape (Greig & Burdett, 1976). It is now a very rare, endangered species although it may formerly have been more common. No examples of these species have been positively identified from archaeological sites, and it seems likely that the bulk of the tortoises eaten by prehistoric people were *C. angulata*. Tortoises have been identified from almost every archaeological site in the research area. In some cases (e.g. at De Hangen) there are more than three times as many tortoises as all the other animals put together.

Angulate tortoises can easily be collected in quite large numbers, even today, in spring and summer. In winter they are much less active and more difficult to see, but still available. Additional evidence of the reliance Stone Age people placed on them as a food source comes from the work of Klein and Cruz-Uribe (1983), whose measurements of tortoise bones from the southern Cape sites of Die Kelders and Byeneskranskop indicates that the population may have been 'farmed down' during the Late Pleistocene/Early Holocene. Tortoises dating from this period are larger, on average, than those from the Late Holocene, suggesting that over-exploitation led to a general reduction of tortoise size after about 6 000 B.P.

Dassies (rock-rabbits or hyraxes : *Procavia capensis*) are common. They are social, diurnal animals that live in colonies on mountains or rocky outcrops (Bigalke, 1978) all over South Africa. The meat is good eating, and animals can be hunted all year round with dogs or chased into crevices in the rocks and fished out with sticks or wire hooks while the escape route is blocked. They can often be stunned with a well-placed stone, especially young animals who tend to be less cautious than their elders. A number of early travellers' reports mention meeting "Soaquas" or "Sonquas" or "Somquas alias Bushmen" who carried roasted rock-rabbits with them in skin bags (Waterhouse, 1932: 117-118; Thom, 1958: 315, 349, 381, 382). They were one of the items used to barter for tobacco.

Of the larger animals identified from archaeological sites, small antelope of the genus *Raphicerus* are by far the most common (see Table I). These are territorial antelope that live in pairs, and are still fairly widespread in the western Cape today. *R. melanotis* (grysbok) is an endemic species in the fynbos (Bigalke, 1978) but *R. campestris* occurs all over southern Africa, as does *Sylvicapra grimmia*, the grey duiker. Grysbok and duiker are browsing antelope, but steenbok are more opportunistic feeders and eat grass as well as bushes, if it is available (Dorst & Dandelot, 1970; Adams, 1980). Klein (1981) believes that the archaeological specimens of these three species were probably caught by setting snares along their habitual runs through the bush. Their age profile resembles that of a live population, which means that the hunting technique used did not differentiate among animals according to their age, and snaring is the easiest way to catch non-gregarious sedentary animals. *Raphicerus* and *Sylvicapra* are much more common in Holocene than in Late Pleistocene deposits. Interestingly, they do not show any decrease in size through time that may be attributed to excessive exploitation or 'farming down', as tortoises (Klein & Cruz-Uribe, 1983) and shellfish (Buchanan *et al*., 1978) do.

Other animals identified in relatively large numbers from western Cape sites include hares and dune mole rats. There are several species of hare in the research area, of which the Cape hare (*Lepus capensis*) is the most common. It is found all over Africa in savannah areas, being a grazing rather than a browsing animal. Large specimens weigh up to 2 kg (Smithers, 1966). Hares are solitary or live in pairs, and are probably all territorial (Bigalke, 1978). Dune mole rats (*Bathyergus suillus*) are burrowing rodents about the size of a large guinea pig and are very common in sandy soils. This species is endemic to the south-western Cape (Bigalke, 1978). They eat *Iridaceae* corms, tuberous roots, leaves and grasses. With a little practice, one can trap them or dig them out of their burrows, and during wet Cape winters, they are sometimes washed out and can be collected on the surface (Jarvis, pers.comm.). They are still eaten in country areas today.

The other animals listed in Table I occur in such small numbers that they probably featured only occasionally in the Khoisan diet. The small carnivores (mongooses and jackals) and the baboons may well just have died in the sites (most of which are caves) rather than been taken there by prehistoric people. Porcupines are present in small numbers, but at quite a number of sites. There are remarkably few really large animals, of which eland are the most common. This is a docile species that Klein (1978, 1981) proposes could have been driven into traps, or over the edges of cliffs. One could argue that the small numbers of large animals might be the result of butchering practices (for instance, cutting the meat off the bones at the kill site so as not to have to carry heavy bones back to the cave), or, perhaps, of the deliberate smashing of large bones for the marrow they contain. While these might be contributing factors, they should also have applied in the Pleistocene and the diminishing ratio of large to small animals from Pleistocene to Holocene faunal assemblages does seem strong evidence of a real shift in dietary emphasis. Seals are a consistent component of the fauna of coastal sites, and stranded whales, although only intermittently available, would have provided huge amounts of food.

Table I thus indicates highly selective hunting of animal foods in the Later Stone Age. Dassies constitute 19% of the identified mammals from archaeological sites in the research area, Raphicerus and Sylvicapra 22% (30% if the unidentified small bovids are included), dune mole rats 12% and hares 6%. Any other species contributes less than 5%. Although all these animals are small, and a great number of dassies would be required to provide as much meat as a single eland, the small animals are consistently present in all the sites, while larger animals are not. This does seem to demonstrate their greater importance as staple foods.

BIRDS

Strong patterning is also obvious in the bird species found in archaeological sites (Table II). Land birds do not seem to have been an important article of diet : the only species that occurs regularly (although in very small numbers) is the Cape Francolin *Francolinus capensis*. Some birds, particularly small passerines and crows, nest in caves (McLachlan & Liversidge, 1978) and probably do not represent the remains of prehistoric meals. On the whole, it seems safe to say that most land birds were not hunted, although they may occasionally have been scavenged, or a sick or injured bird killed.

The picture is very different when it comes to coastal birds : cormorants, penguins and gannets (in that order) provided a significant proportion of the diet of Late Stone Age coastal people.

The Cape cormorant (*Phalacrocorax capensis*) is abundant all along the south-western Cape coast. It eats pelagic surface fish (unlike the other three species of cormorant, which are inshore feeders) (McLachlan & Liversidge, 1978). Avery (1981) points out that *P. capensis* and the White-breasted Cormorant (*P. carbo*) are the only two members of the group that regularly spend time on the shore; the other birds live and breed on offshore islands and do not usually come on to the mainland unless dead or dying. This means that, although *P. capensis* and *P. carbo* might have been hunted, the other cormorants, penguins and gannets are more likely to have been scavenged from the beaches. Considerable numbers of dead or dying birds are washed ashore : 80% of all bird mortality at Eland's Bay occurring between November and April. This seasonal peak is more pronounced for some species (*Morus capensis*) than for others (*Spheniscus demersus*), depending on how markedly seasonal their breeding pattern is. Much of the mortality occurs amongst juvenile birds, and breeding stress is a contributing factor in adult deaths. Other marine birds such as albatrosses, petrels, and prions are present in small numbers : these species, too, can be scavenged off west coast beaches.

A few representatives of the avian fauna of estuaries, lagoons and rivers are found at nearby sites : the ducks, flamingoes and pelicans from Eland's Bay probably come from the Verlore Vlei, and the pelicans at Stofbergsfontein from Langebaan Lagoon.

FISH

Marine fish are well represented in all coastal sites. The dominant species on the west coast are hottentot (*Pachymetopon blochii* white steenbras (*Lithognathus lithognathus*), white stumpnose (*Rhabdosargus globiceps*) and haarders (*Mugil* and *Liza* species). Steenbras and stumpnose are marine fish, but their young swim into estuaries soon after hatching, and remain there until they are sexually mature, when they return to the sea. Haarders can tolerate a wide range of water salinities, from almost fresh to sea-water, and are common (and most easily caught) in lagoons and estuaries. The hottentot is only found in the sea : it is an inshore species usually caught with a line off the rocks, or in kelp beds (Poggenpoel, pers. comm.).

Judging from the figures in Table III, there seems to be a shift in emphasis from steenbras and stumpnose in the northernmost sites (Eland's Bay Cave and Tortoise Cave) to hottentot in sites on the Peninsula and immediately to the east of it (Hout Bay Cave, Simonstown Midden, Smitswinkel Bay Cave and Rooiels Cave). This is unlikely to be the result of differing availability of the three species; it may reflect a real dietary preference or merely the fact that there is a large estuary near Eland's Bay Cave and Tortoise Cave, but not near the Peninsula sites (Poggenpoel, pers.comm.). Most of the haarders come from Stofbergsfontein, and were undoubtedly caught in Langebaan Lagoon.

Small numbers of other fish are present : galjoen (*Coracinus capensis*) is usually caught with a line from rocks, or on sandy beaches. The other species listed might all occasionally be caught in this way, there being very few deep-water fish indeed. The snoek and kingklip from Eland's Bay Cave are deep-water fish, but there is an area of very deep water just around the corner from this site where a mountain rises straight up out of the sea. Deep-water fish could conceivably come quite close inshore here (Poggenpoel, pers.comm.).

At Rooiels some warmer-water fish are evident. The red steenbras (*Petrus rupestris*), carpenter (*Argyrozona argyrozona*) and poenskop (*Cymatoceps nasutus*) are Indian Ocean species found in archaeological sites along the south coast.

Freshwater fish remains are rare in sites. There are three *Labeo seeberi* from Klipfonteinrand, sand- or mudfish presumably present in the nearby Boontjies River, and certainly in the slightly more distant Doorn (Hall, 1977). Andriesgrond, a site next to the Olifants River, yielded the bones of a few Clanwilliam yellowfish (*Barbus capensis*) (Poggenpoel, pers.comm.). One unidentified fish is represented in the (admittedly small) faunal sample from Aspoort, on the banks of the Doorn River (Smith & Ripp, 1978). On the whole, freshwater fish do not seem to have been an important food resource in the south-western Cape.

SHELLFISH

Shells are by far the most common food-waste at any coastal site in the western Cape. There are vast middens along the greater part of the rocky shores (sandy shores support few shellfish) consisting almost entirely of limpet and mussel shells. The black mussel (*Choromytilus meridionalis*) and various species of limpet (the genus *Patella*), especially *P. granatina* and *P. granularis* were a major food source for prehistoric people at the coast. Table IV demonstrates the heavy reliance of prehistoric populations on only three species of shellfish. The pattern is not as marked at Rooiels and Smitswinkel Bay, where a wider variety of shellfish is available in the warm water of the Indian Ocean. Here the brown mussel (*Perna perna*) and a wide range of *Patella* and other species made a significant contribution to prehistoric diet, but as soon as one reaches the cold waters of the Atlantic at Hout Bay Cave, the dominance of *C. meridionalis*, *P. granatina* and *P. granularis* is apparent. These are the three most common intertidal west coast species of shellfish, and can all be obtained at low tide every day, except during storms. *P. barbara*, *P. argenvillei* and *P. cochlear* are usually found in deeper water and are collectable only at spring low tides. *P. miniata* is virtually an infratidal species (Branch & Branch, 1981; Parkington, 1976a).

The percentage of *Choromytilus* in west coast sites varies from 10% to more than 60% of the shell present, while *Patella* ranges from 20% to nearly 90%. Some middens are almost entirely composed of *Choromytilus* shells, others are nearly all *Patella*, and some are mixed. No completely satisfactory explanation for this has so far been advanced. It has been suggested (Robertshaw, 1977) that *Patella* middens might be the result of summer occupations, since *Choromytilus* is often poisoned by red tides in summer. As *Patella* are grazers rather than filter-feeders, they are unaffected by red tides and can safely be eaten even when the mussels are toxic. In some cases, variations in the *Choromytilus* : *Patella* ratio may simply reflect differences in the local availabilities of the species, since Patella usually prefer fairly sheltered rocks, whereas Choromytilus does best on outcrops exposed to the waves (Branch & Branch, 1981).

It is obvious that prehistoric food procurement in the south-western Cape was anything but a random process. In each category of foods, a few items are found in large numbers in the majority of archaeological sites, a range of other items is found in smaller quantities, and there are a great many foods that might have been consumed, but of which we have no record. These clear patterns have been simulated in the collection of samples of edible plants and animals for carbon isotopic analysis.

CHAPTER 5

ISOTOPIC ECOLOGY

In order to understand the major part of this thesis, which consists of an isotopic assessment of the diets of the Holocene inhabitants of the south-western Cape, one needs some appreciation of the isotopic ecology of the area. This requires a slightly different view of the environment from that usually held by plant and animal ecologists. It involves broad subdivisions of the area into categories based on the photosynthetic pathways of the plants at the base of the food-web. These in turn determine the isotopic composition of the bodies of herbivores and carnivores and ultimately people in the area.

BACKGROUND TO THE CARBON CYCLE

The basis of the isotopic evaluation of the food-web rests on the fact that carbon exists in nature in three main forms, ^{12}C, ^{13}C and ^{14}C, which are assimilated at slightly different rates by living organisms. Averaged out over the whole globe, the ratio of $^{12}C : ^{13}C : ^{14}C$ is about $100 : 1{,}1 : 10^{-12}$ (or rather, it was before the testing of nuclear weapons added large amounts of ^{14}C to the atmosphere) (Libby, 1955). ^{14}C is radioactive and so disintegrates with time, but ^{12}C and ^{13}C are stable. Their proportions can change, however, in chemical reactions since ^{12}C, being slightly smaller and lighter than ^{13}C, reacts a little faster. This phenomenon produces systematic differences in the ^{13}C content of the various carbon reservoirs in the global carbon cycle (Bolin, 1974). Early measurements of $^{13}C/^{12}C$ ratios revealed that one of the major sources of fractionation (change in $^{13}C/^{12}C$ ratio) is the photosynthetic fixation of atmospheric CO_2 by green plants (Craig, 1953, 1957). There are three photosynthetic pathways, each fractionating atmospheric carbon dioxide to a different extent. They are called C_3, C_4 and CAM.

C_3 photosynthesis, or the Calvin cycle, is the most widespread system of carbon assimilation. It starts with the conversion of carbon dioxide into a three-carbon molecule, phosphoglyceric acid, in the mesophyll cells of the leaf. This reaction requires the enzyme ribulose - 1,5 - diphosphate. Next, the phosphoglyceric acid is reduced to triose phosphates in the presence of adenosine triphosphate (ATP) and reduced nicotinamide adenine dinudeotide phosphate (NADPH) from light reactions. Thirdly, ribulose - 1,5 - diphosphate is regenerated as five-triose phosphates are converted to three-pentose phosphates and the cycle is repeated. The overall equation for the reaction is :

$$3\ CO_2 + 9\ ATP + 6\ NADPH + 6\ H^+ + 5\ H_2O$$

$$\downarrow$$

$$Triose\text{-}P + 9\ ADP + 8\ P_i + 6\ NADP$$

where P_i = inorganic phosphate

ADP = adenosine diphosphate

(Zelitch, 1979).

Plants using this photosynthetic cycle include nearly all trees and shrubs and those grasses found in temperate environments, e.g. Europe and North America. Almost all plants growing in shaded forests and in winter rainfall areas (including winter rainfall deserts such as those of the western Cape and Peru) are C_3. The controlling factor is a combination of radiation and low temperatures during the growing season.

C_4 photosynthesis : A great many tropical grasses and a few dicotyledonous plants, chiefly members of the families Chenopodiaceae and Amaranthaceae use another photosynthetic pathway. This is known as the C_4 or Hatch-Slack pathway, in which carbon dioxide is initially fixed in the mesophyll into the 4-carbon compound oxaloacetate :

$$\text{Phosphoenolpyruvate} + CO_2 \xrightarrow[\text{carboxylase}]{\text{phosphoenolpyruvate}} \text{oxaloacetate}$$

The oxaloacetate is next reduced to malate and/or aspartate in the chloroplasts, and then transported to the bundle sheath cells where decarboxylation occurs. (Bundle sheath cells are thick-walled cells rich in chloroplasts which surround the vascular bundles in the leaves of C_4 plants.) The CO_2 thus produced goes into the Calvin cycle, while the remaining 3-carbon compound is returned to the leaf blade cells to re-enter the Hatch-Slack cycle by re-carboxylation (Zelitch, 1979).

The C_4 pathway can be divided into three sub-types on the basis of the enzyme most active in decarboxylating the 4-C organic acid in the bundle sheath cells. There are also corresponding anatomical differences (tabulated in Table VII). In malate formers, the decarboxylation occurs in the presence of NADP - malic enzyme (NADP-me). In aspartate formers, the enzyme is either PEP-carboxykinase (PEP-ck) or NAD-malic enzyme (NAD-me) (Ellis *et al*., 1980).

The C_4 pathway thus incorporates the C_3 cycle, but differs in the initial carboxylation step. This is more efficient in C_4 than in C_3 plants, and a combination of this factor and the lack of light respiration makes C_4 crops twice or three times as productive as their C_3 counterparts, i.e. they are more efficient converters of atmospheric CO_2 to plant biomass (Zelitch, 1979).

CAM photosynthesis (crassulacean acid metabolism) is found mostly in succulents. It is not really a separate pathway, consisting rather of the ability to switch between C_3 and C_4 photosynthesis according to environmental conditions (Osmond, 1978).

The importance of C_3 and C_4 photosynthesis to the archaeologist lies in the fact that the two mechanisms fix atmospheric ^{12}C and ^{13}C to different extents. Atmospheric carbon dioxide has a $\delta^{13}C$ value of about -7‰. This means that it is depleted in ^{13}C by seven parts per thousand (or parts per mille) relative to a universally recognised standard, the marine limestone from the Pedee formation in South Carolina (Craig, 1953, 1957). The PDB Standard, as it is called, has been assigned a value of 0‰. Like all marine limestones, it is relatively rich in ^{13}C so that most natural substances have negative $\delta^{13}C$ values, calculated as :

$$\delta^{13}C_{\text{sample}} = \left(\frac{^{13}C/^{12}C_{\text{sample}}}{^{13}C/^{12}C_{\text{standard}}} - 1\right) \times 1\,000‰$$

During photosynthesis, both C_3 and C_4 plants fix ^{12}C in preference to ^{13}C, but the selection is considerably more severe in the C_3 process. This obviously contributes to the relatively low yield of C_3 crop plants. In the Calvin cycle total fractionation involved is about -19,5‰ - the foliage of C_3 plants has an average value of -26,5‰ (range -20 to -35‰) compared with the average of -12,5‰ (range -9 to -16‰) for C_4 plants (Vogel <u>et</u> <u>al</u>., 1978;

van der Merwe, 1982). The range for C_3 plants is more than twice as great as that for C_4 plants, but values as low as -35‰ are unusual. They have been found so far only in marine algae and in plants from dense forests, where the tree canopy prevents mixing of the forest air with the free atmosphere. The latter case (the canopy effect) results in a gradient of isotopic values from very negative on the forest floor (where rotting leaf litter releases isotopically light CO_2) to values which are less negative at the level of the tree-tops. Vogel (1978a) has recorded a $\delta^{13}C$ value of -27‰ for air on the floor of a forest in Bavaria. Similar values have been reported from Amazonian rain forests by Medina and Minchin (1980).

Other factors besides local differences in the carbon dioxide cycle also influence the $\delta^{13}C$ values of plants, even within one photosynthetic pathway. These include temperature, moisture availability, salinity, light intensity and the nutrient status of the soil (Bender & Berge, 1979; Hattersley, 1982). The fact that C_3 plants grow in a wider range of habitats than C_4 plants and are therefore exposed to more variation in all these factors probably contributes to their greater $\delta^{13}C$ range.

CARBON ISOTOPES IN ANIMALS

The lack of overlap in the isotopic ratios of C_3 and C_4 plants and the passing on of these characteristic ratios to consumers allows dietary tracing. A herbivore eating C_3- and/or C_4-based food will have tissue $\delta^{13}C$ values reflecting the proportions of each group of plants consumed. Some additional fractionation takes place in the course of the conversion of plant material to animal hair, skin, muscle, bone or other tissues, and there are different fractionation factors for each of these processes. Living organisms maintain a carbon isotope balance : the total number of ^{12}C and ^{13}C atoms entering an organism in food, drink and inspired CO_2 equals the total number stored in body tissues, excreted and respired as CO_2 (De Niro & Epstein, 1978). However, the organism acts as a carbon isotope separator, recombining ^{12}C and ^{13}C in different proportions during all the physiological processes required to keep it alive. The different fractionation in different tissues probably has two components : the first arising out of the ordinary discrimination between isotopes occurring in every chemical reaction. The second may depend on the direct 'inheritance' of the isotopic signatures of certain kinds of foods used preferentially in the synthesis of particular tissues. For example, dietary fats that are not immediately required as a source of energy are probably converted fairly directly into animal fat.

Excess protein in the diet, however, makes a less significant contribution to fatty tissue (De Niro, 1977; van der Merwe, 1982).

These metabolic pathways are not at all well understood, as yet, but the implications for dietary tracing are clear. If not all foods contribute equally to all the body tissues of consumers, then simple $\delta^{13}C$ measurements of these tissues cannot be translated directly into proportions of C_3- and C_4-based foods consumed. This is one of the problems that will have to be confronted later in this study.

This uncertainty also complicates the diet-to-tissue fractionation factors that a number of authors have attempted to measure (De Niro & Epstein, 1978; Land, Lundelius & Valastro, 1980; Vogel, 1978b; van der Merwe & Vogel, 1978; Chisholm, Nelson & Schwarcz, 1982). For any given species, a given diet should produce tissues with a predictable isotopic composition. This is true, but within broad limits : laboratory animals fed on the same diet show individual variations of up to 2‰ (De Niro & Epstein, 1978). Vogel <u>et</u> <u>al</u>. (1978) estimated the proportions of C_3 and C_4 grass in the different vegetation types of South Africa. They varied from almost 100% C_3 to almost 100% C_4. Ungulate tissue samples (hair, hide, bone, flesh and fat) from a number of biomes yielded average diet-tissue fractionation factors of +5,3‰ for bone collagen,

+3‰ for flesh and -3‰ for fat (Vogel, 1978b). The values are somewhat different from those obtained by De Niro for laboratory mice, and this can probably be attributed to metabolic differences between short-lived mice and large, long-lived ungulates. Differences in diet probably also play a part : there are hints that the fractionation factors for animals with C_3 diets may be slightly smaller than those for animals with C_4 diets (Sullivan & Krueger, 1981). This may be one aspect of the problem discussed in the previous two paragraphs, since there seem to be nutritional differences between C_3 and C_4 grasses. The latter are more fibrous and indigestible (because of their tough bundle sheath cells), and since most of the nutrients are concentrated in these cells, are generally poorer foods for herbivores than C_3 grasses. Their protein content may also be lower (Caswell *et al.*, 1973; Caswell & Reed, 1976).

MARINE CARBON CYCLE

The carbon cycle in the oceans is somewhat different from that on land. Primary sources of carbon here are not only dissolved carbon dioxide, but also bicarbonates and carbonates. Carbonates (e.g. the PDB marine limestone standard) are isotopically very heavy (enriched in ^{13}C), so organisms using these compounds as their sources of carbon tend to be at the positive end of the scale.

Temperature influences $\delta^{13}C$ values : warm water organisms are isotopically heavier than cold water ones. $\delta^{13}C$ values for marine plankton range from -25,7 ± 2,7‰ (mean ± one standard deviation) for samples from water with a temperature of 0 - 15 °C, to -20,8 ± 1,6‰ at 15 - 30 °C (Sackett *et al.*, 1965; Degens *et al.*, 1968; Deuser, 1970). Differences over the same temperature ranges are slightly greater for marine algae (Parker, 1964). Algal photosynthesis is not nearly as well understood as it might be, but both ribulose diphosphate (the enzyme found in C_3 plants) and phosphoenolpyruvate carboxylase (as in C_4 plants) have been identified in seaweeds (Karekar & Joshi, 1973; Steemann Nielsen, 1975; Ting, 1976). Some species have $\delta^{13}C$ values similar to those of terrestrial C_3 plants, while others more closely resemble C_4 types (Wickman, 1952; Craig, 1953; Park & Epstein, 1961; Parker, 1964; Sackett *et al.*, 1965; Smith & Epstein, 1971; Black & Bender, 1976; De Niro & Epstein, 1981; Schell, 1983).

A mixture of both categories contributes to the detritus which, together with plankton forms the base of the marine food-web. The average $\delta^{13}C$ value of this base obviously varies from place to place with species availability and temperature. For the Atlantic Ocean off the west coast of South Africa, where sea temperatures range from 8 °C to 16 °C (Simons, 1976), the first tier of consumers are filter-feeders with $\delta^{13}C$ values ranging from -19,4 to

-15,9‰ (see Table XIII). Grazing molluscs, carnivorous fish and fish-eating animals such as seals and coastal birds become progressively more positive due to stepwise fractionation from one trophic level to another. The marine food-web will be discussed in detail in Chapter 6.

There is thus an extremely wide range of possible $\delta^{13}C$ values in all plants and animals that can be eaten by humans. The meat of an ungulate grazing only on C_4 grasses might be as positive as -6‰, whereas the fat of a browsing animal in a tropical rain forest could well be as negative as -38‰. In any one environment, however, this range is much narrower. We will now consider each of the four environmental zones in the research area with a view to estimating, from the data on climate and flora presented in Chapter 2, the kinds of photosynthetic pathways and the variation in isotopic ratios one would expect in each zone.

