HOLOCENE PALEOECOLOGY AND LATER STONE AGE HUNTER-GATHERER ADAPTATIONS IN THE SOUTH AFRICAN INTERIOR PLATEAU

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by

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Holocene Paleoecology and Later Stone Age
Hunter-Gatherer Adaptations in the
South African Interior Plateau

Advisor: Professor C. Garth Sampson

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Excavations at Blydefontein Rockshelter and Meerkat Rockshelter are used to test models of hunter-gatherer technological organization. Climatic and ecologically driven models that predict differential use of weapons and tool kits among hunter-gatherers were constructed from modern hunter-gatherer studies from throughout the world. Ethnographic, historic and archaeological observations on tools made by still-living Bushmen from the 19th and 20th century were used to predict the specific technological changes that would occur under varying climatic circumstances. Local paleoenvironmental and modern botanic studies are used to predict past hunter-gatherer behavior through the reconstruction of past climates. Tests of these models were conducted with Later Stone Age artifacts from the rockshelter excavations.

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ACKNOWLEDGEMENTS

I would like to dedicate this work to two people: my daughter, Suzanna Blythe Bousman and my father, Kurth Pennington Bousman, Sr. One came and the other passed during the course of this dissertation, and it is fitting that they both share this dedication.

Most importantly, my wife, April Coldsmith, supported me through the project. Without her help and cajoling the project would have taken years longer. She made many sacrifices through the years it took to complete this study. My mother, Peggy Bousman, provided no less encouragement and aid through the years. She sustained and inspired me from my undergraduate years to this conclusion. My brother, Kurth Bousman, Jr. facilitated the final paper work.

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symptoms, when he said "Hey wait a minute, you're not from around here." He then made me give him the usual 20 minute spiel on the Blydefontein Project. All the while I fought off throwing up in his office. The van Rensbergs' hospitality and friendship is well remembered and missed.

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CHAPTER I

INTRODUCTION

This study has three objectives. The first is to present a case study of Holocene paleoenvironmental changes in the heartland of the interior plateau of southern Africa. The second is to examine world-wide processes that contribute to the formation, composition, and appearance of hunter-gatherer material residues. The third goal is met by combining both investigations to show how a series of Later Stone Age hunter-gatherers adapted their material culture to the changing circumstances of one harsh and demanding habitat in the interior plateau.

The central thesis of this research is that changes in population density influence all aspects of Later Stone Age organization and behavior. This approach was prompted by the suggestion of Janette Deacon (1974: 5-9) that Later Stone Age populations were not stable, and that those in the interior plateau had suffered a major decline to minimal levels in the early to mid-Holocene. Her hypothesis was based on an apparent absence of radiocarbon dates from Later Stone Age sites in the interior plateau, in sharp contrast to coastal and Transvaal Later Stone Age sites that evidently span the entire Holocene. Although she proposed (ibid: 8) the purported change in population density could be linked to a deterioration in the interior plateau environment, no direct evidence for this was available.

Furthermore, J. Deacon's model was based on a small sample of dates from three rockshelters in the middle Orange River valley, plus a few outlying shelters. The reliability of the dates was further clouded because the original samples were widely scattered charcoal flecks gathered from thin arbitrary spits of homogeneous unstratified deposit. Virtually all the radiocarbon dates could be challenged on contextual grounds, therefore. By 1979, when we began the Zeekoe Valley Archaeological Project in a small tributary adjacent to the middle Orange River, we were ready to dismiss all but one of the previously acquired radiocarbon dates and start anew.

Thus a search was on for a new rockshelter with visible stratigraphy and charcoal-bearing features from sound contexts. This quest became more urgent as our foot survey began to pile up an inventory of some 5,000 surface lithic scatters attributable to those very levels whose radiocarbon dates we had decided to reject! All these surface sites, with unmistakable affinities to various phases of the Interior Wilton Industry, could never be cross-dated unless we found the right rockshelter sequence to use as a chronological standard. Without reliable cross-dating, their great potential for studying settlement pattern changes could never be realized. After 15 months of searching some 5,000 square kilometers, no suitable rockshelter was discovered that could crack the Interior Wilton chronology. The many we discovered all shared the same shortcomings as those in the Orange River valley: thin, leached deposits without visible stratigraphy or features, all poor in organic materials but stuffed full of microlithic stone tools and debris. We were forced to leave the strict confines of the valley, and turned to a nearby but superior alternative.

Blydefontein Rockshelter, located only a few kilometers east of the Zeekoe River basin had been tested by Garth Sampson in 1967, and its rearmost, best protected deposits had exactly what we needed: a clear stratified sequence of charcoal-packed hearths and shelter fills with highly visible microstratigraphy. Even though it was loaded with lithic materials and relatively well preserved fauna, Blydefontein Rockshelter did have two apparent shortcomings: the last several hundred years was missing from the sequence, and apparently it had no Early Wilton assemblage at its base (Sampson 1974: 325). Thus the site offered only a partial test of J. Deacon's "mid-Holocene abandonment" model. Nevertheless we knew that interlocking roof-fall had prevented Sampson from exploring the lower deposits that might reveal the needed Early Wilton assemblages below, so it was worth the risk, and plans were laid to re-excavated the shelter.

Upon arrival to Blydefontein in early 1985 the landowner, Mr. Dou Lessing, told us that he had discovered a second, smaller rockshelter upstream and in the opposite cliff face from Blydefontein Rockshelter. This was named Meerkat Rockshelter after a decayed and desiccated meerkat carcass found on its floor. During preliminary test excavations here, it became clear that this would provide a detailed view of the last 1000 years or so, including the later segment missing from Blydefontein Rockshelter. But the biggest surprise was the discovery of deep stratified alluvial deposits in front of Blydefontein Rockshelter. These sediments have yielded a superb record of Late Pleistocene and Holocene sediments that contain pollen and other types of paleoecological data.

This dissertation attempts to wring information from the data recovered from all three of these sources in Blydefontein Basin. The basin's geographical setting is described first (Chapter II) in a conventional format. Its bedrock geology, the geomorphological forces that shaped it and its more recent sedimentary infilling are treated first. Annual and seasonal variations of local climate are reviewed, followed by an extended summary of the complex way in which four regional vegetation communities, and the smaller and more local plant communities (the so-called Veld Types) overlap in the basin's vicinity. This is followed by an overview of the relict fauna of the basin and it surrounds, and the chapter closes with a brief evaluation of European impacts on both plants and animals during the past two centuries.

The mechanics of regional climatic circulation systems are briefly reviewed in Chapter III as a background for understanding how climate simulations models are designed. The COHMAP simulation is then reviewed in detail as this provides the best available model of Holocene climate change against which to compare my field data.

With a predictive model of temperature and rainfall fluctuations in place, it becomes feasible to derive another model of plant-community changes (Chapter IV) that is directly testable through pollen analysis. By analyzing a massive unpublished phytogeographic data-base using discriminant function analysis, it is made clear that the previously defined Veld Types are invalid and cannot be used in such a study. This botanical data-base is then reclassified into new plant communities using cluster analyses which are double checked with a second discriminant analysis. These new plant communities form the backbone of the botanical model, which predicts climate-driven shifts in Blydefontein Basin.

The botanical model is tested in Chapter V by pollen analysis of the extensively dated basin fills and buried soils, and these results are cross-checked with molluscan and diatom analysis from the same sediments. A triple check on the younger parts of these sequences is provided by closely spaced pollen spectra from dated hyrax dung middens that provide high resolution for the last 1200 years. The combined fossil pollen record is classified to the new scheme of modern plant communities, executed in the previous chapter. The combined Holocene botanic record is now seen to oscillate between five different plant communities over the last eight millennia, but the terminal Pleistocene pollen spectra have no modern analogs.

These combined data are compared with a sequence of stable carbon isotope ratios in Chapter VI. Bulk organic carbon samples were obtained from the dated alluvial sediments that yielded pollen, and fluctuations in C_3 and C_4 grasses (not accessible by palynology) become apparent. Furthermore, an independent cross-check on the $\delta^{13}C$

humate curve is provided by a second $\delta^{13}C$ curve obtained from from a vertical sequence of ostrich eggshell samples excavated from Blydefontein Rockshelter.

In Chapter VII modern linear transform functions, developed in Chapter IV, are used for predicting temperature and rainfall from botanical associations, and the pollen sequences are used to estimate climatic conditions during their accumulation. The fine-tuned hyrax midden pollen sequences are checked against historical rainfall records with remarkable success. Thus armed, it is finally possible to combined all the Holocene pollen-derived climatic estimations, and compare the estimates with the computer simulations of past climates as presented in Chapter III. The fit between the two climatic estimations is shown to be good, although the Blydefontein data show far superior resolution and many more oscillations that the simulated curves.

The Blydefontein Rockshelter stratigraphy and matrix granulometry are described in Chapter VIII, together with the radiocarbon chronology for the sequence. Phosphate values for the sequence clearly isolate a thin layer of decomposed dung, possibly derived from penned livestock. There is a notable unconformity in the sequence that adds significant support to J. Deacon's "mid-Holocene abandonment" scenario. The suspected terminal Pleistocene layer at the base of the excavation cannot be dated yet by radiocarbon. Meerkat Rockshelter contains a thin and poorly stratified fill that overlaps with the upper part of the Blydefontein Rockshelter sequence.

In Chapter IX, I turn to the temporal changes in artifact designs at Blydefontein and Meerkat Rockshelters, and present evidence for six temporal marker-attributes. It is proposed that these might be used in a future project to cross-date Interior Wilton surface assemblages already mapped in the adjacent Zeekoe Valley.

Chapter X reviews the historical development of models designed by South African archaeologists for explaining variability in Later Stone Age artifact assemblages. Most of these are found to be mono-causal models, so other non-local models that suggest processual approaches are reviewed as possible frameworks for the multi-causal modelling that follows.

In Chapter XI, I outline the basis of a new, four-system model with a central focus on risk-reducing strategies used by dozens of ethnographic hunter-gatherer groups from different habitats around the world. A sliding scale of global habitat types is erected as a framework on which to cross-refer biomass changes, changes in the plant/animal mix of the habitat, and changes in the spacing and seasonal availability of foodstuffs. This cluster of variables is linked to sliding scales of hunter-gatherer risk-buffering responses: changes in overall group mobility, mixed patterns of forager versus collector mobility, and changes in range size.

A six-part technology system is welded on to the model in Chapter XII. A sliding scale of mobility pattern options ranging from extreme forager to extreme collector patterns provides the framework. This is used to organize various hunter-gatherer options for tool design. These include the mix of reliable versus maintainable qualities, the amount of use-life, decisions to replace or repair, decision to transport or cache, the value placed on repair and production kits, and frequency/timing of use and repairs. The chapter ends with some test implications for archaeology and for settlement pattern analysis derived from this model.

A partial test of the model with Blydefontein data is presented in Chapter XIII. Faunal data are not yet available, but the dynamic relationship between the ecological changes in Blydefontein Basin, and changes in Interior Wilton artifact design at Blydefontein Rockshelter can be addressed. The time-calibrated vegetation record is used to predict changes in local population density, mobility, range, territorial packing, and in between-band reciprocity. From these predicted fluctuations, test implications are spelled out in terms of predicted fluctuations in exotic raw material frequencies, endscraper designs, arrow armature (microlith) replacement strategies, and bladelet technology. A factor analysis is used to isolate one cluster of design trends that fit well with the expectations of the multi-causal model.

Finally, in Chapter XIV the significance of these results is reviewed in terms of their potential for explaining regional and supra-regional trends in Later Stone Age lithic design choices.

Obviously a robust test of the model will require a larger spatial data base such as that available in the adjacent Zeekoe Valley. That, however, is for the future, when I hope to put my general model through a more exacting set of tests than can be brought to bear by the data presented in this dissertation. Nevertheless, the model is presented here in the belief that it helps to explain several large-scale, inherently puzzling patterns long known to characterize the Later Stone Age archaeology of southern Africa.

CHAPTER II

THE MODERN ENVIRONMENT

The Physical Setting

Blydefontein and Meerkat rockshelters occur in a perched basin in the western portion of the Kikvorsberg Range which is drained by the Oorlogspoort River (Figure 1). Kikvor means frog and berg is the word for mountain in Dutch. Since the late 1700s this area has been known as the Bo-Hantam or the upper Hantam. These grassy mountains can be considered as the westernmost extension of the alpine Drakensberg Range into the semi-desert interior plateau of southern Africa. The veld (pron.: felt) in the Bo-Hantam is dominated by tall, tough bunch grasses that are not palatable to small stock, and do not retain their nutrients during the winter, while the grasses in the flat Karoo plains below are shorter, much more nutritious and easier for small stock to eat. The Bo-Hantam grasses are called sourveld and the plains grasses are known as sweetveld. Today this area is in the summer rainfall region of southern Africa and, during the summer, clouds driven by westerly and northwesterly winds blow across the flat Karoo plains. On many hot summer afternoons these rain-bearing clouds accumulate on the Kikvorsberg Range and drop their loads on the cooler mountains. Occasionally heavy rains flood the gullies (colloq.: dongas) that drain the mountains. During the winter Blydefontein often remains cold and fogged-in until afternoon while Noupoort, at the base of the Kikvorsberg, only 10 kilometers away is warm and sunny. Heavy snowfalls are not unusual and in the 1940s a group of people, caught in a Kikvorsberg blizzard, froze to death. These topographic and orographic effects result in greater rainfalls and cooler temperatures in the Kikvorsberg as opposed to the flat Karoo and grassland plains below. Many of the animal species that typified the southern African plains are no longer present. Today springbok, steenbok, meerkats, jackals, bat-eared foxes, and ostriches are still common, blesbok and wildebeest occur in small numbers, but many of the other animals are gone. The region is unique, and this distinctiveness is due the combination of its geology, climate, and the biota.

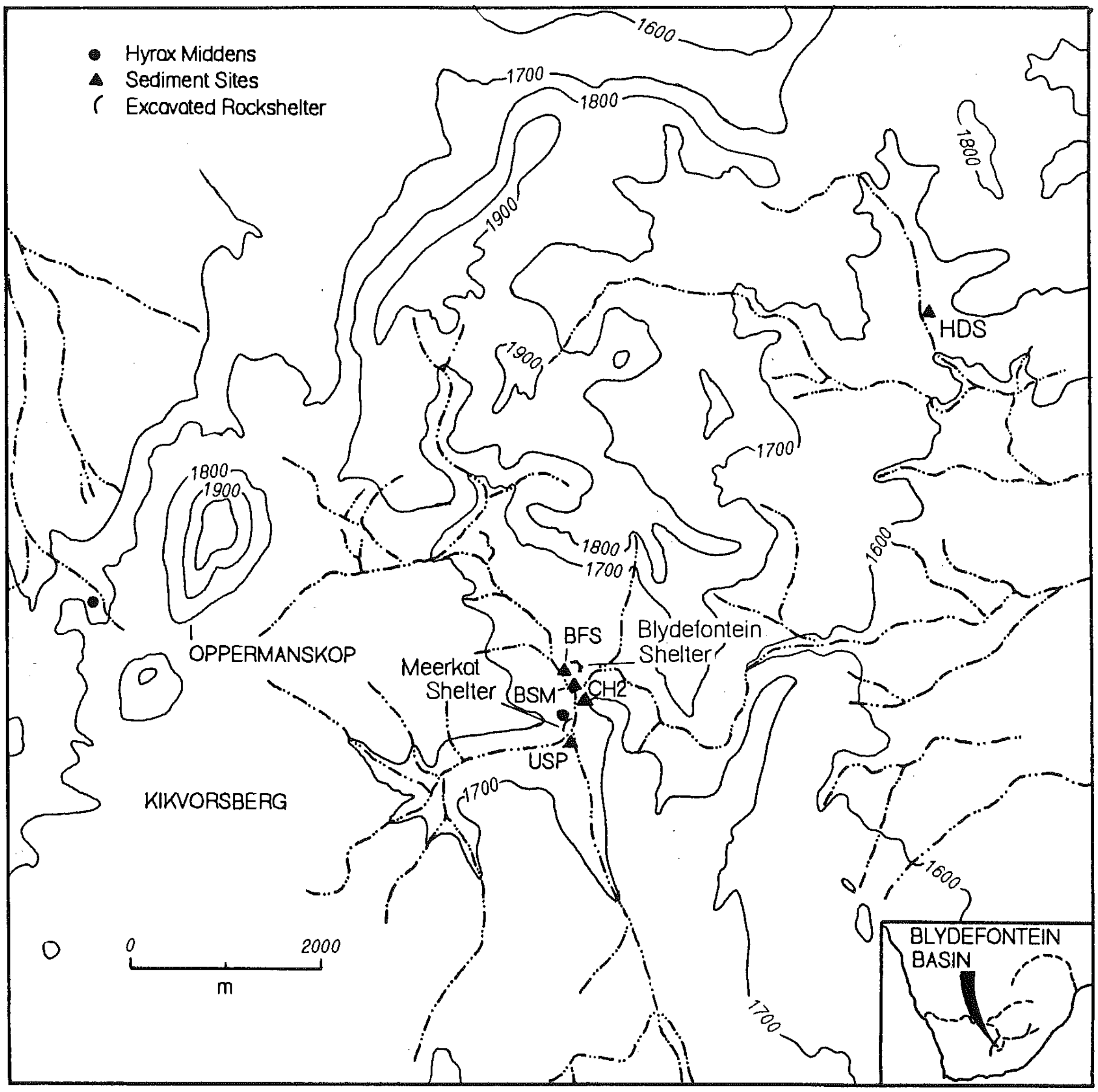

Figure 1. Blydefontein and Meerkat Rockshelters, and paleoenvironmental sites in the Kikvorsberg Range.

Blydefontein Basin Topography and Hydrology

Blydefontein Basin covers approximately 15 square kilometers, and is created by a large north-south trending dolerite ridge on the east through which a narrow constricted gap (colloq.: poort), Diepkloof (1660 msl), provides the only drainage out of the basin (see Figure 1). The Basin is flanked by high peaks such as Oppermanskop (2049 msl) to the north and others to the south, and has rolling topography with a few small dolerite ridges on its floor. The basin forms a small cuesta-like feature with the steep, western edge dropping off into the Zeekoe Valley. The Basin's only drainage divides 1.25km upstream from Diepkloof. One stream flows from the north running in front of Blydefontein Rockshelter, and the other drains the southern portion of the Basin and flows in front of Meerkat Rockshelter. Small gorges occur in the lower reaches where the streams flow year round. These gorges have valley-in-valley cross sections with numerous overhangs and shelters. A more detailed discussion of the bedrock geology and geomorphology is warranted in order to understand the formation dynamics of the landscape.

Bedrock Geology and Geomorphology

Three major processes have formed Blydefontein Basin's geological landscape: plate tectonics, deposition and erosion. Each process has played a major part in creating the landscape as we now see it, and an understanding of the geologic and geomorphic setting can only be gained by discussing the individual roles of these processes.

Most of the surficial bedrock sediments in Blydefontein Basin are from the Karoo Sequence which is capped by the volcanic Drakensberg Formation. Beginning in the late Carboniferous, 290 million years ago (mya), through the early Jurassic, 190mya, southern Africa was in the middle of Gondwanaland, a single ancient continent composed of most known southern hemisphere landmasses (Brink 1983: 18). Southern Africa was a huge basin into which enormous amounts of sediments were deposited. These sediments, up to eight kilometers thick, are known as the Karoo Sequence. The Karoo Sequence, from older to younger, is made up of the Dwyka Formation, the Ecca Group (twelve formations), the Beaufort Group (eight formations) and the Molteno, Elliot and Clarens formations.

At the beginning of the Karoo Sequence glaciers covered much of southern Africa because it was situated near the South Pole (Visser 1986: 14-15). In time Gondwanaland drifted north toward the equator and the glaciers melted leaving a large shallow periglacial lake with lush vegetation (Brink 1983: 20). Lacustrine and deltaic sediments were deposited in this lake to form the Ecca Group (Visser 1986: 14). Eventually the the lacustrine deposits and prograding deltas filled the shallow basin, and floodplains formed. These alluvial deposits are known as the Beaufort Group. By this time central Gondwanaland was drier and warmer due to further northward movement of the continent, and evidence of life, especially animal life, is abundant. Most of the bedrock in Blydefontein Basin are of the Beaufort Group.

Biostratigraphers have divided the Beaufort Group into five zones, however lithostratigraphic units will be discussed here as the lithology is more important to this discussion. Lithostratigraphers have divided the Beaufort Group into two subgroups (the Adelaide and Tarkastad) and eight formations (Brink 1983: 22). Bedrock at Blydefontein Basin is in the Tarkastad Subgroup and probably the Katberg Formation rather than the Burgersdorp Formation, although detailed geological mapping is not available. The Katberg Formation, composed of sandstones with subordinate mudrock lenses, represents a distal alluvial fan and/or a braided fluvial system, while the Burgersdorp Formation, composed of mudrocks with subordinate sandstones, represents a meandering fluvial system (ibid: 22). The sequence of alluvial fan to braided stream to meandering stream in a floodplain suggests that during the deposition of the Tarkastad Subgroup the overall stream gradient was diminishing. In any case moderately thick sand bodies were deposited with subordinate mudrock layers, and these sandstone bodies form rockshelter overhangs, while the backwalls of the shelters are composed of more easily eroded mudrock layers.

Throughout the time of the Karoo Sequence the super-continent continued to move north and become drier and warmer. Termination of the Karoo Sequence is marked by the breakup of Gondwanaland. This enormous rifting is associated with volcanic events that exhumed massive amounts of basaltic lavas, the Drakensberg Formation. These basalts covered much of the ancient Karoo sedimentary basin between 190 and 150mya. This basalt layer was so hard and impenetrable that later magma intrusions were confined to the Karoo Sequence, and formed the numerous dolerite dikes and sills seen on the surface today (ibid: 19, 177). The dikes followed weaker sedimentary bedding planes, and thus usually intrude next to the argillaceous sediments such as shales or mudrocks (ibid: 177-178). Intrusive magma baked the adjoining deposits, and in extreme cases, metamorphic alteration produced hornfels from mudrocks and quartzites from sandstones (ibid: 180). Today these dolerite dikes crisscross the Karoo surface, and the hardened deposits baked by the dikes are an impediment to erosion.

With the breakup of Gondwanaland in the early Jurassic erosion becomes the major controlling process on what had finally become an "African landscape" (ibid: 26; King 1978: 3-17). Erosion of steep scarp faces and the development of flat peneplains dominate later geological processes. A major erosional cycle, stimulated by the breakup of the super-continent and changing base levels in the Early Cretaceous period, removed most of the original surface to form the Post-Gondwanaland Planation Surface (ibid: 11-12).

The most extensive erosional cycle, the African cycle, lasted approximately 100 million years from the Late Cretaceous to the mid-Tertiary (Brink 1983: 23), resulting in the African Surface (ibid: 27; King 1978: 12). In the eastern Cape much of the African Surface remains as mesas or buttes (colloq.: tafelbergs) where resistant Beaufort sandstones and dolerite sills have protected it from later erosion (Brink 1983: 27). The Kikvorsberg is probably African Surface, although the highest hills (colloq.: koppies) or tafelbergs such as Oppermanskop may be erosion features on the African Surface. Thus its uppermost surfaces possibly represent the Post-Gondwanaland Planation Surface (T. C. Partridge, personal communication). The African Surface is usually deeply weathered in places where a pedocrete armor has formed. On African surfaces like the Kikvorsberg these pedocrete remnants are often silcretes (ibid: 27).

Uplift in the Miocene and early Pliocene then stripped most of the Karoo basin (ibid: 27, King 1978: 14). Locally the subdued topography and medium-sized upland remnants suggest that this post-African erosion is extensive and continues today (ibid: 28). The shallow weathering (except for some calcretes) attests to a relatively shorter duration (ca. less than 20 million years) while elsewhere the African cycle lasted some 100 million years (Brink: 28). The active erosional scarp of the Kikvorsberg (≤ 585m in height) was probably initiated by the Post-African event in the Miocene and Pliocene. This is part of the incision limited to a 10-15km wide band on both sides of the Orange and Vaal Rivers. Narrower bands occur on their major tributaries which include the Oorlogspoort and the Zeekoe rivers (ibid: 28; Butzer 1971; Helgren 1979).

In Blydefontein Basin, the Diepkloof poort was created by headward erosion of the Oorlogspoort River which penetrated the resistant dolerite dike that bounds the east side of the Basin. The many small streams which drain the floor of the basin have cut small gorges with numerous overhangs in their lower reaches. These shelters were created by stream erosion and weathering of mudrock layers between more resistant sandstone bodies that form the roofs of both excavated shelters and many other shelters in the Basin. The cross-sections of Blydefontein and Meerkat gorges have a valley-in-valley configuration due to the presence of various resistant sandstone layers.

Thus the modern landscape was created by dynamic forces that were local, regional and worldwide in scope. Although its configuration has been here for a relatively short time in geological terms, in human prehistoric terms it evolves with imperceptible slowness.

Lithic Resources

A number of local knappable lithic resources were identified: hornfels or lydianite, quartzite and silcrete. The most important is hornfels. Hornfels occurs where intrusive dolerite dikes have baked shales or mudrocks for prolonged periods. Hornfels is extremely common in the region, and it was used throughout all of prehistory as the dominant material for chipped stone artifacts. The texture varies from coarse to fine grained, but flaking quality is related to many other characteristics also. Here hornfels occurs in huge sheets that cover the tops of some tafelbergs, adjacent to dolerite dikes in thin linear strands, as fractured and weathered cobble debris below *in situ* occurrences, or as ancient fluvially deposited gravels on terraces overlooking stream floodplains. Blydefontein Basin has only a few dolerite dikes, and no hornfels outcrops. The closest hornfels outcrop and prehistoric quarry is 5 kilometers northeast, at Hughdale.

Quartzites are sandstones metamorphosed by intrusive dolerite dikes. These are not common, and the quartzites are not used extensively for stone tool manufacturing. The silcretes are a product of weathering associated with the African Surface. They are found occasionally *in situ* on the higher mountain ridges in the Sneeuwbergen and presumably the Kikvorsberg, although none has been discovered in or near Blydefontein Basin.

Two non-local raw materials, agate and jasper, were sometimes used at Blydefontein although they are known to occur only in Orange River gravel deposits, apparently originating in the highlands of Lesotho. Orange River terraces extend from five to ten kilometers from the river (Butzer 1971; Helgren 1979; Partridge, personal communication) so agate and jasper gravels should be obtainable from these terraces as well.

Blydefontein Basin Quaternary Sediment Accumulation

The Diepkloof constriction has created a situation, probably due to cyclical floodplain overbank deposition (Patton and Schumm 1981) and changes in local base level because of masswasting events in the narrow gorge (T.C. Partridge, personal communication), whereby moderately thick alluvial deposits of Pleistocene and Holocene age have accumulated in the gorge above the constriction at Diepkloof. King (1942: 52) named these types of sediments rock-defended terraces. This type of perched basin in the mountains above narrow constricted gorges provide more detailed sedimentary records, at least for the Pleistocene and Holocene, than the open broad floodplains in the Karoo, e.g. the Oorlogspoort or Zeekoe valleys. This is because bankfull stage is reached more rapidly in constricted channels and is confined to a smaller floodplain (Magilligan 1985). Also rapid flushing of water off the mountains transports greater sediment loads that are then deposited in the lower reaches of Blydefontein and similarly positioned basins.

Soils

Very little detailed soil mapping and classification is available for the Blydefontein region. However a general soil map is available for the entire Karoo region (Ellis and Lambrechts 1986). Three soil types are mapped for Blydefontein Basin. The lower portion of the Basin has Duplex soils. These are characterized by loams to loamy sand A horizons with massive to platy structure above a red B horizon with clay content at least twice as high as the overlying horizons and moderately to strongly structured. In the Blydefontein region the B horizons are often known as dorbank (MacVicar et al. 1977: 126) which probably represent multiple cycles of pedogenic development over at least the Late Pleistocene. Also present in the lower reaches of the Basin are soils on alluvium with Melanic A horizons (ibid: 126). Eluviated horizons can occur between the A and B horizons. Parent materials consist of shales and dolerites. On the relatively flat area of the Basin above the gorges and below the koppies shallow soils of pedologically young landscapes are mapped. Often these are soils on bedrock. The soils of the koppies and mountains have not been classified, but on the slopes erosion is a dominant process and bedrock exposures without soils are common.

Climate

I have first hand experience with Blydefontein weather between late January and late September (1985). With the beginning of fall in March, frosts or freezes occurred almost every night until the end of the excavations in September. The streams were almost always frozen during the winter. Also light snows occurred in April and September, but the Kikvorsberg, along with the Sneeuwbergen to the southwest, are known for heavy snows so 1985's snows were light. While working in the Zeekoe Valley during early September of 1981, I observed heavy snows in the

Kikvorsberg and temperatures were low enough for the snows to remained on the ground for 10 to 14 days (Jim Meyer, personal communication).

Most rain in Blydefontein Basin falls in the summer and early fall, and during 1985 good general rains occurred in February. The ground was saturated with water and the grass turned a lush green. Often the rains are due to convectional uplift and orographic effects as saturated clouds are blown across the plains in the Zeekoe Valley and uplifted by the Kikvorsberg. General rains are associated with a tropical easterly jet and usually occur in late spring through early fall (Tyson 1986: 127-128). Normally if a good rains occur during the summer or fall then that year is a high rainfall year.

The climate of the region is classified in the Thornthwaite system as mesothermal, semi-arid, cooler-temperate with severe frosts (Schulze and McGee 1978: 43-49), and as dry hot arid steppe (mean annual temperature < 18 ^{o}C), BSk, in the Köppen classification system (ibid: 37-39).

Modern rainfall records were available through Mr. Norman Biggs from the nearby farm of Grapevale. It is important to note that Grapevale is 200m lower in the Kikvorsberg, where the orographic effects are not as great as at Blydefontein. Blydefontein receives more rain, but the differences are of degree rather than of kind. Monthly rainfall records were available from March of 1920 until the conclusion of the excavations in September of 1985. Unfortunately no temperature records were available from Grapevale, but a 20 year record (from 1962 to 1982) was available from Dr. Piet Roux, Grootfontein Agricultural College, Middelberg.

Temperature

At Grootfontein the mean annual temperature for the period 1962-82 was 14.6 ^{o}C (58.3 ^{o}F) with the lowest yearly average of 13.5 ^{o}C (56.3 ^{o}F) and the highest yearly average of 15.4 °C (59.7 °F). Grootfontein is 405 meters below Blydefontein and if one can assume that the normal lapse rate holds (i.e. 6.5 °C change per 1000 meters, Trewartha 1968: 46), then the mean annual temperature at Blydefontein would be some 2.6 °C (4.7 °F) below Grootfontein or 12 °C (53.6 °F). One should realize that this estimation probably errs on the warm side, because the orographically produced cloud-cover increases albedo and rainfall, which would act to reduce the mean annual temperature more that the normal lapse rate.

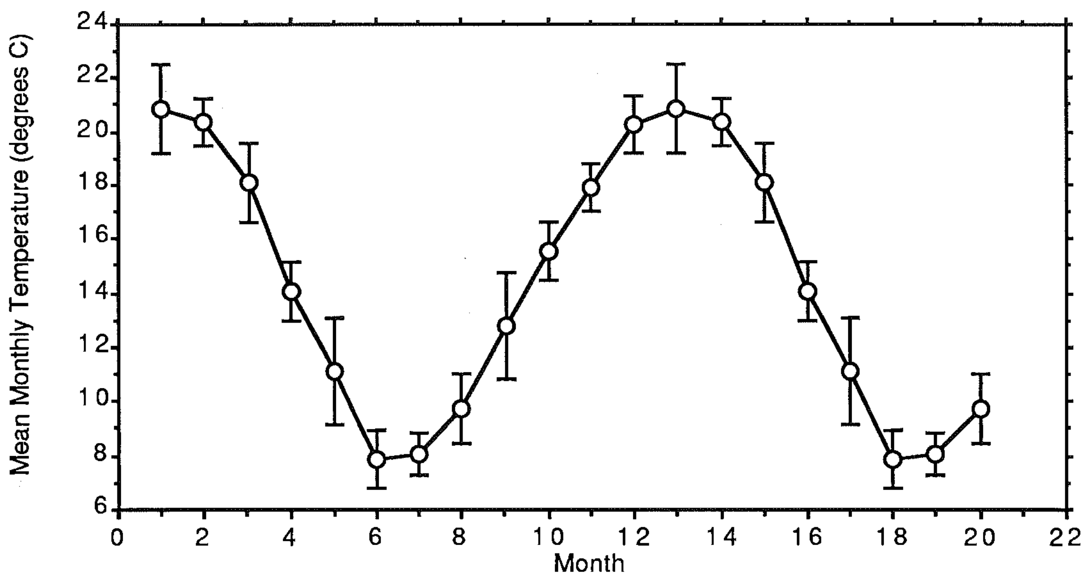

Figure 2. Mean monthly temperatures in °C with one standard deviation bars at Grootfontein over an average twenty month period.

The Grootfontein average monthly temperatures (with one standard deviation bars) have been plotted in Figure 2, over a 20 month period in order to view better a full season's cycle. The average January temperature at Grootfontein is 20.8 °C (69.5 °F) and the average temperature for June is 7.9 °C (46.2 °F). This is a 12.9 °C (23.2 °F) range in the average monthly temperatures. These data show a clear summer high temperature plateau (in December, January and February), and a winter low plateau (in June and July). This is mostly due to seasonal variation in the solar radiation budget which is twice as great in the summer as in the winter (Schulze and McGee 1978: 23). The most variable months are May (no.s 5, 17) and September (no.s 9, 21) The minimum recorded temperature for Grootfontein between 1962 and 1982 was -10.3 °C (13.5 °F) in August 1975 and the maximum recorded temperature was 39.2 °C (102.6 °F)in January 1965.

Rainfall

The mean annual rainfall for the period from 1921 until 1984 at Grapevale is 366 mm (14.4 inches) with the driest year, 1949, receiving only 139.5 mm (5.5 inches) and the wettest year, 1974, receiving 865.5 mm (34.1 inches). The range is 726 mm (28.6 inches). Rainfall from the years 1920 and 1985 were not used because observations were not available for all months in those years.

Figure 3 shows the average distribution of rainfall by month at Grapevale over an average twenty month period. Both the mean monthly rainfall and the percent of months receiving significant rainfall by month are illustrated. Significant rainfall is defined as ≥ 25.4 mm (i.e. ≥1 inch) of rainfall during a single month.

The seasonal rainfall pattern peaks in late summer (February and March) then drops to a four month winter low (June-September). Not surprisingly these four winter months are also much less likely to receive any significant rain. It is important that strong positive correlations exist between mean monthly rainfall, percent of significant rainfall and maximum monthly rainfall. Rainfall varies the most in January, February and March, and March is the only month that has had rain every year from 1920 until 1985. These rainfall patterns result in a significant seasonal climatic pattern that affects plant growth (Vorster and Roux 1983: 19).

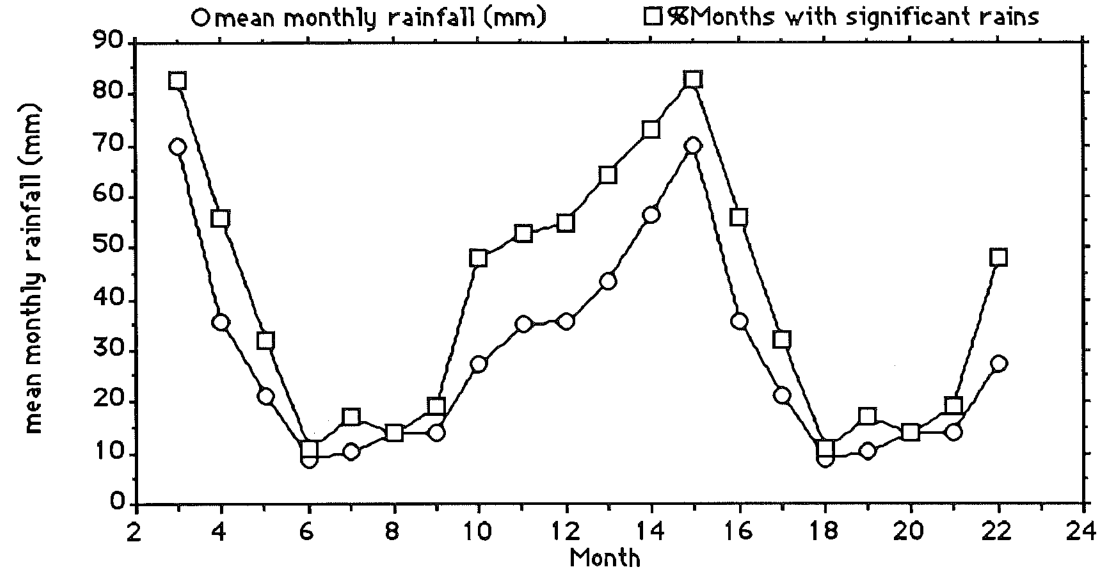

Figure 3. Mean rainfall and percent of significant rainfalls by month over a 20 month period.

The Botanical Setting

The modern vegetation mosaic of the Blydefontein region is diverse and complex. As will be shown, the background history of its development is of central concern to this dissertation because fossil pollen make up a significant part of the new data to be presented. It is appropriate, therefore, that the regional flora be reviewed in some detail.

Major Floral Groups in the Blydefontein Region

Southern Africa has four major floral groups that impinge in varying degrees on the Kikvorsberg: 1) Capensis flora; 2) the Karoo-Namib flora; 3) the Sudano-Zambezian flora and; 4) the Afromontane flora (Werger 1978a). Each group has genera and families that distinguish and characterized its flora, and each is reviewed in turn.

1) Capensis or Fynbos flora are uncommon but nonetheless important in the Kikvorsberg. Taylor (1978: 173-229) distinguishes the Fynbos flora of the southwestern Cape by the presence of three families: Restionaceae, Ericaceae and Proteaceae. Not all plant species are of these families but those from different families represent physiognomically similar forms. Today the Fynbos flora occurs in the winter rainfall region of the southwest Cape. Intensification of the Benguela Current off the southwest coast of Africa by 10mya provides a minimum age for cold water upwelling critical to the development of the modern Mediterranean-type climate in the southwest Cape (Shackleton and Kennett 1975). Presumably the establishment of these climatic conditions allowed for the formation of a Fynbos-type of plant community. Palynological evidence demonstrates that a Fynbos-type of community was well developed by the early Pliocene and appears to be associated with a shift toward a cooler and drier climate in the southwest Cape (Coetzee 1978, 1983, 1986; Coetzee and Rogers 1982).

2) Karoo-Namib flora (Werger 1978a: 231-299) is a xeric flora characterized by the families Compositae, Gramineae (esp. the tribe Stipeae), Aizoaceae, Mesembryanthemaceae, Liliaceae, and Scrophulariaceae. Succulents are common, but trees are rare, and many genera are endemic to the Karoo-Namib flora. It shares many taxa with the Sudano-Zambezian flora, but few with the Capensis flora. Nonetheless Acocks (1975) suggests that the Karoo-Namib flora developed from the Capensis flora. Levyns (1964) argues that the origin of the Karoo-Namib flora is the Sudano-Zambezian flora because of stronger associations. However, as aridity in the region has existed since the late Cretaceous 80 million years ago (Ward, Seely, Lancaster 1983), we can assume that the origins of the Karoo-Namib flora are ancient and complex. Certainly by 10 million years ago the increased intensity of the Benguela Current

would have resulted in extreme arid conditions in the western portion of the subcontinent, and the Namib Desert and Karoo have probably existed ever since.

3) Sudano-Zambezian flora (Werger and Coetzee 1978: 301-462) is composed of vast areas of woodland, savanna or thornveld, and grassveld vegetation. Plant communities of this group cover most of the inland plateau of southern Africa. The woody taxa are as a whole poorly adapted to frosts and most do not occur in regions with significant cold weather. The grassveld is the only Sudano-Zambezian vegetation form to adapt to cold conditions. Characteristic species include Themeda, Cymbopogon and Eragrostis. This floral region intermingles with the Karoo-Namib flora. The origins of some taxa characteristic of the Sudano-Zambezian flora extends back to at least the late Cretaceous (Axelrod and Raven 1978), but other important elements did not evolve until much later (e.g. grasses in the Eocene). At the Miocene/Pliocene boundary the shift toward a cooler Agulhas Current contributed to reduced rainfall in the interior (Martin 1981) and this favored the expansion of grasslands over the savanna especially in the cooler inland plateau (Brain 1980; Vrba 1980).

4) Afromontane flora, which in this discussion includes the Afroalpine flora, occurs on the high mountains throughout Africa (Killick 1978: 514-560; White 1978: 463-513). This floral form is distributed on elevated 'islands' in an arc from Ethiopia to South Africa. The similarity of species between two South African areas implies that a continuity or exchange path existed between the Drakensberg and the Knysna Forest in the past which must have extended across the highland areas of the eastern Cape that could include the Kikvorsberg. Little data are available concerning the origins of this flora, but Axelrod and Raven (1978: 88, 92, 109) suggest that it evolved in the Saharan highlands in the Paleocene and with the creation of highlands in East Africa it spread south so that by the Miocene it was present as far south as Knysna.

Much more research is needed before the questions of origin and chronology of major floras of southern Africa can be resolved. The modern distributions of plant taxa offer some insights into the evolution, migration and development of plant taxa and plant communities, and if linked with paleobotanical studies significant insights can be gained.

Veld Types in the Blydefontein Region

In 1953 J.P.H. Acocks published his Veld Types of South Africa, a nation-wide survey of plant communities. The monograph assesses the grazing potential of different biota, so it is not strictly a botanical classification. Veld Type means "a unit of vegetation whose range of variation is small enough to permit the whole of it to have the same farming potentialities" (Acocks 1975: 1).

The Veld Types in the area of Blydefontein Basin can be divided into three major groups: grassveld, bushveld, and Karoo. Even though all have grasses, the grassvelds are distinguished from the Karoo and savanna by denser plant cover, fewer of the small woody *Compositae* bushes (colloq.: bossies) that distinguish the Karoo Veld Types, and none of the dense shrub and small trees that characterize the savanna. Most of the plants that occur today on Blydefontein, both annuals and perennials, have short generation spans and rapid germination periods, and this is important when considering their response to changing climatic conditions. All the Veld Types within an arbitrary 140km radius of Blydefontein are described below (Figure 4).

Grassvelds

Five grassvelds are recognized by Acocks in the Blydefontein area: 1) Karroid Merxmuellera Mountain Veld, 2) Themeda-Festuca Alpine Veld, 3) Dry Cymbopogon-Themeda Veld, 4) Cymbopogon-Themeda Veld, and 5) Stormberg Plateau Sweet Veld.

1) The Karroid Merxmuellera Mountain Veld is the vegetation type mapped for most of the Kikvorsberg Mountains including Blydefontein Basin and is usually restricted to the higher mountains of the eastern Karoo and adjacent fringes (Acocks 1975: 98). It is dominated by the grass *Merxmuellera* with *Themeda* and *Tetrachne* as co-dominants on high mountain tops. A number of other grass taxa are present including *Eragrostis, Melica, Festuca, Pentaschistis, Brachypodium, Bromus* and *Cymbopogon.* It is unfortunate that pollen analysis cannot distinguish between grass taxa as significant differences exist in the modern plant communities. In the grasslands of the Basin the spectacularly colored red-hot poker (*Kniphofia* sp.) is scattered in amazing profusion during years of good rainfall. A number of Fynbos taxa are often present, especially *Elytropappus rhinocerotis, Euryops* , *Erica caffra, Cliffortia* , *Passerina montana*, and *Anthospermum* . Karoo related composite genera include *Chrysocoma, Helichrysum, Eriocephalus, Nestlera, and Felicia* bossies. Another major group of plants are the semi-succulents such as *Ruschia, Aloe, Euphorbia* and *Crassula.* On the few dolerite koppies and ridges in the Basin the shrubs, *Rhus* and *Diospyros*, are common. *Rhus* and *Diospyros* have edible berries as does a small rose bramble (*Rubus* sp.) observed growing in the gorge near Blydefontein Shelter. The *Diospyros* berries are very pungent. Other potential plant foods include springbok (*Senecio radicans*), veldpatat (species unknown) and the vinkel (species unknown). Many of the edible plants occur in the plains below the Kikvorsberg, and one farm in the Zeekoe Valley is named Vinkelfontein (colloq.: fennel-spring). Often along the streams hardbees reeds (*Cyperus marginatus*) and swamp grass (*Phragmites australis*) line the banks in such dense stands that it is impossible to reach the stream. Hardbees reeds were used by early European settlers (colloq.: trekboers) to construct huts. Abundant diatom-producing algae are also found

in the streams and pools in the Basin. These same riverine plants are found in the plains below the Kikvorsberg.

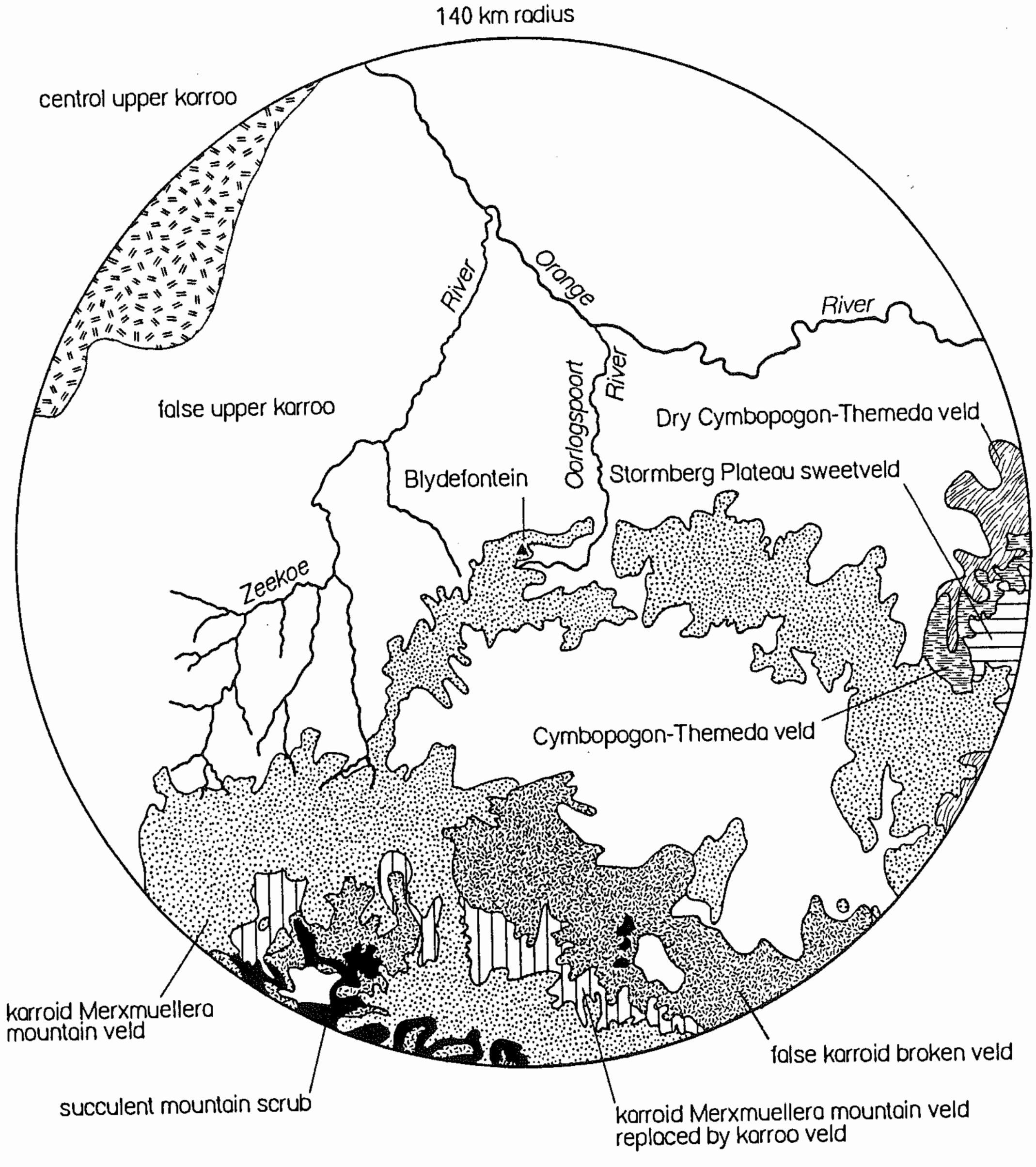

Figure 4. Veld Types within 140km radius of Blydefontein Rockshelter (after Acocks 1975).

2) Themeda-Festuca Alpine Veld grows in small patches on the highest peaks of the Kikvorsberg(Acocks 1975: 95-96). It is dominated by the grass *Themeda* with *Festuca, Merxmuellera, Eragrostis, Andropogon, Cymbopogon, Microchloa, Diheteropogon, Trachypogon* and others. Sometimes associated with the Themeda-Festuca Alpine Veld on the high peaks in the Kikvorsberg is the Karroid False Fynbos of Acocks (1975: 97), or the Subalpine Fynbos of Killick (1978: 538). The largest occurrence of the Themeda-Festuca Alpine Veld/Karroid False Fynbos is found well to the east of Blydefontein in the Drakensberg, but patches are found between the Drakensberg and Blydefontein on the tops of the higher mountains, and even 350km west of Blydefontein (Acocks 1975: 95). This distribution suggests that relict patches survive from a time when Themeda-Festuca Alpine Veld/ Karroid False Fynbos enjoyed a much greater distribution.

3) Dry Cymbopogon-Themeda Veld can be found today in small stands in the plains below the Kikvorsberg. These are dominated by the grasses: *Themeda*, *Tetrachne*, *Tragus*, *Eragrostis*, *Digitaria* and *Cymbopogon*. Also present, but not numerous, are typical Karoo composit bossies: *Helichrysum*, *Felicia*, *Pentzia* and *Chrysocoma*. On dolerite hills and ridges the shrubs, *Rhus* and *Diospyros*, are common. Acocks (1975: 78, 91) argues that the Dry Cymbopogon-Themeda Veld is almost totally altered to Karoo due to overgrazing and poor veld management by Europeans.

4) The Cymbopogon-Themeda Veld is dominated by *Themeda, Setaria, Microchloa, Elionurus, Heteropogon, Eragrostis, Tristachya, Helichrysum, Brachiaria, Cymbopogon, Harpochloa* and *Hermannia*. Other less common genera include *Digitaria, Senecio, Anthospermum, Felicia, Aristida* and *Andropogon*. The Cymbopogon-Themeda Veld usually occurs on sandy soils, receives a high amount of rainfall, and usually occurs at elevations higher than Blydefontein.

5) The Stormberg Plateau Sweetveld is transitional to the Karroid Merxmuellera Mountain Veld and the grassvelds of the higher Drakensberg range such as the Themeda-Festuca Alpine Veld. The Stormberg Plateau Sweetveld enjoys greater rainfall than the Karroid Merxmuellera Mountain Veld, slightly higher elevation, and is on flat plateau areas rather that steep mountain slopes. This grass veld is dominated by *Themeda* and *Elionurus*. Other grass genera are *Pennisetum, Tetrachne*, *Festuca, Eragrostis*, and *Digitaria*.

Karoo Velds

Open dwarf shrub Karoo Veld Types include 1) False Upper Karoo, 2) Central Upper Karoo, 3) False Karroid Broken Veld, and 4) Succulent Mountain Scrub.

1) The False Upper Karoo represents the easternmost Karoo Veld Type and is transitional with the grassvelds. Werger (1978b: 446-454, 1980) has studied this region in detail and recognizes two main communities: 1a) dwarf shrub Pentzio-Chrysocomion communities on the peneplains, and 1b) the *Rhoetea erosae* community composed of small trees, shrubs and grasses on the rocky ridges and koppies. The latter communities have two major forms with eight recognizable associations governed by bedrock type and aspect.

2) The Central Upper Karoo occurs west and northwest of the False Upper Karoo in areas receiving 200-250 mm of rainfall and ranging from 1050m to 1700m above sea level (Acocks 1975: 63-64). Karoo bossies are dominant but some grasses, such as *Eragrostis*, *Aristida* , *Stipagrostis* and *Merxmuellera* in the hills, do occur. The major taxa of Karoo composites include *Eriocephalus*, *Pentzia*, *Pteronia*, *Nestlera, Chrysocoma*, and *Osteospermum*. Other important taxa are *Euphorbia*, *Rhus, Ruschia*, and *Salsola*. Although this is a Karoo Veld Type, stands of pure grassveld do occur in the moist floodplains.

3) The False Karroid Broken Veld characteristic genera are *Euclea, Pappea, Cussonia, Acacia, Schotia, Aloe, Pentzia, Becium, Chrysocoma, Asparagus, Drosanthemum* and *Eragrostis*. Acocks (1975: 79) suggests that invasions of the Karroid Broken Veld and the Central Lower Karoo into a region once occupied by Dry Cymbopogon-Themeda Veld created this veld type. The closest portion of this Veld Type is in the Upper Fish River Basin 60km south of Blydefontein.

4) Succulent Mountain Scrub or Spekboomveld (colloq.: fattree veld) is the only bushveld that is within 140km of Blydefontein (Acocks 1975: 58-59). Dense shrub and small trees dominate the plant taxa.

These diverse plant communities provide the ultimate food source to which the animals and prehistoric human inhabitants of the northeastern Cape were adapted. The animals were as diverse as the plants, and prehistoric hunter-gatherers of the Bo-Hantam had a rich bountiful supply of game.

Animals

Historically Blydefontein Basin and the surrounding plains had a very abundant fauna. Today after 200 years of European hunting and some 170 years of European stock farming most of the wild animals have been affected significantly, and many are locally extinct. It is surprising how many wild animals remain in either a free ranging state or as managed herds on the farms of the area. The area has few nature preserves, however, Mountain Zebra National Park located 145km south of Blydefontein Basin, was repeatedly visited during 1980 and 1981 in order to observe as many animals as possible under natural (or near natural) conditions. Mountain Zebra National Park is too small, 65 square kilometers, to support a complete ecosystem with a full host of predators. It has no large cats, wild hunting dogs, or hyenas, and the herds are not free ranging. However, it is 50 years old and its higher elevations support a Merxmuellera Mountain Veld in very good condition. Topographically the higher elevations are also similar to Blydefontein Basin and it is the best natural system we can use for comparison. The following discussion uses the taxonomy presented in Bigalke (1978: 981-1048) and is based primarily on discussions with local farmers and on my own observations.

Large Mammals

The Kikvorsberg today have retained a variety of larger mammals even though the area is completely utilized as sheep farms and fenced into small camps, i.e. pastures. Mountain reedbuck (*Redunca fulvorufula*), vaal rhebuck (*Pelea capreolus*), steenbok (*Raphicerus campestris*), rare klipspringers (*Oreotragus oretragus*), and a small herd of managed springbok (*Antidorcas marsupialis*) were all observed on the farm of Blydefontein. The Merxmuellera Mountain Veld is a sourveld with hard tough grasses, and the masticatory architecture of a springbok or any small grazer is not robust nor strong enough to efficiently eat these grasses (Dou Lessing, personal communication). Thus, without managed herds it is questionable whether springbok would live in any great numbers in the Bo-Hantam. However, during the late 1700s and 1800s springbok herds were observed by the thousands in the plains below the Kikvorsberg, and large springbok herds, known as *trekbokken*, moved *en masse* to escape particularly harsh droughts. A more complete montane fauna is found at Mountain Zebra National Park in the Merxmuellera Mountain Veld, where additional species include black wildebeest (*Connochaetes gnou*), blesbok (*Damaliscus dorcas*), red hartebeest (*Alcelaphus buselaphus*), eland (*Taurotragus oryx*), and mountain zebra (*Equus zebra*).

The only primate in the Bo-Hantam is the chacma baboon (*Papio ursinus*), and on Blydefontein during the winter of 1985 two troops were competing over the control of a sheep feeder, one of their most reliable winter food sources. A third troop is known to habitually raid the farm of Grapevale. Numerous other troops can be found scattered in the Kikvorsberg, although population numbers are unknown. Remote rockshelters are often used as protected sleeping areas by baboons as evidenced by abundant baboon scats in many shelters. However, no baboon dung was found in Blydefontein or Meerkat shelters probably because these shelters are too close to human dwellings.

The carnivores are still amazingly abundant despite intensive trapping and hunting. Canine species in the Kikvorsberg include the black-backed jackal (*Canis mesomelas*) which is similar in size to the North American coyote, the silver fox (*Vulpes chama*), and the insectivorous and fructivorous bat-eared fox(*Otocyon megalotis*). In the mountains, the most common cats are the wild cat (*Felis libyca*) and the rooikat or caracal (*Felis caracal*). The rooikat is midway in size between the North American bobcat and the North American mountain lion. During the eight month field season five rooikats were trapped on Blydefontein and surrounding farms in the Kikvorsberg. The nocturnal rooikat can kill considerable numbers of sheep even in one night and the males travel great distances. Today trapping for these cats as well as jackals is intensive and often conducted by professional trappers.

Small carnivores include the Egyptian mongoose (*Herpestes ichneumon*), the suricate (*Suricata suricatta*), and the yellow mongoose or rooimeerkat (*Cynictis penicillata*). Along stream banks, especially in Diepkloof, clawless otter (*Lutra maculicollis*) scats full of freshwater crab exoskeletons are often seen, but the otters themselves were never observed.

Other large mammals that are found in the region include porcupines (*Hystrix africae-australis*) which are still fairly numerous, the nocturnal and rare aardvaark or antbear (*Orycteropus afer*), rare honey badgers (*Melivora capensis*), and the very rare pangolin or scaly anteater (*Manis temminckii*).

Dassies or hyraxes (*Procavia capensis*) are small diurnal woodchuck-sized animals (weighs up to 5.5 kg.) that live in groups known as colonies in rocky outcrops. One colony lives in the cliff (colloq.: krans) that forms Blydefontein Shelter. Abundant colonies can be found all along the gorges carved by the Basin's streams and in almost any large rock outcrop in the plains below the mountains where they seem to be as common as in the Basin. The dassie population in Mountain Zebra National Park was recently estimated at 195 dassies per square kilometer (Swart et. al. 1986). Two species of hare are known from the region, *Lepus capensis*, and *Pronolagus* sp. Morphologically and ecologically *Lepus capensis* , the Cape hare, resembles the jackrabbit of North America; the smaller bunny *Pronolagus* sp., the red hare or rooihaas, lives on rocky or boulder strewn koppies. The long-hind-legged, nocturnal spring hare (*Pedetes capensis*) is common and still hunted by farm workers. Significant micromammals in rockshelter deposits include the vlei rats, *Otomyinae*, and molerats, *Bathyergidae* (Avery 1988).

Other Animal Life

A number of additional species occur in the Kikvorsberg and surrounding plains that have archaeological or ethnographical significance. These include birds, reptiles, amphibians, molluscs, crustaceans and insects.

Reptiles, Amphibians, Molluscs and Crustaceans

The most common amphibians are frogs (*Pyxicephalus* sp.) which are abundant in streams. Other significant reptiles include the large leguaan(*Veranus albigularis*) which is often found under large flat rocks near water in the plains below Blydefontein, but not in the Basin itself where it is too cold. Cape and yellow cobras (*Naja* spp.) are the most common snakes, and during the first month of excavation a large yellow cobra was killed in Blydefontein Shelter. Although not seen during 1985, another venomous snake is the puff adder (*Bitis arietans arietans*). Puff adders are more aggressive than cobras, and thus more dangerous even though their venom is less toxic. A number of tortoises are present at Blydefontein, including the geometric tortoise (*Psammabates tentoria*), the mountain tortoise (*Testudo pardalis*), and the padloper (*Homopus femoralis*). Freshwater molluscs (*Unio caffra*) and freshwater crabs (*Potamonautes perlatus*) represent significant aquatic animals in Blydefontein Basin.

Birdlife

The avifauna is very diverse with at least 198 species present today in the Blydefontein Basin area (Sinclair 1984). The most significant species for archaeological studies is the ostrich, *Struthio camelus*. Common birds include the terrestrial and gregarious guinea fowl (*Numida meleagris*), the secretary bird (*Sagittarius serpentarius*), korhaans (*Eupodotis* spp.), bustards (*Neotis* spp.), and the blue crane (*Anthropoides paradisea*). Also present are numerous birds of prey that range from falcons and kestrels (*Falco* spp.) to hawks (*Accipiter* spp.), harriers (*Circus* spp.), buzzards (*Buteo* spp.), osprey (*Pandion* sp.), owls (*Tyto* spp. and *Bubo* spp.) and eagles (*Circaetus* spp., *Aquila* spp., *Polemaetus* spp., *Hieraaetus* spp.). The owl *Tyto* is believed to be a major contributor of microfaunal remains to rockshelter deposits. Scavengers such as the Cape vulture (*Gyp coprotheres*) are rare today but were commoner in the not too distant past. Another bird that inadvertently is archaeologically significant is the swallow (*Hirundo* spp.). These insectivores build nests of saliva-cemented dirt pellets stuck to the roofs of rockshelters and overhangs. The roof of Blydefontein Shelter has numerous swallow nests. Through time these nests break or dislodge, and become incorporated in rockshelter sediment matrix.

Significant Insects

Termites, especially the ant hill genera such as *Trinervitermes* and harvester termites of the genera *Hodotermes,* are certainly present in the Kikvorsberg and surrounding region, but not in great densities. It is possible that termite nests were used as grass temper sources by prehistoric potters. The red and black brightly colored brown locusts (*Locustana pardalina*) are known to form great swarms after drought-breaking rains. Clouds of these locusts descend on the veld, eating everything in their path. The *trekboers* were terrified by the locust swarms, and modern farmers still dread the locust plagues. Between swarming periods we now know that the locusts change morphologically into dusk brown nongregarious grasshoppers. Near to water and limited to warm days is the carnivorous stickfly (Diptera). Camping near a water source with active stickflies would be very unpleasant today and in the past. Lastly the Karoo caterpillar (*Loxostege frustalis)* can be very abundant and may have served as a food source to prehistoric inhabitants.

European Impacts

A detailed review of historical records will not be attempted here as a new project dealing with 18th and 19th century European activity in the eastern Cape is planned (Sampson 1987). However, a few words that briefly outline early European history and possible environmental effects is required.

Historical Background

The Dutch established settlements in Cape Town in 1652 and by the 1760s pioneer farmers or *trekboers*, who lived in reed huts or camped by their wagons, began to colonize the Sneeuwbergen. By the late 1770s the Sneeuwbergen *trekboers* began to graze their stock in the Zeekoe Valley below the mountains during the winter, and these *trekboers* founded the first town in the region, Graaff Reinet, 100 kilometers southwest of Blydefontein in 1786. By the 1790s the Hantam was prized by *trekboers* as good horse country. Farmer populations increased so that by 1830 the town of Colesberg was established north of Blydefontein. Other farming villages sprang up in the area during the mid to late 1800s, and use (and abuse) of the veld increased accordingly.

Before the veld was fenced in the early 1920s the sheep herding pattern was very different then than today (N. Biggs, personal communication). A farmer's herd was divided into a number of flocks. Each flock was the charge of a shepherd. A shepherd moved his flock to and from grazing areas as the quality of grazing dictated. Numerous small kraals and associated huts were constructed of dry walled stone and these are still abundant throughout the landscape. The kraals were used to confine sheep at night in order to protect them from predators, especially cats and hyenas. Rockshelters were perfect places for kraals, and both Blydefontein and Meerkat shelters have stone walled kraals.

At the close of the Boer War in 1902 an organization called the Rhodes, Beit & Bailey Syndicate began to purchase farms in the Hantam in a grand plan to introduce modern farming techniques such as irrigation and crop farming. Farms, such as Oorlogspoort and Grapevale, were bought by the Syndicate, but with the death of Rhodes and Beit eventually the Syndicate was split into private individual farms. Many were sold to the Syndicate's own managers. With the Fencing Act of 1912 these managers introduced fencing in the early 1920s. This greatly altered the old system of sheep farming. No longer were shepherds needed for each flock and no longer could predators move about so freely. Also the Drought Investigation Commission of 1923 argued that fenced camps would increase the carrying capacity of the veld (Roux and Opperman 1986: 96). In response to these suggestions sheep stocking levels reached an all time high in 1933 which also was a period of extremely low rainfall, and the veld was more seriously overgrazed than ever before.

In the last 30 or 40 years a more systematic and research-founded approach to sheep farming has been gaining popularity in the northeastern Cape. Acocks and Roux are major advocates of this approach. The philosophy is one of conservation, and the technique is through rotational grazing of clustered camps. The general strategy is that the veld must be 'rested' for long periods between grazing sessions. In this way the heavily grazed, more palatable and more nutritious plants have a chance to grow back after being eaten. When a camp is managed properly plant diversity and grass density increase. It is believed that this rotational system is similar to the grazing patterns of the endemic fauna.

Impacts on the Vegetation

The False Upper Karoo, according to Acocks (1975: 78), represents the most dramatic of all the European induced vegetation changes in South Africa. Basing his argument on 18th century travelers' accounts from in the plains below Blydefontein, and the presence of supposed relict stands of Dry Cymbopogon-Themeda Grassveld in what is now Karoo, he believed that most of the area now covered by the False Upper Karoo (e.g. 32,200 square kilometers) was grassveld 170 years ago. He argued that overgrazing by European stock allowed this area to be invaded by Karoo plants. First the grasses were destroyed by overgrazing, then erosion removed the top soil, and finally the Karoo bossies invaded (Acocks 1975: 78). Werger (1978b: 446-454, 1980: 27-29) generally agrees with the Acocks' model except that he suggests that many of the bossies were already present in reduced numbers and were less visible in the luxuriant northeastern Cape grassland before its destruction by overgrazing. As a distinct group of supposed Karoo invaders have a distribution restricted to both sides of the eastern Karoo/western grassland boundary, Werger (1978b: 447, 1980: 29) argues that this is an area long influenced by fluctuations due to climatic changes. Thus in Werger's model Karoo plants became the dominants by default and this seems to have occurred from domestic stock overgrazing and climatic fluctuations. Without doubt the severe erosion of top soil that followed overgrazing has retarded grass recolonization. Today not all botanist agree with the Acocks-Werger model, but few other models are available in its stead.

Roux and Vorster (1983) have provided more detail, and elaborated on the Acocks-Werger model for the eastern Cape (Figure 5). Their study is based on observed changes in the modern conditions of the Veld Types in the eastern Karoo from east to west (assuming a gradient of progressive degradation). Five phases have been identified: 1) primary degradation, 2) primary denudation, 3) re-vegetation, 4) secondary degradation, and 5) desertified.

The first phase marks the rapid destruction and thinning of the primary plant communities. The second phase is characterized by extreme devegetation with increased runoff, high erosion rates, and high sedimentation in catchment basins; carrying capacity is greatly reduced. Phase 3 represents the closing of the devegetation lag that created Phase 2, however a slightly different suite of plants is established. If Werger is correct, then most of these plants were present in the eastern Cape before destruction by overgrazing.

Different grasses, *Eragrostis* and *Aristida*, and other bossies such as *Augea*, *Chrysocoma*, *Eriocephalus*, *Galenia*, *Lycium*, *Pentzia*, *Pteronia*, *Ruschia* and *Zygophyllum*, now dominate the landscape. In the mountains the most successful Phase 3 invaders are *Elytropappus* and *Euryops*. Phase 3 is characterized by increased plant density and reduced erosion and runoff. However the loss of soil during Phase 2 would prevent the primary vegetation communities from returning. Most of the eastern

Karoo is (circa 1985) in a Phase 3 state according to Roux and Vorster (1983), but veld conditions in the western Karoo suggest further potential deterioration to these researchers. Phase 4 marks a second episode of degradation due to continued veld mismanagement, i.e. overgrazing. Taxa typical of this phase are *Acacia, Augea, Asparagus, Eriocephalus, Galenia, Lycium, Pentzia, Rhigozum, Pteronia* and *Ruschia.* In the mountains, plants such as *Dodonaea, Elytropappus, Euclea, Euryops, Merxmuellera* and *Rhus* gain dominance in Phase 4. The final Phase, 5, desertification occurs with *Aloe, Euphorbia,* and *Mesembryanthemum* as the most important endemic taxa.

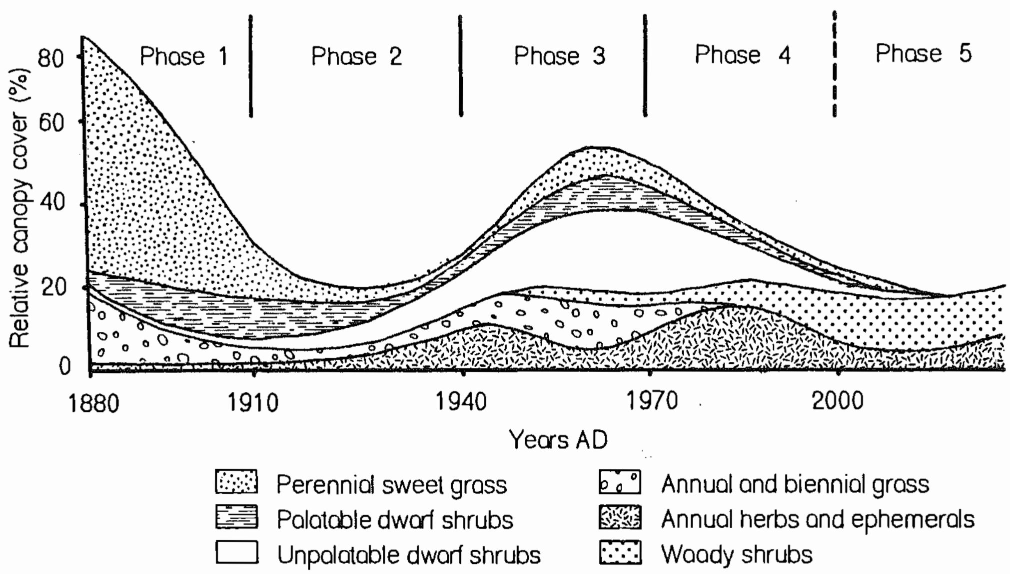

Figure 5. Roux and Vorster's (1983) model of vegetation change in the eastern Cape due to overgrazing.