PHOTOSYNTHETIC PATHWAYS IN THE SOUTH-WESTERN CAPE

Vogel _et_ _al_. (1978) estimated the proportions of C_3 and C_4 grass in each vegetation type in South Africa. According to their breakdown, strandveld has 0 - 5% C_4 grass, coastal fynbos and coastal renosterveld have 5 - 25%, mountain fynbos has 0 - 5% and succulent Karoo 95 - 100% (see Map VI). These figures, however, refer to the percentage of the total number of grass species present that are C_3 or C_4, rather than the amount of ground covered by each type. While this is sensible from a botanical point of view, ground cover is more important in dietary tracing. The only comment on this is in a later paper : "the C_3 grass species in predominantly C_4 areas are found to be mostly rare and localised and vice versa" (Vogel, 1978b: 298). In the second paper, he actually simplifies the previous scheme into three categories : $> 90\%$ C_3, mixed, and $> 90\%$ C_4. These two classifications are somewhat inconsistent, but nevertheless they provide an invaluable starting point for a closer examination of the area.

ISOTOPIC RATIOS OF ANIMALS IN THE RESEARCH AREA

In theory, an unselective pure grazer (i.e. an animal that eats only grass, not bushes, and consumes everything in its path without picking out some more palatable species and leaving others behind) would reflect the relative amounts of ground covered by C_3 and C_4 grasses. Unfortunately no such animal exists. Many species previously thought to have definite strong preferences for grazing or browsing are being found to be much more opportunistic feeders (Lee Thorp, 1983; Lee Thorp & van der Merwe, unpublished data). Moreover, the degradation of the environment in the research area, and the fact that much of it is now under cultivation, means that grazers that lived there in prehistoric times (e.g. zebra) no longer do so. Finally, it is quite probable that many grazers are in fact highly selective about the grasses they eat : Evans and Tisdale (in Caswell et al., 1973) describe the take-over of a C_3 grassland by a C_4 species, and attribute it to the selective overgrazing of the more palatable C_3 grass by cattle, sheep and mule deer.

Although all these factors complicate the interpretation of the $\delta^{13}C$ values of animals collected in the research area, one would still expect a range of values - for animals that eat some grass - becoming more positive from the 0 - 5% C_4 areas through the intermediate categories to the 95 - 100% C_4 zone. This pattern has been demonstrated for deer in North America (Land, Lundelius and Valastro, 1980). Moreover, if soil moisture affects $\delta^{13}C$ values (Tieszen, 1979), it would not be surprising if there were a gradient within the 0 - 5% C_4 area from parts of the Cape Peninsula, with up to 600 mm of rain per year, to Eland's Bay which received less than 200 mm (see Chapter 2). Although more or less the same kinds of plants grow in both places, climatic differences could well result in small differences in their isotope ratios (see discussion earlier in this chapter about the greater variability in the $\delta^{13}C$ values of C_3 plants compared with C_4 plants). Climatic and other differences (frequency of fires, grazing pressure) might also result in different areas within one vegetation type having different amounts of grassland compared with bushy scrub. A mixed feeder (grazer as well as browser) would then ingest more C_4 food in grassier areas, and more C_3 food in bushy patches. Hendey (1983) gives a concise account of the problem of the role played by grasses in fynbos vegetation. He suggests that a moderate increase in fire frequency favours the spread of grasslands. If fires are too frequent, however, certain pioneer shrubby bushes (e.g. Elytropappus rhinocerotis, the renosterbos) may successfully compete with grasses, resulting in the shrubland communities found in the coastal lowlands today (Heydorn & Tinley, 1980). Also, the large mammals that used to browse on these shrubs (elephant, rhinoceros, eland) are no longer found in the western Cape. They probably helped reduce the shrub cover, thus promoting the growth of stands of grass (Hendey, 1983).

Yet another complication may exist in C_4 grasslands. It has been shown, in a study done in Namibia, that the three subtypes of C_4 grasses have different distributions. While C_4 grasses on the whole are adapted to climates where the temperature during the growing season is high, they are found in quite moist as well as arid areas. Malate formers are commonest in wetter regions, whereas aspartate formers favour dry areas. The latter can be subdivided into NAD-me and PEP-ck, with the first predominating in areas of very low or unpredictable rainfall. PEP-ck grasses do best where the rainfall is about 350 mm/year (Ellis *et al.*, 1980). Controlled laboratory experiments show malate formers to have slightly heavier $\delta^{13}C$ values, on average, than aspartate formers, and within the aspartate group PEP-ck are somewhat enriched in ^{13}C compared with NAD-me grasses (Hattersley, 1982). It is not yet known whether these isotope ratio differences are significant in natural vegetation. Hattersley doubts it, and correlation of published $\delta^{13}C$ values for South African C_4 grasses (Vogel *et al.*, 1978; Ellis *et al.*, 1980) with anatomical evidence for their division into the various subtypes (Ellis, 1977) does not reveal significantly large differences (mean ± one standard deviation for each type is as follows : Malate formers : -12,4 ± 1,0‰, n = 31; PEP-ck aspartate formers : -13,1 ± 1,1‰, n = 17; and NAD-me aspartate formers : -13,5 ± 0,99‰, n = 14). However, these samples were very randomly collected from widely scattered localities, probably with very different microclimates. No-one has so far sampled systematically along a transect from wet to dry C_4 grassland in an otherwise uniform environment. Until this has been done, the possibility of C_4-subtype affecting the carbon isotope values of the food-web in different areas must be borne in mind.

There are thus a number of factors that could complicate the $\delta^{13}C$ values of animals collected in the research area. The sampling programme was set up with all these problems in mind, and in the hope that the results would help determine which factors, if any, actually influence the isotopic structure of the food-web.

ISOTOPIC RATIOS OF EDIBLE PLANTS IN THE RESEARCH AREA

So far the discussion has related mainly to animal samples. There are grey areas in our knowledge of the isotope ratios of plants, as well, although the situation here is less involved because plants are primary producers rather than consumers, so one whole level of fractionation that complicates animal $\delta^{13}C$ values does not exist for plants. An attempt will be made to investigate three main problems. The first is the degree of variation of carbon isotope ratios in different parts of an individual. The vast majority of the published $\delta^{13}C$ measurements on plants have been on foliage. This is useful as an indicator of photosynthetic pathway, but very often the foliage is not the part of the plant eaten by humans. Fruits, berries, seeds, flowers or storage tissues such as corms or tubers are frequently consumed, and there is very little information available on their isotope ratios. It is known that different tissues in a plant do have different $\delta^{13}C$ values : Leavitt and Long (1982) report a constant difference of

2 - 4‰ between the leaves and wood of juniper trees. Other authors have done similar measurements on woody and non-woody plants (Craig, 1953; Mooney et al., 1977). All found differences of a few per mil between different tissues from the same individual. This is not surprising when one considers that different parts of plants contain different proportions of various chemical compounds. These vary in their isotopic composition : Smith and Jacobson (1976) analysed a potato tuber and found that, while whole slices of potato had a $\delta^{13}C$ reading of -25,8‰, amino acids were -27,1‰, sugars -23,8‰, starch -25,5‰ and a CCl_4 extract -35,8‰. Park and Epstein (1960, 1961) and Degens et al. (1968) also discovered that lipid fractions of plants were markedly isotopically lighter than other fractions. Vogel (1982) has measured the $\delta^{13}C$ values of C_3 plant proteins as compared with leaves and seeds.

To characterise the plant menu isotopically, a number of variables require consideration. Firstly, it is necessary to analyse some of the food plants of the western Cape to find the $\delta^{13}C$ values of their edible parts, rather than their foliage. The vast majority are C_3 plants (see Table VI). A few may be CAM, e.g. some of the succulent Asclepiadaceae important as water sources in the Karoo. One or two may perhaps be C_4 (members of the family Amaranthaceae). Staple foods, including all the Iridaceae, are likely to be C_3 and it would be useful to have some idea of the range of isotope values the edible tissues display.

The second point worth investigating is the variation in $\delta^{13}C$ in these plants in different seasons. Lowdon and Dyck (1974) found a 6‰ difference in maple tree leaves in spring compared with late autumn, and Leavitt and Long (1982) report a seasonal variation of 3‰ in juniper leaves.

These differences can be attributed to seasonal temperature variations, and hence to increased activity in the plant in some seasons while in others it is dormant. Leavitt and Long calculated that the temperature coefficient for their junipers was about -0,27‰ $°C^{-1}$. This functuation would be particularly interesting in plants with corms, because of the considerable alterations in the composition of the corms through the year. Seasonal differences in $\delta^{13}C$ would then be the result of temperature changes and of variations in the chemical composition of the plants. The cycle begins as new growth is initiated in autumn, and starchy photosynthetic products accumulate to form a corm, which is then dormant during the following dry season. With the onset of more favourable environmental conditions in the autumn it is used up in the formation of new leaves and stems, which in turn make another new corm. It has been shown that the levels of the various complex polysaccharides that constitute the stored nutrients in the corms of Watsonia spp. change seasonally (Waher, 1974). This dynamic cycle ought to result in considerable isotopic changes in the corms in different seasons, although only a small part of the $\delta^{13}C$ range would be important in the human food-web as these plants are thought to have been eaten only at certain times of year.

A number of plant foods are of course not amenable to this kind of study, as they are only available for a short season. Edible flowers such as those of Aponogeton and Trachyandra and many fruits and berries fall into this category, but there are species for which useful information might be forthcoming from a seasonal study.

The final source of variation in the isotope ratio of plant foods is that between different individuals of the same species in (1) the same environment and (2) different environments. Any variation between different individuals of the same species in the same environment must be due merely to the slight variations in normal metabolic processes that inevitably occur in living organisms. This variability must be known so that it can be used as a baseline in the measurement of differences between individuals of the same species in different environments. These differences have been demonstrated in laboratories, and may be due to local differences in the carbon dioxide cycle, or to differences in temperature, moisture availability, salinity, light intensity or soil nutrients (Degens *et al.*, 1968; Bender & Berge, 1979; Farquhar, 1980; Hattersley, 1982).

The finer details of the way plants respond to all these environmental factors is of interest to plant physiologists, rather than to archaeologists, and no attempt was made in this project to perform sophisticated experiments. The approach will be specifically archaeological, and aimed merely at being able to assess the range of $\delta^{13}C$ values in the indigenous plant foods of the research area. As in the section on animals, this listing of the possible sources of isotopic variation is meant as a framework within which to design a sampling programme, rather than as a series of subjects for exhaustive research.

ISOTOPIC RATIOS OF MARINE ORGANISMS

The final group of prehistoric foods consists of the marine organisms. There is a considerable amount of literature on marine plants and animals, with a large number of published $\delta^{13}C$ values (Wickman, 1952; Craig, 1953, 1957; Park & Epstein, 1961; Parker, 1964; Sackett *et al.*, 1965; Degens *et al.*, 1968; Smith & Epstein, 1971; Black & Bender, 1976; Thayer *et al.*, 1978; De Niro & Epstein, 1981; Rau *et al.*, 1981; Schell, 1983).

None of these refers specifically to the South African situation, however, and although many marine species are very widespread, their isotopic ratios vary with water temperature (as described above), pH, etc. (Deuser & Degens, 1967).

At the time when the research for this thesis was planned, only a pilot study of $\delta^{13}C$ in the marine food-web of the western Cape had been completed. This comprised a series of results obtained by van der Merwe, Vogel and Rawlinson on materials collected in the Oudekraal kelp bed (Cape Peninsula) or raised in the laboratory by Field and Griffiths (Rawlinson, 1982). The results include plants and animals from different trophic levels in the kelp bed food-web, and showed that there is quite considerable fractionation from the phytoplankton (-17,9‰) through filter-feeders such as mussels to scavengers right at the top of the chain (crayfish at -13,1‰). One of the most interesting aspects of this set of results was the values for two different kinds of kelp; one, Ecklonia maxima, had a C_4-like $\delta^{13}C$ value (-12,0‰) whereas the other, Laminaria pallida, was C_3-like (-20,9‰). Other algae were also C_3-like (Gigartina at -22,0‰, Pachymenia at -21,9‰), raising the question of whether the value for Ecklonia was anomalous or whether there are indeed a group of algae with relatively low $^{13}C/^{12}C$ ratios and another with much higher ratios.

The first problem in the marine cycle is therefore to ascertain the degree of $\delta^{13}C$ variability among seaweeds. This is necessary before proceeding with the analysis of organisms higher in the food-web, since seaweeds (together with phytoplankton) are the primary producers in the sea. It is not known whether seaweeds were ever eaten directly by prehistoric people, but a number of animals feed off them and they contribute a large part of the detritus that sustains filter-feeders. Their carbon isotope ratios thus directly determine those of all the higher trophic levels in the inshore marine food-web.

The second aspect of the marine carbon cycle to be investigated is the fractionation at different trophic levels. Although the Oudekraal sample did yield some information on this, it did not include many animals at the top of the food-chain. These, especially fish, seals, cormorants, gannets, penguins and crayfish were eaten in large numbers in prehistoric times. Also, analysis of further samples will help determine the degree of isotopic variation between individual animals, and between animals collected from different localities.

Lastly, it is necessary to determine any seasonal variations in the $\delta^{13}C$ content of small filter-feeding animals. One would expect to see seasonal variations only in small organisms which replace most of their carbon in less than a year. (The $\delta^{13}C$ values of larger animals represent an integration of several years' diet.) The carbon turnover time in black mussels (or at least in parts of them) is fairly short. This species spawns twice a year, and an individual may lose up to half of its body weight in each spawning. Carbon in the reproductive system is therefore replaced regularly, although carbon in other parts of the body may remain fixed for much longer periods (Griffiths, pers.comm.). Mussels, being filter feeders, consume the plankton that 'blooms' periodically after the upwellings of cold, nutrient-rich waters described in Chapter 2. These upwellings are more frequent in summer, this being the time when the south-easterly winds prevail (Branch & Branch, 1981). It is therefore possible that mussels collected in summer have slightly different $\delta^{13}C$ values from mussels collected in winter.

This chapter has summarised the reasons for $^{13}C/^{12}C$ variations in different classes of living organisms. The factors likely to produce $\delta^{13}C$ variations in three major categories of prehistoric human foods have been examined, thus supplying the framework for a sampling scheme designed to ascertain the range of carbon isotope values in the edible plants and animals of each of four resource zones in the western Cape.

CHAPTER 6

FIELD SAMPLING & LABORATORY ANALYSIS OF THE PREHISTORIC HUMAN FOOD-WEB

In order to characterise the food-web of the south-western Cape in isotopic terms, a large-scale sample collection programme was undertaken, including both terrestrial and marine flora and fauna. The specimens were then analysed for their stable carbon isotope ratios. The collecting programme stretched over some two years, which made it possible to provide a set of values for a full annual cycle, where appropriate. Although the specimens are all modern, they were collected from sampling stations in relatively undisturbed areas chosen to represent the 'average Holocene'. As the laboratory results became available, the collecting programme was altered to fill in the overall picture or to explicate puzzling results. In this, the proximity of laboratory and fieldwork area played an important part, joining the two components into a coherent whole. In this chapter, field and laboratory procedures are consequently described together with the isotopic results.

1. THE FIELD SAMPLING PROGRAMME

1.1 Plants

A fairly intensive plant sampling programme was initiated at the beginning of this project, although not all the samples collected were eventually analysed. Plants were obtained

(1) on field trips to selected field stations;

(2) from a convenient and well-established cultivated colony of Watsonias (for the seasonal study);

(3) on excursions with ethnographic informants; or

(4) by donation from other fieldworkers, farmers, etc.

1.1.1 Field Stations

Regular plant collections were made at Eland's Bay (in the strandveld vegetation type), at De Hangen in the Nardowsberg and at Boontjieskloof (in arid fynbos). Since many plant foods are only seasonally available, regular collecting trips are imperative if one is to gain a complete picture of the resources offered by any particular area. Collections and observations were made in November 1981 and February, May, July and September 1982. In addition, two-monthly monitoring of an area of mountainside at Kalk

Bay on the Cape Peninsula was carried out. Several trips were also made to Doringbos in the Karoo (May, July and September 1982) and one or two trips each to Piketberg mountain (mountain fynbos), Aspoort (succulent Karoo), Andriesgrond (in the Olifants River Valley) and Hopefield (on the coastal fynbos/renosterveld boundary) (see Maps III and V).

These sampling stations were chosen because they were all situated in relatively large tracts of uncultivated land. They were also picked to yield a reasonably representative cross-section of the vegetation types of the south-western Cape. Several (Eland's Bay, De Hangen, Andriesgrond, Boontjieskloof, Aspoort) are also near excavated archaeological sites.

1.1.2 Cultivated *Watsonia* Colony

Originally, seasonal studies of the $\delta^{13}C$ values within a single plant species were planned at some of the field stations mentioned above. This rapidly became impractical, since most of the field stations are some distance from the laboratory. Many more samples, collected at short intervals, were needed for a seasonal study than for any of the other research objectives, so a large colony of cultivated *Watsonia pyramidata* on the Peninsula was chosen for this purpose. This colony had the advantage of being accessible and also of containing a sufficiently large number of plants to allow a total of more than 60 individuals (five each month for a year) to be removed. Wild Watsonias usually grow in small clumps, so that it is almost impossible to find 60 wild plants grown in exactly the same micro-climatic conditions. The colony samples had been undisturbed, except by weeding, for at least five years.

1.1.3 Excursions With Ethnographic Informants

Most of the plants collected in the Karoo were pointed out by ethnographic informants. The edible plants of the Karoo have not been as well documented as those of the less arid areas, and some of them (e.g. *Fockea comaru*) are very difficult for an inexperienced person to find because most of the plant is below the ground. Two collecting trips at Doornbosch with an ethnographic informant yielded a number of plants that would not otherwise have been obtained, as well as two new records of edible species, and two new medicinal uses (Metelerkamp & Sealy, 1983).

1.1.4 Donations

Several plants were donated by interested archaeologists and by farmers. Fiona Archer, who is doing ethnobotanical work in Namaqualand, provided a number of samples including the *Hydnora africana* analysed.

1.2 Animals

Most of the animals in Tables VIII, IX, X and XI were either found dead during plant collecting trips, or donated by farmers. Samples of hares, tortoises, bat-eared foxes and even a steenbok were taken from road-kills. Many of the specimens for which only collagen values are given died natural deaths, and the bones were found while walking through the bush. A number of farmers donated parts of animals they had trapped or shot, and a few samples came from nature reserves at Churchhaven or at Cape Point (the latter mainly donations from the South African Museum).

1.3 Marine Specimens

Marine specimens, too, were obtained in a variety of ways : shellfish and some algae were collected in intertidal rock pools, while others were collected by scuba divers. An initial set of samples was donated by the Zoology Department. Many marine birds, one of the seals and the whale bone were found washed up on the beach. The albatross and penguin were donations from the Percy FitzPatrick Institute for African Ornithology and the South African Museum respectively, while the other seal was donated by Sea Fisheries. Fish were purchased from fishermen.

2. LABORATORY PROCEDURE

All analyses were done in the Archaeometry Laboratory at the University of Cape Town. Three steps are involved : sample preparation, carbon dioxide production and purification, and carbon dioxide measurement on the mass spectrometer.

2.1 Sample Preparation

Sample preparation techniques vary according to the type of material to be analysed. Meat, plants, marine algae and shellfish require very little pre-treatment. These samples were merely cleaned of any surface contaminants, freeze-dried and ground to a powder. Bone samples require more careful preparation : all the measurements in this thesis were done on bone collagen, the organic fraction of bone. This is extracted by decalcifying whole bone in 1% to 5% hydrochloric acid. The time required for complete decalcification varies depending on sample size and on whether the bone consists mainly of compact or cancellous bone. It ranges from a few days to more than a month. Thereafter, the collagen is soaked in distilled water which is changed every two days until all traces of hydrochloric acid have been washed out of the sample. It is then freeze-dried and ready for analysis. Bone collagen, rather than whole bone, is the preferred material for $\delta^{13}C$ readings on archaeological samples since the strongly-bound protein chains that make up collagen maintain their isotopic integrity when the bone is buried underground (Tamers & Pearson, 1965; Sellstedt et al., 1966; Taylor & Slota, 1979; Taylor, 1980).

In addition, the slow turnover time of collagen carbon in the bones of adult animals (it is about 30 years in humans (Stenhouse & Baxter, 1979)) means that the reading obtained represents long-term averaging of the diet.

2.2 Gas Production and Purification

Sample combustion was carried out in sealed glass tubes as described by Sofer (1980). A 5 mg sample, excess copper oxide (at least 0,5 g) and a twist of silver wire were loaded into 6 mm O.D. tubes which were then evacuated to less than 10^{-2} Torr, sealed off with a glassblower's torch and combusted in a furnace overnight. Initially, Pyrex tubes and a combustion temperature of 500 °C were used, but this was found to give incomplete combustion on some samples (particularly plants), so quartz tubes and a temperature of 800 °C were substituted.

After combustion, the carbon in the sample is in the form of CO_2 while some of the copper oxide has been reduced to copper metal. Any sulphur or halides present should have reacted with the silver wire, which also acts as a catalyst. Some sulphur dioxide may combine with copper oxide to form copper sulphate (Sofer, 1980). The tube also contains water vapour and if the furnace has been cooled down slowly, all the nitrogen should be present as nitrogen gas, N_2. Slow cooling allows recombination of the mixture of oxides of nitrogen that may have formed initially. The oxygen re-oxidises reduced copper metal while the nitrogen produces N_2 (Sofer, 1980).

The tube is then removed from the furnace, the end scored to ensure easy cracking, and inserted into a 'cracker' of the type described by Desmarais and Hayes (1976). The cracker is attached to a stainless steel gas-separation line (see Figure 1) and the whole line evacuated to $< 10^{-4}$ Torr. During this procedure the lower end of the sample tube is immersed in liquid nitrogen, which freezes all the carbon dioxide and water vapour it contains. Nitrogen remains gaseous so that when the line is eventually ready for use, the tube is cracked and the nitrogen pumped away (after measurement on a manometer), leaving the CO_2 and water vapour behind.

These two substances are separated by passing the mixture through cold traps immersed in an alcohol/dry ice slurry, which freezes water vapour but not carbon dioxide. When

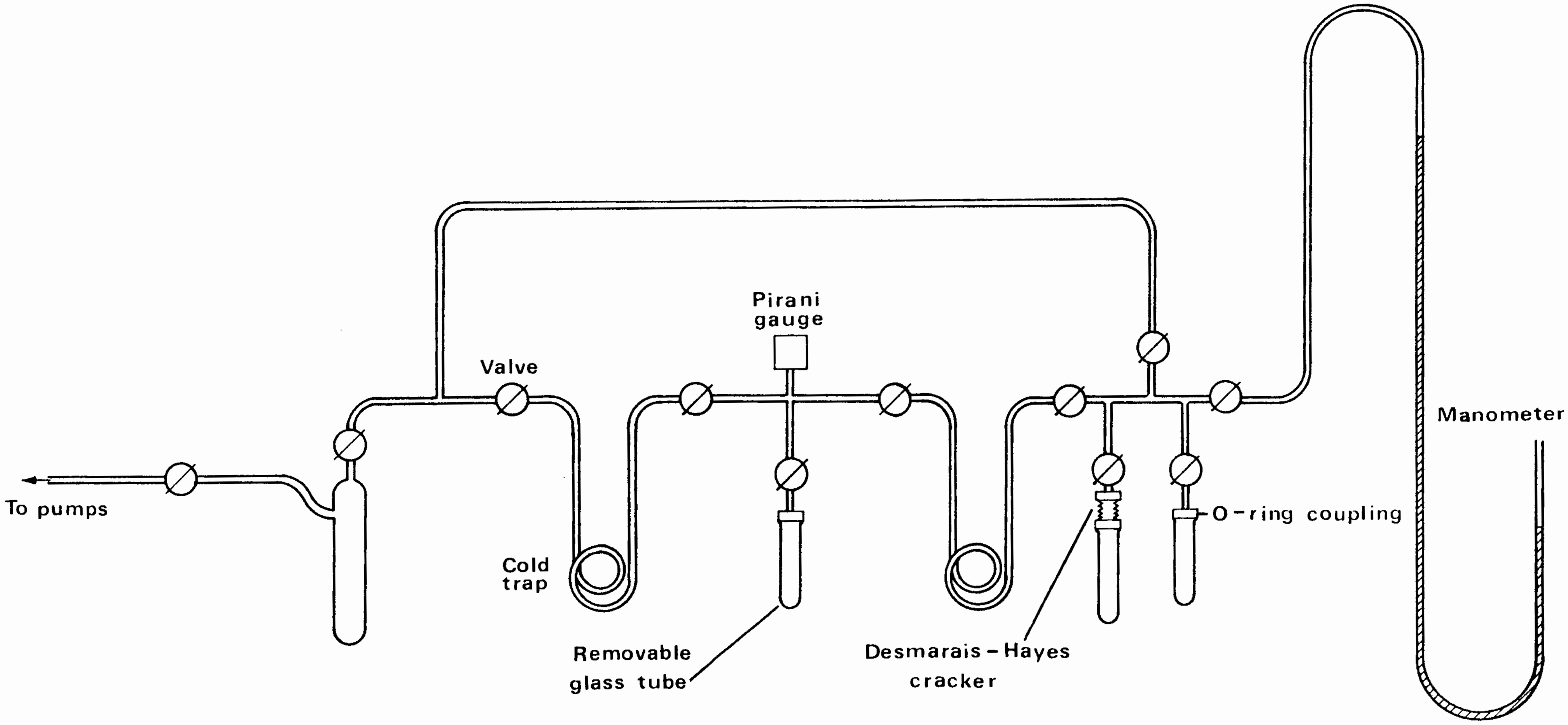


Figure I: Gas separation line in the Archaeometry Laboratory, U.C.T.

sufficiently free of water, the carbon dioxide yield is measured on a manometer and the gas frozen into a clean 6 mm tube with liquid nitrogen. The tube is sealed off with a glassblower's torch and is then ready for insertion into another cracker on the mass spectrometer.