Certainly the Dry Cymbopogon-Themeda Veld was at the edge of the Karoo before overgrazing by European domestic stock affected the area, and climatically induced fluctuations in the distribution of Veld Types occurred in the past. Droughts in the northeastern Cape are well known historically (C. Vogel 1988: 11, 1989), and the response of the grasslands to these droughts was a definite reduction in the quantity of grass. It is extremely likely that a transition from grassveld to Karoo is a natural response in the ecosystem to drought conditions or to changes in rainfall seasonality (Bousman et. al. 1988; Coetzee 1967; Meadows et al. 1987; Meadows and Sugden 1988; Scott 1988a, 1988b; Scott and Bousman 1990; van Zinderen Bakker 1957, 1967, 1982a), and that these two modern plant biomes can be used to model past Karoo-grassland fluctuations in the Kikvorsberg and surrounding region. At least one palynologist has suggested that Karoo patches in eastern grasslands represent relict stands and not invasion (Van Zinderen Bakker 1967: 147). Additionally one problem with the Roux and Vorster (1983) model is that the predicted phase 4 and phase 5 occur only in areas of the Karoo that are much drier and warmer than the eastern Karoo, and it is questionable whether the more xeric forms could ever dominate the eastern Karoo plant communities without a significant change of climate. Today the Karoo is expanding at an amazing rate, up to 2-3.5km per year in some areas (Werger 1978b: 447), but the verdict on the cause(s) is still undecided and the jury may be forever hung!

Impacts on the Fauna

Although never present in Blydefontein Basin, one of the first species to become locally extinct was the hippo (*Hippopotamus amphibius*). Gutsche (1968: 158) records that by the 1830s no hippos remained in the Zeekoe River, and one of the last hippos in the Orange River was killed in 1868. Large carnivores were removed from the area as quickly as possible because of their danger to humans and their killing of stock. Numerous references (Skead 1987) are made about lions (*Panther leo*) in the early travelers' accounts, but also present in the mountains and koppies were leopards

(*Panther pardus*). Cheetahs (*Acinonyx jubatus*) were known historically in the plains below Blydefontein as well as brown hyenas (*Hyaena brunnea*), spotted hyenas (*Crocuta crocuta*), wild hunting dogs (*Lycaon pictus*), and aardwolves (*Proteles cristatus*). During the 1800s many species of antelope were virtually exterminated locally, and these include wildebeest (*Connochaetes gnou*), red hartebeest (*Alcelaphus buselaphus*), blesbok (*Damaliscus dorcas*), and eland (*Taurotragus oryx*). Quagga (*Equus quagga*), a horse with fewer stripes than zebras, became extinct by the 1870s and is now known only through early explorer descriptions and paintings. Mountain zebra were almost totally exterminated, but a few remained in the western portion of southern Africa and these were reintroduced to the northeastern Cape with the establishment of Mountain Zebra National Park in 1937. Other locally extinct fauna are black rhinoceros (*Diceros bicornis*), warthog (*Phacochoerus aethiopicus*), and buffalo (*Syncerus caffer*), although these animals were never very numerous in historic times.

Summary

Even though wild animals remain in numbers and the vegetation is beginning to respond to modern management practices, the last 200 years of European land use has had lasting and possibly irreversible consequences. Many animals are locally extinct, one is completely extinct, and all remaining animals have had to adapt to the overwhelming presence of humans. Loss of soil due to erosion is a significant factor affecting modern plant distributions. The above conditions present serious problems for using modern environmental data to reconstruct past environments. Nonetheless, as is argued in the following chapters, certain approaches may be used to gain an understanding of past botanical and faunal communities, and the climates that influenced and controlled these communities. The environmental chapters that follow will present a paleoclimatic model, attempt to form bridges between present environmental patterns and modern climate, and then test the climatic model by using the modern climate/plant relationships to reconstruct paleoclimates with the fossil pollen data. Finally the adaptations of prehistoric human inhabitants can be assessed against the dynamic past environmental background.

CHAPTER III

A REGIONAL MODEL OF LATE QUATERNARY AND RECENT CLIMATIC CHANGE

Although paleoecological data for the Upper Pleistocene and Holocene of southern Africa are accumulating rapidly (e.g. Deacon and Lancaster 1988; Vogel 1984), these are still insufficient to provide a regional framework within which to fit new, local sequences like the one to be presented in this dissertation. This is especially true of the Interior Plateau where the paleoecological record is almost nonexistent (Deacon and Lancaster 1988: 56-59). In addition, the inductive fitting of local data to such chrono-stratigraphic frameworks is of somewhat limited use since it only describes rather than explains the nature and timing of the climatic changes being examined.

In this dissertation I have opted for a deductive approach to the analysis by starting with a mechanistic model of climate change, to be tested in the chapters that follow. This general model is derived from existing computer simulations. They in turn were built from current models purporting to explain the global mechanics that drive the modern climate of the world and thus of southern Africa. What follows, therefore, is a brief review of the modern circulations patterns now thought to control today's climate in southern Africa, so that the logic behind the simulation programs can be better understood. After the simulation results are described, historically recorded rainfall fluctuations are briefly reviewed.

The General Circulation Systems

These are the basic building-blocks of the computer simulation. South African climate is controlled by the interaction of two circulation systems, one flowing north-south and the other flowing east-west (Hurry and van Heerden 1984; Trewartha

1968; Tyson 1986). Both are complex chains of interacting convection cells, linked in turn to oceanic circulation (Cane 1983; Rasmusson and Wallace 1983; Tyson 1986). The north-south system is called Hadley and Ferrel circulation, for its constituent cells of those names. The east-west system is called Walker Circulation.

North-south circulation is caused by the fact that the equator receives more solar energy than the south pole, so heat is wind-transfered from low to high latitudes. Transfer takes place in a series of circulation cells. Starting in the tropics, where the earth's spin has less effect, circulation is fueled by low pressure cells that link together to form the low trough called the Inter-Tropical Convergence Zone (ITCZ). Over Africa this grows a southwesterly extension called the Zaïre Air Boundary where warm air rises and is pushed southwards (Figure 6a). Once cooled, it subsides again to create a high pressure ridge called the Subtropical Ridge. Over the oceans on either side of southern Africa are high pressure cells that are linked to the Hadley-Ferrel circulation.

These two oceanic high pressure cells shift their positions seasonally, following the seasonal, north-south movements of the ITCZ. The oceanic cell on the east side of southern Africa (Figure 6b), called the South Indian Ocean High (SIOH), is more mobile than its Atlantic counterpart, especially in its east-west wanderings toward and away from Africa (Bryson and Murray 1977: 102; Tyson 1986: 96). Feeding into these oceanic high pressure cells is upper level circulation from the circumpolar Ferrel cells linked to form a low pressure trough called the Antarctic Trough (see Figure 6a). As the effect of the earth's spin increases pole-wards, these cells create strong westerly air flow known as the Westerlies.

The Westerlies have semi-stationary meanders that control polar storm paths, and any changes in meander position, strength or degree have an impact on South African weather (Tyson 1986: 147-158). During winter the Westerlies track expands away from the pole and their meander amplitudes grow, pushing cold fronts northwards from their normal polar positions. In the summer the entire circular Westerlies path contracts around the south pole, drawing moist tropical air down during summer.

The east-west (Walker) circulation is linked to the patchy distribution of land and sea across the southern hemisphere, and is more complex in that it has two states, one is normally in position and the other is episodic. Both states are summarized in Figure 7. The normal state, called High Phase, causes subsiding air in the West Indian Ocean to feed into the South Indian Ocean High to the east of southern Africa. When southeasterly trade winds from the SIOH reach the subcontinent they are forced upwards over the Zaïre Air Boundary, and made to recurve south. Thus on the surface Interior Plateau summer rains often appear to be delivered from the northwest. The high pressure cell on the Atlantic side of southern Africa feeds moist air into lows over the African interior, bypassing the southwest Cape. The interior low pressure cells fuel summer rainfall over the eastern parts of southern Africa only.

The episodic state of Walker Circulation, called Low Phase, is also known as the Southern Oscillation and linked to El Niño events off the west coast of South America. It occurs about every 3.5 years and lasts about 18 months (Barber and Chavez 1983; Cane 1983; Rasmusson and Wallace 1983; Tyson 1986: 168). When the Pacific cells divides into two, a chain of cell reversals occurs with the end result that over Africa the interior low pressure cells on the eastern side change to highs, and new lows form over the west. This has a notable effect on rainfall patterns, and Tyson (1986: 166-175) has argued that Walker Circulation accounts for about 20 percent of rainfall variance in the interior, and there is partial evidence linking interior droughts with El Niño events, but the mechanics of the connection are still not understood well.

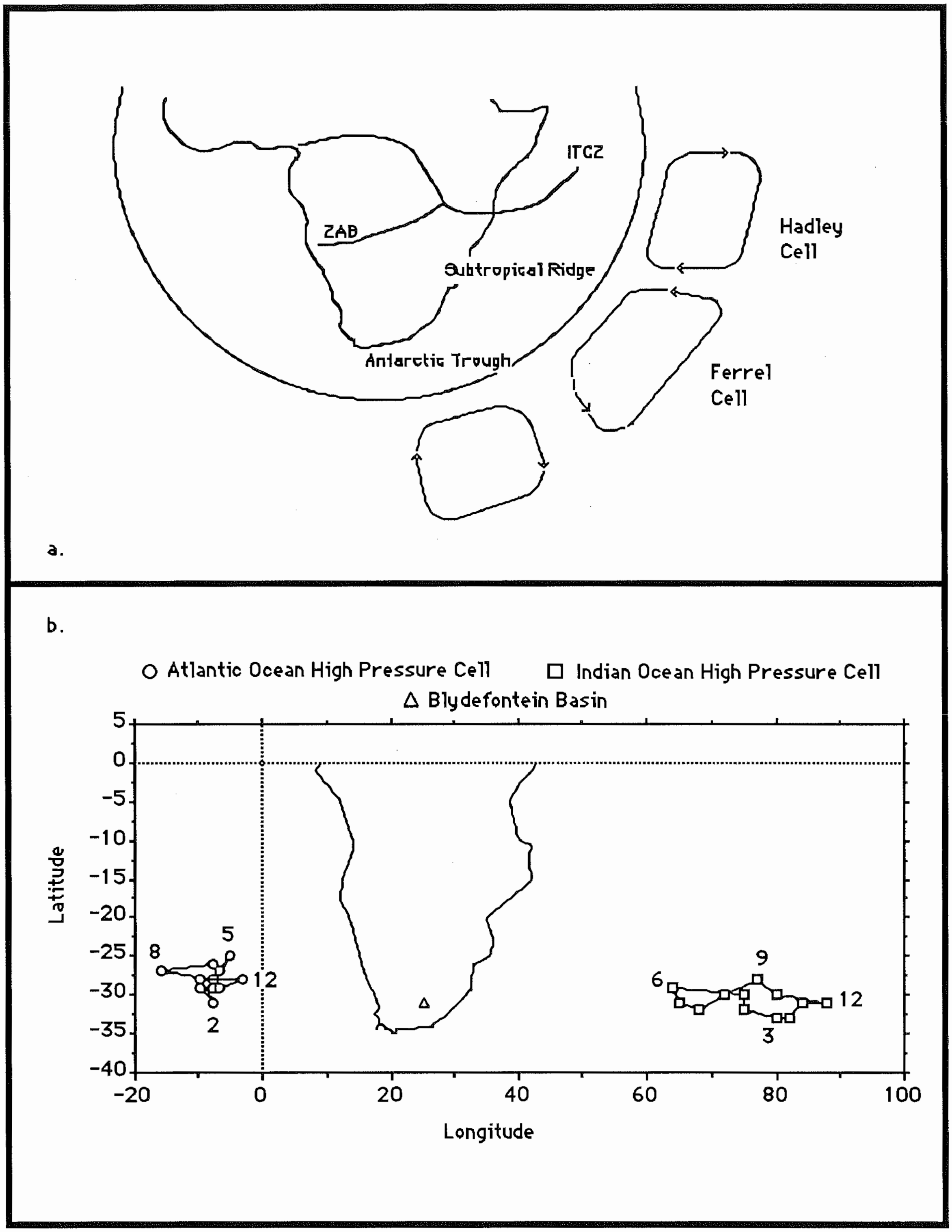

Figure 6. General north-south circulation systems in Southern Hemisphere; a: circulation cells and summer convergence zone positions; b: monthly movements of oceanic high pressure cells (after Tyson 1986).

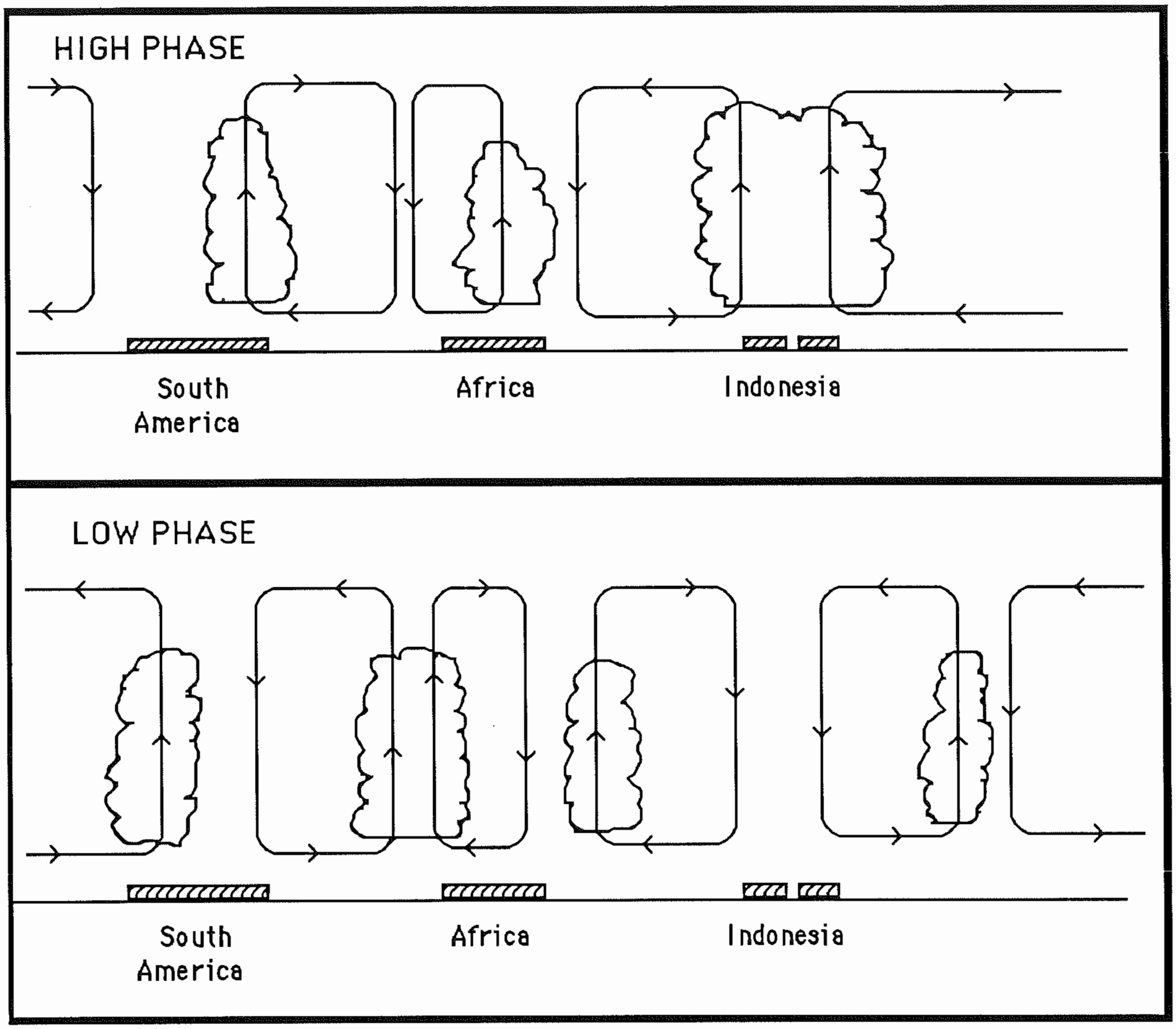

Figure 7. Walker Circulation in High and Low Phases over Southern Hemisphere (after Tyson 1986).

Now that the working parts of the mechanism are in place, the consequences of its motions for southern African weather can be reviewed.

Circulation Systems and Rainfall Patterns in Southern Africa

The dynamics of a mirror-image relationship are diagrammed in Figures 8 and 9. Wetter conditions in the Interior Plateau occur when the South Atlantic High Pressure Cell is strengthened and also when the upper level Westerlies display greater meander amplitude. Under these conditions, moisture flowing with the South East Trades is steered south over central and southern Africa where cloud bands often form. When this happens, a low pressure cell forms south-center of the cloud band (about 20°S), aided by the ascending arm of the Walker Circulation, and a high pressure cell forms off the southern coast at about 30°S. This in turn displaces the upper level Westerlies southwards although it increase their velocity, thus winter storms are denied access to the coast and the southwest Cape experiences drier winters while the Interior Plateau usually is wetter.

Inversely, drier conditions in the interior are induced by weakening the Westerlies and the South Atlantic High Pressure Cell. Now, a descending arm of the Walker Circulation is positioned over the interior, thus impeding the formation of any interior low pressure cells. The amplitude of meanders in the Westerlies are reduced, and this leads to the Westerlies meander being shifted to the east, causing cloud bands over the South Indian Ocean rather than the subcontinent. These in turn inhibit the growth of strong highs off the southern coast. With weaker lows inland and weaker highs offshore, the amount of interior rain is dramatically reduced. The weakened Westerlies are displaced north, however, so winter storms reach the southern coast and increase winter rain in the southwest Cape with some even reaching the normally dry interior.

Tyson (1986) has proposed that the causal mechanics of these modern weather patterns could be used to model climatic variations in the past. Since the inverse dry or wet conditions of the Interior Plateau and the southwestern Cape are controlled by the changes in positions and strengths of these two general circulation systems, especially in the upper troposphere, it would be interesting to see what might happen to those systems during episodes of global cooling and rewarming.

It is now apparent that three atmospheric circulation systems influence the modern climate of southern Africa, including the local climate of the Blydefontein region (see Appendix 1 for details of the latter). The Westerlies meander path and the Southern Oscillation both control winter temperature and rain, while the Southeastern Trades control summer temperature and rain. Computer simulations allow these three systems to respond to global temperature changes computed from the principles of Milankovitch forcing. The first step in simulation is to model the above system interactions, then to superimpose them on a baseline of global temperature fluctuations.

It is well known that annual and seasonal solar radiation budgets have changed significantly during the Late Pleistocene and Holocene (Berger 1978; Hopkins 1981 in Kutzbach 1981; Milankovitch 1930). Several computer simulations of past climates based on different solar radiation conditions have been attempted (see Schneider 1987 for general discussion; and Gates 1976; Kutzbach 1981; Kutzbach and Guetter 1984, 1986; Manabe and Hahn 1977; Williams et al. 1974 for more detailed studies). Most of the climatic simulations are based on changes in the radiation budget due to variations in three of Earth's orbital parameters: orbital eccentricity, axial tilt, and axial precession (see Imbrie and Imbrie 1979 for a history of discoveries). The respective periodicity of these three cyclic variables are given as 100,000 years, 41,000 years and 22,000 years. The interaction of these three orbital parameters with their different periodicities are now thought to account for the major climatic changes observed in the Pleistocene and Holocene (COHMAP Project Members 1988; Hays, Imbrie and Shackleton 1976; Kutzbach 1981).

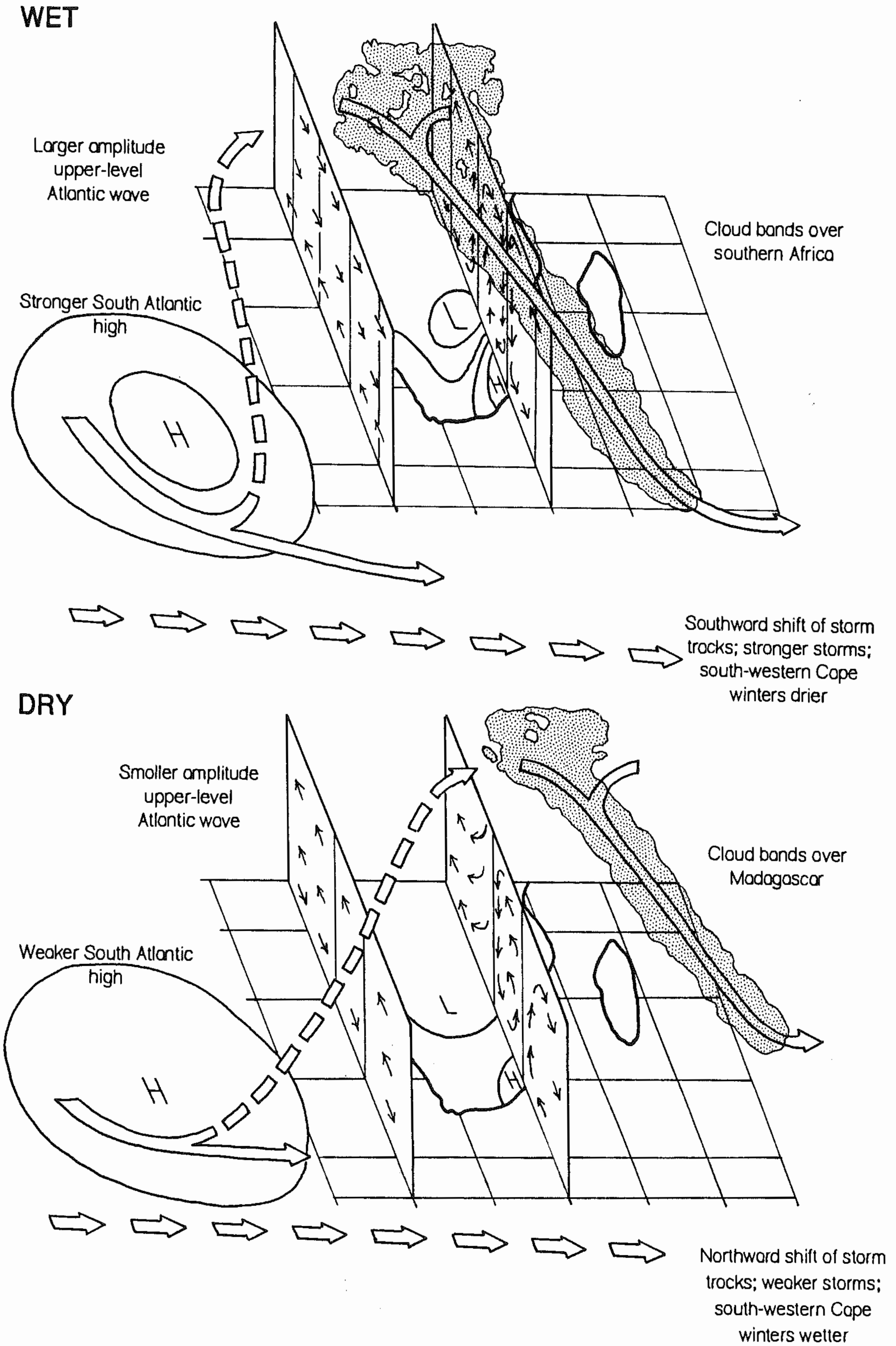

Figure 8. Wet and dry climatic conditions and meridonial atmospheric circulation in southern Africa (after Tyson 1986).

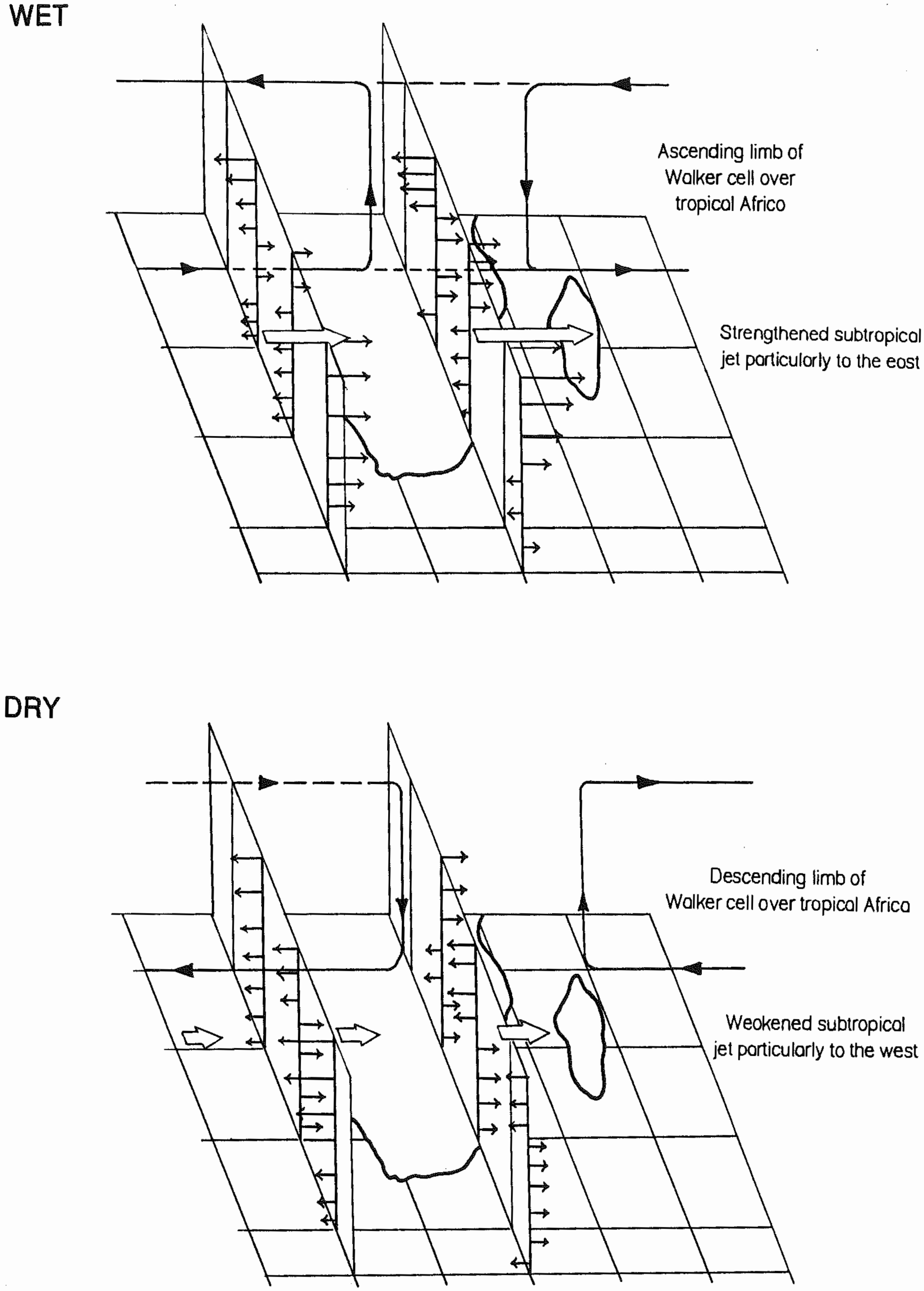

Figure 9. Wet and dry climatic conditions and zonal atmospheric circulation in southern Africa (after Tyson 1986).

Of computer simulations that cover the last glacial maximum (COHMAP Project Members 1988; Gates 1976; Kutzbach and Guetter 1986; Manabe and Hahn 1977; Williams 1974), all show significant decreases in temperature in southern Africa, but they differ in details about the amount of rainfall. The last glaciation was stimulated by a reduction in obliquity, thus reducing summer temperatures, an increase in eccentricity, and perihelion (the point where the earth is closest to the sun) occurred during the Northern Hemisphere's winter (Berger 1978). These factors acted in concert with the negative feedback mechanism of increased reflection of solar radiation by snow to reduce the amount of summer snow melt which led to the growth of glaciers.

Kutzbach and Guetter (1986) present a series of climatic simulations calculated every 3000 years from 18 thousand years ago (kya) so that simulations are available for 18kya, 15kya, 12kya, 9kya, 6kya, 3kya and 0kya. They suggest that for the Holocene at 9000 B.P., orbital parameters differed most from modern conditions. When compared to today, at 9000 B.P obliquity or tilt was 0.38 degrees greater, eccentricity was slightly greater or more elongated, but most importantly perihelion was during the Southern Hemisphere's winter (30 July) while today it is in the summer (3 January). Given these differences winter would have received more solar energy and summer less at 9000 B.P. than today. Even though the annual radiation budget at 9000 B.P. does not differ significantly from today's, all simulations (both a low resolution General Circulation model and a high resolution National Center for Atmospheric Research-Community Climatic Model) show a seasonal climate in southern Africa at 9000 B.P. that was more equitable than today with warmer winters and cooler summers (COHMAP Project Members 1988; Kutzbach 1981; Kutzbach and Guetter 1984, 1986). Furthermore, increased monsoonal circulation in North Africa, caused by stronger pressure cells in the Northern Hemisphere, actually sucked

Southern Hemisphere wind and water across the equator (Kutzbach and Street-Perrott 1985).

COHMAP Temperature and Precipitation Simulations

John Kutzbach and a group of collaborators on the Cooperative Holocene Mapping (COHMAP) Project have run simulations on the high resolution NCAR-CCM model for each 3000 year point from 18,000 B.P. until present with run times of 450 days and global ice distributions based on CLIMAP (1981). The NCAR-CCM model covers the world with grids, and five grids cover the southern portion of Africa (Figure 10). These five grids include most of Namibia and Botswana, southern Zimbabwe and Mozambique, and all of South Africa. This is a large heterogeneous area that has deserts and rain forests, and winter and summer rainfall areas. However the NCAR-CCM model is of global scale so that isolation of individual environments is not possible, and greater spatial resolution would sacrifice the reliability of the predictions. Dr. Kutzbach has generously made available these unpublished simulated data for Africa south of 20°S latitude (Figures 11, 12 and 13).

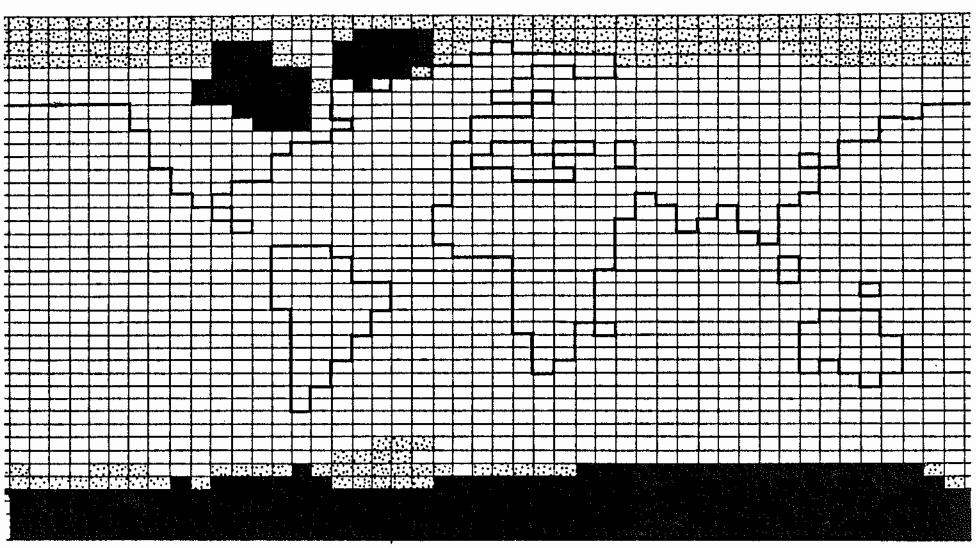

Figure 10. Computer simulation grids used in COHMAP simulations.

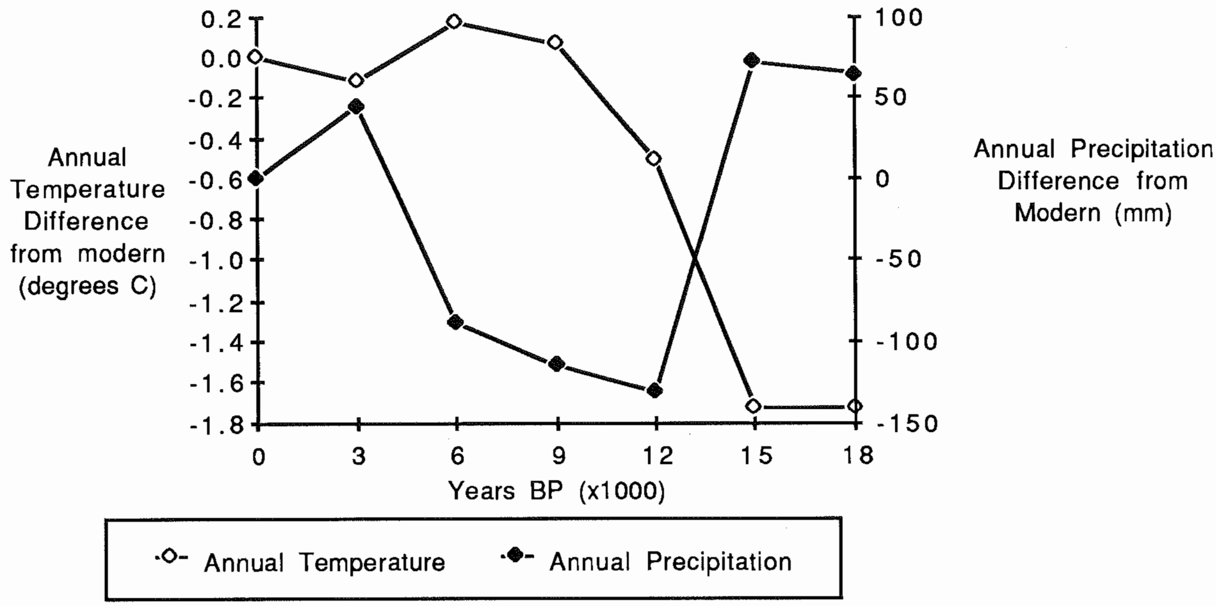

Figure 11. COHMAP Project high resolution NCAR-CCM model simulated annual temperature and annual rainfall differences from modern for southern Africa.

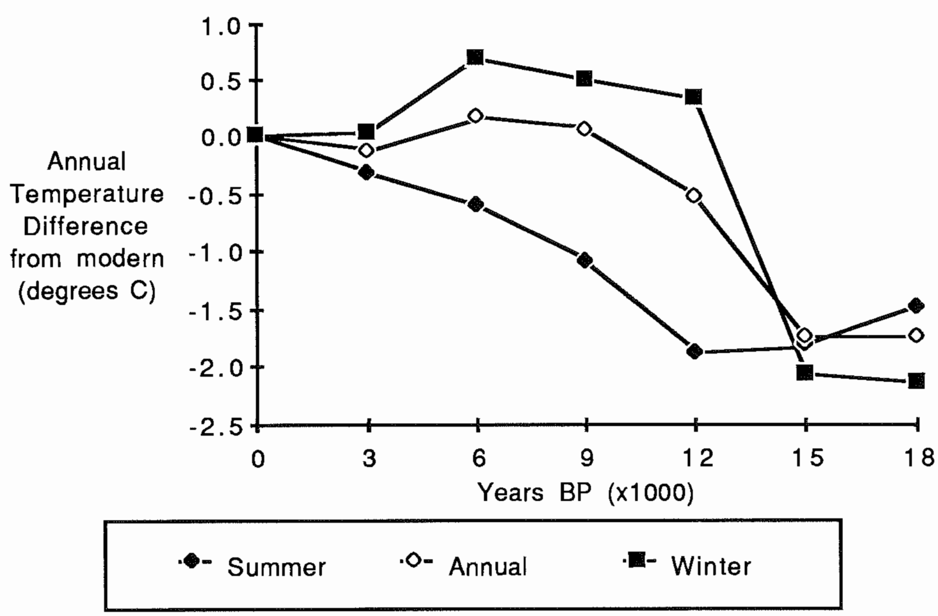

Figure 12. COHMAP Project high resolution NCAR-CCM model simulated annual, winter and summer temperature differences from modern for southern Africa.

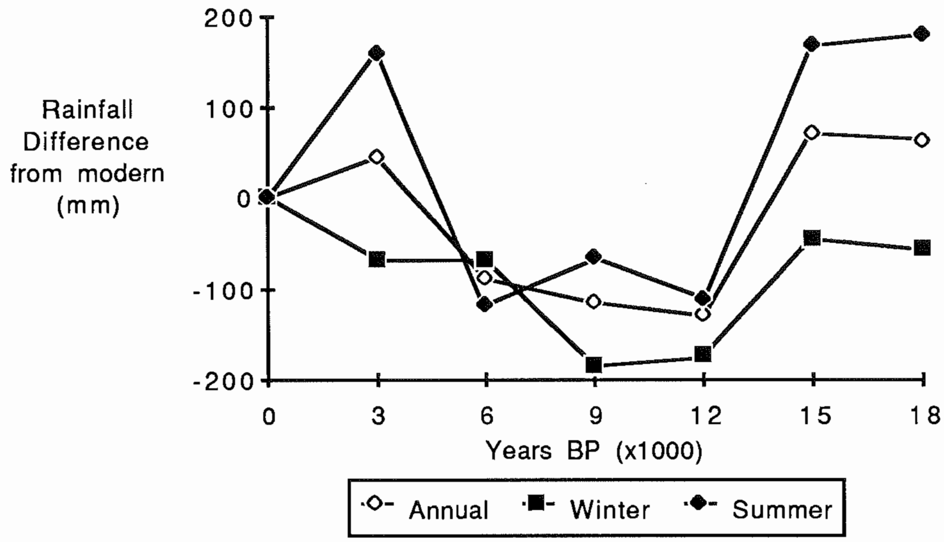

Figure 13. COHMAP Project high resolution NCAR-CCM model simulated annual, winter and summer rainfall differences from modern for southern Africa.

The simulated annual temperatures indicate that the climate was coldest from 18kya to 15kya, and rapidly warmed between 15kya and 12kya (see Figure 11). The estimates for 18kya and 15kya are only 2 degrees Celsius lower than the modern annual temperature, and many researchers would argue that the height of the temperature during the Last Glacial Maximum was much colder in southern Africa (Talma and Vogel in Deacon and Lancaster 1988; Talma et al. 1974; Vogel 1983). After 12kya the rate of warming declines, and the point of maximum temperature is 6kya. From 6kya to 12kya winters are significantly warmer than modern winters, and summers are significantly cooler than modern (see Figure 12). Thus the climate is more equitable than the modern climate, and it is possible that conditions were similar to the dry climate conditions presented by Tyson (1986). The simulations suggest that at 3kya annual temperature dropped, but the seasonality of the climate approaches modern levels with colder winters and warmer summers.

Annual rainfall simulations suggest that very high levels occurred at 18kya and 15kya, but a dramatic drop followed 15kya (see Figure 11). Between 12kya and 6kya rainfall increased slowly, but estimates for 6kya are still well below modern levels. The simulations suggest that a significant increase between 6kya and 3kya, and that the rainfall levels at 3kya was well above the modern level. Simulated rainfall seasonality is revealing (see Figure 13). The two periods of high rainfall (15-18kya and 3kya) also have high summer rains. One period (6kya) demonstrates a significant drop in summer rains which increases the importance of winter rains, however summer rains are still higher than winter rains at this point. At no point are winter rains as high as the modern simulations.

It is a pity that these simulations have such low spatial resolution, but at least they are based on modelled atmospheric processes (reviewed above) and on known variations in solar radiation. Even though they cannot predict short-term fluctuations, they do provide a testable sketch of major climatic changes for the Late Pleistocene and Holocene.

The Short-term Rainfall Oscillations

The computer simulations do not model short term climatic fluctuations on the order of 1,000 years or less, however, if present, some of these fluctuations might be expressed in proxy paleoclimatic data such as pollen. A brief review of three rainfall records provides local evidence of short term fluctuations. The first record is derived from historic observations from the Eastern Cape spanning the years of 1821-1900 (C. Vogel 1988, 1989). A second record is a measured record from Aliwal North and it spans the years 1884-1940. A third record is the nearby Grapevale record (see

Chapter II) and it spans the years 1920-1985. Taken together these records provide evidence of rainfall fluctuations over 165 years.

C. Vogel (1988: 11, 1989) published a rainfall record for the Eastern Cape that dates from 1821 until 1900 (Figure 14). In her rainfall histogram each year is classified as above or below normal, and three rainfall 'states' were recognized in each category.

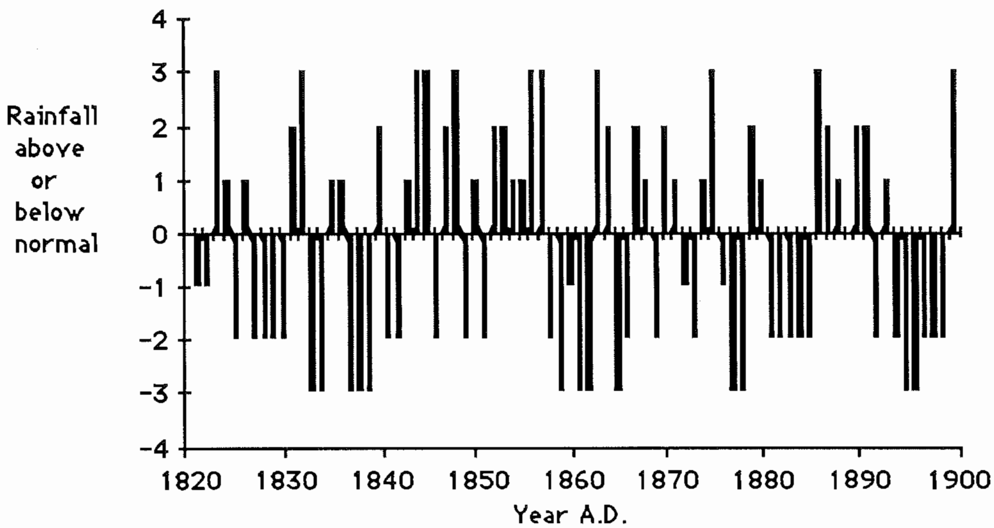

Figure 14. Eastern Cape rainfall variability from 19th Century historic records (after C. Vogel 1988: 11).

The Grapevale and Aliwal North rainfall records are best viewed as moving averages (Figure 15). Five year periods were selected and these show the short term variations, while reducing the large year to year fluctuations. The period of overlap between Aliwal North and Grapevale is 1920-1940, and they both indicate low rainfall amounts in the late 1920s.

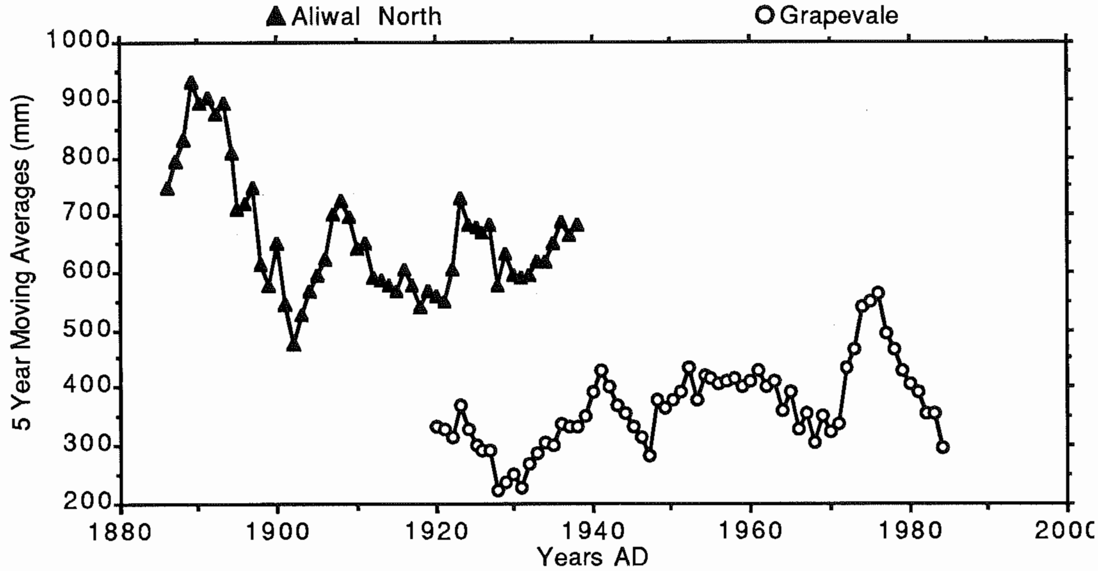

Figure 15. Five year moving averages of Aliwal North and Grapevale rainfall.

Aliwal North is near the foothills of the Drakensberg, and approximately 165 km east of Blydefontein and Grapevale. Rainfall at Aliwal North appears to be systematically greater because of its more eastward location (see Chapter IV). The average difference between Grapevale and Aliwal North (337.7 mm) was used to standardize the Aliwal North record to the Grapevale amounts. Then 5-year moving averages of the two records were combined and averaged for the years of overlap, i.e.1920-1940 (Figure 16). In order to compare the East Cape record to the combined measured rainfall records and eventually to the proxy paleoclimatic data (see Chapter VII), a single year's rainfall classification was treated as an actual rainfall measurement. This was coded by the length and sign of the bar on C. Vogel's histogram so that each year was assigned a positive or negative 1, 2 or 3. Then 5-year moving averages of these numbers were calculated and plotted as rainfall scores (see Figure 16).

The combined Aliwal North/Grapevale record shows an amazing amount of agreement with the East Cape historic record by a high rainfall estimate in the mid-

1880s followed by a rapid drop in rainfall thereafter. Taken as a whole these records can be used to suggest that long and short, albeit irregular, cycles do exist in rainfall patterns, and that long cycles might be as long as 90 years and span the period from 1890-1980. It might be possible to calibrate the historic rainfall records with the Aliwal North and Grapevale records, and the two scales on Figure 16 provide a rough indication of the approximate conversion. The patterns presented here are supported by another historic rainfall record where a major drop in rainfall is documented for the 1890s further to the west on the edge of the Karoo region (Venter et al. 1986).

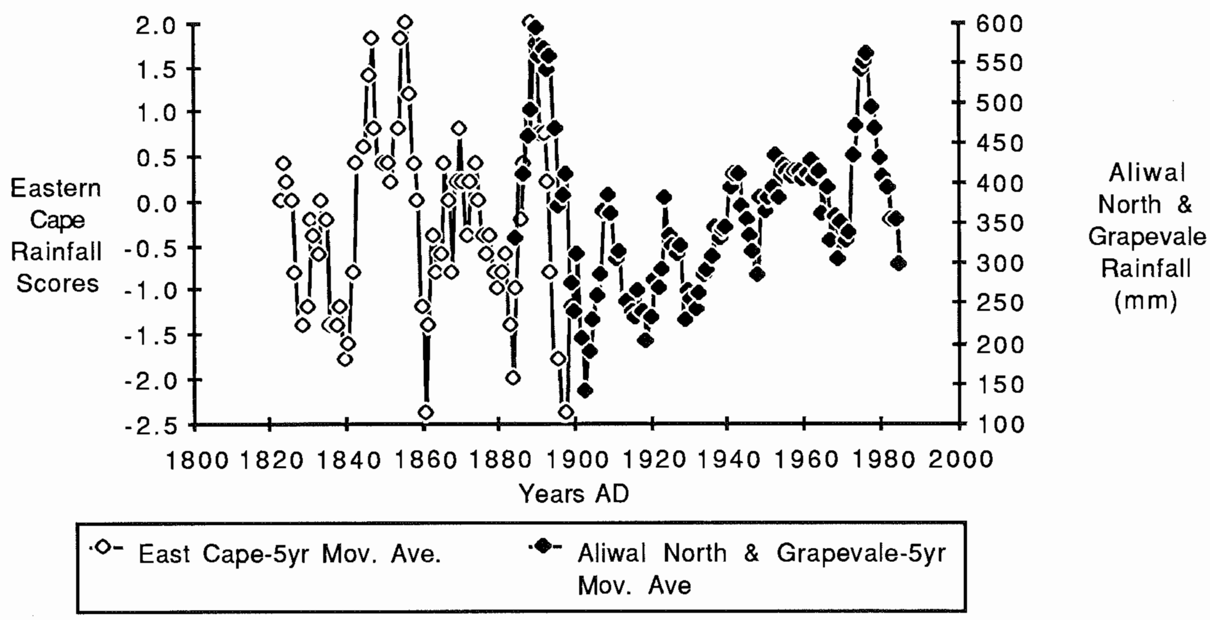

Figure 16. Measured and observed rainfall estimates for the eastern Cape.

An even shorter oscillations show up clearly in the Grapevale annual rainfall data (Figure 17). As the minima show, there are drought cycles of 17-18 years duration. This 18-year cycle is well documented throughout southern Africa, and in many areas they account for 20-30 percent of rainfall variance (Tyson 1986: 68-80). When the summer rainfall totals, i.e. the high ends of oscillations, are extracted from the Grapevale record they magnify the 18-year oscillation. Tyson (ibid: 160) suggests that the high ends may be associated with a situation in which there is a trough of lows along the west coast and the South Atlantic High is about 2500km to the southwest near Gough Island.

Clearly, forcing mechanisms other than those incorporated in the simulations must be sought to explain these phenomena. These are interesting because high resolution proxy paleoclimatic evidence might capture some of these short-term oscillations. Additionally, one should remember these short fluctuations when considering hunter-gatherer adaptations to past environments.

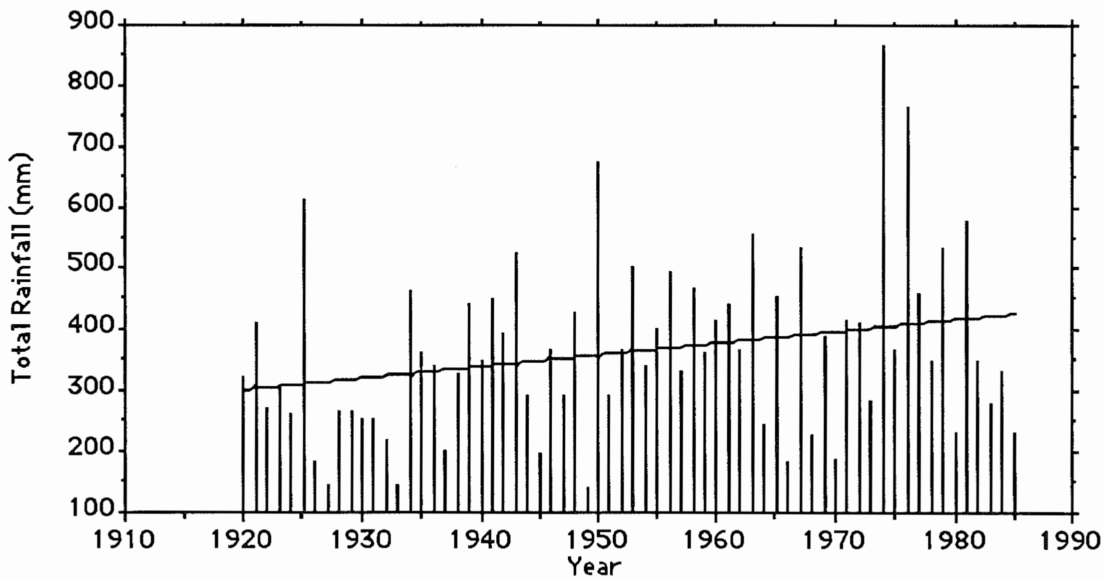

Figure 17. Yearly rainfall at Grapevale from 1921 to 1984.

Conclusions

In this model, rainfall estimates for 18kya and 15kya are much higher than those suggested by some paleoecological studies (Deacon 1984; Deacon et al. 1984; Scott

1984; Tyson 1986 and many others), but they are similar to those of other simulations (Gates 1976; Williams et.al. 1974) and some proxy paleoclimatic data (Grindley 1979; Kent and Gribnitz 1985; Lancaster 1979). As the temperature gradient in the Southern Hemisphere is greater than that for the Northern Hemisphere (Pittock 1978: 4), it is reasonable to presume that during the Last Glacial Maximum this temperature gradient was great enough to drive wind circulation systems with enough force to actually increase rainfall. Also, the simulated temperatures are warmer than is generally believed (Deacon 1984; Deacon and Lancaster 1988; Deacon et al. 1984; Scott 1984; Tyson 1986; Vogel 1983).

The drop in summer rainfall in the terminal Pleistocene, and in early to mid Holocene times suggests that reduced temperature gradients (caused by warmer winters and cooler summers) were too weak to drive the summer rainfall system at modern levels. The implication is that the the South Indian Ocean High Cell and the Zaïre Air Boundary did not deliver the same quantity of moisture to southern Africa as it does today. It is possible that the Low Phase of the Walker Circulation was the normal condition during these times.

The shift to modern seasonal dynamics (i.e. warmer summers and cooler winters) by at least 3kya and probably by 5kya would increase the strength of circulation systems and thus elevate rainfall, especially summer rainfall (Kutzbach 1981). Simulated winter rainfall amounts do not change significantly from 18kya until 0kya. Support of the simulated shift to more marked seasons in the Late Holocene is that the length of the Antarctic ice season and thus the amount of Antarctic pack ice is strongly related to solar insolation in late spring and early summer (Kukla 1978: 127). Increases in summer solar radiation would reduce the amount of Antarctic ice. World wide Late Holocene sea level high stands suggest that warmer Southern Hemisphere summers caused increased Antarctic pack ice breakup and melting which raised ocean levels throughout the world (Simmons et. al. 1981: 83-89; Yates et. al. 1986: 164-165). Cooler temperatures are reconstructed for the Northern Hemisphere and would not have been responsible for the Late Holocene sea level rises (Gribbin and Lamb 1978: 68-82; Simmons et. al. 1981; Wright 1983).

Although over-generalized in both space and time, the COHMAP simulation nonetheless affords the best available explanatory model for paleoclimatic change in the southern African interior. Before it can be made truly testable, however, it must be manipulated into an alternative form that makes it suitable for direct comparison with proxy paleoenvironmental data.

CHAPTER IV

CONSTRUCTING A REGIONAL MODEL OF VEGETATION CHANGE

In this chapter the modern botanical environment is searched for suitable analogs by which to interpret Holocene pollen spectra from the Blydefontein region. Using new, quantified botanical survey data, it is shown that the widely used Acocks Veld Type system is fatally flawed. By re-grouping the new quantified data with cluster analysis, eight revised plant communities for the Blydefontein area are presented. These have the advantage that they are dominated by plant taxa with identifiable pollens. Next, the climatic implications of dominant taxa are explored, thus making it possible to model botanical changes based on the COHMAP Simulation model of climate change.

Analysis of the Modern Plant Mosaic

Today, the major dichotomy in plant communities of the region is one between Karoo scrub (Compositae) and grassveld (Gramineae). Altogether, 84 modern plant surveys have been completed in the region (Roux and Blom 1979). These surveys use the Acocks Veld Types (see Chapter II) as a starting point, then measure the basal cover percent of species by three similar methods: wheel-point, chain-point and descending point. The sample population includes some 228,750 plants from the 84 individual surveys, making this one of the largest quantified botanical studies in southern Africa.

This analysis begins by using all 84 Roux-Blom botanical surveys, then 73 surveys (from seven Veld Types) near Blydefontein are selected for detailed analysis. First, species were regrouped into palynologically diagnostic taxa. Once grouped into the palynological taxa, the percent-of-basal-cover measurements for each taxa in each individual survey were transformed into relative frequencies of basal cover. Relative frequencies based on number of plants was not possible. However, it seems reasonable that a higher correlation would exist between basal cover and pollen production than between number of plants and pollen production. An analysis of the relative frequencies can provide an assessment of how well pollen analysis can identify the Acocks Veld Types. Descriptions of Acocks Veld Types near Blydefontein are given in Chapter II.

The Acocks Veld Type System Re-examined

In southern Africa virtually all archaeologists plus some botanists and palynologists rely heavily on the Acocks Veld Type system as a framework for predictive modelling. It has become so entrenched that users tend to forget that Acock's pioneer work was a brilliant and intuitive effort, but not based on quantitative data. Now that the Roux-Blom surveys make those data available for the first time in the eastern Karoo, it becomes possible to evaluate the quantitative reality of these intuitive groupings. Dr. Piet Roux, Grootfontein Agricultural College and Research Station, generously provided me with the raw data gathered from 12 of the Acocks Veld Types. There are eight Karoo scrub types: False Upper Karoo (FUK), Central Upper Karoo (CUK), Karroid Broken Veld (KBV), Arid Karoo/False Desert Grassveld (AK/FDG), Central Lower Karoo (CLK), False Succulent Karoo (FSK), Noorsveld (NV) and Orange River Broken Veld (OBV). The four grassvelds are: Karroid Merxmuellera Mountain Veld (KMMV), Stormberg Plateau Sweetveld (STM), Dry Cymbopogon-Themeda Veld (DCT), Cymbopogon-Themeda Veld (CTV) and the Cymbopogon-Themeda Veld/Themeda-Festuca Alpine Veld (CTV/TFAV). Their compositions and backgrounds are reviewed in Chapter II. As discussed in Chapter II, the reader should be aware that the modern vegetation patterns are a result of complex interactions between domestic stock overgrazing, edaphic, and climatic patterns. Nevertheless, the Acocks Veld Types are based on the modern distribution of plants, and the Roux-Blom botanical surveys provide quantitative data on these plant communities. It is suggested here that the Roux-Blom botanical surveys are an adequate representation of the range and associations of plants that occurred during the Holocene in the eastern Cape.

The most basic assay of these Veld Types is to plot of relative frequencies of all scrub species (Compositae) against all grasses (Gramineae) for each survey. When this is done (Figure 18) it is obvious that a rough binomial relationship exists between these two plant taxa: as the relative frequency of one increases, the other decreases in proportion. This is especially true for the False Upper Karoo and the Central Upper Karoo versus the grassvelds. However, this binomial characterization is not as accurate for the remaining Karoo Veld Types. It emerges, therefore, that the Orange River Broken Veld, the Arid Karoo, the Noorsveld, the False Succulent Karoo, the Central Lower Karoo and the Karroid Broken Veld form a single western group of plant communities with an ecology that is structurally different from an eastern group of Veld Types.

Clearly, there are relatively fewer Karoo composites in the western group than there is in the eastern group, and grass percentages decrease at a slower rate in the western group. These relationships are represented by linear regression formulas for each group:

Eastern Group Compositae % = -0.724 (Gramineae %) +71.123

$r^2 = 0.762$

Western Group Compositae % = -0.494 (Gramineae %) +45.774

$r^2 = 0.789$

I should state at this point that these statistics are not intended to be used for predicting, but rather only describing the differences between the two groups. One

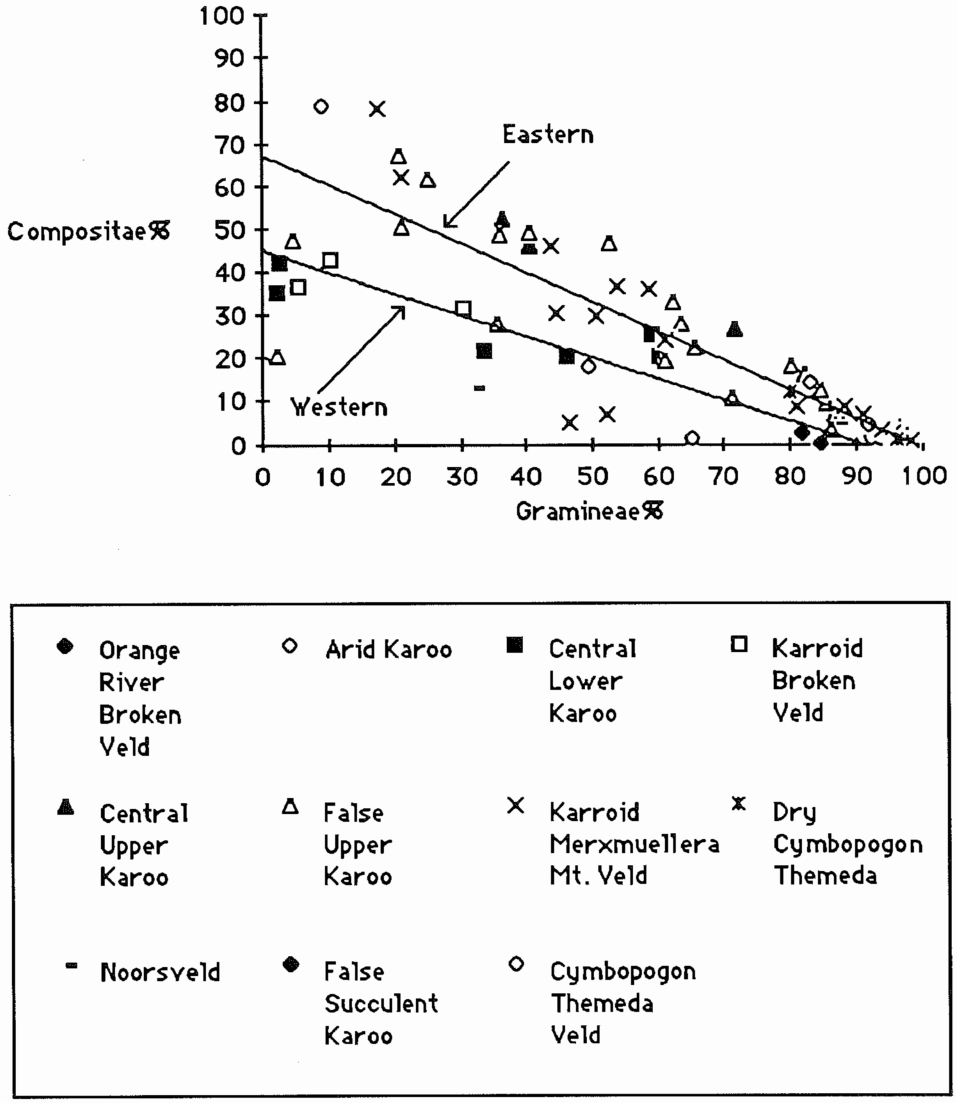

Figure 18. Relative frequency of Compositae plotted against relative frequency of Gramineae for eleven Veld Types (data from Roux and Blom, 1979).

might expect the relationships to be reversed, i.e. more composites in the drier western Karoo, but it is the greater number of plant forms adapted to more xeric conditions, that distort western Compositae/ Gramineae ratios. Although, Gramineae can occur in high frequencies in the western group, when they decrease, the composites and xeric forms increase at more or less equal rates. Also many grasses in the western

Karoo group are annuals that germinate rapidly after unpredictable rains, while many of the grasses in the eastern group are perennials. The latter presumably respond to changes in rainfall more slowly (Acocks 1975; Seely 1978).

Obviously, there are scrub-to-grassland continua in both east and west, and not a western and eastern Karoo-to-grassland dichotomy. This causes one to wonder if the Veld Types themselves are not parts of the same continua rather than discrete entities, as originally conceived. Of course the same question has been aired before by botanists (Campbell et al. 1981: 4), but this is the first time that quantitative data have been brought to bear on the problem. The new data are sufficiently promising to warrant further analysis.

Analysis of Local Plant Communities

The next step was to check the integrity of local Acocks Veld Types through discriminant function analysis. First, the relative frequencies of four taxa (Gramineae, Compositae, Chenopodiaceae/Amaranthaceae, and Aizoaceae/Ruschia) from the Roux-Blom surveys were grouped by Veld Type. These taxa were selected because they are the most common taxa in both the Roux-Blom surveys and also in the fossil pollen spectra, to be examined later. Also these are the only taxa for which modern pollen rain data are available. The data were entered by Veld Type into a discriminant analysis which reclassified the individual Roux-Blom surveys based on the groups' discriminant functions. A BIOSTAT II Version 2.0 discriminant analysis for Macintosh computers was used with an association matrix based on euclidean distances (Pimentel and Smith 1985). At the outset it was expected that the discriminant analysis would support the Veld Type groupings. Seven predefined groups, (KBV, CLK, CUK, FUK, CTV, STM, and MER), were used. The reclassification of the same individual Roux-Blom surveys resulted in 43 errors out of 73 classifications (Table 1). This means that

Table 1.--Discriminant analysis scores of individual Roux-Blom (1979) botanical surveys by Veld Type. Highest score of each underlined and * indicates a classification error. KBV: Karroid Broken Veld, CUK: Central Upper Karoo, CLK: Central Lower Karoo, FUK: False Upper Karoo, CTV: Cymbopogon Themeda Velds, STM: Stormberg Plateau Sweetveld, MER: Karroid Merxmuellera Mountain Veld.

Individual		Veld Type Discriminant Scores						
Surveys	Errors	KBV	CUK	CLK	FUK	CTV	STM	MER
KBV 10		1.00	0.00	0.00	0.00	0.00	0.00	0.00
KBV 11		1.00	0.00	0.00	0.00	0.00	0.00	0.00
KBV 33	*	0.00	0.03	0.66	0.14	0.03	0.01	0.13
CUK 15		0.01	0.77	0.01	0.12	0.03	0.02	0.05
CUK 16	*	0.00	0.17	0.02	0.27	0.17	0.16	0.21
CUK 17		0.01	0.77	0.01	0.12	0.03	0.02	0.05
CUK 18		0.00	0.36	0.03	0.31	0.06	0.04	0.21
CUK 19	*	0.00	0.05	0.02	0.19	0.24	0.25	0.25
CLK 12	*	0.00	0.09	0.05	0.30	0.12	0.08	0.36
CLK 13	*	0.00	0.17	0.05	0.27	0.13	0.10	0.29
CLK 27		0.00	0.00	0.99	0.00	0.00	0.00	0.00
CLK 28		0.00	0.01	0.96	0.02	0.00	0.00	0.01
CLK 29		0.00	0.01	0.76	0.09	0.03	0.01	0.10
CLK 31		0.00	0.03	0.75	0.09	0.05	0.03	0.05
FUK 21	*	0.00	0.37	0.05	0.33	0.04	0.02	0.19
FUK 22	*	0.00	0.14	0.18	0.30	0.04	0.02	0.33
FUK 35	*	0.00	0.06	0.06	0.26	0.13	0.08	0.40
FUK 36		0.00	0.06	0.10	0.24	0.19	0.17	0.23
FUK 38		0.00	0.20	0.02	0.31	0.13	0.11	0.24
FUK 45	*	0.00	0.37	0.02	0.29	0.09	0.07	0.16
FUK 46		0.00	0.10	0.05	0.30	0.15	0.13	0.28
FUK 47		0.00	0.11	0.01	0.23	0.21	0.22	0.22
FUK 48	*	0.00	0.07	0.01	0.20	0.24	0.25	0.23
FUK 49	*	0.00	0.05	0.01	0.14	0.29	0.34	0.17
FUK 50	*	0.03	0.00	0.97	0.00	0.00	0.00	0.00
FUK 51	*	0.00	0.08	0.01	0.18	0.25	0.26	0.22
FUK 52	*	0.00	0.05	0.01	0.14	0.28	0.33	0.19
FUK 53	*	0.00	0.10	0.01	0.22	0.22	0.23	0.21
FUK 54		0.00	0.20	0.02	0.30	0.13	0.11	0.23
FUK 55	*	0.00	0.07	0.30	0.22	0.06	0.03	0.32
FUK 58		0.00	0.29	0.04	0.34	0.06	0.04	0.23
FUK 60	*	0.00	0.06	0.01	0.16	0.27	0.30	0.20
FUK 62	*	0.00	0.45	0.05	0.30	0.03	0.02	0.15
FUK 64		0.00	0.22	0.06	0.36	0.06	0.03	0.28
FUK 65	*	0.00	0.04	0.02	0.18	0.24	0.24	0.28
FUK 71	*	0.00	0.05	0.01	0.13	0.30	0.36	0.16
FUK 77	*	0.05	0.63	0.02	0.15	0.03	0.02	0.09
FUK 78		0.00	0.21	0.04	0.35	0.08	0.05	0.27
FUK 81	*	0.00	0.08	0.01	0.20	0.23	0.25	0.22

Individual Surveys	Errors	Veld Type Discriminant Scores KBV	CUK	CLK	FUK	CTV	STM	MER
CTV 59	*	0.00	0.05	0.01	0.14	0.29	0.33	0.19
CTV 80	*	0.00	0.05	0.01	0.13	0.29	0.36	0.17
CTV 82	*	0.00	0.07	0.02	0.22	0.21	0.20	0.28
CTV 83	*	0.00	0.09	0.01	0.21	0.23	0.23	0.23
CTV 84	*	0.00	0.05	0.01	0.16	0.27	0.31	0.20
STM 66		0.00	0.05	0.01	0.13	0.30	0.36	0.17
STM 67		0.00	0.05	0.01	0.12	0.30	0.37	0.16
STM 68		0.00	0.05	0.01	0.13	0.30	0.36	0.17
STM 72		0.00	0.05	0.01	0.14	0.28	0.33	0.18
STM 74		0.00	0.06	0.01	0.17	0.26	0.29	0.21
STM 75		0.00	0.05	0.01	0.13	0.29	0.35	0.17
STM 76		0.00	0.05	0.01	0.15	0.28	0.32	0.19
STM 79		0.00	0.07	0.01	0.17	0.26	0.29	0.20
MER 20	*	0.00	0.33	0.07	0.34	0.04	0.02	0.21
MER 23	*	0.00	0.01	0.77	0.07	0.04	0.03	0.08
MER 24	*	0.00	0.06	0.01	0.18	0.26	0.28	0.21
MER 25	*	0.00	0.21	0.02	0.32	0.11	0.09	0.24
MER 26	*	0.00	0.05	0.01	0.13	0.29	0.35	0.17
M/F 30	*	0.00	0.07	0.01	0.18	0.25	0.27	0.22
MER 32		0.00	0.10	0.04	0.30	0.13	0.09	0.34
MER 37	*	0.01	0.03	0.47	0.08	0.12	0.04	0.27
MER 39		0.00	0.08	0.12	0.28	0.08	0.04	0.40
MER 40		0.00	0.09	0.04	0.30	0.12	0.09	0.35
MER 41		0.00	0.12	0.06	0.31	0.09	0.06	0.36
MER 42	*	0.00	0.27	0.03	0.34	0.07	0.05	0.23
MER 43	*	0.00	0.67	0.02	0.19	0.03	0.01	0.07
MER 44	*	0.00	0.24	0.03	0.32	0.09	0.07	0.25
MER 56	*	0.00	0.06	0.01	0.14	0.28	0.33	0.17
MER 57		0.00	0.05	0.02	0.21	0.22	0.20	0.30
MER 61	*	0.00	0.05	0.01	0.14	0.29	0.34	0.18
MER 63	*	0.00	0.05	0.01	0.14	0.28	0.33	0.18
MER 69	*	0.00	0.06	0.01	0.17	0.26	0.30	0.20
MER 70	*	0.00	0.05	0.01	0.13	0.29	0.36	0.17
MER 73	*	0.00	0.05	0.01	0.15	0.28	0.32	0.19
TOTALS								
Predicted		2	8	8	13	0	30	12
Actual		3	5	6	25	5	8	21

about 60 percent of the Roux-Blom surveys were actually in Veld Types other than the ones to which Acocks had intuitively assigned them. The classification errors cut across most Veld Types. It follows that taken on whole Acocks Veld Types are not homogeneous units in terms of the most common taxa diagnostic to pollen analysis. If the Roux-Blom survey data cannot be used to identify consistently Veld Types using these taxa, then one would not expect an analysis of pollen samples to discriminate Veld Types either!