2.3 Measurement on the Mass Spectrometer

The Micromass 602E mass spectrometer used for $\delta^{13}C$ measurements is a 90° sector double-collector instrument with a dual inlet system.

All measurements are done against a laboratory reference gas that has been related to the Chicago PDB marine limestone standard by calibration against six NBS isotopic reference materials, NBS 16, 17, 18, 19, 20 and 21. Results of the analyses are tabulated in Tables VIII - XVIII. The reproducibility of the method is better than 0,1‰.

3. RESULTS

3.1 Terrestrial Animals

There are four tables of the results of analyses of terrestrial animals. Table VIII presents $\delta^{13}C$ readings on collagen from the same species of animals collected in different resource zones. Table IX contains measurements on meat and collagen from the same individuals. Table X is a list of $\delta^{13}C$ values for meat from animals eating a C_3-based diet and Table XI is a comparison of the meat-collagen spacings from herbivores and carnivores collected from one area.

The species of animals initially selected for Table VIII had to fulfil three requirements :

- they had to be important in the diets of prehistoric people in the area;
- they had to occur in more than one of the resource zones;
- they had to be widespread today so that samples would be readily available.

There are five columns in Table VIII, although only three terrestrial resource zones (the coastal plain, the Fold Mountain Belt and the Karoo) have been mentioned up to now. The first, second and fourth columns respectively correspond to these areas. The "Karoo margin" column merely refers to the extreme edge of the Karoo vegetation, almost on the Karoo/Fold Mountain Belt boundary. The reason for the separation of this area from the "Karoo proper" is obvious if one looks at the measurement on the hare collected here. This will be discussed under the section on hares. The "Bushmanland" column is meant to provide animals from an unequivocally C_4 environment for comparison with the other columns, although the northern Cape is actually outside the research area.

These criteria led to the choosing of steenbok, hares, tortoises and dassies. All occur in considerable numbers in the food-waste from archaeological sites (see Table I), and all are still abundant in the south-western Cape today. Steenbok are known to include some grass in their diets (Smithers, 1966; Dorst & Dandelot, 1970; Adams, 1980), so their $\delta^{13}C$ values were expected to change along a transect from the coastal plain to the Karoo. Steenbok were chosen in preference to grysbok or grey duiker, since the latter two are virtually pure browsers (Smithers, 1966; Dorst & Dandelot, 1970; Adams, 1980). Their $\delta^{13}C$ values would not be expected to change from the C_3bushes/C_3 grass of the coastal region to the C_3bushes/C_4 grass of the Karoo. In addition, grysbok are restricted to habitats within the fynbos vegetation type, and so are not found in the Karoo (Bigalke, 1978). The values for steenbok do indeed change from -19,4 to -21,4‰ at the coast to -17,4‰ in the Karoo. This presumably reflects an increase of at least 2‰ in the $\delta^{13}C$ value of the food being consumed. Adams (1980) observed two steenbok feeding in the Strandveld, and found that the frequency of grass in their diets was

9.5% and 4,5% respectively; the rest of the time they were browsing. The Karoo steenbok was probably eating more than 10% grass, since a change of $\delta^{13}C$ value from -26,5‰ to -12,5‰ in only 10% of its diet would probably be insufficient to increase the average $\delta^{13}C$ value of the whole diet by 2%. At least in the spring, more grass is available in the Karoo than in the Strandveld and so a mixed feeder would probably eat more of it. John Glyphis and Gillian Puttick (1980) in a study of Raphicerus feeding habits in a Strandveld community, found that these animals altered their diets seasonally so as to make the best use of fresh new plant growth and to avoid the secondary chemicals that accumulate in many plants at certain times of year. In summer, all vegetation is more or less equally utilised, in autumn there is a strong preference for broad-leaved shrubs, and in winter plants in the ground layer of the vegetation are preferred, probably because of the growth of winter grass. The steenbok from Bushmanland is slightly less enriched in ^{13}C than the one from the Karoo in the research area : this may be due to individual variation (see below) or perhaps it was browsing more and grazing less.

Several species of hare occur in the south-western Cape, the most common being Lepus capensis, the Cape hare; Lepus saxatilis, the bush or scrub hare, Bunolagus monticularis, the Bushman hare and Pronolagus rupestris, the red rock hare, are also found. All feed almost entirely on grass (Smithers, 1966; Dorst & Dandelot, 1970). Lepus capensis was collected from a variety of localities. The $\delta^{13}C$ values for its collagen range from -18,0‰ and -20,0‰ on the coastal plain to -15,1‰ in the northern Cape (see Table VIII). The coastal readings fall more or less within the range of values for other animals in this zone, perhaps lying slightly to the positive side. A larger sample would be required to show whether this is merely individual variation, or reflects some real, slight difference. The specimen from the Karoo margin (-21,0‰) is extremely interesting : although it was collected in an area of distinctly Karoo vegetation (Acock's succulent Karoo), it was only a few kilometres from the Karoo/fynbos boundary, where the grass species must still be predominantly C_3. Meat (but not collagen) from two individuals from the Fold Mountain Belt was also analysed. The results are, as expected, typically C_3 (Table X).

At the beginning of the sampling programme, it was hoped that tortoises too would yield some environmental information due to grass in their diet. Tortoises are easy to collect, and the carapaces of dead animals common and readily identifiable, so a large collection of specimens was amassed. Those from the coastal plain, the mountains and the Karoo margin are Chersina angulata, and those from the northern Cape Psammobates tentorius verroxii. Very little information on tortoise diet is available : in fact there is no reliable published study. Dr Bill Branch of the Port Elizabeth Museum is monitoring the activities of a group of Chersina angulata in the eastern Cape, and he has a collection of about 50 as yet unidentified plants that he has watched tortoises consume. Most are small herbaceous annuals or weeds. There are no grasses, and perennial bushes seem to be browsed rarely, except perhaps as small seedlings (Branch, pers.comm.). The vegetation in the eastern Cape is of course very different from that in the western Cape, but this kind of picture would certainly fit in with the $\delta^{13}C$ values in Table VIII, which show pure C_3 diets. Remarks made by herpetologists working in the research area confirm that tortoises are not usually seen eating grass in the wild, and are reluctant to do so in captivity (John Greig & Atherton de Villiers, pers.comm.). John Greig also mentioned that tortoises in vegetation rich in succulent plants, such as the Strandveld, have been seen eating these and that they are often attracted to a plant by brightly coloured flowers, which they then consume. This does not seem to be a behaviour pattern likely to lead to the consumption of grasses, which have inconspicuous flowers. The $\delta^{13}C$ values of tortoises in Table VIII are remarkably consistent, and clearly show an entirely C_3 diet. Although this means that these animals cannot be used as environmental indicators, it is useful to know that such an important component of prehistoric human diet would have contributed a C_3-derived isotopic signature in any environment.

Dassies, too, were such a regular item of diet for Holocene hunter-gatherers that is was deemed essential to measure their $\delta^{13}C$ values. There is some doubt as to the details of their diet : Milton (1978) has suggested that Procavia capensis browsing and grazing activity maintains the areas bare of vegetation often seen surrounding rocky outcrops in the western Cape. This means that they would eat a mixture of bushes, annual weeds and grasses. Shortridge (1934) and Smithers (1966) both claim that P. capensis eats leaves, grass, twigs and fruits and berries. Dorst and Dandelot say that "they feed mostly on grass but also on berries, small fruits, bark, lichens and leaves" (Dorst & Dandelot, 1970: 153).

However, the isotope values for dassie collagen in Table VIII reflect a diet made up more or less entirely of bushes and herbaceous plants, with little or no grass.

The specimen from the Karoo yields a value right in the middle of the C_3-derived range, whereas all the other animals from this area reflect a C_4 grass component in their diets. It therefore seems that dassies, like tortoises, are pure browsers and will have C_3-derived $\delta^{13}C$ values in any environment in the western Cape. It would be interesting to analyse some dassies from elsewhere in South Africa to see whether this pattern is confirmed.

As the animal sampling programme progressed, other species were added to the short list above. Springbok were readily available from the coastal plain, and from the Karoo. They are really an arid environment species not found on the coastal plain in historic times, although they are recorded from the Olifants River Valley (Skead, 1980). However, they are mixed feeders (Shortridge, 1934; Smithers, 1966; Dorst & Dandelot, 1970), and their isotope ratios are probably not unlike those of other ungulates that did occur in the area, but no longer do so. The specimen from the Karoo is 1,9 to 2,6‰ more positive than those from the coast. An animal from the northern Cape is somewhat more positive still (-18,4‰ compared with -19,0‰). This is certainly within the range of individual variation, but like many mixed feeders, springbok probably change their proportions of browsing and grazing according to the relative availability of bush and grass in their immediate environment (see comments in discussion of values for steenbok). Vogel (1978b) reports a value of -16,5‰ for a springbok from Keetmanshoop in Namibia (Table IX).

Dune mole rats, too, are mixed feeders. They are entirely herbivorous, but eat roots, stems, leaves, bulbs, tubers and grasses and the structure of their gut seems adapted to a high-bulk, low-nutrient diet (Jarvis, pers.comm.). The $\delta^{13}C$ values of the specimens from the coastal plain (-22,1‰, -20,3‰ and -17,8‰) and from the Karoo margin (-19,2‰) are mainly C_3-derived. The latter value confirms the suggestion made in the discussion of the hare from the Karoo margin : namely, that there is a gradual change-over from C_3 grasses in the Fold Mountain Belt to C_4 grasses in the Karoo. It seems a much more gradual change than that between vegetation types; a distinct change in vegetation type coinciding with the geological boundary between sandstone and shale is visible to the west of the locality where these samples were collected.

Unfortuantely no dune mole rats could be obtained from the 'Karoo proper' and it may be that they do not occur further into the Karoo, preferring the sandy soils of the coast (Jarvis, pers.comm.).

The isotope ratios of herbivores shown to be partly grazers (steenbok, hares, springbok and dune mole rats) and those shown to be pure browsers (tortoises and dassies) are almost indistinguishable in specimens collected on the coastal plain. One can infer from this that even grazing animals on the coastal plain either do not eat C_4 grasses at all, or consume such small quantities that they are isotopically insignificant. The only exception is one hare that is relatively enriched in ^{13}C (-18‰) and may have been eating some C_4 grasses or perhaps even some seaweed. C_4 grasses do occur in the coastal plain, and Themeda triandra and Cymbopogon spp. are regarded as typical of certain plant communities (Acocks, 1953), although they are never common. Quite possibly, herbivores avoid them when other species are available (see discussion in previous chapter).

The last two animals listed in Table VIII were not important food sources for prehistoric people. Baboons were included for an entirely different reason : they eat many of the same items, particularly plants, that Holocene hunter-gatherers did. Their diet is largely vegetable, consisting of many species of corms, roots, berries and also the seeds, young shoots and juicy lower stems of grasses. Some animal food is consumed, especially locusts, caterpillars and termites (Dorst & Dandelot, 1979; Davidge, 1976). Just as for the herbivorous animals already discussed, the boundary between an entirely C_3-based and a partly C_4-based diet for baboons occurs at the Fold Mountain Belt/Karoo interface.

Bat-eared foxes are recent immigrants to the research area (except perhaps in the extreme east). This species is extending its range southwards and westwards from the Karoo into the south-western Cape, which may be an indication of the increasing aridification of the fynbos biome (Hendey, 1974, 1983). It is principally insectivorous, eating termites and other large insects, but will also take eggs and the young of ground-nesting birds, lizards, berries and tuberous roots (Shortridge, 1934; Smithers, 1966; Dorst & Dandelot, 1970).

Table VIII shows that its collagen $\delta^{13}C$ ratios are C_3-based on the coastal plain and in the Fold Mountain Belt, but include a C_4 component in the Karoo and the northern Cape. In some cases the readings are comparable to those of herbivores from the same zone (at the coast and in the mountains), but the specimen from the Karoo is isotopically much heavier than the herbivorous animals in that column. This may relate to the proportion of the diet that is made up of animal food.

It is very clear from Table VIII that indigenous animal foods from the western Cape are entirely C_3-based in the coastal plain and the Fold Mountain Belt. These two zones cannot be distinguished from one another, and their browsing and grazing animals have virtually identical stable carbon isotope ratios. The C_3 zone extends a little way into the succulent Karoo vegetation type, but grazing animals soon start to reflect a C_4 grass component in the latter environment. Animals collected along the road from Ceres to Aspoort have $\delta^{13}C$ values comparable to specimens from the northern Cape, an unequivocally C_4-grass zone. Animals that do not eat grass (tortoises, dassies) still have C_3-

derived $\delta^{13}C$ values, and these are within the range of variation for the same species from the coastal plain and the Folded Mountain Belt. Herbivorous animals that eat some grass (steenbok, springbok and baboons) show a $\delta^{13}C$ increase of about 2 - 3‰. The magnitude of this shift is almost low enough to be attributed to individual variation, but because it is a consistent increase in four separate species with widely differing diets, one may confidently accept that it represents the crossing of a real ecological boundary.

The numbers and distributions of samples in Table VIII are obviously far from ideal. In order to provide absolutely watertight answers to the questions posed in the previous chapter, one would need large numbers (probably at least 30 individuals) of each animal from each ecological zone. This would provide a statistically significant data base. Unfortunately such a sample would take many years to collect, or require the wholesale slaughter of the few remaining indigenous animals in the south-western Cape. The picture that emerges from the samples we already have seems sufficiently clear and consistent to allow us to draw some conclusions, although perhaps not as many as one would like.

Two other pieces of information can be extracted from Table VIII. The first is the amount of $\delta^{13}C$ variation one can expect amongst different individuals of the same species in the same environment. Two baboons from Boontjieskloof, three springbok from Churchhaven and three dassies and two dune mole rats from Eland's Bay were measured. The range of $\delta^{13}C$ values in each set of results varied from 0‰ to 2,5‰. The two baboons with identical carbon isotope ratios were both juveniles found drowned in a farm dam. They were the same age, had probably been members of the same troop, and as such would be quite likely to have had almost identical diets. The three dassies from Eland's Bay are a better sample : all were adult but they were of different ages, and collected at different times. The most positive and most negative $\delta^{13}C$ values differed by 2,2‰, which is in good agreement with the figure obtained for animals raised in a laboratory on a controlled diet. Their individual variation was 2‰ (De Niro & Epstein, 1978).

The other question that can now be answered relates to possible trends in the isotopic composition of animals where there is a climatic gradient (within one vegetation type) (e.g. from the relatively high rainfall of the Cape Peninsula to the low rainfall of Eland's Bay). The figures in Table VIII do reveal such a trend : in the three cases in which the same species of animal could be obtained from Cape Point and from Eland's Bay, the values from Eland's Bay are always heavier (more positive) than those from

Cape Point. The difference is 2,2 to 2,8‰ for tortoises, 2‰ for steenbok and 1,8 to 4,3‰ for dune mole rats. This is a considerable shift, comparable to that between the coastal plain and the Karoo.

Table IX presents the results of analyses of different tissues from the same individual for three kinds of animals : tortoises, springbok and bat-eared foxes.

There are eight tortoises, six of which are Chersina angulata, while two are Psammobates tentorius verroxii. Meat and collagen show C_3-derived $\delta^{13}C$ values, and, in Chersina angulata, the collagen is 2,2 ± 0,6‰ (mean ± one standard deviation) more positive than the meat. The mean value for the collagen is -22,4 ± 1,4‰. Referring back to Table VIII, this seems somewhat more negative than the collagen readings for most animals with a C_3 diet. Perhaps this is due to some slight dietary preference in tortoises or maybe the diet-collagen spacing is different for cold-blooded tortoises and warm-blooded mammals. (There is, of course, a chance that the difference - if it is significant - is caused by the mammals consuming a very small amount of C_4 grass.) The two Psammobates tentorius verroxii yielded extremely interesting results : the values for UCT 781 are no different from those for C. angulata, but UCT 782 has meat more positive than its collagen. This is the first time, to the author's knowledge, that this phenomenon has been reported. The analyses were repeated to check their accuracy, yielding essentially the same results (the small differences are due merely to the repeat analyses having been done on different samples). There is no obvious reason for this inversion of expected $^{13}C/^{12}C$ ratios; almost nothing is known about tortoise metabolism and processes of collagen synthesis, but there may be some biochemical difference between reptiles and mammals that would explain it. It is certainly a topic for future investigation.

Five springbok were analysed in this study, and three values obtained from work reported by Vogel (1978b). Their average meat-collagen spacing is 2,6 ± 0,9‰, and that for five bat-eared foxes 2,2 ± 0,7‰. When one compares these with the average for _C_. _angulata_ (2,2 ± 0,6‰), all three figures are remarkably similar, considering the diversity of the animals (a reptile, an ungulate and a carnivore). The values are too scattered to enable the detection of different meat-collagen spacings in C_3-based as against C_4-based food-webs. Although additional analyses might reveal information of use to animal physiologists, these data seem adequate for the reconstruction of archaeological diets. They enable estimation of the carbon isotope ratios of the meat that was actually eaten from analyses of the bones recovered from archaeological sites.

Table XI contains the $\delta^{13}C$ values of meat and collagen from three herbivores and two carnivores collected from one small area. The meat-collagen spacings are not significantly different in the two groups (2,6, 2,5 and 2,8‰ vs 2,6 and 1,9‰). Assuming that the herbivores are eating C_3 plants whose average $\delta^{13}C$ value is -26,5‰, their diet-collagen spacing is +5,9‰. Carnivores eating the meat of these herbivores have a diet-collagen spacing of +4,7‰. There has been some speculation (an der Merwe, 1982) that spacings between different tissues of an animal, and quite possibly diet-tissue spacings as well, may be smaller when the diet contains a large proportion of animal products. This may relate to the possible incorporation of 'blocks' of ready-made proteins, carbohydrates and fats, or parts thereof, into the bodies of carnivores. Herbivores, perhaps, have to break down these compounds from plants into their constituent building-blocks before recombining them into forms more appropriate for animals. This would be likely to involve a greater degree of fractionation than occurs in carnivores. If this is true one would expect the meat-collagen spacing in carnivores to be smaller than in herbivores, but it seems so variable that large numbers of samples would be required to test this hypothesis.

The diet-collagen spacing of +5,9‰ for herbivores seems reasonable. It is similar to Vogel's (1978b) value of +6,1‰ for South African ungulates, although re-calculation of this figure from the data actually presented in his paper yields a value of 5,3‰. This is closer to the figure for human populations in Woodland North America given by van der Merwe and Vogel (1978), i.e. +5,1‰. Chisholm *et al*. (1982) calculated that this value should be +6,1 ± 0,4‰ for the prehistoric human population of the Ottawa Valley. Differences in the components of the diet, the kind of animal being studied or errors in the estimation of the $\delta^{13}C$ value of the diet probably account for some of this variation. We know, for instance, that the diet-collagen spacing in small animals with a high metabolic rate and a short lifespan is different from that for larger animals (De Niro & Epstein (1978) obtained values of +2,8‰ and +3,9‰ for mice). It is, therefore, probably unrealistic to group small herbivores (e.g. hares) together with large antelope. Nevertheless, even a rough estimate of diet-collagen spacings provides a source of information about both past and present environments from which animal bones are available.

Table X lists the $\delta^{13}C$ values of 15 meat samples from animals from C_3 vegetation zones (the coastal plain, the Fold Mountain Belt and the Karoo margin). They range from -20,9‰ for a francolin (a seed-eater) to -25,6‰ for a tortoise, with a mean of -23,6 ± 1,3‰. This is probably a reasonable estimate for the stable carbon isotope ratio of the terrestrial animal component in the diet of Holocene people in the south-western Cape. (It equals the average for browzing ungulates in East and South Africa (Lee Thorp, unpublished data; Vogel, 1978b).)

Tables VIII - XI thus provide answers to most of the questions about $\delta^{13}C$ values of terrestrial animals, that were discussed in Chapter 5. We now know that animals on the coastal plain, in the Fold Mountain Belt and even on the edge of the Karoo have C_3-based diets, and that the average $\delta^{13}C$ value of their meat is likely to be about -23,6‰. Individual variation between animals of the same species raised on the same diet can be up to 2,5‰ and climatic gradients within the western half of the research area can affect the isotope ratios by a similar amount. There does not, however, seem to be any difference between specimens from Vogel's original 5 - 25% C_4 grass area (e.g. those from Hopefield) and specimens from the 0 - 5% area. A prehistoric hunter-gatherer would have had to go some distance into the Karoo to find animals that were isotopically heavier from eating C_4 grasses, and even then, they would be likely to be only 2 - 3‰ more positive than those from the coast. Some important items in prehistoric menus (tortoises, dassies) would not show any shift at all, since their diets do not include grasses. The meat-collagen spacings of three kinds of animals measured (tortoises, springbok and bat-eared foxes) averaged out fairly consistently at just over 2‰, although individual variation was too great to enable one to see if the values were different in C_3 and C_4 environments, or for carnivores compared with herbivores. Diet-collagen spacings seem slightly lower for carnivores than for herbivores.

3.2 Terrestrial Plants

$\delta^{13}C$ values for edible parts of plants from the research area are presented in Table XII. The majority are clearly C_3; the exceptions are two species of succulent plants from the Karoo (Caralluma mammillaris and Hoodia sp.) and Hydnora africana from Namaqualand. The latter is a parasite, usually on the roots of Euphorbia spp. The specimen analysed was parasitic on Euphorbia gummifera in a hot, dry area. Euphorbia is largely a CAM genus (Mooney et al., 1977) and so could easily supply isotopically heavy photosynthetic products to a parasite in this kind of environment. It is unlikely that any of these plants were ever very important as food : Hoodia and Caralluma being consumed more for their water content than their kilojoule value (Smith, 1966; Archer, 1982). No information is available on the nutritional quality of Hydnora.

The other plants listed are all C_3 species. The stable carbon isotope ratios of their edible parts are slightly different from the standard value for C_3 foliage (-26,5‰), but the variation is random. Some are more positive than -26,5‰, some more negative, with a mean of -25,4 ± 1,8‰. Even Aponogeton distyachos, a fresh-water plant, yields an entirely unremarkable value of -26,9‰. Fresh-water plants are known to be C_3, on the whole, but they are affected by factors such as pH, water state and carbon dioxide source (Broecker & Walton, 1959; Oana & Deevey, 1960). They can also be very light due to the 'lake effect' which is similar to the 'canopy effect'. Vogel has reported some values approaching -50‰ for plants from German lakes (Vogel, 1980).

3.2.1 Variability in the $\delta^{13}C$ Values of Terrestrial Plants

Figure 2 contains more specific information on (1) variation in $\delta^{13}C$ between different tissues in the same plant, (2) between the same tissue in different individuals in a group of plants collected at the same time and place, and (3) between samples of the same species collected at different times of the year. All these measurements were done on Watsonia pyramidata, a large species of Watsonia with pink flowers. About five individuals were dug up from the same large patch of plants in a suburban garden each month for a year. In a homogenised sample of five individuals collected in November 1982, the new corms had a $\delta^{13}C$ value of -27,9‰, while the flowers were -24,5‰, a difference of 3,4‰ between different tissues of the same plants.

These spacings can vary considerably from plant to plant : the differences between the new corms and the old corms of six specimens collected in July 1983 varied from 0,1 to 1,4‰.

The latter sample and that collected in May 1983 give an idea of the individual variation to be expected in the same tissues in different plants. The $\delta^{13}C$ values of new corms of five plants collected in May varied from one another by up to 1‰. This figure rose to 1,8‰ for six new corms collected in July 1983, while it was 1,3‰ for the corresponding old corms. Interestingly 1,8‰ is quite similar to the maximum value of 2,5‰ obtained for individual variation between animal samples (Table VIII).

Figure 2 also shows the cyclical seasonal variation that occurs in the $\delta^{13}C$ values of Watsonia pyramidata corms. The most positive and most negative values for homogenised samples of five new corms were -23,2‰ and -29,2‰ : a difference of 6‰. The curve approximates a sinusoidal wave with the most positive values occurring in summer (December - February), the period during which the plant is dormant after flowering. $\delta^{13}C$ values for the new corms remain more or less constant during these months becoming increasingly negative as the plant initiates new growth in autumn and the starch stored in the corm is used to make new leaves and flowers. The isotope ratios are at

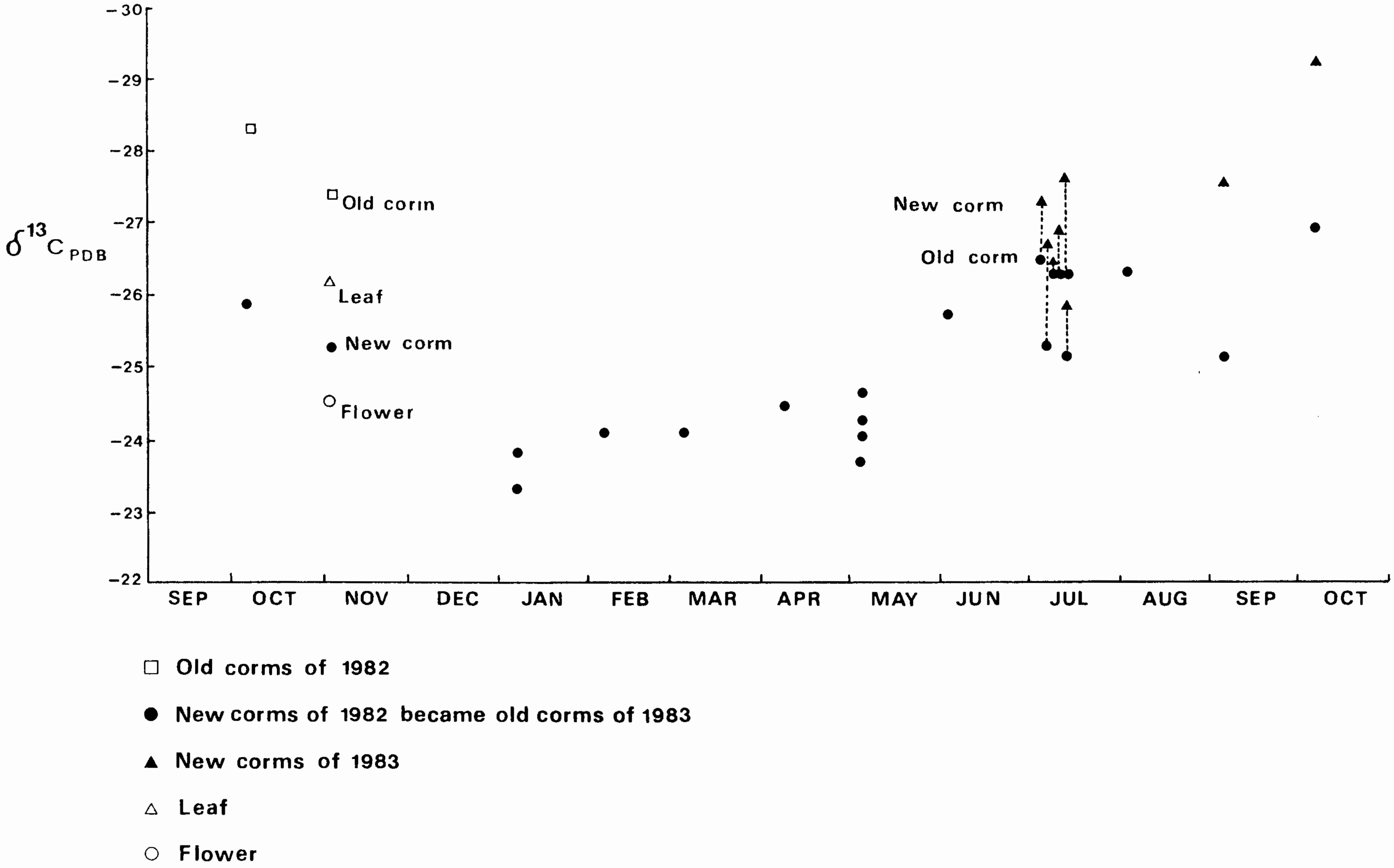


Figure 2:

Seasonal changes in $\delta^{13}C$ values of <u>Watsonia pyramidata</u>

their lightest when the plants are flowering (in September - October). They then rapidly become heavier, as the new corm grows, until the period of summer dormancy, after which the cycle is repeated. Each year's 'new corms' will become the following year's 'old corms'.

The cycle undergone by photosynthetic products in plants such as Watsonia is a complex one; fortunately only a small part of it is of direct importance to archaeologists. Corms are most palatable in the summer - at this stage they are white, floury and of maximum size. From autumn onwards astringent waste-products are deposited in them and they become pinkish, resinous and unpleasant to eat. The new corms that start to be formed are white, but they are very small until after the flowering season. Thus the best time to eat them is in summer, when the $\delta^{13}C$ values are at their most positive. It is likely that only the most positive part of the range of isotope values described above will be important in the human food-web; for this sample, perhaps, -23‰ to -25‰.

The graph in Figure 2 is of the same shape as those described by Lowdon and Dyck (1974) and Leavitt and Long (1982). It is not as neat, however, since these authors were measuring seasonal differences in trees, and so could take monthly samples from the same plant. They found differences of 6‰ and 3‰ respectively in maple and juniper leaves at different times of year.

Figure 2 thus provides an estimate of the intra- and inter-individual $\delta^{13}C$ variation and also the seasonal variation in at least one important food plant in the south-western Cape. Not all of this is likely to be reflected in the human food-web, since Watsonias were probably eaten only at certain times of year. $\delta^{13}C$ variation due either to individual differences or to the season of sampling would be unlikely to exceed 2‰ in Watsonia pyramidata. This is probably true for other plants as well, both because Watsonia has more strongly-differentiated seasonal growth phases than most other plants, and because of the similar results reported by Lowdon and Dyck (1974) and by Leavitt and Long (1982). As in the animal sample, differences of this magnitude would be unlikely to have much effect on the average values for C_3 plant foods in Table XII. They would probably not constitute a major source of error in calculations of the isotopic signature of the human food-web in the south-western Cape.

3.3 The Marine Foodweb

The final set of samples of indigenous foods consists of marine organisms available at the coast.

3.3.1 Primary Producers - Algae

A range of algae was collected, not because they were eaten by humans (although they might have been) but because they are so important in determining the isotope ratios of organisms higher in the food-web. Their $\delta^{13}C$ values ranged from -34,5‰ to -9‰. The most isotopically negative species tend to be deep-water red weeds, whereas the most positive are intertidal greens (see Table XIV). When these results are drawn out on a histogram (Figure 3), one can see that the red seaweeds encompass almost the whole range of values, whereas greens and browns tend to cluster at the positive end. There is a great deal of overlap between -9‰ and -25‰, but only red weeds exhibit values as negative as -30 to -24‰.

On further examination of the data, some correlation between depth and $\delta^{13}C$ value seems apparent. There is a certain amount of zonation of green, brown and red seaweeds on the sub-littoral shore : red light, with its long wavelength, is filtered out by only a few centimetres of seawater, so that seaweeds with complementary pigmentation (green) can only survive in the intertidal or shallow edge of the subtidal zone. Yellow-green light penetrates much further into the water, so that red seaweeds can live at far greater depths. Brown weeds are most common at intermediate depths. On the South African coast, photosynthetically significant light is limited to the top 30 metres of sea-water, and this determines the boundaries of possible seaweed colonisation (Simons, 1976).

Of the species in Table XIV, the most isotopically negative are those collected from the deepest water (although this was not very deep, only 6 - 8 m). These include *Thamnophyllis discigera*, *Kallymenia agardhii*, *Botryocarpa prolifera*, *Hymenena venosa* and *Neuroglossum binderianum*. All are reds, but some other reds collected from shallow water had comparatively positive carbon isotope ratios (*Aeodes orbitosa*, *Gelidium pristoides* and *Porphyra capensis*). To test whether deep-water seaweeds do indeed have more negative $\delta^{13}C$ values than those from shallow-water, simultaneous collections of the same species from deep (25 - 29 m) and shallow (a few metres) water were made at Vulcan Rock off Hout Bay. The results are shown in Table XV. Depth clearly does contribute to very negative carbon isotope ratios : in all cases the deeper samples were more negative than the shallow ones, but the difference varied from 1,5‰ (*Hymenena venosa*) to 11,3‰ (*Pachymenia cornea*). Several of the species with very light isotopic ratios displayed these values in shallow as well as in deep water : *Neuroglossum binderianum*, *Hymenena venosa* and *Botryocarpa prolifera* all had $\delta^{13}C$ values below -30‰ in both samples. Others were comparatively positive in both samples. The results for *Ecklonia maxima* and Laminaria pallida were interesting : previous measurements had yielded C_3-like values for Laminaria (-20,9‰ at Oudekraal, -19,0‰ at Paternoster) and C_4-like values for Ecklonia (-12,0‰ at Oudekraal and -14,1‰ at Paternoster). The new samples gave values of -16 to -17‰ for both species in shallow water, and -22 to -23‰ in deep water. Earlier samples of Laminaria were probably from much deeper water than those of Ecklonia.

Although depth is a contributing factor to the final $\delta^{13}C$ value of a marine alga, there must also be some other reasons for the large range of values between different species. Physiological work has revealed that some algae contain enzymes of C_4 acid metabolism such as malate dehydrogenase (Ting, 1976). Karekar and Joshi (1973) also observed C_4 photosynthesis in certain marine algae, but noted that only aspartate seems to be produced.

Other algae contain ribulose diphosphate (Steemann Nielsen, 1975), or exhibit features characteristic of C_3 photosynthesis, such as a carbon dioxide compensation point. This is the point at which an equilibrium is reached between the rate of photosynthetic carbon dioxide fixation and the rate of carbon dioxide loss from the plant in light and dark respiration. Laboratory values are typically 30 - 80 ppm CO_2 ($\mu\ell CO_2/\ell$) for C_3 plants and low values near 0 ppm for C_4 plants. Tolbert and Garey (1976) measured this feature in a number of marine algae, some of them the same species as Ting used in his study of NADH malate dehydrogenase activity. The results, together with the $\delta^{13}C$ values given by Black and Bender (1976) are tabulated in Table XVI. Some of the carbon dioxide compensation points approach those of C_4 plants (e.g. the value for Enteromorpha) while others (Avrainvillea erecta) are more like C_3 plants. Unfortunately there does not seem to be any clear correlation between CO_2 compensation point, enzyme activity and $\delta^{13}C$ value. It may be that all the measurements would have to be done on the same individual plants for these relationships to be perceived. Factors unimportant in terrestrial photosynthesis have to be taken into account in interpreting this kind of data in marine algae : both Ting (1976) and Hough (1976) have suggested that there may be extensive refixation of respired carbon dioxide in the sea because the diffusional resistance of seawater to carbon dioxide is 10^5 times that of air.

In spite of the very unsatisfactory state of theoretical knowledge of marine algal photosynthesis, a number of $\delta^{13}C$ values have been published (Wickman, 1952; Craig, 1953; Park & Epstein, 1961; Parker, 1964; Sackett et al., 1965; Smith & Epstein, 1971; Black & Bender, 1976; De Niro & Epstein, 1981; Schell, 1983). These are distributed, on the whole, in a very similar manner to the samples from the western Cape (see Figure 4), except that the number of very negative values reported is far fewer. Many measurements show considerable ^{13}C enrichment, leading to some speculation as to whether bicarbonate as well as dissolved carbon dioxide could be acting as a source of carbon (Craig, 1954). Vogel (1980) has pointed out that it is unnecessary to assume this in explaining positive $\delta^{13}C$ values : the increased diffusional resistance to CO_2 in water compared with air can account for any differences. Bicarbonate may act as a carbon reservoir, but the fractionation associated with its equilibrium conversion to carbon dioxide ensures that the gas is isotopically light (Deuser & Degens, 1967).

The algae reported in the literature are more or less evenly divided between green, brown and red species, and are probably largely shallow-water plants. Only one is isotopically lighter than -30‰ : this is a sample of *Halymenia durvillaei* from Cape Flattery, Australia measured by Black and Bender (1976). They remarked that

> "although we conclude that RUDP carboxylase is involved in CO_2 fixation in *Halymenia* it also appears that *Halymenia* has some features of CO_2 assimilation which are not clear, and which should be investigated further, since this is an unusual degree of ^{12}C enrichment"

(Black & Bender, 1976: 28).

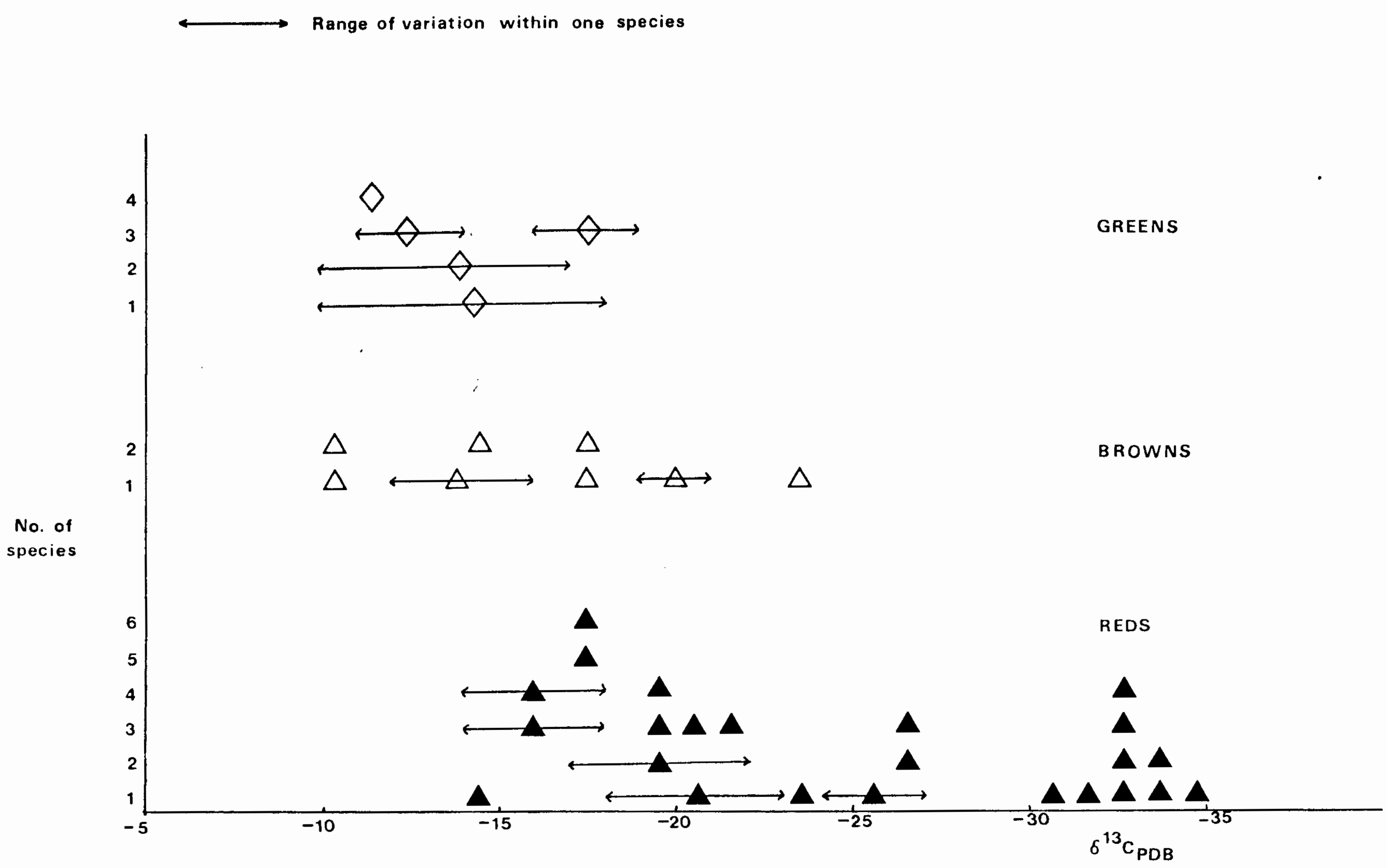


Figure 3: δ^{13}C values of seaweeds from the South-Western Cape

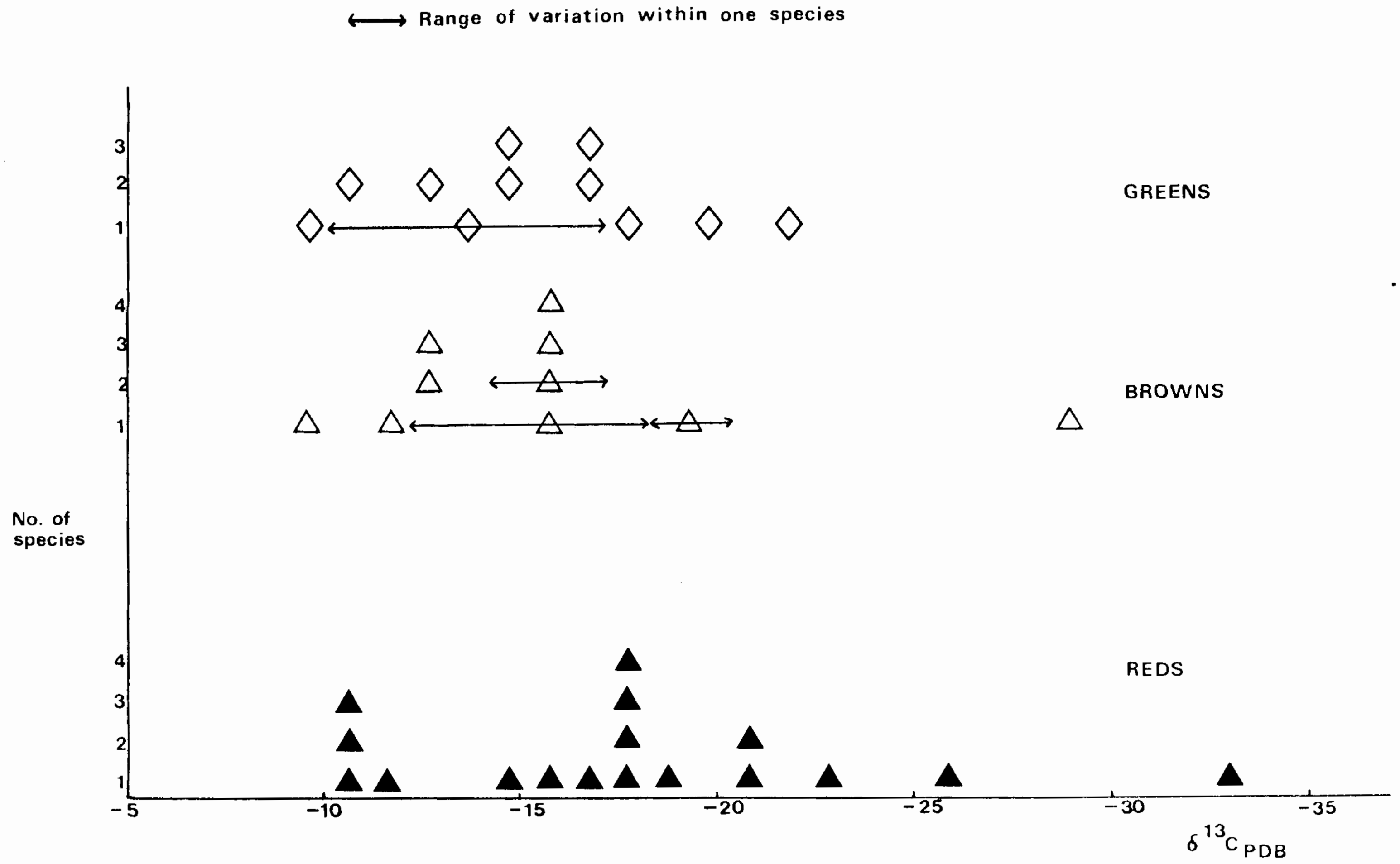


Figure 4: $\delta^{13}C$ values of seaweeds from publications

3.3.2 Marine Fauna

A great deal more work will be needed before the patterning in the $\delta^{13}C$ values of marine algae is well understood. For the purposes of this study, however, it is enough to know the carbon isotope ratios of the detritus formed by mechanically and biologically degraded algae. This depends not only on the original $\delta^{13}C$ values of the different species, but also on their relative abundances. In South African waters, much of the biomass is concentrated in kelp beds : large stands of Laminaria pallida and/or Ecklonia maxima and associated flora and fauna. Ecklonia is the dominant kelp in communities occurring close inshore, while Laminaria predominates in deeper water (Branch & Branch, 1981). Detritus from these seaweeds, together with phytoplankton, provide food for filter-feeders such as mussels, sponges, sea-cucumbers and red bait. As one proceeds up the marine food-chain, the $\delta^{13}C$ values of the organisms become increasingly positive (see Table XVII). Organisms from a range of trophic levels, from filter-feeders (mussels) to scavengers (crayfish) were eaten by prehistoric people. This means that marine-based diets included items with a range of $\delta^{13}C$ values. Probably, they were usually made up of a mixture of the animals catalogued in Table XIII, whose mean value is -15,6 ± 1,6‰ (excluding the whale).

Collagen from an unidentified species of whale had a carbon isotope reading of -20,2‰, much like the values for terrestrial animals with C_3-based diets in Table VIII. Whale meat is therefore likely to have a $\delta^{13}C$ value similar to that of terrestrial animal meat, and to have made the average isotopic signature of marine-based human diets slightly more negative. It is difficult to estimate the contribution whales made to prehistoric diets : whale strandings are regular, if infrequent occurrences along these coasts today. They were probably much more common in the days before commercial hunting drastically reduced whale populations. A single animal would have provided a vast amount of food, which could perhaps have been stored by drying, or by burying in the sand which, when wet, is a saline anaerobic environment.

On average, the $\delta^{13}C$ value of a mixed marine-based diet in the south-western Cape was probably about -16,5‰. This is similar to the figure of -17,8 ± 1,4‰ obtained by Chisholm _et_ _al_. (1982) for the east coast of Canada, a marine environment quite similar to that of the south-western Cape, but colder and therefore isotopically somewhat more negative.

Table XIII also lists the $^{13}C/^{12}C$ ratios of black mussels collected from Eland's Bay at different times of the year. All the values are tightly clustered, with no discernible seasonal variation. Seasonal factors do not, therefore, contribute to the spread of $\delta^{13}C$ values of prehistoric human diets.

4. EXTRAPOLATION BACK INTO THE PAST

The analyses already discussed provide a reasonably complete picture of the modern isotopic ecology of the south-western Cape. These samples were carefully chosen to minimise possible contamination from exotic vegetation (including cultigens). Nevertheless, the possibility that recent ecological disturbances have affected the picture gained must be considered. The kinds of disturbances already discussed (overgrazing, increased fire frequency) have a tremendous impact on plant ecology and community structure, but much less effect on the isotopic character of the vegetation since this is principally determined by climate and, to a lesser extent, geology. The use of modern collections of edible indigenous plants and animals therefore seemed justified, but this assumption obviously requires testing. Moreover, there have probably been some small climatic changes during the Holocene (see Chapter 3) that could well have influenced the distribution of the different vegetation types. In order to ensure that the readings obtained on the modern environment can indeed be used in the interpretation of the $\delta^{13}C$ values of prehistoric human skeletons, a short series of animal bones from an archaeological excavation were also analysed.

The site chosen was Eland's Bay Cave, since this has the longest sequence of deposits of any excavated site in the research area. Only animals of which modern specimens had already been analysed were used, so that the results could be compared. Two species of grazers/mixed feeders were used : hares and steenbok. Browsing animals have been shown to have similar $\delta^{13}C$ values in very different environments (Table VIII, Lee Thorp, 1983), and so cannot be used as environmental indicators. Marine animals can only be expected to show changes in their $\delta^{13}C$ values if the sea temperature changes. An increase in the proportion of C_4 grasses on the coastal plain in prehistoric times is the environmental change most likely to have occurred, and this should be reflected in the $\delta^{13}C$ values of prehistoric grazers or mixed feeders. Such a change would also be the one most likely to invalidate conclusions about prehistoric diets based on the modern dichotomy between the isotopic signatures of marine and coastal terrestrial foods.

A series of prehistoric hare and steenbok bones were chosen from the specimens identified by Richard Klein. The sample of diagnostic faunal material is not large, so only seven bones were chosen. (It is often difficult to tell, especially from post-cranial material, whether the various bones from any excavation unit are from the same animal or not. This problem, together with reluctance to destroy valuable cranial bones, meant that only a few samples were taken, although more may be analysed in the future). The results of the analyses are tabulated in Table XIX.

The δ^{13} values are somewhat surprising and not entirely consistent. Those for steenbok are slightly more positive than the modern readings (-18,5‰ in Layer 6, -17,3‰ and -18,4‰ in Layer 9 and -19,4‰ and -18,6‰ in Layer 12 compared with two values of -19,4‰ for modern steenbok at Eland's Bay). These are the kinds of values one would expect in an environment with more C_4 grass than today. This conclusion is not borne out by the readings on hares (-22,6‰ in Layer 6 and -20,7‰ in Layer 12 compared with modern values of -20,0‰ and -18,0‰ for hares on the coastal plain). These values are, if anything, more <u>negative</u> than the modern ones. Since hares are virtually pure grazers and steenbok mixed feeders, one would expect any increase in C_4 grass in prehistoric times to show up more strongly in hares than in steenbok (as in the 'Bushmanland' column in Table VIII). One can only conclude that the relatively positive $\delta^{13}C$ values for steenbok are not caused by eating C_4 grass; they must have been eating some other plants not favoured by hares, perhaps succulents, or maybe some salt-marsh grasses from the edges of the Verlorevlei estuary (then open to the sea, now cut off from it).