An Alternative System of Plant Community Classification

Obviously, an alternative classification system must be developed that will be of direct use for comparisons between modern pollen rains and fossil pollen spectra. Now that the Roux-Blom data allow a quantifiable basis for reclassification, to double check these results a cluster analysis (Pimentel and Smith 1985) was run on the data using the same four taxa as was used in the discriminant analysis. The association coefficient was euclidean distance, and the clustering method was group average (i.e. unweighted pairs grouped using arithmetic averages with a BIOSTAT II Version 2.0 cluster analysis). The resulting dendrogram produced eight clusters of varying homogeneity (Figure 19). It should be reiterated that such clustering techniques will force groupings on any data set, and these groups will not necessarily be homogeneous. As a cross-check on the accuracy on the homogeneity of the clusters, and for a comparison to the previous discriminant analysis of Veld Types, a second and methodologically similar, discriminant analysis was run on the Roux-Blom data using these eight clusters as the pre-defined groups. In the second discriminant analysis all the individual sample surveys were reclassified correctly with no mistakes. These statistical analyses suggest that the botanical environment is, after all, significantly patterned in terms of palynologically diagnostic taxa. The mean and standard deviations of the four taxa used in the cluster analysis were calculated for each cluster along with the total average percent of the four taxa in the Roux-Blom botanical surveys. This gives an indication of the relative frequency not included by these four taxa (Table 2).

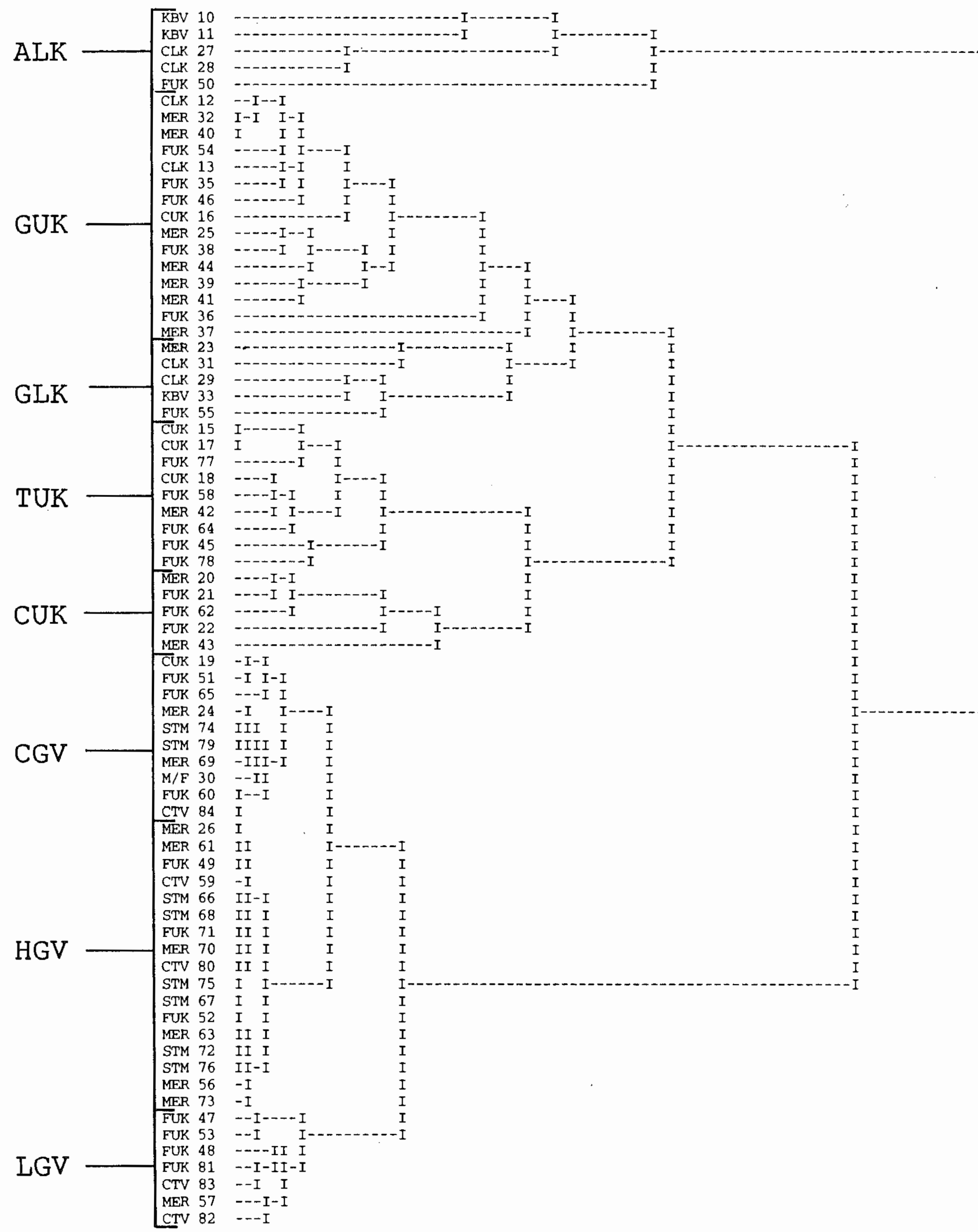

Figure 19. Cluster analysis of Roux-Blom botanical surveys.

Table 2.--Mean and standard deviations of Gramineae, Compositae, Chenopodiaceae/ Amaranthaceae (Cheno/Ams), and Aizoaceae/*Ruschia* relative frequencies for Roux-Blom botanical survey clusters.

Cluster	Gramineae	Compositae	Cheno/Ams	Aizo/*Ruschia*	TOTAL AV. %
1(GLK)	39.8±9.1	21.5±9.3	1.0±0.7	17.3±8.5	79.6
2(GUK)	59.6±7.9	24.5±8.6	0.7±1.1	1.2±2.7	86.0
3(TUK)	40.9±6.2	47.3±3.2	3.0±3.7	0.4±0.8	91.6
4(CUK)	21.3±2.8	63.5±10.2	0.0	0.2±0.3	85.0
5(CGV)	89.5±2.1	6.1±1.6	0.2±0.3	0.2±0.4	96.0
6(HGV)	97.0±1.6	1.3±1.1	0.03±0.09	0.03±0.08	98.36
7(LGV)	82.5±2.2	12.7±3.5	0.03±0.08	0.1±0.3	95.33
8 (ALK)	4.7±3.5	35.3±9.1	14.0±11.9	36.1±17.3	90.1

The spatial distributions of these clusters are significant. Most surveys classified as either Cluster 1 or Cluster 8 occur below the Great Escarpment near Graaff Reinet or near Beaufort West. They are Karoo plant communities with high Aizoaceae/Ruschia relative frequencies, and will be termed Lower Karoo for the purposes of this study. The major difference between Clusters 1 and 8 is the low Gramineae and high Chenopodiaceae/Amaranthaceae relative frequencies in Cluster 8. Generally, Cluster 1 occurs in the east, while Cluster 8 is found to the west.

Three grass-dominated communities were identified: Clusters 5, 6 and 7. The major botanical difference between these Grassveld communities is the ratio between Gramineae and Compositae. Cluster 6, the most grassy, on the average occurs furthest to the east and at higher elevations. Cluster 7 also occurs in the east but at lower elevations, and has the highest relative frequencies of Compositae. Cluster 5 has the broadest longitudinal distribution of the grass plant communities, but occurs at medium elevations usually in montane settings.

Lastly, Clusters 2, 3 and 4 represent a group of plant communities that are between the the Lower Karoo group (Clusters 1 and 5) and the Grassvelds (Clusters 5, 6 and 7). The main distinguishing criterion is the relative amount of Gramineae versus Compositae. In general the distribution of the clusters ranges from east to west starting with Cluster 2 and ending with Cluster 4. These three clusters are called Upper Karoo.

In summary, the distributions and relative frequencies of the eight clusters suggest that three major groups are present: Lower Karoo, Upper Karoo, and Grassvelds (see Table 3). The Lower Karoo can be subdivided into grassy and nongrassy groups. Cluster 1 is called here Grassy Lower Karoo (GLK), and Cluster 8 is termed Aizoaceae Lower Karoo (ALK). The Upper Karoo can be subdivided into three groups that range from west to east. Cluster 2 is Grassy Upper Karoo (GUK), Cluster 3 is a general or Typical Upper Karoo (TUK) and Cluster 4 is Compositae Upper Karoo (CUK). The Grassvelds are composed of three groups (Clusters 5, 6 and 7). Cluster 6 is a high and eastward lying grassveld (High Grassveld or HGV), Cluster 7 is a low and eastward grassveld (Low Grassveld or LGV), while Cluster 5 is a widely distributed grassveld usually in montane settings (Central Grassveld or CGV). These names are not intended for use outside of the area, or beyond palynological analysis. A more detailed botanical analysis based on species most likely would distinguish different groups, however for palynological analysis the above eight groups do appear to be significant.

Climates of the Eight Revised Plant Communities

The eight newly defined plant communities will be used as analogs for the interpretation of pollen spectra to be examined in the next chapter. Ultimately, however, those spectra will have to be fitted to the simulated climate-change model presented in Chapter III. Direct comparisons are impossible unless the pollen data can be converted to climatic analogs. In this section I explore the climatic parameters of key plant taxa in the revised plant communities.

To this end, forward stepwise regressions were calculated using the relative frequency of key plant taxa in the new plant communities as the dependent variable, and proxy estimates of mean annual temperature and precipitation as the independent variables. Mean annual temperatures of the interior plateau decrease from north to south (Venter et al. 1986: 46), but the Roux-Blom survey samples were taken in a narrow east-west transect which limits the effect of latitude on temperatures. On the other hand, elevation strongly affects local temperatures. The average change in temperature with elevation is known as the normal lapse rate (Trewartha 1968: 46). Through increases in elevation and thus decreases in temperature, elevation is accepted in this analysis as a second temperature variable.

As average annual rainfall in southern Africa systematically declines from east to west (Venter et al. 1986: 40),the longitudinal reading (degree of longitude) approximates mean annual precipitation (Figure 20). Only Roux-Blom surveys from summer rainfall areas near Blydefontein were included in this analysis, because Blydefontein is now in the summer rainfall region and it is highly unlikely it would have received significantly more winter rains during the Holocene. Surveys from areas with winter or year-round rainfall patterns were omitted.

The forward stepwise regression for Gramineae entered elevation first, then degree of longitude (Table 3). Correlations with degrees south were not high enough to be entered. This suggests that both temperature (elevation) and rainfall (longitude) influence the relative frequency of grass. Numerous studies have shown that, for a single location, precipitation is very important in affecting grass growth (Seely 1978; Vorster and Roux 1983), however this analysis suggests that over large areas temperature is also important. Thus it is the combined affect of temperature and rainfall that jointly influence the growth of grasses in southern Africa.

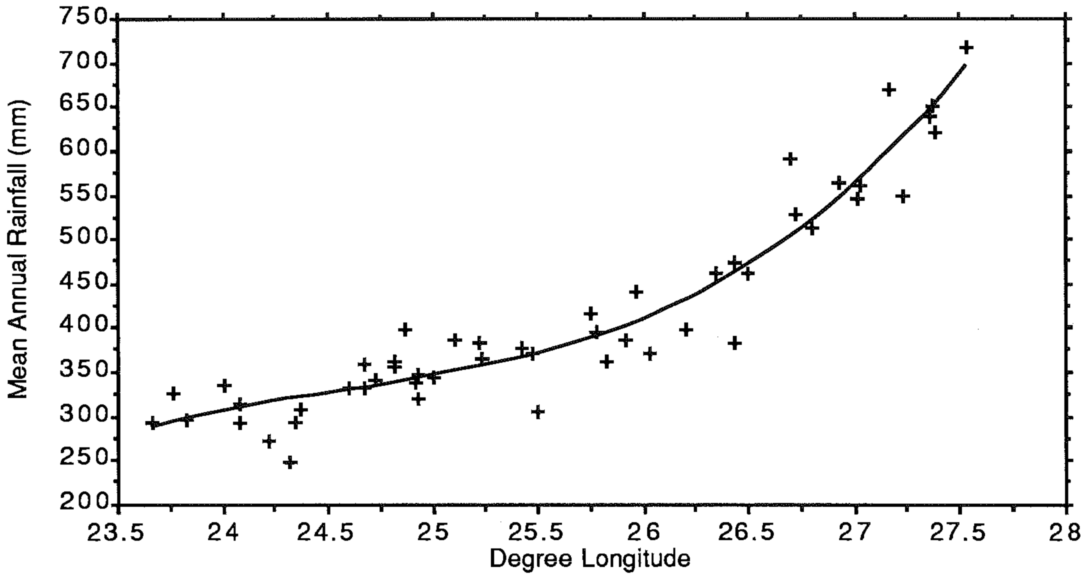

Figure 20. Plot of mean annual rainfall (mm) and degree of longitude for region surrounding Blydefontein (data from Werger 1980). Third order polynomial fitted curve (r^2 0.918, p value = 0.0001)

A forward stepwise regression between Karoo composites (as the dependent variable) and the independent variables of elevation, degree of longitude, and degree of latitude resulted in only degree of longitude (precipitation) being entered into the regression (see Table 3). A negative correlation exists between precipitation and relative frequency of composites. A number of other taxa produced significant correlations which are included in Table 3.

The stepwise regressions indicate that elevation and/or degree of longitude significantly affect the distributions of all major taxa. As the Roux-Blom botanical surveys are scattered along an east-west trending swath, the latitudinal influence on mean annual temperature was not great enough to influence plant relative frequencies. Apparently elevation more strongly influence temperatures than latitudinal position in the sampled region. Taxa that are not in this table occurred in such low frequencies that their calculations were not acceptable. This is unfortunate because many of these excluded taxa could be highly indicative of climatic parameters such as low temperatures associated with high elevations. Other taxa had no linear correlation with the variables. Those taxa that are most strongly correlated with temperature include Gramineae, Chenopodiaceae and Amaranthaceae (Cheno/Am), Aizoaceae, Zygophyllum, *Crassula*, *Elytropappus/ Stoebe*, *Lycium*, Acanthaceae, *Ruschia*, and *Euphorbia*. Taxa that have the greatest correlation with precipitation are Gramineae, Compositae, Chenopodiaceae and Amaranthaceae, and *Ruschia*. Only Gramineae and *Ruschia* were significantly influenced by both temperature and rainfall, and temperature was the most important variable in each case.

Table 3.--Stepwise regressions with relative frequencies of Gramineae and Compositae as dependent variables and elevation, degree of longitude, and degrees south as independent variables. Statview 512+ stepwise regressions for a Macintosh computer were used (Abacus Concepts, Inc. 1986).

	Independent Variables Correlation		
Dependent Variable	Elevation	Degrees East	Degrees South
Gramineae	0.279(R^2)	0.380(partial R^2)	insignificant
Compositae	insignificant	-0.237(r^2)	insignificant
Cheno/Am	-0.226(partial R^2)	-0.175(R^2)	insignificant
Aizoaceae	-0.208(r^2)	insignificant	insignificant
Lycium	-0.287(r^2)	insignificant	insignificant
Zygophyllum	-0.130(r^2)	insignificant	insignificant
Acanthaceae	-0.249(R^2)	insignificant	-0.293(partial R^2)
Ruschia	-0.261(R^2)	-0.309(partial R^2)	insignificant
Euphorbia	-0.150(r^2)	insignificant	insignificant
Crassula	-0.094(r^2)	insignificant	insignificant
Elytropappus/Stoebe	0.062(r^2)	insignificant	insignificant

These relationships can be reversed so that the relative frequencies of the taxa predict the environmental variables through the use of multiple regressions and the strength assessed through multiple correlations. In the first calculation elevation was chosen as the dependent variable with the relative frequencies of Gramineae, Chenopodiaceae and Amaranthaceae (Cheno/Am), Acanthaceae, Aizoaceae, *Ruschia*, *Lycium*, Zygophyllum, *Euphorbia*, *Elytropappus/Stoebe*, and *Crassula* as the independent variables. These are the variables that were best predicted by elevation. The multiple $R^2 = 0.871$, and the least-squares-fit equation is:

Elevation = 1710.204 - 1.027(Gramineae) - 17.856(Cheno/Am) - 97.575(Acanthaceae) - 15.379(Aizoaceae) - 49.448(Zygophyllum) + 299.120(Crassula) - 64.775(Ruschia) - 13.139(Lycium) + 3.720(Elytropappus/Stoebe) + 13.909(Euphorbia)

Degree of longitude was also used as a dependent variable with the relative frequencies of the Gramineae, Compositae, Chenopodiaceae and Amaranthaceae and *Ruschia* as independent variables. Gramineae and *Ruschia* were included in both regressions because elevation and degree of longitude both entered into their stepwise regression. The multiple $R^2 = 0.485$, and the least-squares-fit equation is:

Degree of longitude = 24.686 + 0.013(Gramineae) -0.023(Compositae) - 0.053(Cheno/Am) + 0.031(Ruschia)

In theory, any local pollen spectrum could be plugged directly into these formulae to predict the elevation and degree of longitude, thus temperature and rainfall parameters for an individual pollen sample. In practice, however, this assumes that pollen production, dispersion, deposition, and preservation are all equal for all plants. Methods for coping with these distortions are discussed later. Another important variable, which may further hinder a direct use of these formulae is that rainfall seasonality also affects plant growth.

Seasonal Rainfall and Plant Growth

Vorster and Roux (1983) demonstrate that plant groups in the eastern Karoo and adjacent grassvelds have different growth cycles, and that variations in rainfall season can select for or against plant growth. Plant growth was measured by month for different plant groups and the relative percent of growth was plotted (Figure 21). The most important pattern is that grass growth varies seasonally more than Karoo composite growth. Karoo bossies retain a higher level of growth during the winter when grasses virtually cease growing. Also the season of highest growth activity of both climax and subclimax grasses is late summer/early fall, while the greatest growth activity of Karoo scrub is during the fall and spring. Trees and shrubs attain their highest growth activity during summer. Except for trees and shrubs, all plant groups exhibit a decline in growth activity during mid summer due to high temperatures and associated water stress, and this decline is more marked in the Karoo composites than in the grasses.

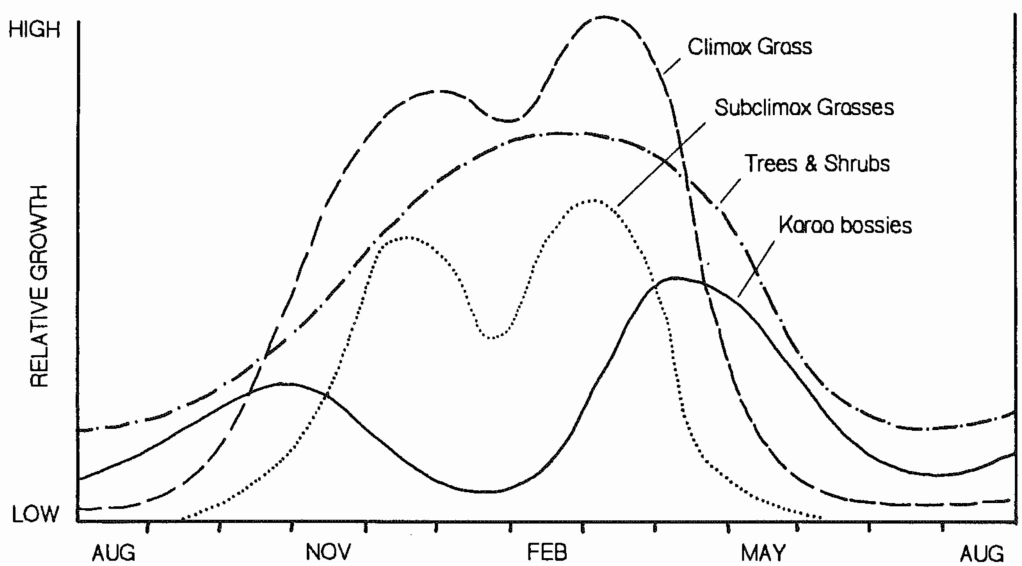

Figure 21. Seasonal growth cycles for major plant groups in the northeastern Cape (after Vorster and Roux 1983).

These growth patterns can be used to predict environmental changes that might occur with changing seasonal rainfall patterns. Obviously grassvelds are better adapted to summer rainfall than are Karoo scrub communities, and this is supported by observations that good summer rains in the eastern Karoo are known to produce blanketing grass cover (Roux and Vorster 1983: 26). However grasses generally require more water than Karoo bossies, and summer droughts can significantly hinder grass growth while Karoo scrub is capable of suffering through summer droughts and making use of rain in any season because they grow throughout the year. Thus superficially it appears that significant drought or a change from summer to winter rainfall could produce similar patterns in plant distributions and abundances, however, this is not the case. In the beginning of this chapter I demonstrated that an eastern and western group of plant communities can be isolated with the Roux-Blom botanical surveys, and it is the the increase of winter rainfall in the region of the western group that most likely causes this difference. Thus an increase in winter rainfall by itself could be identified by an increase of succulents that now characterize the western portion of the Karoo and the Namib, while a simple change in rainfall that retains a summer maximum pattern would most likely affect the relative frequencies between composites and grasses.

A Model of Botanical Change for the Eastern Cape

The relationships between climate and plant taxa identified in the above sections are used to model vegetation changes under the various climatic conditions suggested by the COHMAP simulations. Three climatic variables are considered: annual temperature, annual precipitation and seasonal precipitation. These variables can be viewed as axes on a three dimensional chart (x,y, z), and, for the purposes of this discussion, are viewed as independent variables.

As temperatures increase the model predicts that Aizoaceae, *Lycium*, Zygophyllum, Acanthaceae, *Ruschia*, *Euphorbia*, Cheno/Ams and *Crassula* to increase, while grasses would decrease. *Elytropappus/Stoebe* would only be present with cool temperatures and abundant with cold temperatures. As annual precipitation increases the relative frequencies of the Compositae, Cheno/Ams and *Ruschia* would decrease, and the relative frequencies of Gramineae would increase. As summer rainfall declines and as winter rainfall increases the grasses are less able to survive from year to year. At that point Karoo composites, already in the grassvelds in low frequencies, increase because of reduced competition with the grasses.

The COHMAP simulations of mean annual temperature and precipitation are coldest and wettest for 18kya and 15kya when summer rainfall was greater than today (see figures 3.7-3.9 in Chapter 3). The model predicts plant communities to have been dominated by grasses and *Elytropappus/Stoebe*. These grassy communities could be represented by the HGV community, however, modern plant communities may not provide appropriate analogs for the Pleistocene, because ecological conditions seem so different from today.

By 12kya this changes to much warmer annual temperatures with cooler summers and warmer winters than the annual mean. Precipitation drops to its lowest point. Now, the model predicts a plant community dominated by Karoo composites with cool temperature indicators like *Elytropappus/Stoebe*. A CUK or a TUK community could have existed at this time and possibly a GUK if conditions became wetter.

The climatic situation at 9kya is similar to 12kya except mean annual temperature is similar to modern levels. The plant communities at 9kya would be similar to those hypothesized for 12kya except with an increase in thermophilous or warm-loving taxa. Plant communities at this time could be GLK or CUK.

By 6kya mean annual temperature is at its highest with warmer winters and cooler summers than before. Mean annual precipitation is still low, but winter rains increase. The model predicts a plant community dominated by Karoo composites, but the cold-hardy taxa would be replaced by thermophilous plants. Either CUK, GLK or ALK communities could have colonized Blydefontein at this time.

Major climatic changes occur between 6kya and 3kya, so that by 3kya climatic conditions are more similar to the modern patterns than ever before. Mean annual temperature is only slightly cooler than today, and warmer summers and cooler winters are established. Rainfall dramatically increases with summer rains much greater than today. The implications for modelling vegetation are that by 3kya we would have grass dominating plant cover with warm indicators such as Aizoaceae, *Lycium*, Zygophyllum (*Tribulus*), Acanthaceae, *Ruschia*, *Euphorbia*, Cheno/Ams and *Crassula*. Karoo composites would certainly be present, but dominant only during brief droughts. Cool temperature indicators like *Elytropappus/Stoebe* would be present only on the highest peaks of the Kikvorsberg. This translates to expect TUK, GUK or even LGV communities at 3kya.

Historical Vegetation Change as an Analog of Holocene Changes

Any attempt to use historical trends in the local vegetation as a first test of the Botanical Model will be complicated by additional factors even though Roux and Vorster (1983: 26) suggest that droughts have contributed to the change from grassveld to Karoo in the northeastern Cape. The Grapevale record for the last 60 years shows that the drought lows in the 18-year cycle have actually become less severe in the later portion of the 20th century, along with an increase of average annual rainfall.

One line of argument could say that this implies that drought is not a significant contributing factor in the continuing spread of Karoo plants in this portion of the eastern Cape during most of the 20th century. Today Karoo scrub is invading apparent healthy as well as overgrazed grasslands. In healthy grassveld with Karoo scrub bare halos are observed around the plant *Chrysocoma tenuifolia*, Bitter Karoo (Squires and Trollope 1979). These bare areas quickly re-vegetate with grasses and forbs if the above-ground portion of Karoo plants are destroyed by fire or some other mechanism (ibid: 88), especially when followed by rain (pers. obs. 1985). Squires and Trollope discovered that *Chrysocoma* emits an allelopathic chemical that inhibits the germination and seedling growth of plants. Rain washes this chemical to the ground below the plant and a small barren patch is formed where it is absorbed.

Based on these observations an alternative hypothesis to explain historical Karoo expansion into grassveld is that the slight increase in winter rainfall in this region over the last 60 years may be coupled with with the production of allelopathic chemicals or as yet other undiscovered inhibiting mechanisms by Karoo scrub (however see above discussion on effects of winter rainfall on plant communities). When reduced veld burning, especially after the fencing of farms in the 1920s, this provided just enough selective advantage for the Karoo scrub to overtake healthy grassveld and overrun poorly managed land. Without doubt some 200 years of overgrazing has been a major factor governing eastward Karoo expansion, but no one single factor completely explains the modern rapid spread of Karoo plants.

Returning to climatic explanations it is important to realize that in Roux and Vorster's (1983) model of historic impacts on eastern Karoo vegetation the shift from Phase 1-destruction of natural plant communities to Phase 2-devegetation and on to Phase 3-re-vegatation corresponds to extremely high rainfall amounts in the 1880s that decline to drought conditions in the 1920's, and thereafter begin to recover to nondrought conditions in the later portion of the 20th century. It seem clear that the way the plant communities responded in the Phase 3 re-vegetation was influenced by grazing pressures from domestic stock as this was a period of high stock densities, but it also seems very likely that the Phase 1 destruction of "natural" plant communities and the Phase 2 devegetation are responses to climatic changes. Today many farms, including Blydefontein, have not been overgrazed for many years (others are and can easily be identified), and plant distributions and plant community compositions on these well managed farms may be approaching their natural limits as imposed by climatic conditions.

CHAPTER V

A TEST OF THE BOTANICAL MODEL

Five alluvial exposures and two hyrax dung middens in the vicinity of Blydefontein Rockshelter were sampled for fossil pollens and dating materials. Altogether 22 radiocarbon dates were obtained from these sequences, so that an unusually complete chronometric framework is available. Thus all eight pollen diagrams can be correlated. Together, these overlapping sequences present a composite picture of vegetation changes in and around the Blydefontein Basin from late Pleistocene times through most of the Holocene.

When analogs for past pollen spectra are sought among the eight newly defined plant communities found in the Blydefontein region today, the pollen data allow a fairly robust test of the vegetation-change model presented in Chapter IV.

Fossil Pollen Sites

Two types of fossil pollen traps were documented in the Kikvorsberg mountains: alluvial sites and stratified hyrax dung middens (see Figure 1). The following summaries are based in part on Bousman et al. (1988), and Scott and Bousman (1990). The analyses were carried out by a number of scientists who generously made their data available: Dr. L. Scott analyzed the pollen, Dr. T. C. Partridge studied the sediments in the geological sites, Dr. J. C. Vogel dated the sites, Dr. S. E. Metcalfe investigated the diatoms, Dr. M. Seaman analyzed the molluscan fauna, and Mr. J. S. Brink identified the large mammalian fauna.

Five geological sites have been studied from Blydefontein and Hughdale Basins in the Kikvorsberg Range: Blydefontein Section (BFS), Blydefontein Stream Mouth (BSM), Channel 2 (CH2), Upper Section-Pond (USP), and Hughdale Section (HDS). Most geological sites occur in the lower reaches of Blydefontein and Meerkat streams at or above their confluence, but Hughdale Section is in a perched basin on the farm of Hughdale approximately 5km northeast of Blydefontein Rockshelter (see Figure 1). The alluvial sediments in Blydefontein Basin have been divided into two major groups: the Older and Younger Fills. Both are present at most geological sites in the basin. The single profile from the nearby Hughdale Basin has both Older and Younger fills, but the lowest sediments differ from the Older Fills at Blydefontein Basin and are identified as dorbank, i.e. a hard cemented subsoil horizon such as a B horizon (MacVicar 1977: 126; Partridge, personal communication 1989).

Radiocarbon Dates and Alluvial Chronology

Seventeen radiocarbon dates were run by Natural Isotopes Laboratory, DEMAST, CSIR, Pretoria on material from the geological sites (Table 4). All dates are based on the 5568 year half-life, corrected for ^{13}C fractionation, but uncalibrated. These dates were obtained on organic humates in buried soils and stream deposited silts, carbonates, and charred reeds.

All dates from the Younger Fills in Blydefontein Basin and Hughdale Basin are of Holocene age and most are restricted to the Late Holocene. Radiocarbon samples Pta-4459 and Pta-4465 represent radiocarbon ages on carbonates and humates from the same sample at USP, and a comparison of these two dates indicates a small enrichment of more recent carbonate has made Pta-4459 younger.

The age of the Older Fills can be inferred from an extinct giant hartebeest (*Megalotragus priscus*) metacarpal from BFS. Also the dorbank deposit in Hughdale

Table 4.--List of radiocarbon dates from geological sites in Blydefontein Basin

LAB NO.	DATE AND RELATIVE 13C CONTENT	MATERIAL	PROVENIENCE
Pta-4259	290±40 B.P. $\delta^{13}C$= -22.7°/oo	charred reeds	BFS, upper buried soil, 60cm below surface (BS)
Pta-4417	1360±100 B.P. $\delta^{13}C$= -19.0°/oo	humates	BFS, organic silts in Channel 4, 140cm BS
Pta-4792	2080±50 B.P. $\delta^{13}C$= -21.0°/oo	humates	BFS, middle buried soil, 130cm BS
Pta-4390	3290±60 B.P. $\delta^{13}C$= -16.8°/oo	humates	BFS, lower buried soil, 320cm BS
Pta-4392	4010±60 B.P. $\delta^{13}C$= -20.8°/oo	humates	BSM, black silty clay in pond deposits, 50cm BS
Pta-4237	4430±70 B.P. $\delta^{13}C$= -21.1°/oo	humates	BSM, black silty clay in pond deposits, 110cm BS
Pta-4273	5080±70 B.P. $\delta^{13}C$= -19.8°/oo	humates	BSM, black silty clay loam in pond deposits, 230cm BS
Pta-4947	5270±70 B.P. $\delta^{13}C$= -23.3°/oo	humates	BSM, organic clay in pond deposit, 302-312cm BS
Pta-4458	4260±60 B.P. $\delta^{13}C$= -17.8°/oo	humates	CH2, organic silts, top of channel fill, 240cm BS
Pta-4461	7790±90 B.P. $\delta^{13}C$= -24.0°/oo	humates	CH2, organic silts, bottom of channel fill, 340cm BS
Pta-4796	410±40 B.P. $\delta^{13}C$= -3.1°/oo	humates	USP, clay loam in pond deposit, 161cm BS
Pta-4459	1870±50 B.P. $\delta^{13}C$= -3.1°/oo	carbonate	USP, clay loam in pond deposit, 181cm BS, same sample as Pta-4465
Pta-4465	2000±60 B.P. $\delta^{13}C$= -18.7°/oo	humates	USP, clay loam in pond deposit, 181cm BS, same sample as Pta-4459
Pta-5126	840±50 B.P. $\delta^{13}C$= -16.8°/oo	humates	HDS, 1st buried soil, 20cm BS
Pta-4977	2520±60 B.P. $\delta^{13}C$= -15.6°/oo	humates	HDS, 2nd buried soil, 110cm BS
Pta-4950	3990±70 $\delta^{13}C$= -18.3°/oo	humates	HDS, 3rd buried soil, 270cm BS
Pta-5131	4750±100 B.P. $\delta^{13}C$= -15.2°/oo	humates	HDS, 4th buried soil, 365cm BS

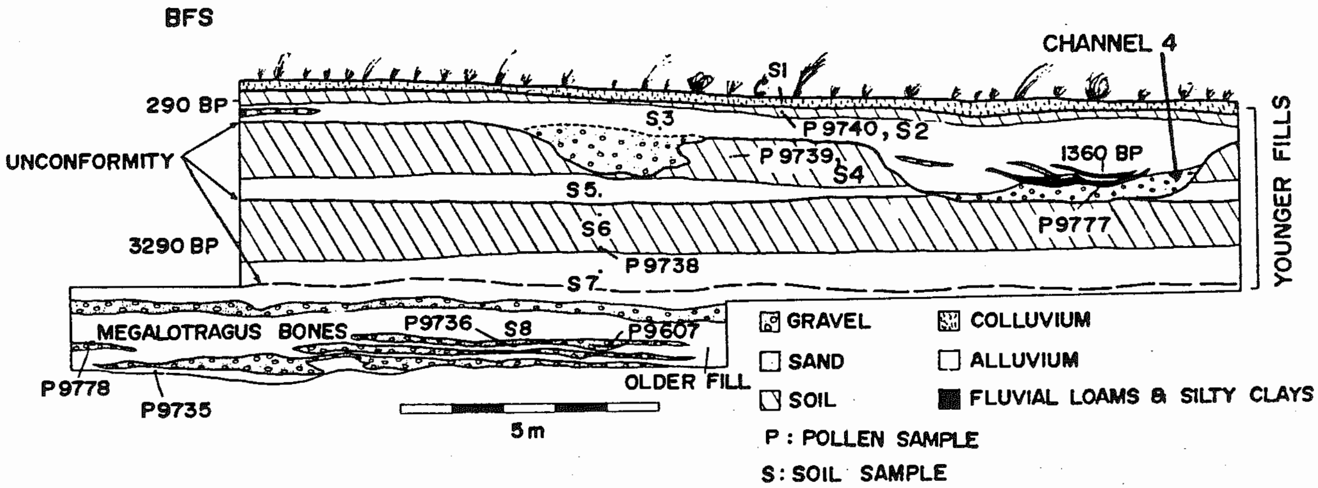

Figure 22. Blydefontein Section stratigraphy.

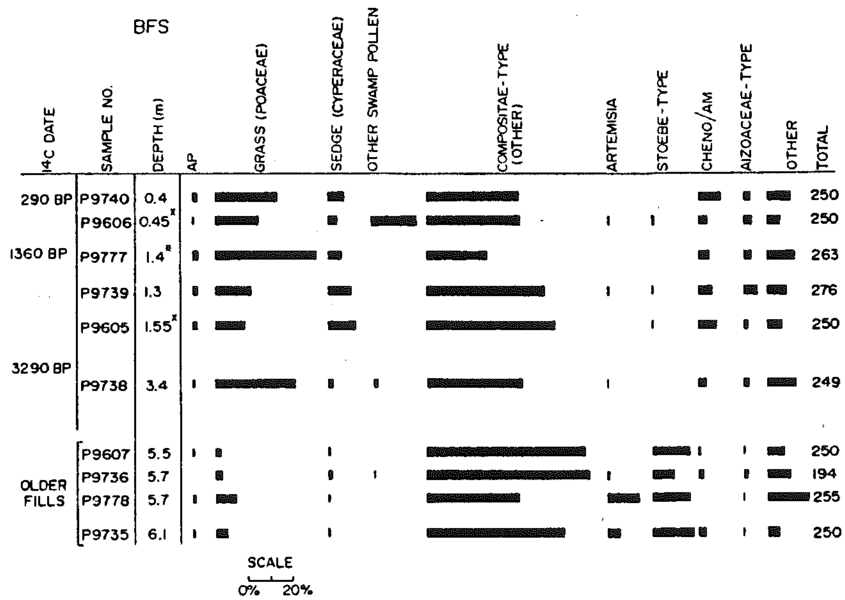

Figure 23. Blydefontein Section pollen diagram.

Basin had *Megalotragus priscus* remains as well as an immature wildebeest (*Connochaetes* sp.) tooth. The youngest radiocarbon dated *Megalotragus priscus* is ca. 7500 B.P. at Wonderwerk Cave in the Northern Cape (Klein 1980, 1984; Thackeray 1981), however the oldest date for the Younger Fills at Blydefontein Basin is 7790±90 B.P. (Pta-4461) from CH2. As the Older Fills in Blydefontein Basin are stratigraphically below this date they must be older, possibly terminal Pleistocene in age. The age of the dorbank deposit in Hughdale Basin is even less secure, but two Middle Stone Age sites were found in dorbank a few kilometers down stream of the geological site of Hughdale Section and a few kilometers upstream from Blydefontein Section in a side tributary. The youngest chronometric ages for nearby Middle Stone Age occupations are the thermoluminescence assays of 39,700±4300 B.P. and 26,300±3000 B.P. on sediment samples from Driekoppen Rockshelter in the Zeekoe Valley, and 30,840±480 B.P. and 38,900±1200 B.P. from radiocarbon assays on charcoal from Highlands Rockshelter (Deacon 1976: 222; Wallsmith 1990: 14).

Thus it is possible that the dorbank at Hughdale Section also dates to the latter half of the Late Pleistocene.

Blydefontein Section (BFS)

BFS provides the most complete section documented in Blydefontein Basin. BFS is 6.5 meter deep terrace, informally named the Blydefontein Terrace. It consists of Older Fills in the bottom 2.5 meters with approximately 4 meters of Younger Fills above (Figure 22). The Older Fills consist of stratified layers of brown and mottled yellowish brown alluvial sandy loams, sandy clay loams with pollen and mammalian fauna, and a few lenses of sand and gravel. Generally the Older Fills are of coarser texture than the Younger Fills, and this suggests that either sediment supply increased because of reduce plant cover or erosive energies were higher during the accumulation of the Older Fills. The clay mineral halloysite is only present in the Older Fills. This implies that a period of time separates the Older Fills from the Younger Fills, and that a humid period occurred during or shortly after the accumulation of the Older Fills (Birkeland 1974: 238). This humid period may be responsible for the erosional unconformity between the Older and Younger Fills. Two bones were discovered together in the Older Fills at BFS: the distal portion of a *Megalotragus priscus* metacarpal, and a complete *Syncerus caffer* radius. These bones were submitted for radiocarbon dating, but no collagen was preserved. Four pollen samples were analyzed from the Older Fills, and these are characterized by high pollen percentages of Compositae, *Artemisia,* and *Stoebe*-type (i.e. either *Stoebe* or *Elytropappus* plants), and low Gramineae relative frequencies (Figure 23). Dr. Louis Scott (1987 personal communication) suggests that these samples are characteristic of Pleistocene pollen spectra.

In the Younger Fills at BFS is overbank alluvium with three buried soils and one paleochannel with pollen, as well as a non-pollen bearing buried channel (see Figure

22). Younger Fills sediments are much more variable than those documented in the Older Fills. Bulk humate samples from the lowest soil dated to 3290±60 B.P., similar material from the middle soil dated to 2080±50 B.P. and charred reeds in the uppermost buried soil dated to 290±40 B.P. Humic rich silts in Channel 4 dated to 1360±100 B.P. The clayey soils are separated by sandy loam alluvial overbank deposits, and the youngest buried soil is covered by a thin surface mantle of colluvial deposits which are slightly altered by modern pedogenesis. At BFS the Younger Fills are characterized by three cycles of alluviation and relative stability marked by pedogenesis and non-deposition. A linear regression between soil radiocarbon ages and mean depth of sample demonstrates a fairly regular accumulation of sediments at BFS (radiocarbon age = 10.771 (sample depth) + 32.857; r^2 = 0.917), which averages 0.093cm/yr (Figure 24). A close look at the radiocarbon dates and depths suggests that the accumulation rate between the first and second soil was slower than the overall mean. One possible explanation is that it could be due to the removal of sediments by stream erosion as two channels occur stratigraphically between these two soils (see Figure 22).

The pollen samples from the Younger Fills at BFS have varying amounts of Gramineae, Compositae and Cyperaceae (see Figure 23), and it is suggestive of a grassy karroid plant community with increases in Compositae during dry conditions or possibly during periods of increased winter rainfall (Scott, personal communication).

Blydefontein Stream Mouth (BSM)

BSM is in the Blydefontein Terrace, and consists of 6.8 meters of dark organic clayey silts and diatomaceous lenses representing a buried pond stratified below the three buried soils documented from BFS (Figure 25). The pond deposits have been dated to 4010±60 B.P. at 50cm below the top of the pond, 4430±70 B.P. at 111cm,

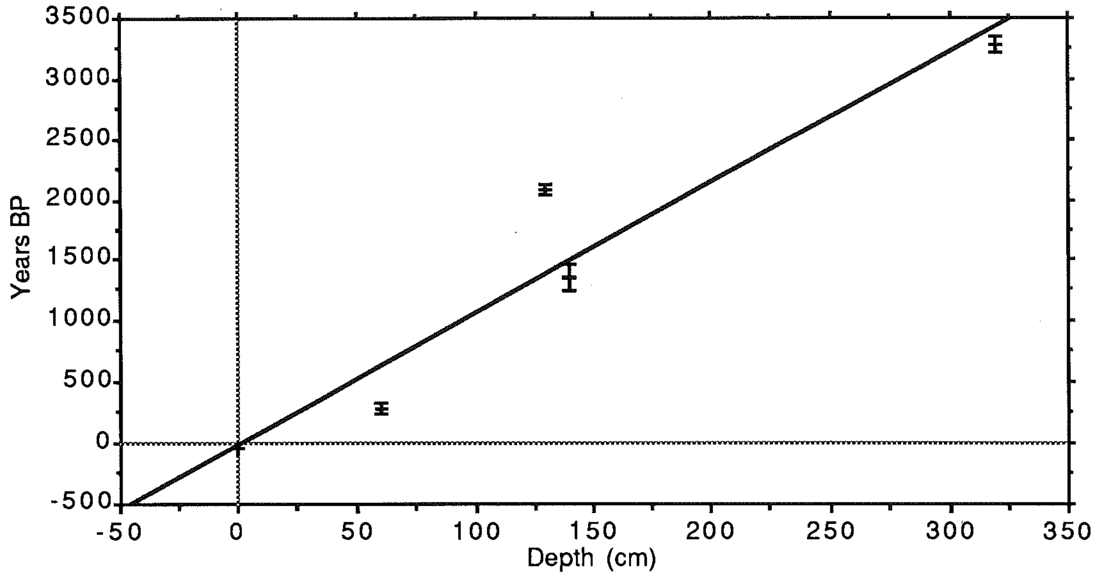

Figure 24 BFS radiocarbon dates with one sigma bars plotted by sample depth.

5080+70 B.P. at 236cm, and 5270±70 B.P. at 295cm (Figure 26). The regularity and strength of the relationship between depth and age ($r^2 = 0.988$), as well as a consistent depositional environment allows an extrapolation of ages for undated pollen samples at BSM between and below the radiocarbon samples. Extrapolating the ages of pollen samples below the radiocarbon samples is risky as it is based on the untested assumption that sediment accumulation rates have not changed. With this assumption in mind, sample age can be estimated through the formula:

Radiocarbon Years B.P. = 5.158(cm below top of pond deposits) + 3805.242

The lower three meters of pond deposit is below the modern water table, and samples were obtained by coring. However, the core never reached the bottom of the pond. Diatom samples are available only from the upper 1.8 meters of pond deposit, but pollen samples are available throughout. In the upper portion of the pond black organic silts interfinger with overbank alluvium which finally transgresses the pond deposits, and this represents normal pond infilling that does not appear to be indicative of climatic change. Four diatom samples show a clear fall in water level with a shift from euplanktonic to epiphytic and aerophilous species up the profile (Figure 27). Diatom preservation was too poor in the highest sample to allow quantification, plus an increase in chrysophyte cysts suggest water depths became unsuitable for diatoms. Pollen spectra indicate fluctuating grassy karroid plant communities (Figure 28).

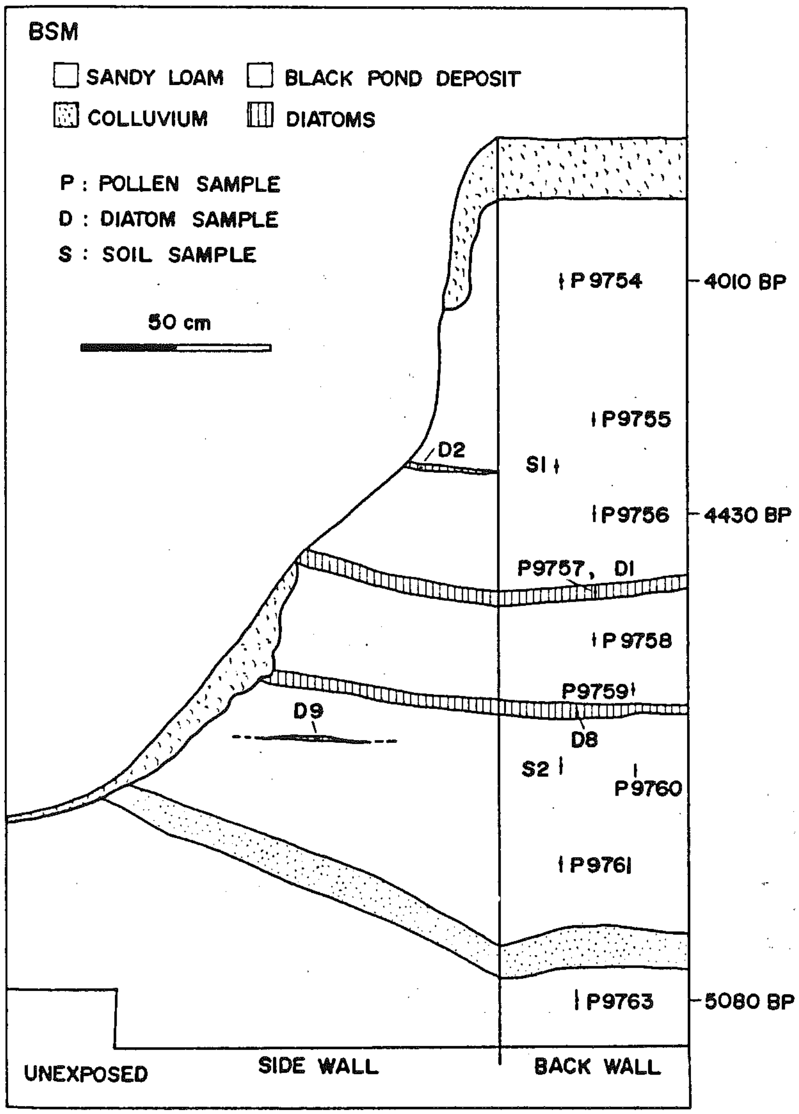

Figure 25 Blydefontein Stream Mouth geological profile.

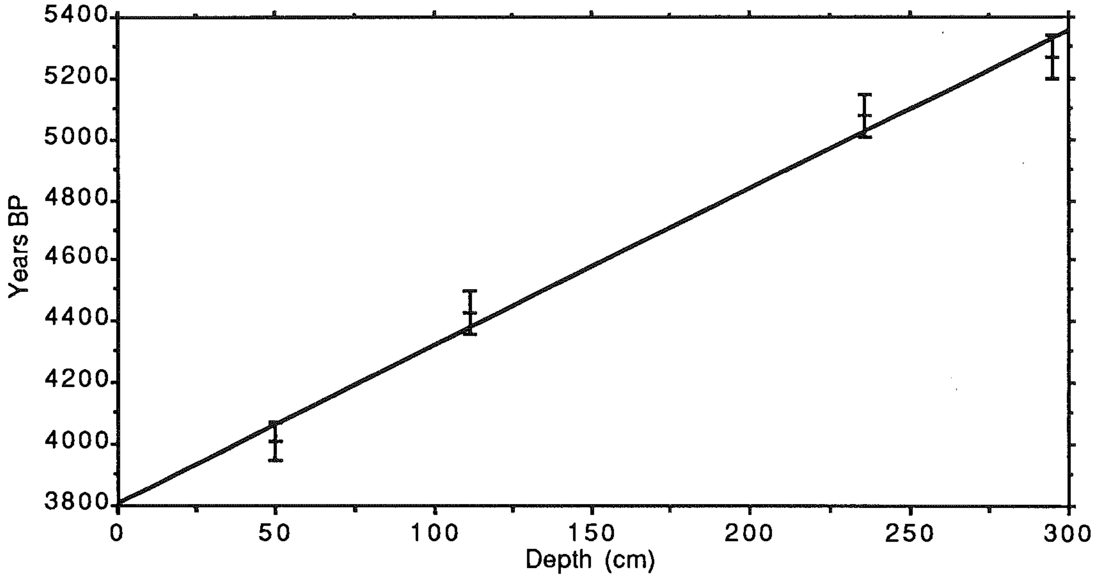

Figure 26 Linear regression of BSM radiocarbon dates with one sigma bars plotted by sample depth.

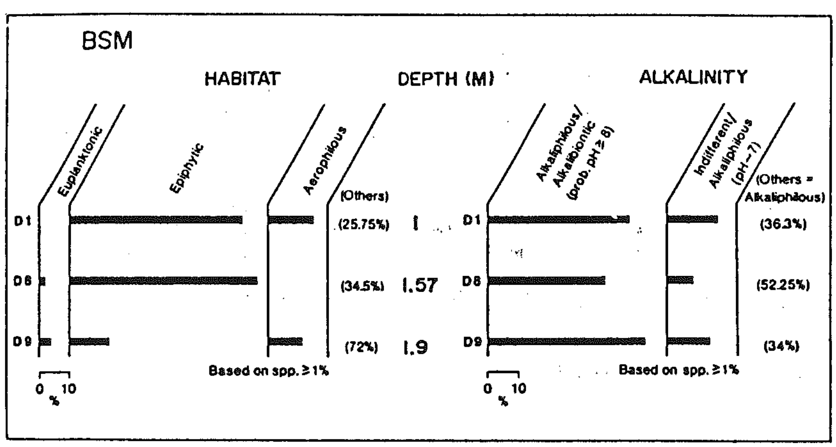

Figure 27 Diatom diagram for BSM.

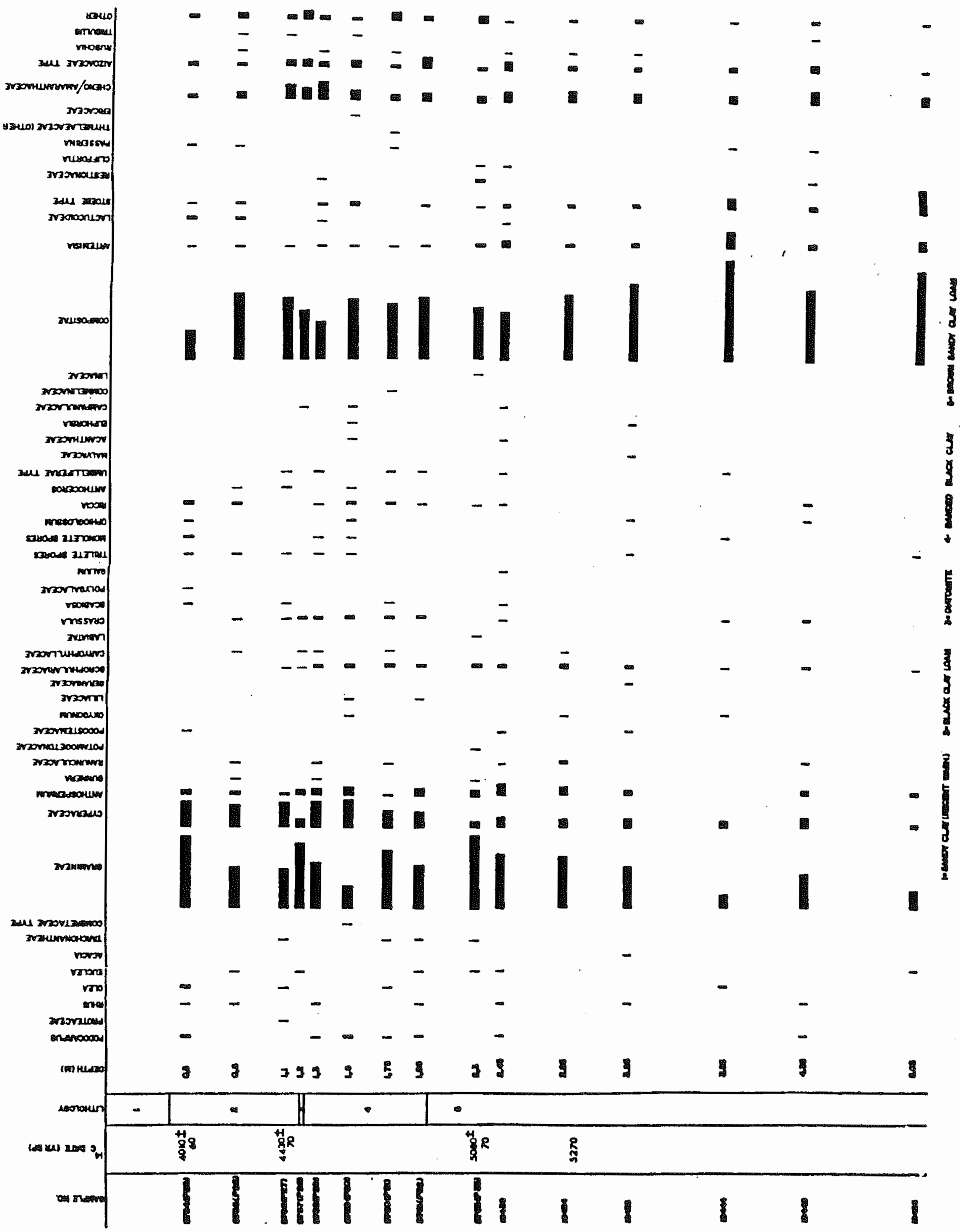

Figure 28. Pollen diagram for Blydefontein Stream Mouth.

Channel 2 (CH2)

CH2 deposits sit unconformably on the Older Fills (Figure 29). The channel deposits consist of of two units separated by an unconformity, and CH2 provides the only radiocarbon dated Early Holocene pollen sample. The lower channel fill is dated to 7790±90 B.P., and the upper channel fill is dated to 4260+60 B.P. The pollen spectra in the lower channel fill is dominated by Compositae, and is most similar to pollen spectra from the Older Fills (Figure 30). The upper channel fill pollen spectra are similar to samples from the Younger Fills in BFS and BSM. Three diatom samples from the upper channel fill suggest a shift from flowing water in the bottom sample to a marsh habitat with abundant epiphytic plants in the upper two samples (Figure 31).

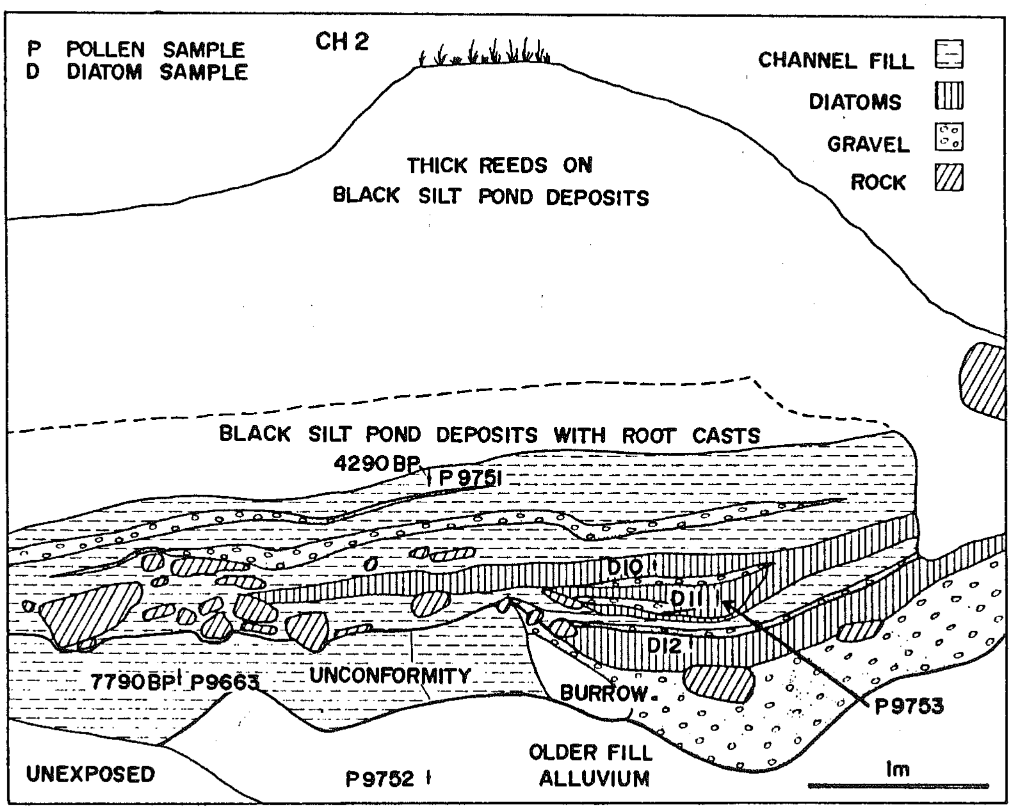

Figure 29 Geological profile for Channel 2.

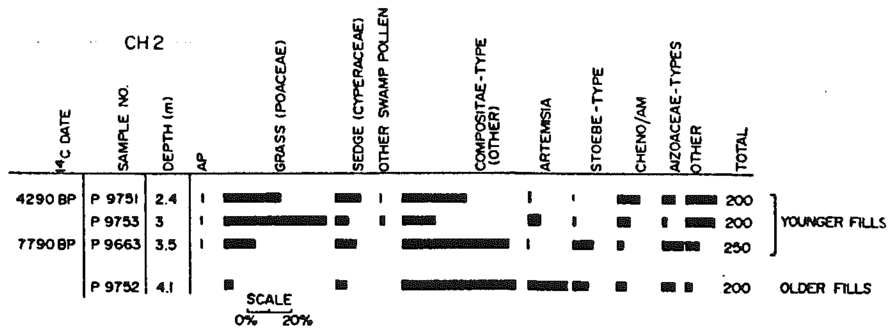

Figure 30 Pollen diagram for Channel 2.

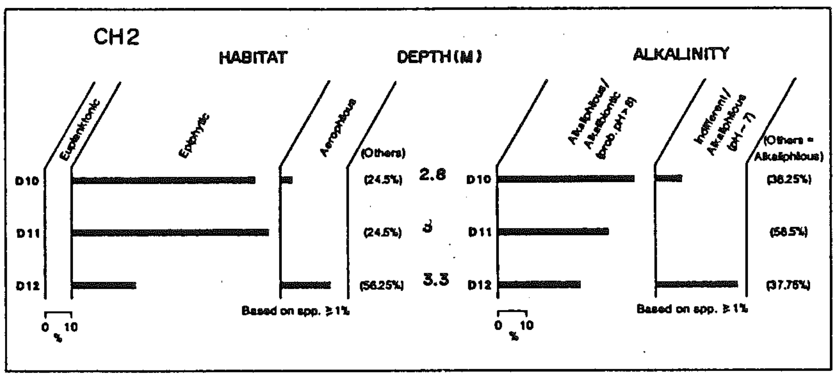

Figure 31 Diatom diagram for Channel 2.

Upper Section Pond (USP)

USP is 70cm of carbonaceous and diatomaceous pond deposits that sit unconformably on the Older Fills, and are buried by ca. 150cm of overbank alluvium with a thick surface soil (Figure 32). Bulk humates from the lower portion of the pond have been dated by radiocarbon to 2000±60 B.P. Carbonates extracted from the same sample yielded an age of 1870±50 B.P., however the 2000 B.P. date is used here for consistency. The thick surface soil at USP previously was correlated to the middle buried soil at BFS (Bousman et al. 1988), but that soil has recently been dated to 2080±50 B.P. at BFS and it is unlikely that this correlation is correct. The top of the pond deposit has been dated at 410±40 B.P., but this date is questionable as it is unlikely that the overlying soil could have formed in so short of a period. A plotting of radiocarbon age by depth can be used to suggest that the 410 B.P. sample was contaminated by more recent carbon that moved down profile through illuviation (Figure 33). The pollen spectra from the pond are fairly homogeneous and dominated by grass pollen, except for one sample (9748a) which has high Compositae and Cyperaceae relative frequencies (Figure 34). Pollen spectra in the overlying alluvium and soil exhibit a fairly consistent decrease in Gramineae pollen and increases in Cyperaceae and Compositae pollen.

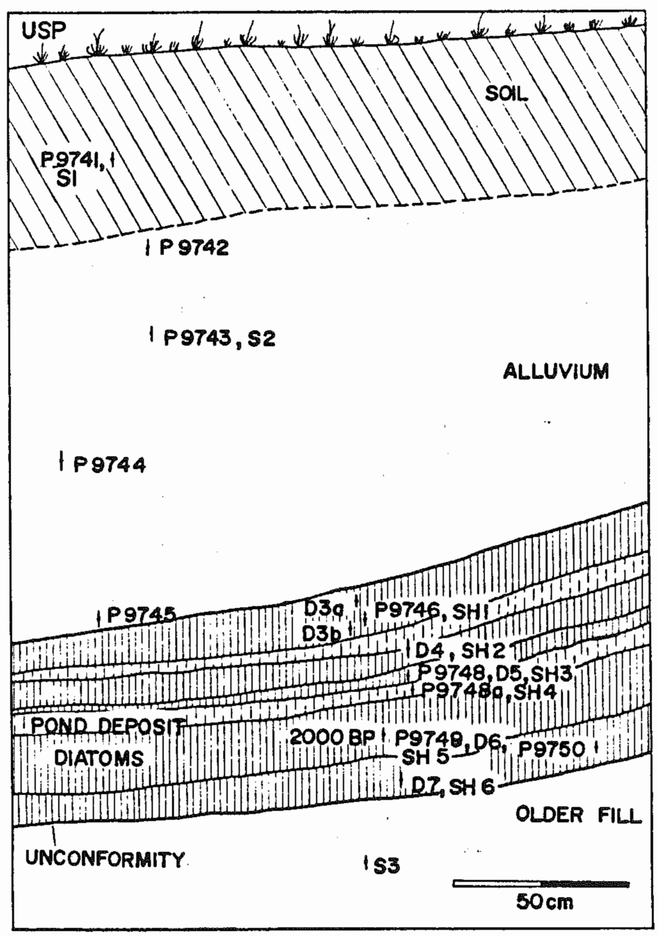

Figure 32 Geological profile for USP.

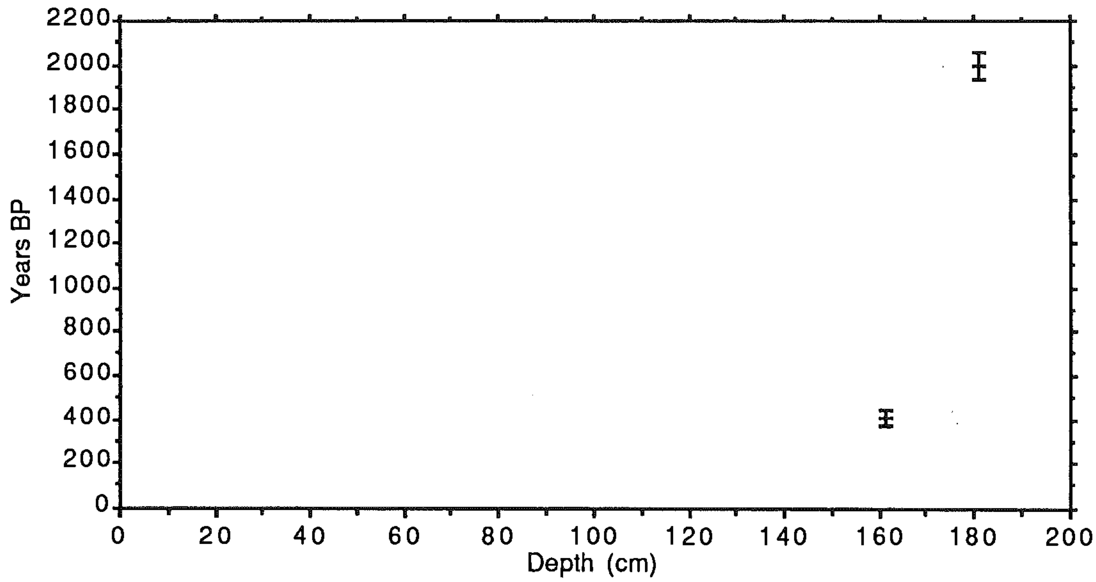

Figure 33 USP radiocarbon dates with one sigma bars plotted by sample depth.

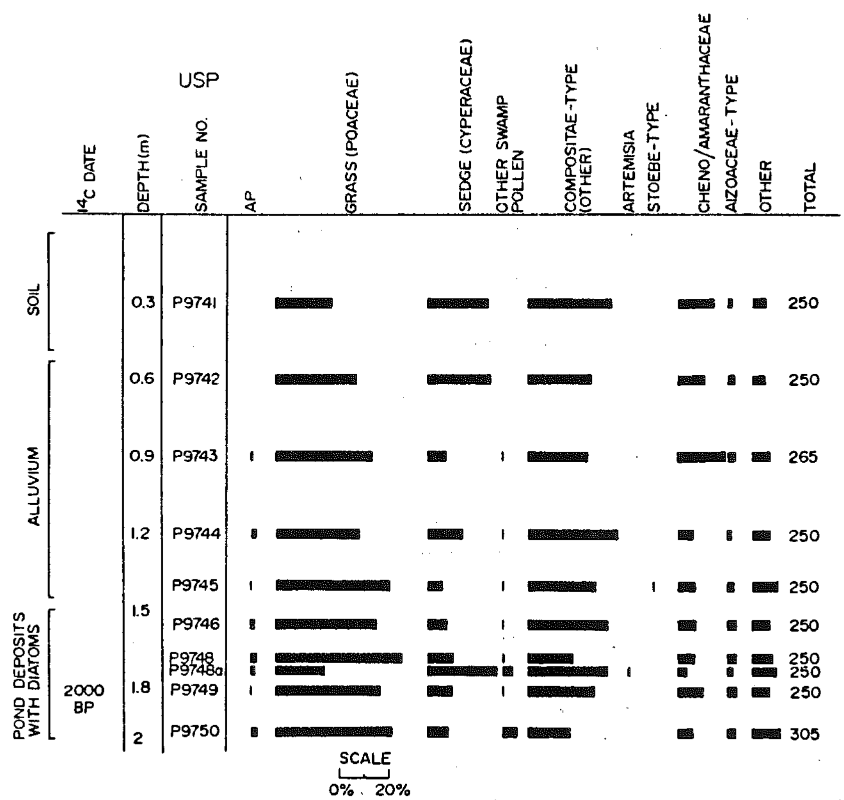

Figure 34 Pollen diagram for USP.