This is obviously a topic for further investigation; more samples from Eland's Bay Cave itself (animals such as buffalo and hartebeest are also represented in the deposits) and other nearby sites will have to be analysed. This should help explain the rather puzzling results above. It is safe, however, to conclude that there has been no major increase in the C_4 grass component of the coastal plain during the time-span represented at Eland's Bay Cave. The isotopic picture gained from analyses of modern animals can therefore be applied to the interpretation of $\delta^{13}C$ results on Holocene human skeletons excavated in the south-western Cape.

5. SUMMARY

The data presented in this chapter allow the estimation of the $\delta^{13}C$ values of prehistoric human diets in each of the four resource zones available to Holocene hunter-gatherers in the south-western Cape, as defined by Parkington (1972, 1976a). Average figures are likely to be about -16,5‰ for marine foods and -24‰ for terrestrial foods on the coastal plain and in the Fold Mountain Belt. In the Karoo, plant foods and the meat of browsing animals have the same isotopic ratios as they would on the coastal plain or in the mountains, but the meat of grazing animals is about 2‰ more positive. There is a slight isotopic gradient from the high rainfall Cape Peninsula to the more arid area around Eland's Bay. In addition, the diet-collagen and meat-collagen isotopic spacings have been measured for several groups of animals, and the individual variation between animals of the same species in the same area assessed. The edible parts of a number of species of plants and marine organisms have been measured, and seasonal and individual variations estimated. The overall impression is that people in the south-western Cape had two distinguishable sources of diet available to them (short of trekking deep into the Karoo), namely seafood at -16,5‰ and terrestrial food at -24‰. A few preliminary archaeological measurements indicate that this pattern is likely to hold true throughout the Holocene. Using these two values, it is now possible to evaluate dietary information and theories about subsistence strategies arrived at from archaeological remains.

CHAPTER 7

ISOTOPIC ANALYSES OF PREHISTORIC HUMAN SKELETONS

In attempting to assess human diets in archaeology, the most direct evidence comes from the human skeletons themselves. The chemical constituents of bones reflect prehistoric diet in a much more direct way than does the food-waste recovered from excavations, which is subject to a number of biases discussed in Chapter 4. In addition, such measurements represent long-term integrations of an individual's diet, probably about 30 years in the case of $\delta^{13}C$ (Stenhouse & Baxter, 1979).

THE SKELETAL SAMPLE

A considerable number of prehistoric human skeletons have been recovered from the south-western Cape. Seventy-four relatively complete individuals (listed in Rawlinson, 1982) are housed in the Anatomy Department of the University of Cape Town or in the South African Museum and are available for study. Unfortunately, a large proportion were collected long ago, or were exposed by eroding sites or by construction projects, and so have little or no contextual information or associated artefactual material. A few are radiocarbon-dated (all these are listed in

Table XX), but the vast majority are not.

In view of current archaeological research objectives in the south-western Cape, particularly the hypotheses advanced about changes in subsistence patterns during the Holocene, only dated skeletons are included in this study. Ten skeletons have radiocarbon dates on the bone itself. Two more (UCT 334 and one of the skeletons from Eland's Bay) come from well-dated excavations, so that one can estimate their ages from their stratigraphic positions. An additional half dozen or so have associated artefactual material that enables rough dating - usually pottery which, whenever so far found in western Cape sites, has dated to the last two millenia. A basic assumption here is that the skeleton is directly associated with the pottery. Although this cannot always be demonstrated to be the case, it is probably true for the majority of skeletons listed in Table XX.

SKELETONS IN THE ARCHAEOLOGICAL CONTEXT

The total number of skeletons dated by all of these methods is small - a mere eighteen individuals. Moreover, only four are 'inland' specimens (all from or near the Olifants River Valley) (see Table XX and Map VII). A sample this size is obviously not amenable to statistical analysis especially after having been divided into six categories, and so the comments below should be regarded as qualitative.

The skeletons were divided into three chronological categories : older than 8 000 B.P., 4 000 - 2 000 B.P. and younger than 2 000 B.P. Those in the first category pre-date the hiatus in human activity at Eland's Bay. They are the remains of people who were living at the time at which the sea-level was rising to more or less its present position as the climate warmed up after the last Ice Age. They were probably still hunting some of the large grazing animals that are now extinct (see Chapter 3). Their life-style is likely to have been different from that of Later Holocene people in a number of ways, including social organisation, tool technology and subsistence behaviour.

There are no coastal skeletons dating to between 8 000 - 4 000 B.P. Sequences at Eland's Bay certainly show a real absence of prehistoric settlement there at this time, but there is no data as yet for other sections of the coast, so we have no way of knowing how localised this phenomenon was. One inland skeleton (UCT 331) is dated to about 7 000 B.P. - it comes from an isolated grave in the Nardouwsberg, near the site of De Hangen.

Four coastal and one inland skeleton fall into the 4 000 - 2 000 B.P. category. Unfortunately, only one coastal skeleton is from Eland's Bay. This is the time for which

Parkington's classic version of the seasonal mobility hypothesis is most plausible. There are plenty of sites, both inland and at the coast, and pastoralism was not yet a disruptive force. People lived by hunting (mostly small animals), and by gathering, although plant foods were perhaps not as important as they were later to become.

The post-2 000 B.P. time period must have been one of rapidly changing life-styles as pastoralism spread through the research area Indigenous herds of wild animals were probably partly replaced by domestic stock. Parkington (1983, in prep.) has hypothesized that the focus of hunter-gatherer settlement shifted to areas less attractive to pastoralists seeking grazing for their animals, perhaps the sea shore and rocky, mountainous areas, instead of the coastal foreland.

STABLE CARBON ISOTOPE RATIOS OF SKELETONS

Viewed against this archaeological background, the $\delta^{13}C$ values of the skeletons listed in Table XX are startling. The isotope ratios of the coastal skeletons are markedly different from those of the inland ones, and they are very consistent right throughout the Holocene. $^{13}C/^{12}C$ measurements for the coastal group vary from -11,2‰ to -15,1‰ with a mean of -13,5 ± 1,4‰. Inland skeletons have isotopic ratios between -17,3‰ and -19,6‰. Additional unpublished $\delta^{13}C$ values for 15 coastal skeletons are available, listed in Rawlinson (1982); they are undated finds without cultural associations. If these values are taken into account, the mean for the coastal group becomes -13,9 ± 1,8‰.

This is not at all what one would have predicted from the archaeology of the area. A seasonally transhumant population which intermittently exploited the resources of the sea shore should have bone collagen reflecting a largely C_3-based diet (from terrestrial plant and animal foods). Marine foods would tend to increase the isotopic ratio in proportion to the amount consumed. This situation should result in similar $\delta^{13}C$ values in coastal and inland skeletons, which quite clearly is not the case. The isotope ratios of the coastal individuals indicate that a very large proportion of their diet was of marine origin, perhaps, in some cases (e.g. UCT.112 at -11,2‰) almost 100%. The inland skeletons are the remains of people who may well have visited the coast - the highest value for an inland skeleton (-17,3‰ for SAM-AP 1449) is not very different from the lowest value for a coastal specimen (-15,1‰ for skeletons from Bokbaai and False Bay, on the Cape Peninsula). They did not spend a large proportion of their time there, however, and it is clear that if they did plan their subsistence activities in such a way as to make the most of seasonal food resources, their programme was not the same as that of the coast-dwellers. This is somewhat surprising, especially in view of the extremely short distance between the Olifants River Valley and the coast.

It would obviously be extremely useful to be able to translate these $\delta^{13}C$ values into percentages of marine and terrestrial foods consumed. Using the estimates of the isotopic ratios of all the different kinds of food arrived at in the previous chapter, someone eating an entirely marine diet (average $\delta^{13}C$ value -16,5‰), and having a diet-collagen fractionation factor of +5,1‰ would have a bone collagen $\delta^{13}C$ reading of -11,4‰. At the other end of the scale, an entirely terrestrial diet (average $\delta^{13}C$ value -24‰) would produce bone collagen of -18,9‰. Fifty percent marine food and 50% terrestrial food would give a bone collagen of -15,2‰.

Calculations such as these are probably more or less correct, but too much reliance should not be placed on the exact proportions of the different foods consumed since an as yet unsolved metabolic problem must be considered here. This is the question of the possible differential contributions of the various components of foods to any particular tissue in the consumer, in this case bone collagen. Collagen is a protein, and protein synthesis is a complicated process which can make use of different starting materials in individuals with different diets.

Like any protein, collagen is made up of essential and non-essential amino acids. Essential amino acids have to be derived from protein in the diet : they cannot be synthesised by the body. One-fifth of the amino acids in bone collagen are essential. The other four-fifths are non-essential amino acids (mainly proline and glycine) that can be derived from dietary carbohydrate. This is the preferred pathway in an individual whose diet contains plenty of carbohydrate, but if the diet is rich in protein but low in carbohydrate, the non-essential amino acids in bone collagen may also be derived from dietary protein. In a 'normal' modern Western diet consisting mainly of carbohydrate with a protein supplement, as much as four-fifths of bone collagen could be carbohydrate-derived (Gevers, pers.comm.).

Most prehistoric hunter-gatherer and pastoralist diets were probably not as rich in carbohydrate as those of modern Westerners. Nevertheless, many foods (<u>Iridaceae</u> corms, shellfish) contain considerable amounts of carbohydrate that must be reflected in human skeletal collagen. In order for all collagen $\delta^{13}C$ readings to be directly comparable, the collagen must come from people whose dietary protein/carbohydrate ratio is standardised. In the sample in Table XX, this is probably not the case. If coastal people gathered shellfish (15% protein - unpublished lists compiled by Bill Buchanan) as a staple whereas inland people collected Iridaceae corms (3% - 7% protein according to Archer, 1982), there is likely to be some built-in bias in the $\delta^{13}C$ values of the two groups. Moreover, if underground plant food collection became more important in the last 2 000 years, boosting the carbohydrate component of the diet at the expense of protein, this can be expected to have an effect on collagen $\delta^{13}C$ values.

Fortunately the south-western Cape situation is less complicated than it could have been. The terrestrial food resources have C_3 signatures for both their protein and carbohydrate components, whereas marine organisms likely to have been eaten by prehistoric people are isotopically much heavier in both protein and carbohydrate. This means that the observed difference in $\delta^{13}C$ values between inland and coastal prehistoric human skeletons is likely to be meaningful.

A further point requiring comment is the remarkable consistency of the $\delta^{13}C$ values in the coastal skeletons throughout the Holocene, and along the whole length of coast of the research area. (The inland sample is too small to reveal information of this kind.) The oldest skeleton in the sample, an individual from Eland's Bay, 8 000 - 10 000 years old, has a $\delta^{13}C$ value of -12,5‰. This person ate little else besides marine foods for at least the last 10 to 20 years of his life, and so must have spent much, if not all of his time at the coast. This is particularly interesting in view of the food-waste dating to this time period recovered from Eland's Bay Cave. These remains contain a high proportion of terrestrial animal bones, much higher than later Holocene levels, and one might therefore have expected early Holocene coastal skeletons to have had a more terrestrially-orientated diet than their later counterparts. This is obviously untrue : all three Eland's Bay skeletons dating to 8 000 - 10 000 B.P. had strongly marine-based diets. This is a good illustration of the difference between site-based and individual-based studies; and of the fact that the two cannot be equated. Individuals almost certainly moved between a number of archaeological sites during their lifetimes. The food-waste in any particular site depends on local environmental conditions which may or may not be reflected in the isotope ratios of the bones of people who used that site, depending on how much time they spent there.

Four skeletons dating to between 4 000 and 2 000 B.P. have a mean value of -12,3‰, whereas seven from within the last 2 000 years have a mean $\delta^{13}C$ reading of -14,4‰. This difference may or may not be significant, but either way there is no support for the idea that a population that occasionally visited the coast in the early and mid-Holocene was driven by competition with pastoralists to spend more time there in the last 2 000 years. It is quite possible that the population at the coast increased in the last 2 000 years, thus accounting for the proliferation of archaeological sites, at least at Eland's Bay, dating from this recent period. However, this increase did not result from a breakdown in a previous cyclical system as postulated by Parkington (1983, in prep.).

It should be emphasised that many of the theories about subsistence patterns on the west coast were devised in order to explain the archaeological record in one very small area. John Parkington's seasonal mobility hypothesis applies mainly to the northern part of the research area : Eland's Bay, the Olifants River Valley and the area in between. It is obviously unfair to generalise about this as though it were meant to describe the whole research area. The situation in the south, particularly in the Cape Peninsula where the Fold Mountain Belt reaches right to the coast, is completely different. All the inland skeletons and those from Eland's Bay fall within Parkington's research area. Ysterfontein, Saldanha and the Darling coast are some distance away (see Map VII) and Robertshaw (1977, 1979a) has argued that people living here might well have had a somewhat different schedule of resource exploitation from those further north. The coastal foreland at this latitude was probably once prime grazing land, much grassier than the Sandveld around Eland's Bay (see Chapter 2), and if hunter-gatherer subsistence patterns were altered by the arrival of pastoralists anywhere in the research area, this is the most likely location. Even here, coastal skeletons dating to the last two millennia are no more positive than those dating to 2 000 - 4 000 B.P., in fact they are somewhat more negative.

It seems safe to infer from this that people exploiting coastal resources did so intensively throughout the Holocene, and all along the coast. Population densities may have changed, and competition for resources increased, thus leading to an increase in the number of people at the coast, but adaptations to these perturbations did not involve greater use of a previously intermittently exploited resource.

CHAPTER 8

IMPLICATIONS OF SKELETAL ANALYSES FOR ARCHAEOLOGICAL RESEARCH IN THE SOUTH-WESTERN CAPE

Since the results of the isotopic analyses of the human skeletons presented in Chapter 7 clearly do not fit into the prevailing interpretation of the archaeology of the south-western Cape, it is appropriate to examine this interpretation more closely in an attempt to reconcile the more conventional archaeological and isotopic points of view. The best place to begin is with the evidence that led to the formulation of the seasonal mobility hypothesis. This has already been summarised in Chapter 3 so discussion here will be limited to the pointing out of problems and inconsistencies in this approach, and the mention of new evidence that has emerged from more recent research.

Most of the seasonal indicators used to demonstrate summer occupation of the Fold Mountain Belt and winter occupation at the coast are positive indicators. The case for both phenomena is fairly convincing, but insufficient attention has been paid to the problem of showing that winter occupation of the mountains and summer occupation at the coast did not occur. It is difficult to find evidence that people were not somewhere at any particular season, but this must be done, or some other way found to show that the people who were at the coast at one season were the same as those who were inland at another.

The technique of measuring juvenile dassie and seal bones has a built-in bias. It has been shown quite conclusively that many of the dassies at De Hangen were killed in the summer, and that the site must therefore have been occupied in summer. 46% of the dassie mandibles from this site are juvenile, and can be aged; the results of this aging are shown in Table XXI (a table published in Parkington & Poggenpoel, 1971). These figures have been interpreted as follows :

> "Almost all of these dassies could have been killed between November and February and very few of them could only have been killed during the winter"

(Parkington & Poggenpoel, 1971: 30). Technically, this is true, but the seasonality is not as clearly demonstrated as these authors would have us believe. Their conclusion means that we have to assume that the 27 dassies whose dentition indicates that they were killed any time from September to November were, in fact, clustered towards the end of this period, while the 26 individuals who could have died during February, March or April happen to fall at the beginning of their range. A similar skewing of the other 31 animals is necessary. Thus, although nearly all the dassies could have been killed between November and March, it is more likely that they were actually killed between September and April - a time range extending over two-thirds of the year. Five animals were killed in the other third of the year. In addition, the 54% of the jaws in the sample that are adult or adiagnostic are assumed to be those of animals killed at the same time of year as the diagnostic individuals. When one takes into account the greater ease with which juvenile dassies can be killed, it seems quite possible that people concentrated on dassies at times at which they were easy to obtain, and, perhaps, on other food resources at other times. When using this kind of evidence to show that a site was occupied in one season only, it is vital to be able to show that it was not occupied at other seasons.

This also applies to other seasonal indicators, such as the stalks of bedding grass from De Hangen which have inflorescences on them. Grasses flower in summer. The high incidence of tortoise bones at the same site has also been taken as evidence of summer occupation; while it is true that tortoises are more active, and hence more visible, in spring and summer, it is quite possible to find them even in the middle of winter. A recently initiated tortoise monitoring programme at Eland's Bay confirms this.

Seasonal evidence from plant food remains too is at best ambiguous. The seeds of *Euclea* spp., *Olea*, *Rhus* and *Nylandtia* (referred to as "Seed X" in Parkington, 1976a) are certainly from fruits that would have ripened in summer, but the kinds of plant foods that are available in winter are generally soft and fleshy and would not leave any trace in an archaeological site (e.g. *Trachyandra*, *Albuca*, *Cyphia* and many others). Moreover, all the above fruits are eaten by birds and baboons and are known to be carried into caves by non-human agencies. Their presence in a cave site is not, therefore, an infallible indicator of summer occupation of the site by humans. Corms of *Moraea*, *Babiana* and *Watsonia* are most palatable and easily found in summer, but are also available at other seasons. The baboons in the Cape Point Nature Reserve include corms in their diet in every month except June and July (Hall, 1962).

The final strand of evidence which suggests summer occupation of the mountains comes from reports by early travellers. Parkington records that "almost all meetings with Soaqua in the Olifants River valley took place during the dry season" (Parkington, 1977: 152), but this was probably also the best time to undertake trips into the interior. The evidence is not confirmed by early travellers who did *not* meet Soaqua in the Olifants River valley during the wet season.

Quite obviously, a river valley would have been a good place to be when annual watercourses were dry during the summer, and some of the reports of early travellers confirm that the Khoisan did adopt this policy. Whether or not they also spent the wet season "away from the river in order to exploit the more temporary potentials to the east and west" (Parkington, 1977: 156) remains a subject for future research. One place where they did not spend it, at least on any regular basis, was at the coast.

Seasonal indicators from Eland's Bay Cave are just as inconclusive as those from De Hangen. The post-4 000 B.P. layers contain the bones of birds that are winter visitors to the nearby Verlore Vlei, such as flamingoes. The seal mandibles are largely those of yearlings, although why this should be so if the seals were collected washed-up on the beach rather than hunted is a little difficult to explain (see discussion in Chapter 3). At any rate, seals have a restricted breeding season and pups become yearlings in winter, which is also when wash-ups from winter storms are most common. Perhaps the combination of stormy winter weather and suddenly having to find their own food, instead of being able to drink their mothers' milk, is a fatal one for some pups. The idea that black mussels are best eaten in winter because they are more likely to be toxic from red tide organisms in summer, was originally advanced with caution (Parkington, 1976a). Nevertheless, it has been repeated as a truism in nearly all subsequent work that has been done on west coast sites (Robertshaw, 1977, 1979a, 1979b; Buchanan *et al.*, 1978). Since mussels can remain toxic for up to four months after a red tide has disappeared (Grindley & Sapeika, 1969), one can argue that it would be extremely unsafe to eat mussels at *any* season on a short visit to the coast. To eat mussels at all requires an intimate and full-time knowledge of coastal waters.

Some positive evidence for summer occupation of the Eland's Bay Cave is starting to emerge. Beach surveys reveal that 80% of the shorebird mortality in this area occurs between November and April, and that 80% of the Cape cormorants recovered from the cave were collected during these months. Moreover, the presence of juvenile Cape cormorants on open middens nearby also points to summer occupation (Avery, 1981). In Avery's words :

> "It is becoming apparent that peak availability of different resources does not necessarily coincide and that any strategy involving exploitation of the various peaks must be more complex than the straight forward seasonal transhumance so far proposed"

(1981: 86).

Thus, several lines of evidence point to the necessity for the seasonal mobility hypothesis to be reviewed. Stable carbon isotopic measurements do not confirm that the coast and the mountain belt supplied different facets of a single subsistence economy for prehistoric people. Much of the evidence on which the theory was originally based requires re-examination, with particular attention paid to demonstrating that sites were not occupied in certain seasons. The approach employed up to now, i.e. "Ruling out occupation of archaeological sites is generally tackled by ruling in occupation nearby and suggesting a movement between sites" (Parkington, 1976a: 77), is no longer adequate. Moreover, since the recognition of the likely effects of pastoralism on seasonal mobility (Parkington, 1983; in prep.), De Hangen can no longer be regarded as a typical summer occupation site in the mountains (Parkington, 1971, 1977). The whole of the sequence in this cave post-dates 2 000 B.P., so that it falls in the period for which Parkington is now hypothesizing fragmentation of the hunter-gatherer population into small bands, some based in the mountains and others on the coast. According to this scheme, access to a variety of resource zones would be greatly restricted and the bands in the mountains would have to remain there for much of the year. This is a plausible hypothesis, but means that much of the evidence that was previously taken to indicate that seasonal mobility occurred will have to be turned around to show that it did not occur or at least not in the form originally proposed.

The idea that some groups of Khoisan people relied heavily on coastal resources, spending most of their time collecting shellfish and combing the beaches for stranded whales, seals and coastal birds is an old one. Jan van Riebeeck mentions 'strandlopers' in his journal soon after his arrival at the Cape in 1652 :

> "This Table Valley was visited annually by three tribes of people, similar in dress and customs. One is called the Strandlopers or . . . Watermen, because they live on mussels which they find on the rocks and some roots from the earth . . . They . . . have no cattle . . . the Watermen live permanently in this Table Valley"

(Thom, 1952: 81). On several occasions Dutch settlers hoping to trade for sheep and cattle at Saldanha Bay were disappointed to encounter "no Hottentots other than destitute Strandlopers" on the coast, those with cattle having moved inland (Thom, 1958: 152, 193, 243). The Dutch despised them because of their poverty : "these poor people had nothing to barter but tortoises, ostrich egg shells and similar trash" (Thom, 1952: 93) and cattle-owning Hottentots seem also to have victimised them :

> "All of them with their following are rebels and outlaws . . . these people living hereabouts, being far away, weak and poor, are

> left alone, except when some of the other tribes come this way, when they are driven into their hiding-places"

(Thom, 1954: 172).

At least one archaeologist has supported the idea that there were some Later Stone Age people who lived on the shore nearly all the time. Garth Sampson (1974) has divided Southern African stone tool assemblages with "Cape coastal" pottery (thick quartz-tempered pottery, vessels often with rounded or pointed bases, and having lugs or spouts) into three types, one of which he calls "strandloper". These assemblages are associated with shell middens, and have numbers of large unretouched flakes and flaked cobbles, but few formal tools.

This view has not been popular in recent years, most archaeologists preferring to see coastal sites as seasonally-used segments of an annual round (Deacon, H.J., 1969, 1970, 1972, 1976; Parkington, 1972, 1976a, 1976b, 1977, 1981). Parkington (1976a) and Robertshaw (1979a) have suggested that historical records of people who spent a large proportion of their time on the coast (as quoted above from Thom, 1952, 1954, 1958) might indeed be accurate, but that these people were not typical Holocene hunter-gatherers. Instead, they had adapted to a new resource (trading with sailors) which made year-round coastal occupation an attractive and viable proposition. This behaviour pattern would thus be expected to have occurred only after European exploration of the coast.

The data presented here refute both these hypotheses, at least in the western Cape. A number of people do seem to have lived almost entirely off marine foods, as expected by Sampson (1974) and by Lee (1965). Lee believed that hunter-gatherers with access to coastal resources would have used these as a staple just as the !Kung San rely on the mongongo nut. Moreover, it is a behaviour pattern with a time-depth of at least 10 000 years, as the consistently positive carbon isotope ratios for coastal skeletons throughout the Holocene show.

Alice Hausman, in a physical anthropological study of prehistoric populations in South Africa (Hausman, 1980) found that the cranial measurements of the coastal members of her sample were different from those of skeletons from elsewhere in the country. This must mean that there was some genetic, as well as economic differentiation between coastal and inland populations. More work needs to be done on this, since her samples were small and distributed through a large time range, but as the number of dated skeletons increases, the situation will improve.

Many authors (Parkington, 1976b; Robertshaw, 1979a;

Buchanan, in prep.) have expressed reservations about whether the carrying capacity of coastal resources (particularly shellfish, if these were a staple) would be sufficient to support a human population of any size for more than a few months of the year. Parkington (1976b) calculated that a single kilometre of rocky shoreline at Eland's Bay could support 10 people for six months of the year if they harvested 40% of the shellfish population, and if a third of their diet consisted of limpets and mussels. This is a very short length of coastline, and even if people had to go some distance over sandy beaches to reach the next rocky outcrop, as would have been the case at Eland's Bay, the total area required to support a band would probably be no greater than that necessary inland.

Other sites have access to greater lengths of rocky shoreline. At Paternoster 10 km of rocky coast are available within a 5 km radius of the midden excavated by Robertshaw. Twenty people culling 30% of the shellfish population and eating a diet of which one-third was shellfish could have lived there all year round (Robertshaw, 1979a). All the terrestrial plant and animal foods available in the coastal plain and the Fold Mountain Belt are also to be found near the coast. Certain plants may be somewhat less abundant, but it would certainly not have been necessary to go very far to achieve a varied and balanced diet (if this was not supplied by marine food).

CONCLUSIONS

$\delta^{13}C$ measurements of a number of human skeletons from the research area, combined with a knowledge of the isotopic ratios of the foods available in different resource zones, indicate at least two subsistence patterns amongst Holocene people. Inland-dwellers consumed an almost negligible amount of marine-based foods, whereas coastal dwellers ate little else. These results contradict subsistence strategy models which involve seasonal movements between coast and mountains.

A better model would be one in which the exploitation of coastal resources is regarded as a separate, and possibly self-contained, way of life. The remains of inland people are too scanty to allow any conclusions to be drawn about their patterns of subsistence behaviour, but it is quite possible that they did have some sort of annual round, and may occasionally have visited the coast. This seasonal cycle was, however, very different from that of people who lived almost permanently on the seashore.

The isotopic data also demonstrate that intensive coastal exploitation is not a new phenomenon in the western Cape; it dates back at least as far as the beginning of the Holocene. While coastal population density may well have increased during the last 2 000 years in response to the arrival of pastoralism at the Cape, adaptations to this new way of life did not include more intensive use of previously intermittently-exploited marine foods.

These conclusions have considerable implications for archaeological research in the south-western Cape. Further work on seasonal population movements must show that people were not in particular areas in some seasons, as well as that they were there in others. Students of coastal sites will have to recognise that these are likely to represent a larger segment of the subsistence economy of certain prehistoric groups than previously supposed. Estimates of group size, kilojoule intake from various foods and the relative importance of different resources will need to be adjusted accordingly. The possible relationships between, and social organisation within two economically discrete groups in one small geographical area constitute a fascinating new field of study.

TABLES

TABLE I

MAMMAL REMAINS FROM ARCHAEOLOGICAL SITES IN THE SOUTH-WESTERN CAPE

	Rooiels (Smith, 1981)	Bonteberg (Maggs & Speed, 1967)	Hout Bay (Buchanan, 1977)	Duiker Eiland (Robertshaw, 1979a,b)	Stofbergsfontein (Robertshaw, 1979a)	Paternoster (Robertshaw, 1977, 79a)	Tortoise Cave (Robey, in prep.)	Eland's Bay (Parkington, 1976a)	Diepkloof (Parkington, 1976a)	De Hangen (Parkington & Poggenpoel, 1971)	Andriesgrond (Parkington, 1979)	Aspoort (Smith & Kipp, 1978)	
Procavia capensis (dassie)	x	x	3		1		30	20	12	64	8	2	>140
Lepus capensis (Cape hare)							15 cf.						
Pronolagus crassicaudatus	x cf.												
Bunolagus monticularis							8 cf.						> 41
Lagomorpha gen. et sp. indet.								6	2	6	4		
Raphicerus campestris (steenbok)					1		13	8					
Raphicerus melanotis (grysbok)							3	4					>134
Raphicerus sp.	x			1	6	1	46	31	8	6	6		
Sylvicapra grimmia (grey duiker)	x			1		4	4	11		1	4		> 25
Oreotragus oreotragus (klipspringer)	x									3			> 3
Hippotragus leucophaeus (bloubok)								1					[illegible]
Taurotragus oryx (eland)		x				2 cf.	1	1		1			> 5
Bovini/Taurotragus							8						8
Taurotragus/Syncerus	x												x
Syncerus caffer (Cape buffalo)								2					2
Alcelaphus buselaphus (red hartebeest)	x cf.												x
Alcelaphus buselaphus/ Connochaetes gnou (hartebeest/wildebeest)								3					3
Antidorcas marsupialis (springbok)										1			1
Bos taurus (cow)										1			1
Bovidae gen. et sp. indet. :													
Small (e.g. steenbok)			5-7	4	7	8		38)	2				62-64
Small-med. (e.g. sheep)			3		1	2		18)					24
Large-med. (e.g. wildebeest)			2		3	3		4)					12
Large (e.g. eland)			2					5)			1	1	9
Ovis & Capra (sheep & goats)							13	6		1?			20
Equus sp.										1	1	2-3	4-5
Suids (wild)	x												x
Suids (domesticated)									1				1
Hippopotamus amphibius	x							3			1		> 4
Rhinocerotidae gen. et sp. indet.							1						1
Panthera pardus (leopard)	x						1	1					> 2
Canis mesomelas (black-backed jackal)	x				1	2 cf.	3 cf.	7		1 cf.			> 14
Herpestes pulverulentus (Cape grey mongoose)			1		1	1 cf.	11	5	4?	8	3		34
Herpestes ichneumon (Egyptian mongoose)	x						1	1					> 2
Herpestes sp.		x											x
Herpestes/Genetta										2			2
Genetta tigrina (genet)										2			2
Genetta sp.								2					2
Felis caracal (rooikat)							1 cf.	3			1		5
Felis libyca (wild cat)				3	1			4			x		8
Felis sp.			1										[illegible]
Unident. carnivore									1		1		2
Papio ursinus (baboon)	x	x	2				1	4		1			> 8
Mellivora capensis (honey badger)							1	2		1			4
Hystrix africae-australis (porcupine)						3	1	4		1	1?		10
Ictonyx striatus (zorilla)							6				1		7
Erinaceus frontalis [illegible]								2					

	Rooiels (Smith, 1981)	Bonteberg (Maggs & Speed, 1967)	Hout Bay (Buchanan, 1977)	Duiker Eiland (Robertshaw, 1979a,b)	Stofbergsfontein (Robertshaw, 1979a)	Paternoster (Robertshaw, 1977, 79a)	Tortoise Cave (Robey, in prep.)	Eland's Bay (Parkington, 1976a)	Diepkloof (Parkington, 1976a)	De Hangen (Parkington & Poggenpoel, 1971)	Andriesgrond (Parkington, 1979)	Aspoort (Smith & Ripp, 1978)	
Erinaceus sp.							1						1
Orycteropus afer (aardvark)							2	2					4
Bathyergus suillus (dune mole rat)		x	3-4	1	1	2	58	17	5		3		>90-9
Aonyx capensis (Cape clawless otter)	x												x
Arctocephalus pusillus (Cape fur seal)	x	x	6-9	8	7	5		*	2?				Many
Cetaceae sp. gen. et indet. (whale)					1?			1					2
	x	x	28-34	18	31	33	229	7217	37	101	35	5-6	>734 -741
Tortoises	*	x	4-5	>4	>27	58	**	*	25	313	x	1	

* Abundant
** Common

TABLE II

BIRD REMAINS FROM ARCHAEOLOGICAL SITES IN THE SOUTH-WESTERN CAPE

	Rooiels (Smith, 1981)	Hout Bay (Buchanan, 1977)	Duiker Eiland (Robertshaw, 1979a)	Stofbergsfontein (Robertshaw, 1979a)	Paternoster (Robertshaw, 1979a)	Eland's Bay (Parkington, 1976a)	Diepkloof (Parkington, 1976a)	De Hangen (Parkington & Poggenpoel, 1971)	
Spheniscus demersus (Jackass penguin)	23	9	36	7	27	39			141
Phalacrocorax capensis (Cape cormorant)	15	8	27	6	32	142	1		231
Phalacrocorax carbo (White-breasted cormorant)	8	3	12	2	8	12			45
Phalacrocorax africanus (Reed cormorant)				1	3	1			5
Phalacrocorax neglectus (Bank cormorant)		1	11	2		5			19
Morus capensis (Cape gannet)	19	1	1	2	1	6			30
Diomedeidae gen. et sp. indet. (Albatross)	4			1		x			> 5
Macronectes giganteus (Giant petrel)						x			x
Macronectes sp.	1								1
Procellariidae : *Pachyptila* (Petrel prion)		1?		1?					2
Procellariidae : *Daption capensis* (Cape pigeon)				1?					1
Procellariidae gen. et sp. indet.						x			x
Puffinus griseus (Sooty shearwater)	7								7
Haematopus moquinii (Black oystercatcher)					3				3
Larus dominicanus (Blackbacked gull)				2	2	x			> 4
Larus hartlaubii (Hartlaub's gull)						x			x
Sterna bergii (Swift tern)					2 cf.				2
Sternidae sp. indet.					2	x			> 2
Sturnidae : *Onychognathus morio* (Redwinged starling)		2?							2
Passerinae sp. indet.		1	3				48		52
Gen. et sp. indet.		1	2						3
Fulica cristata (Redknobbed coot)						x			x
Phoenicopterus ruber (Greater flamingo)	1					x			> 1
Pelecanus onocrotalus (White pelican)				1		x			> 1
Anatidae (Ducks)						x			x
Francolinus capensis (Cape francolin)	1	1		1		x			> 3
Numididae/Phasianidae (Guinea fowl/ francolin)								1	1
Corvus sp. (Crow)	1								1
Tytonidae/Corvidae (Barn owl/crow)		1							1
Corvidae (Crows, ravens)						x			x
Burhinus sp. (Dikkop)				1					1
Columba guinea (Rock pigeon)							2?		
Elanus caeruleus (Blackshouldered kite)						x			x
	80	29	92	28	80	>205	49	1	564

TABLE III

FISH REMAINS FROM ARCHAEOLOGICAL SITES IN THE SOUTH-WESTERN CAPE

	Rooiels (Smith, 1981)	Smitswinkelbay (Poggenpoel & Robertshaw, 1981)	Simonstown (Poggenpoel & Riley, unpubl. data)	Hout Bay (Buchanan, 1977)	Duikereiland (Robertshaw, 1979a)	Stofbergsfontein (Robertshaw, 1979a)	Paternoster (Robertshaw, 1979a)	Tortoise Cave (Robey, in prep.)	Eland's Bay (Poggenpoel & Parkington, unpubl. data)	Diepkloof (Parkington, 1976a)	
Pachymetopon blochii (hottentot)	204	281	14	38	17	11	72	1	3		641
Pachymetopon sp.		8									8
Lithognathus lithognathus (white steenbras)	5	1	1	3		50		134	126	11	331
Rhabdosargus globiceps (white stumpnose)	17	4	2	1		2		119	55		200
Liza/Mugil spp. (haarders)	2		1	24	10	277		16	11	3	344
Coracinus capensis (galjoen)	22	1	1	1					2		27
Diplodus sargus (dassie)	6	2						5	20		33
Diplodus cervinus/trifasciatus (zebra)									1		1
Johnius hololepidotus (kabeljou)				1				3	6		10
Pomatomus saltator (elf)						1		10	7		18
Tachysurus feliceps (sea barbel)									2		2
Galeichthus teliceps (catfish)								1			1
Genypterus capensis (kingklip)									1		1
Thyrsites atun (snoek)									1		1
Clinnidae (klipvis)	5		3						1		9
Petrus repestris (red steenbras)	1										1
Argyrozona argyrozona (carpenter)	9										9
Cymatoceps nastus (poenskop)	40	84	3								127
	311	381	25	68	27	341	72	289	236	14	1764
Jasus lalaudii (rock lobster)	39	0	?	3	418	331	335	x	*	17	

* Abundant

TABLE IV

SHELLFISH REMAINS FROM ARCHAEOLOGICAL SITES IN THE SOUTH-WESTERN CAPE

	Rooiels (Smith, 1981)	Smitswinkel Bay (Poggenpoel & Robertshaw, 1981)	Hout Bay (Buchanan, 1977)	Duiker Eiland (Robertshaw, 1979a)	Stofbergsfontein (Robertshaw, 1979a)	Eland's Bay (Parkington, 1976a)	Diepkloof (Parkington, 1976a)
Perna perna as % total shell	5	32	-	-	-	-	-
Choromytilus meridionalis as % total shell		3	51	10	37	59	62
Patella spp. as % total shell	26	41	23	86	52	27	31
Other spp. as % total shell	69	24	26	4	11	14	7
Patella granatina as % total Patella	3	17	43	51	52	38	Information not available
Patella granularis as % total Patella	x	8	19	37	18	22	
Patella barbara as % total Patella	x	x	4	x	2	2	
Patella argenvillei as % total Patella	5	x	4	x	9	4	
Patella cochlear as % total Patella	5	25	15	x	3	-	
Patella oculus as % total Patella	7	24	2	x	8	-	
Patella miniata as % total Patella	-	x	2	-	-	-	
Patella longicosta as % total Patella	4	x	-	-	-	-	
Other spp. as % total Patella	75	26	11	12	8	34	

The numbers in Tables I - V refer to Late Holocene food-waste. Most of the sites listed do not, in any case, date back further than the mid-Holocene. Eland's Bay Cave, Tortoise Cave and Aspoort all have early Holocene deposits (although the lower layers at Aspoort are undated); but these faunal assemblages are not included in Tables I - V.

TABLE V

EDIBLE PLANT REMAINS FROM ARCHAEOLOGICAL SITES IN THE SOUTH-WESTERN CAPE

	1	2	3
Restio setiger (seed edible but *male* inflorescences found)	+		
Willdewonia striata (seeds & seed-cases)	+		+
Cannamois sp. (seeds)	+		
Ficinia sp. (inflorescences) (? bedding)	+		
Leucadendron sp. (seeds & seed-cases)	+++		++
Dioscorea elephantipes (bark of tuber)	+++	++	
Euclea tomentosa (seeds, leaves)	++	+	
Euclea linearis (seeds, leaves)	+++		
Euclea sp.			+
Olea africana (seeds)	+++		+
Rhus undulata (leaves)		+	
Rhus sp. (seeds)	+++	++	+
Secale cereale (stems & ears) (?)	+++		
Pelargonium spp. (tuber casings)	++	+	
Brabejum stellatifolium (fruit casings)	++	++	
Carpabrotus edulis (stems)	+		++
Moraea sp. (corms & corm casings)	+++	+++	
Babiana sp. (corms & corm casings)	+++	+++	++
Watsonia sp. (corms & corm casings)	+++		++
? *Lycium* sp. (thorn & twig)	+		
? *Asparagus* sp. (twig)	+		
Gladiolus sp.			++
Nylandtia spinosa (seeds)	++	++	+++
Diospyros sp.	+		
Hexaglottis sp.		+++	
Antholyza plicata		?+	
Oxalis spp.		+	
Cotyledon paniculata		+	

Key

1 = De Hangen (Parkington & Poggenpoel, 1971)
2 = Andriesgrond (Robey *et al.*, 1978)
3 = Diepkloof (Parkington, 1976a)

+	trace
++	present
+++	abundant

TABLE VI

EDIBLE INDIGENOUS PLANTS OF THE SOUTH-WESTERN CAPE

1. PLANTS WITH EDIBLE ROOTS/CORMS/TUBERS

Family : Apiaceae

Annesorhiza spp. (anyswortel)
Chamarea capensis E. & Z. (gammare, vinkelbol)
Glia gummifera Sond. (gliwortel, moerwortel, dronkwortel)

Family : Apocynaceae

Pachypodium bispinosum A. DC. (bobbejaankos, kafferkambro)

Family : Araliaceae

Cussonia thyrsiflora Thunb. (kiepersol, kiepersolboom, cabbage tree)

Family : Asclepiadaceae

Brachystelma spp. (hottentotbrood, kambro)
Ceropegia spp.
Fockea spp. esp. *F. comaru* N.E. Br. (kambro)

Family : Campanulaceae

Cyphia spp. (baroe). Phillips (1917) lists eight species of *Cyphia* from the south-western Cape, namely *C. phyteuma*, *C. incisa*, *C. bulbosa*, *C. schechteri*, *C. digitata*, *C. zeyheriana*, *C. volubilis* and *C. crenata*.

Family : Cyperaceae

Cyperus usitatus Burch. (boesmanuintjie)

Family : Dioscoreaceae

Dioscorea elephantipes (L'Herit.) Engl. (hottentotsbrood, olivantsvoet)

Family : Geraniaceae

Pelargonium spp.

Family : Iridaceae

Antholyza plicata L.F. (hanekom)
Antholyza ringens L. (rotstert)
All *Babiana* spp.
Gladiolus spp.
Hexaglottis spp.
Ixia spp.
Lapeirousia spp.
Moraea spp. esp. *M. fugax* (de la Roche) Jacq. (not all Moraeas are edible; a few are poisonous)
Romulea spp.
Sparaxis spp.
Tritonia spp.
Watsonia spp.
and probably other genera.

Family : Liliaceae

Allium dregeanum Kunth. (ajuin, wild onion, wildeui)
Asparagus spp. (katdoring, haakdoring, wild asparagus)
Eriospermum spp.
Massonia depressa Houtt. (suikerkannetjie, botterkannetjie)
Tulbaghia alliacea L.F. (wild garlic)

Family : Nymphaeaceae

Nymphaea capensis Thunb. (blouwaterblom, blue water lily)

Family : Oxalidaceae

All *Oxalis* spp. (suring)

Family : Portulacaceae

Anacampseros spp.

Family : Rosaceae

Grielum humifusum Thunb.) pietsnot,
Grielum grandiflorum (L.) Druce) duikerwortel

Family : Tecophilaceae

Cyanella hyacinthoides L. (raap, raaptol, lady's hand)

2. PLANTS WITH EDIBLE LEAVES AND/OR STEMS

Family : Aizoaceae

Hypertelis salsoloides Adams (haassuring, braksuring)
Tetragonia fruticosa L. (slaaibos)
Sceletium spp. esp. S. strictum L. Bol. (kanna, kougoed, Hottentots kougoed). Leaves chewed as a narcotic.

Family : Amaranthaceae

Amaranthus spp. (pigweed, misbredie). Some exotic spp.

Family : Araceae

Zantedeschia aethiopica (L.) Spreng (arum lily, varkblom)

Family : Asclepiadaceae

Caralluma spp. esp. C. mammillaris N.E. Br. (aroena)
Hoodia spp. (ghaap, ngaap)
Trichocaulon spp. (ghaap, ngaap)

Family : Asteraceae

Didelta spinosa (L.F.) Ait. (doringslaaibos)
Tarchochnanthus camphoratus L. (kanferhout)
Leaves chewed as a narcotic.

Family : Cunoniaceae

Cunonia capensis L. (rooiels, botterboom). Oily substance at the bases of young bracts edible.

Family : Geraniaceae

Pelargonium spp.

Family : Graminae

Phragmites communis Trin. (fluitjiesriet, Sonquasriet)

Family : Juncaceae

Prionium serratum Drège (palmiet)

Family : Liliaceae

Albuca spp. esp. A. altissima (Jacq.) Dryand and A. canadensis (L.) Leighton (slymstok)
Allium dregeanum Kunth. (ajuin, wild onion, wildeui)
Asparagus spp. (katdoring, haakdoring, wild asparagus)

Family : Liliaceae (continued)

Bulbine spp.
Trachyandra spp. (hottentotskool)
Tulbaghia alliacea L. (wild garlic, wildeknoffel)

Family : Mesembryanthemaceae

Carpanthea pomeridiana (L.) N.E. Br. (vetkousie)
Conophytum truncatellum N.E. Br. (clock plant)
Dorotheanthus spp. (Bokbaai vygies)
Mesembryanthemum crystallinum L. (brakslaai, soutslaai, ice plant)

Family : Oxalidaceae

All *Oxalis* spp. (suring)

Family : Polygonaceae

Emex australis Steinh. (duiweltjie, Cape spinach)
Rumex spp. (tongblaar, rooisuring, veldsuring)
(European plants introduced by the first White settlers.)

Family : Polypodiaceae

Pteridium aquilinum Kuhn. (bracken fern)
Young unopened leaves edible, but large leaves poisonous.

Family : Portulacaceae

Anacampseros spp.

Family : Typhaceae

Typha latifolia L. ssp. *capensis* Rohrb. (bulrush, papkuil)

3. PLANTS WITH EDIBLE FLOWERS OR NECTAR

Family : Aponogetonaceae

Aponogeton spp. esp. *A. distyachos* L.f. (waterblommetjie)

Family : Asclepiadaceae

Microloma tenuifolium (L.) Schum. (kannetjies)
Microloma sagittatum (L.) R. Br. (bokhorinkies)

Family : Crassulaceae

Crassula alpestris Thunb. (boesnap)

Family : Graminae

Agropyron distichum P. Beauv. (suikerriet, strandkoring)

Family : Liliaceae

Massonia depressa Houtt. (suikerkannetjie, botterkannetjie)
Trachyandra spp. esp. *T. falcata* (L.f.) Kunth. (hottentotskool)

Family : Melianthaceae

Melianthus major L. (heuningblom, kruidjie-roer-my-nie)

Family : Proteaceae

Protea spp. esp. *P. repens* (L.) L. (suikerbossie)

Family : Scrophulariaceae

Hyobanche sanguinea L. (soetpop, rooipoppies, kannie)

Family : Thymelaeaceae

Struthiola ciliata (L.) Lam. (heuningbossie, stroopbossie)

4. PLANTS WITH EDIBLE SEEDS

Family : Asclepiadaceae

Microloma sagittatum (L.) R. Br. (bokhorinkies)
Microloma tenuifolium (L.) Schum. (kannetjies)

Family : Crassulaceae

Cotyledon paniculata L.f. (botterboom, botterbos)

Family : Fabaceae

Acacia karroo Hayne (acacia, kareedoring, mimosa) Gum also eaten.

Family : Mesembryanthemaceae

All *Carpabrotus* spp. esp. *C. edulis* (L.) N. E. Br. (hottentotsvy, suurvy, perdevy) and *C. quadrifidus* L. Bol. (elandsvy). Also *C. acinaciforme* and *C. sauerae*.

Family : Proteaceae

Seeds of all spp. probably edible but especially :

Brabejum stellatifolium L. (wild almond, hottentotsamandel, bitter almond)
Leucodendron spp.
Leucospermum spp. esp. *L. conocarpodendron* (L.) Buek. (bobbejaanbos, brandhoutboom, goudsbos)

Family : Restionaceae

Large-seeded spp. e.g. *Willdenowia striata* Thunb. (Sonquasriet) and *Cannamois virgata* Steud. (besemsriet, olifantsriet)

5. PLANTS WITH EDIBLE FRUITS

Family : Amaryllidaceae

All *Gethyllis* spp. (koekoemakranka, kukumakranka)

Family : Anacardiaceae

All *Rhus* spp.

Family : Asteraceae

Chrysanthemoides monilifera T. Norl. (boetabessie, brother berry, bietou)

Family : Celastraceae

Cassine parvifolia Sonder (mountain saffronwood)
Cassine peragua L. (lepelhout, kububessie, bastard saffronwood)
Maurocenia frangularia Miller (Hottentots' cherry)

Family : Ebenaceae

Diospyros austro-africana De Winter (kritikom)
Diospyros glabra (L.) De Winter (bloubessie, blue berry)
Diospyros ramulosa (E. Meyer ex A. DC) De Winter (Namaqua kritikom, appelkoosbessie)
Diospyros whyteana (Hiern.) F. White (bladder-nut)
Euclea linearis Hiern. (smalblaar)
Euclea racemosa Murr. (seeghwarrie)
Euclea tomentosa E. Mey. (heuningghwarrie, jakkalsbos, cargosang)

Family : Fabaceae

Dipogon lignosus (L.) Verdc. (wilde-ertjie)

Family : Hydnoraceae

Hydnora africana Thunb. (jakkalskos, bobbejaankos, kannip)

Family : Iridaceae

All *Romulea* spp. (froetang)

Family : Lauraceae

Cassytha ciliolata Nees. (vrouehaar, devil's tresses)

Family : Mesembryanthemaceae

All Carpabrotus spp. esp. C. edulis (L.) N.E. Br. (hotnotsvy, suurvy, perdevy) and C. quadrifidus L. Bol. (elandsvy)
Carpanthea pomeridiana (L.) N.E. Br. (vetkousie)

Family : Moraceae

Ficus cordata Thunb. (Namaqua fig)
Ficus ilicina Sonder ex Miq. (laurel fig)

Family : Oleaceae

Olea capensis L. (ironwood, ysterhout)
Olea europaea L. subsp. africana (Miller) P.S. Green (wild olive, olienhout)
Olea exasperata Jacq. (coast olive, basterolienhout)

Family : Podocarpaceae

Podocarpus latifolius (Thunb.) R. Br. ex Mirb. (yellowwood, opregte geelhout)

Family : Polygalaceae

Nylandtia spinosa (L.) Dumort. (skilpadbessie, bokbessie)

Family : Rhamnaceae

Scutia myrtina (Burm.f.) Kurz. (katdoring)

Family : Rubiaceae

Canthium inerme (L.f.) Kunth. (Cape date, bokdrolletjie, turkey-berry)

Family : Santalaceae

Colpoon compressum Bergius (sumach, pruimbas)

Family : Sapotaceae

Sideroxylon inerme L. (melkhout, milkwood)

Family : Scrophulariaceae

Halleria lucida L. (kinderbossie, nutseng)

Family : Solanaceae

Lycium ferrocissimum Miers. (bokdoring)

Family : Tiliaceae

Grewia occidentalis L. (kruisbessie, buttonwood)

Family : Vitaceae

Rhoicissus tomentosa (Lam.) Wild & Drummond (wild vine, bobbejaantou)

(From Phillips, 1917; Smith, 1966; Levyns, 1966; Mason, 1972; Le Roux & Schelpe, 1981; Palgrave, 1981; Kidd, 1983)

TABLE VII

ANATOMICAL DIFFERENCES BETWEEN PLANTS WITH DIFFERENT SUB-TYPES OF C_4 PHOTOSYNTHESIS

Malate Formers	Aspartate Formers
- Single Kranz sheath with centrifugal chloroplasts around the larger vascular bundles	- Double bundle sheath with variable chloroplast position (see below)
- No cells are present between the metaxylem vessel elements and the Kranz sheath cells of the first order vascular bundles	- Mestome, or inner bundle sheath, present between metaxylem elements and Kranz sheath cells
- Well-developed grana lacking in the chloroplasts	- Well-developed grana present in the chloroplasts
- Low mitochondrial frequency	- High mitochondrial frequency
- No post-illumination CO_2 burst	- Post-illumination CO_2 burst observed.