Diatoms show a significant drop in epiphytic species, and increases in aerophilous species as well as alkaliphilous/alkaibiontic species in samples below 9748a which suggest that water depths were dropping (Figure 35). 9748a is a pollen sub-sample, and the diatom sample that corresponds to 9748a was not analyzed. However diatoms samples above this pollen sample show a return to deep water conditions with an increase in euplanktonic species and a dramatic decrease in alkaliphilous/alkaibiontic species. It is important that the greatest frequency of euplanktonic species occurs at the top of the pond. This suggests that deposits representing the final infilling of the pond have been eroded, and this is substantiated by the fact that the overlying alluvial deposits sit unconformably on pond deposits.

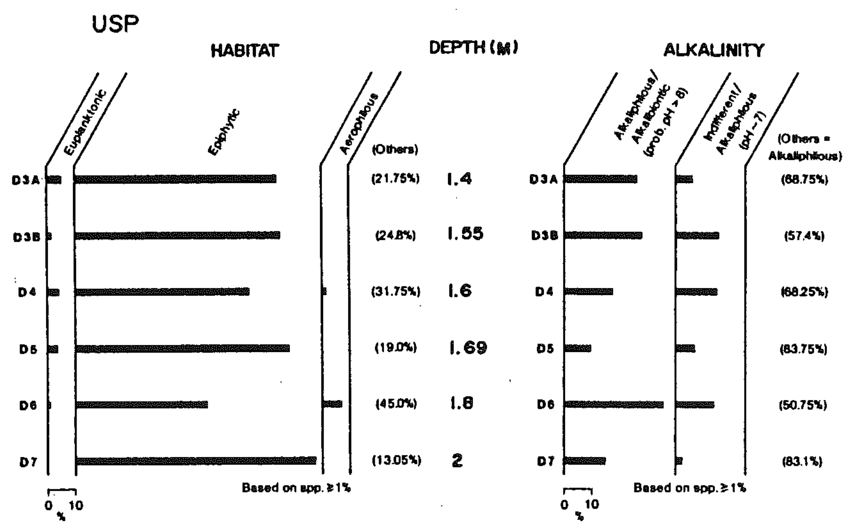

Figure 35 Diatom diagram for USP.

Molluscan samples from the lower portion of the pond deposits (samples SH5 and SH6) are dominated by *Burnupia*, and show deep water conditions (Table 5). The molluscan sample that matches 9748a indicates a major shift to the semi-aquatic *Succinea* which favors marshy conditions, and the terrestrial *Trachycystis* (Seaman, personal communication). SH1-3 demonstrate a return to *Burnupia* dominated samples, and deep water conditions. Thus the diatoms and the molluscs show the pond was deep, then dried to a marsh, and then became a pond again. Cyperaceae is at its greatest relative frequency when the pond dries to a marsh, however in the past palynologists have used Cyperaceae pollen percentages as an indication of relative wetness. At USP, dogmatic adherence to this logic would result in an incorrect climatic and micro-habitat reconstruction.

Table 5.--USP molluscan fauna raw counts (%) by sample

Sample	Burnupia	Pisidium	Lynmaea	Succinea	Trachycystis	Total
SH1	55(93)	0	2(3.5)	2(3.5)	0	59
SH2	26(72)	1(3)	2(6)	1(3)	6(16)	36
SH3	14(52)	6(22)	0	6(22)	1(4)	27
SH4	0	0	0	8(67)	4(33)	12
SH5	98(87)	12(11)	0	1(1)	1(1)	112
SH6	20(63)	2(6)	1(3)	7(22)	2(6)	32
Total	213	21	5	25	14	278

Hughdale Section (HDS)

One geological section documented on the farm of Hughdale in 1987 was discovered by searching aerial photographs and topographic maps for topographic situations similar to that in the lower reaches of Blydefontein Basin, i.e. rock defended alluvial terraces. Hughdale Section displayed a fairly simple alluvial stratigraphy. This section is similar to the section at BFS except that it has more buried soils, lacks infilled stream channels, plus the basement alluvial deposit is dorbank and probably is older than the Older Fills in Blydefontein Basin (see discussion above). Five buried soils were documented in a 6 meter thick alluvial section (Figure 36). The soils are numbered in sequence from top to bottom, and the first (10-30cm), second (80-130cm), third (250-290cm) and fourth (360-375cm) soils were dated by radiocarbon to 840±50 B.P., 2520±60 B.P., 3990±70 B.P. and 4750±100 B.P., respectively. The fifth (505-525cm) soil had too little organic carbon for a radiocarbon assay, but probably dates to the early or middle Holocene. The lowest soil sits unconformably on a firm red loam with yellowish brown and grey mottles. This is dorbank (MacVicar et al. 1977: 126). A similar dorbank deposit occurs on another feeder stream lower in the drainage near the Hughdale farm house. These two dorbank deposits are very similar in texture, structure and weathering, but not necessarily correlated stratigraphically. Nevertheless, the deposit near the farm house has MSA artifacts *in situ*, and it is possible that the Hughdale Section dorbank may be of similar age.

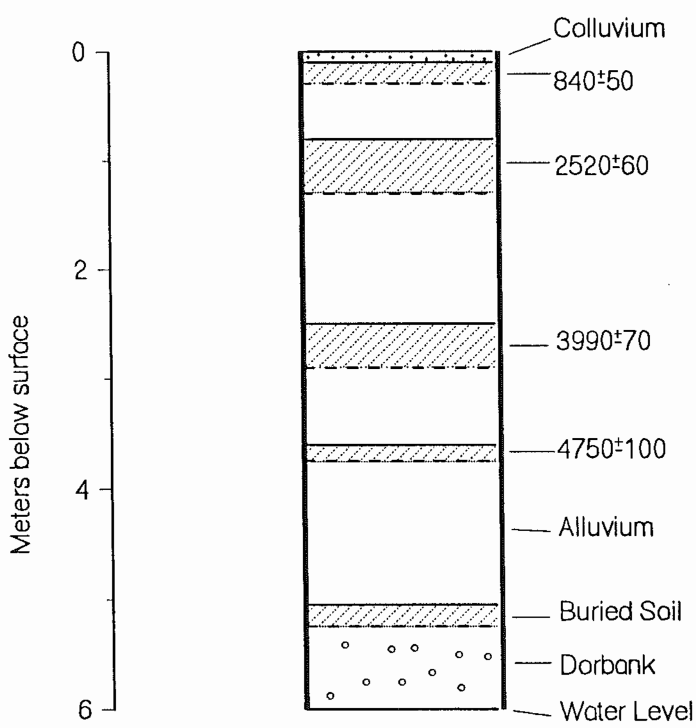

Figure 36. Geological profile from Hughdale Section.

The sequence of buried soils and alluvium represents various episodes of surface stability and deposition. The four radiocarbon dates plotted by age by mean depth below the modern surface in 1987 shows a variable accumulation rate (Figure 37). Nevertheless a linear regression between age and depth adequately models the accumulation rate, and the resulting linear regression ($r^2 = 0.968$) is:

$$\textit{estimated radiocarbon age} = 933.4 + 10.937 \text{ (cm depth)}$$

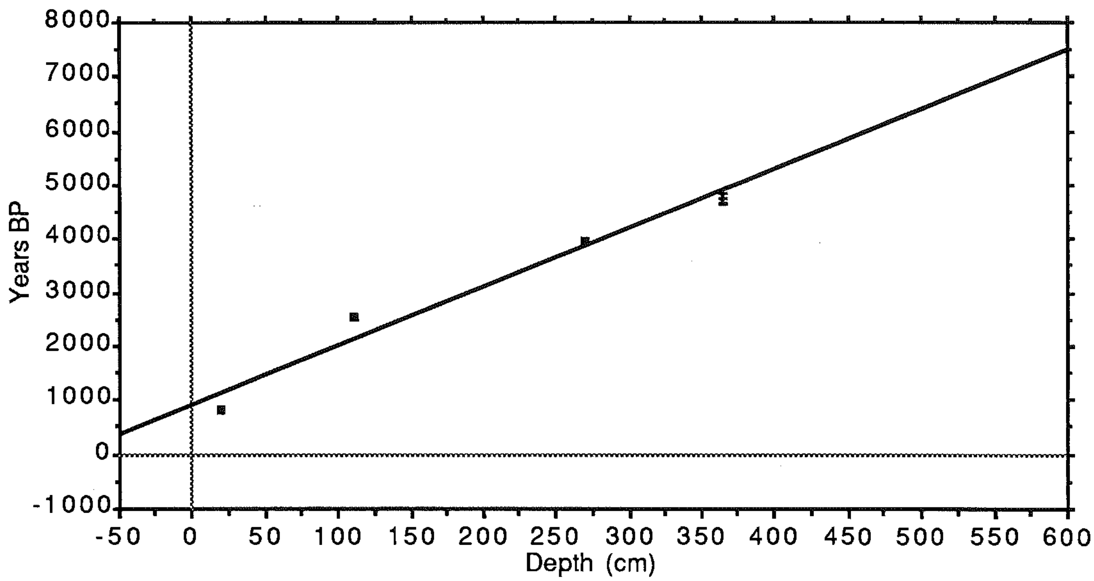

Figure 37. Linear regression of HDS radiocarbon dates with one sigma bars by sample depth.

The pollen sequence from HDS was obtained entirely from the five buried soils and no samples were collected from the intervening alluvium (Figure 38). Pollen frequencies from the uppermost soil are dominated by Compositae, Gramineae, Aizoaceae, Cheno/Ams and *Artemisia*. The second soil is dominated by Gramineae and lacks significant numbers of xeric adapted taxa such as Aizoaceae and Cheno/Ams, but does have moderate amounts of Compositae. The third soil is dominated by Graminaea

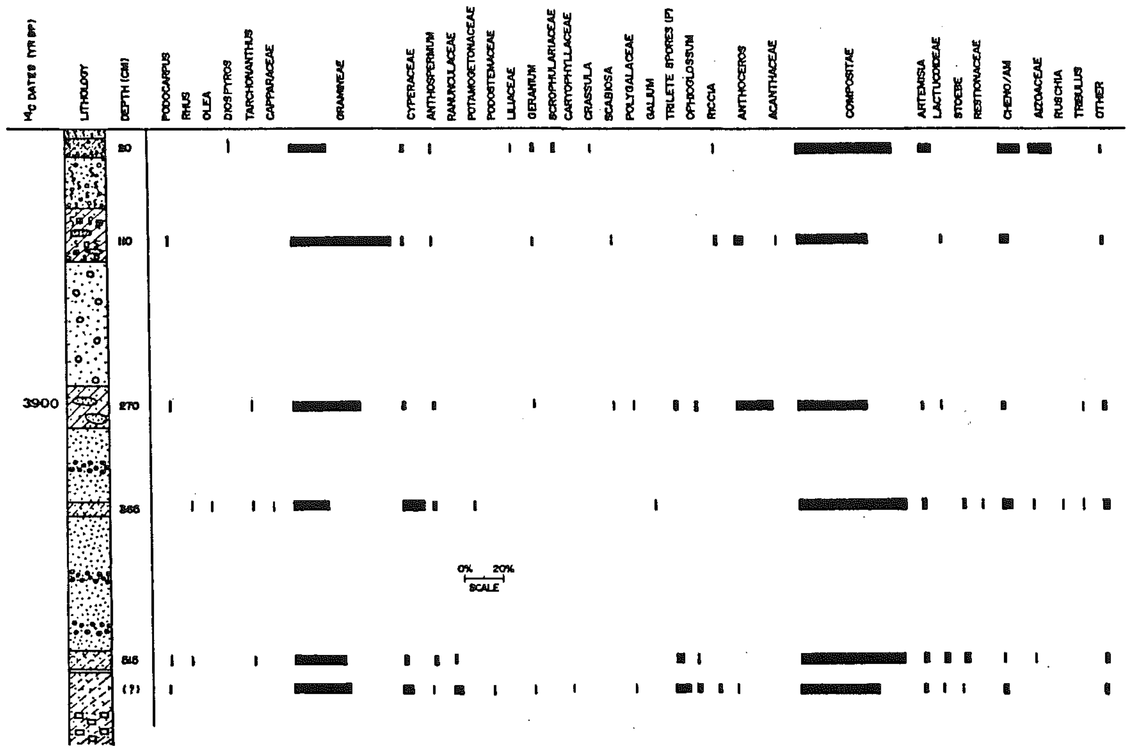

Figure 38 Pollen profile from Hughdale Section.

and *Anthroceros*, and it has the lowest relative frequencies of composits from the entire section. Pollen spectra from the lowest three soils are more similar the the first soil. These soils are dominated by Compositae and other xeric adapted taxa, have low percentages of Gramineae, and have the only occurrence of *Stoebe*-like pollen, which indicates cooler conditions. The lower three soil pollen spectra are similar to the Early Holocene spectra from CH2. If the accumulation rate for the overlying sediments is relevant for the age of the fifth soil at Hughdale, then the regression formula can be used to provide an estimate of 6500-6600 B.P. for this bottom soil. At this point there is no independent way to assess the accuracy of this age estimate, but it is possible that the lower soil at HDS is roughly coeval with the Early Holocene sample from CH2.

Hyrax Dung Middens

Two hyrax (*Procavia*) dung middens were collected from Blydefontein Basin: Meerkat Midden and Oppermanskop Midden (see Figure 1). Hyrax live in colonies among large rocks and overhangs which provide easy escape from predators. Hyrax defecate and urinate in selected spots known as latrines. In these latrines orderly dung and urine piles (middens) accumulate, and chronological samples can be extracted for pollen analysis. Hyrax urine is very concentrated and sticky, and it dries to hard amber-like hyracium which traps and preserves airborne pollen (Scott 1988a). Preliminary analysis of fossil pollen trapped in the dung middens indicates that hyrax diet contributes little if any pollen to the midden, and the majority of pollen extracted from the middens is probably derived from atmospheric pollen rain but dietary additions cannot be excluded completely (Scott and Bousman 1990). The middens appear to be one of the least biased fossil pollen traps known in Africa. The first palynological analysis of a hyrax midden was by Pons and Quezel (1958). They analyzed a midden from the Hoggar Mountains in the Sahara Desert, but thirty years passed since anyone else extracted pollen from a hyrax midden (Scott 1988a). Additionally, macrobotanical rests are found in small numbers in hyrax middens, and this research demonstrates further lines of investigation for hyrax middens (Lindquist and Fall 1987).

Radiocarbon Dates

Five radiocarbon dates from the two hyrax dung middens are available (Table 6). Natural Isotopes Laboratory, DEMAST, CSIR, Pretoria ran four dates, and Professor Paul. S. Martin, University of Arizona, funded the fifth date at Beta Analytic, Inc. All dates are based on the 5568 year half-life, corrected for ^{13}C fractionation, but uncalibrated.

Table 6.--Radiocarbon dates from hyrax middens in Blydefontein Basin

LAB NO.	DATE AND RELATIVE 13C CONTENT	MATERIAL	PROVENIENCE
Pta-5026	200±45 B.P. $\delta^{13}C$= -22.7°/oo	hyrax dung	Meerkat Midden, 15cm bs
Pta-4403	300±35 B.P. $\delta^{13}C$= -?°/oo	hyrax dung	Meerkat Midden, 18-22cm bs
Pta-4571	460±45 B.P. $\delta^{13}C$= -?°/oo	hyrax dung	Oppermanskop Midden, 4.3-7.3cm bs
Pta-5003	1070±50 B.P. $\delta^{13}C$= -23.0°/oo	hyrax dung	Oppermanskop Midden, 8-12cm bs
Beta-14658	1130±80 B.P. $\delta^{13}C$= -?°/oo	hyrax dung	Oppermanskop Midden, 15-18cm bs

Meerkat Midden

Meerkat Midden was found in an overhang adjacent to the Later Stone Age rockshelter, Meerkat Shelter. It is on an east facing valley wall in the lower reaches of the Basin. The midden was 22cm thick and two radiocarbon dates are available. If one assumes that the midden has continued to accumulate at a constant rate until the time of collection (1985) then a linear regression of radiocarbon ages and depth (r^2 = 0.997) can be used to estimate the ages of undated pollen samples (Figure 39) by the formula: *Years B.P.* = 16.5 (depth cm) -37.5

The pollen record from Meerkat Midden suggests that in the last 300 years Gramineae, Cyperaceae and Ranunculaceae pollens have declined, while Compositae and Cheno/Am pollen have increased, especially in the last two samples (Figure 40).

Oppermanskop Midden

Oppermanskop Midden was located in a small rockshelter in a very narrow and steep ravine on the north facing slope of the Kikvorsberg. Oppermanskop Midden was

18cm thick, and three radiocarbon dates were obtained: 1130±80 B.P. (15-18cm), 1070±50 B.P. (8-12cm), 460±45 B.P. (4.3-7.3cm). It appears that the midden

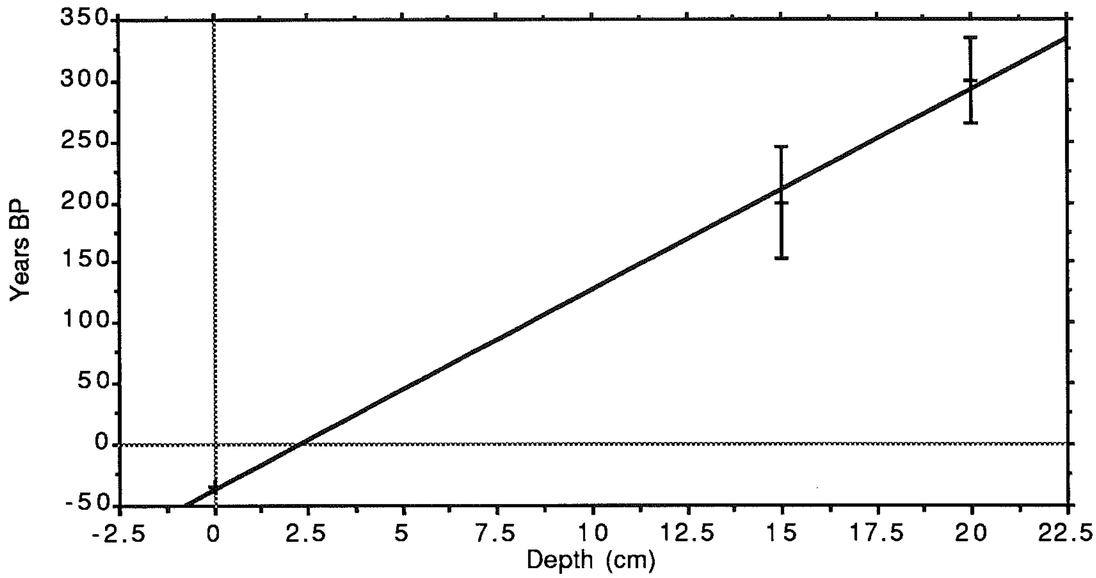

Figure 39 Linear regression Meerkat hyrax midden radiocarbon dates with one sigma bars plotted by sample depth.

accumulated at varying rates (Figure 41), and it is very likely that the midden was a secondary accumulation that flowed off of a primary latrine area. A curvilinear regression can be used to estimate the ages of undated pollen samples. The formula is:

$$\textit{Years B.P.} = -74.549 + 140.714\ x - 3.984\ x^2$$

The Oppermanskop Midden has a Gramineae peak in the oldest sample at ca. 1200 B.P. (Figure 42). Gramineae declines sharply and Compositae and Scrophulariaceae increase equally at 17 and 14cm (ca. 1000-900 B.P.). The Gramineae increases again and remain dominate until the upper 5cm when Compositae, *Euclea*, *Rhus*, Cheno/Am and Scrophulariaceae increase. This last grass decline in the Oppermanskop Midden is roughly coeval with the Meerkat Midden grass decline at ca. 300 B.P.

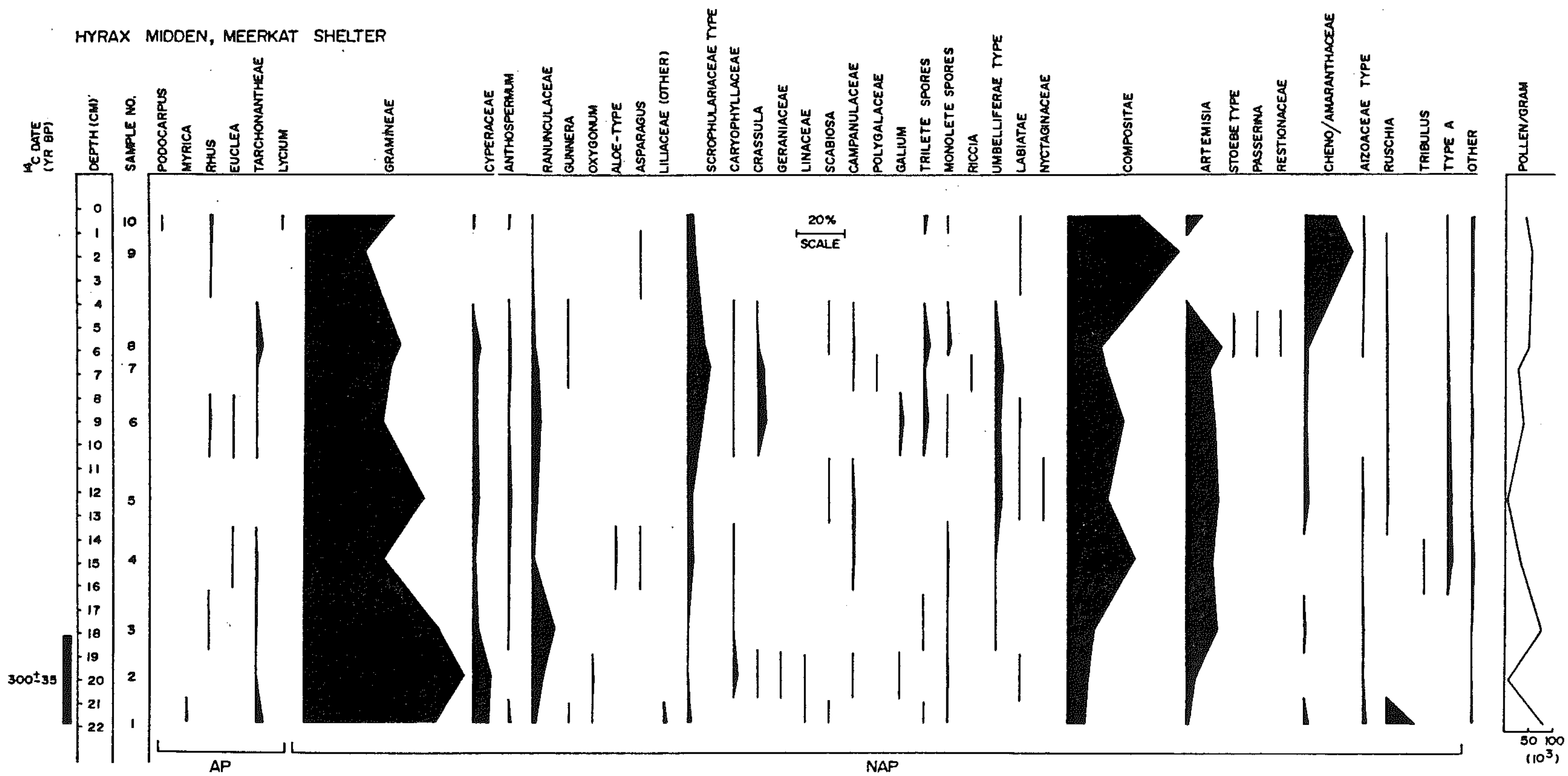

Figure 40. Pollen diagram for Meerkat hyrax dung midden.

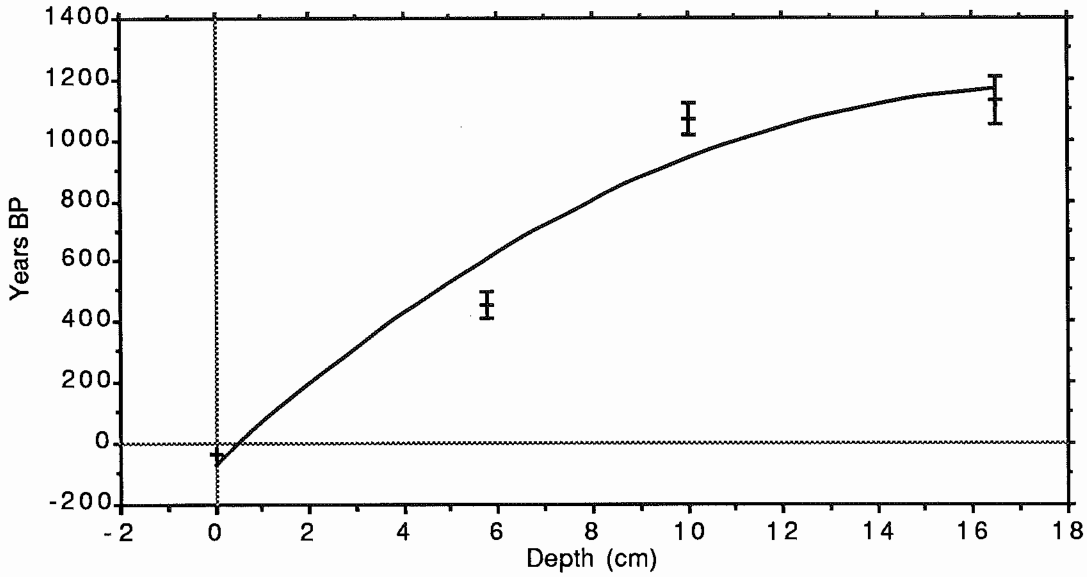

Figure 41 Curvilinear regression Oppermanskop hyrax midden radiocarbon dates with one sigma bars plotted by sample depth.

Pollen Analysis

The pollen data used in the following analysis were collected and analyzed by Dr. Louis Scott, who very generously has made available all the raw pollen data on which the following analysis is based.

Preliminary Manipulations of the Pollen Samples

If pollen production, dispersion, deposition, and preservation was equal for all plants, then pollen relative frequencies could be plugged directly into the climatic formulae (Chapter IV) to predict temperature and rainfall parameters for each pollen sample. However, it is well known that pollen taphonomy is complex, and direct pollen relative frequencies cannot be used. A first step toward investigating pollen taphonomy is to document the different atmospheric pollen rain of the taxa in question. This controls for differential production and dispersion, but not deposition and preservation.

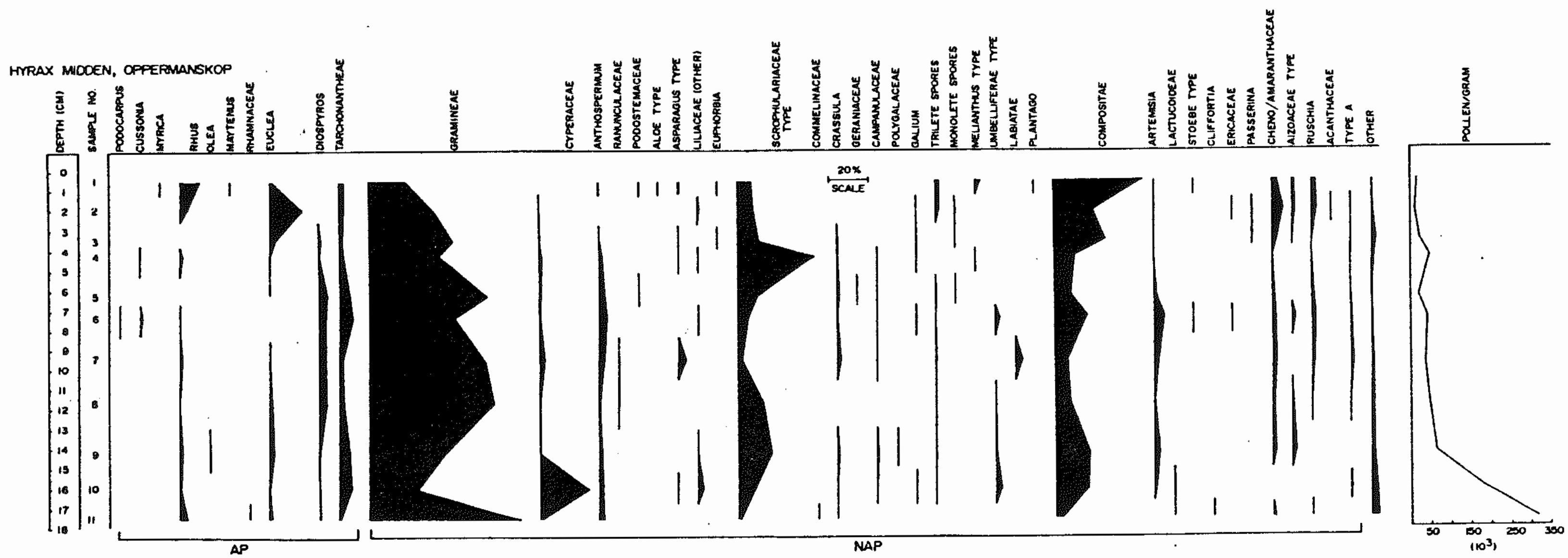

Figure 42. Pollen diagram for Oppermanskop hyrax dung midden.

It has long been known that the number of pollen grains in a sample does not correctly reflect the numerical representation of individual plants or plant cover (Erdtman 1943; von Post 1918). In southern Africa some plants produce great amounts of pollen that are widely dispersed by wind, while others produce very small amounts that are transported by insects and their distributions are limited (Rebelo 1987). Correction coefficients or R values of Davis (1963) were one of the first strategies palynologists devised to help correct taphonomic biases due to differences in pollen production and dispersal among various taxa.

At present only a small number of modern surface pollen samples have been collected from the research area. These data are insufficient to estimate the effects of differential pollen production, transportation and preservation for all taxa, but preliminary assessments of Gramineae, Compositae, Cheno/Am and Aizoaceae pollen are possible. These four taxa always equal over 50 percent, and usually much more, of any single fossil pollen sample from the Kikvorsberg and, unless stated otherwise, the following analysis is restricted to these taxa. More information is needed on pollen production, and many more modern plant communities are in need of quantitative survey. Also significant temporal gaps exist in the fossil pollen record from the Kikvorsberg, and only more research can bridge these gaps.

Coetzee (1967: 116) presents relative frequencies of pollen rain from the plant communities at Middelburg, C.P. collected in 1952 and 1953 (Table 7). Fortunately, a number of the modern botanical surveys were conducted at Middelburg from the late 1940s through the 1960s so a rough match between pollen rain and plant composition is possible. These calculations use the available data which were not collected for the objective to which they are now used. In a properly designed study of modern pollen rain and vegetational correlates, multiple modern botanical surveys and matching surface pollen samples should be collected. In this way more statistically rigorous and accurate estimates can be derived that avoid many of the pitfall of R-values (Birks and Gordon 1985: 182-204). Nevertheless, with the data at hand, only correction coefficients can be calculated, and these should be considered preliminary. Relative frequencies from all the Middelburg modern botanical surveys were averaged and compared to the average pollen rain data, and then correction coefficients estimated (Table 7). The calculation is straightforward for each taxa:

correction coefficient = mean botanical survey % ÷ pollen rain %.

These correction coefficients can be used to adjust each taxon's palynological relative frequency to estimate its composition in the veld. Unfortunately pollen rain data for only four taxa were published. However, these are the dominant taxa in all pollen samples. Pollen samples are "corrected" by multiplying a fossil pollen sample's transformed relative frequencies by the appropriate correction coefficients.

Table 7.--Middelburg pollen rain relative frequencies from Coetzee(1967), Middelburg plant community composition(Roux and Blom 1979) and correction coefficients

	Taxa (relative frequencies)			
Sample	Gramineae	Compositae	Cheno/Am	Aizoaceae
Middelburg plant surveys	71.23%	16.81%	1.41%	6.53%
Middelburg pollen rain	70.65%	12.41%	2.25%	3.90%
Correction Coefficients	1.008	1.354	0.627	1.674

One criticism of this approach is that it uses modern plant relative frequencies without regard for distortion by overgrazing and veld mismanagement by European farmers. However it has been argued above (see Chapter IV) that what has been presumed to be vegetation change due only to overgrazing may also be due to climatic change.

Recently Fall (1987) has shown that different environments of deposition can also bias alluvial pollen records, however preliminary assessment of the Blydefontein and Hughdale pollen samples does not reveal strong patterns in pollen relative frequencies corresponding to depositional environment. However, biases introduced by differential deposition and preservation cannot be fully assessed with the data at hand, and should be the focus of future research.

Finally, the Roux-Blom surveys did not sample marsh or riverine plant communities, and a comparison with the pollen samples requires that pollen types restricted to these environments be omitted from the relative frequency calculations in the fossil pollen samples. Relative frequencies of fossil pollen samples minus marsh pollen (i.e. Cyperaceae, *Typha*, *Gunnera*, Monolete and Trilete spores) are called marsh-adjusted samples in this study.

Palynology of the Older Fills and Younger Fills

In this comparison the pollen frequencies are marsh-adjusted but not corrected because certain taxa do not have pollen rain correction coefficients. In most pollen samples the Compositae/Gramineae ratio is the most clear cut relationship, however a comparison of Younger Fills and Older Fills pollen provides evidence that a major difference exists between the plant communities that grew during the accumulation of both sedimentary units. It was also discovered that *Artemisia* had a linear relationship with Gramineae in the Older Fills at BFS, but not in the Younger Fills (Figure 43). In both cases grasses are represented by the x-axis and composites and *Artemisia* are on the y-axis. The linear relationships are ecological relationships and do not represent temporal sequences. The composite/grass differences are clearly illustrated by a comparison of the regression slopes between Older and Younger Fills at BFS (Table 8). These regression statistics are presented for descriptive purposes and they are not intended for predictive purposes in a statistical sense.

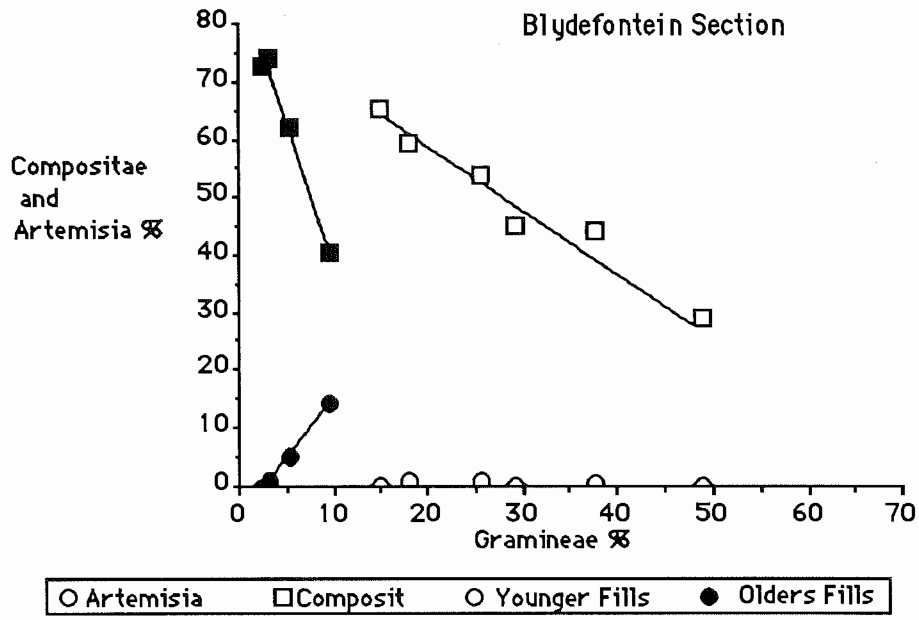

Figure 43 Graph of Gramineae versus Compositae and Artemisia relative frequencies in the Older and Younger Fills at BFS.

Table 8.--Comparison of Compositae/Gramineae and *Artemisia*/Gramineae linear regression slopes, intercepts and correlation coefficients between Younger and Older Fills at BFS

Sedimentary Unit	Taxa	Slope	Intercept
Younger Fills	Comp/Grass	-1.000	78.322
	Artem/Grass	-0.011	0.717
Older Fills	Comp/Grass	-4.864	86.984
	Artem/Grass	2.054	-5.336

Grass relative frequencies in the Older Fills are never very high, but much higher in the Younger Fills. The Younger Fills composite/grass regression slope of -1.0 is similar to the regression slope of the eastern Karoo group (-0.724) from the

Roux-Blom botanical surveys presented in Chapter IV. However it is clear that the composite/grass regression slope for the Older Fills (-4.864) is much steeper than the regression slope for the Younger Fills or eastern Karoo group. Also the regression slopes for the Older Fills and the western Karoo group (-0.494) diverge in opposite directions from the Younger Fills and eastern Karoo regression slopes. This suggests that the eastern Karoo plant communities and the plant communities from the Younger Fills at BFS may share similar distributional relationships among Compositae and Gramineae taxa, but that the plant communities reflected by the Older Fills pollen spectra have no modern counterparts sampled by the Roux and Blom botanical surveys.

The *Artemisia*/Gramineae patterns also highlight the differences between the Older Fills and the Younger Fills. A strong positive linear correlation is present between *Artemisia* and Gramineae in the Older Fills at BFS ($r^2 = 0.999$), but not in the Younger Fills ($r^2 = 0.095$). These correlation coefficients and graphs support the thesis that the herbaceous and grass components in plant communities that grew in the Basin during the accumulation of the Older Fills are different in terms of spatial distributions and ecological structure from those in the Younger Fills. In addition, *Artemisia* only occurs in two of the modern botanical surveys, and a correlation coefficient between *Artemisia* and Gramineae indicates a lack of correlation in the modern botanical surveys ($r^2 = 0.007$). The Older Fills pollen spectra are not similar to any modern plant community sampled by Roux and Blom (1979), and possibly distinct from any modern plant community extant in southern Africa today.

The high composite percentages in Older Fills suggests dry conditions, and high *Artemisia*, *Passerina* and *Elytropappus/Stoebe* relative frequencies suggest cool conditions. The most similar modern plant community is probably some form of Alpine Fynbos present in high elevations in the Drakensberg, but for which no quantitative modern botanical survey was available. Similar conditions are known at

7790 B.P. from Channel 2 where pollen sample no.9663 has high composite, low grass, low *Artemisia*, high *Elytropappus/Stoebe*, and high Aizoaceae percentages. This probably still represents a dry climate, but the high Aizoaceae relative frequencies suggests that it occurred when conditions were warmer than during the accumulation of the Older Fills sediments. This Early Holocene sample may date to a transitional period when the plant communities were switching from some type of Alpine Fynbos to Karoo/Grassland community. Coarser sediments in the Older Fills suggests that greater erosive energies or a less effective vegetation mat existed during their accumulation as opposed to the Younger Fills (Partridge, personal communication). Some sort of Alpine Fynbos would be a less effective vegetation cover when compared to the grassy karroid plant communities present in the post 8000 B.P. sediments.

In order to assess the hypothesis that the plant communities of the Holocene are represented by the modern botanical surveys, composite/grass ratios for all Blydefontein Basin fossil pollen samples dating within the last 8000 years have been plotted (Figure 44), and linear regressions calculated. The regression slope of the post 8000 B.P. pollen spectra is -0.915 (r^2 = 0.743), which compares even more favorably to the eastern Karoo regression slope of -0.724. These data suggest that the modern biota was established by approximately 7-8000 B.P. in Blydefontein Basin, but distinctly different plant communities were present in the Late Pleistocene.

The Test Results

A comparison between the plant communities defined by the cluster analysis of the Roux-Blom botanical surveys and the post 8000 B.P. pollen samples is possible with marsh-adjusted and corrected pollen samples used in Figure 44. The discriminant functions used to assess the accuracy of the cluster analysis of the Roux-Blom

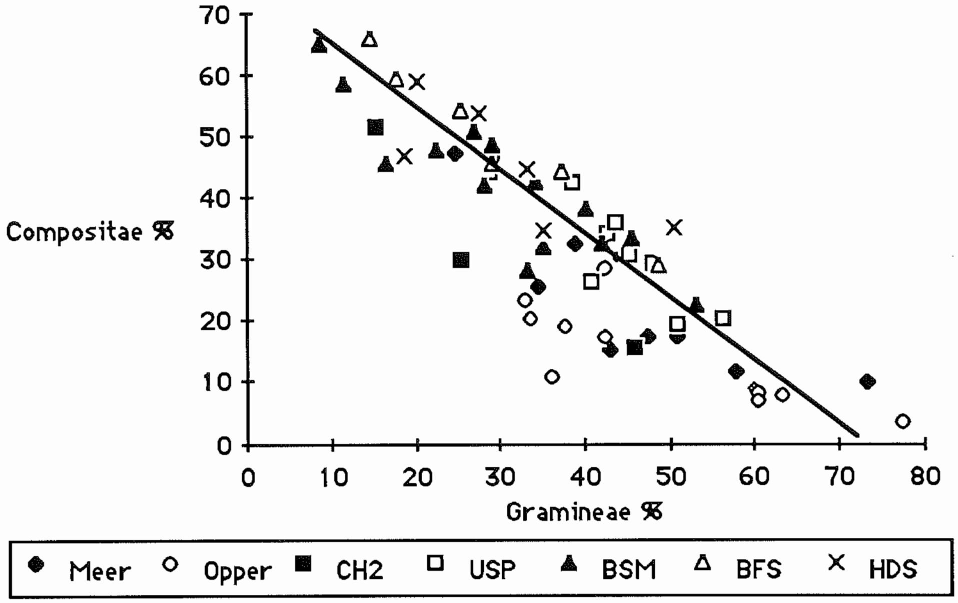

Figure 44. Graph of composite/grass relative frequencies for all Holocene pollen spectra.

botanical surveys in Chapter IV, were saved and then used to classify the transformed and corrected pollen samples from Blydefontein Basin (Table 9). The procedure assigned pollen samples to the newly defined plant communities. A similar study west in the Nuweveldberg used modern pollen rain samples grouped by Acocks' Veld Types assigned fossil pollen samples to Veld Types with multiple discriminant analysis (Sugden and Meadows 1989). Unfortunately in this study the modern pollen rain samples were not submitted to a cluster analysis first so the homogeneity of the groups could be assessed with discriminant analysis.

The totals indicate that only five of eight modern plant communities defined by cluster analysis can be identified in the last 7900 years. The Meerkat 10 sample can be considered as modern, and it was classified as Grassy Lower Karoo. The Aizoaceae Lower Karoo, Central Grass Veld, and High Grass Veld do not occur.

Table 9.-- Discriminant analysis canonical scores for transformed and corrected pollen samples, samples arranged in chronological order from younger to older

Site & Sample		Aizoa. Lower Karoo	Grassy Lower Karoo	Composite Upper Karoo	Typical Upper Karoo	Grassy Upper Karoo	Low Grass Veld	Central Grass Veld	High Grass Veld
BFS	9740	0.00	0.14	0.06	0.79	0.00	0.00	0.00	0.00
BFS	9606	0.00	0.00	0.90	0.10	0.00	0.00	0.00	0.00
BFS	9777	0.00	0.17	0.00	0.23	0.60	0.00	0.00	0.00
BFS	9739	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
BFS	9605	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
BFS	9738	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
BSM	9754	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BSM	9755	0.00	0.00	0.19	0.81	0.00	0.00	0.00	0.00
BSM	9756	0.00	0.20	0.10	0.70	0.00	0.00	0.00	0.00
BSM	9757	0.00	0.71	0.00	0.29	0.00	0.00	0.00	0.00
BSM	9758	0.00	0.99	0.00	0.01	0.00	0.00	0.00	0.00
BSM	9759	0.00	0.07	0.90	0.03	0.00	0.00	0.00	0.00
BSM	9760	0.00	0.03	0.00	0.97	0.00	0.00	0.00	0.00
BSM	9761	0.00	0.49	0.06	0.45	0.00	0.00	0.00	0.00
BSM	9763	0.00	0.06	0.00	0.80	0.13	0.00	0.00	0.00
BSM	10430	0.00	0.08	0.01	0.91	0.00	0.00	0.00	0.00
BSM	10434	0.00	0.00	0.35	0.65	0.00	0.00	0.00	0.00
BSM	10438	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
BSM	10444	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
BSM	10449	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
BSM	10456	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
CH2	9751	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
CH2	9753	0.00	0.60	0.00	0.00	0.39	0.00	0.00	0.00
CH2	9663	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
USP	9741	0.00	0.55	0.03	0.42	0.00	0.00	0.00	0.00
USP	9742	0.00	0.76	0.00	0.24	0.00	0.00	0.00	0.00
USP	9743	0.00	0.99	0.00	0.01	0.00	0.00	0.00	0.00
USP	9744	0.00	0.01	0.00	0.99	0.00	0.00	0.00	0.00
USP	9745	0.00	0.44	0.00	0.33	0.23	0.00	0.00	0.00
USP	9746	0.00	0.18	0.00	0.82	0.00	0.00	0.00	0.00
USP	9748	0.00	0.03	0.00	0.00	0.97	0.00	0.00	0.00
USP	9748a	0.00	0.01	0.11	0.87	0.00	0.00	0.00	0.00
USP	9749	0.00	0.81	0.00	0.19	0.01	0.00	0.00	0.00
USP	9750	0.00	0.22	0.00	0.00	0.78	0.00	0.00	0.00

Table 9—Continued.

Site & Sample	Aizoa. Lower Karoo	Grassy Lower Karoo	Composite Upper Karoo	Typical Upper Karoo	Grassy Upper Karoo	Low Grass Veld	Central Grass Veld	High Grass Veld
HDS 10419	0.01	0.00	0.99	0.00	0.00	0.00	0.00	0.00
HDS 10420	0.00	0.00	0.00	0.99	0.01	0.00	0.00	0.00
HDS 10421	0.00	0.00	0.01	0.99	0.00	0.00	0.00	0.00
HDS 10422	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
HDS 10423	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
HDS 9781	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00
OPPER 1	0.00	0.01	<u>0.95</u>	0.04	0.00	0.00	0.00	0.00
OPPER 2	0.00	<u>1.00</u>	0.00	0.00	0.00	0.00	0.00	0.00
OPPER 3	0.00	<u>0.34</u>	0.00	0.33	0.33	0.00	0.00	0.00
OPPER 4	0.00	<u>0.85</u>	0.00	0.00	0.15	0.00	0.00	0.00
OPPER 5	0.00	0.00	0.00	0.00	<u>0.99</u>	0.01	0.00	0.00
OPPER 6	0.00	<u>0.80</u>	0.00	0.00	0.20	0.00	0.00	0.00
OPPER 7	0.00	0.00	0.00	0.00	<u>0.99</u>	0.01	0.00	0.00
OPPER 8	0.00	0.00	0.00	0.00	<u>0.94</u>	0.06	0.00	0.00
OPPER 9	0.00	<u>0.93</u>	0.00	0.01	0.06	0.00	0.00	0.00
OPPER 10	0.00	<u>0.91</u>	0.00	0.04	0.04	0.00	0.00	0.00
OPPER 11	0.00	0.00	0.00	0.00	0.00	<u>0.66</u>	0.33	0.01
MEERK10	0.00	<u>0.75</u>	0.00	0.25	0.00	0.00	0.00	0.00
MEERK 9	0.01	<u>0.46</u>	0.19	0.35	0.00	0.00	0.00	0.00
MEERK 8	0.00	0.22	0.00	0.00	<u>0.78</u>	0.00	0.00	0.00
MEERK 7	0.00	0.01	0.00	0.00	<u>0.99</u>	0.00	0.00	0.00
MEERK 6	0.00	<u>0.91</u>	0.00	0.07	0.02	0.00	0.00	0.00
MEERK 5	0.00	0.00	0.00	0.00	<u>1.00</u>	0.00	0.00	0.00
MEERK 4	0.00	0.03	0.00	0.18	<u>0.79</u>	0.00	0.00	0.00
MEERK 3	0.00	0.00	0.00	0.00	<u>1.00</u>	0.00	0.00	0.00
MEERK 2	0.00	0.00	0.00	0.00	0.02	<u>0.89</u>	0.09	0.00
MEERK 1	0.00	0.20	0.00	0.00	<u>0.79</u>	0.00	0.00	0.00
TOTALS	0	19	10	11	13	2	0	0

Each site provides a sequence of alternating plant communities. The classifications have been arranged chronologically in Figure 45. In Figure 45 samples with good chronological control have horizontal lines marking shifts from one plant community to another, otherwise classifications are plotted in their approximate chronological position.

BSM begins with Composite Upper Karoo in the lower four samples, and then shifts to Typical Upper Karoo. It briefly changes to Grassy Lower Karoo, and then to Typical Upper Karoo. This is followed by a shift to Composite Upper Karoo which drops to Grassy Lower Karoo and then shifts back to Typical Upper Karoo and the sequence ends with a Grassy Upper Karoo plant community. Channel 2 only has Grassy Lower Karoo communities. Blydefontein Section (BFS) begins with a Typical Upper Karoo community that shifts to Composite Upper Karoo, then to Grassy Lower Karoo which is followed by a shift back to Typical Upper Karoo and the sequence ends with a Grassy Upper Karoo plant community. Upper Section Pond (USP) begins with a Grassy Upper Karoo plant community which shifts to Grassy Lower Karoo and is followed by Typical Upper Karoo, then Grassy Upper Karoo back down to Typical Upper Karoo that drops to Grassy Lower Karoo then back to Typical Upper Karoo and ending with a Grassy Upper Karoo plant community. Hughdale Section (HDS) begins at approximately 7900 B.P. with Central Lower Karoo. This community is present once more at approximately 5500 B.P., but by 4000 B.P. a Typical Upper Karoo community is established, and it is again present at about 2500 B.P. The last sample at HDS is roughly 500 B.P. in age, and a Central Lower Karoo community is present. Oppermanskop Hyrax Midden (OPPER) begins with the extremely grassy Low Grassveld, and this is followed by several cycles between Grassy Lower Karoo and Grassy Upper Karoo plant communities. The beginning plant community in Meerkat Hyrax Midden (MEERK) is Grassy Upper Karoo which changes to Low Grassveld, and is followed by several cycles between Grassy Upper Karoo and Grassy Lower Karoo.

The modern plant community, as identified in the final pollen sample in Meerkat Midden, is Grassy Lower Karoo. These comparisons, agree with the predictions of the botanical model presented in Chapter IV, and also with the general discussion on Older and Younger Fills pollen spectra. Clearly, vegetation has not remained stable for long

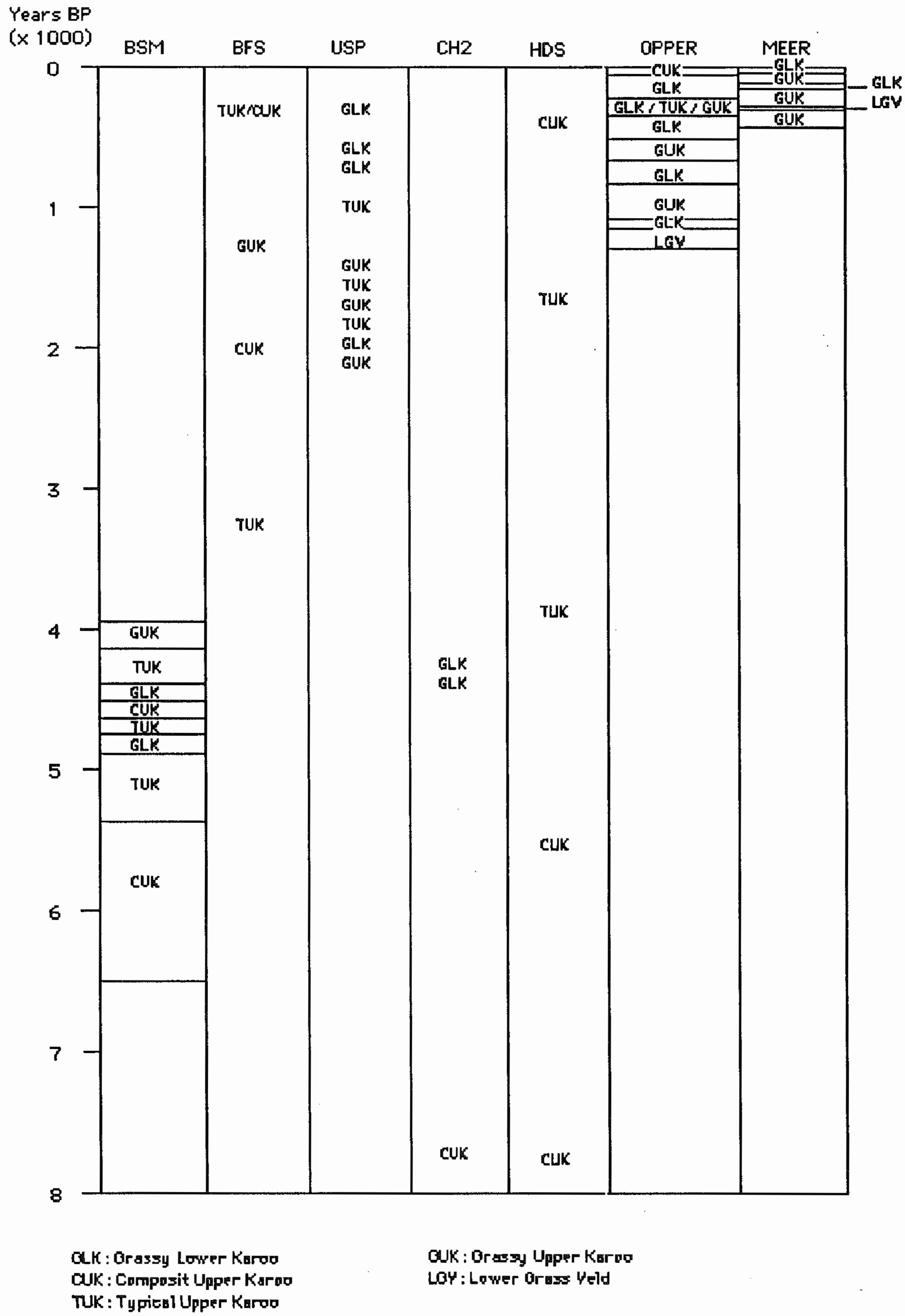

Figure 45. Temporal distribution of paleo-plant communities at geological sites and hyrax middens.

periods of time in the Holocene. Also important to the assessment of plant communities is the length of time represented by a pollen sample. Pollen spectra from the Meerkat Midden demonstrate that significant changes can take place over very short periods. Apparently, then, the time span represented by an individual sample can affect the relative frequencies in the sample, and thus the mix of plant communities represented by the sample.

CHAPTER VI

STABLE CARBON ISOTOPE ANALYSIS

The use of the stable carbon isotopes ^{13}C and ^{12}C for correcting radiocarbon dates is well known, but for the last 13 years these isotopes have served as analytical tools for a variety of purposes in archaeology (van der Merwe 1982; van der Merwe and Vogel 1983). Vogel and van der Merwe (1977) pioneered the use of stable isotopes in archaeology for deciphering prehistoric diets. Other analyzed materials include inorganic and organic fractions of bone, plant material, pedogenic calcium carbonate, speleothems, soil humates, snail shells and even ostrich eggshell. While many African applications in archaeology still focus on prehistoric human diets (Ambrose and DeNiro 1986; Rightmire and van der Merwe 1976; Sealy 1986 and 1989), analysis of $^{13}C/^{12}C$ ratios promises to provide important information on past environments (Heaton 1987; Heaton et al. 1986; Stuiver 1975; Vogel 1983; von Schirnding et al. 1982). The application discussed here involves an analysis of ^{13}C and ^{12}C ratios from bulk radiocarbon humate samples with matching pollen samples and from ostrich eggshell in Blydefontein Rockshelter.

Principles and Techniques

Before a discussion of the present applications can proceed, however, both the technique and the occurrence of carbon isotopes in the natural environment of southern Africa is required. ^{12}C and ^{13}C are stable isotopes that do not decompose into other elements (as does ^{14}C). ^{12}C and ^{13}C occur in relatively constant amounts on earth, and the ratio is approximately 100 to 1.1, respectively (van der Merwe and Vogel 1983). However, the ratio varies slightly between materials, or from environment to environment depending on a variety of factors discussed below. The measurement of ^{12}C and ^{13}C represents the ratio of $^{13}C/^{12}C$ in the sample as compared to the ratio of these isotopes in a piece of marine limestone, known as the PDB standard. The ratio, written as $\delta^{13}C$, is measured in parts per mil (expressed as °/oo). The PDB standard has a very high amount of ^{13}C and as its ratio of $^{13}C/^{12}C$ is set arbitrary at zero, most terrestrial $\delta^{13}C$ measurements register as negative values. Increased amounts of ^{13}C in a sample cause a $\delta^{13}C$ value to become less negative. The formula for calculating $\delta^{13}C$ values is:

$$\delta\,^{13}C = \left[\frac{(^{13}C/^{12}C)_{sample}}{(^{13}C/^{12}C)_{standard}} - 1\right] \times 1000$$

As ^{12}C and ^{13}C have different atomic weights, they react differently in chemical and physical reactions such as photosynthesis (ibid). This is because lighter isotopes have higher vibrational frequencies, form weaker bonds, and are more reactive in chemical processes than heavier isotopes (Faure 1986). The differential use of these two isotopes in chemical reactions cause the ratios of the isotopes to change, and this is known as isotopic fractionation. It is now well known that photosynthesis causes the most significant fractionation of stable carbon isotopes.

Photosynthesis uses carbon atoms from the atmosphere, and the unpolluted atmospheric $\delta^{13}C$ value is approximately -7.0 °/oo (van der Merwe and Vogel 1983). Photosynthesis begins at this fractionation starting point. Three forms of photosynthesis are identified in plants. These three photosynthesis types or pathways are known as C_3, C_4, and CAM, and each fractionates carbon isotopes to produce its own characteristic average $\delta^{13}C$ (Mooney et al. 1977; Vogel et al. 1978).

Natural Occurrences of Stable Carbon Isotopes

C_3 plants, which include all trees, most shrubs, and a number of grasses that have adapted to temperate or shaded conditions, strongly fractionate carbon isotopes in favor of ^{12}C, and have an mean $\delta^{13}C$ value of -26.5 $^{o}/oo$ (Vogel et al. 1978). C_4 plants are more efficient at using ^{13}C than C_3 plants, and the mean $\delta^{13}C$ value of C_4 plants is much higher, -12.5 $^{o}/oo$, than C_3 plants (ibid). C_4 plants include a wide variety of grasses, but also species in the Cyperaceae, Chenopodiaceae, Aizoaceae and Amaranthaceae. C_4 plants are normally those adapted to hot and arid conditions. CAM species are plants that can switch from a C_4 to a C_3 pathway as the environmental conditions allow. Most CAM plants are succulents, and the mean $\delta^{13}C$ is -16.5 $^{o}/oo$. CAM plants can confuse the dichotomous signal between C_3/C_4 plants, but normally CAM plants do not occur in great enough numbers in this portion of southern Africa to be a serious problem.

Vogel (1978), Vogel et al. (1978), and Ellis et al. (1980) have mapped the distribution of C_3/C_4 grasses in southern Africa, and the grass communities in the Kikvorsberg are dominated by over 90 percent C_3 grasses, while the surrounding Karoo plains is dominated by over 90 percent C_4 grasses. Thus a clear C_3/C_4 dichotomy exists today in the grass species in and near Blydefontein Basin, which should be translated to unambiguous $\delta^{13}C$ measurements if a fossil collector can be found.

Stable Carbon Isotopes in Soil

Haas et al. (1986) submit that the $\delta^{13}C$ from bulk soil humate radiocarbon samples can be used to infer C_3-C_4 botanic changes. Dr. John Vogel measured $\delta^{13}C$ from Blydefontein Basin's geological radiocarbon humate samples and these samples are used below. A comparison of grass pollen relative frequency, and $\delta^{13}C$

measurements for matched humate and pollen samples is an improvement on using only humate $\delta^{13}C$, as discussed for Lubbock Lake (ibid).

However some problems do exist. The first concern is the addition of new carbon through illuviation. In radiocarbon dating this tends to make radiocarbon dates too young, so that the resulting age is generally believed to represent the mean residence time (MRT) of the deposit (Taylor 1987). It seems reasonable to expect that stable isotopes may also reflect MRT averages, but analysis by Hillaire-Marcel et al. (1989) suggest that MRT problems are limited for aquatic depositional environments such as lakes and ponds, although this is not necessarily the case for buried soils. Future research should address this problem directly. As long as each sample is independently dated by radiocarbon, the major issue is how much time span is represented in a single $\delta^{13}C$ value and how much bias is created by looking at samples representing greatly varying time spans. A second consideration is an apparent fractionation of carbon isotopes in sediments. This fractionation process is believed to be the result of microbial decomposition in sediments and soils, and estimates of the effect range from +3°/oo to +4°/oo (Dzurec et al. 1985; Natelhoffer and Fry 1988), and I have accepted the fractionation effect at +3°/oo with the realization that fractionation in sediments may not be consistent. The third problem is one of equality of catchments between isotopes and pollen. In other words it is assumed in the following analysis that the source areas (and source plants) for pollen and isotopes are equal. Intuitively this assumption is difficult to accept, nevertheless on a general level the differences may not be significant. It is important in this analysis to include pollen percentages based on all pollen, including marsh pollen, and the following analysis does this. Finally one radiocarbon age estimate from BSM does not have matching pollen sample (Pta-4947), and it has not been used in the following comparisons.

Blydefontein Soil $\delta^{13}C$ and Pollen Spectra Compared

Starting with the oldest date and working up through time in Figure 46, at 7790 B.P. the grass pollen percent and the associated $\delta^{13}C$ value are both very low. No matter how much or how little the stable carbon isotope ratios have been fractionated due to microbial decomposition, a complete or almost complete C_3 plant environment, including grasses, must have existed at this time. The slopes of the two lines leading to 5080 B.P. both increase. The pollen spectra indicate that the major change is a large increase in grasses, and significant decreases in C_3 Compositae and *Stoebe*-type pollen (either *Stoebe* spp. or *Elytropappus* sp.). This implies that C_4 grass species increased between 7790 B.P. and 5080 B.P., otherwise the younger $\delta^{13}C$ value would have remained the same or nearly so. One radiocarbon date, 5270±70 B.P. (Pta-4947) from BSM, has a low $\delta^{13}C$ value (-23.3°/oo), but unfortunately it is not associated with an analyzed pollen sample and cannot be plotted on this graph. Nevertheless, this low $\delta^{13}C$ value suggests that few or no C_4 plants were present at that time either; thus implying that the increase in C_4 grasses occurred between 5300 B.P. and 5000 B.P.

The slopes between 5080 B.P. and 4750 B.P. indicate that grass pollen drops dramatically while the $\delta^{13}C$ slope shoots up. The pollen spectra in the 4750 B.P. sample shows that Compositae, mainly C_3 plants, increase and Cheno/Am, Aizoaceae and Ruschia remain stable, thus it is likely that the grasses in this sample are dominated by C_4 grasses otherwise the $\delta^{13}C$ value would have been much lower. Between 4750 B.P. and 4430 B.P. grass pollen percentage increases, but the $\delta^{13}C$ value drops significantly. Pollen spectra show that the most significant changes are an increase of grass, Cyperaceae (C_3 species), Aizoaceae (CAM species) and Cheno/Am (mostly C_4 species) pollen percentages, and the decrease of Compositae. However, the increase in Cyperaceae and decrease of Compositae are not great enough to account for the $\delta^{13}C$ drop without a shift from C_4 grasses to C_3 grasses by 4430 B.P. In the next sample, 4290 B.P., grass pollen percentages change very little (ca. 1 percent), while the $\delta^{13}C$ value increase is quite large (>3°/oo). Cheno/Am increases a little, but other pollen taxa likewise remain fairly stable. This suggests that C_4 CHENO/AMs increased, as well as C_4 grasses in relation to C_3 grasses, with little change in overall grass relative frequency at this time.

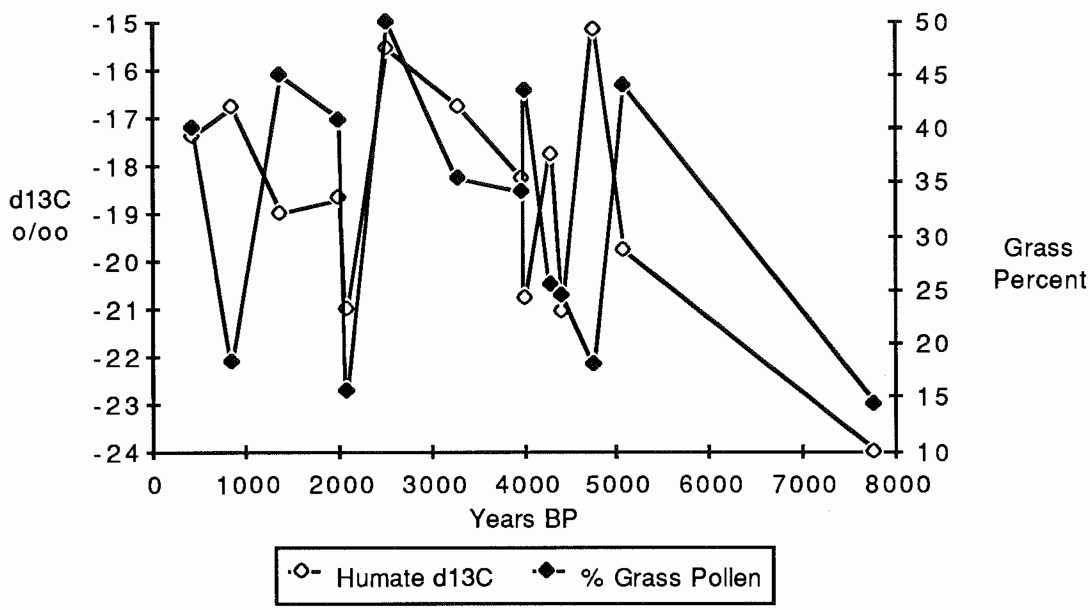

Figure 46 $\delta^{13}C$ ratios and relative frequency of grass pollen from matched samples.

The slopes between 4290 B.P. and 4010 B.P. show a marked change. Here, grass pollen increases, but the $\delta^{13}C$ slope drops sharply. The pollen spectra indicate that the most significant difference is the increase of Gramineae at the expense of Compositae and Cheno/Am. If grasses were dominated by C_4 species then the $\delta^{13}C$ value would not have dropped, thus a shift back to C_3 grasses is the most reasonable interpretation.

The slopes leading to the next sample, at 3990 B.P., show another C_3-C_4 grass exchange. Pollen spectra indicate that the only significant change is a reduction of grass and an increase in composite pollen, but the $\delta^{13}C$ value sharply increases. Again this suggests an increase in C_4 grasses over C_3 grasses. This trend continues to the next sample at 3290 B.P., which has even less grass pollen, more composites, and higher $\delta^{13}C$ values. The values 2520 B.P. demonstrate the highest grass pollen percentages and one of the highest $\delta^{13}C$ values. This must reflect an increased C_4 grass dominance. Between 2520 B.P. and 2080 B.P. the $\delta^{13}C$ value and grass pollen percent decline markedly. Composites increase equally rapidly, in fact this sample has the highest composite percentages in the dated samples. This most likely represents a slight change in C_3/C_4 grass relative frequencies but the addition of other C_3 species might be enough to pull down the $\delta^{13}C$ value at 2080 B.P.

The next shift to 2000 B.P. shows an increased $\delta^{13}C$ value, but much less so than the grass pollen increase. The pollen spectra indicate that the major change is a trade-off between grasses and composites accompanied by a minor increase in CHENO/AMs. This implies a slight increase of C_3 grasses versus C_4 grasses, otherwise the $\delta^{13}C$ value would have increased at a greater rate. The slope between 2000 B.P. and 1360 B.P. suggests a further increase in C_3 grasses since grass percent increased while the $\delta^{13}C$ values decreased. This pattern reverses between 1360 B.P. and 840 B.P. when composite and Cheno/Am pollens increase at the expense of grass pollen, and $\delta^{13}C$ values increase. While the increase in CHENO/AMs might be responsible for a portion of the $\delta^{13}C$ rise, it is suggested that a significant shift from C_3 to C_4 grasses also occurred. A reversal appears to occur between 840 B.P. and 410 B.P., when C_3 grasses appear to increase but possibly not to the level of dominance.

It is possible to estimate the relative amount of C_3 plants represented by the humate isotope ratios by the formula:

$$\text{Percent of } C_3 \text{ Plants} = (\delta^{13}C \text{ value} - 3.0 + 12.5) / -0.14$$

This formula assumes that the humate $\delta^{13}C$ values had been fractionated by microbial decomposition by 3‰, and that the mean value for C_4 plants is -12.5‰ and the average difference between C_3 and C_4 plants is 14‰. Hypothetically from a C_3 plant community with no grass, as C_4 grasses begin to colonize Blydefontein Basin then one would expect the C_3 plant estimates to decrease with higher grass pollen percentages, i.e. they would have a negative relationship. Additionally, as C_3 grasses take over from C_4 grasses or other C_4 plants then C_3 plant estimates should begin to increase as grass percentages increase, and the relationship between grass percent and C_3 plant estimates should have a positive slope.

The second order polynomial fitted curve ($r^2 = 0.233$) in Figure 47 shows a slope that changes from negative to positive and strongly suggests that the relationship between C_3 plants and percent of grass pollen switches as predicted by a shift between C_3 and C_4 grasses. It appears that C_4 grasses are dominant when grass occurs in very low percentages (less than 30-33%). This is interpreted as an increase in C_4 grasses versus non-grass C_3 plants such as the Compositae. At approximately 30-33 percent grass pollen it appears that C_3 grasses begin to increase in relation to C_4 grasses, and thus the C_3 plant estimates increase. It should be noted that a single sample from Hughdale Section, pollen sample 10420 (2520 B.P., 50% grass pollen, C_3 plant estimate = 0.7%) , was dropped from the regression. This single sample seems to have an unusually large amount of C_4 plants considering the overall abundance of grass pollen, and it anomalous position on this scatterplot will be considered below. The diagonal line shows the expected C_3 plant estimates assuming that all grasses were C_4 plants and that no other C_4 plants occurred. This theoretical function can be used to suggest that samples that fall above the line may have had C_3 grasses, and that samples that fall below this line must have had other C_4 plants in addition to grass. Additionally this theoretical function implies that the grass in the pollen sample dated to 2520 B.P. is less of an anomaly that the curvilinear regression implies.

A comparison between modern botanical survey data (see Chapter IV) and climatic records shows a negative relationship between mean annual rainfall, composite percent and C_4 grass percent, while overall grass percent, C_3 grass percent and rainfall have a positive relationship. One implication of Figure 47 is when C_4 grasses are believed to dominate over C_3 grasses, as grass pollen decreases it is replaced by C_3 plants, ie. composites. This is logical because the local C_4 grasses are drought resistant-warm weather species (Vogel et al. 1978, Ellis et al. 1980), and as conditions become too dry for C_4 grasses, they would be replaced by C_3 composites. However, as conditions become more moist C_3 grasses appear to replace C_4 grasses and

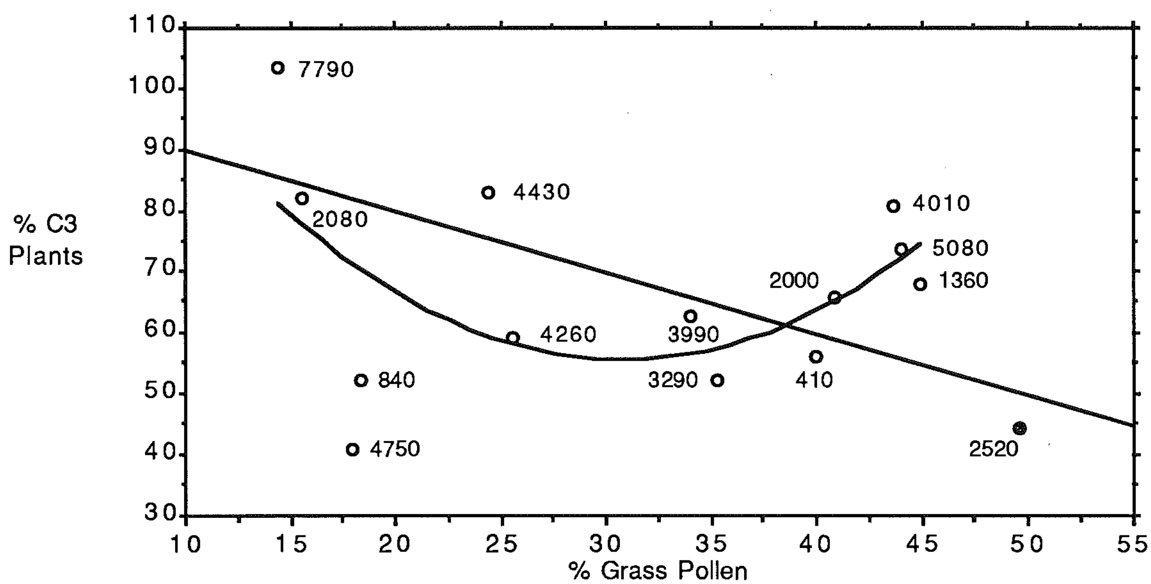

Figure 47 Curvilinear correlations of C_3 plant estimates based on $\delta^{13}C$ ratios and relative frequency of grass pollen for matched samples, minus pollen sample dated to 2520 B.P. from Hughdale Section. Numbers represent radiocarbon years B.P. Theoretical linear function for percent of C_3 plants given all grass is C_4.

other C_3 non-grass species. Thus warmer and drier conditions seem to increase the relative frequency of composites, and they cause a shift from C_3 to C_4 grasses. During wetter conditions, not only do grasses increase in overall relative frequency, but C_3 grasses appear to replace C_4 grasses. These interpretations agree with a number of modern studies on the distribution of C_3 and C_4 grasses in Africa and, in fact, throughout the Southern Hemisphere (Cavagnaro 1988; Cowling 1983; Ellis et al. 1980; Tieszen et al. 1979; Vogel et al. 1978; Young and Young 1983).

It should be noted that the general pattern does not seem to hold for the pollen sample dated to 2520 B.P., but the reason for this disjunction is not entirely clear (see Figure 47). This sample may represent a plant community which was colonized by the C_4 grass Themeda trianda, rooigrass, (Cowling 1983: 123) commonly found today at higher elevations to the east such as in the Stormberg and other areas covered by grass velds (Acocks 1975:88-98). Many other grasses found at these elevations are C_3 species including the now dominant Merxmuellera (Vogel et al. 1978: 213). Thus it is possible that Themeda trianda becomes dominant only after a significant amount of grass is established.

The stable isotope value associated with the 7790 B.P. sample suggests that few C_4 plants were present at that time and, if that was the case, then no matter what changes occurred in the pollen spectra the $\delta^{13}C$ based C_3 plant estimates would remain low because no C_4 plants were available to raise the ^{13}C /^{12}C ratios. It is possible that different seasonal rainfall and temperature patterns existed during the Early Holocene (Kutzbach and Guetter 1986), and the manner in which plant taxa associated with each other differed in comparison to Middle and Late Holocene plant communities. Vogel and Talma's (*in* Deacon and Lancaster 1988: 144) carbon isotope analysis of the Cango Cave speleothem has $\delta^{13}C$ values that are indicative of an almost exclusive C_3 plant biota in the southern Cape during the Early Holocene as well. These data have been used to suggest that a sharp increase in $\delta^{13}C$ values and apparently C_4 plants occurred only after 5500 B.P. with the establishment of modern plant communities (Deacon and Lancaster 1988: 144). The Cango Cave, Blydefontein Basin and other carbon isotope data from southern Namibia and Lesotho (Vogel 1983) might indicate the existence of an Early Holocene C_4 grass reservoir in southern Namibia. As more data are collected it might be possible to actually delimit the boundaries of an Early Holocene C_4 grass reservoir from which climatically induced migratory pulses originated.

Stable Carbon Isotopes in Ostrich Eggshell

Ostrich eggshell is ubiquitous in paleolithic archaeological sites throughout Africa and western Asia. Often, because of poor preservation, these sites lack more traditional sources of data used for reconstructing past environments such as other faunal remains or pollen. If present, these traditional sources are often biased by human selection in ways that limit their usefulness in reconstructing past environments. If palaeoenvironmental information can be extracted from ostrich eggshell, then analysis of past human behavior in a more complete environmental context will be possible. Moreover, the data are not biased by human selection.

A preliminary study stable of carbon isotopes in ostrich eggshell by von Schirnding et al. (1982) suggests that the organic fraction in eggshell rapidly decomposes within 1000 years. Thus carbon isotope analysis of the organic fraction has very limited applicability to many archaeological sites. However carbonate from well preserved eggshell appears to be free from diagenetic chemical changes over, at least, the last 10,000 years or more. von Schirnding et al. (1982) argue that eggshell carbonate $\delta^{13}C$ values are enriched by approximately 16.2‰ in relation to diet during metabolism (carbonate $\delta^{13}C$ values are enriched by 14.1‰ in relation to the organic fraction, and the organic fraction is enriched by 2.1°/oo in relation to diet), and they argue this fractionation effect is constant. Their published data (ibid) can be used to show that this model of isotopic fractionation is not correct, at least for the fractionation between the organic and inorganic fractions of shell. But a complete study that links the two fractions of eggshell to diet is lacking, and their (ibid) model of fractionation is used here in absence of a better controlled study. As ostriches are thought to be indiscriminate generalized feeders, it is expected that carbon isotope ratios in eggshell carbonate represent a fairly accurate estimate of the C_3/C_4 plant composition in the environment.

Fluctuations in Blydefontein Ostrich Eggshell $\delta^{13}C$

A sample of ostrich eggshell (n=121) from Blydefontein Rockshelter was measured for stable carbon isotopes, and a histogram of the $\delta^{13}C$ values shows that most of the samples form a slightly skewed (skewness = -0.306) unimodal distribution (Figure 48). However two individual measurements above -4.0 are suspected as outliers. Reinspection of these two samples showed they were taken from weathered shell, and we believe that oxidation of the shell enriched the $\delta^{13}C$ values. These two measurements have been omitted from further analysis.

In Figure 49 mean and individual ostrich eggshell $\delta^{13}C$ values from twenty four superimposed excavation units from Blydefontein Rockshelter are plotted. A single Early Holocene sample has been omitted for clarity, but it will be included below. The chronological sequence is based on radiocarbon dates from associated excavation units, termed analytical units and described in the following chapter, and ages of intervening excavation units without radiocarbon dates were estimated by assuming a constant accumulation rate between the two nearest radiocarbon dates. As the top and bottom of most sedimentary units in the rockshelter were dated, each

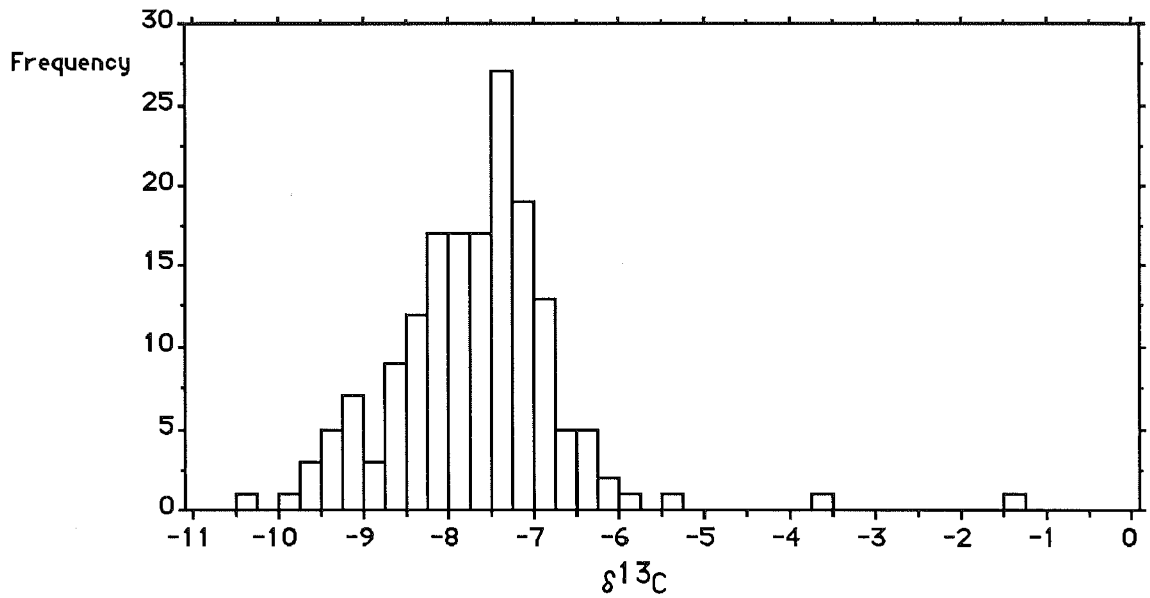

Figure 48. Histogram of ostrich eggshell $\delta^{13}C$ values.

major layer has its own estimated accumulation rate. Nevertheless, an assumption of a constant accumulation rate is obviously not correct in every case or even most cases, but it is a necessary starting point. Also one must assume that the period of time represented by some analytical units probably spans multiple, diverse climatic episodes, even though the excavation units represent relatively short periods of time (ca. 70-150 years). This cautionary note is supported by analyses of modern and historical climates which demonstrate that significant climatic and biotic changes can be very rapid in the Karoo (Cowling et al. 1986; C. Vogel 1988, 1989).

The mean $\delta^{13}C$ curve (see Figure 49) has at least three major dips during the last 4300 years: ca. 4100 B.P., 2000 B.P. and 900-1300 B.P. Also a dip at ca. 3200 B.P. may have palaeoenvironmental significance. If ostriches are truly indiscriminate feeders then lower $\delta^{13}C$ values reflect periods when ostriches ate more C_3 plants because the coeval plant communities had more C_3 versus C_4 plants. This is a difficult assumption to test without conducting a modern controlled experiment. However, other data are available that reflect on the validity of this assumption.

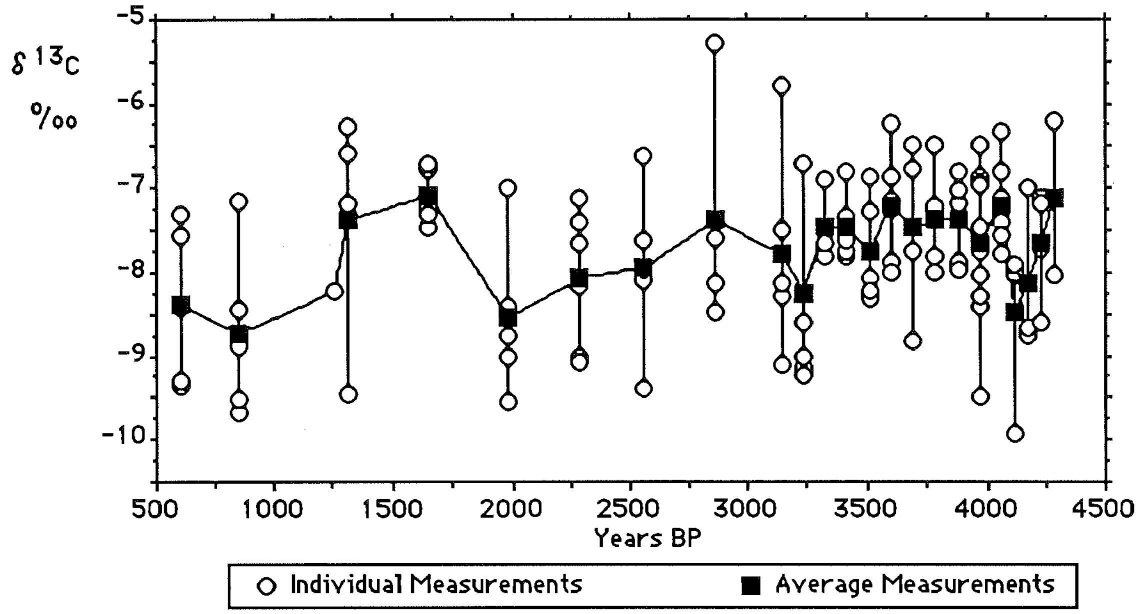

Figure 49. Individual and mean ostrich eggshell (OES) $\delta^{13}C$ values grouped by excavation unit. Lines connect mean values between each excavation unit and individual values within excavation units.

Blydefontein Basin Soil $\delta^{13}C$ and Rockshelter Ostrich Eggshell $\delta^{13}C$ Compared

The independent $\delta^{13}C$ curve from dated sediment humates in the geological sites discussed above can be used. A comparison between radiocarbon dated humate and ostrich eggshell $\delta^{13}C$ values shows that the two curves are similar, even though many fewer points occur on the humate curve (Figure 50). The ostrich eggshell $\delta^{13}C$ values are corrected (ie. reduced by 16.2°/oo) according to the data presented in von Schirnding et. al. (1982), and the fit of the humate curve to the ostrich eggshell curve suggests that the humate $\delta^{13}C$ values are too high. These elevated humate values are probably due to fractionation caused by microbial decomposition in soils (Dzurec et al. 1985; Flexor and Volkoff 1977; Natelhoffer and Fry 1988). Also the ostrich eggshell curve is flatter. This could be due to dietary selection, ostrich metabolism and incorrect understanding of fractionation between diet and eggshell carbonate, or averaging the values in either the eggshell or soils. Two major points of disagreement are the high $\delta^{13}C$ values for humate samples dating to 3290 B.P. and 2520 B.P., and low values of the contemporaneous ostrich eggshell samples. However fairly high individual $\delta^{13}C$ values (> -6.0) are present in the ostrich eggshell samples estimated to date to 2855 B.P. and 3135 B.P. (see Figure 50). These could represent a short period with increased amounts of C_4 plants which is more or less coeval with the high sediment $\delta^{13}C$ values discussed above, or an alternative possibility is that the $\delta^{13}C$ values in these sediment samples reflect a local plant community that has significantly more C_4 plants than the regional biota as registered by the diet of ostriches. The remaining dips and peaks especially at ca. 4000 B.P. and 2000 B.P. are much closer to the ostrich eggshell curve, and can easily be considered as coeval and reflecting the same local environmental changes.

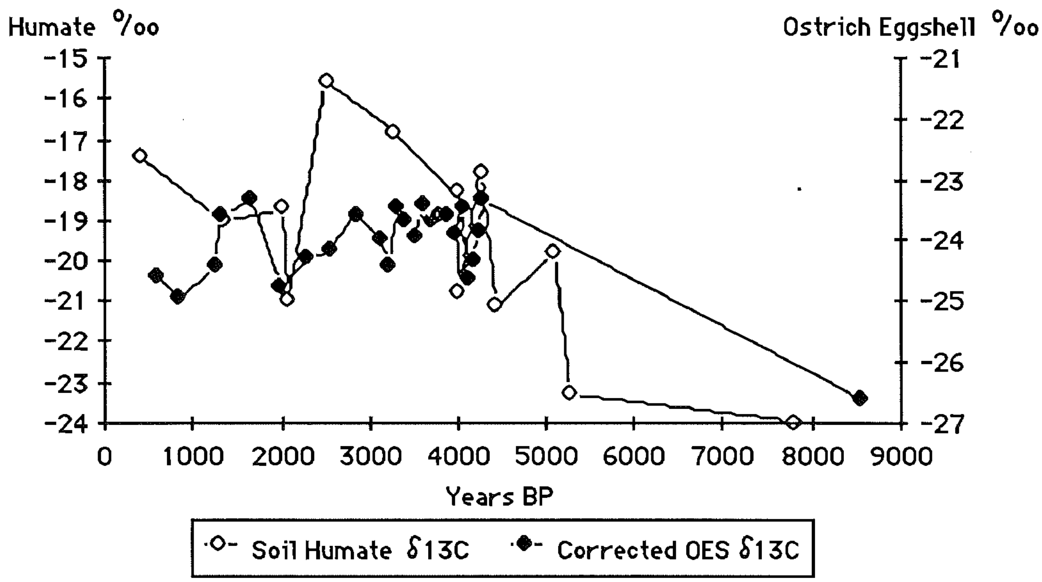

Figure 50. Corrected mean ostrich eggshell (OES) and C-14 dated sediment $\delta^{13}C$.

Conclusions

In this chapter stable carbon isotope evidence from two separate sources, dated sediments and ostrich eggshell, provide additional insights on paleoenvironmental changes in the Kikvorsberg range. Variations in carbon isotope ratios provide evidence of fluctuations in C_3 and C_4/CAM plants over the last 8500 years. The $\delta^{13}C$ samples from sediments have matching pollen samples, and when both sets are compared fluctuations in C_3 and C_4 grasses can be identified. Similarities between sediment and ostrich eggshell $\delta^{13}C$ sequences show that these two different sources are recording the same past botanical changes. This analysis suggests that few, if any, C_4 plants were in the Kikvorsberg before 5500 B.P., and significant decreases in C_4 plants occur at ca. 4000 B.P., 2000 B.P. and 1300-1000 B.P. As the ostrich eggshells are from Blydefontein Rockshelter, this $\delta^{13}C$ sequence provides an unbiased, high resolution record of paleoenvironmental change that unquestionably can be associated directly with the archaeological record from this rockshelter. Rarely in Stone Age archaeology are such clear cut paleoenvironmental associations possible.

CHAPTER VII

RECONSTRUCTION OF THE BLYDEFONTEIN PALEOCLIMATE

In this chapter Blydefontein palynological and stable isotope results are used to reconstruct climatic conditions through the Holocene. The reconstruction is then compared with the predictive model for rainfall and temperature, outlined in Chapter III.

Palynological Estimates of Climate

A number of studies have reconstructed past climatic conditions from pollen data, using a variety of statistical methods known cumulatively in pollen studies as transfer functions (Adam and West 1983; Birks and Birks 1980; Birks and Gordon 1985: 252-259; Bryson and Kutzbach 1974; Cole and Bryson 1968; Guiot 1987; Guiot et al. 1988; Hooghiemstra 1984; Huesser et al. 1980; Huesser and Streeter 1980; Webb and Bryson 1972; Webb and Clark 1977). In general transfer functions use quantitative modern plant or pollen-climate relationships to statistically estimate past climatic parameters.

As shown in Chapter IV, the relative frequencies of various plant taxa in the eastern Karoo can be used to estimate approximate elevation and degree of longitude. Marsh-adjusted and corrected fossil pollen frequencies can be used in multiple regressions to reconstruct temperature (i.e. elevation) and rainfall (i.e. degrees of longitude). This assumes (1) fossil pollen assemblages accurately reflect the eight modern plant communities defined in Chapter IV, and (2) that these reconstructed plant communities respond to climatic parameters in the same way as living plant communities do today.

Elevation, Degree of Longitude, Climate and Taxa

Multiple regression estimates for elevation and degree of longitude were calculated with the Roux-Blom survey data. The estimates of elevation and degree of longitude can be used to predict expected mean annual temperature and rainfall. Gramineae, Cheno/Am and Aizoaceae were used as independent (predictor) variables for elevation. In these equations Aizoaceae includes *Ruschia*. Compositae was not included in this equation, as elevation was not a good predictor of Compositae percent (See Table 3). However, all four taxa are independent variables for estimating degree of longitude.

elevation = 1680.7279+ 1.489(Gramineae) - 7.58(Cheno/Am) - 21.817(Aizoaceae)

The associated $R^2 = 0.582$.

degree of longitude = 24.7373 + 0.029(Gramineae) -0.005(Compositae) -0.058 (Cheno/Am) + 0.039 (Aizoaceae)

The associated $R^2 = 0.497$.

The mean annual temperature at 1275 msl in Middelburg is 14.6 degrees C, and temperature can be estimated for Blydefontein (1680 msl) at 12^o C using the normal lapse rate (6.5^o C per 1000 meters). However it is the difference from the modern temperature that is the unit of study. The formula estimating temperature difference is:

estimated temperature difference = ((1680 - *elevation*) * 0.0065)

An estimate of the correlation between rainfall and degree of longitude can be gained by analyzing the annual rainfall and degree of longitude for 49 stations in the upper Orange River drainage (Werger 1980: 12-13), and calculating a regression curve from the data (see Figure 20). A third order polynomial curve provided the best fit and the associated r^2 was 0.918, p value = 0.001. This equation estimated Grapevale's mean annual rainfall as 352mm, but the actual mean annual rainfall is 14mm above this estimate (i.e. 366mm). The discrepancy is probably due to orographic effects. The Grapevale data were used to fine-tune this equation by increasing the intercept by 14mm. With X representing *degree of longitude*, the resulting third order polynomial equation for rainfall difference from the modern average is:

$$\textit{mm rainfall difference estimate} = -150700.4759 + 18362.547*X - 745.587*X^2 + 10.111*X^3 - 366.$$

Temperature and Rainfall Estimates

Four geological sites and two polleniferous hyrax dung middens are used to estimate climatic parameters: Blydefontein Section, Blydefontein Stream Mouth, Channel 2, Upper Section Pond, Oppermanskop Hyrax Midden, and Meerkat Hyrax Midden. Pollen frequencies for these four taxa with pollen rain data were adjusted for marsh taxa and corrected. The resulting values were assumed to accurately represent those taxa in the ancient vegetation. These frequencies were then entered into the above multiple regression formulas.

The multiple regression formulas estimated the elevation and degrees longitude of the pollen sample, and these two variables were used to estimate the difference from modern rainfall and temperature. The multiple regression formulas have large standard deviations, so these estimates should not be accepted with a high degree of confidence. Nonetheless, the technique offers a promising approach for estimating climatic parameters using fossil pollen frequencies. From the outset the influence of European veld mismanagement, and its consequences on plant distributions has been a concern in this study. This problem is believed to be at least one cause of the large standard deviations of the regressions, but the general relationships indicated by the regressions are thought to be due to climatic restrictions on the distributions of plants. No doubt European influences have acted to weaken the plant-climate relationships. Also, if European influences have affected the multiple regressions, then the estimates will err on the warm and dry side of the scale and not the cool and wet end, because it is the composites and warm/xeric forms that have expanded their ranges to the east and thus distort the plant-climate relationships.

Blydefontein Section

Blydefontein Section (BFS) temporally is the longest geological section. The sediments are divided into two major units: Older Fills and Younger Fills. The pollen spectra from the Older Fills are distinctly different from the pollen spectra from the Younger Fills. The plant communities represented by the pollen from the Older Fills are not represented by any of the plant communities sampled by the modern botanical survey, thus these methods are not applicable to Older Fills pollen spectra. Pollen frequencies from the Younger Fills are presented below along with the temperature and precipitation estimates shown as differences from modern levels (Table 10). Samples 9740, 9739 and 9738 are buried soils, and sample 9777 is from a silt lens in a buried stream channel. The general pattern shifts from cool-moist to warm-dry back to cool-moist with a return to warm-dry. The upper two soils seem to have formed under warm-dry conditions, while the lower soil formed under cool-moist conditions.

Table 10.--BFS Younger Fills relative frequencies of selected pollen taxa and estimated climatic parameters

sample	Gramineae	Compositae	Cheno/Am	Aizoaceae	Mean Annual Climate Estimates from modern Temperature oC	Rainfall
9740	29.3	45.0	11.4	3.1	0.1	-7
9606	25.5	53.7	5.9	4.3	-0.1	-2
9777	48.8	28.9	5.0	2.9	-0.3	52
9739	17.9	59.2	7.1	5.8	0.0	-11
9605	14.8	65.3	9.7	1.9	0.2	-29
9738	37.6	44.0	3.0	2.1	-0.3	19

Blydefontein Stream Mouth

Blydefontein Stream Mouth (BSM) represents the upper 1.8m of pond deposits. It is not unreasonable to accept a constant sedimentation rate for these deposits because they are from a single depositional environment. An estimated age of each sample was calculated by a linear regression using sample depth and radiocarbon age (see Figure 27). The general temperature pattern changes from slightly cooler temperatures to a warm period from 4300 to 4700 B.P. with a short cool interval at 4500 B.P., and after 4300 B.P. back to cooler temperatures (Table 11). Rainfall is less than modern levels between 4700 and 4100 B.P. with a short moist period coincident with the cool temperatures at approximately 4500 B.P.

Channel 2

Pollen was recovered from both Older and Younger Fills at Channel 2 (CH2), but the Older Fills sample could not be used in these equations because its pollen spectrum does not represent a plant community sampled by the modern botanical survey. Sample 9751 was dated to 4290 B.P., and it is roughly coeval with Sample 9757 from BSM. It is difficult to estimate the age of Sample 9753, but as it is stratified in channel fill a few centimeters below Sample 9751, it is probably no more than a few hundred years older. Sample 9663 was dated to 7790 B.P., and represents the only radiocarbon dated early Holocene sample.

Table 11.--BSM relative frequencies of selected pollen taxa and estimated climatic parameters

	Taxa				Mean Annual Climate Parameters from modern	
sample	Gramineae	Compositae	Cheno/Am	Aizoaceae	Temperature oC	Rainfall
9754	53.2	22.4	2.9	2.4	-0.4	74
9755	29.3	48.2	4.5	2.3	-0.2	1
9756	28.9	45.0	10.4	5.2	0.0	0
9757	42.2	32.1	7.6	5.1	-0.2	37
9758	33.5	28.1	14.0	4.1	0.1	3
9759	16.5	45.0	8.3	5.5	0.1	-11
9760	40.4	37.7	4.0	2.2	-0.3	26
9761	28.3	41.6	5.3	8.0	-0.1	22
9763	45.6	33.2	4.2	1.2	-0.3	34
10430	35.2	31.8	6.3	5.4	0.2	27
10434	34.2	42.2	6.8	3.4	0.1	10
10438	27.2	50.2	5.5	2.6	-0.1	-3
10444	8.8	64.6	4.6	2.5	0.1	-27
10449	22.6	47.2	8.9	4.3	0.0	-9
10456	11.7	58.2	5.6	1.2	0.1	-27

Table 12.--CH2 Younger Fills relative frequencies of selected pollen taxa and estimated climatic parameters

	Taxa				Mean Annual Climate Estimates from modern	
sample	Gramineae	Compositae	Cheno/Am	Aizoaceae	Temperature oC	Rainfall
9751	25.5	29.5	10.0	5.5	0.1	2
9753	46.0	15.5	6.0	2.5	-0.3	46
9663	16.0	52.9	3.1	10.2	-0.1	9

Upper Section Pond

Ten pollen samples were collected from a diatomaceous pond deposit and overlying alluvium. Samples 9750, 9749, 9748a, 9748 and 9746 are from pond sediments, and 9749 is dated to 2000 B.P. Samples 9745, 9744, 9743 and 9742 are from alluvium. The uppermost pond sample (9746) has a radiocarbon age of 410±40 B.P., but it difficult to accept this assay as correct (see Chapter V). The uppermost pond deposits were truncated by erosion so that the depositional record preserving the desiccation of the pond was destroyed by an erosional unconformity. The pond samples show a shift from wetter conditions to much drier conditions without increased temperature just after 2000 B.P. (9748a), and then a return to greater precipitation and cooler temperatures (Table 13). Initially the rainfall estimated in the lowermost alluvial sample (9745) shows no great difference from the previous precipitation level from the pond deposit, but very quickly estimated rainfall drops and estimated temperature increases. The uppermost sample indicates even drier-warmer conditions.

Table 13.--USP relative frequencies of selected pollen taxa and estimated climatic parameters

	Taxa				Mean Annual Climate Estimates from modern	
sample	Gramineae	Compositae	Cheno/Am	Aizoaceae	Temperature oC	Rainfall
9741	29.1	43.9	18.0	2.1	0.3	-19
9742	42.7	34.1	14.1	3.8	0.0	15
9743	40.8	26.1	20.8	3.3	0.2	-1
9744	38.6	42.3	6.5	1.9	-0.2	13
9745	48.3	29.1	7.7	2.6	-0.2	40
9746	43.9	35.5	7.9	3.5	-0.2	30
9748	56.3	20.3	7.7	4.1	-0.3	80
9748a	29.3	46.1	5.4	3.0	-0.1	2
9749	45.5	30.4	11.2	3.6	-0.1	28
9750	51.1	19.2	6.9	3.6	-0.3	62

Hughdale Section

Six pollen samples were collected from five buried soils in Hughdale Basin (HDS). The lowest soil was sampled twice for pollen. All but the lowermost soil have been dated and the dates, in sequence from top to bottom are: 840 B.P., 2520 B.P., 3990 B.P., and 4750 B.P. When first discovered it was believed that the lower soil might date to the Pleistocene, but this seems unlikely considering the radiocarbon ages of the soils above and the general stratigraphy in nearby Blydefontein Basin. HDS rainfall estimates indicate a dry middle Holocene, and then conditions begin to become more moist by 3990 B.P. (Table 14).

Table 14.--HDS relative frequencies of selected pollen taxa and estimated climatic parameters

	Taxa				Mean Annual Climate Estimates from modern	
sample	Gramineae	Compositae	Cheno/Am	Aizoaceae	Temperature oC	Rainfall
10419	18.8	46.5	10.2	11.4	0.1	6
10420	50.6	34.8	3.6	0.0	-0.4	40
10421	35.3	34.4	2.1	0.0	-0.3	12
10422	20.3	58.6	5.4	1.4	0.0	-17
10423	27.6	53.5	1.2	0.3	-0.2	-4
9781	33.5	44.2	2.8	0.0	-0.2	4

Meerkat Hyrax Midden

Ten pollen samples were extracted from a 22 cm thick consolidated hyrax midden (Table 15). This midden was discovered under a very small overhang adjacent to Meerkat Rockshelter. A radiocarbon age of 300 B.P. was obtained on dung from the bottom 4 cm of the midden and an age of 200 B.P. was obtained on dung from 15 cm below the top of the midden. The top of the midden was assumed to date to 0 B.P., and using these three points a linear regression was calculated to estimate the age of individual pollen samples (see Figure 40).

The rainfall estimates show a sharp decrease from a high mean annual amount relative to today during the interval 300 to 200 B.P., which is followed by a fluctuating plateau until approximately 86 B.P., i.e. AD 1864 . After 86 B.P. rainfall estimates drop dramatically. The age estimate for this point is 30 B.P. (AD 1920). Rainfall estimates increase after AD 1920. The temperature estimates are a negative mirror image of the rainfall estimates except for the oldest sample which is warmer than might be expected.

Table 15.--Meerkat Hyrax Midden relative frequencies of selected pollen taxa and estimated climatic parameters

	Taxa				Climate Estimates from modern	
sample	Gramineae	Compositae	Cheno/Am	Aizoaceae	Temperature oC	Rainfall
10	38.91	32.30	12.45	0.39	set at 0	set at 0
9	24.80	46.80	20.00	1.20	0.4	-29
8	43.10	15.09	1.29	1.29	-0.4	48
7	47.60	17.20	1.20	0.80	-0.4	56
6	34.73	25.52	1.26	1.26	-0.3	22
5	51.03	17.28	2.06	1.64	-0.4	68
4	44.49	29.92	0.00	0.39	-0.4	41
3	57.96	11.43	1.22	0.82	-0.5	95
2	73.57	9.69	0.00	0.44	-0.7	174
1	60.09	8.33	2.19	14.91	-0.5	284

Oppermanskop Hyrax Midden

Eleven pollen samples were extracted from a consolidated 18 cm thick hyrax midden discovered in a small rockshelter in a protected kloof below Oppermanskop. Age estimates of individual pollen samples uses the second order polynomial regression in Figure 42.

Rainfall estimates are generally higher and temperature estimates somewhat lower than modern levels between 1200 and 450 B.P. However within this period a significant reduction in rainfall and increase in temperature is estimated to have occurred between 1200 and 900 B.P. At or shortly after 450 B.P. rainfalls are estimated to have dropped and temperatures climbed (Table 7.7). Since the Europeans had a significant influence on the environment only in the last 170 years, and mostly in the last 100 years, sample 1 is the only sample that might reflect this disruption.

Comparison of the Pollen-Derived Rainfall Estimates

Rainfall estimates for the sites and hyrax middens were compared by plotting them together. Even though the sites do not overlap greatly in time, such a comparison allows for a further assessment of the consistency of the estimations. It also provides

Table 16.--Oppermanskop Hyrax Midden relative frequencies of selected pollen taxa and estimated climatic parameters

	Taxa				Mean Annual Climate Estimates from modern	
sample	Gramineae	Compositae	Cheno/Am	Aizoaceae	Temperature oC	Rainfall
1	19.3	45.9	2.9	3.3	-0.1	-6
2	33.6	20.1	5.7	4.1	-0.2	24
3	42.4	28.4	3.1	0.8	-0.3	30
4	36.1	10.7	0.8	0.4	-0.3	30
5	60.5	8.2	1.2	1.2	-0.6	112
6	42.5	17.0	1.6	4.5	-0.4	64
7	60.4	6.9	2.5	1.6	-0.5	110
8	63.4	7.7	1.2	1.2	-0.6	125
9	37.8	18.7	2.0	2.0	-0.3	34
10	33.0	23.0	0.0	0.0	-0.3	18
11	77.7	3.1	1.6	0.4	-0.7	195

a first step toward constructing a long term estimate of Holocene rainfall fluctuations. Temperature estimates have not been presented because the range of temperature fluctuation estimated was not great, and because a strong correlation exists between rainfall and temperature so that one mirrors the other at least as modeled here and for other quantitative Holocene climatic estimates (Scott and Thackeray 1987: 93-98). First both hyrax middens rainfall curves are compared, and then these curves are plotted along with the remainder of the sites.

A comparison of the Meerkat and Oppermanskop hyrax midden estimates shows some similarity between the two sites in terms of rainfall decline over the last 300 years (Figure 51). However, the Meerkat estimates appear to be consistently higher than the Oppermanskop estimates, and the Meerkat estimates suggest greater fluctuations. As the accumulation rate is faster in the Meerkat Midden, the resolution of the Meerkat samples is finer and samples span short periods. If the biotic environment can respond rapidly to climatic changes then the higher estimates may be correct as they reflect less temporal averaging. Another potential influence is that today the micro-habitats of the two sites differ, and this may be reflected in the rainfall estimates. Oppermanskop Midden is in a very steep and narrow north-facing ravine with abundant trees species, and Meerkat Midden, in a shallow gorge in the middle of the Basin, has an eastern aspect and more open vegetation (Scott and Bousman 1990). Nevertheless, both records produce the same general pattern.

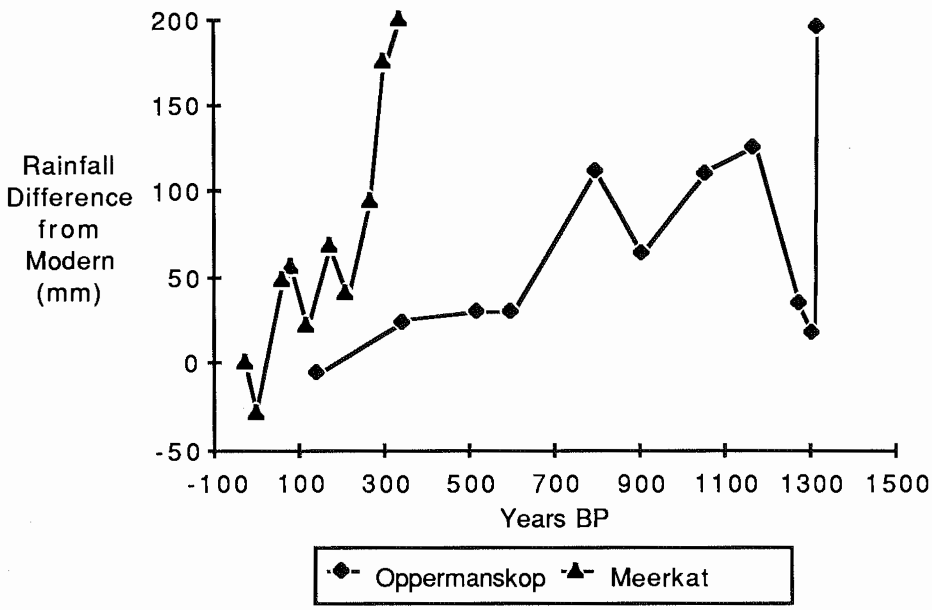

Figure 51. Rainfall estimates from Oppermanskop and Meerkat Hyrax Middens.

A comparison of geological site rainfall estimates allows a further assessment of the technique, and, if accepted, produces a more lengthy, although still patchy, estimate of rainfall for the Holocene. Ages for the five USP pond samples were calculated by using the sedimentation rate of the BSM pond deposits. The margin of error of this calculation is totally unknown, but the importance of the USP samples warranted their inclusion. The USP alluvium and soil samples were not included.

Even with the gaps and lack of overlap the sites appear comparable except for the samples from the soils at BFS and HDS. A comparison between the BFS sample and contemporaneous estimates from other sites suggests that the soil pollen sample estimates are too low. Two upper soils at BFS exhibit low grass percentages, however the lower soil has high grass relative frequencies. If one looks at the remaining and unplotted samples from overbank alluvium or buried soils from any of the sites the rainfall estimates appear to be low in these contexts. This is probably a preservation problem due the alternative wetting and drying of pollen in soils, and it probably biased the relative frequencies of the samples (Holloway 1989). The estimate for the BFS upper buried soil could be 'calibrated' to an average of the contemporaneous hyrax midden estimates, and a coefficient calculated. However this does not really address the problem, and goes over the edge as too much data manipulation. It appears that the hyrax middens, the stream deposits, and the pond deposits trap and preserve pollen reasonably well. However, in water laid sediments pollen is deposited as any clast or particle, and the strength of the current influences the size of pollen trapped in a stratum (Fall 1987). This suggests that a bias might occur against the deposition of very small pollen in flowing water. More research is needed to investigate taphonomic problems, and develop strategies for dealing with biased samples. In Blydefontein Basin it appears that hyrax middens and pond deposits are the best pollen traps and preservers. Soils appear to be the worst context and this is probably a preservation problem The taphonomic characteristics of alluvium and stream deposits require more study. Even considering these problems it is worthwhile to inspect the rainfall estimations for pollen samples from hyrax middens and pond deposits (Figure 52).

The resultant rainfall record has some large gaps and inconsistencies (see Figure 52). Meerkat Midden estimates were omitted due clarity as all the samples crowd together near the 0 B.P. mark. Quantitative estimates were not possible for Pleistocene pollen samples from the Older Fills, because of significant differences in

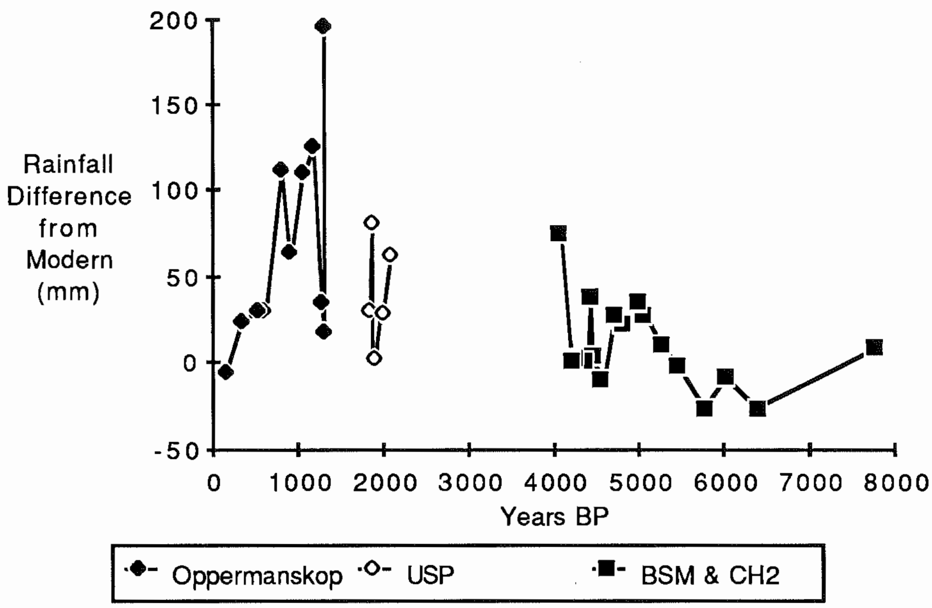

Figure 52. Combined rainfall estimates from hyrax middens and pond deposits except Meerkat Midden.

the structure of Pleistocene plant communities (see above and Chapter V). The earliest rainfall estimate dates at 7790 B.P. from CH2, and indicates conditions about the same as present. Between 6500-5500 the estimates from BSM suggest that, except for this century, this is the driest period recorded in the Holocene at Blydefontein Basin. By 5000 B.P. the estimates from BSM indicated that the Basin was much better watered. Between 5000-4000 B.P. another dry period occurs, and the youngest sample could indicate a wetter period although more samples are needed to be sure. Approximately 2000 years pass before another acceptable documented record exists. The only samples from this intervening period are soils from BFS and HDS, and these samples appear to be biased by preservation. The 2000 B.P. USP pond sequence shows a moderately moist sequence that is split by a short drought. This drought is well recorded by diatoms and molluscs from USP (Bousman et. al. 1988). The Oppermanskop Midden estimates show a sharp reduction in rainfall at approximately 1300 B.P. which is followed by an equally sharp rainfall increase soon thereafter. Then there is a general decline in precipitation from approximately 900 B.P. until the present century.

Pollen Rainfall Estimates Compared to Historic Precipitation Records

The Meerkat rainfall estimates overlap with the composite rainfall records discussed in Chapter III: the local Grapevale rainfall record spans 1920-1985, the rainfall record from Aliwal North extends from 1884-1940, and the historic record from Eastern Cape that spans the years of 1821-1900 (C. Vogel 1988, 1989). In order to gauge the accuracy of the pollen derived estimates, comparisons with these records are required.

The comparisons between the smoothed Eastern Cape, Aliwal North, and Grapevale rainfall records, and the Meerkat pollen derived rainfall estimates are reasonably close (Figure 53). In this comparison it was assumed that the East Cape historic records could be converted to actual rainfall estimates by using the scales on Figure 15 (rain estimate = (111.111 * East Cape Score) + 27.778). Obviously the pollen samples reflect a much grosser sampling interval than the rainfall records, and a great amount of variability is not reflected in the pollen derived estimates. These longer sampling intervals also would tend to smooth the curve, and it is why the pollen rainfall estimates are more constricted than the historic or measured rainfall moving averages. The hyrax middens were sampled at irregular intervals, and thus the samples represent different time spans. An improvement of detail and accuracy would be to date a midden first, and calculate accumulation rates. Then, based on the accumulation rates, select samples of given time spans, and compare these to rainfall measures averaged by a similar time interval. This would entail much more detailed sampling and chronological control than achieved by the middens used in the analysis presented here.

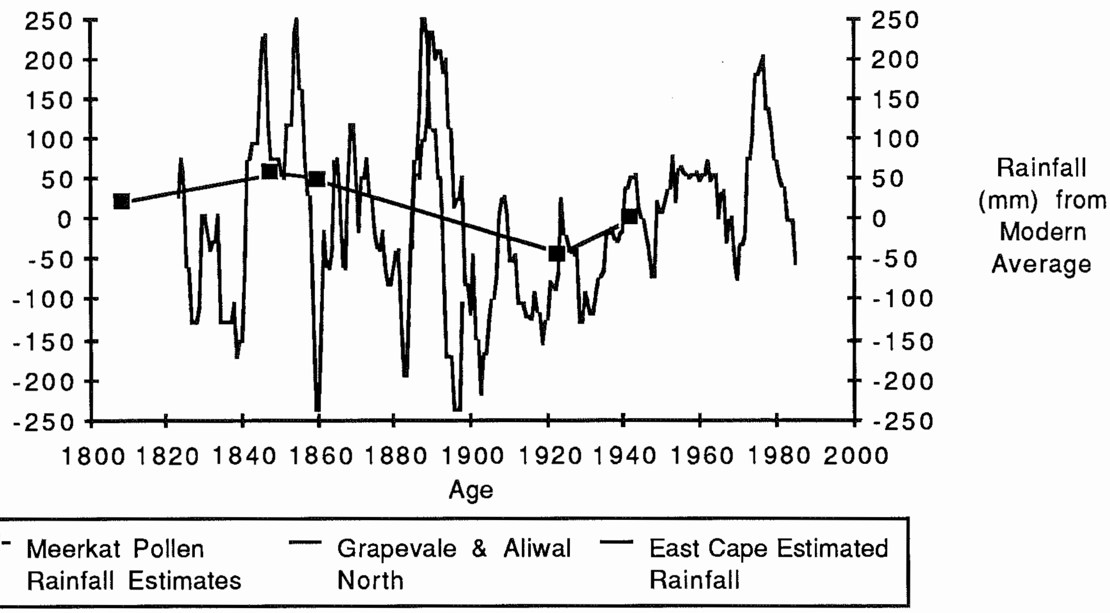

Figure 53. 5-yr moving averages for Vogel's Eastern Cape and Grapevale rainfall records, and Meerkat hyrax midden rainfall estimates.

In Figure 53 a number of important patterns are present in the pollen derived rainfall estimates from Meerkat Midden. Firstly, the 20th century increase in rainfall is very clear. Also an inspection of the 19th century portion of the record suggests that a slight decline is present as well. When considering the pollen estimates along with the historic records it seems reasonable to suggest that at least one and possibly two long rainfall cycles are present. The pollen data would suggest that it begins ca. 1850, and declines to the late 1920s, and then rapidly rises until the 1970s, but the rainfall records suggest two cycles. The pollen estimates provide another link between the two drastically different types of historic records.

The similarity between the pollen rainfall estimates and the historic rainfall records, both measured and estimated, provides credence to the technique of estimating climatic parameters with pollen data. The contention that vegetation response to European veld abuse overwhelmed or nullified vegetation responses to climatic fluctuations in the last 200 years is brought into question by the degree of agreement between the pollen estimates and the historic rainfall records. The possibility that man and climate acted in tandem to dramatically alter the indigenous vegetation in the 19th and 20th centuries appears to be a more accurate assessment of changes in vegetation observed over the same period. Lastly, in the future pollen records may help to provide a bridge for calibrating other 19th century quasi-quantitative rainfall record based on documentary evident with actual rainfall measurements collected systematically in the 20th century.

Comparison Between Pollen-Derived Rainfall Estimates and $\delta^{13}C$ Sequences

In order to see more clearly the similarities and differences between the eggshell $\delta^{13}C$ values and the rainfall estimates, rainfall estimates from two pond deposits (USP and BSM) and the Oppermanskop hyrax dung midden were used as these depositional contexts have the most reliable and continuous pollen samples (Bousman et al. 1988; Scott and Bousman 1990). As stated above dry periods in the rainfall estimates date to approximately 4100-4200 B.P. at BSM, 3200 B.P., 2000 B.P. at USP, and 1300 B.P. as well as the modern 20th century drought at Oppermanskop. Drier rainfall estimates are closely matched by negative dips in the eggshell $\delta^{13}C$ curve (Figure 54). Generally samples with high rainfall estimates are characterized by pollen spectra with high grass relative frequencies, while pollen spectra producing low rainfall estimates are dominated by composits. In this portion of southern Africa composits consist mostly of small, drought resistant, mainly C_3 bushes typical of the Nama-Karoo biome, and grasses include both C_3 and C_4 species and especially the C_4 species *Themeda trianda* (Cowling 1983; Rutherford and Westfall 1986; Sealy 1986; Vogel et al. 1978). During period when rainfall is predicted to be high because of high grass relative frequencies the $\delta^{13}C$ curve is also elevated, and during periods of low estimated rainfall associated with increased composits and other Karoo flora the $\delta^{13}C$ values are low. These data can be used to suggest that the biotic changes reflected in the pollen spectra are also reflected in the eggshell $\delta^{13}C$ values. The two are linked to the same phenomena.

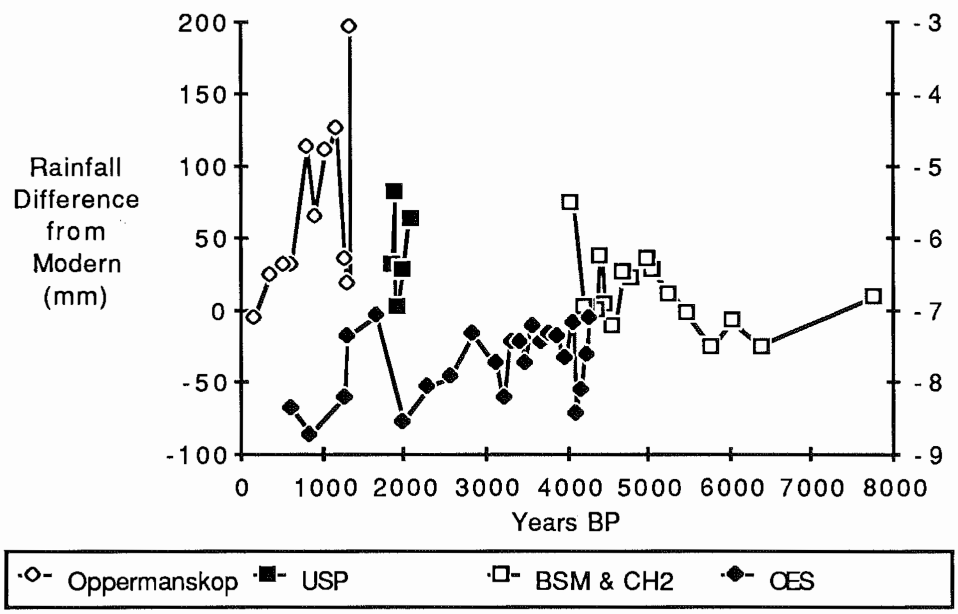

Figure 54 Pollen derived rainfall estimates and average ostrich eggshell $d^{13}C$ values.

As argued in Chapter VI, similarities between ostrich eggshell and sediment humate $\delta^{13}C$ curves imply that major shifts in relative frequencies of C_3 and C_4

plants are registered by both mediums. Different degrees of isotopic fractionation occurs in both materials, but, nevertheless, reasonable correlations are possible. The $\delta^{13}C$ changes registered in ostrich eggshell and sediment humates are supported by fluctuations in contemporaneous pollen spectra as well. Based on these data it appears that Holocene biotic changes in the upper Oorlogspoort drainage were registered by all three independent sources of evidence. Thus carbon isotopes in ostrich eggshell can provide important proxy palaeoenvironmental data from a wealth of archaeological sites, and often when no other evidence is available. Ostrich eggshell has the added benefit of being directly associated with archaeological remains which allows a direct comparison between biotic and human behavioral changes.

A Test of the Climatic Model

The palynologically estimated rainfall record can be compared to the COHMAP simulations for a visual assessment of the similarity between the two (Figure 54). The temporal resolution of the simulated rainfalls is very low by comparison to the pollen samples. Nonetheless, Figure 54 demonstrates a reasonable fit between the rainfall estimates derived from the pollen spectra and the COHMAP simulations. No major conflict is apparent between the simulated rainfall record and the pollen data, but the Early Holocene COHMAP estimates appear to overestimate the drought. Without doubt this is a period when a continuous and complete record could add a great deal. It should be remembered that the computer simulations are for all of southern Africa below 20°S latitude, and the Blydefontein rainfall estimates apply to only a very small portion of this region. Also short term climatic events of 100-1000 years duration are not factored into the climatic model, and events of this scale probably dominate the pollen derived rainfall estimates and single floating samples could provide a very biased view of the general rainfall during a period. This comparison provides good circumstantial evidence that seasonal variations in solar insolation influenced climates during the Holocene, and that the simulations may be roughly correct for the Pleistocene when pollen samples are very scarce. The pollen samples from the Older Fills all reflect cold and dry conditions, and if the COHMAP simulations are correct for the Pleistocene then these samples could date more recently than 15kya, or considering the clay mineralogy, the Older Fills could predate the wet period predicted for the Last Glacial Maximum. However, these samples must be dated by radiocarbon before they can be used to test the Pleistocene segment of the COHMAP simulations.

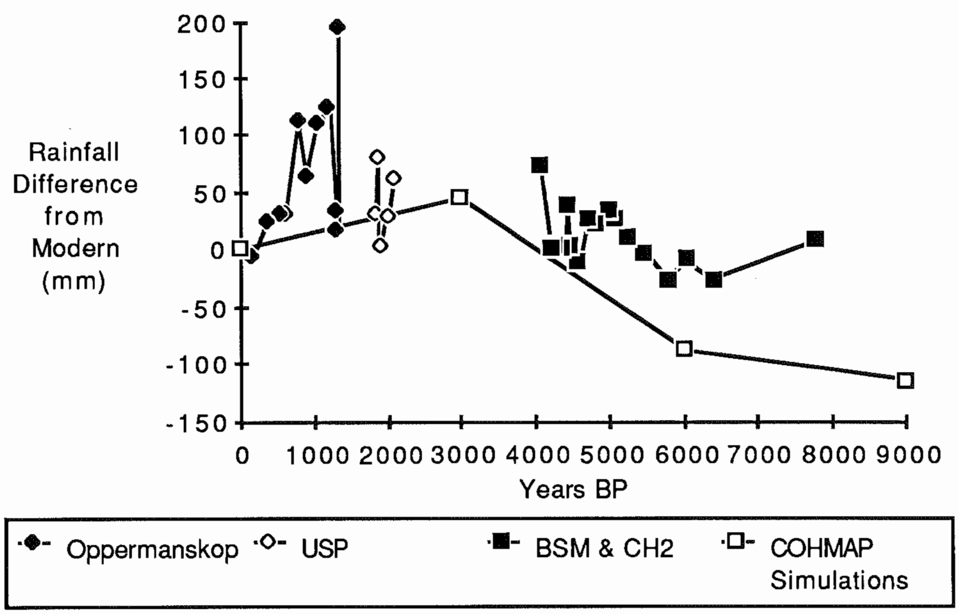

Figure 55 Comparison of palynologically estimated rainfall record and COHMAP simulated rainfall record.

Conclusions

Climatic controls on modern taxa can be used to estimate temperature and rainfall for each pollen sample. These rainfall estimates indicate a major drought between 6500 B.P. and 5500 B.P., and another occurred between 5000 B.P. and 4000 B.P. Throughout the remainder of the Late Holocene rainfall appears to be high except for a very short period at about 2000 B.P., another period at 1300 B.P., and possibly a minor one at 3200 B.P. This long period of high rainfalls ends in the later part of the 19th century according to historic and measured rainfall records. The 20th century is dry. The timing and intensity of these climatic estimates can be used to understand at least some of the causes behind prehistoric human behavior in the region during the Late Stone Age.

Thus the comparison between the rainfall estimates derived from pollen samples and COHMAP simulated rainfalls shows a reasonably good fit. This suggests that the long term climatic changes of the Quaternary are influenced by variations in solar insolation caused by perturbations in the orbit of the earth around the sun. This has been well documented for the comings and goings of glaciers during the Pleistocene (Hays, Imbrie and Shackleton 1976), and strongly implicated for Holocene climates in other regions as well (Kutzbach 1981). The data presented here provide unusually clear evidence that the system is detectable in unglaciated regions. It also shows clearly that the system continues today.

Short variations are not well understood (Berger 1988), but considering the amazing overriding influence of solar radiation one should not rule out short term astronomical effects (Gribbin 1978: 150-154). Other factors such as major volcanic eruptions (Bryson 1989) or rapid surges in glacial meltwaters at the end of the Pleistocene (Emiliani et al. 1975; Jones and Ruddiman 1982; Schneider 1987) could also have short term effects on worldwide climates.

CHAPTER VIII

THE ROCKSHELTERS: STRATIGRAPHY, CHRONOLOGY, AND SEDIMENTS

Two archaeological sites were excavated in Blydefontein Basin in 1985: Blydefontein Rockshelter and Meerkat Rockshelter. Blydefontein Rockshelter had been excavated twice previously. The first excavation was by A. C. Hoffman and D. J. Esterhuyse in the 1957, and the second excavation was by C. G. Sampson in 1967. Hoffman and Esterhuyse kept no field records and never published their results. Sampson reanalyzed their artifacts and published them along with the results of his excavations (Sampson 1970: 87-105). Based on the results of Sampson's Orange River Scheme research (Sampson 1970, 1972 and 1974), and on the Zeekoe River Valley survey (Sampson 1985), it became obvious that Blydefontein Rockshelter was one of the largest and potentially deepest rockshelters in the entire region that had the added benefits of good faunal preservation and intact stratigraphy (Klein 1979; Sampson 1970: 88-89). In order to obtain a time-calibrated settlement pattern from the Zeekoe Valley surface sites, it was clear that a cross-dating scheme with tight chronological controls was needed for the region. Blydefontein Rockshelter, with its good stratigraphy, could be the corner stone of such a cross-dating scheme.

The shelter was revisited in 1980 during the first season of the Zeekoe Valley Project, and excavation plans were begun at that time. Funds were secured in 1984 for renewed excavation of Blydefontein Rockshelter, and in early 1985 C. G. Sampson revisited Blydefontein in order to liaise with the landowner, Mr. D. Lessing. At that time Mr. Lessing showed Sampson an unknown smaller rockshelter, later named Meerkat Rockshelter. Meerkat Rockshelter had never been investigated.

Blydefontein Rockshelter Excavations

Blydefontein Rockshelter is situated in a sandstone overhang with two main lobes: north and south (Figure 56). The deposits in the northern lobe are shallow, but the deposits in the southern lobe are at least one meter or more in depth. The shelter talus deposits slope down to the edge of a terrace where a historic stone wall stands. Beyond the stone wall is the 6 meter thick alluvial terrace known as Blydefontein Section (see Chapter V). Three areas were excavated at Blydefontein Rockshelter in 1985 (Figure 57). The major excavation effort was placed adjacent to Sampson's excavations in the south lobe, while a single one-by-one meter test pit was placed in

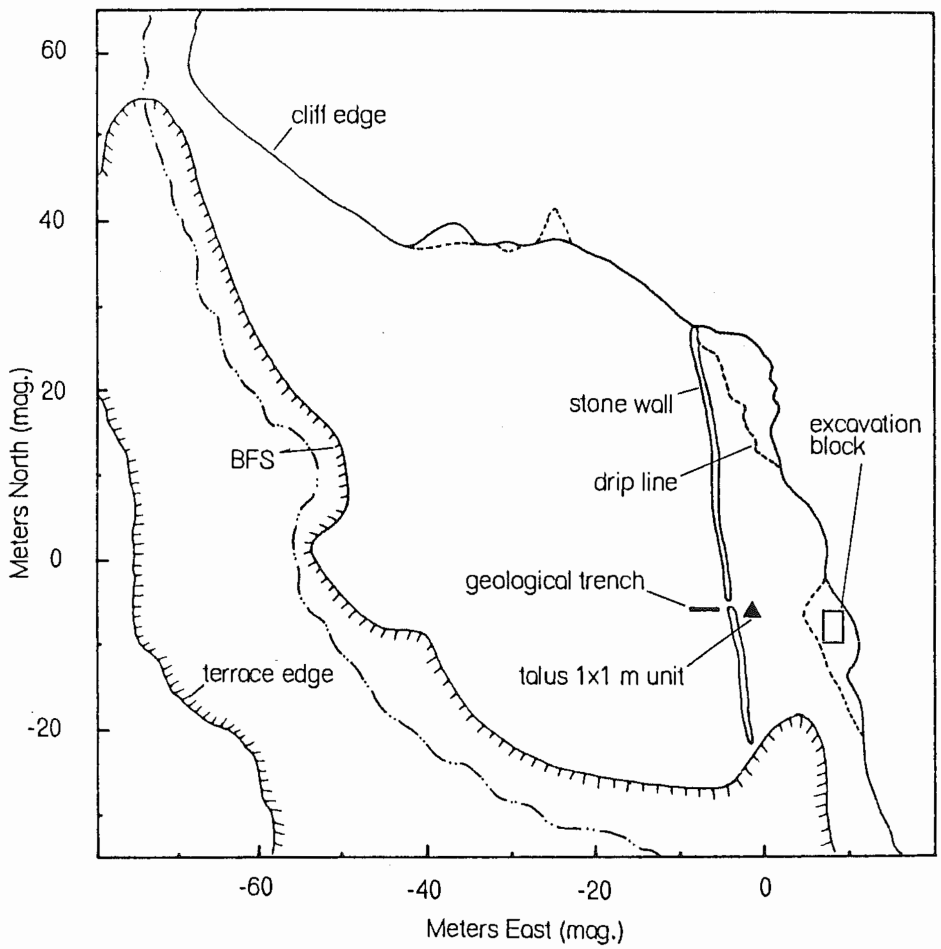

Figure 56. Map of Blydefontein Rockshelter and surrounding terrace area.

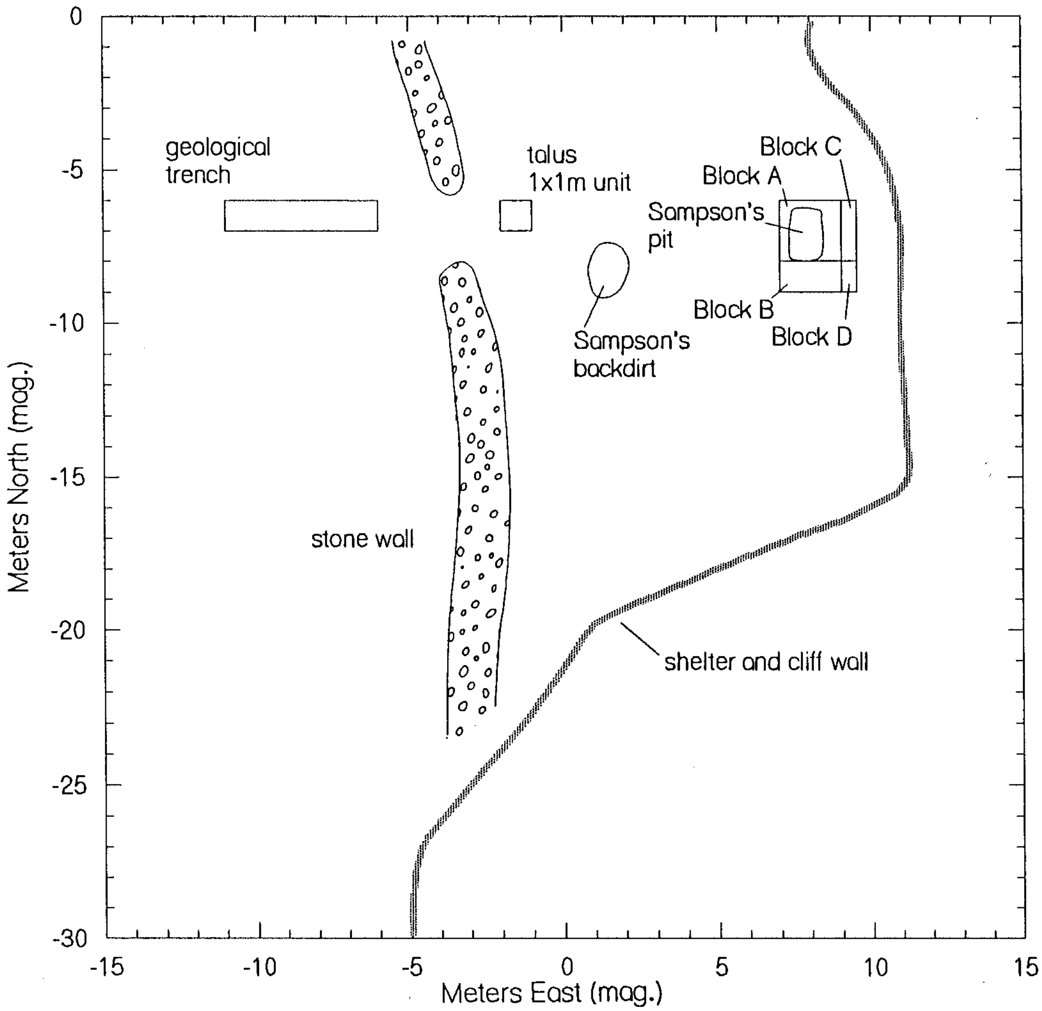

Figure 57. Map of current and previous excavation units at Blydefontein Rockshelter.

front of the south lobe excavations in the talus deposits. A large deep geological trench was placed in front of the one-by-one meter test trench on the terrace surface. The geological trench had the same stratigraphy as the alluvial cutbank in front of the shelter known as Blydefontein Section.

Excavation Methods

Sampson's pit was relocated, and permanent datum established on a large flat boulder laying midway between the north and south lobes of the shelter. A grid system aligned with magnetic north and centered on the datum was established over the site.

Then the site was mapped with a transit. Even though Sampson had backfilled the pit with large sandstone slabs, erosion had slumped the uppermost sediments, especially on the outside (west) side of the pit. The slabs were removed and the profiles cleaned. I placed a two-by-two meter excavation block (Block A) over Sampson's five-by-five foot (5 feet = 1.524 meter) pit. Three additional two-by-two meter blocks (B through D) were laid out on the south and east side of Sampson's pit with blocks C and D on the inside of the shelter on the east, and blocks A and B on the out (west) side. The two-by-two meter blocks were subdivided into 25-by-25 cm excavation units. Each two-by-two meter block had 64 smaller excavation unit blocks. The sediments were excavated by arbitrary unit, numbered from top to bottom in sequence. When possible, arbitrary units were subdivided by natural stratigraphic layer. The notation system used can best be described by example: $B5_{3.2}$ indicates Block B, excavation unit 5, arbitrary level 3, and natural layer 2. The sediments west of blocks C and D in blocks A and B are heavily leached and few natural stratigraphic boundaries can be deciphered. Excavation proceeded out from Sampson's pit walls.

Stratigraphy

Seven major stratigraphic layers were observed in the main excavation block at Blydefontein Rockshelter. These layers were defined in the field by Munsell soil colors and sediment texture. At least one sediment sample from each of the layers were submitted to the Soils and Physical Geography Lab, University of Wisconsin-Milwaukee for quantitative textural analysis and phosphate analysis. The textural analysis calculated the relative frequency (i.e. percentages) by weight of seven sediment texture classes. The size classes are gravels, very coarse sand, coarse sand, medium sand, fine sand, very fine sand, and silt and clay. A phosphate fraction analysis was undertaken to identify the nature of two of the layers in Blydefontein

Rockshelter (Eidt 1977). Every major stratigraphic layer contained minor stratigraphic units which usually consisted of ash or charcoal lenses. These were not analyzed individually. As shown in Figure 58 and from top to bottom the major layers are: Surface Dust (SD), Hard Grey (HG), Tan Sand (TS), Gray Ash & Charcoal (GAC), Tan Grit/Charcoal Ash & Crab (TG/CAC) and Compact Yellow (CY). Figures 59-66 and Figures 67-72 provide histograms of the sediment texture analysis.

Layer Descriptions

SD is a loose dark brown to dark grayish brown (10YR 3/3 to 4/2) loam on the surface. Sediment textures are weakly bimodal with approximately 60 percent of sediments are smaller or equal to fine sands (Figure 59). Modern sheep dung pellets are found throughout SD and this sediment is the surface deposits that are churned by modern sheep or other animals trampling.

The second layer, HG, is a slightly more firm dark grayish brown to dark gray (10YR 4/2 to 4/1) loam composed mostly of fine sand, and silts and clays (Figure 60).

CPB occurs in the northeast corner of the main excavation block at Blydefontein, and artifactually it is almost sterile. This is a very light and fluffy, but firm dark gray (10YR 4/1) loam composed of clays, silts, very fine sand, fine sand, and medium sands (Figure 61). This layer is sandwiched between HG.