NAD-me Sub-type	PEP-ck Sub-type
- Chloroplasts round inner walls of Kranz sheath cells	- Chloroplasts round outer walls of Kranz sheath cells
- Mesophyll consists of a single layer of distinct, radially-arranged narrow tabular cells	- Radial arrangement irregular and chlorenchyma cells larger and less elongated than in NAD-me sub-type

(From Ellis *et al.*, 1980)

TABLE VIII

$\delta^{13}C$ VALUES OF COLLAGEN FROM ANIMALS IN THE SOUTH-WESTERN CAPE (in ‰)

	Coastal Plain	Fold Mountains	Karoo Margin	Karoo Proper	Bushmanland
Tortoises (*C. angulata*, except for Bushmanland where both specimens are *Psammobates tentorius varroxii*)	UCT 780 -23,0 (CP)	UCT 777 -23,9 (DeH)	UCT 724 -23,3 (Db)		UCT 782 -24,9
	UCT 776 -23,1 (K)	UCT 779 -22,2 (Bjkf)			UCT 781 -22,8
	UCT 778 -22,5 (Pat)				
	UCT1075 -20,2 (EB)				
	UCT1076 -20,8 (EB)				
Hares (*Lepus capensis*)	UCT 728 -18,0 (Dw)		UCT 734 -21,0 (Db)		UCT 738 -15,1
	UCT 733 -20,0 (Hf)				
Steenbok (*Raphicerus campestris*	UCT 735 -21,4 (CP)			UCT 722 -17,4 (Ap)	UCT 721 -18,5
	UCT 063 -23,5 (Bok)				
	UCT 732 -21,2 (Hf)				
	UCT 876 -19,4 (EB)				
	UCT1074 -19,4 (EB)				
Springbok (*Antidorcas marsupialis*	UCT 819 -20,9 (Ch)			UCT 720 -19,0 (Ap)	UCT 822 -18,4 (Kimberley)
	UCT 820 -21,2 (Ch)				
	UCT 821 -21,6 (Ch)				
Dassies (*Procavia capensis*)	UCT 878 -22,1 (EB)	UCT 783 -21,1 (Ag)		UCT 723 -21,4 (Ap)	
	UCT 879 -20,4 (EB)				
	UCT 883 -19,9 (EB)				

	Coastal Plain	Fold Mountains	Karoo Margin	Karoo Proper	Bushmanland
Dune mole rats (*Bathyergus suillus*)	UCT 877 -22,1 (Pen)		UCT 717 -19,2 (Db)		
	UCT 880 -20,3 (EB)				
	UCT1077 -17,8 (EB)				
Baboons (*Papio ursinua*)		UCT 881 -20,3 (Bjkf)		UCT 718 -18,1 (Ap)	
		UCT 882 -20,3 (Bjkf)			
Bat-eared foxes (*Otocyon megalotis*)	UCT 842 -19,6 (Pik)	UCT 841 -19,2 (DeH)		UCT 875 -15,2 (Ap)	UCT 872 -15,7
					UCT 873 -14,2

Key to Table VIII

Each $\delta^{13}C$ value refers to one animal : where there are three numbers for, say, dassies from Eland's Bay, each refers to a separate individual.

Localities where the animals were collected are shown on Map V; the abbreviations used in Table VIII are as follows :

CP	Cape Point Nature Reserve
Pen	Cape Peninsula
K	Koeberg
Pat	Paternoster
Ch	Churchhaven
Hf	Hopefield
Pik	Piketberg
EB	Eland's Bay
DeH	De Hangen
Bjkf	Boontjieskloof
Ag	Andriesgrond
Ap	Aspoort
Bok	Bokbaai
Db	Doringbos
Dw	Dwarskersbos

The UCT number given is the laboratory analysis number for that animal.

TABLE IX

$\delta^{13}C$ SPACING BETWEEN DIFFERENT TISSUES OF THE SAME ANIMAL (in ‰)

UCT No.		Bone Collagen	Meat	Difference
	Tortoises			
777	De Hangen (*Chersina angulata*)	-23,9	-25,8	1,9
776	Koeberg (*C. angulata*)	-23,1	-25,3	2,2
836	Jonkershoek No. 1 (*C. angulata*)	-22,9	-25,1	2,2
837	Jonkershoek No. 2 (*C. angulata*)	-20,1	-23,2	3,1
838	Jonkershoek No. 3 (*C. angulata*)	-21,4	-23,8	2,4
839	Jonkershoek No. 4 (*C. angulata*)	-22,7	-24,0	1,3
				$\bar{x}$ = 2,2
				±0,6‰
781	De Tuin (*Psammobates tentorius verroxii*)	-22,8	-24,4	1,6
782	Calvinia (*P. tentorius verroxii*)	-24,6	-24,0	-0,6
		-25,2	-24,4	-0,8
	Springbok			
819	Churchhaven X	-20,9	-24,0	3,1
820	Churchhaven Y	-21,2	-24,3	3,1
821	Churchhaven Z	-21,6	-25,0	3,4
822	Kimberley	-18,4	-21,8	3,4
823	Hutchinson	-20,0	-20,8	0,8
-	Phillipstown*	-20,8	-22,6	1,8
-	De Aar*	-18,9	-21,9	3,0
-	Keetmanshoop*	-16,5	-18,5	2,0
				$\bar{x}$ = 2,6
				±0,9‰
	Bat-eared Foxes			
842	Piketberg	-19,6	-22,0	2,4
841	De Hangen	-19,2	-21,6	2,4
840	Nieuwoudville	-20,8	-22,6	1,8
873	Brandvlei	-14,2	-15,4	1,2
872	Kenhardt	-15,7	-18,9	3,2
				$\bar{x}$ = 2,2
				±0,7‰

* From Vogel, 1978b

TABLE X

$\delta^{13}C$ VALUES OF MEAT FROM ANIMALS WITH C_3-BASED DIETS IN THE SOUTH-WESTERN CAPE

UCT No.	Animal	Locality	$\delta^{13}C$ (‰)
734	Hare (*Lepus capensis*)	Db	-23,0
771	Hare (*Lepus capensis*)	Ced.	-22,2
772	Hare (*Lepus capensis*)	Ced.	-22,0
728	Hare (*Lepus capensis*)	Dw	-23,6
733	Hare (*Lepus capensis*)	Hf	-22,6
732	Steenbok (*Raphicerus campestris*)	Hf	-23,7
735	Steenbok (*R. campestris*)	CP	-24,3
731	Duiker (*Sylvicapra grimmia*)	Hf	-23,5
737	Eland (*Taurotragus oryx*)	Ch	-23,7
819	Springbok X (*Antidorcas marsupialis*)	Ch	-24,0
820	Springbok Y (*A. marsupialis*)	Ch	-24,3
821	Springbok Z (*A. marsupialis*)	Ch	-24,9
787	Francolin (*Francolinus capensis*)	YZ	-20,9
776	Tortoise (*Chersina angulata*)	K	-25,3
777	Tortoise (*C. angulata*)	DeH	-25,8
			$\bar{x}$ = -23,6 ±1,3‰

Key

Ced = Cedarberg

YZ = Yzerfontein

TABLE XI

CHANGE IN $\delta^{13}C$ VALUES OF ANIMAL TISSUES WITH TROPHIC LEVEL

UCT No.	Animal	Bone Collagen	Meat	Difference
	Herbivores			
733	Hare (*Lepus capensis*)	-20,0	-22,6	2,6
732	Steenbok (*Raphicerus campestris*)	-21,2	-23,7	2,5
731	Duiker (*Sylvicapra grimmia*)	-20,7	-23,5	2,8
	Carnivores			
730	Lynx (*Felis caracal*)	-19,2	-21,8	2,6
729	Jackal (*Canis mesomelas*)	-17,9	-19,8	1,9

All animals collected at Hopefield

TABLE XII

$\delta^{13}C$ VALUES OF THE EDIBLE PARTS OF PLANTS

UCT No.	Plant	Locality	$\delta^{13}C$ (‰)
756	*Moraea fugax* corms (n=3)	EB	-26,7
Various	*Watsonia pyramidata* corms (New corms collected every month over a period of one year)	Pen	-23,2 to -29,2
1103	*Nylandtia spinosa* berries	EB	-22,3
884	*Carpabrotus* sp. seeds & sap	EB	-23,2
757	*Grielum humifusum* roots (n=5)	EB	-26,3
758	*Prionium serratum* stem	Bjkf	-27,0
759	*Dioscorea elephantipes* tuber	Db	-28,2
761	*Fockea comaru* tuber (n=1)	Db	-24,4
760	*Caralluma mammillaris* stem (n=1)	Db	-10,9
-	*C. mammillaris*	*	-14,4
-	*Hypertelis salsoloides* leaves	*	-23,7
885	*Cyanella hyacinthoides* corms (n=3)	EB	-26,3
886	*Allium dregeanum* bulbs (n=12)	Db	-24,7
887	*Aponogeton distyachos* flowers	EB	-26,9
889	*Hydnora africana* fruit (n=1)	**	-11,4
890	*Hoodia* sp. stem (n=1)	Db	-11,9
1047	*Cyphia digitata* subsp. *digitata* tuber (n=1)	Ag	-23,0
1046	*Colpoon compressum* berries	Pen	-26,2
1045	*Oxalis* spp. corms	EB	-26,4

$\bar{x}$ = -25,4
C_3 values only
±1,8

* From Robertson Karoo (Mooney *et al.*, 1977)

** From Namaqualand

TABLE XIII

$\delta^{13}C$ VALUES OF MARINE ANIMALS (all meat)

UCT No.	Animal	Locality	$\delta^{13}C$ (‰)
095	*Choramytilus meridionalis* (n=10)	EB 1. 2.76	-19,4
097	*C. meridionalis* (n=3)	EB 24. 4.76	-18,1
1013	*C. meridionalis*	EB 11.11.81	-17,4
1014	*C. meridionalis*	EB 1. 3.82	-16,2
1015	*C. meridionalis* (n=7)	EB 24. 5.82	-15,9
1016	*C. meridionalis* (n=2)	EB 10. 7.82	-16,4
1017	*C. meridionalis* (n=8)	EB 15. 7.82	-16,4
1018	*C. meridionalis* (n=9)	EB 12. 9.82	-16,2
519	*Aulacomya ater*	OK	-16,7
585	*Burnupena* sp.	OK	-14,8
096	*Donax serra* (n=16)	EB 27. 4.76	-17,2
1020	*Patella granatina*	EB 11.11.81	-15,2
1021	*P. granularis*	EB 11.11.81	-13,6
1022	*P. argenvillei*	EB 11.11.81	-12,3
1023	*P. cochlear*	EB 11.11.81	-12,8
1019	*Haliotis midae* (n=1)	Pat	-16,8
742	*Liza ramada* (n=1)	EB	-15,8
766	*Lithognathus lithognathus*	KB	-14,9
769	*Pachymetopon blochii* (n=1)	EB	-16,5
586	*Pachymetopon blochii*	OK	-15,9
740	*Spheniscus demersus* (n=1)	Sal	-15,1
767	*Phalacrocorax capensis* (n=1)	EB	-16,3
768	*Morus capensis* (n=1)	Yz	-15,0
743	*Diomedea melanophris* (n=1)	HB	-16,4
770	*Arctocephalus pusillus* (n=1)	Pat	-14,3
741	*A. pusillus* (n=1)	HB	-14,6
818	*Jasus lalandii* (n=1)	Pat	-14,0
786	*J. lalandii* (n=1)	EB	-14,6
517	*J. lalandii*	OK	-13,1
			$\bar{x}$ = -15,6 ± 1,6‰

788	Whale (collagen) (n=1)	-20,2

Key

OK = Oudekraal
Sal = Saldanha Bay
HB = Hout Bay
KB = Kalk Bay

TABLE XIV

$\delta^{13}C$ VALUES OF MARINE ALGAE

UCT No.		Locality	$\delta^{13}C$ (‰)
	DIVISION : RHODOPHYTA (red weeds)		
	CLASS : FLORIDEOPHYCEAE ORDER : CRYPTONEMIALES FAMILY : Kallymeniaceae		
797	*Thamnophyllis discigera*	Pat	-34,5
796	*Kallymenia agardhii*	Pat	-33,0
	FAMILY : Cryptonemiaceae		
815	*Aeodes orbitosa*	Pat	-14,6
807	*Pachymenia cornea*	Pat	-23,7
1090	*Pachymenia carnosa*	OK	-17,8
520	*Pachymenia* sp.	OK	-21,9
	ORDER : CERAMIALES FAMILY : Delesseriaceae		
794	*Botryocarpa prolifera*	Pat	-32,8
800	*Hymenena venosa*	Pat	-32,4
802	*Neuroglossum binderianum*	Pat	-32,6
	FAMILY : Ceramiaceae		
829	*Carpoblepharis flaccida*	Pat	-19,9
826	*Ceramium planum*	Pat	-21,2
831	*Centroceras clavulatum*	EB	-17,8
	ORDER : RHODYMENIALES FAMILY : Rhodymeniaceae		
798	*Epymenia obtusa*	Pat	-31,3
810	*Rhodymenia* sp.	Pat	-20,1
	ORDER : GIGARTINALES FAMILY : Gigartinaceae		
795	*Gigartina radula*	Pat	-26,1
795	*Gigartina radula*	Pat	-24,8
825	*Gigartina bracteata*	Pat	-22,3
1088	*Gigartina bracteata*	OK	-18,5
809	*Gigartina* sp.	Pat	-26,1
518	*Gigartina* sp.	OK	-22,0

UCT No.		Locality	$\delta^{13}C$ (‰)
	FAMILY : Plocamiaceae		
824	*Plocamium rigidum*	Pat	-32,6
813	*Plocamium corallorhiza*	Pat	-33,3
813	*Plocamium corallorhiza*	Pat	-33,9
	FAMILY : Sphaerococcaceae		
827	*Heringia* sp.	Pat	-26,4
	FAMILY : Sarcodiaceae		
817	*Trematocarpus affinis*	Pat	-19,4
806	*Trematocarpus fragilis*	Pat	-21,3
806	*Trematocarpus fragilis*	Pat	-18,0
	FAMILY : Nemastomaceae		
801	*Nemastoma lanceolata*	Pat	-30,4
	ORDER : NEMALIALES FAMILY : Gelidiaceae		
812	*Gelidium versicolor*	Pat	-21,0
832	*Gelidium pristoides*	FK	-17,5
093	*Gelidium pristoides*	Pen	-14,5
	CLASS : BANGIOPHYCEAE ORDER : BANGIALES FAMILY : Bangiaceae		
816	*Porphyra capensis*	Pat	-14,2
835	*Porphyra capensis*	EB	-18,2
092	*Porphyra capensis*	Pen	-14,9
	DIVISION : PHAEOPHYTA (brown weeds)		
	ORDER : LAMINARIALES FAMILY : Laminariaceae		
774	*Laminaria pallida*	Pat	-20,3 (stipe)
774	*Laminaria pallida*	Pat	-19,0 (fronds)
521	*Laminaria pallida*	OK	-20,9
	FAMILY : Alariaceae		
775	*Ecklonia maxima*	Pat	-15,2 (stipe)
775	*Ecklonia maxima*	Pat	-14,1 (fronds)
522	*Ecklonia maxima*	OK	-12,0

UCT No.		Locality	$\delta^{13}C$ (‰)
	ORDER : FUCALES FAMILY : Fucaceae		
1089	*Axillariella constricta*	OK	-17,8
	FAMILY : Cystoseiraceae		
833	*Bifurcariopsis capensis*	FK	-14,5
833	*Bifurcariopsis capensis*	FK	-14,9
	FAMILY : Sargassaceae		
828	*Sargassum longifolium*	Pat	-17,7
	ORDER : DESMARESTIALES FAMILY : Desmarestiaceae		
808	*Desmarestia firma*	Pat	-23,0
	ORDER : ECTOCARPALES FAMILY : Spermatochnaceae		
804	*Chordariopsis capensis*	Pat	-10,6
	FAMILY : Splachnidiaceae		
811	*Splachnidium rugosum*	Pat	-10,8
	DIVISION : CHLOROPHYTA (green weeds)		
	ORDER : ULOTRICHALES FAMILY : Ulvaceae		
799	*Enteromorpha* sp.	Pat	-11,2
1085	*Ulva capensis*	OK	-16,0
830	*Ulva* sp.	EB	-10,2
094	*Ulva* sp.	Pen.	-13,8
	ORDER : CLADOPHORALES FAMILY : Cladophoraceae		
834	*Cladophora* sp.	EB	-11,7
834	*Cladophora* sp.	EB	-14,0
	ORDER : SIPHONALES FAMILY : Codiaceae		
803	*Codium fragile*	Pat	-18,6
1087	*Codium fragile*	OK	-16,0

UCT No.		Locality	$\delta^{13}C$ (‰)
	FAMILY : *Codiaceae* (continued)		
814	*Codium prostratum*	Pat	-17,3
1086	*Codium prostratum*	OK	-10,3

FK = Franskraal

TABLE XV

$\delta^{13}C$ VALUES OF MARINE ALGAE FROM DEEP AND SHALLOW WATER AT HOUT BAY, CAPE PENINSULA

Species	$\delta^{13}C$ Value in Deep Water (*ca.* 25m)	$\delta^{13}C$ Value in Shallow Water (1 - 3 m)
Ecklonia maxima (fronds)	-23,5 (UCT 977)	-16,3 (UCT 976)
Laminaria pallida (fronds)	-22,7 (UCT 989)	-17,0 (UCT 988)
Pachymenia carnosa	-18,0 (UCT 979)	-14,0 (UCT 978)
Pachymenia cornea	-34,2 (UCT 981)	-23,0 (UCT 980)
Neuroglossum binderianum	-35,0 (UCT 983)	-31,5 (UCT 982)
Hymenena venosa	-34,7 (UCT 985)	-33,2 (UCT 984)
Botryocarpa prolifera	-34,2 (UCT 987)	-32,0 (UCT 986)

TABLE XVI

PHYSIOLOGICAL MEASUREMENTS ON GREAT BARRIER REEF SEAWEEDS

	1		2	3
Species	Total C (‰)	Organic C (‰)		
Chlorophyta				
Enteromorpha flexuosa	-21,2	-21,3	96	2
Halimeda macroloba	-14,8	-15,8	46	-
Halideda opuntia	-14,4	-21,3	37	-
Halimeda cylindracea	- 9,8	-15,3	154x	5
Chlorodesmis fastigiata	-19,5	-25,8	108	-
Avrainvillea erecta	-	-18,2	69	8
Boodlea composita	-	-	28	5
Phaeophyta				
Sargassum sp.	-14,1	-	18	-
Padina tenuis	-11,4	-	53	-
Turbinaria ornata	- 9,2	-11,3	-	6
Rhodophyta				
Laurencia sp.	-11,0	-15,4	-	4
Halymenia durvillaei	-32,0 -32,4	-	23	-

x = PEP carboxylase present

1 = $\delta^{13}C$ (from Black & Bender, 1976)

2 = NAPH malate dehydrogenase (from Ting, 1976)
In µmol. min.$^{-1}$ (mg.chlorophyll)$^{-1}$

3 = CO_2 equilibrium point (from Tolbert & Garey, 1976)
In mg.dm.$^{-3}$

TABLE XVII

δ^{13}C VALUES OF MARINE ORGANISMS AT DIFFERENT TROPHIC LEVELS

Scavengers

UCT 517 Crayfish (*Jasus*) : -13,1‰

↑

UCT 586 Fish (*Pachymetopon*): -15,9‰
UCT 515 Starfish (*Henricia*) : -13,3
UCT 590 Starfish (*Marthasterias*) : -13,5

↑

Filter-Feeders

UCT 583 *Mysids* : -16,5‰
UCT 519 Mussels (*Aulacomya*) : -16,7‰
UCT 516 Sea-cucumber (*Pentracta*) : -14,3%
UCT 589 Red-bait (*Pyura*) : -15,6%

↑

Primary Producers

Algae

UCT 520 *Pachymenia* : -21,9%
UCT 518 *Gigartina* : -22,0%
UCT 521 *Laminaria* : -20,9%
UCT 522 *Ecklonia* : -12,0%

Phytoplankton & Zooplankton

UCT 581 : -19,8%
UCT 582 : -17,9%

All organisms from Oudekraal kelp bed

TABLE XVIII

$\delta^{13}C$ VALUES OF MISCELLANEOUS INDIGENOUS FOODS FROM THE SOUTH-WESTERN CAPE

UCT No.		Locality	$\delta^{13}C$ (‰)
716	Rock pigeon egg	Bjkf	-22,8
888	Honey	Hf	-23,7
726	Clanwilliam yellowfish (*Barbus capensis*) meat (n = 1)	Doorn River	-19,0
725	*Barbus andrewi* meat (n = 1)	Hex River	-22,6

TABLE XIX

$\delta^{13}C$ VALUES OF ARCHAEOLOGICAL ANIMALS FROM ELAND'S BAY CAVE

UCT No.		$\delta^{13}C$
	Ga K-4335 1120 ± 85 B.P. (top of layer) Layer 6 Ga K-4337 1520 ± 80 B.P. (bottom of layer)	
1078	Steenbok	-18,5
1079	Hare	-22,6
	Layer 9 Ga K-4339 2950 ± 115 (bottom of layer)	
1080	Steenbok	-17,3
1081	Steenbok	-18,4
	Layer 12 Pta-686 9600 ± 90 B.P.	
1082	Steenbok	-19,4
1083	Steenbok	-18,6
1084	Hare	-20,7

TABLE XX

δ^{13}C VALUES OF DATED WEST COAST ARCHAEOLOGICAL HUMAN SKELETONS

COASTAL

Archaeometry Lab. No.	Skeletal Register No.	Locality	Date (B.P.)	δ^{13}C (‰)	
UCT 1050	SAM-AP 1153	False Bay	Assoc. pottery (?)	-15,1	< 2000 B.P.
UCT 622	UCT 158	Sandy Bay	Assoc. pottery (?)	-15,0	
UCT 623	UCT 159	Sandy Bay	Assoc. pottery (?)	-13,6	
UCT 625	UCT 248	Noordhoek	Assoc. pottery (?)	-12,9	
UCT 459	SAM-AP 5083	Ysterfontein	Pta-926 1490±55	-14,5	
UCT 1048	UCT 60	Saldanha	Pta-2005 955±50	-14,6	
UCT 451	SAM-AP 4813	Bokbaai	Assoc. pottery (?)	-15,1	
					2000-4000 B.P.
UCT 1049	SAM-AP 1443	Gordon's Bay	Pta-2309 2050±50	-11,8	
UCT 1052	UCT 162	Ysterfontein	Pta- 929 2880±50	-11,5	
UCT 1092	-	Eland's Bay	Pta-1754 3835±50	-14,7	
UCT 1051	UCT 112	Darling Coast	Pta-2003 4445±50	-11,2	
					4000-8000 B.P.
					> 8000 B.P.
UCT 1091	-	Eland's Bay	Pta-1829 8000±95	-14,6	
UCT 206	-	Eland's Bay	Pta-3086 9750±100	-12,3	
UCT 202	-	Eland's Bay	8000-10000	-12,5	

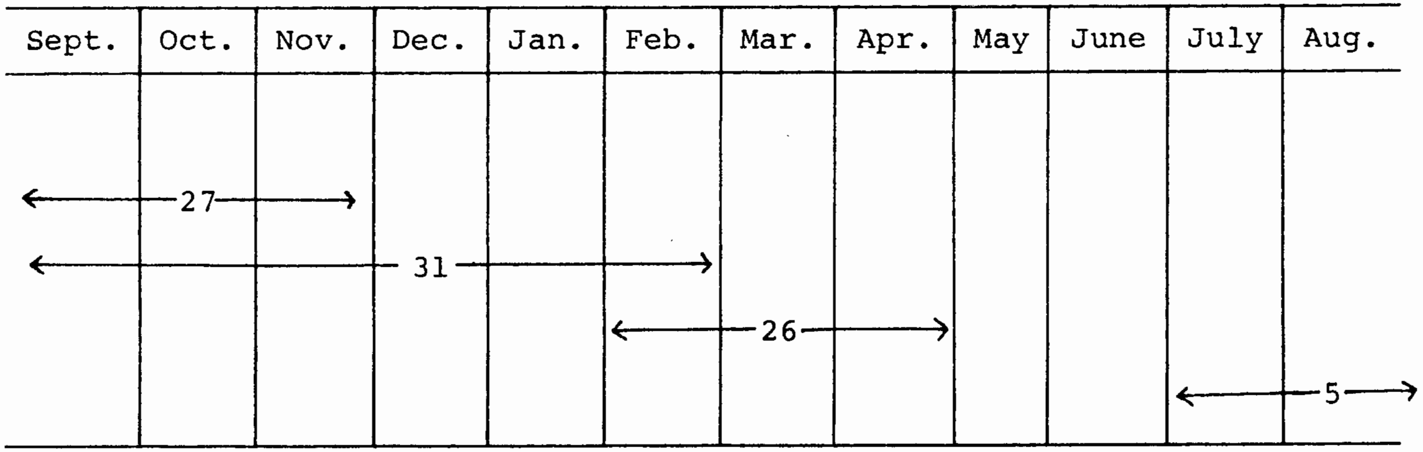
INLAND

Archaeometry Lab. No.	Skeletal Register No.	Locality	Date (B.P.)	δ^{13}C (‰)	
					< 2000 B.P.
UCT 457	SAM-AP 1449	Clanwilliam	?	-17,3	
UCT 203	UCT 334	Andriesgrond		-20,2	
					2000-4000 B.P.
UCT 1093	-	Klipfonteinrand	Pta-1642 3540±60	-19,6	
					4000-8000 B.P.
UCT 1053	UCT 331	Wyegang	Pta-1649 6900±70	-18,4	
					> 8000 B.P.