TS is a discontinuous, almost sterile yellowish brown to light brownish gray (10YR 5/4 to 6/2) loose sand composed of medium sand, fine sand, very fine sand, silt and clay (Figure 62). Fragments of partially unconsolidated swallow nest were found in this layer, and the textural analysis of a modern swallow nest is more like TS than any other layer in Blydefontein Rockshelter (see Figure 63). A number of swallow nests were observed on the roof of the rockshelter during excavation and it is

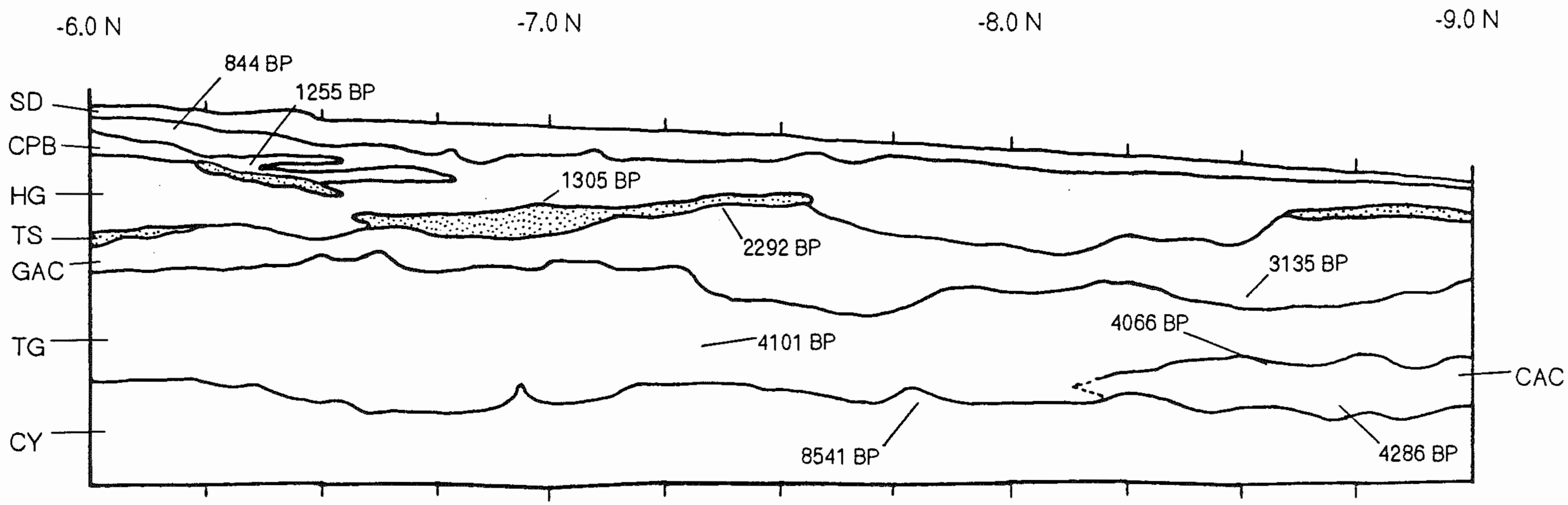

Figure 58. Stratigraphy at Blydefontein Rockshelter.

likely that swallows also used the rockshelter in prehistoric times. It is suggested that TS is mainly decomposed swallow nest, and represents a stratigraphic marker between Layers HG and GAC in this portion of the rockshelter deposits.

GAC is a dark gray (10YR 4/1) sandy loam with a bimodal distribution (Figure 64). Distribution peaks occur in gravel sized particles and very fine sands. Abundant charcoal from prehistoric hearths characterized this layer, and clearly GAC represents a period of intensive prehistoric occupation.

TG is a brown to grayish brown (10YR 5/3 to 5/2) loam with a single modal peak in the fine sands range near the top of the layer and an increase in very fine sands and silt/clay toward the bottom of the layer (Figures 65 and 66).

CAC is a hearth complex in the bottom of and interfingering with Layer TG. Originally it was thought to be a separate layer, but radiocarbon dates (discussed below), and stable carbon isotope analysis of ostrich eggshell from excavation units in both sedimentary units all point to Layer CAC as overlapping and coeval with the bottom of Layer TG (Figure 67). The sediment analysis indicates that CAC is very similar to the lower TG sample as well with almost equal amounts of fine sands, very fine sands and silt/clay (Figure 68).

CY is a thick yellow silt loam layer that was divided into subunits. Three brown loam sub-layers (Brown 1, Brown 2 and Brown 3 from top to bottom) were discovered in the lower half of this unit, but only the Brown 2 layer extended across the entire east profile. The yellow silts (Upper Yellow) were sampled above the Brown 1 layer, between the Brown 1 and 2 layers (Middle Yellow), and between the Brown 2 and 3 layers (Lower Yellow). Upper Yellow is a brownish yellow to yellowish brown (10YR 6/6 to 5/6) silt loam with the highest percentage of material in the silt/clay texture clay and stepwise reductions of material in each larger texture class (Figure 69). The large amounts of silt/clay may be due to decomposition, but as the bedrock is sandstone, it is more likely that the greater amount of silt/clay in this layer represents an increased amount of wind deposited materials. Neither this layer, nor any sub-layer in CY has evidence of intense human occupation.

Middle Yellow is a very pale brown to light yellowish brown (10YR 7/4 to 6/4) silt loam (Figure 70). It's textural distribution is very similar to that in the Upper Yellow with the greatest percentage of material occurring within the silt/clay size range and decreasingly less material in each larger size class.

Brown 2 is a brown (10YR 5/3 to 7.5YR 5/2) loam. The sediment texture of Brown 2 is slightly more coarse than the texture of Upper or Middle Yellow (Figure 71). It is assumed that the textures of Brown 1 and Brown 3 would be of similar texture to Brown 2.

Lower Yellow is a reddish yellow to brown (7.5YR 6/6 to 5/4) loam. The texture distribution shows a weakly bimodal distribution with a major peak of very fine sands and a weak gravel peak (Figure 72).

The sediments in CY, except for the Brown sub-layers, are believed to represent natural depositional processes with most of the material occurring in the silt/clay range. These sediments probably were deposited through aeolian processes. In layers with more intensive human occupations coarser grained materials occur. Usually the fine sands form the largest mode and a second mode occurs in the gravels. As the analysis of the swallow's nest indicates, at least one source of the fine sands could be decomposed swallow's nests, and it is possible that humans dislodged nests stuck to the overhang roof incorporating swallow nests into the sediment matrix at a faster rate that would normally occur. It should be mentioned that in some layers, eg. CAC and GAC, charcoal, ash, artifacts, and faunal remains formed a significant amount of the matrix, and that true sediment, ie. gravels, sand, silt and clay, was not the dominant constituent of these layers. Another texture size that sometimes forms a secondary mode in the texture analysis is gravels. One obvious source is from the walls and roof of the shelter itself. It is also possible that the prehistoric inhabitants also tracked in a significant amount of this material as gravel modes seem to occur in layers with more intensive occupations.

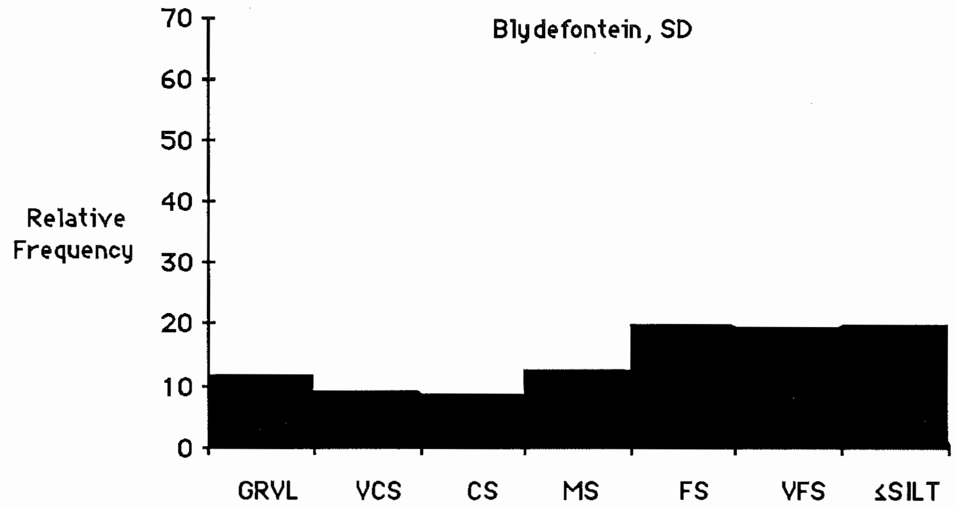

Figure 59. Sediment texture analysis of layer SD, Blydefontein Rockshelter.

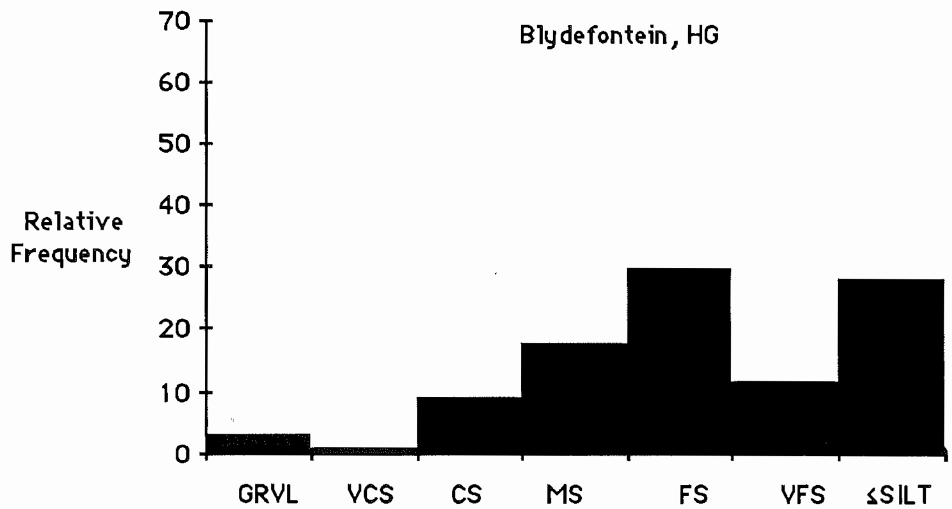

Figure 60. Sediment texture analysis of layer HG, Blydefontein Rockshelter.

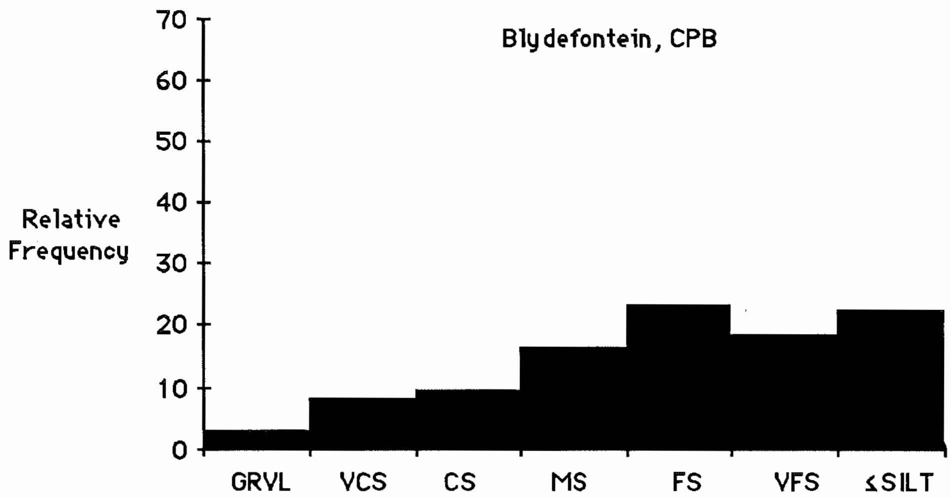

Figure 61. Sediment texture analysis of layer CPB, Blydefontein Rockshelter.

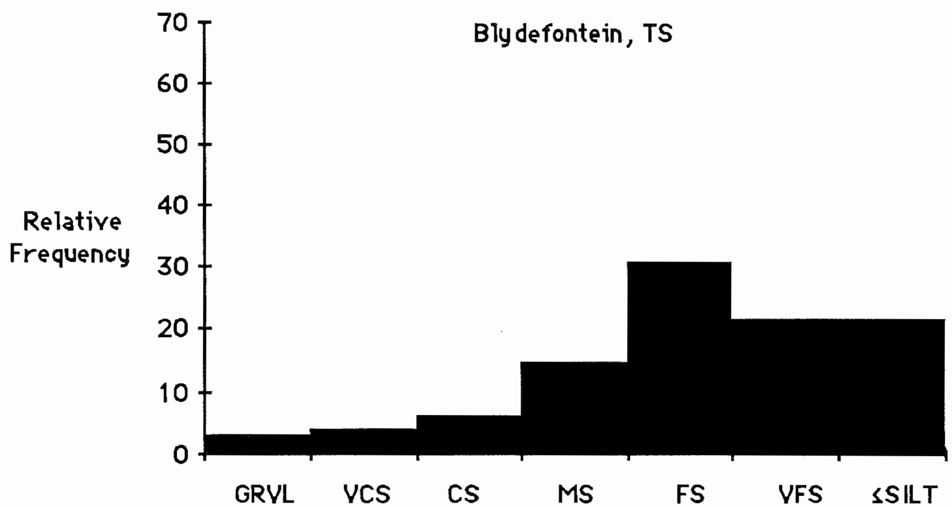

Figure 62. Sediment texture analysis of layer TS, Blydefontein Rockshelter.

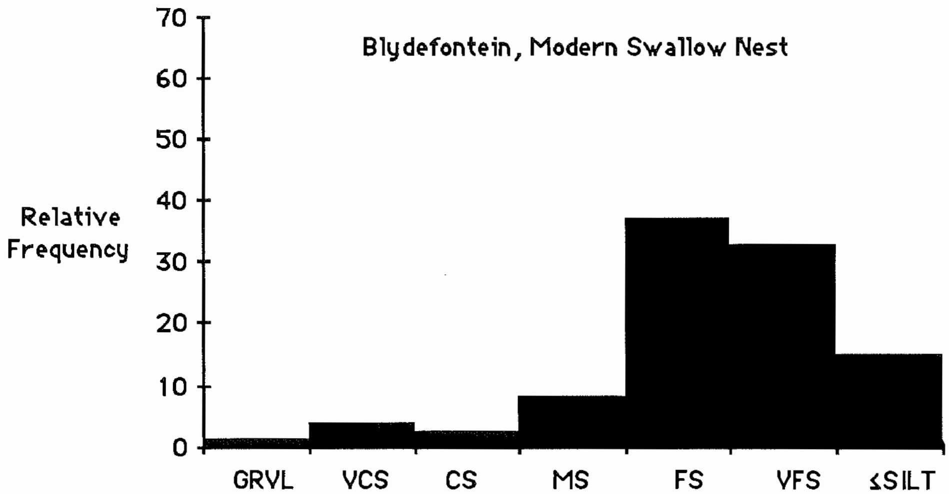

Figure 63. Sediment texture analysis of modern swallows nest from Blydefontein Rockshelter.

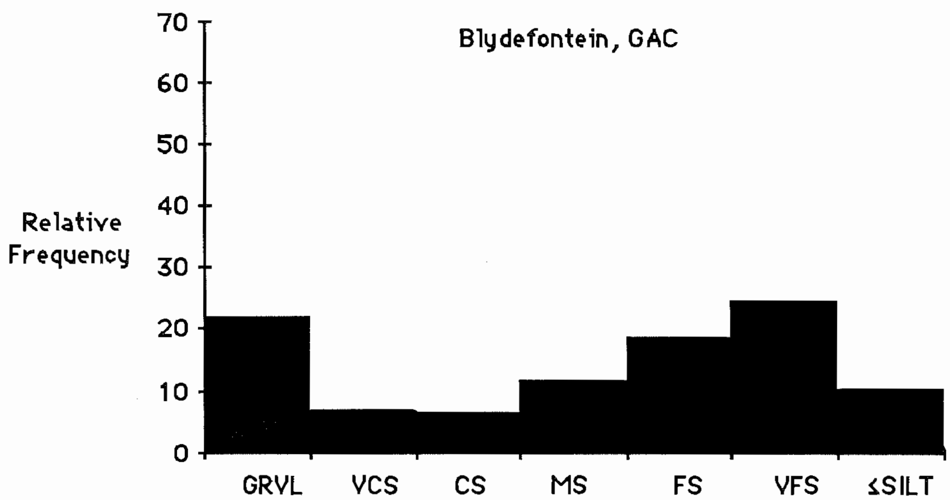

Figure 64. Sediment texture analysis of layer GAC, Blydefontein Rockshelter.

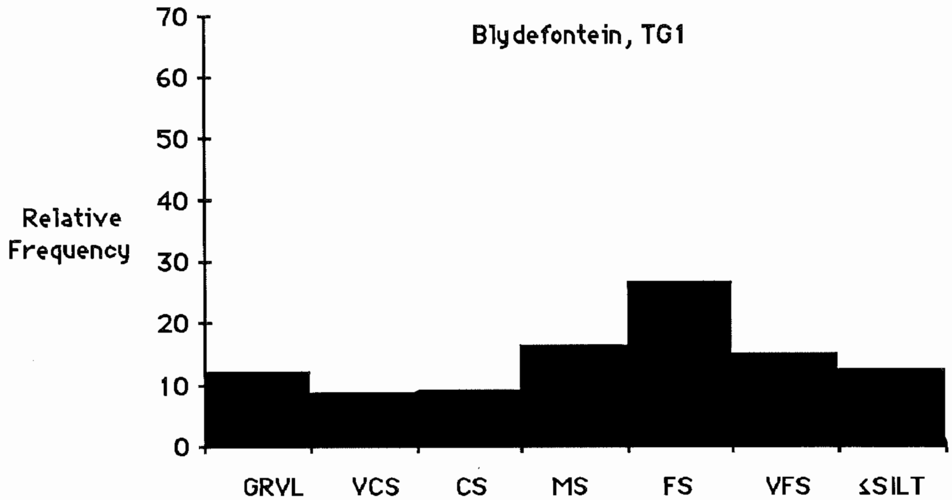

Figure 65. Sediment texture analysis of layer upper TG, Blydefontein Rockshelter.

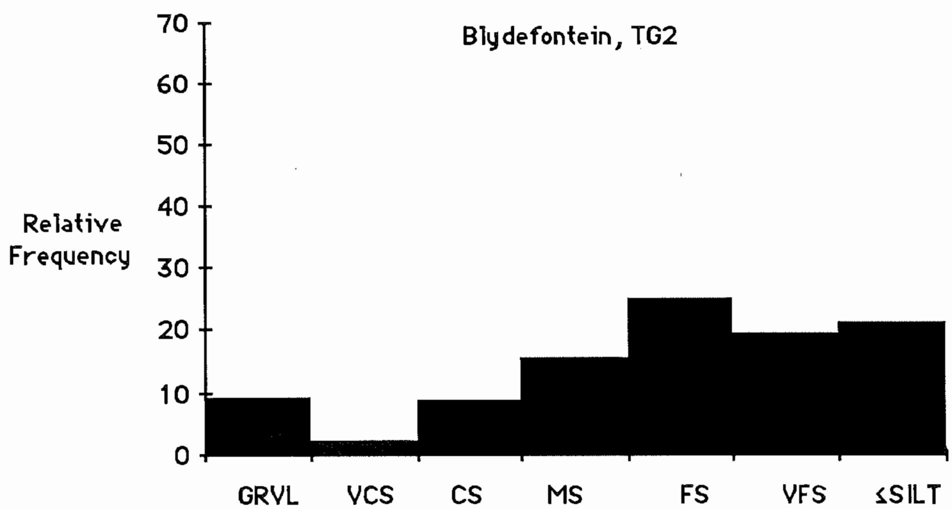

Figure 66. Sediment texture analysis of layer lower TG, Blydefontein Rockshelter.

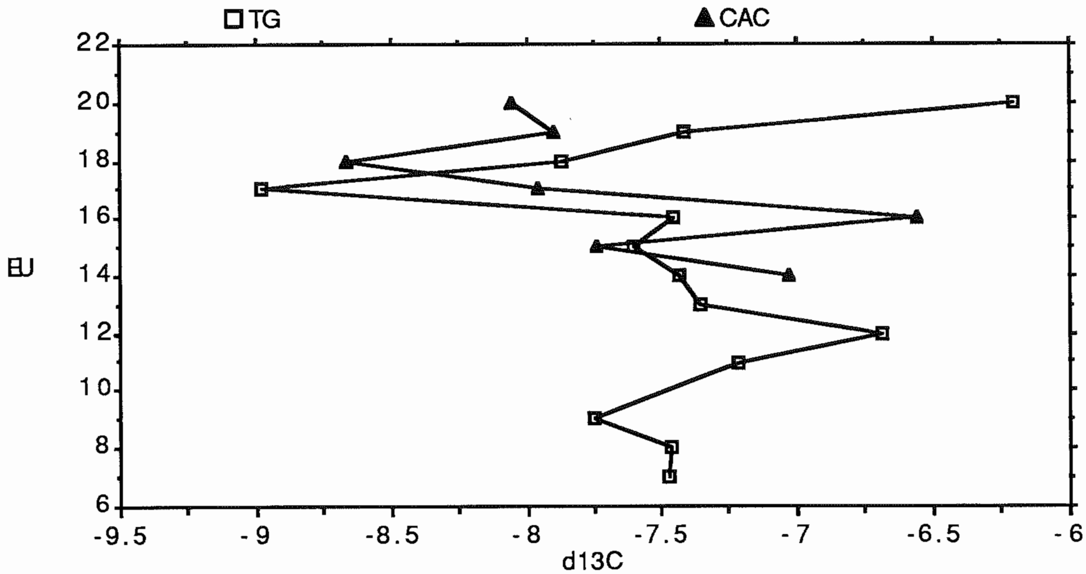

Figure 67. Ostrich eggshell d13C values from Layers TG and CAC plotted by excavation units (EU). Excavation units plotted in reverse order from top to bottom.

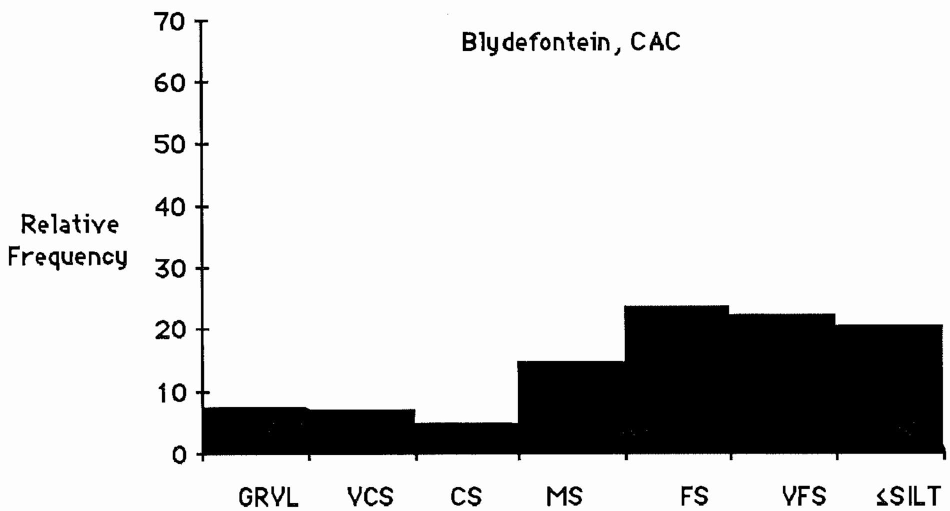

Figure 68. Sediment texture analysis of layer CAC, Blydefontein Rockshelter.

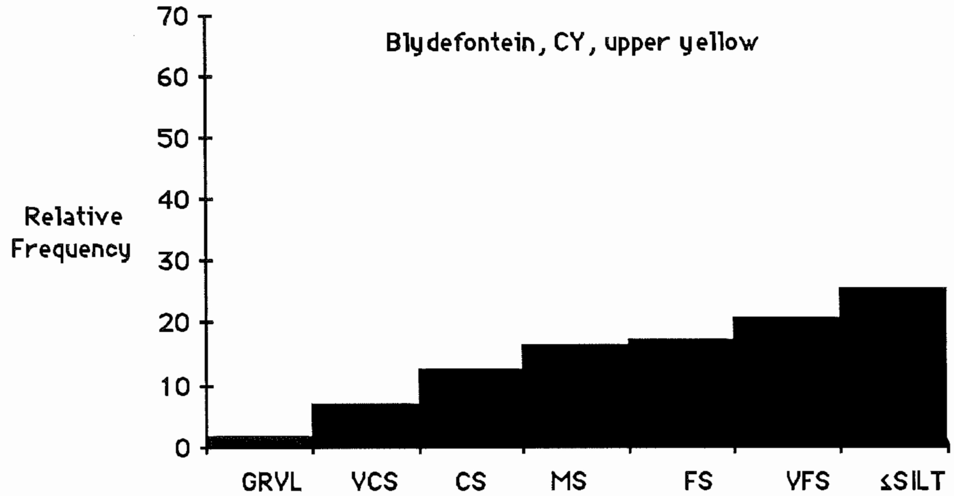

Figure 69. Sediment texture analysis of layer upper CY, Blydefontein Rockshelter.

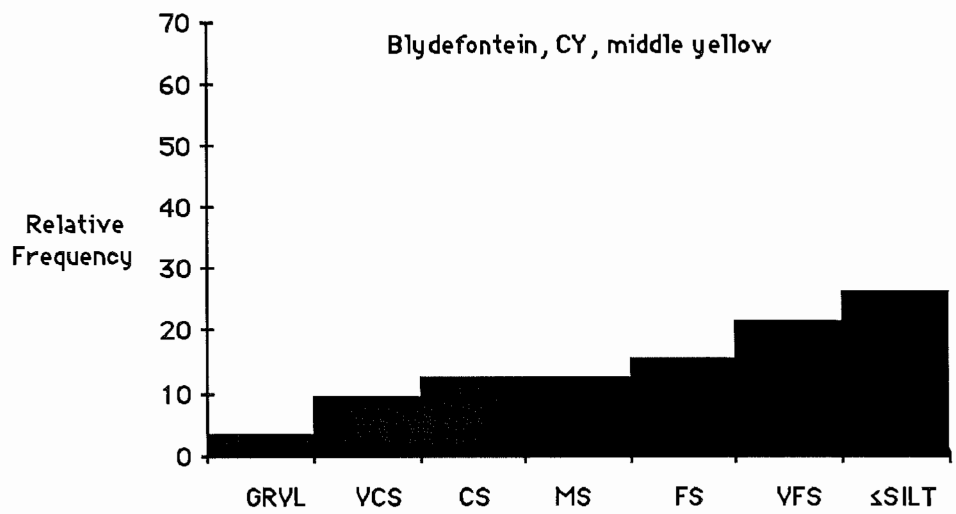

Figure 70. Sediment texture analysis of layer middle CY, Blydefontein Rockshelter.

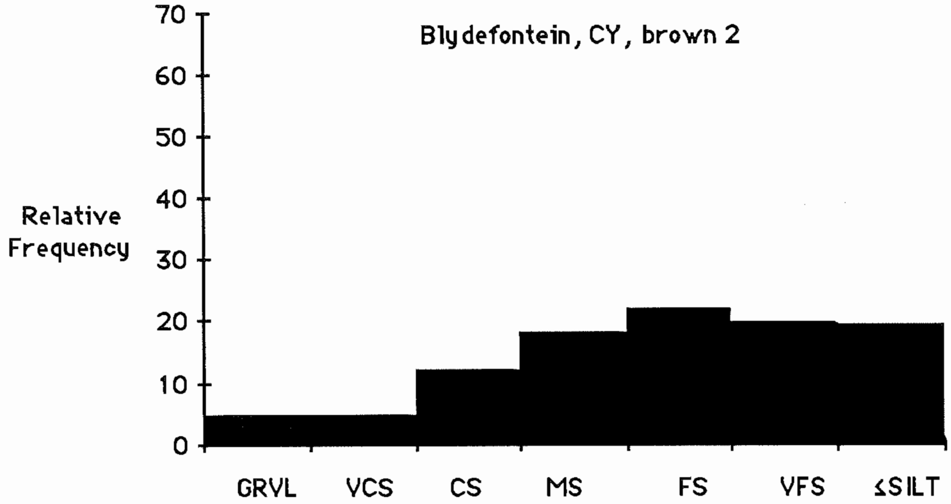

Figure 71. Sediment texture analysis of layer Brown 2 in CY, Blydefontein Rockshelter.

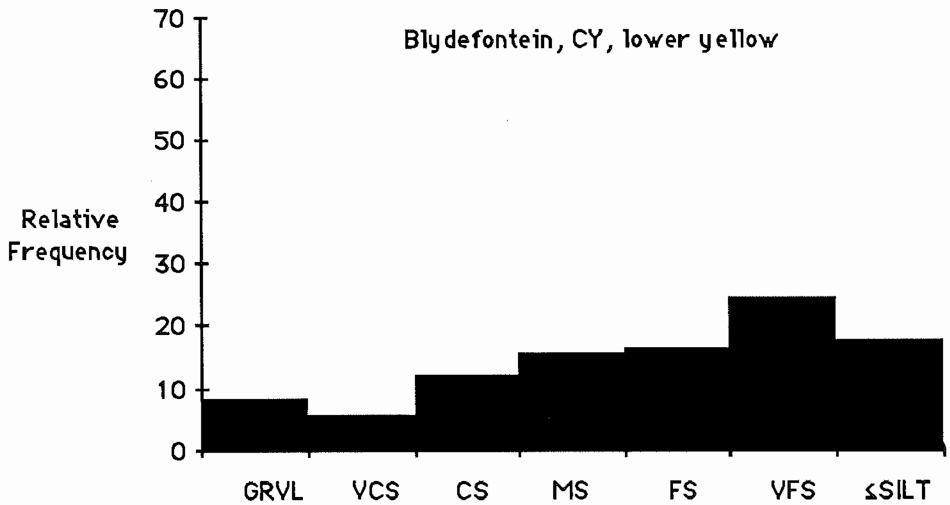

Figure 72. Sediment texture analysis of layer lower CY, Blydefontein Rockshelter.

Radiocarbon Chronology

Nine radiocarbon assays were run on charcoal from Blydefontein Rockshelter (Table 17). All samples were charcoal and collected from discrete occurrences within a single 25-by-25cm excavation unit. The dates were calculated with the 5568 year half-life, corrected for carbon isotope fractionation, and calibrated with the Stuiver and Pearson (1986) and Person and Stuiver (1986) calibration. An attempt was made to date the tops and bottoms of layers as well as select samples with abundant charcoal remains.

Table 17.--Radiocarbon dates from Blydefontein Rockshelter. Only approximate calibrations are possible for dates older than 8100 B.P.

Layer	Excavation Unit	Lab Number	Corrected B.P.	Calibrated B.P.
HG	$C2_{2}$	SMU-1902	844±119	768±105
CPB	$C10_{3}$	SMU-1925	1255±109	1187±112
HG	$C42_{3}$	SMU-1850	1305±31	1256±36
GAC	$C50_{5}$	SMU-1853	2292±117	2318±141
GAC	$D18_{8}$	SMU-1849	3135±33	3372±33
TG	$C18_{14}$	SMU-1901	4101±273	4613±365
CAC	$D26_{16}$	SMU-1851	4066±55	4578±108
CAC	$D17_{20}$	SMU-1852	4286±149	4855±193
CY	$C57_{23}$	SMU-1823	8541±417	ca. 9440

The results of the radiocarbon dates suggest that the accumulation of deposits represents a coherent chronological succession. No datable charcoal was recovered from the bottom of CY. The single radiocarbon date is from Upper Yellow sub-layer and it indicates that this portion of Layer CY dates to the Early Holocene. Three radiocarbon ages are available for TG/CAC. Unfortunately at the time the radiocarbon samples were selected it was believed that TG and CAC were separate layers, and samples from the top and bottom of Layer CAC were dated by radiocarbon but only the middle of Layer TG. This resulted in no radiocarbon date for the top of Layer TG.

Radiocarbon samples from the top and bottom of Layer GAC were dated, as well as top and bottom samples from HG. These dates suggest that Layer TG/CAC began to accumulate at approximately 4300 B.P. Layer GAC accumulated between 3135 B.P. and 2292 B.P. and possibly as late as 2000 B.P. as implied by Sampson's radiocarbon date 1980±120 B.P. (SR-132) that appears to come from the top of Layer GAC. Layer HG appears to have accumulated between 1305 B.P. and 844 B.P. with the age of CPB estimated at 1255 B.P. Sediment deposition dramatically slowed after 844 B.P. as evidence by the thinness of the surface Layer SD. The lack of sediments after 844 B.P. is believed to be due to the lack of human occupation in Blydefontein Rockshelter during this period.

Phosphate Analysis

Phosphate fraction analysis (Eidt 1977: 1327-1333, 1985: 155-190) was undertaken in order to understand better the mode of sediment deposition in Blydefontein Rockshelter. Based on field observations two layers, CPB and TS, appeared to originate from animal sources. Analysis of the inorganic phosphates from these deposits was undertaken to help assess the possibility of contamination from human or animal sources. Inorganic phosphates can be divided into three types or fractions. The first fraction is the available or non-occluded phosphates. This fraction is further divided into phosphates loosely bound to aluminum and iron (Fraction 1a), and phosphates (re)sorbed by calcium carbonate (Fraction 1b). Fraction II is the occluded or tightly bound phosphate incorporated with aluminum and iron oxides, and hydrous oxides. Fraction III is apatite or other tightly occluded calcium phosphates such as that found in the inorganic fraction of bone or in mineral grains. These individual fractions summed equal the total inorganic phosphates. Eidt (1977) indicates that Fraction I phosphates change to Fraction II phosphates systematically through time, and thus the ratio of Fraction II to Fraction I is time dependent.

Unfortunately sediment samples were too small for phosphate fractionation analysis of all layers at Blydefontein Rockshelter. Four layers and a series of control samples were selected for analysis. An inspection of total inorganic phosphates in Table 18 shows that the SD and CPB samples have high levels of total inorganic phosphate, and these compare well with levels from modern hyrax and sheep dung. As the SD sample had modern sheep dung mixed with the sediments, its high total inorganic phosphate level is not surprising. The total phosphate level of CPB strongly suggests that animal dung is a major constituent of this deposit, and the field observations support this hypothesis. The two most obvious animal species that could be responsible are hyrax or domestic sheep.

Prehistorically many rockshelters were used by sheep herders (Hall and Smith 1986; Hart 1989; Schweitzer 1979), and at least one shelter, Boomplaas, has burned sheep dung that makes up a significant portion of its deposits (H. Deacon et al. 1978). Prehistorically sheep are documented in the coastal zone of southern Africa from approximately 2000 B.P. (Klein and Cruz-Uribe 1989; Schweitzer and Scott 1973), so the possibility of sheep are responsible for the deposition of CPB is chronologically feasible. Blydefontein shelter was used by modern herders as a kraal, but the cliffs surrounding the shelter are also favored by hyrax for habitation. Unfortunately the phosphate analysis cannot identify which animal species contributed the phosphates in the CPB layer. However hyrax middens have significant amounts of well preserved pollen, but CPB had little pollen and it was poorly preserved (Louis Scott personal communication). Nevertheless no sheep bones were recovered from the rockshelters (Richard Klein personal communication), so more analysis is required before this layer can be definitely identified as sheep dung and thus indicative of a herder occupation.

Table 18.--Phosphate fractions ($^o/oo$) of selected sediment samples from Blydefontein Rockshelter. Percent of Fraction II is minus Fraction III

Sample	Fraction Ia	Fraction Ib	Fraction II(%)	Fraction III	Total
SD	16	1304	413(23.8)	777	2510
CPB	215	767	404(29.1)	1059	2444
TS	33	289	284(46.9)	854	1461
CY	35	360	440(52.7)	1130	1965
Modern Swallow nest	26	30	20(26.3)	422	499
Modern Hyrax Midden	250	472	279(27.9)	272	1273
Modern Hyrax Midden	434	1412	253(12.1)	512	2611
Modern Sheep Dung	213	2800	174(5.5)	93	3280

Analytical Units at Blydefontein Rockshelter

As Blydefontein was excavated in such a disjointed manner the analysis required that the site be considered as at least two separate units. The artifacts from Block B were analyzed as a unit in the arbitrary spits in which they were dug with the exceptions that $B_{4.5}$ levels were combined with B_4 levels, and $B_{8.5}$ levels were lumped with B_8 levels. In addition some levels, usually B_{12} levels, were split stratigraphically when Layer CY was encountered. Blocks C, D and a portion of A, hereafter called Block C-D, were much more complex to correlate. The approach used was to arrange analytical units by arbitrary spits within major layers, eg. GAC, and then arrange each stratigraphic layer's stack end-on-end in their correct vertical order. Artifacts from some of the Block A spits were not included in this analysis. This was done because these artifacts came from those spits in the northwest corner of

Block A where no stratigraphy survived and I attempted to teach the crew to excavated. This experiment resulted in irregularly excavated arbitrary spits that could not be correlated with the remainder of the excavations without a dramatic loss of stratigraphic resolution. As artifact numbers were low in this portion of Block A, artifacts from these excavation units were dropped from the analysis. The resulting units, called Analytical Units (AU) were used for all analysis, and these are shown in Figure 73.

The integration of Block B with Block C-D required a loss of stratigraphic resolution, however because of small artifact numbers the resulting Combined Analytical Units (CAU) form the basic units for most of the analysis in the final chapter. The Combined Analytical Units were consolidated by visually matching the placement of the excavation units for Block B with Block C-D for the upper layers. In Layer CY, because of low artifact numbers and sporadic distributions, artifact numbers among the arbitrary spits were inspected in Block B which did not have any continuous Brown sub-layers recognized during excavation. The vertically and horizontally clustered distributions of artifacts were used to define CAUs in Layer CY (Figure 74).

Meerkat Rockshelter Excavations

Meerkat Rockshelter is approximately 0.75km south of Blydefontein Rockshelter. It is a much smaller overhang and nearer to the stream channel. Terrace deposits appear to extend below the overhang, but excavations did not reach fluvial sediments. Two adjacent one-by-one meter test pits were excavated at Meerkat Rockshelter. Meerkat was excavated in order to support and confirm the Blydefontein Rockshelter sequence.

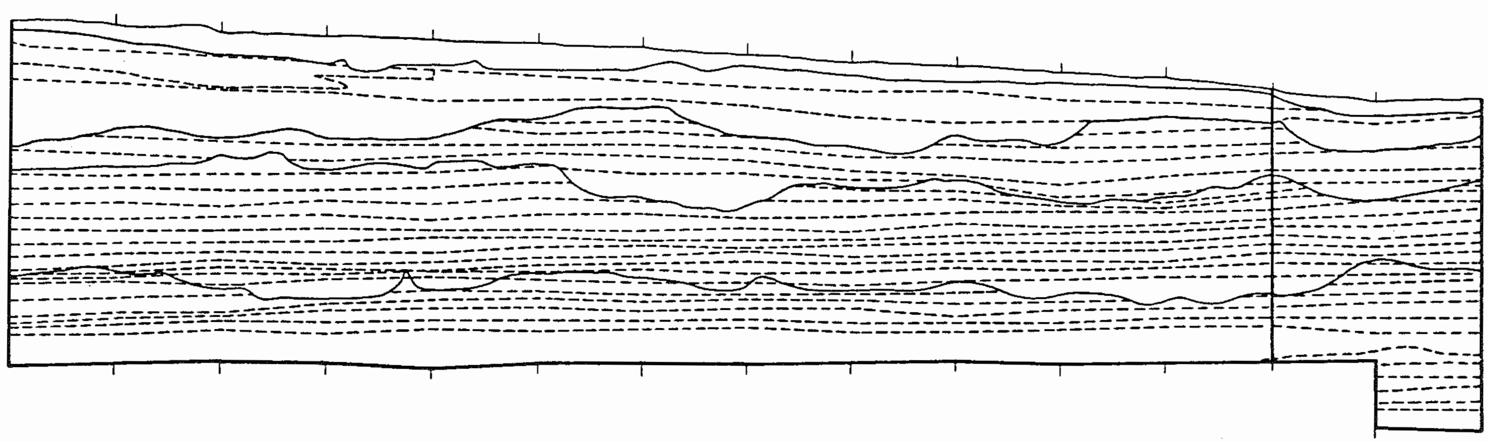

Figure 73. Analytical Units at Blydefontein Rockshelter.

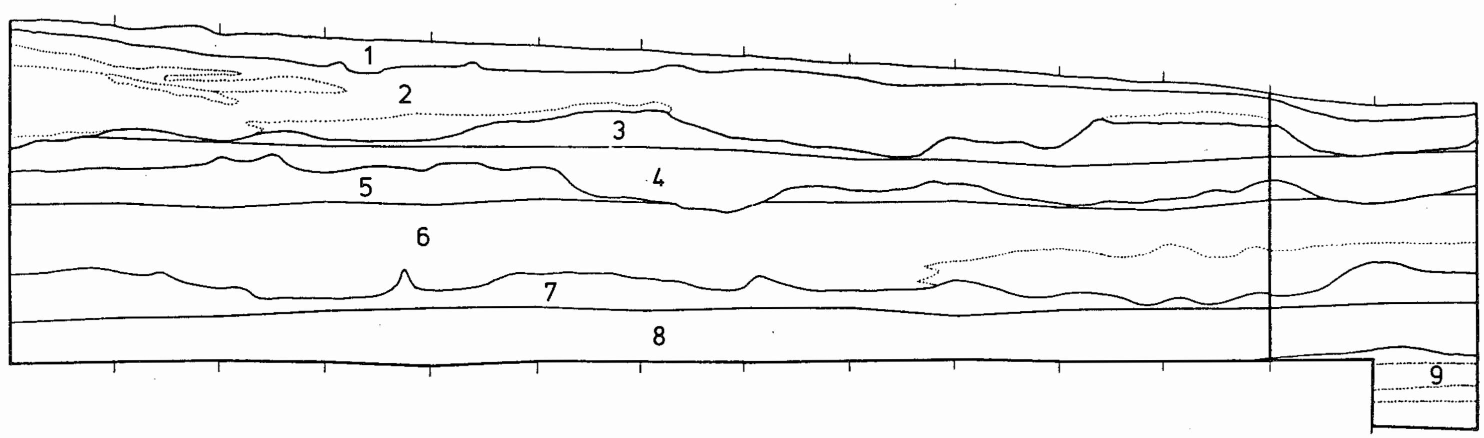

Figure 74. Combined Analytical Units at Blydefontein Rockshelter.

Two one-by-one meter blocks were excavated at Meerkat Rockshelter (Figure 75). Each one-by-one meter block was subdivided into 25-by-25 cm excavation units producing 16 smaller excavation unit blocks. The sediments were excavated by arbitrary unit, numbered from top to bottom in sequence. When possible, arbitrary units were subdivided by natural stratigraphic layer. The notation system is the same used at Blydefontein Rockshelter and can best be described by example: $A6_{5.2}$ indicates Block A, excavation unit 6, arbitrary level 5, and natural layer 2 within level 5.

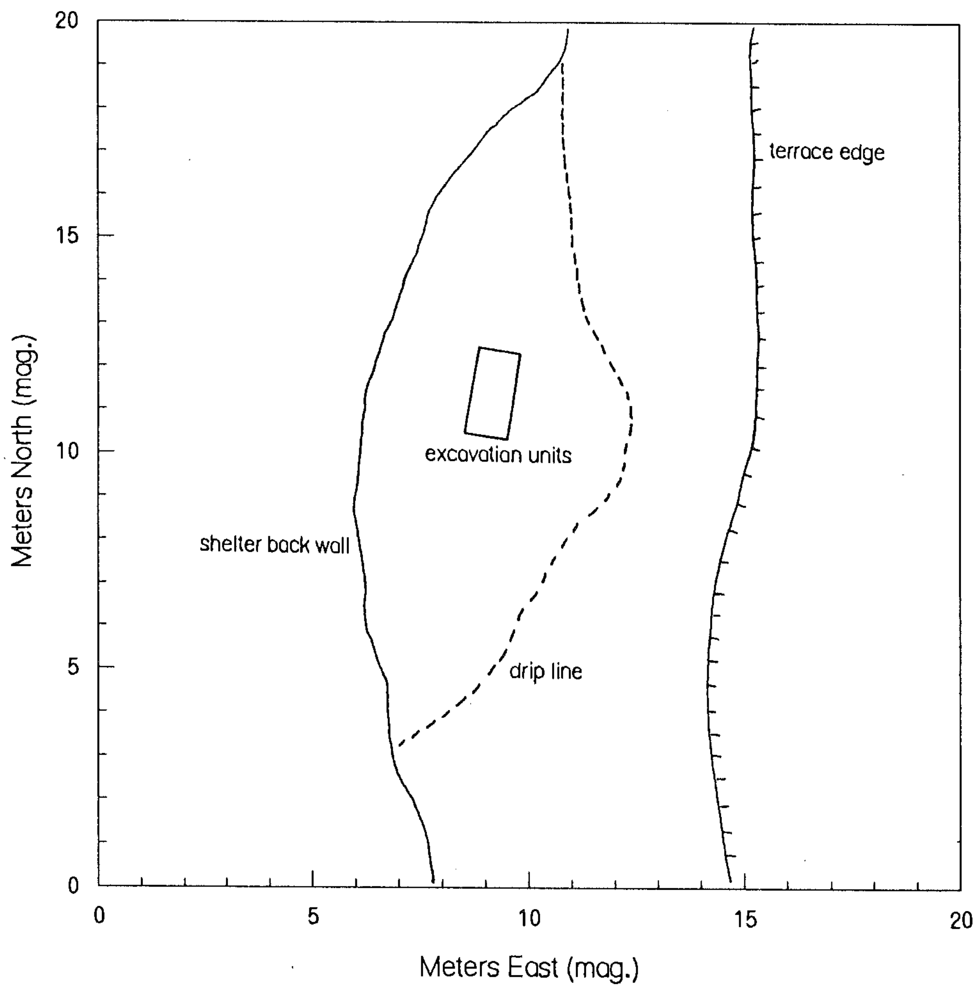

Figure 75 Map of Meerkat Rockshelter.

The stratigraphy at Meerkat Shelter was not as complex as at Blydefontein. Five major layers were identified (Figure 76). These layers were defined in the field by soil color (Munsell Soil Color Chart) and sediment texture. At least one sediment sample from each of the layers were submitted to the State Soils Lab, University of Wisconsin-Milwaukee textural analysis. The same textural classes applied to the Blydefontein Rockshelter were used for the Meerkat Rockshelter sediments. Some major stratigraphic layers contained minor stratigraphic units which usually consisted of ash or charcoal lenses. These were not analyzed individually. From top to bottom the major layers are: Surface Dust (SD), White Ash (WA), Brown Silt (BS), Gray Ash & Charcoal (GAC), and Yellow Silt (YS).

Layer Descriptions

SD is a surface deposit that has been churned by trampling. In a few excavation units untrampled deposits were excavated and identified as Brown Above Ash. SD and Brown Above Ash are a grayish brown (10YR 5/2) silty sand (Figure 77). These surface stratigraphic units are separated from deposits below by the White Ash layer, which is a thin layer of burnt material that might be dung.

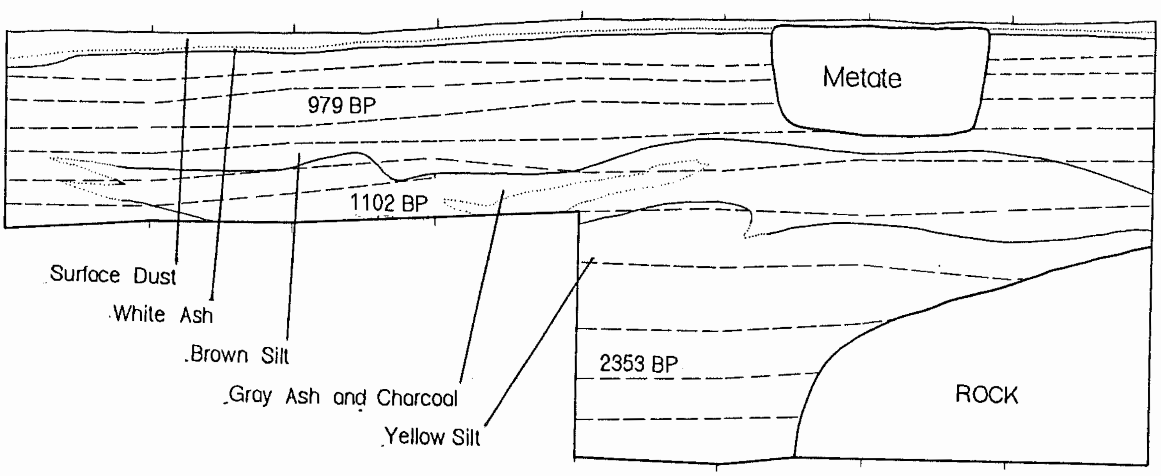

Figure 76. Stratigraphy at Meerkat Rockshelter.

Below the thin White Ash layer is a grayish brown (10YR 5/2) silt called Brown Silt (BS). The major components of this layer are very fine sand and silt (Figure 78). Within the Brown Silt layer is a thin lens of gray ashy sediment.

Below the Brown Silt layer is a relatively thick dark grayish brown (10YR 4/2) silt loam layer that consists of interlocking hearths, and scattered charcoal and ash. This is called Gray Ash and Charcoal (GAC). These sediments are similar to the Brown Silt layer above with very fine sands and silts, but the Gray Ash and Charcoal Layers also has a slightly greater amount of gravels (Figure 79). In the middle of this layer is a thin brown zone with less charcoal and ash. This allowed layer GAC to be divided into three minor layers: Upper Gray, Mid Brown and Lower Gray.

Below the complex of hearths in Lower Gray is a thick layer of brown (10YR 4/3) silt loam. In the field this was label Yellow Silt and it consists of very fine sands and silts (Figure 80).

The sediment analysis at Meerkat Rockshelter demonstrates less textural variability between layers as compared to Blydefontein Rockshelter. Except for the surface sample, all samples are dominated by the fine textural classes, and these layers are very similar texturally to Layer CY at Blydefontein. However Layer CY was much firmer, and of different color. It is possible that aeolian processes and slopewash of aeolian sediments contributed a major source of sediments documented in the Meerkat Rockshelter deposits. Even though Meerkat is very close to the stream no evidence of fluvial depositional processes was discovered at the level excavated, and in fact the shelter is approximately 5-6 meters above stream level.

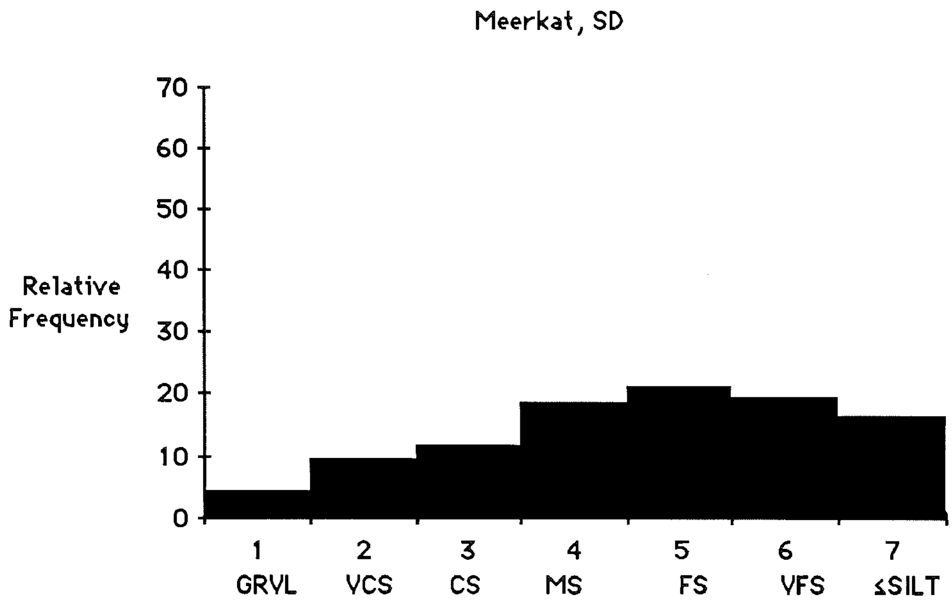

Figure 77. Sediment texture analysis of layer SD, Meerkat Shelter.

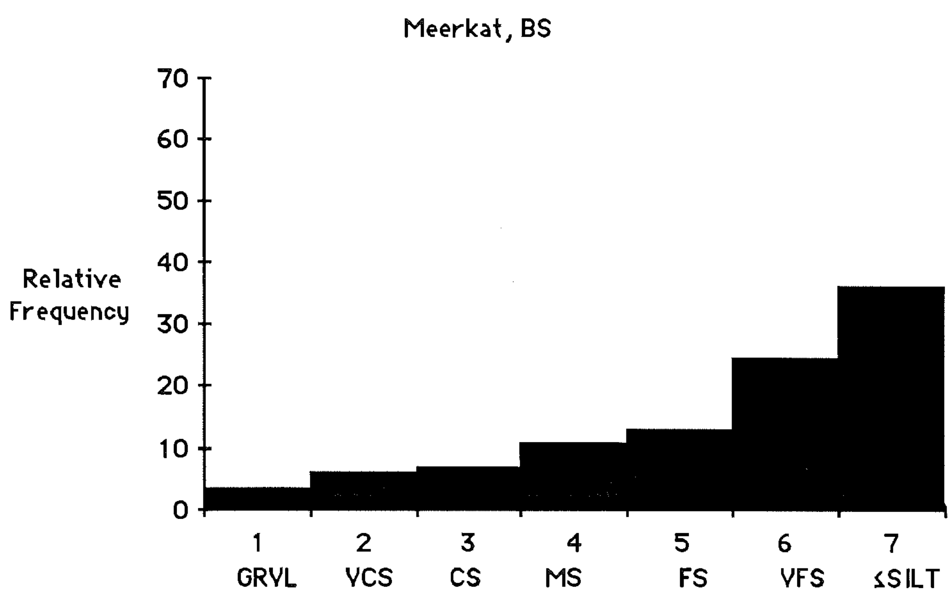

Figure 78. Sediment texture analysis of layer UB, Meerkat Shelter.

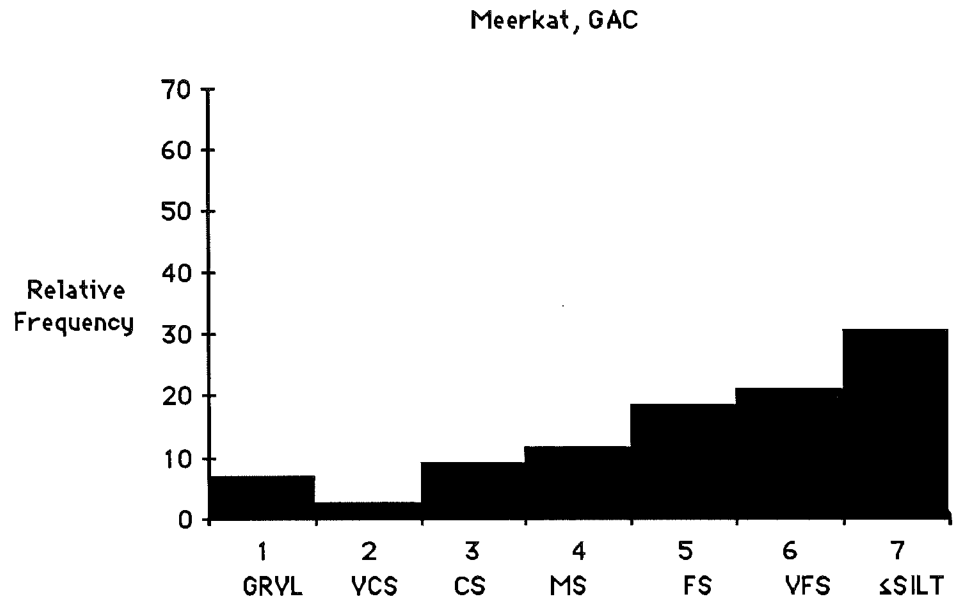

Figure 79. Sediment texture analysis of layer Gray, Meerkat Shelter.

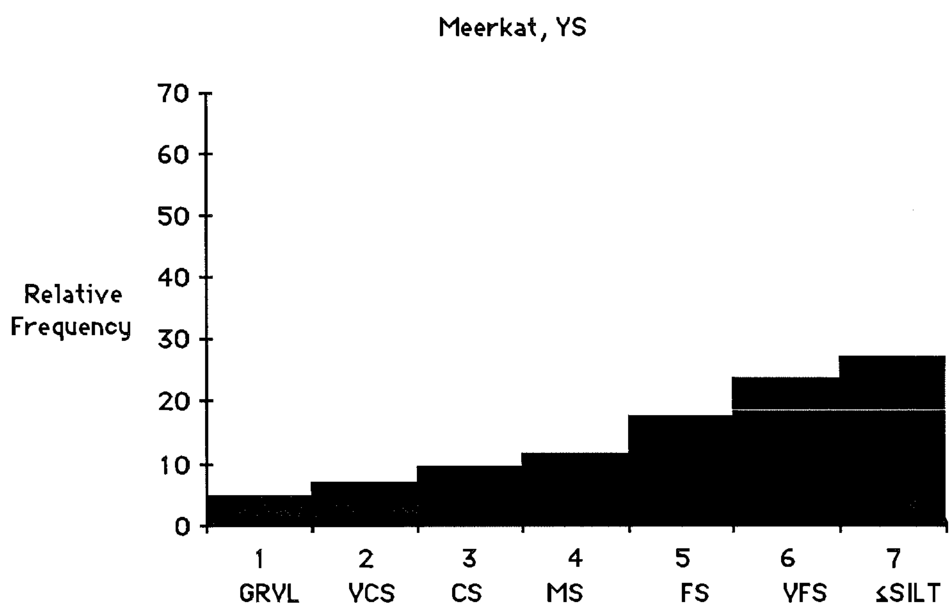

Figure 80. Sediment texture analysis of layer YS, Meerkat Shelter.

Radiocarbon Chronology

Three charcoal samples were submitted for dating to the Radiocarbon Dating Laboratory at Southern Methodist University (Table 19). All samples were charcoal and collected from discrete occurrences within a single 25-by-25 cm excavation unit although these were not clear identifiable hearths. The dates are calculated with the 5568 year half-life, corrected for carbon isotope fractionation, and calibrated with the Stuiver and Pearson (1986) and Pearson and Stuiver (1986) calibration. Unlike the sampling strategy used in Blydefontein Rockshelter, no attempt was made to date the tops and bottoms of layers. Natural layers in Meerkat were too few and too diffuse to allow that type of dating scheme. Rather samples were selected based on their association with diagnostic tools or depth.

Table 19.--Radiocarbon dates from Meerkat Rockshelter

Layer	Excavation Unit	Lab Number	Corrected B.P.	Calibrated B.P.
GAC	$B2_5$	SMU-1899	979±70	895±77
GAC	$B3_7$	SMU-1898	1102±62	1015±73
YS	$A13_{12}$	SMU-1931	2353±122	2389±159

Summary

The results of the stratigraphic investigations suggests that the sediments in to two shelters accumulated with a significant contribution from the human occupants. Blydefontein Rockshelter provides the long term view of occupations in the Basin, but with little possibility of truly fine chronological separation of assemblages. Chemical analysis of sediments from Blydefontein Rockshelter can be used to suggest a brief interval of stock herding at 1255 B.P. It is unfortunate that no charcoal was recovered from the lower portion of CY at Blydefontein as these sediments could date to the Late Pleistocene as will be suggested below from the archaeological remains recovered from these sediments. Meerkat, on the other hand, represents a much shorter period of time and has the possibility of providing a much more detailed view of prehistoric occupations in the Basin, especially within the last 2500 years.

CHAPTER IX

CHRONOLOGICAL MARKERS OF THE INTERIOR WILTON SEQUENCE

About 5000 Interior Wilton sites were discovered in the adjacent Zeekoe valley (Sampson 1985). Our survey records include "phase" labels for each site (early, classic, developed or ceramic), based on the presence or absence of diagnostic stone tool types and ceramics. This was a direct field application of Sampson's (1972, 1974) four-phase system of classification derived from rockshelter sequences, including Blydefontein, in the Middle Orange River.

Many of the surface sites which we examined and classified by these criteria emerged as apparently mixed palimpsests of two or more phases. It remains to be seen whether this is the correct interpretation. Given the unstated assumptions of the original four-phase system (unilinear evolution), and given the shortcomings (see Chapter I) of the excavated sites from which it was built (Sampson 1967a, 1967b, 1970, 1972; Sampson and Sampson 1967), our field classifications are of limited use at present. For this reason, separate distribution maps of each "phase" of the Interior Wilton have not been published (Sampson 1985: 69).

One of the objectives of the Zeekoe Valley Archaeological Project is to trace changes in the Interior Wilton (IW) settlement pattern through time. These in turn can be compared with the environmental trends summarized in Chapter VII. The comparison cannot be made, however, unless the existing IW site distribution map can be broken down chronologically to show trends in the IW settlement pattern. It is of the utmost importance, therefore, that an improved system of cross-dating of surface sites be established. Surface sites lack associated organics, so the only viable method is the conventional one: to compare stone tool designs with those from a tightly dated and stratigraphically secure sequence. Blydefontein and Meerkat Rockshelters were excavated to establish that sequence.

The Artifact Samples

Blydefontein Rockshelter was divided into four blocks. Block A, covering Sampson's (1970) excavation, was not used in this analysis. Block B is a larger area where rain and roof drip has leached out the visible stratigraphy. Here, nothing but the boundary between CY and all the above deposits can been seen. Except at this boundary, all of Block B was excavated in thin, arbitrary spits only a few centimeters thick. Blocks C and D, being the most protected, contained finely stratified sediments. These were excavated by individual micro-layer and some thicker layers were arbitrarily split into sub-layers.

Although the artifact assemblages from C and D have the best contextual integrity of any assemblage in the Karoo, some of them are too small for statistical analysis. I was thus compelled to combine them with material from the adjacent Block B. Correlations between stratified layer assemblages and adjacent spit assemblages was based on shared elevations. This procedure undoubtedly detracts from the integrity of the Combined Analytical Units (CAUs), but the compromise is essential to obtain statistically valid samples that can provide meaningful results. Artifact counts for individual layers and/or spits in each block are given in Appendix B.

Meerkat Rockshelter was test excavated with two adjacent, 1-meter square blocks. Time did not permit larger excavations, and the samples are small. Meerkat had less visible stratigraphy than Blocks C-D in Blydefontein, and it was excavated in arbitrary spits subdivided by natural stratigraphic boundaries when possible. Nevertheless, Meerkat artifact distributions have chronological patterning, but small sample size makes the Meerkat results less reliable than those obtained from Blydefontein Rockshelter.

The Artifact Analysis

Design changes through time of four Interior Wilton artifact classes are examined. These include backed microliths and projectile points, endscrapers, ostrich eggshell beads, and ceramics. These artifacts were chosen because observations could be made easily on surface site assemblages in the field. Also, a number of other attributes were also found to have temporal patterning (to be discussed in Chapter XIII), but these were not included here because their documentation on surface site assemblages would be too time consuming, or their chronological patterns were too variable, or their inclusion produced no increased resolution for the chronological placement of undated surface assemblages. Thus the set of artifacts used here provide easy-to-recognize attributes that display maximum chronological patterning.

Analytical Procedures

The selection of units-of-comparison has generally followed the procedure identified by Sackett (1982) as isochrestic style analysis. This approach attempts to analyze changes through time in functionally similar artifacts (as suggested by morphology). Collaboration of artifact function would benefit through a wear pattern study of use-damage on artifacts, but ethnographic observations (Clark 1959, 1977; Dunn 1880, 1931; Kannemeyer 1890; Rudner 1979) and previous wear pattern studies (Binneman 1982, 1983, 1984; Binneman and Deacon 1986) conducted locally can be used to infer stone tool functions with a reasonable amount of confidence. The four groups of formal artifacts analyzed in this chapter were selected, in part, because they also provide a reasonable amount of morphological variety within individual functional classes.

Backed Tools and Projectile Points

The Interior Wilton artifacts that are most likely to display some form of stylistic patterning are the backed microliths and projectile points. Dunn (1880), Goodwin (1945) and Clark (1959, 1977) discuss the probable uses of these artifacts through an analysis of ethnographic collections from southern Africa, and it appears that they are used, for the most part, as arrow armaments. This may be correct in a general sense, although they may have had secondary uses for a variety of purposes including drills for ostrich egg shell beads or inserts in composite cutting tools. Morphological variations have long been recognized and these will be discussed below, however it should be noted that double backed tools with tip damage indicative of use as drills were not used in this analysis.

Eight variations of backed tools have been identified. Diagnostic criteria are backing, location of trimming and flaking technique. Traditionally a distinction has been made between straight backed bladelets and crescents, also called lunates or segments (J. Deacon 1972: 14). High frequencies of crescents are known to be common in mid-Holocene assemblages and then replaced by straight backed bladelets in the late Holocene (J. Deacon 1984: 297). Careful examination of the Blydefontein and Meerkat Rockshelter backed tools has revealed more variability than the simple straight backed bladelet and crescent dichotomy. The most numerous group at Blydefontein Rockshelter is simple straight backed bladelets, and the majority of the ones tabulated in Table 20 are broken medial sections with proximal and distal snap fractures. Most complete straight backed bladelets are backed points, however it is not the pointed end that appears to offer the greatest opportunity for cross-dating. A small number of straight backed bladelets are trimmed on all sides by pressure-flaking and these are called pressure-flaked straight backed bladelets (Figure 81).

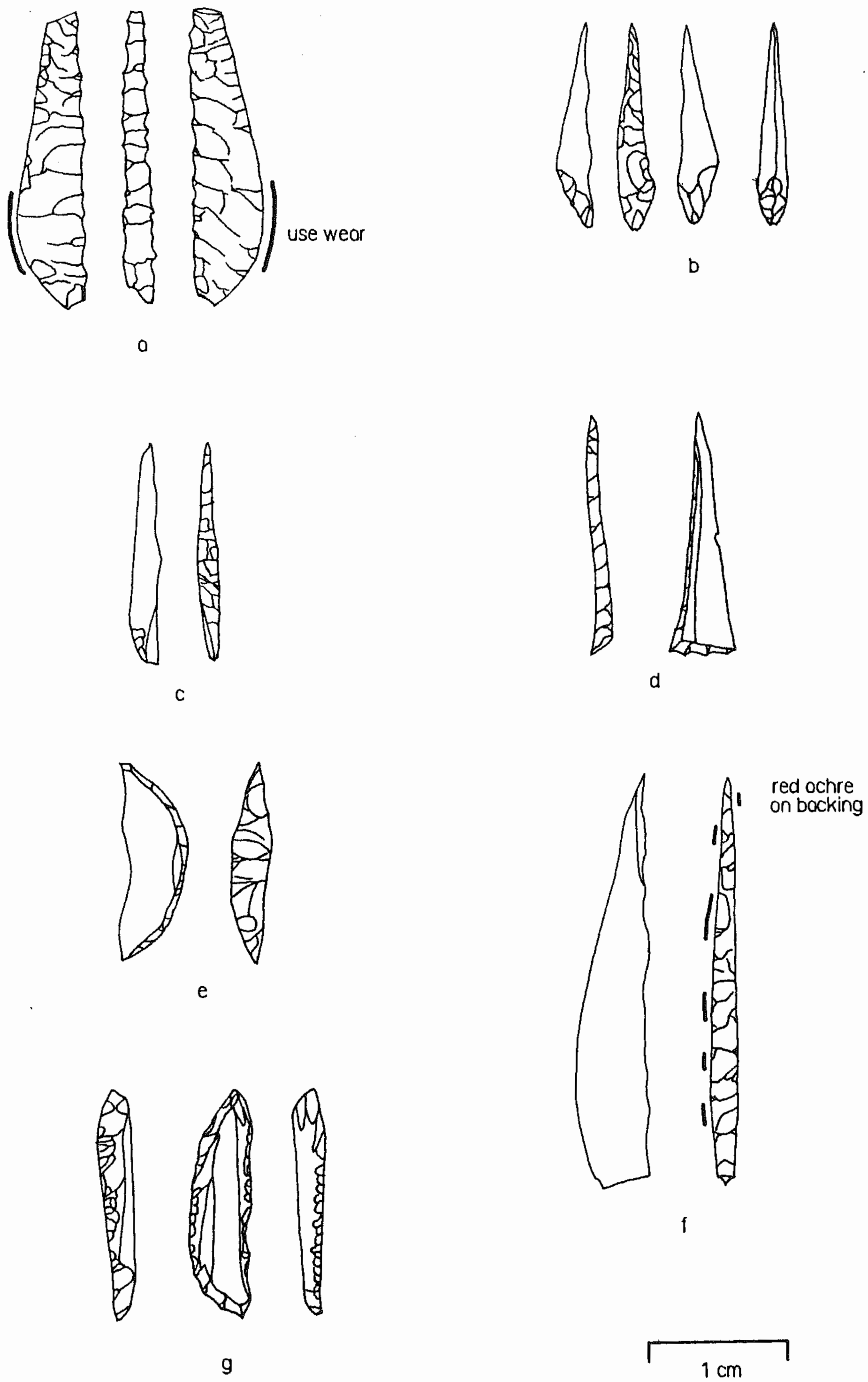

Figure 81 Backed bladelets and projectile points from Blydefontein and Meerkat Rockshelters. a) Pressure-flaked straight backed, b) straight backed with bifacial trimming, c) straight backed with unifacial trimming, d) truncated straight backed, e) crescent, f) simple straight backed, g) double backed cresent.

Similar tools were found at Glen Elliot Shelter (Sampson 1967: 145), at Riversmead Shelter (Sampson and Sampson 1967 : 30), Moshebi's Shelter in Lesotho (Figure III-5 in Carter 1969) and in previous excavations at Blydefontein Rockshelter (Sampson 1970: 90-91). Most backed bladelets are not pressure-flaked, but a small number do exhibit evidence of curved bifacially-trimmed bases or butts. Others had only curved unifacially-trimmed butts, and still others had convex, straight or concave abruptly trimmed bases that could be classified as truncations, i.e. triangle scaléne of Tixer (1963) or other strictly geometric forms. Tixer's typology of Maghreb backed tools seems to have little applicability for forms found in southern Africa, however. Backed tools that do not have straight backing include, in addition to crescents, curved backed bladelets and backed flakes.

Also shown in Figure 81 are bifacially pressure-flaked tanged and barbed projectile points. Although none of these is a backed tool, the pressure-flaking technique on these projectile points is very similar to the pressure-flaking observed on the trifacial straight backed bladelets. They are included because of the presumed functional similarity to backed tools.

Table 21 lists the percentages for the backed tools from Blydefontein Rockshelter listed in Table 20, and the available ages for the CAUs. Straight backed bladelets remain the dominant form throughout the sequence, however other forms vary in frequency through time and I will focus on these changes. Starting with CAU9 at the bottom of Layer CY it is clear that very few backed tools were found, but crescents, curved backed bladelets and backed flakes occur. This assemblage remains undated, but it tentatively is identified as an "Early Microlithic" assemblage (*sensu* Mitchell 1988). Much larger samples are necessary before this assemblage can be characterized with reliance.

Table 20.--Backed tools in Combined Analytical Units at Blydefontein Rockshelter

Combined AU	Straight Backed Bladelet	Pressure Flaked Projectile Point	Pressure Flaked Backed Bladelet	Straight Backed Bifacial Trimmed Base	Straight Backed Unifacial Trimmed Base	Straight Backed on Truncation	Crescent	Curved Backed	Double Backed	Backed Flake	Proximal & Distal Discard	Total
1	-	-	-	-	-	-	-	-	-	-	1	1
2	6	2	-	-	2	-	-	-	-	1	4	15
3	19	-	-	3	5	-	-	1	-	-	8	36
4	35	-	1	1	11	2	-	1	-	-	14	65
5	17	-	-	1	4	3	2	1	1	1	3	33
6	58	-	-	-	11	8	10	11	4	1	23	126
7	4	-	-	-	2	-	3	-	-	1	1	11
8	-	-	-	-		-		-	-	-	-	-
9	1	-	-	-	-	-	0	1	1	-	-	3
Total	140	2	1	5	35	13	15	15	6	4	54	290

Table 21.--Percentages of backed tools in Combined Analytical Units at Blydefontein Rockshelter

Combined AU	Straight Backed Bladelet	Pressure Flaked Projectile Point	Pressure Flaked Backed Bladelet	Straight Backed Bifacial Trimmed Base	Straight Backed Unifacial Trimmed Base	Straight Backed on Truncation	Crescent	Curved Backed	Double Backed	Backed Flake	Proximal & Distal Discard	14C Age BP
1	-	-	-	-	-	-	-	-	-	-	100.0	
2	40.0	13.3	-	-	13.3	-	-	-	-	6.7	26.7	844-1305
3	52.8	-	-	8.3	13.9	-	-	2.8	-	-	22.2	1980-2292
4	53.8	-	1.5	1.5	16.9	3.1	-	1.5	-	-	21.5	3135
5	51.5	-	-	3.0	12.1	9.1	6.1	3.0	3.0	3.0	9.1	
6	46.0	-	-	-	8.7	6.3	7.9	8.7	3.2	0.8	18.2	4066-4286
7	36.7	-	-	-	18.2	-	27.3	-	-	9.1	9.1	
8	-	-	-	-	-	-	-	-	-	-	-	8541
9	33.3	-	-	-	-	-	-	33.3	33.3	-	-	

No backed tools were recovered in CAU8, from the middle of Layer CY, and this absence is an important attribute used to identify this assemblage as a macrolithic Lockshoek assemblage (Bousman 1989). A single radiocarbon date comes from the top of AU8 so most of the artifacts attributable to this assemblage are slightly older than the radiocarbon date.

CAU7, from the top of Layer CY, shows that crescents and truncations occur in high frequencies, while straight backed bladelets with unifacially-trimmed butts occur for the first time. CAU7 probably represents a long period of time, and it is reasonable to expect that this CAU provides evidence of a mid-Holocene Interior Wilton assemblage that could span the period from 8000-4300 B.P., although not necessarily with continuous occupations throughout this period.

CAU6, the bottom of Layer TG and all of Layer CAC, has crescents, curved backed bladelets, straight backed truncations and straight backed bladelets with unifacially-trimmed butts in equal frequencies, and double backed bladelets in slightly lower frequencies. These assemblages occur between 4000-4300 B.P. and seem to represent a transition from mid-Holocene to late Holocene Interior Wilton assemblages, i.e. Classic to Developed, but with larger samples it is possible that rapid step-like changes rather than general shifts might emerge. It is important to remember that CAU6 occurs during a period of rapid climatic change, and hunter-gatherers certainly had to respond to climatic induced changes in resource diversity, density and availability (see Chapters XI and XII for additional discussions).

In CAU5 straight backed bladelets with unifacially-trimmed butts and truncations occur in high frequencies, straight backed bladelets with bifacially-trimmed butts appear, and crescents occur for the last time. It is not clear whether truncations simply represent variations of unifacial butt trimming or if the truncated backed bladelets are stylistically different. As with CAU6, this backed tool assemblage appears to be transitional toward later backed tool assemblages.

At the bottom of Layer GAC in CAU4 a significant shift occurs. A single pressure-flaked straight backed bladelet occurs, and crescents are found no longer. In CAU3 at the top of Layer GAC straight backed bladelets with bifacially-trimmed butts occur in their greatest frequencies, and are not found above this.

In CAU2, i.e. Layer HG, another distinctive change is documented. In CAU2 pressure-flaked bifacial tanged and barbed projectile points occur. Given the young radiocarbon age of this assemblage (844-1305 B.P.) it is likely that the projectile points were manufactured to emulate metal Iron Age projectile point styles even though the nearest coeval Iron Age communities were still restricted to Natal and the Transvaal (Hall 1990). CAU1 represents artifacts in the mixed surface layer that apparently post-date 850 B.P. It is clear that only limited occupation occurred at Blydefontein Rockshelter at this time and that the production of backed bladelets was not a major activity. The absence of microlithic tools is used to signify the shift from Interior Wilton to Smithfield assemblages (Sampson 1974, 1985), and the presence of pressure-flaked bifacial tanged and barbed projectile points in CAU2 indicates that these represent terminal Interior Wilton assemblages. The shift from Wilton to Smithfield represents a change, but the significance of this change is hotly debated and few people are in agreement.

At Meerkat Rockshelter many fewer backed tools were recovered (Table 22). This is due to the small area excavated, and more rapid sedimentation accumulation. Meerkat Shelter appears to provide a detailed or exploded view of the termination of the Interior Wilton Industry and the beginning of the Smithfield Industry and correlates to the uppermost two or three CAUs at Blydefontein Rockshelter. The backed bladelet sequence from the two rockshelters are in strong agreement. The

Table 22. Distribution of backed tools and projectile points in analytical units from Meerkat Rockshelter

AU	Straight Backed Bladelet Count/%	Pressure Flaked Projectile Point Count/%	Pressure Flaked Backed Bladelet Count/%	Total	14C Age B.P.
10	-	1/100	-	1	
11	1/33	1/33	1/33	3	1102±62
12	2/33	-	4/ 67	6	
13	1/50	-	1/50	2	
14	-	-	-	0	
15	1/50	-	1/50	2	
16	2/100	-	-	2	
17	-	-	-	0	2352±122
18	1/100	-	-	1	
Total	8	2	7	17	
Percent	47.0	11.8	41.2		

upper nine AUs at Meerkat Rockshelter correlate to CAU1 at Blydefontein Rockshelter. These Smithfield assemblages from both rockshelters are characterized by an absence of backed tools. The backed bladelet sequence at Meerkat Rockshelter begins with straight backed bladelets. Then toward the middle of the deposits, in AU12, pressure-flaked straight backed bladelets occur, and above this pressure-flaked tanged and barbed projectile points occur. It is possible that with larger sample sizes from Meerkat Rockshelter pressure-flaked straight backed bladelets will assume a wider temporal distribution, as at Blydefontein Rockshelter, or alternatively the Meerkat sequence may be a more accurate representation of the true temporal patterning of these distinctive backed bladelets. At both sites bifacially pressure-flaked tanged and barbed projectile points mark the termination of the Interior Wilton and appear to have a very limited temporal distribution. One pressure-flaked projectile point at Meerkat is directly associated with the radiocarbon sample dated to 1102±62 B.P. It is possible that the single tanged and barbed bone projectile point from Glen Elliott Rock Crevice (Sampson 1970: 64) could be contemporaneous to these flaked projectile points. It is tempting to suggest that the termination of the Interior Wilton is associated with the drought identified in the Oppermanskop pollen profile (see Chapter V).

Endscraper Length

Numerous archaeologists have documented increases in mean endscraper length through time during the Later Stone Age (Sampson 1970: 97; Sampson and Sampson 1967: 18-20; H. Deacon 1976: 61-63; J. Deacon 1984: 283, 301; Opperman 1987: 176-177), and various arguments have been presented to account for this change. Sampson (Sampson and Sampson 1967: 6) divided end scrapers into different types, in part, defined by length. However, nowhere in the literature has length or other metric attributes been used to statistically define morphological distinct and naturally occurring groups of end scrapers. He (ibid: 20; Sampson 1970: 97) suggests that in the Orange River Scheme area and at Blydefontein Rockshelter an increase through time in mean endscraper lengths was due to changes in response to shifts in lithic raw material usage. Now it is known that the size increase occurs over much of southern Africa with end scrapers made of many different types of raw material, and this pattern clearly is not just a function of a change in raw material (J. Deacon 1984).

For a number of years J. Deacon (1972: 15, 1984: 282) has argued that stylistic "norms of manufacture" can be identified in scrapers through the calculation of means and standard deviations, however few assemblages actually have scraper length distributions that can be statistically documented as having normal gaussian distributions (J. Deacon 1972: 20). This by itself suggests that mean scraper lengths do not represent stylistic norms that are adhered to closely. Also J. Deacon (1972: 36) observed that small scraper means are associated with small standard deviations, and she argues that this reflects less stylistic variability. But it should be realized that assemblages with small mean endscraper lengths must have small standard deviations. This is because small scrapers do not have the same potential metric range as large scrapers. Thus small end scraper mean values will have small standard deviations and large end scraper means can have large or small standard deviations. Obviously standard deviations are not providing a measure of normalized stylistic choices.

In addition, and most importantly, the extension of Dibble's (1987) Middle Paleolithic scraper analysis to end scrapers from southern Africa would suggest that the final form, including length, of end scrapers is a function of intensity of use and not a reflection of "norms of manufacture". By considering end scrapers from this viewpoint, it is logical that endscraper length can be strongly conditioned by hafting or lack of hafting, and that the final form in many cases does not represent a preconceived shape of the tool upon its manufacture but rather its condition, perhaps exhausted perhaps not, upon discard. Under these circumstances endscraper lengths would not be expected to have normal distributions. Recent ethnoarchaeological observations on chipped stone scrapers used by modern Ethiopian hide tanners shows that intensity of utilization and condition upon discard have a significant effect on scraper morphology especially length (Clark and Kurashina 1981: 309; Gallagher 1977: 411). The concept of hafted and nonhafted end scrapers in southern Africa is not new (Clark 1959; H. Deacon 1966, 1972: 40; H. Deacon and J. Deacon 1980; Kannemeyer 1890; Sampson and Sampson 1967: 19), but the full implication of hafted or unhafted end scrapers for analysis of stone scrapers in southern Africa is not appreciated yet (Humphreys and Thackeray 1983: 10-14, 275-282). It can be argued that shorter end scrapers often with trimmed butts probably represent hafted end scrapers that have been utilized near or to the point of exhaustion and possibly curated, while long unretouched end scrapers probably represent scrapers that are not intensively used and, in fact, may be expedient tools that are little curated. This has further implications for assemblage formation processes that will be discussed in the next chapter.

Figure 82 plots the mean lengths and standard error bars for Blydefontein endscraper samples (N ≥ 5) from analytical units only within Blocks C-D. As Blocks C-D have the finest stratigraphic control and directly associated radiocarbon dates, these values show in detail the nature of temporal change for mean endscraper lengths for samples that have a reasonable number of end scrapers. This line chart shows that endscraper lengths are small and fairly stable in AU15-20 (Layer CAC and the lower portion of TG). In the upper portion of TG, i.e. AU12-14, end scrapers begin to increase in length. Only one analytical unit from the lower portion of Layer GAC has more than five end scrapers, i.e. AU9. This sample is stratified above a 3135±33 B.P. radiocarbon date so AU9 is approximately 1000 years older than AU17. The sample from AU9 does not represent a significant increase from the last sample, i.e. AU13. The next sample is from AU7 and is dated by radiocarbon to ca. 700 years later than AU9. A sharp drop occurs in AU6 and this is roughly dated by Sampson's radiocarbon date of 1980±120 B.P. Interestingly this is virtually the exact time of the drought documented at USP. A dramatic increase in mean endscraper length occurs by AU4 which is dated to 1305±31 B.P., and this is very close in age to the drier conditions demonstrated by pollen from Oppermanskop hyrax midden (see Chapter V). Finally a moderate drop in mean endscraper lengths is evident by the AU2 sample dated to 844±119 B.P. These minor fluctuations demonstrate the complexity of the record, but in general very consistent patterns are evident. These data can be used to suggest that end scraper length increases through time, but minor fluctuations may be tied to paleoenvironmental changes.

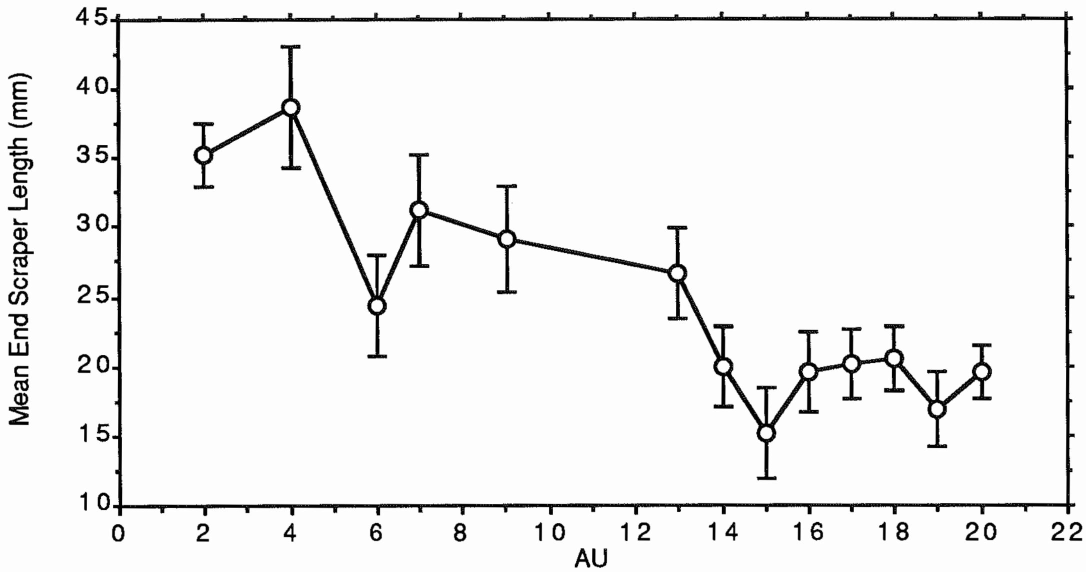

Figure 82. Mean endscraper lengths and standard error bars for Blydefontein Rockshelter Blocks C-D.

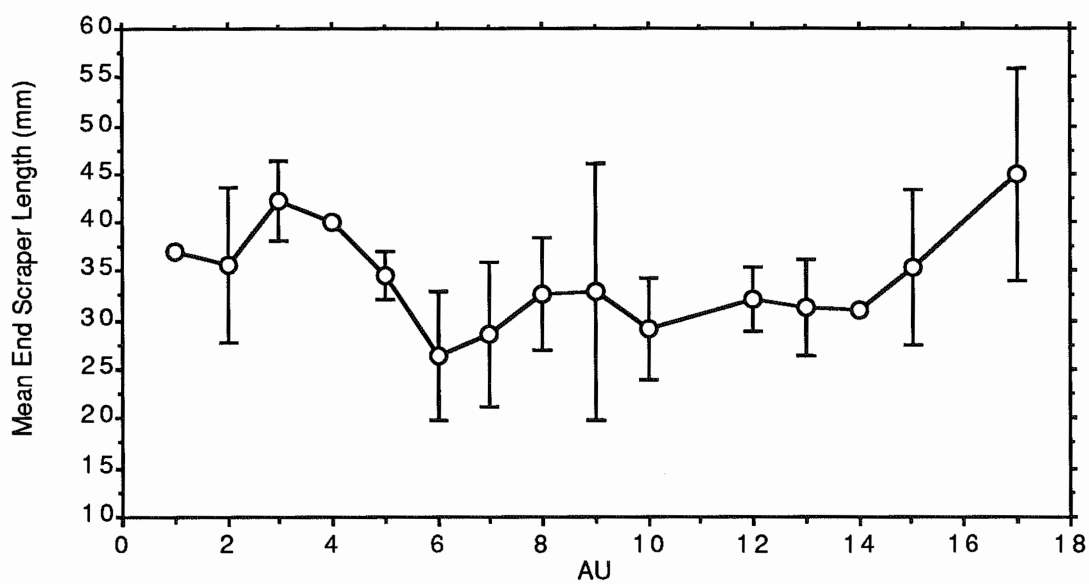

Figure 83. Mean endscraper lengths and standard error bars for Meerkat Rockshelter AUs.

Mean endscraper lengths at Meerkat Rockshelter do not change significantly through time (Figure 83). An ANOVA test which is more sensitive than a nonparametric test, failed to demonstrate any significant difference between endscraper lengths among the AUs (p value = 0.926). Also by grouping the AUs into assemblages with and without backed tools (AU1-9 and AU10-18) no difference could be distinguished between endscraper lengths with an ANOVA test (p value = 0.651). The mean endscraper length for AU1-9 is 34.4±12.1 mm (N = 35) and the mean endscraper length for AU10-18 is 32.9±13.7 mm (N = 25).

Ostrich Eggshell Beads

Meerkat Rockshelter produced many more ostrich eggshell beads than Blydefontein Rockshelter especially considering the size of excavations at the two rockshelters. Both shelters have more ostrich eggshell beads in the upper levels. It is well known that through time wider and wider ostrich eggshell beads were manufactured in Namibia (Jacobson 1987), and the data from Meerkat and Blydefontein Rockshelters suggests a similar trend as well. As complete ostrich eggshell beads were not extremely numerous a histogram of all measurements of complete finished beads from Blydefontein and Meerkat Rockshelters was plotted (Figure 84). This histogram shows that a gap occurs between 4.8-5.0 mm. An inspection of the distribution of these two size classes demonstrated that most of the smaller beads are in Interior Wilton microlithic assemblages, and most of the larger beads do not occur with microlithic tools, i.e. with Smithfield. As Figure 85 shows the shift to larger ostrich eggshell beads occurs by AU10 in Meerkat Rockshelter. Interestingly this analytical unit lacks backed bladelets, but does have a single pressure-flaked tanged and barbed projectile point. It is tempting to suggest that the small ostrich eggshell beads actually were made with Wilton backed microlithic tools, but this is only a guess. However wear pattern analysis might be capable of demonstrating this possibility.

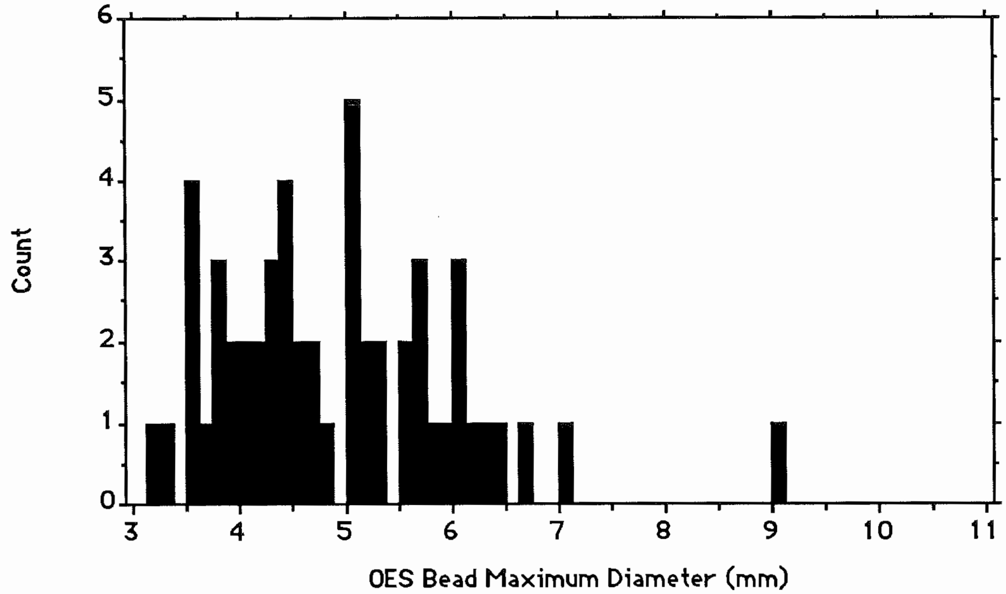

Figure 84. Histogram of Blydefontein and Meerkat ostrich eggshell bead maximum diameters.

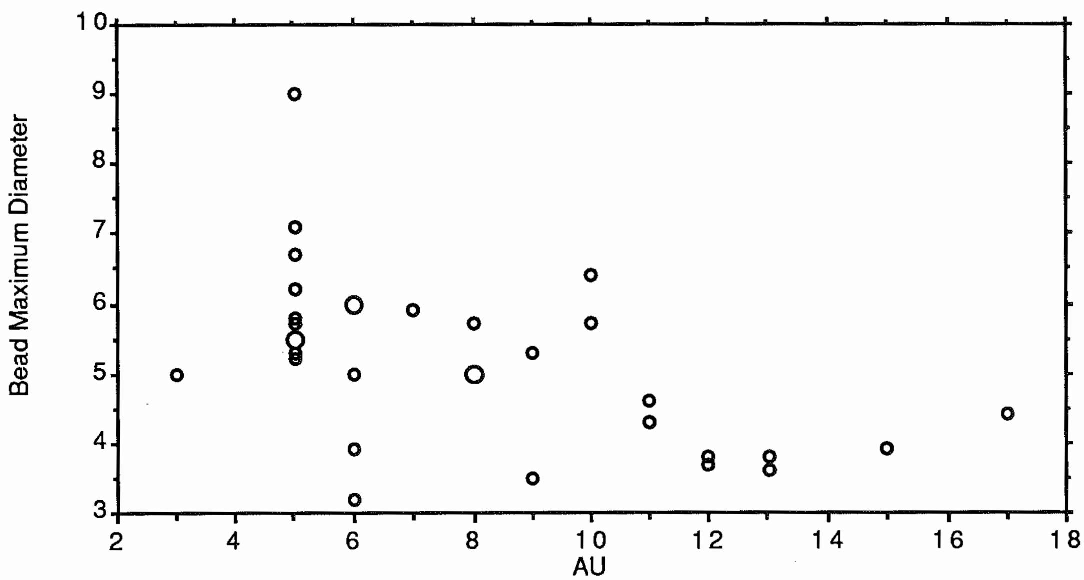

Figure 85. Distribution of individual ostrich eggshell measurements by analytical unit at Meerkat Rockshelter.

The only published site with good samples of finished ostrich eggshell beads is Glen Elliot Shelter near the Orange River (Sampson 1967b: 136-137). A plotting of the mean diameter measurements reported by Sampson shows a clear temporal trend (Figure 86). Interestingly Sampson's Level 4 assemblage has a pressure-flaked projectile point, and a few backed bladelets as well.

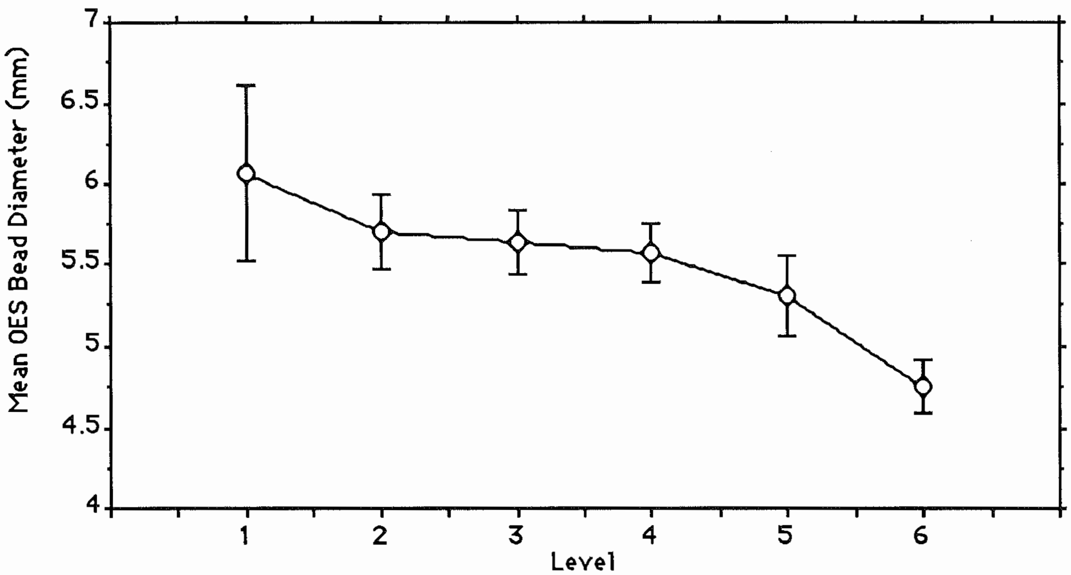

Figure 86. Mean OES bead diameters and standard error bars from Glen Elliot Shelter (data after Sampson 1967b).

Ceramics

Neither Blydefontein nor Meerkat Rockshelters produced many ceramic sherds, however a few stratigraphic relationships are clearly significant for cross dating, and for the regional ceramic record. Sampson (1967a: 52-53) original defined two ceramic types (A and B) occurring in the Later Stone Age occupations at Zaayfontein Rockshelter. Class A ceramics are most easily distinguished by abundant grass temper and a variety of punctate or impressed outer surface decorations. Class B ceramics generally lacks grass temper and often has a light brown (buff) exterior that may or may not be burnished. Sampson (1970: 93-94) classified the 46 ceramic sherds excavated from Blydefontein Rockshelter in 1967 as Class B ceramics. Humphreys (1979) reanalyzed the ceramics from the Orange River Scheme sites and concluded that many of Sampson's Class B sherds also had grass tempering and only one ceramic tradition was present. Renewed research in the Zeekoe Valley, south of the Orange River Scheme area, resulted in a intensive analysis of the ceramics (Sampson 1988; Sampson et al. 1989). These studies recognized three major groupings: grass tempered plain ware (GTPW), silt tempered plain ware (STPW) and Khoi. GTPW are slab-built with fairly thick walls and fired with low heat. The known shapes include bowls and bag-shaped pots, and surfaces may be burnished or decorated with a variety of motifs (ibid: 4). STPW are coil-built with thin walls, sand, silt and grass temper. The sherds appear to be well fired, and surfaces may be burnished. Khoi sherd are similar to STPW except they may have an orange-to-red-to-mauve slip on their surface and Khoi sherd lack any evidence of grass temper. Additionally some Khoi sherds do have surface decorations. Many of the GTPW sherds from the Zeekoe Valley are decorated and Sampson (1988) has recently studied the spatial distributions of the different decorative motifs. Clearly GTPW is the same as Class A, but it is unclear whether Class B ceramics are Khoi or STPW. The present analysis uses Sampson's more recent classification scheme, in fact, Sampson classified the sherds from both Meerkat and Blydefontein Rockshelters.

The ceramic sherd counts from Blydefontein Rockshelter are presented individually in Block B AUs and Blocks C-D AUs, and then correlated in Combined AUs (Table 23, Table 24, Table 25). No decorated ceramics were recovered from Blydefontein Rockshelter. In Block B STPW and Khoi sherds are restricted to AUs 3 and 4. In AU3 GTPW occurs and it continues to the surface. In Blocks C-D three small GTPW sherds, called crumbs by Sampson (personal communication 1989) were recovered in AUs 7 and 8, and it is likely that these were not in their original stratigraphic context. The sherd in AU5 is thin buff-colored sherd with grass and silt temper. In AU4 a single Khoi spout fragment was recovered and the radiocarbon date (1305 B.P) is in direct association with this Khoi sherd. Except for one STPW sherd the remainder of the ceramics from Blocks C-D are GTPW sherds. In the Combined AUs it is clear that Khoi and GTPW begin at about the same time, then Khoi ceramics stop.

Table 23. Ceramic sherd counts at Blydefontein Rockshelter, Block B

AU	GTPW	STPW	KHOI	Total
Surface	1	-	-	1
1	7	-	-	7
2	6	-	-	6
3	4	1	2	7
4	-	1	1	2
Total	18	2	3	23

Table 24. Ceramic sherd counts at Blydefontein Rockshelter, Blocks C-D

AU	GTPW	STPW	KHOI	Total	^{14}C Date B.P.
1	4	1	-	5	
2	4	-	-	4	844±119
3	-	-	-	0	1255±109
4	6	-	1	7	1305±31
5	1	-	-	1	
6	-	-	-	0	1980±120
7	1	-	-	1	2292±117
8	1	-	-	1	
Total	17	1	1	19	

Table 25. Ceramic sherd counts at Blydefontein Rockshelter, Block B

Combined AU	GTPW	STPW	KHOI	Total
1	12	1	-	13
2	21	1	3	25
3	2	1	1	4
Total	35	3	4	42

At Meerkat Rockshelter 49 sherds were recovered (Table 26), and this represents a much higher density than at Blydefontein Rockshelter. Nevertheless a very similar pattern is presented by the Meerkat sherds. Both GTPW and Khoi appear in the shelter stratigraphy at virtually the same time and this pre-dates the 1102 B.P. date. Khoi sherds are only found in AU12, and from AU1-11 GTPW occur as the overwhelming majority. STPW do not appear to reflect chronological patterns. Lastly, in AU3 two refitted GTPW sherds with a quill-groove decoration were recovered. Unfortunately this level was not radiocarbon dated, but they are only a short distance above the 979 B.P radiocarbon date and it seems likely that they are only a few hundred years, at most, younger than this date. The sherds recovered from the surface are both decorated. One is covered with large smooth spatulate, oblique stab-and-lift, parallel entry pattern, and the other is decorated by a large multi-notch spatulate, vertical stab-lift, diagonal entry pattern. These sherds were recovered from the edge of the shelter where slope erosion is beginning to remove the upper 10-15cm of deposit, and it is impossible to know if these sherds originally were in the upper layers or on the surface.

Table 26. Ceramic sherd counts at Meerkat Rockshelter

AU	GTPW	STPW	KHOI	Total	^{14}C Date B.P.
Surface	2 *	-	-	2	
1	1	-	-	1	
2	2	1	-	3	
3	4 *	-	-	4	
4	5	-	-	5	
5	4	1	-	5	979±70
6	7	-	-	7	
7	5	-	-	5	
8	8	-	-	8	
9	-	1	-	1	
10	3	-	-	3	1102±62
11	2	-	-	2	
12	1	-	2	3	
Total	44	3	2	49	

* Decorated sherds in sample

Conclusions

The chronological sequence of backed tools and projectile points from Blydefontein and Meerkat Rockshelters demonstrates clear temporal patterning that can be used for cross-dating. Within the Holocene assemblages a temporal sequence of backed bladelet tools can be demonstrated from (1) crescents and curved backed bladelets, to (2) truncations and straight backed bladelets with unifacially-trimmed butts, to (3) straight backed bladelets with bifacially-trimmed butts, to (4) pressure-flaked straight backed bladelets, to (5) pressure-flaked tanged and barbed projectile points, and finally to (6) an apparent lack of these tool types. Through most of the sequence, i.e. from ca. 4300-1300 B.P. plain straight backed bladelets are numerically dominant, but it is only at the beginning of the Blydefontein sequence, and the end of the Blydefontein and Meerkat sequences that straight backed bladelets occur in frequencies that fall below their overall average. These patterns have not been documented at other sites in southern Africa, and at present it is unclear how large of a region such patterns can be expected to extend.

A small number of ethnographic collections have San arrow points made with backed tools (Clark 1977). These often consist of two straight backed bladelets mounted in a well formed mastic tip on a foreshaft (Figure 87). It seems logical that straight backed bladelets were shaped, sharp on one end and a corner on the other, so that they would securely fit into the mastic and not dislodge even upon impact, or at least not until after penetrating an animal. Crescents, on the other hand, lack a flat abrupt corner, and, in fact, have a shape that might cause the implement to rock in a haft. It is unlikely that they would have been used in exactly the same fashion as straight backed bladelets. One possibility, suggested to me by Steve Tomka, a lithic specialist at the University of Texas at Austin, is that crescents were hafted like straight backed bladelets, i.e. at the tip of a projectile, and that the rocking motion was an intended function of the tool. The rocking motion could increase the effectiveness of the weapon by forcing the distal ends of crescents to splay upon impact and cause increased bleeding (Figure 88). This increased destruction would be especially important if poisons were not used with crescents. The smooth curved surface would act to force an unstable rocking motion in virtually any haft, and for example this would reduce a crescent's effectiveness in a composition cutting tool. Also, if crescents were hafted in a similar manner to the ethnographic examples, then this might explain why no slotted hafts for microlithic tool have been recovered from excavations in southern Africa even though a reasonable number of sites have extremely good preservation of organic materials. Of course, the transverse hafting of crescents could have occurred as well.

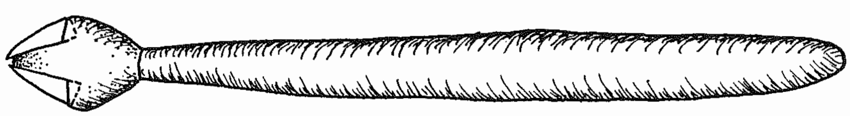

Figure 87. Ethnographic projectile point with straight backed bladelets mounted in mastic.

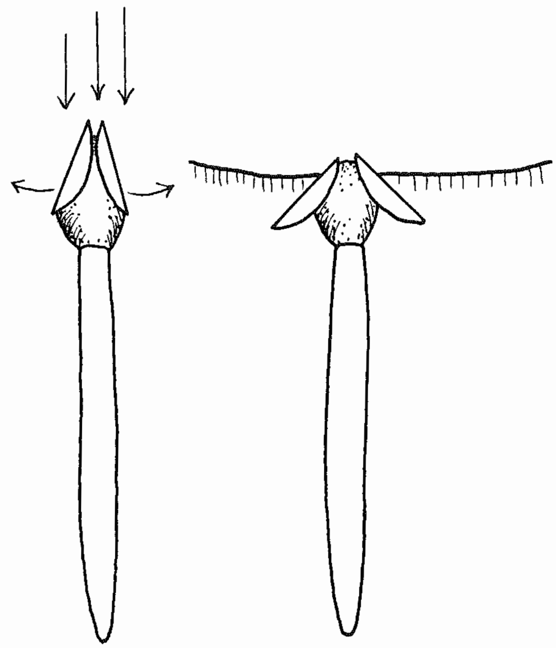

Figure 88. Hypothetical mounting and function of crescents as projectiles.

All end scrapers from Blocks B, C and D are shown by Combined AUs, and the same general trend is evident (Figure 89). As these samples are much larger than those used above form Blocks C-D, the pattern is more reliable. These data demonstrate that single endscraper in CAU8, the Lockshoek, is long, but beginning in CAU7 and continuing through CAU1, the Interior Wilton and Smithfield assemblages, a dramatic shortening and then a consistent increase in mean endscraper length occurs. Assuming that CAUs represent equal periods of time (which they do not) a linear regression was calculated for estimating CAU with mean endscraper length (Figure 90). The formula is: CAU= -0.395 x (mean endscraper length) + 13.85, (r^2 = 0.961). The reader should be cautioned that this is a misapplication of linear regression analysis, and is only included as a tentative and rough estimate of relative age of mean endscraper samples. Once the range and mean ages of the CAUs are better dated, then it might be possible to estimate the ages of surface endscraper samples with a similar method, but more radiocarbon dates are needed that completely bracket the age span of these samples. The mean length for all end scrapers at Meerkat Rockshelter equals 33.77 mm. Using this value in the linear regression equation for estimating CAUs at Blydefontein, the resulting product is 0.5 CAU. This is in close agreement with correlations based on radiocarbon dates and separately on backed bladelets.

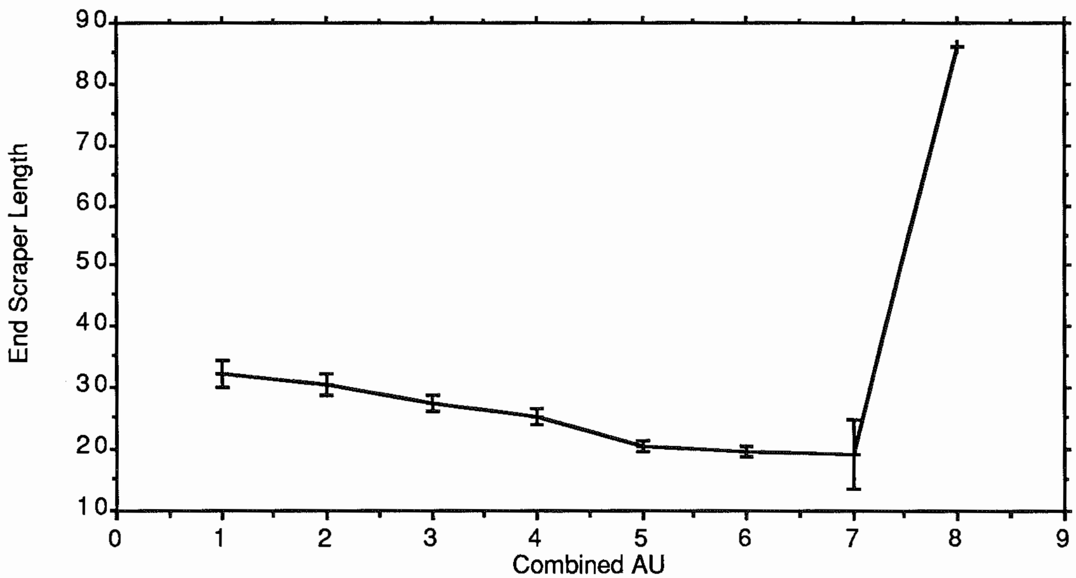

Figure 89. Mean endscraper lengths and standard error bars for Blydefontein Rockshelter Combined AUs.

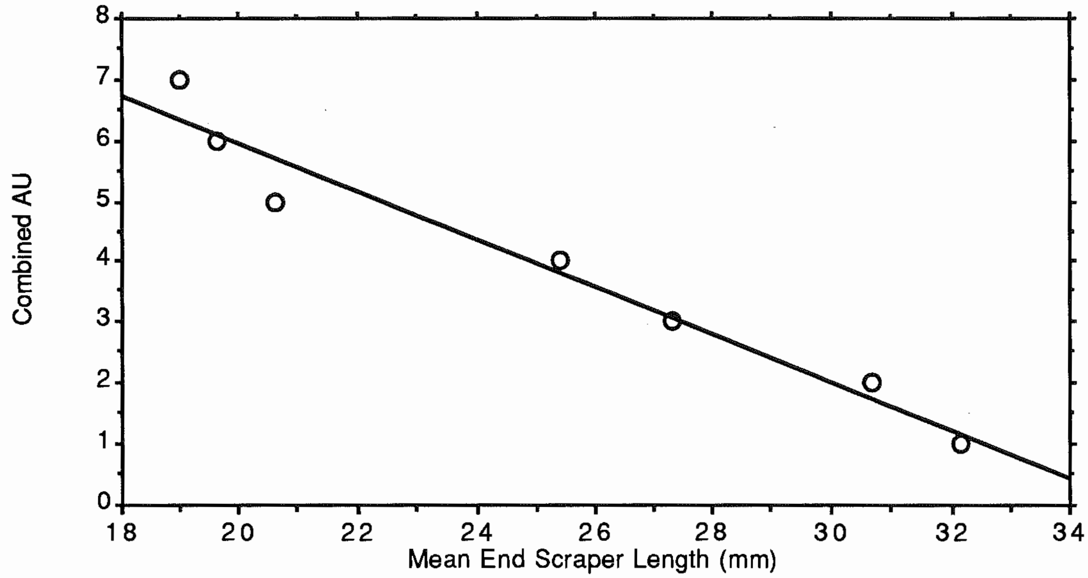

Figure 90. Linear regression of mean end scraper lengths and Combined AU.

This analysis suggests that the Interior Wilton is, in part, characterized by small (< 5 mm) ostrich eggshell beads. At the termination of the Interior Wilton and at the beginning of the Smithfield Industry ostrich eggshell beads increase significantly in size. It has been suggested above that the size shift might be due to a change in the types of tools used to drill the beads, but other interpretations are equally as valid at this point. It is possible that ostrich eggshell beads were used in the same manner as glass beads are today by the Kalahari San (Wiessner 1984). In other words ostrich eggshell beads functioned in assertive style manipulations. Even though the Zeekoe Valley survey data lack high temporal resolution it is clear that some sort of population increase occurred in the region during the Late Holocene with the advent of the Smithfield Industry (Sampson 1985: 104-109). With greater population densities it is possibly that both types of stylistic behavior identified by Wiessner (1983, 1984, 1985) would also increase in occurrence. It may also be reasonable that the shift to larger ostrich eggshell beads was part of this increased stylistic behavior. At the least the larger ostrich eggshell beads would be more noticeable than the smaller sizes, and this may have played a role in the process. Clearly this hypothesis will be very difficult to conclusively demonstrate, but the change in ostrich eggshell beads and the associated diversification in projectile points at this time strikes similarities to Wiessner's San artifact study.

The ceramics at Meerkat and Blydefontein Rockshelters indicates that ceramics became part of the assemblage during the later part of the Interior Wilton. Both grass tempered plain ware and Khoi ceramics appear at approximately the same time. This event is best dated at Blydefontein Rockshelter at 1305 B.P.. Khoi sherds are no longer part of the assemblage by 1255 B.P. at Blydefontein Rockshelter and by 1102 B.P. at Meerkat Rockshelter. This is significant as Sampson et al. (1989: 13) and Hart (1989: 158-163) argue that three radiocarbon dates, 1140±60 B.P. (SMU-1790), 560±170 B.P. (SMU-1791), 544±43 B.P. (SMU-1636) mark the ages of Khoi sherds at two sites, Haaskraal Shelter and Volstruisfontein Shelter, in the Zeekoe Valley. The tree ring calibrated ages for these dates are 1050 B.P., 560 B.P., and 555 B.P., respectively. The calibrated age for the Khoi sherd from Blydefontein Rockshelter is 1256 B.P., and this is 200 tree-ring calibrated years before the earliest Khoi ceramics in the Zeekoe valley. Surprisingly Khoi ceramics do not reappear in either rockshelter sequence at Blydefontein Basin, as occurs at Haaskraal and Volstruisfontein Shelters in the Zeekoe Valley. However it is not evident that either Meerkat or Blydefontein Rockshelters were occupied in so recent times and this may be the reason for the absence of Khoi sherds.

Taken as a whole the temporal shifts in artifacts can be used to cross-date surface sites in the Zeekoe Valley. Simplistically it appears that increasing mean end scraper lengths could be the most regular and reliable chronological tool for most Interior Wilton sites. However, arguments presented below will call this conclusion into question. Backed tools and projectile points also provide a extremely useful temporal patterns that may be more reliable than those presented above for end scrapers. For the terminal Wilton and Smithfield periods ceramics may be the best for cross-dating, but the possibly sporadic occurrence of Khoi sherds (and possibly herding as an economic activity) and effects on the transition from STPW to GTPW as well as the variations in decorative patterns still requires a much more complete data base than is presently available for the Zeekoe Valley and Blydefontein region. Ostrich eggshell beads can also be helpful at diagnosing the difference between Interior Wilton and Smithfield, but their rare occurrence on surface sites limits the usefulness of ostrich eggshell beads.

In terms of cross-dating surface sites, it is clear that the temporal span of the surface sample, as well as the temporal span of the excavated sample, could be a significant stumbling block in successful cross-dating. It is clear for the calculation of mean end scraper lengths that the longer the temporal span of the excavated sample the less variation is shown in the mean end scraper values. This phenomenon would be reflected in surface samples as well.

An added complication for surface sites is reoccupation, especially in different temporal periods. Care must be taken to separate assemblages of different temporal periods on surface sites. Under the assumption that hornfels patina changes color through time in a regular fashion (Sampson 1985), one possible method for sorting distinctly different occupations on surface sites is the color coding of patina using a Munsell Color Chart as used by soil scientists, and statistically separating distinctive patina colors. A preliminary and limited test has shown that this procedure may be possible (Bousman, nd). The soils derived from dolerite, sandstone, and shale must be considered as surface artifacts sit on these soils and these bedrocks can produce soils with very different chemical properties (Tim Dalbey, personal communication).

Obviously much more work is required and care must implemented before reliable cross-dating of surface assemblages can take place.

CHAPTER X

EXPLANATORY MODELS OF LATER STONE AGE LITHIC VARIABILITY

The cross-dating scheme developed in the previous chapter does not address the more interesting question of why the various changes in lithic design took place. Before developing my explanatory model, it is useful to review the development of pioneer models that also purport to explain variability and change in Later Stone Age lithic assemblages from southern Africa. In most of them, two sorts of variability are considered: the relative frequencies of stone tools within an assemblage, otherwise known as assemblage composition, and the morphological shapes of these tools. These topics have been debated hotly over the last 20-30 years in archaeology, and still are as few solid conclusions have been agreed upon. However, in the last 15-20 years many new approaches have been developed to account for these two types of variability, and these require consideration as well.

Models for Explaining Assemblage Composition

Indigenous Models

There have been several attempts to explain Later Stone Age assemblage change by different South African archaeologists. In 1929 Goodwin and van Riet Lowe published The Stone Age Cultures of South Africa. In this landmark study the authors established a classification system for South Africa's local Stone Age archaeological record, and their basic categories still are in use today, including the terms Earlier, Middle and Later Stone Age. Goodwin and van Riet Lowe clearly associated the Later Stone Age with modern Homo sapiens, called Neo-anthropic groups, and two coeval traditions were recognized: the Smithfield and Wilton cultures. The Wilton, at that time known mostly from the coastal region, was characterized by microlithic tools, especially crescents, and small convex scrapers. Goodwin (Goodwin and van Riet Lowe 1929: 150) suggested that the Wilton represented an "offshoot from the Capsian Group of North Africa".

The Smithfield, discussed by van Riet Lowe (ibid: 187), occurred in the Interior Plateau of South Africa, where he proposed a sequence of three phases, Smithfield A, B and C, with Smithfield B and C overlapping in time to an unknown degree. Smithfield A was characterized by large round and curved (concavo-convex) scrapers. The Smithfield B lacked these large scrapers but had numerous end scrapers, and Smithfield C, known from rockshelters, had small convex scrapers and backed bladelets. Smithfield C was essentially a crescent-less Wilton. Smithfield A and B artifacts were made from indurated shale known as hornfels, but agate and jasper were commonly used to produce Smithfield C tools. The Smithfield was seen by van Riet Lowe as a local development restricted to the Inland Plateau of South Africa, and believed to be the result of interaction between Middle Stone Age groups and in-migrating modern Homo sapiens. Thus both Goodwin and van Riet Lowe accounted for the development and existence of Later Stone Age groups by invoking population movement and immigration. Obviously, they used the presence of stone tools to reflect ethnic groups in a direct, unambiguous, and unquestioning manner.

From the 1930s into the 1960s numerous new variants of the Smithfield and Wilton cultures were defined; each with slightly different assemblage compositions. One variant of the Smithfield, the Smithfield N, was restricted to Natal and characterized by notched scrapers or spokeshaves. The Smithfield N assemblage was thought to reflect the intensity of wood working in this region, and this represents one of the first times, even though in a limited manner, that stone tool function rather that ethnic identity was used to explain assemblage composition in southern Africa (van

Riet Lowe 1936). Clark (1959) in his synthesis of Stone Age archaeology in southern Africa elaborated on this concept of adaptation. He explained assemblage differences as reflecting regional specialization in terms of hunting specific animals, but he continues to see these differences in mostly cultural terms. Thus Clark suggests that the Wilton and Smithfield cultures represent differences in adaptation to hunting different game.

The next major research in southern Africa focused on the Interior Plateau was in the Orange River Scheme area (Sampson 1967a, 1967b, 1970, 1972; Sampson and Sampson 1967). He presented the most detailed Later Stone Age culture chronology available at the time for southern Africa, and it represents a refinement of the research begun by Goodwin and van Riet Lowe, and developed by Clark. Sampson (1972) suggested that six phases, numbered 1-6, were present in the Later Stone Age of southern African and all were present in the Orange River Scheme area. He provided the first radiocarbon-dated culture chronology, and quantified the range of variation in the relative frequencies and metric attributes of tool types between the phases.

In 1974 Sampson presented a new synthesis of Stone Age archaeology in southern African that was a departure from his 1972 monograph. In this he followed the recommendations of the 1965 Burg Wartenstein Symposium by dropping the term "Later Stone Age" and replacing it with three major "Industrial Complexes": the Oakhurst (formerly Smithfield A), Wilton and Smithfield. Each Industrial Complex could have regional industries and temporal phases. In the Interior Plateau the Oakhurst Complex was called the Lockshoek Industry, and the Wilton in the same area is termed the Interior Wilton Industry with four phases (early, classic, developed, and ceramic). The Interior Wilton is followed by the Smithfield Complex but only in the Interior Plateau. In this synthesis Sampson applied a standard typology for analysis so that the range of "stylistic preferences" selected by a prehistoric group could be compared through space and time. Thus the culture/style paradigm used by Goodwin and van Riet Lowe, although now quantified, still was being followed by Sampson.

Concurrent with Sampson's research was another large research project in the southeast Cape Province initiated by H. and J. Deacon. J. Deacon (1972) suggested that the chronological differences documented by her at Wilton Large Rockshelter were due to the birth, life and death, known as ontongeny, of a single cultural system. J. Deacon (1972) discusses assemblage variability in terms of relative frequencies of tool types reflecting activities or function, which is an acceptance of Binford and Binford (1966) hypothesis of tool kits and assemblage variability in the Middle Paleolithic, and suggests that metric attributes (means and standard deviations) can be used to identify cultural norms and deviations.

Two years later J. Deacon (1974) presented a distribution of radiocarbon dates organized by region in southern Africa. In this study she argued that the Interior Plateau had no assemblages dated in the mid-Holocene between 9500 BP and 4500 BP, while the coastal zones had numerous assemblages dated to this period. Assemblages during the mid-Holocene contain high frequencies of crescents, and these are lacking in all Interior Plateau artifact assemblages. In this paper she proposed that if the number of radiocarbon dates could be used as a rough indicator of population density, then the Interior Plateau supported a very small population of hunter-gatherers during the mid-Holocene. Deacon attributes this population decline to reduced carrying capacity because of drier conditions during this period. This model was in direct conflict with Sampson's chronological scheme for the Interior Plateau which did not recognized an occupational hiatus in the region.

The next major contribution to Later Stone Age archaeology was by Klein (1974). In his excavations at Nelson Bay Cave, he discovered and dated a bladelet industry that was older than the Oakhurst Complex assemblages, and the people responsible for producing this industry exploited large gregarious herd animals. This was named the Robberg Industry, which is now known to date to the Late Pleistocene, ca. 18,000-12,000 BP (Deacon 1984; Mitchell 1988).

At the same time, H. Deacon was developing a new paradigm for explaining assemblage variability. By selecting sites for excavation with well preserved plant and animal food remains, H. Deacon (1972, 1976) was able to develop a model of culture change based on the concept of adaptation that incorporated the exploitation of plants, animals and other resources. This differs significantly from Clark's and van Riet Lowe's approaches by systematically including plant food resources and by utilizing general systems theory. The argument takes the form of a punctuated equilibrium model with positive and negative feedback mechanisms to explain adaptations and artifact assemblage variability. He suggests that long periods of homeostatic plateaus interrupted by short spurts of rapid change characterize the known stone tool assemblages and economic adaptations in southern Africa. This model implies that between the big jumps, a number of small scale readjustments occur, but directional change is limited because of negative feedback. H. Deacon's contribution represents one of the most sophisticated uses of the concept of adaptation in southern Africa.

Another major research approach is represented by the work of Parkington and his students. Parkington (1972, 1984), Mazel and Parkington (1978, 1981) and Manhire (1987) discuss the nature of variability in lithic assemblages. Their concern is with the determinants inter-assemblage patterns and assemblage change. They state that at a local scale much assemblage variability is probably due to the seasonal scheduling of activities by prehistoric groups that utilize stone artifacts. Parkington (1972, 1976) has argued that a series of excavated coastal and mountainous rockshelter sites in the western Cape were occupied sequentially on a seasonal basis. Mazel, Manhire and Parkington elaborate on this pattern with a discussion of artifact assemblages from coastal surface sites in what became known as the "Sandy Bay Problem". Mazel and Parkington noted that adzes are common at inland sites in the mountain range some 50km from the coast, but often adzes are virtually absent on sites near the coast. In fact, the only coastal areas were adzes are common occur in or near fynbos plant communities. This pattern had been known for some time (Rudner and Rudner 1954), and Sampson (1974) had argued that two separate ethnic groups were responsible for the difference in assemblages with Coastal Wilton groups in the mountains and marine adapted groups termed "Strandloper" or Sandy Bay near the shores. Alternatively, Mazel and Parkington (1978, 1981) posit that only a single group was responsible for this pattern and the artifact differences were due to certain activities (i.e. woodworking with adzes) occurring at the mountain sites but not at the coastal sites which had no local sources of wood. Initially Mazel and Parkington did not consider the possibilities of chronological change, but later Parkington (1984: 111) and Manhire (1987) indicate that this pattern occurred only within the last 3000 years. Parkington (1984) has extended this type of reasoning to earlier time periods and suggested that the undated Lockshoek Industry in the Interior Plateau is coeval with the Robberg Industry known along the coast. Parkington suggests that the Robberg Industry represents marginal Late Pleistocene hunter-gatherers who make a macrolithic Lockshoek assemblage when they are in an area with abundant hornfels, but on the margins of their range in the Cape Folded Belt Range, where only quartz and quartzite are available, these same hunter-gatherers produce a bladelet dominated, ie. Robberg assemblage, because of the lack of hornfels.

Recently Parkington's Late Holocene model of seasonal mobility and transhumance has been challenged from an unexpected direction. Dietary analysis using stable carbon isotopes from human burials in the southwest Cape have shown that a significant dietary difference exists between individuals buried in the mountains and individuals buried in the coastal zone (Sealy 1986 and 1989; Sealy and van der Merwe 1985, 1986, 1987 and 1988). Thus the stable carbon isotope studies support Sampson's (1974) thesis that two distinct groups were present with dramatically different adaptations and diets. Additionally, Bousman (1989) and Mitchell (1988) has argued that Parkington's Robberg/Lockshoek model does not fit the available data as Robberg-like assemblages, coeval with the coastal Robberg, termed Early Microlithic by Mitchell, are found in the Interior Plateau and Lockshoek assemblages from Blydefontein are not coeval with any Early Microlithic assemblages. Mitchell (1988:247-250) goes on to suggest that the major factor that causes the difference between the Late Pleistocene Early Microlithic Complex and the Early Holocene Lockshoek is the use of the bow-and-arrow by groups that produced Lockshoek assemblages.

Recently a shift away from ecological-adaptation explanations toward socially orientated explanations has emerged. Wadley (1986, 1987) has proposed that hunter-gatherer bands have two settlement phases. These are aggregated and dispersed phases, and during these two phases she argues that hunter-gatherers engaged in different activities which are reflected in artifact assemblages recovered from archaeological sites. Wadley suggests that "public" activities occur at San aggregation sites, and this "public" behavior is marked by the production of gifts for exchange (especially ostrich eggshell beads and arrows), and ritual ceremonies such as trance dances and marriages. Dispersed sites are characterized by "private" behavior which lacks evidence of exchange, ritual or the manufacture of gifts. She further argues that formal, curated stone tool assemblages and evidence of symbolic behavior (art work) are more likely to occur at aggregation sites with "public" behavior, and that dispersal sites with "private" behavior should have more expedient tools and a lack of evidence suggestive of symbolic behavior. Wadley (1986, 1987) suggests that the mid-Holocene "classic" Wilton assemblages from Jubilee Shelter in the Magaliesberg of the Transvaal reflects aggregation occupations with abundant evidence of "public" behavior. Contemporary assemblages from Cave James are considerably different and are the result of dispersed phase occupations reflecting "private" behavior. Analysis of Later Stone Age settlement patterns and rockart distributions in Lesotho support some of these conclusions (Bousman 1988).

Mazel (1989) also invokes social processes for explaining changes in the Thukela River basin Later Stone Age. He argues that the ecological-adaptation arguments are flawed, and that social processes account for the significant changes observed. Mazel ascribes fluctuations in artifact densities to variations in the exchange network which he posits is driven by social needs (mainly mate recruitment) rather than economic forces associated with risks in the food quest as originally described by Wiessner (1977, 1982). Also, on purely theoretical grounds, he proposes that the underlying forces in social change are due to "conflict and tensions in social relations" (Mazel 1989: 46). Mazel steadfastly refuses to acknowledge any role that changing carrying capacities (due to environmental fluctuations) may have played in population changes, and social responses to these changes or unpredictable fluctuations in food amounts or availability thus ignoring an enormous amount of solid research on these topics. He also did not turn to any of the recorded stories or myths of the Southern and Mountain Bushmen to strengthen his case (Bleek 1933; Bleek and Lloyd 1912; Lewis-Williams 1981; Vinnicombe 1976), which have ample documentation in the Bushmen's own words on the importance of rain (water, !khwa). Mazel (1989: 119-

132) identifies the only possible source of "social tension" in egalitarian hunter-gatherer societies as the division of labor between the sexes. He presents cross-cultural comparisons that seem to suggest that as women contribute more and more economically, their status within a hunter-gatherer society changes to greater equality with men. Mazel suggests that from the mid-Holocene to the late Holocene, the economy shifted from meat oriented to a more equal balance between plant and meat, and women's status increased accordingly. However, Mazel (ibid: 156) acknowledges that he ultimately fails to identify gender associated archaeological correlates (artifacts or any other demonstrated class or pattern of archaeological data including plant/meat ratios), and this highlights the most serious flaws with his study. First and foremost, he has not provided a systematic and coherent linkage between social theory and archaeological data. Mazel has developed the workings of his theory, but he relied on vague, unexplicit and untested assumptions that traditional archaeologists often use when theory is translated into archaeological signatures. Many of his underlying assumptions about the meaning of observations on artifacts (epistemology) remain unchanged from earlier works going all the way back to Goodwin and Van Riet Lowe. For example, how do we know that changes in artifact densities are due to proposed variations in exchange systems, and not simply due to changes in sediment deposition rates in the rockshelters (low deposition rate = high artifact density and vice versa)? Under these circumstances it is difficult, if not impossible, to arrive at correct conclusions. As will be shown below in this chapter and in Chapters XII and XIII, much of what archaeologists thought was indicated by certain artifact patterns is probably not what really is reflected by these patterns. Both his and Wadley's research would greatly benefit with a careful consideration of how and in what condition artifacts are discarded, and the ways this affects their archaeological observations.

One additional and unstated assumption by the adherents of the "social process" approach, is that it represents some type of "emic" form of analysis or, in other words, it attributes culture change to the internal workings of that individual society and it claims to understand this from the point of view of the society. Mazel's claims of writing a society's history implies this as well as statements like early Thukela Basin society "perceived its environment as hostile" (ibid: 121). However, the social approach is as hopelessly "etic" as the cultural-adaptational or ecological-adaptational approaches. This is not to say that social factors do not cause social change, they can and do, but social process practitioners need to state much more clearly their assumptions and models under which they work. Through middle range studies they need to develop clear, concise, unambiguous archaeological signatures of the social processes they study, because these linking mechanisms are completely absent in their work in southern Africa. Until this is done their arguments can only be accepted through special pleading or theoretical faith.

Thus South African archaeologists have through the years employed a number of different models to account for assemblage variability and composition. The most common model is the cultural-adaptation model, however, since the mid 1970s many archaeologists have more intensely stressed, in one form or another, the concept of adaptation with its overtly functional explanation. If the cultural-adaptation model accounted for the majority of assemblage variability then assemblage composition could be used directly to construct a cross dating scheme. Only Wadley's and Mazel's research and models might seriously question the utility of using simple assemblage composition for cross dating purposes, although they do not make the point. Outside of southern Africa other more general models have been presented that further diminish the utility of the cultural-adaptation model for explaining assemblage composition.

A more theoretical approach to explain assemblage composition was suggested by Ammerman and Feldman in 1974. These authors proposed a model that accounts for relative frequency differences in stone tools without invoking cultural changes or adaptational changes on the scales implied by H. Deacon (1976) or Sampson (1974), or the social changes suggested by Wadley (1987) and Mazel (1989). Ammerman and Feldman (1974: 610) suggest that three elements affect artifact relative frequencies [μ], and these are (1) the relative frequency of each activity [a] from the total set of activities performed by a single group within a given period of time, (2) the 'mapping' relations [m] between tools [T] and activities, and (3) the tool droppage rate [d]. Some of the elements of the model are intuitively understood, but others require comment. The mapping relations refer to the relations between tools and activities. For example, stone tools may be single- or multi-functional, or tasks can be completed by a variety of different tools. Variations in these mapping relations will affect the numerical relationship between a single activity and the number of tools required to complete that task or activity. The droppage rate refers to the probability at which a tool is abandoned and incorporated into the archaeological record. Droppage rate reflects the longevity of a tool, and longevity of a tool can be conditioned by raw material, intensity of use or a number of other factors. This attribute will be discussed in more detail below. Ammerman and Feldman's model must be calculated in a series of steps and the first step is to calculate the expected abundance of each tool type:

$$\text{Expected Abundance of } T_1 = d_1(m_1a_1+m_2a_2+...m_na_n)$$

where
d: droppage rate
m: mapping relation

The relative frequency of T_1 is calculated by totalling the expected abundance values for all tool types as per the formula above and dividing the individual T values by the total:

Relative frequency of a tool: $\mu_1 = T_1/\Sigma T_i$

Ammerman and Feldman (1974: 616) stated a number of years ago that archaeologists underestimate the effect of droppage rates on the formation of archaeological assemblages. After 15 years this observation is still pertinent, but some researchers, especially ethnoarchaeologists, have begun to tackle the problem.

Yellen (1977: 73-84) proposed a model for assemblage composition among foraging hunter-gatherers. Yellen states that material found on modern San sites can be classified as maintenance or subsistence related. He argues that subsistence related artifacts or debris clearly reflect activities that relate to the local resources, but maintenance activities such as refurbishing tools occur as needed in a quasi-random or unpredictable cycle. Thus it appears that the San ethnoarchaeological evidence indicates that assemblage composition is strongly controlled by the need to replenish exhausted, broken, or lost tools. This is not necessarily related to site location, local resources, or even subsistence activities that occur at a particular site, but rather to the need of tool replacement. He states that the likelihood of maintenance activities (and associated discarded artifacts) to occur on a site is related to the length of time the site is occupied. Thus site assemblage diversity is related to length of occupation and possibly the number of occupants.

Recently, Shott (1986,1989) has suggested that hunter-gatherer mobility and tool use-life can affect assemblage composition significantly. Shott argues that higher settlement mobility leads to smaller tools and fewer tools with a wider range of uses. Additionally he argues that tool use-life is similar in concept to Ammerman and Feldman's (1974) tool droppage rate, however Shott realizes that the situation is more complicated that simply dropping tools. Shott relates ethnoarchaeological assemblages from !Kung San and Ingalik to manufacturing costs and curation rate. Thus, in general, the more time and energy spend manufacturing a tool, and the longer the tool is curated, maintained or rejuvenated, then the slower individual items are incorporated into the archaeological record. Shott (1989: 17-26) discusses the "discard process" and notes that more than one process accounts for tools entering the archaeological record. These processes, with slight modification, are (1) breakage during manufacture, (2) abandonment during or after manufacture [normally due to material flaws], (3) breakage during use, (4) loss or abandonment during use, (5) recycling [change in tool form and use through rejuvenation], and (6) exhaustion or total depletion. Additionally each of these six processes influence discard rates and are conditioned by activities, manufacturing complexity, material brittleness, and intensity of use. For example in a Later Stone Age assemblage the discard rate for ostrich egg shell beads would be different for those broken during manufacture than for those discarded from use-breakage. Also manufacture discards are probably more frequent for artifacts that require many stages of production (eg. pressure flaked backed bladelets versus end scrapers) or for artifacts that are made of more brittle or breakable material (eg. ostrich eggshell versus skin).

The above discussion suggests that simple artifact relative frequencies do not provide a robust data set for understanding cultural groupings. Variations of activities, tool/activity mapping relations, tool use-life can all independently affect the occurrence of artifacts in an assemblage and these variables may not be significant to culture history.

In 1966 Sackett presented one of the first really elaborate applications of morphometric Paleolithic tool typology. He suggested that an artifact type should represent formal variation that is culturally meaningful, and he further argues that an artifact type is a configuration of formal elements that comprise an attribute cluster. By designing a comprehensive attribute system, formal variation within and between tool types could be defined. In the first application of an attribute analysis to South African artifact assemblages, J. Deacon (1972) has suggested that among lithic artifact assemblages in southern Africa metric attributes within a single artifact group, e.g. scrapers, can be used to identify "stylistic" norms using the mean moment measures, while the standard deviation provides an indication of how tightly the "style" is defined. In Africa, as in much of the world, the attribute analysis approach has not been entirely successful because too much variation exists within artifact "types" and well defined attribute clusters do not occur often. The source of much of this variation has not been identified in southern Africa.

Dibble (1987) and Barton (1990), however, have successfully argued that Middle Paleolithic stone tool morphology can be altered by the intensity of use, reuse, maintenance, and rejuvenation before discard. This is an ontongeny model for individual stone tools, rather than cultural systems. Thus tools classified as side scrapers can change to transverse scrapers or to other "types" simply through continued use. Especially for stone tools which easily wear and are quickly exhausted, this developmental model of changing tool morphology can be used to suggest that the attribute analysis approach, subjectively or quantitatively applied, does not identify "types" in terms of preconceived and idealized forms of formal stone tool shapes, but rather many stone tool attributes best reflect the degree of wear or exhaustion at the time of discard. Examples of stone scraper exhaustion in ethnoarchaeological contexts are the analysis of hide scrapers by Ethiopian hide tanners (Clark and Kurashina 1981; Gallagher 1977). These studies help to explain why attribute analysis of stone tools rarely provides clear, concise and interpretable patterns (J. Deacon 1972; Sackett 1966).

Recently Sackett (1982, 1985, 1989) has taken a slightly different approach to style and suggests that ethnic groupings can be identified by analyzing "isochrestic" style. Isochrestic means "equivalent in use". Sackett argues that artifacts that have identical functions can be made in a variety of forms, and it is the "tradition" of craft production that seems to govern the morphology of an artifact. Sackett argues that if functionally equivalent artifacts change in any way through time or space then this is stylistic change. His approach to style in archaeology is to compare functionally similar artifacts, eg. end scrapers to end scrapers or burins to burins, and look for temporal changes. Even if these can be related to functional differences, he argues this still represents isochrestic style. Isochrestic style is very tempting for the paleolithic archaeologist, because generally we are able to define functional similarity between tool types through wear pattern analysis (Binneman and Deacon 1986; Keeley 1980; although see Shackley and Kerr 1986), through ethnographic or historic observations (Dunn 1880; Kannemeyer 1890; Lee 1979; MacCalman and Grobbelaar 1965; Rudner 1979; Silberbauer 1980), or by well preserved archaeological specimens or good archaeological context (Clark 1959, 1977; H. Deacon 1966; although see Wendorf 1968).

Close (1978, 1989) and Close et al. (1979) have proposed a method for identifying style in backed bladelet artifacts that generally follows Sackett's (1982) strategy of studying isochrestic style, and her approach is worth discussing as she analyzed backed microlithic tools. Close has attempted to chose attributes that would be unlikely to change through use and thus have little or no functional significance.

The first attribute is the side chosen for backing; left or right termed sinister and dexter, respectively. Secondly she suggests the type of backing (Ouchtata, obverse, inverse, sur enclume, alternating or any combination) is also reflective of nonfunctional stylistic choice. The third stylistic attribute chosen is which end was trimmed to a point; distal or proximal. Close (1989: 12) states that these attributes were assessed for their functional nature by comparing the distribution of these three attributes to "functional" parameters such as size, shape, and completeness. It would be advantageous to combine Close's approach with a wear pattern analysis, but it is unlikely that a single tool type as limited as backed bladelets would change functionally. Using both cluster analysis and principal component analysis, Close (1989: 16-20) has been successful at identifying assemblages that are restricted in time and, to a limited extend, in space.