The radiocarbon dates given here were run for John Parkington and are cited with his permission, or are listed in Hausman (1980).

TABLE XXI

MONTHS IN WHICH JUVENILE DASSIES FROM DE HANGEN WERE KILLED



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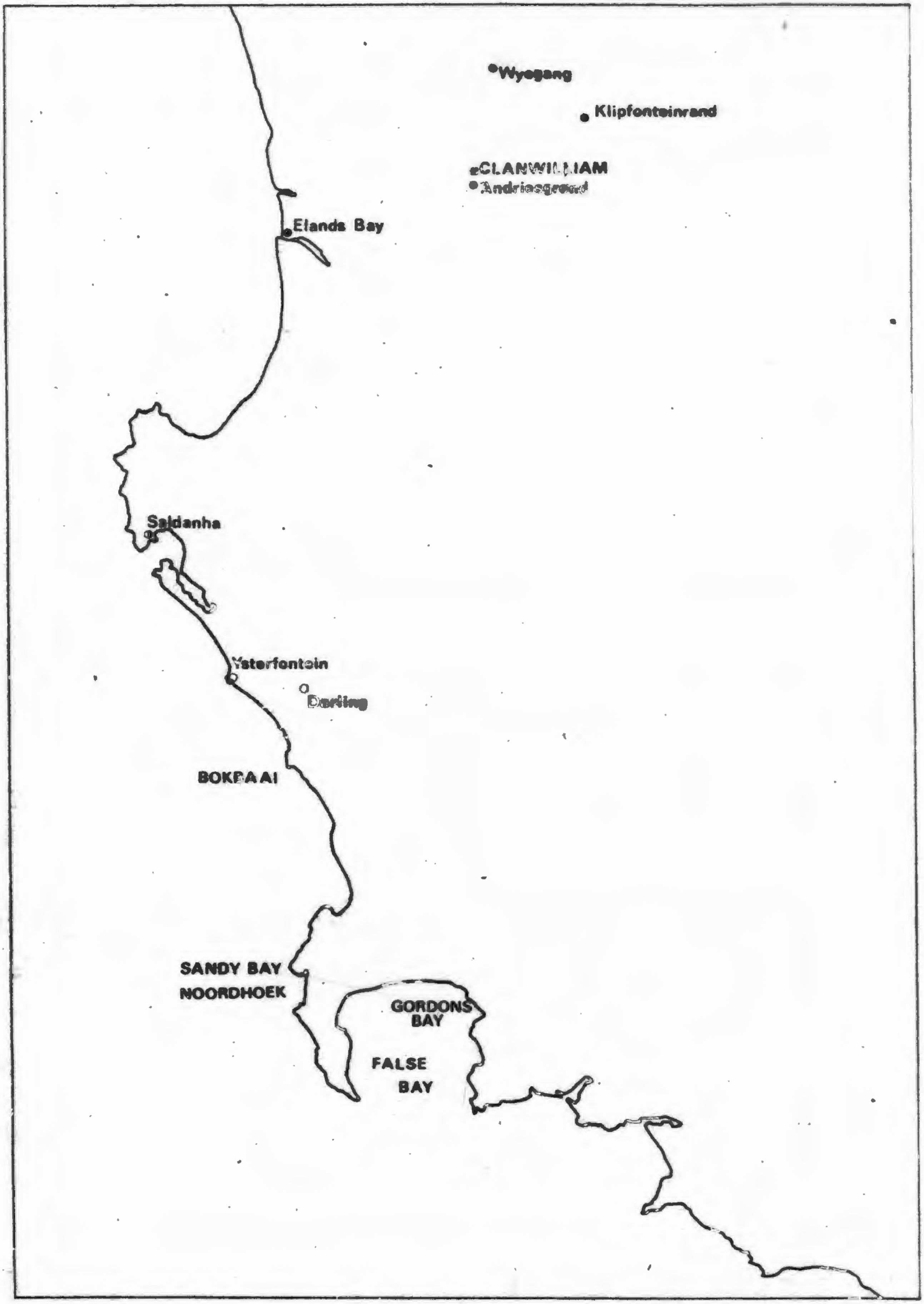
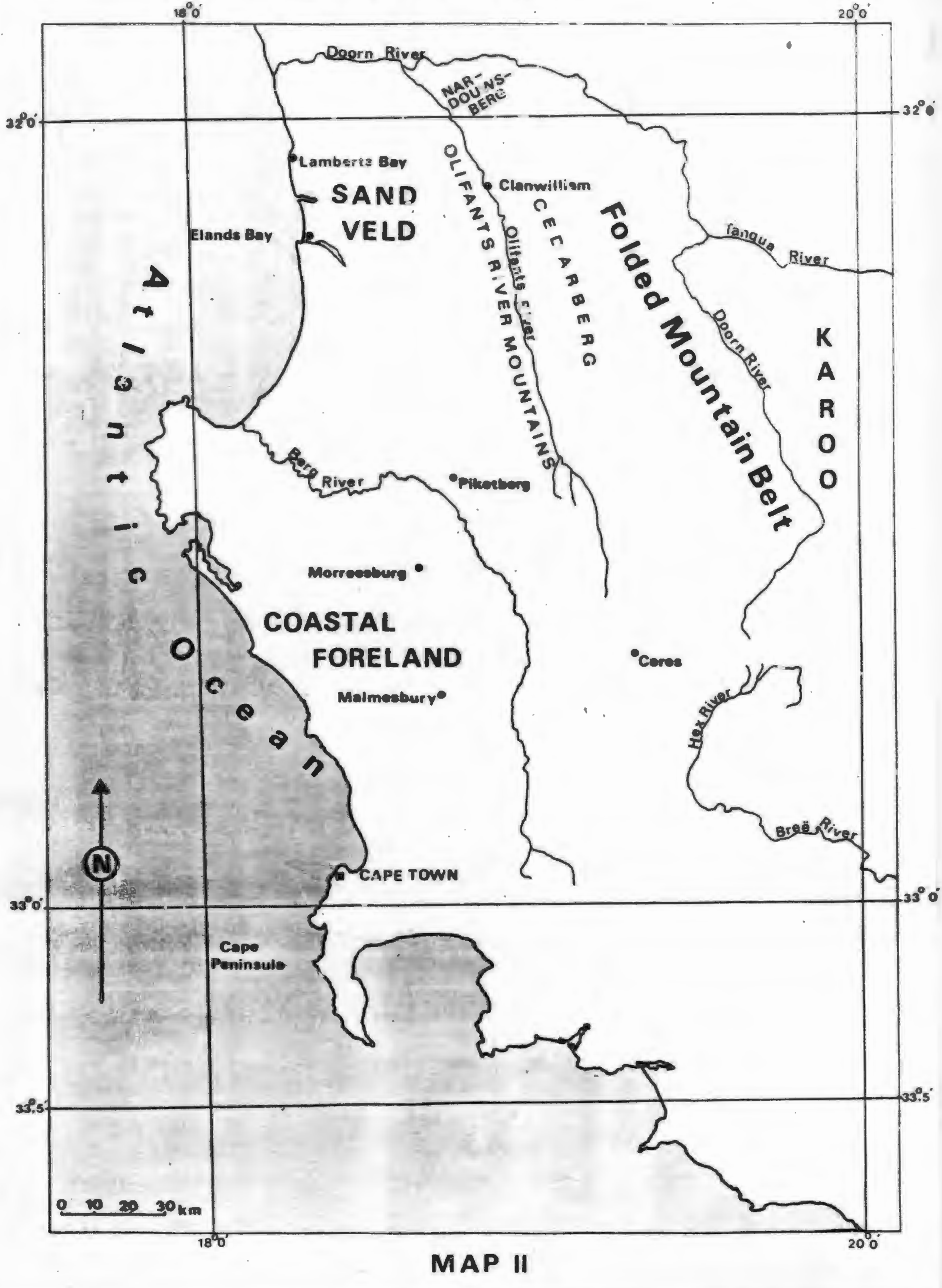
HUMAN SKELETONS



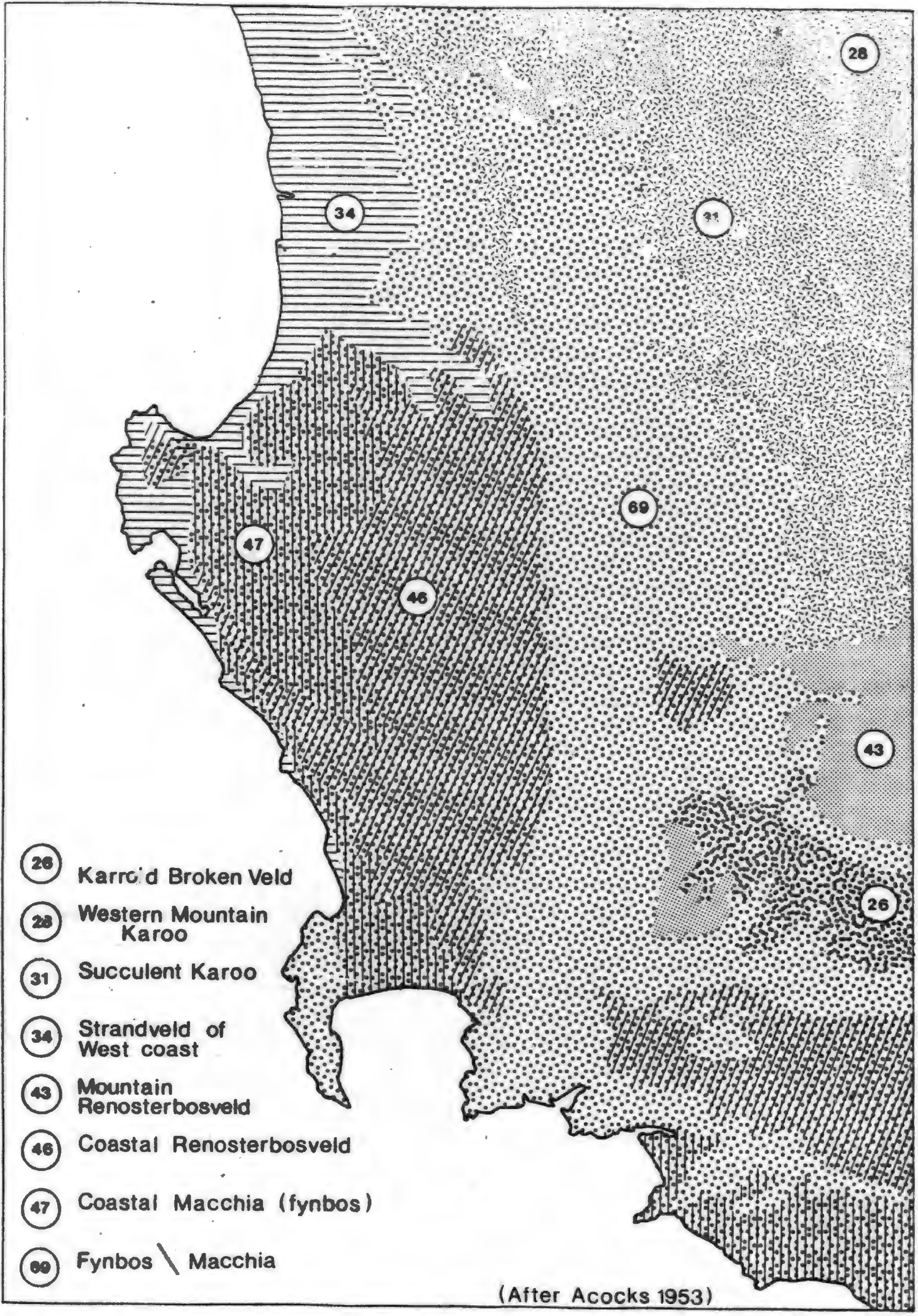
MAP VII

RESEARCH AREA



MAP II

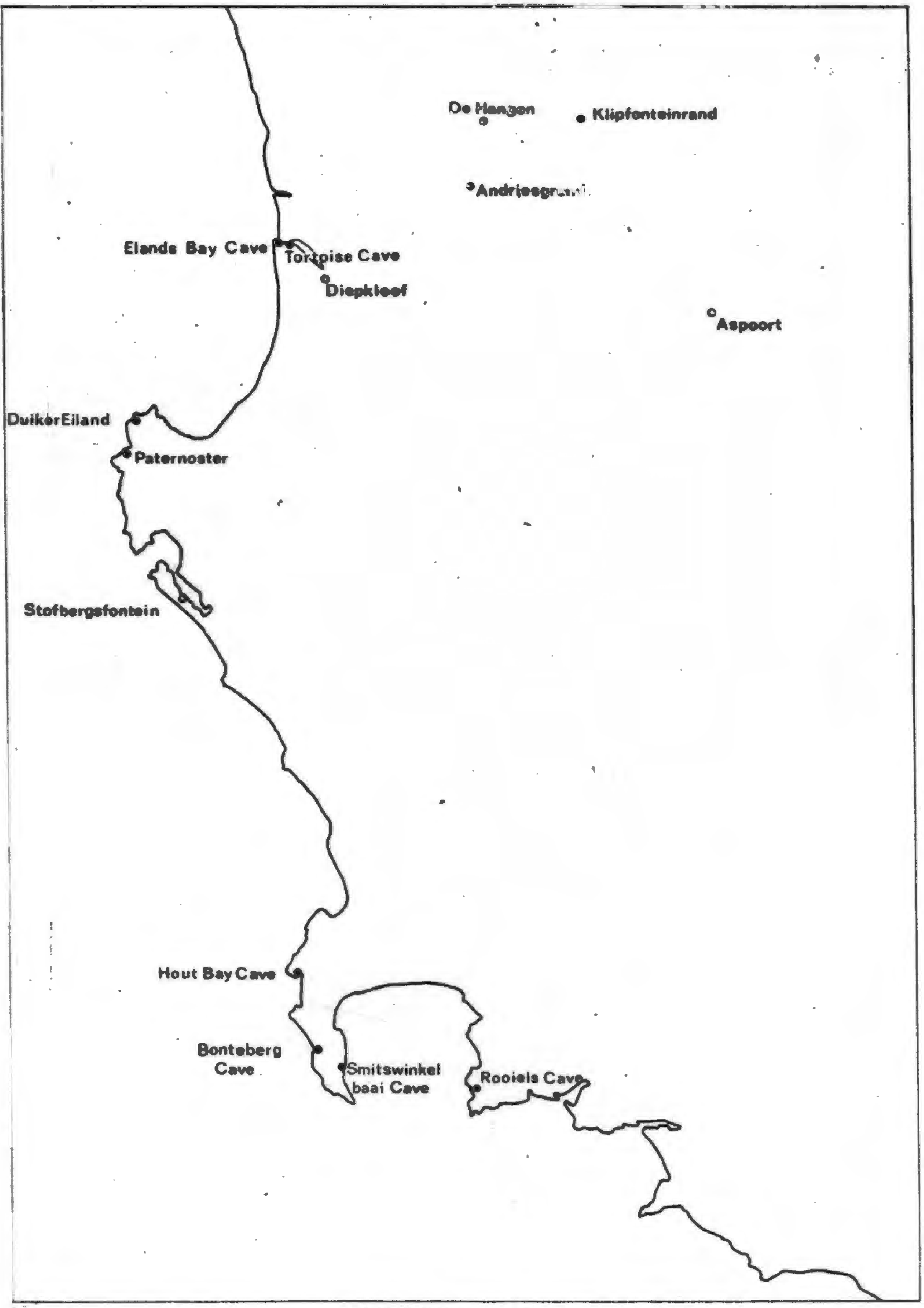
VEGETATION TYPES



(After Acocks 1953)

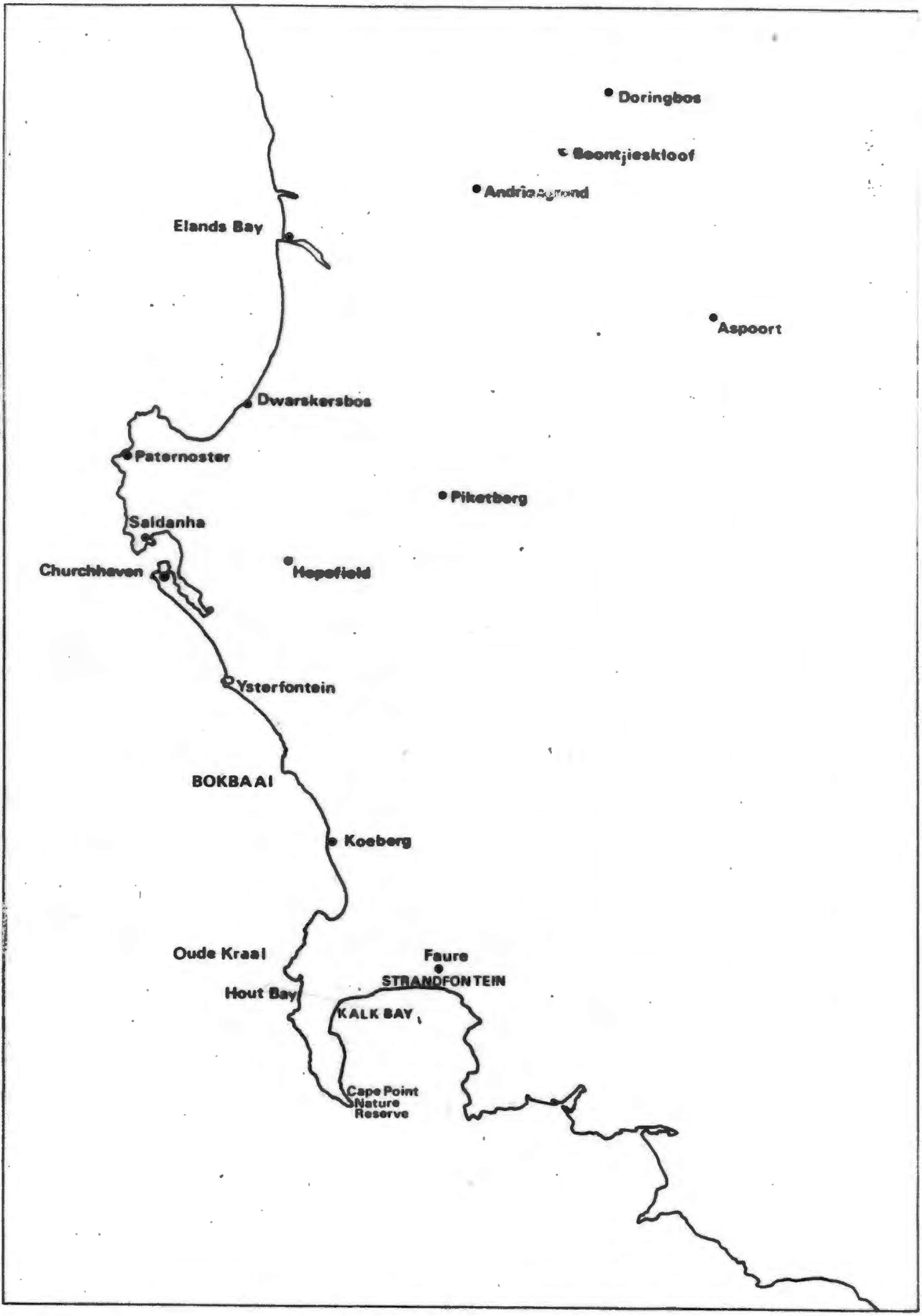
MAP III

ARCHAEOLOGICAL SITES



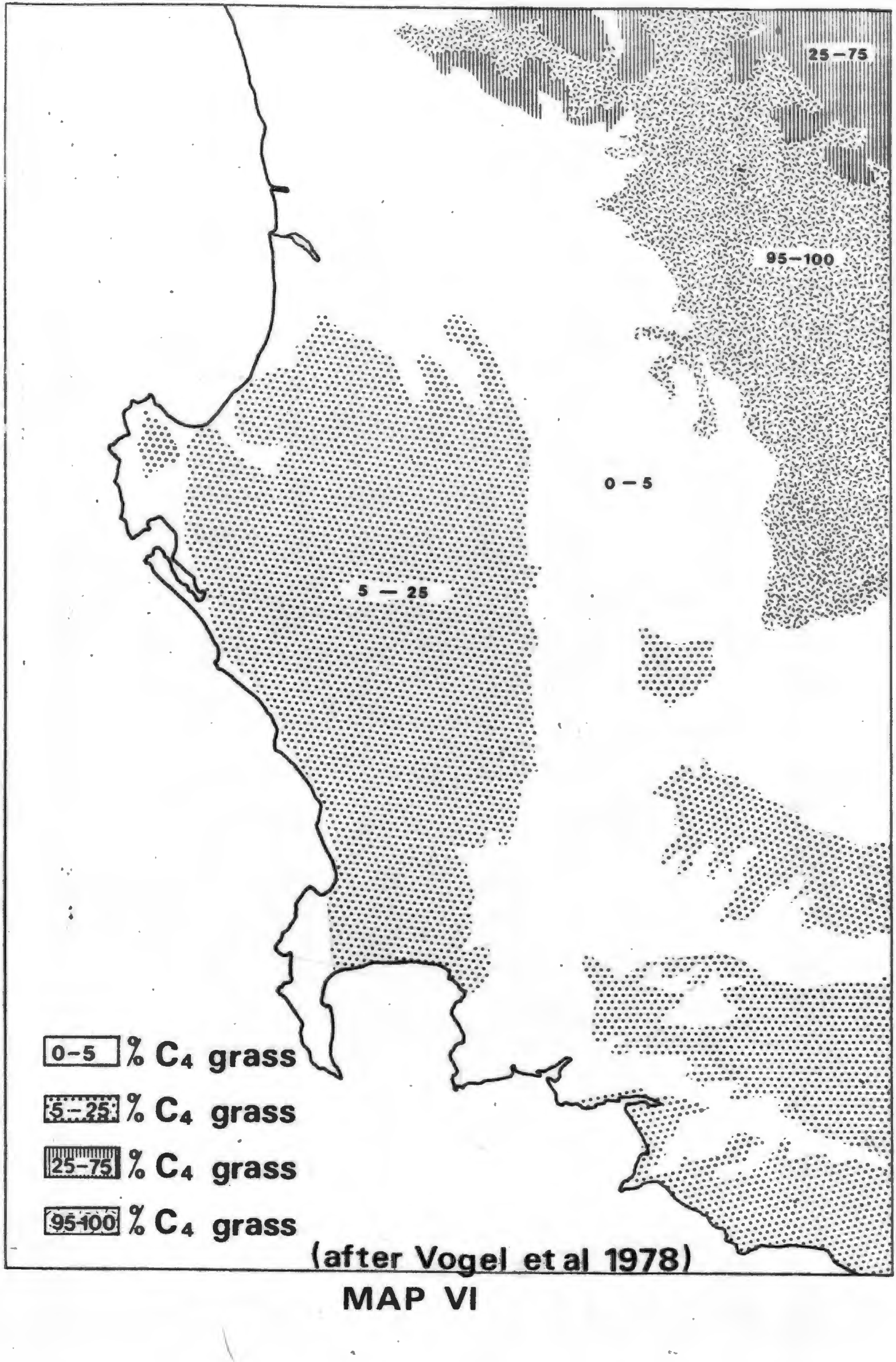
MAP IV

PLANT AND ANIMAL SAMPLES



MAP V

C_3/C_4 ZONES



(after Vogel et al 1978)

MAP VI