Even though Close and other archaeologists have enjoyed success with the isochrestic approach, it is theoretical deficient in that it offers no true explanation of why stylistic change occurs. Alternatively Wiessner (1983, 1984, 1985) has proposed a new "theory" of style that is more robust. She argues that in many cases "style" is used as a mechanism for communication in social settings. More specifically style is used for personal and social identification by comparison with other individuals or groups. Individuals may not be able to put the message into words, but a message is communicated nonetheless. She identifies two types of style, and calls these assertive and emblemic styles. Wiessner, studying projectile points and beaded headbands made and used by living Kalahari San, argues that morphological variations in projectile points reflect social groupings and carry emblemic stylistic information. Different designs on beaded headbands, on the other hand, do not indicate group identities. Wiessner argues that these are used by the San to show the uniqueness of the individual maker or owner, and reflect assertive style. Wiessner's theory of style is dynamic, and it can be postulated that as population densities increase and as social interactions increase so does the need for both social and personal identification. This implies that the stylistic "load" carried by an artifact assemblage will increase as population density increases, and Hodder (1979) has argued that stress (social or environmental) can also create situations where the stylistic loads in artifact assemblages may increase. However a major operational problem exists in terms of identifying emblemic or assertive styles in prehistoric contexts. Obviously an artifact must be used in a manner so that it is clearly visible, otherwise individual or group comparisons would not be possible, but Wiessner offers no solution or strategy to help resolve the problem of style identification. Thus ethnoarchaeologists have a glimmer of hope, but prehistoric archaeologists have little.

Sampson (1988: 16) now embraces Wiessner's approach to style in his analysis of decorations on prehistoric Smithfield ceramics, and he suggests a method for determining the presence of Wiessner's emblemic style from archaeological data. It should be added that decorative motifs on ceramics are unlikely to have functional significance in terms of vessel use, or change through use, and they are not obscured from view as are hafted lithic tools such as scrapers or backed tools. Thus ceramic motifs have many advantages over stone tools for stylistic studies. However Sampson's approach requires detailed quantified data from all sites within a large area so that isopleth maps can be constructed for individual motifs on ceramics. It is especially helpful if the ages of ceramic motifs are known as well. In this way motif boundaries presumably representing emblemic style changes along group territorial boundaries through space and time can be represented by steep drop-off gradients with clear shoulders. Unfortunately no approach has been developed for identifying emblemic or assertive styles in lithic assemblages excavated from a few or single sites. It appears that at a minimum detailed spatial information is necessary for the application of Wiessner's approach.

Conclusions

Theoretically, analysis of assertive or emblemic styles would seem to provide the most robust patterns for any cross-dating scheme, but because of the difficulty in identifying assertive or emblemic styles with prehistoric lithic artifact assemblages the cross-dating scheme (Chapter IX) has, by default, focused on isochrestic styles. It is possible that assertive or emblemic styles might be registered in the isochrestic styles analyzed from the rockshelter assemblages, but one cannot know for sure. In a very narrow sense and solely for the purposes of developing a cross-dating scheme, it is more important to identify chronological patterns than to understand why these patterns exist. Although as more refined models are developed an explanation of these patterns becomes increasingly important for a specific research area. In the following chapters a model and a series of hypotheses are presented in an attempt to explain some of the chronological patterns, however a robust test of these hypotheses must await future research that incorporates larger artifact samples with better paleoenvironmental associations, comparisons with faunal and other economic remains, and surface site distributional data.

CHAPTER XI

ECOLOGICAL AND BEHAVIORAL BASIS FOR A NEW MODEL

With the single exception of H. Deacon's (1976) processual model, all other pioneer models generated by South African archaeologists (Chapter X) offer monolithic (single-cause) explanations of Later Stone Age assemblage variability and design change. Here, I present the theoretical underpinning for a more elaborate processual model that attempts to take into account several interacting forces. The model, firmly based within the paradigms of Culture Ecology and Foraging Theory, is essentially deterministic and views environmental changes as the primary causal agent. It incorporates some social processes and interactions, but it does not give them a primary causal role as do the models of Wadley (1988) and Mazel (1989).

It focuses instead on problems arising from the ebb and flow of food supplies on the landscape, and on the ways that hunter-gatherer-foragers go about acquiring food resources and insuring that they have access to food sources. Unlike the other models from southern Africa, this one attempts to take full advantage of the available ethnological data on global hunter-gatherer ecology and behavior. However, it eschews the use of ethnographic analogies with specific groups. It also avoids much of the systemic jargon used by hunter-gatherer theorists, although processual terms will be mentioned parenthetically.

For clarity, the model will be compiled into two stages. In this chapter I outline the man-land interactions that constitute the model's foundations. In Chapter XII, I show how the model predicts various patterns of archeological fallout in changing circumstances. Finally, the combined ecofact and artifact data from Blydefontein will be used as a first and partial test of the new model.

Design and Structure

The model is designed to take advantage of the huge spatial data-base offered by the Zeekoe valley survey (Chapter I). The goals of the design are to explain assemblage composition and changes in artifact shape within a framework of settlement pattern changes. Thus the dominant mechanism within the model will be hunter-gatherer mobility patterns.

Figure 91 summarizes the model's four basic components. There are two ecological parts (climate and resources) and two adaptive-behavior parts (risk response and range). Each component is modelled as a system of interacting variables. The first system (climate) serves here as a prime mover, thus it acts as an essentially closed system, not influenced directly by the others. The second system (resources) directly influences both the third system (risk response), and the fourth system (range). The resource system is neither closed not is it fully open. Thus, the risk and range systems have some feedback effect on resources. Figure 91 shows influence-arrows of different thicknesses to diagram weaker feedback and the porous (rather than open) nature of the resource system. Again, the third system (risk response) has a stronger influence on the fourth (range) than vice versa. Although range has less feedback-influence on resources, there is a stronger connection to risk response.

The climate system has two variables. Both rainfall and temperature will be shown to affect, through resources, several different aspects of hunter-gatherer adaptive behavior.

The resource system has four interacting variables embedded in it: abundance, the plant/animal ratio, seasonal timing, and patchiness. Different strengths of feedback influence exist between the four variables but they cannot be generalized, so arrows are diagrammed at equal thickness in Figure 91.

Response to risk entails another five interacting variables: camp moves, collecting trips, plant/meat ratio in the diet, exchange, and storage. Each one is an adaptive response to uncertainty about future supplies of resources. No attempt is made to model different strengths of feedback influences between the five variables.

The range system contains three interacting variables. No attempt is made here to distinguish between range and territory. Population density has a dominant influence on range size and mobility, with some feedback from the other two. Range size and mobility are heavily interdependent, however.

Responses to Risk Posed by Resource Variability

Hunter-gatherers calculate daily where they will get their next meal, and the several meals thereafter. This calculation deals with partly predictable changes in the total amount (richness, abundance) of food/water, called food hereafter, in their range. Also, changes will occur in the food's seasonal availability, in its patchy distribution across the range, and in plant/animal content (diversity). Of course other items are of concern, but food is so basic that secondary items (resources) play an insignificant role in the calculation of risk. Thus the food quest is the central drive mechanism of the model. Throughout, the model assumes that responses to perceived risk are aimed at reducing uncertainty. Strategies for reducing risk (coping strategies) may include changes in mobility patterns within the range, different emphasis on plant or animal inclusion in the diet, changes in food storage patterns, increased sharing/exchange, and increased between-band visits (Cashdan 1983, 1985; Wiessner 1977, 1982; Winterhalder 1986).

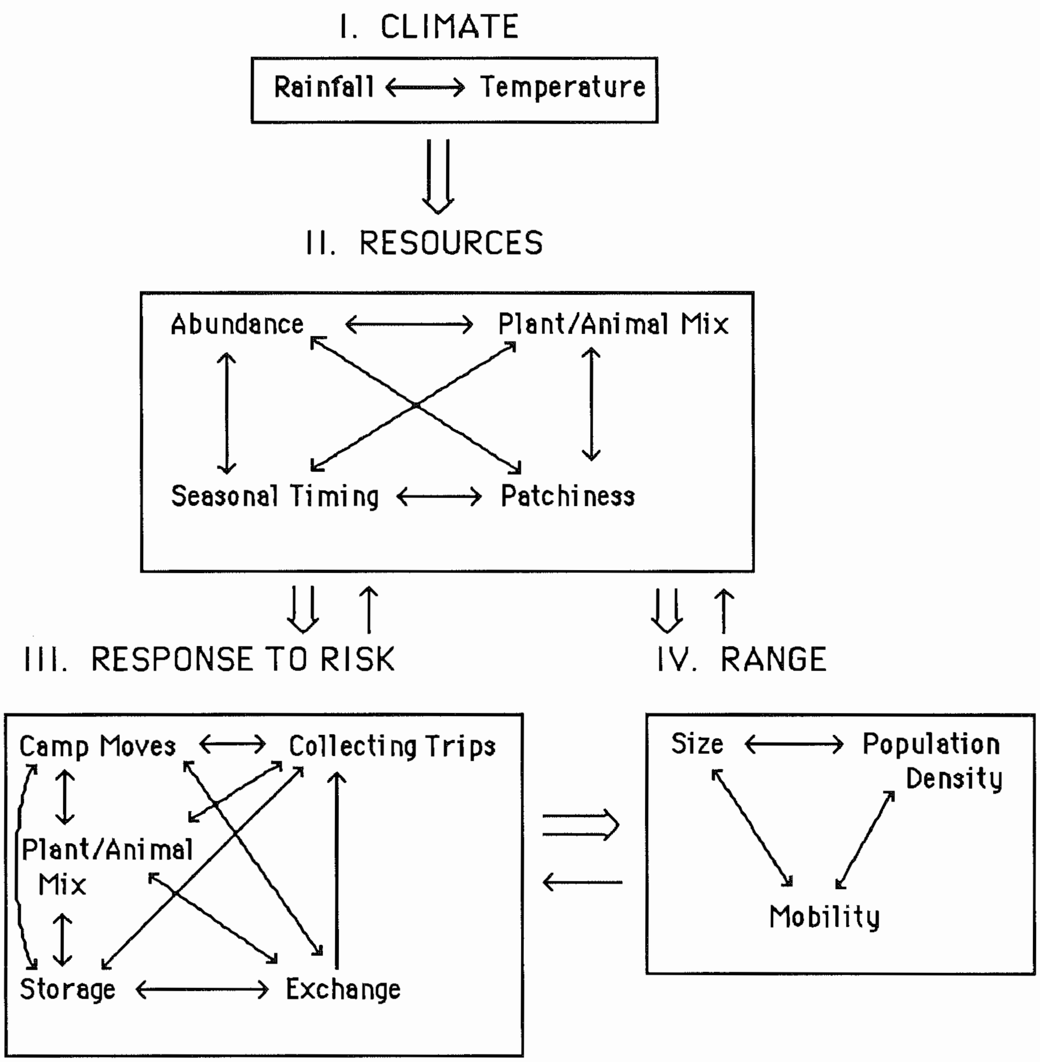

Figure 91. Ecological and behavioral model's four components.

Mobility Patterns: Foraging and Collecting

It is useful to distinguish between two options (exploitation strategies) by which a band can acquire food from its home range: foraging and collecting (Binford 1980).

Foragers gather foods daily, normally return to residential camps at the end of each day. Daily forays involve visiting a few places within the camp's catchment area, and food is not extensively processed at places outside of the camp. They tend not to store great quantities of food, but rather foragers transport people to resources by moving residential camps frequently. Residential sites are abandoned when resources within local site catchments are depleted. Foraging strategies are designed to exploit foods that have a fairly even distribution through space and time. However variations in the abundance, distribution, availability and predictability of foodstuffs determine how often a camp is moved. Foragers rarely organize special task groups who leave camps for extended periods of time in order to exploit distant but rich food patches.

Collectors live in higher-risk, more stressful environments with very limited and patchy food supplies, such as the arctic, and they depend heavily on mobile animals and less on plants. They tend to transport resources to people, and acquire food in bulk whenever they can. They also store it for seasons when nothing else is available. For this reason, their mobility pattern involves relatively few camp moves each year, but organized task groups leave camp on long trips (logistic mobility) and stay at selected areas (procurement sites) to take advantage of some briefly available plants or animals. These foods are partly processed here, and brought back to camp. It is in this light that collectors are seen as moving food to people and not vice versa as with foragers.

There are few ethnographic examples of "pure" foragers or collectors, and most hunter-gatherers use a judicious mix of the two. In fact, Kelly (1983: 299) comparison of 37 groups shows that as the average number of yearly camp moves per group decreases, so the average number of task-group trips per year increases exponentially. This pattern is especially strong for hunter-gatherers who are heavily dependent on hunting rather than gathering or fishing. In fact, Winterhalder (1986: 377) has argued that as risk increases there is a tendency for hunters to focus on fewer prey species. However, where gathering increases in importance, it can be shown that the number of camp moves may decrease without any increase in task-group trips. According to Kelly's (1983: 282, 299) data the Dobe !Kung and the G/wi have some of the highest rates of gathering plant foods, and they are among the groups with the lowest mobility (residential and logistical) that still would be classified as mobile hunter-gatherers. The Kalahari San do not need to move a great deal, presumably because of the abundance and density of plant resources. What determines the exact mix employed by a particular band is explored next.

Ecological Determinants of the Mobility Pattern Mix

Murdock's (1967) survey of hunter-gatherer societies can be used as a rough guide to climate/mobility relationships. Unfortunately Murdock uses a system of three mobility categories that does not match exactly with Binford's (1980) forager/collector dichotomy, although an approximation can be made (ibid: 14-15). In Table 27 the number of ethnographic groups in each of Murdock's mobility classes is tabulated against six gross habitats distributed from tropics to arctic. Using standardized deviates (high values underlined) the table suggest that mobility decreases with decreasing temperature until arctic environments are encountered, at which point the preferred pattern reverts back to highly mobile. It is likely that the most mobile groups in the tropical and semi-tropical zones are foragers who move camp frequently, while the arctic groups are collectors who take long task-group trips from a base camp. Murdock's semi-nomads in the warm-temperate and cool zones probably represent a mix in which both strategies are used. Semi-sedentary and sedentary groups in boreal environments include the Northwest Coast Indians who were sedentary hunter-gatherer-fishermen exploiting the highly predictable and abundant salmon.

Table 27.--Number of groups tabulated by categories of nomadism and environment. Numbers in parentheses represent standardized deviates and unusually high values underlined (data from Binford 1980:14, Table 2).

Environment	Fully Nomadic		Semi-Nomadic		Semi-Sedentary&Sedentary	
tropics	9	(4.1)	2	(-1.6)	1	(-1.3)
semi-tropics	9	(3.6)	4	(-1.1)	1	(-1.5)
warm temperate	3	(-1.4)	21	(1.3)	8	(-0.4)
cool temperate	4	(-2.1)	32	(1.1)	17	(0.4)
boreal	5	(-1.4)	21	(-0.3)	19	(1.6)
arctic	5	(1.6)	4	(-0.8)	3	(-0.3)
Total	35		84		49	

Primary Plant Production as a Determinant of Forager Mobility

The number of camp moves by foragers is controlled, in part, by the richness of the above ground productivity of the exploited plant communities (Figure 92). The curvilinear regression shows that for foragers, in general, at the low end of the primary production scale, as plant productivity drops the number of camps moves increases. The number of camp moves increases at the high end of the scale because most of the plant biomass is locked up in trees and other inedible plant materials (Kelly 1983).

Climate as a Determinant of Food Selection

Climate also affects the plant and animal biomass of the band's range, and this in turn influences decisions about how much hunted food versus plant food will become incorporated in the diet. Both annual rainfall and mean annual temperature are used.

Kelly's (1980, 1983) uses a temperature measurement, known as effective temperature (Bailey 1960), that is based on the average annual temperature (T) and the average annual range of temperature (AR). Effective temperature (ET) is calculated by the formula:

$$ET = (8T + 14\ AR)/(AR+8)$$

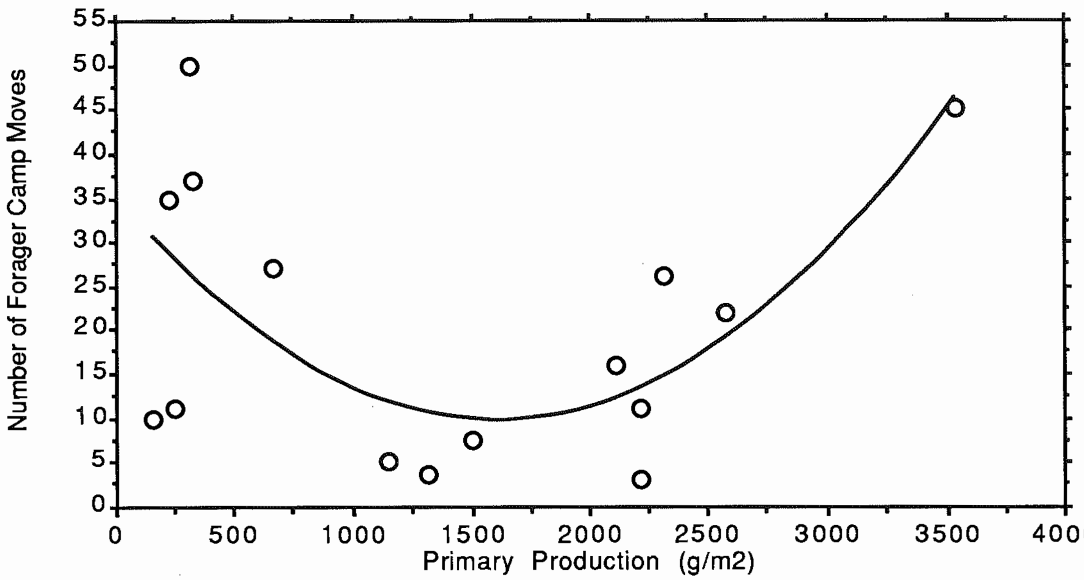

Figure 92. Changes in average number of forager camp moves with changing plant primary production (*Number of camp moves* = 35.381 - 0.032x + 9.901^{-6} x^2, r^2 = 0.437, p value = 0.0318) (data from Kelley 1983).

Effective temperature considers the average temperature as well as the variation of temperature through the seasons for any specific region. Thus effective temperature increases as average annual temperature increases or as the annual range of temperature increases. The average ET value at the equator is 26 and the average ET value at the poles is 8 (Kelly 1980: 12), thus ET is a fair measure of the insolation available for plant growth.

A scatterplot between ET and percent of hunted resources in the diet of terrestrial hunter-gatherers (Figure 93) demonstrates that a curvilinear regression best fits the data. Between 8 (arctic) and 18 (temperate) the contribution of hunted resources to hunter-gatherer diets declines with increased ET, but between 18 and 26 (equator) the regression reverses to a positive relationship. This change must be related to the major shifts in global plant communities and primary production, especially in tropical forests.

The relationship between mean annual rainfall and hunting is also complex, and it can be explored with two studies. First the amount of large herbivore biomass in east and southern African environments increases as rainfall increases (Figure 94) at least within the range of measurement (Coe et al. 1976: 341-354). This relationship shows that moderate changes in rainfall can bring about important increases in the herbivore biomass. Individual species do not all respond in tandem to changes in precipitation because of interspecies competition and other local factors, but large herbivores as a single group do. It would be expected that as animal abundance increases so might its use by hunter-gatherers.

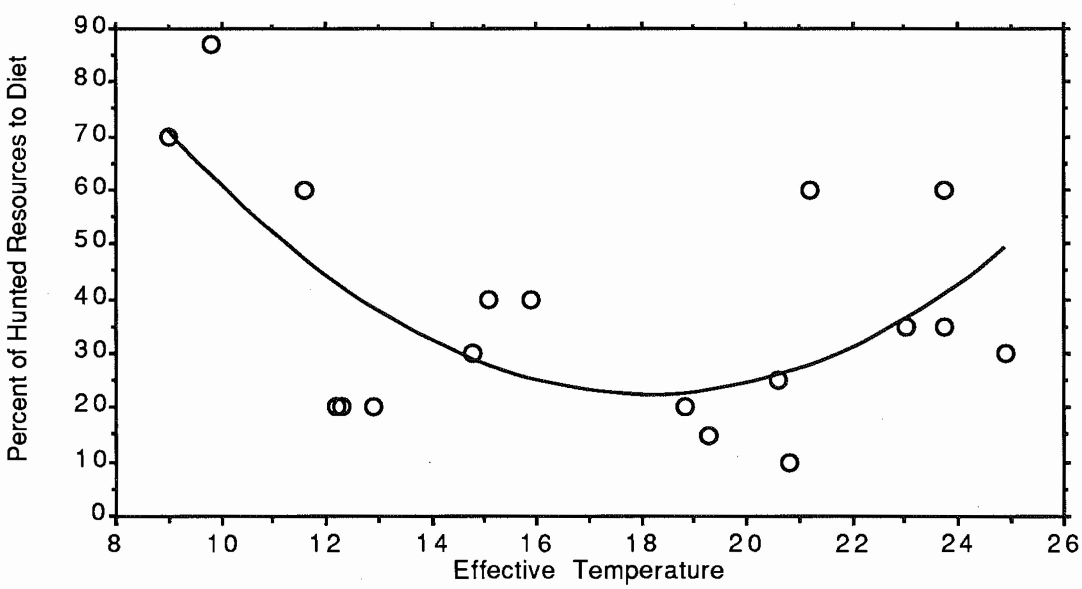

Figure 93. Scatterplot of effective temperature and percent of hunted resources contributed to diet (Second Order Polynomial, r^2=0.407, p value = 0.0198). Hunter-gatherer groups include Punan, Mbuti, Vedda, Bihor, Aeta, Semang, Chenchu, Siriono, Guayaki, Hadza, G/wi, Dobe !Kung, Aranda, Walapai, Maidu, Northern Paiute, Montagnais, and Ona (data from Kelly 1983: 280-281, Table 1).

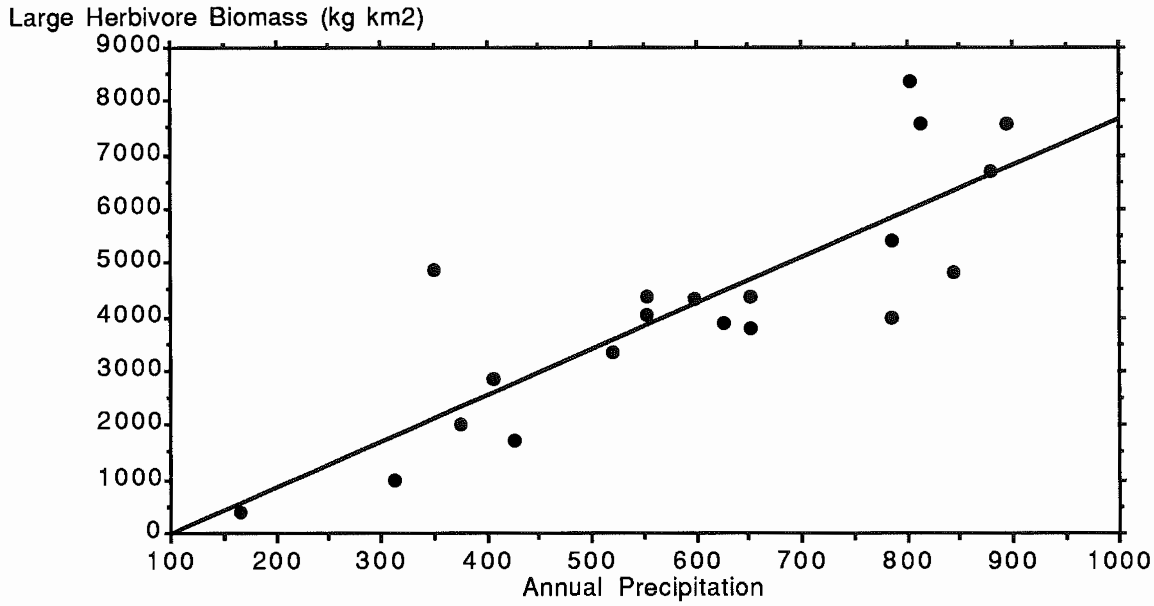

Figure 94. Regression between annual precipitation and large herbivore biomass in east and southern Africa (data from Coe et al. 1976). *Herbivore biomass* = 8.52 (annual precipitation) - 833.5, r^2 = 0.709, p value < 0.0001.

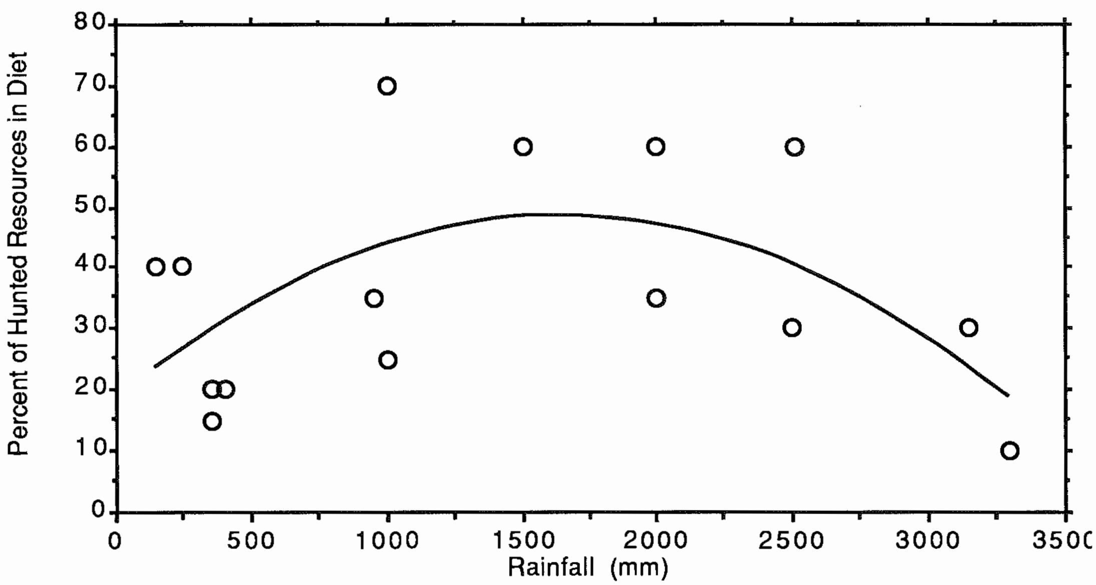

Figure 95. Scatterplot of annual rainfall and percent of hunted resources contributed to diet (Second Order Polynomial, r^2=0.324, p value = 0.0785). Hunter-gatherer groups include Punan, Mbuti, Vedda, Bihor, Aeta, Semang, Chenchu, Siriono, Guayaki, Hadza, G/wi, Dobe !Kung, Aranda, Walapai, Maidu, Northern Paiute, Montagnais, and Ona (data from Kelly 1983: 280-281, Table 1, and Fullard and Darby 1975: climatology maps).

Rainfall-diet relationships can be further explored with Kelly's (1980, 1983) data and climatic figures gleamed from world climatic maps (Fullard and Darby 1975). A second order polynomial (*Percent hunted resources* = 18.168 + 0.037x - $1.113^{-5}x^2$) provides a weak although significant fit to the data (r^2 = 0.324, p value = 0.0785), and a plotting of the data with the regression curve shows (Figure 95) that a simple linear regression between rainfall and hunted resources does not exist. Between 0 to 1750 mm rainfall the percent of hunted resources increases as rainfall increases, then between 1750 to 3500 mm the percent of hunted resources declines as rainfall increases.

Food Selection as a Determinant of Mobility Pattern

Hunting versus Gathering

The amount of hunting versus gathering practised by a band will have a marked effect on its selection and mix of mobility patterns. Kelly's (1980, 1983) data cover many groups, and the data include useful measurements such as the average number of camp moves per year, average distance of camp moves, total distance of camp moves, length of winter site occupation, average distance of task-group moves, average length of time of task-group forays, and total exploited area. In spite of the several gaps in this data base, particularly for hunter-gatherers in temperate zones, a rough measure of overall mobility is obtainable. The average number of camp (residential) moves of a group multiplied by its yearly average duration of special task-group trips (logistic forays) provides a measure of overall mobility. When the overall mobility for eleven groups is plotted against the percent of hunted food in hunter-gatherer diets (Figure 96), it appears that overall mobility increases as the percent of hunting increases (Overall mobility = $-5.283 + 4.229x - 0.11x^2 + 0.001x^3$). One implication of this is that mobility decreases as the amount of gathered plants in the diet increases. For example, the Dobe !Kung and the G/wi ranked among the highest percentages of plant food in the diet, and they are among the groups with the lowest mobility. The Kalahari Bushmen (San) do not have to move a great deal, presumably because of the abundance and density of plant foods.

Fishing and Mobility

At one extreme in Murdock's array of hunter-gatherers from temperate zones are the semi-sedentary and sedentary groups in rainy, boreal habitats where they could exploit highly predictable and abundant resources such as the salmon runs used by the Northwest Coast Indians. These cases suggest strongly that local, specialized selection of prey/plant species can distort any global trends in the mix of mobility patterns used.

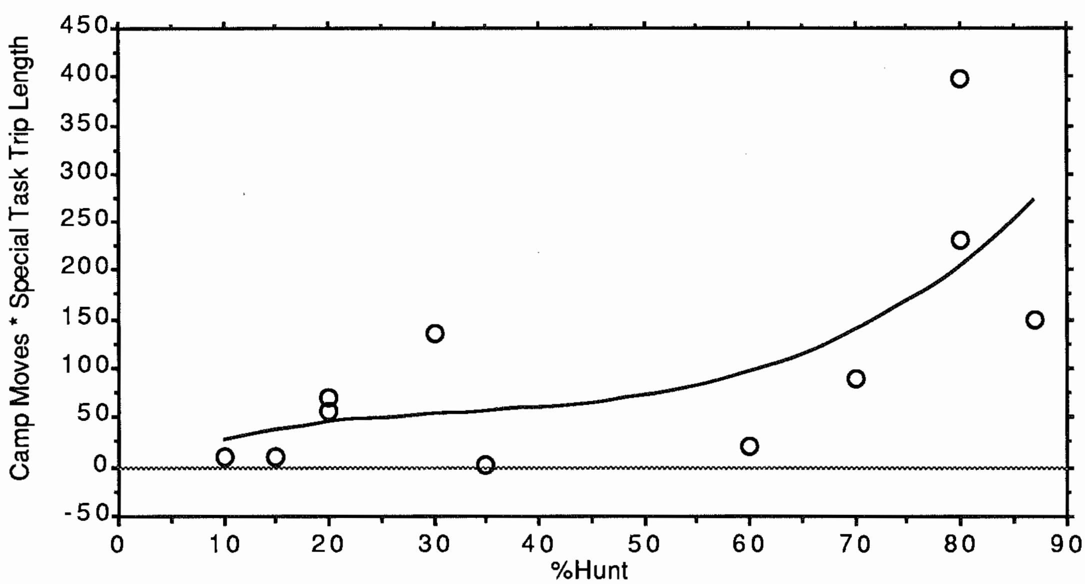

Figure 96. Scatterplot of overall mobility (average number of camp moves * average length of special task trip) and percent of hunting (Third Order Polynomial, r^2=0.501, p value = 0.1591). Hunter-gatherer groups include Punan, Vedda, Aeta, Chenchu, Guayaki, G/wi, Dobe !Kung, Cheyenne, Crow, Sanpoil, Numamiut, and Ona (data from Kelly 1983: 280-281, Table 1).

More useful is Kelly's (1980, 1983) between-group comparison using various measurements of hunter-gatherer mobility patterns. For fifteen groups there is a rough but inverse correlation between length of time spent at a winter camp and the amount of fish in the diet (Figure 97). As winter residence time is a rough indicator of overall mobility (the longer the time in camp, the less mobile the group) these data lend quantitative support to the notion that fishing specialization will override the effects of climate, especially in temperate zones, on the choice and mix of mobility patterns.

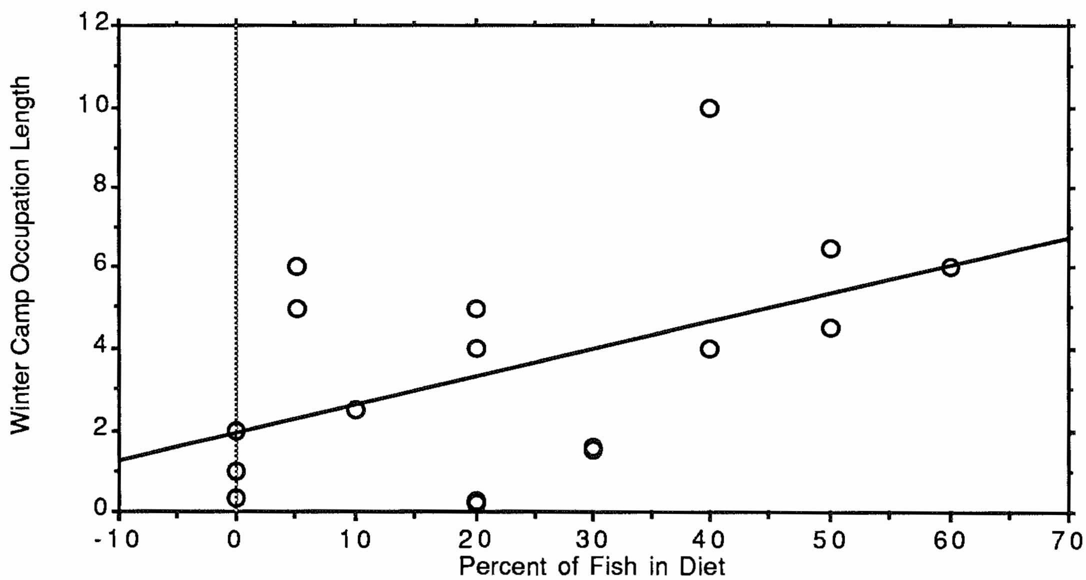

Figure 97. Scatterplot of percent of fish in diet and winter camp occupation length (r^2=0.241). Hunter-gatherer groups include Punan, Vedda, Anadmanese, Chenchu, Siriono, G/wi, Dobe !Kung, Crow, Sanpoil, Numamiut, Mistassini Cree, Montagnais, Ainu, Maidu, Northern Paiute, Nootka, Klamath, and Ona (data from Kelly 1983: 280-281, Table 1 and 2).

Food Patchiness and Mobility

There are two aspects to patchiness: the one spatial and the other temporal. Conaty (1987) makes another useful distinction by pointing out that spatial patchiness can be viewed on a sliding scale from clumped to dispersed (Table 28).

Temporal patchiness may be stable to transient. Obviously, habitats characterized by clumped, transient plants and animals promote collector mobility patterns, while dispersed, stable food distributions promote foragers. Habitats with dispersed and transient resource patterns are not viable because they are not rich enough to support hunter-gatherers.

Table 28. Resource temporal and spatial patterns and optimal associated hunter-gatherer mobility patterns.

Resource Temporal Pattern	Resource Spatial Pattern	
	Clumped	Dispersed
Stable	Sedentary H-G	Foragers
Transient	Collectors	abandonment

Hayden (1986: 85-86) makes a further distinction between habitats with animals having long reproductive cycles (K-selected resources) and those with short reproductive cycles (r-selected resources). Habitats dominated by K-selected foods yield prey with with few offspring per generation and large body sizes, and they promote collector mobility patterns. On the other hand, habitats with r-selected foods yield animals with high numbers of offspring per generation that provide an abundant, reliable food base for a short time each year. He argues that they also promote collector patterns among hunter-gatherers in temperate climates. Foraging, it is asserted, is the best option in warmer habitats with dispersed, transient foods, but this does not take overall habitat richness into account.

In some patchy habitats, hunter-gatherers are likely to switch mobility pattern in the course of the annual round. When foragers move camp to another location, they try to select an area where the food supply has been rested and allowed to recover since the previous cropping. They also prefer to move to a site where foods are as evenly distributed in the the camp's catchment as in the one from which they have just left. If they are forced to move to an area where vital foods are unevenly distributed, and clustered such that daily foraging will not produce enough food for group use, then they may resort to long collecting trips, and store enough for future use.

However, Binford (1980: 5-10) notes some interesting cases where collectors switch to a variant of forager-style camp moves. This pattern occurs among the Yahgan, Slave and Copper Eskimo who position their camps to take advantage of predictable foods as they become available sequentially. These "serial specialists" (ibid: 17) are solving problems like foragers although they live in more stressful and risk prone environments that often do not promote foraging mobility patterns. Serial specialists can be expected in any environment with highly predictable animal migrations and/or patchy plant foods with short, rapid growing seasons.

The type of patchiness involved may also affect storage decisions among hunter-gatherers. Even though collectors tend to store food, their decisions to form caches is dictated more by a temporally patchy food supply than by spatial patchiness (Bamforth 1988: 16). Spatial patchiness, however, is more likely to provoke decisions to organize long, special task-group trips, and not by itself promote storage.

One final point about food patchiness is that not all of the food in a habitat may be accessible to humans. This is especially so in tropical environments, particularly in rain forests where most of the above-ground biomass in either inedible or out of reach (Kelly 1983). In fact for tropical hunter-gatherers, the number of camp moves increases exponentially as the primary biomass increases (ibid: 291).

Carrying Capacity and Range Size

The richness, diversity and distribution of food supplies within a band's range (territory) determines the number of people in a band, and, in part, the size of the band's range. As usual the needed detailed environmental information is not available for hunter-gatherer groups, however estimates of primary productivity in a formula developed by Rosenzweig (1968) was published by Kelly (1983). The formula is:

$$\log_{10}NAAP = (1.66 \pm 0.27)\ \log_{10}AE - (1.66 \pm 0.07)$$

where NAAP is net annual above-ground productivity of plants in grams per square meter, and AE is actual evapotranspiration in millimeters (Rosenzweig 1968: 71). Evapotranspiration (water loss from respiration of plants and evaporation) can be viewed as the opposite of rainfall, and it is based on precipitation and temperature. As AE increases net above-ground primary productivity of plants increases. Even though primary productivity is a crude estimate of plant food availability, it is useful to see the response that hunter-gatherer range size has in relation to this variable (Figure 98).

The curvilinear regression in Figure 98 is weak and the p value shows that the correlation is a borderline significance level at best ($r^2 = 0.155$, p value = 0.185). As stated above primary productivity is not the best estimator of hunter-gatherer carrying capacities, but unfortunately it is the only one we have. Nevertheless, it shows that range size increases with low or high primary productivity values. The increase in range size as primary productivity (carrying capacity) drops is expected, but the increase in range size with higher primary productivity values is surprising. This is due to reduced amounts of edible foods in tropical ecosystems where greater and greater amounts of biomass are locked up in tree trunks and other materials that cannot be eaten by humans (Kelly 1983: 286). The high variability at the low end of the primary productivity scale is probably due to some desert or semi-desert environments with fairly high carrying capacities for hunter-gatherers due to an abundance of edible below ground roots and bulbs. By averaging winter and summer potential evapotranspiration from Venter et al. (1986: Figure 13a and 14a) modern primary production for the Blydefontein area is approximately 100 g/m^2.

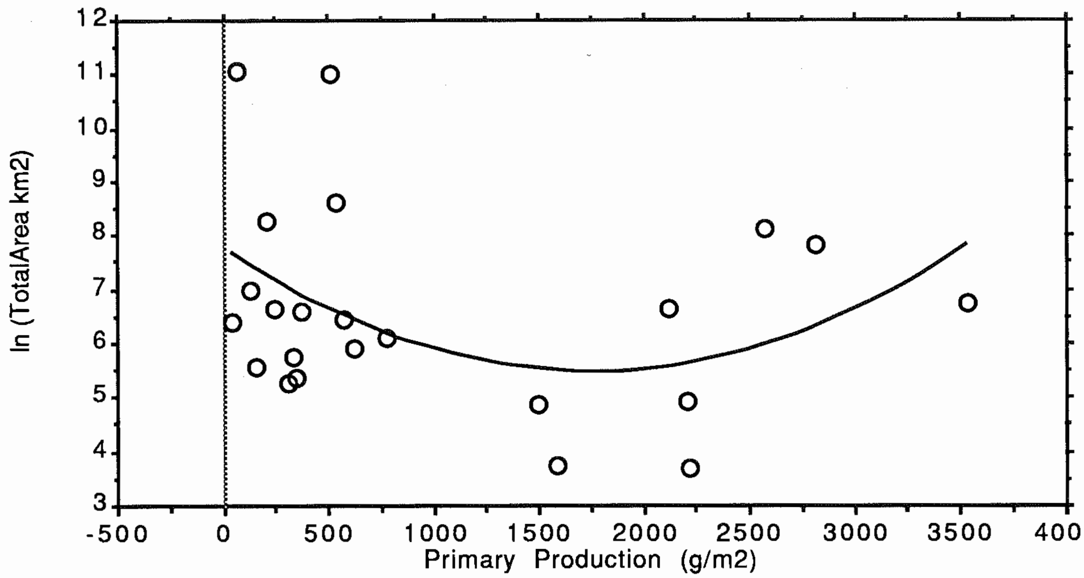

Figure 98. Curvilinear regression between hunter-gatherer range size and primary productivity, r^2 =0.155, p value = 0.185. Groups include the Punan, Mbuti, Semang, Vedda, Anadamanese, Aeta, Siriono, G/wi, Dobe !Kung, Aranda, Walapai, Crow, Maidu, Micmac, Nootka, Twana, Southern Kwakiutl, Klamath, Ainu, Makah, Mistassini Cree, and Nunamiut (data from Kelly 1983: 280, 282).

Population and Range Size

Population density also controls the size of the range. Many theoretical studies have argued that as population density increases, all other factors being equal, range size decreases due to greater territory constriction and population packing. Thirty-eight observations from Kalahari San groups (Hitchcock 1982; Silberbauer 1981;

Wiessner 1977; Yellen 1976) show that this premise is correct for most modern San (Figure 99). These data consist of multiple and single observations taken during the 1960s and 1970s, and represent groups experiencing a variety of social processes that include group fission, transition toward sedentism due to increased population constriction, and increased interactions with agro-pastoralists Bantus and Europeans who drew the San into their own economic systems. Notwithstanding all these complicating factors, population density as measured by the natural logarithm of persons per square kilometer has a significant (p value = 0.0012) although weak correlation (r^2 = 0.25) with the natural logarithm of territory size (see Figure 99).

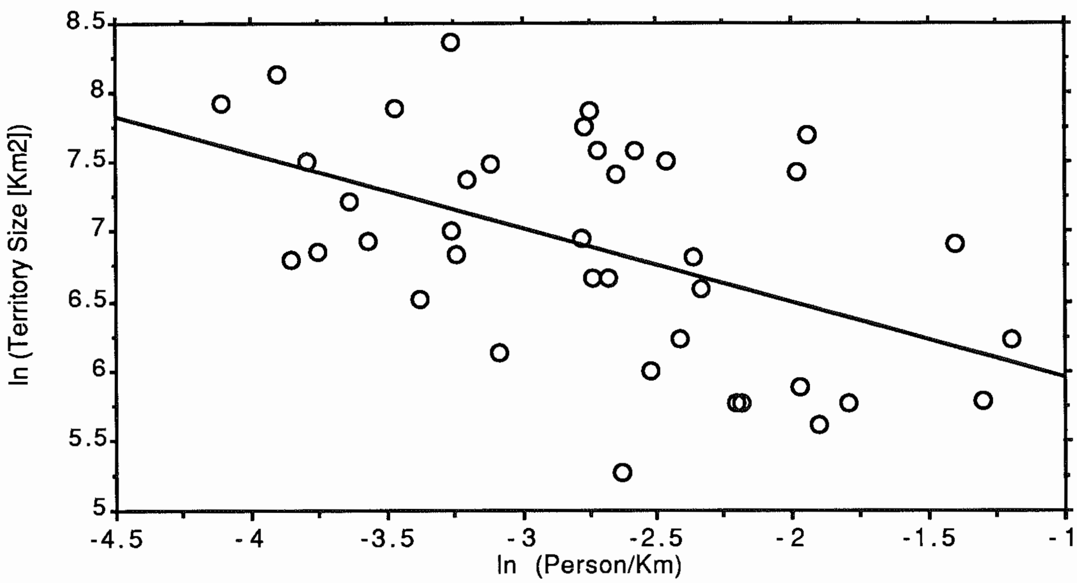

Figure 99. Scatterplot of territory area (km^2) and population density as measured by persons per km^2, r^2 = 0.25, p value = 0.0012. San groups include Kúa (Khwee1, Khwee2, Diphala, Ana-O, Go/to, Ramokgophane, and Pulenyane), !Kung (Dobe 1964, Dobe 1968, Dobe 1969, and /Xai/Xai), G/wi (≠xade, G!õ:sa, Easter Pan, Kxaotwe, Tsxobe, Piper Pans, G≠wi/dom, Dantukwe, Lana, //oege, Sibobane, //Hue, Kikao, Monatsha, Metse-a-monong, /o≠we, and Molapo-Gyem), and !Xõ (N≠haite-Hukuntsi-Nwatle, Pepane-Lehututu-Monong, Hukuntsi-Tshotswa, Tshane-Lotlhake, and Kang) (data from Hitchcock 1982: Table 11.5; Silberbauer 1981: 193; Wiessner 1977: 19, 282; Yellen 1976: 54-60).

This demonstrates that as population densities increase, San territory size decreases, and it is suggested here that greater densities of people on the ground are associated with tighter territorial packing and greater constriction of territories. Hunter-gatherers with lower population densities and larger territories have greater mobility than groups with smaller territories and greater densities.

Food Selection and Range Size

Kelly (1983: 298) argues that range size (total exploited area) is strongly related also to the amount of hunted food in the diet. It is unfortunate that there are no comparable data for the San groups discussed above, but Kelly's data for 23 groups do show clearly that as the amount hunting increases so does the range size (Figure 100). This makes sense as animals must be less dense on the landscape than the plants on which they survive. Because energy is lost as it is transferred up trophic levels, a (hypothetical) group that depends entirely on animals for food is one complete trophic level above another (hypothetical) group that depends solely on plants for food. Thus hunters have less available energy per km^2 than gatherers.

Mobility Patterns and Range Size

Among foragers, it is axiomatic that the number of camp moves per year will increase as range size increases. It is again unfortunate that San data are incomplete, but Kelly's (1983) figures can be used to show the relationship (Figure 101). They also show total distance moved per year against range size (Figure 102). Of interest are two groups (the Aeta and Semang) do not move as far in relation to the size of their ranges, compared to others. Both have clustered, stable and predictable food supplies that allow long sojourns at individual camps. In spite of these two exceptions, both regressions show positive relationships between the two variables.

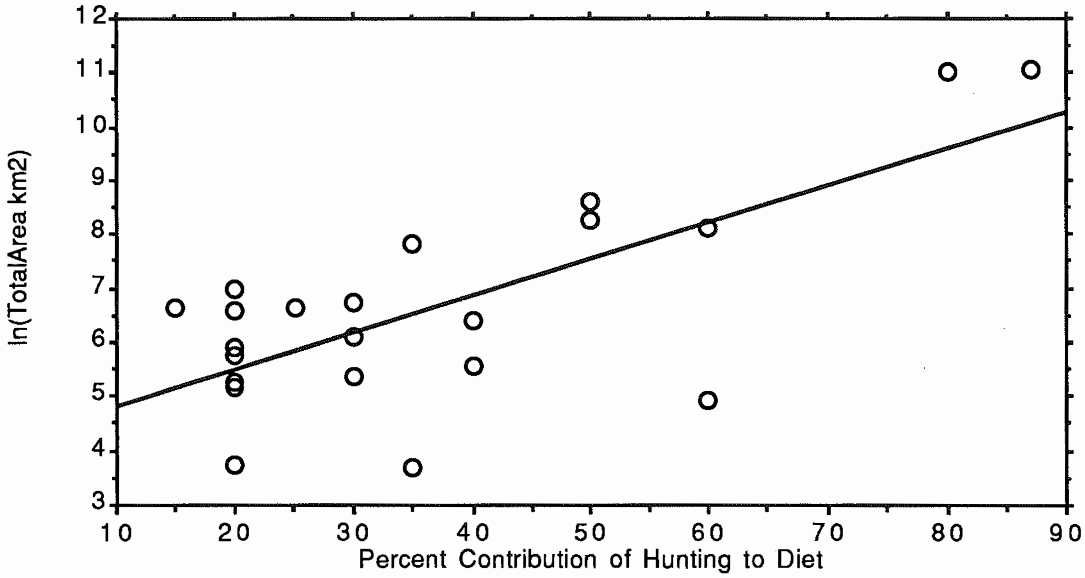

Figure 100. Linear regression between percent contribution of hunting to diet and natural logarithm of total area exploited, r^2 =0.509. Groups include the Punan, Mbuti, Semang, Vedda, Anadamanese, Aeta, Siriono, G/wi, Dobe !Kung, Aranda, Walapai, Crow, Maidu, Micmac, Nootka, Twana, Southern Kwakiutl, Klamath, Ainu, Makah, Mistassini Cree, and Nunamiut (data from Kelly 1983: 280, 282).

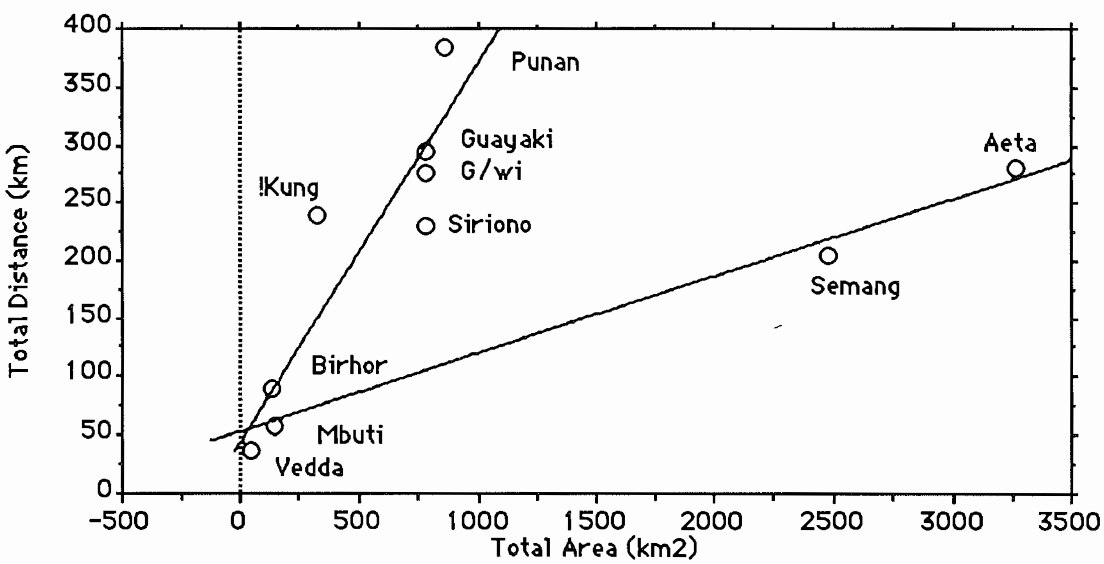

Figure 101. Scatterplot of total exploited area (km^2) and total distance moved between forager residential camps. Birhor, Mbuti and Vedda used in both linear regressions (data from Kelly 1983: 280-282).

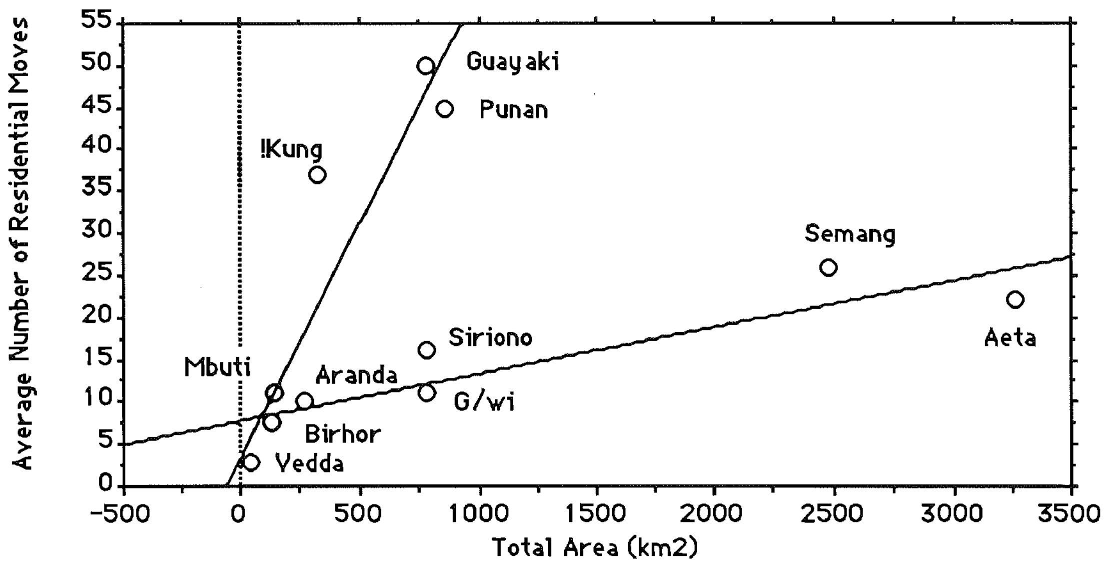

Figure 102. Scatterplot of total exploited area (km^2) by number of forager residential camp moves. Mbuti, Aranda, Birhor and Vedda used in both regressions (data from Kelly 1983: 280-282).

Range Size and Reciprocity

A change in the productivity of plant or animal foods can influence range size and even the use of an individual range, but Wilmsen (1989: 180-225) argues that specific Kalahari San kin groups have long associations with given tracts of land and this suggests long established home ranges. Wiessner (1977, 1982) argues that among Kalahari foragers a common way to reduce economic risk is to use social obligations to pool or share risk among the regional population. One important social mechanism that the Kalahari !Kung use to bond their social obligations is an exchange system known as hxaro which provides a tight but nevertheless far-flung network of complex social obligations that can be called upon by needy families during times of food shortage. Wiessner (1977) and Wilmsen (1989) argue that hxaro is intimately linked with kinship obligations and mate recruitment, and a line chart of the distance between spouse birth places and the distance between hxaro partners in two !Kung groups shows the spatial similarity between mate recruitment networks and hxaro networks (Figure 103).

Wiessner (1977:211-214) identifies three ever-increasing spatial scales of risk (personal, local and regional) which are absorbed by larger and large social units (extended family, local bands, regional populations). It is expected that regional responses to uncertainty would be most visible in the archaeological record. Wiessner (1977: 60) and Yellen (1977: 41-47) provide models of individual movements (band fission) in response to risk which is channelled by hxaro and kin ties. Even though detailed information is lacking on how exchange systems and individual movements react to environmental change, it is clear that during periods of low production and great risk when food sharing among the local band cannot compensate for food shortages, but before population densities drop, increased levels of exchange occur (Wiessner 1977: 154-160). Then with continued shortages individual families move to areas with kin and/or hxaro partners with more plentiful resources.

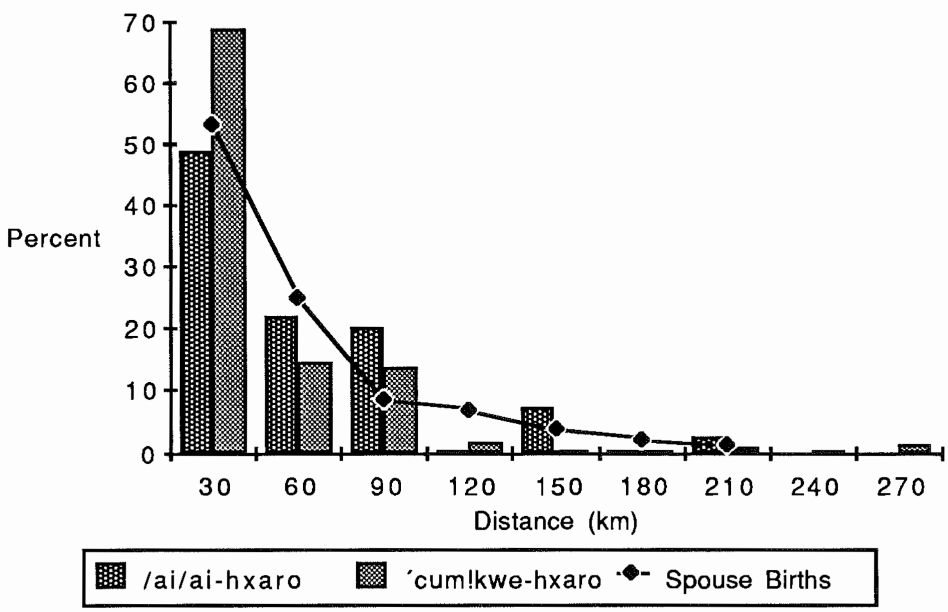

Figure 103. Distances between hxaro partners in two exchange systems (/ai/ai and ´cum!kwe), and distances between spouse births (data from Wilmsen 1989).

Global Trends in Hunter-Gatherer Risk Reduction

An integrated summary of all the variables discussed in the foregoing sections is best organized on a framework of sliding scales of temperature and precipitation that combine to produce gross global habitat types. These are flagged in the two columns on the left of Figure 104 where arctic conditions are arbitrarily divided from plains, plains from temperate forest, and so on through desert, savannah and tropics. Intermediate habitats (eg. semi-desert, woodland savannah, etc.) fit between these arbitrary units, but are omitted from Figure 104 to reduce clutter.

Under Resources, total biomass is diagrammed in the third column to peak in the temperate arboreal habitats and again in the rain forests at the top of the diagram. The plant/animal mix in the biomass is diagrammed in the fourth column so that plant frequencies peak in temperate boreal forests, in deserts, and again in the tropics. Animal frequencies peak under arctic, semi-desert and savannah habitats. Appropriate food spacing is generalized in the fifth column to indicate maximum clumping in arctic and plains habitats, with steadily reduced clumping covarying with increasing temperature. Food timing (in the last column under Resources) is modelled to show maximum stability in the temperate forests and again in the tropics.

The first column under Mobility attempts to generalize the appropriate mix of collector/forager strategies best suited to each habitat. There is a rough decrease in the frequency of collecting (logistic strategies) until semi-sedentary mobility patterns are reached in peak temperate forests. Collecting increases somewhat in semi-deserts, then declines with rainfall until the disperse/transient conditions of full desert are met and the landscape is essentially abandoned. Collecting increases again then declines erratically towards full rain forests. Storage is more frequently adopted in habitats with erratic timing in the food supply, such as the arctic and deserts, and decrease again in the tropics with a slight increase in rain forests.

Diversions from the trends are built in at random to accommodate niches where fishing is an alternative option so that total mobility can be reduced. Finally, range size covaries with mobility, except in rain forests.

Application of Global Trends to the Blydefontein Region

The diagram in Figure 104 also serves to show how the model will be converted so that it can be applied to regional data. In Figure 104 the layout is designed vertically to cover global space from pole (bottom) to equator (top). It can be rapidly converted for regional use by redesigning the vertical layout to represent an elapsing time scale of a single area. In this layout, older is at the bottom and younger is at the top. In this scenario, a single region has experienced the whole gamut of global habitat changes. Although this is possible for the real world during very extended (geological) time, the model in this form is of limited use in human prehistory.

It will be the central portion of the diagram that will be most useful for modelling purposes in the Blydefontein area during the Late Pleistocene, Holocene and to recent times. The base of this portion starts close to the arbitrary arctic/plains boundary, and extends up to the beginning of the temperate arboreal habitat (represented by the Fynbos vegetation in South Africa). It starts again above the full arboreal habitat and extends to full desert conditions. This is the range of habitats with which hunter-gatherers of the Blydefontein region had to contend. This model predicts in a general fashion their appropriate risk-reducing responses to each.

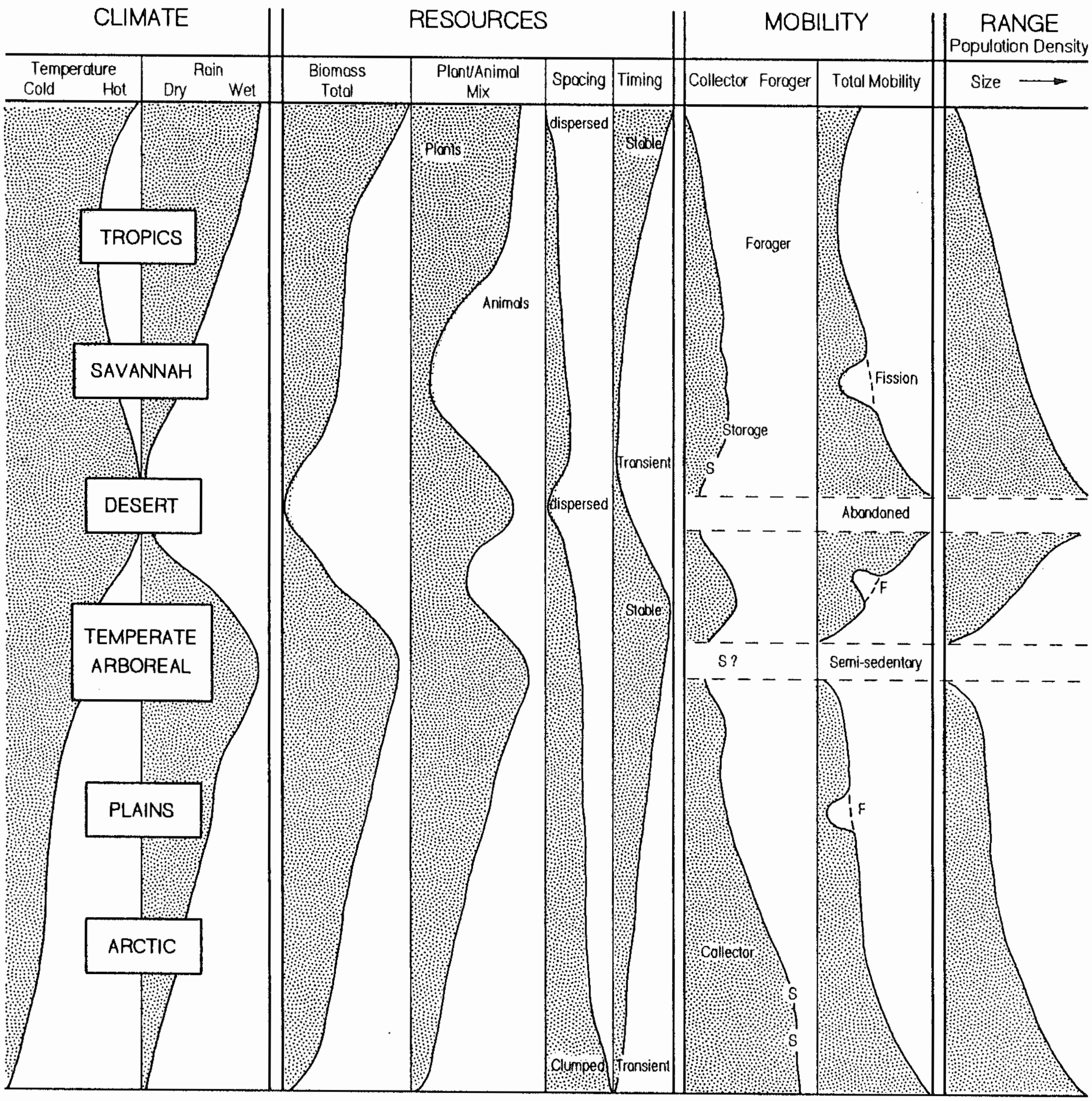

Figure 104. Diagram of the ecological and behavioral model variables on world scale.

CHAPTER XII

THE ROLE OF TECHNOLOGY AMONG FORAGERS AND COLLECTORS

The new model readily can be fitted to frequency data derived from ecofacts, but it is not useable yet for archaeological purposes. A fifth system, technology, must be connected to the other four (Figure 105) before the model can be made to produce any test implications that fit archaeological data. In this extension of the model, the technology system contains several interacting variables (see Figure 105). These are six groups of variables that refer to the qualities of tools and weapons made by hunter-gatherers to help buffer risk. The pairs of qualities are: expedient/reliable/ maintainable tools, specialized/generalized tools, cached/carried tools, finished/ unfinished tools, use-life/production cost of tools, and use lives of repair kit/tools-weapons. Each group will be shown to articulate with the sliding scale of collector/forager mobility ratios outlined in Chapter XI. It is these pairs of variables that allow test implications for archaeological data to be presented.

Responding to Risk with Technology

Not only do hunter-gatherers combine mobility patterns, store food, and adjust plant food/meat intakes to buffer themselves against risk, but they also adjust their technology with the express purpose of reducing risk (Torrence 1989: 60). There is a small body of ethnoarchaeological evidence from which to derive rules about the ways in which hunter-gatherers make tools (design strategies) in order to stave off risk. Furthermore, those rules produce global trends that can be compared with the trends in the adaptive behavior reviewed in Chapter XI. The development of such trends are essential if the new model is to become testable through archaeological data.

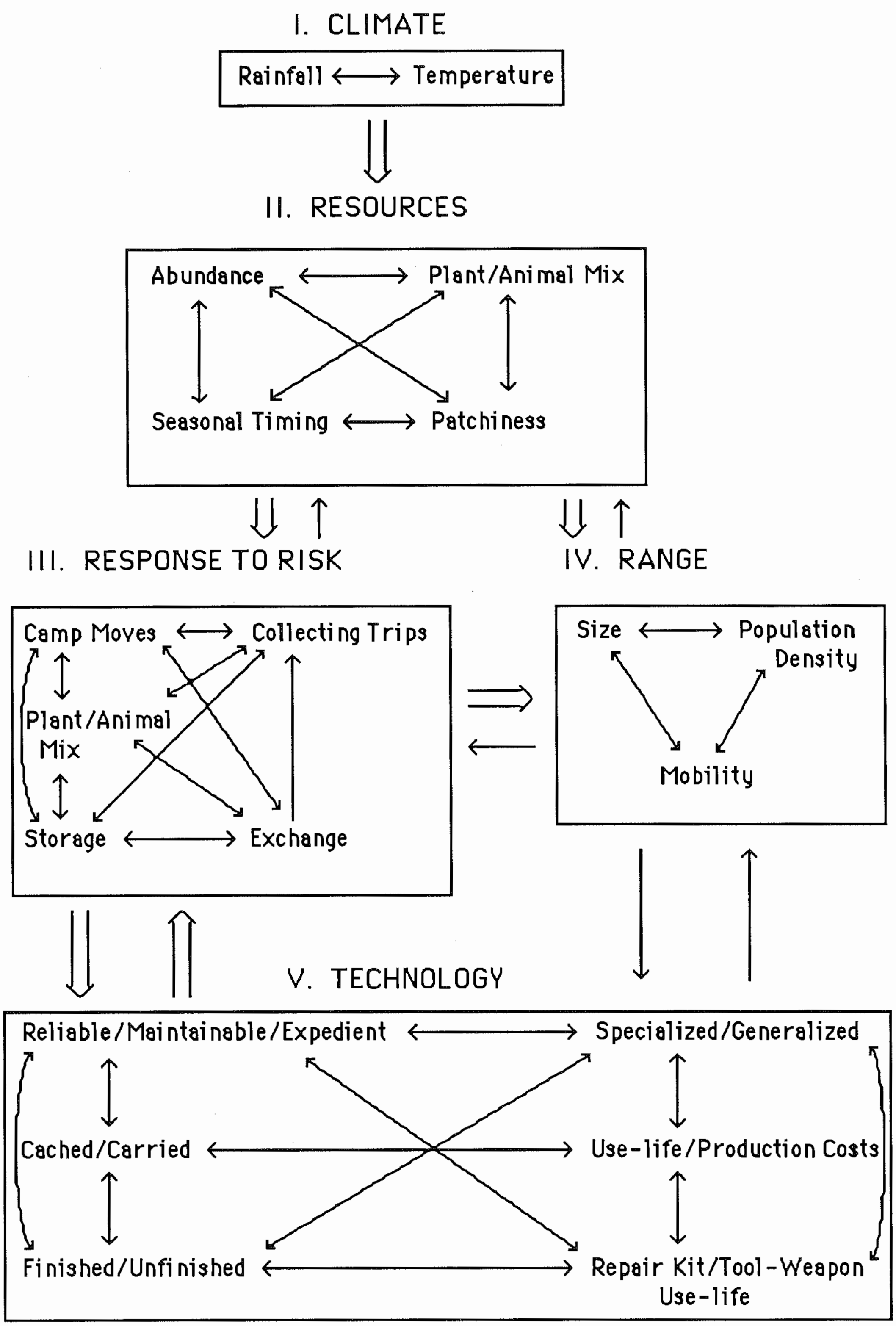

Figure 105. Ecological and behavioral model with technological component.

Bleed (1986) points out that modern engineers design tools with one objective in mind: efficiency. Tool efficiency means a combination of four different things: increased effectiveness (a sharper knife); increased use-life (a longer lasting knife); a quicker production time (the knife costs less in energy and material); increased production volume (more knives per unit of material). These qualities reflect the manufacturer's view. From the user's viewpoint, the second quality is of major interest: how long does the tool stay in working order? To make an effective tool, therefore, modern engineers strike a compromise between these four qualities. The exact mix depends on their decision either to stress the first two qualities and make a reliable tool, or to stress the second two qualities and make a maintainable tool. These decisions do not produce two mutually exclusive types (Torrence 1989: 63), as both reliability and maintainability can be designed into the same tool.

A reliable tool lives up to its name and functions when needed. It will have these salient features: move invested (over-design) in its critical parts, eg. the knife edge; extra sturdy construction; quality fitted parts; spare parts; repair kit, including raw materials. One typical example of a hunter-gatherer's reliable tool would be any hunting weapon used to kill migratory animals. If the weapon failed, this could result in partial or complete loss of food with dire consequences. Thus reliability in a weapon aims to buffer the hunter against the severity of the risk that he faces (ibid: 63).

A maintainable tool can be made to work in part, even if broken, and it can be used for other tasks than the one for which it was designed. It is light and portable, has a modular design, and it comes with a specialized repair kit. Also, it can be repaired quickly and easily by the user in the middle of a job. A good example of a hunter-gatherer's maintainable tool is the digging stick. If it broke and simply could not be resharpened, then a new one could be made right away or soon afterward, and used on the same roots or tubers being excavated with the stick that broke. By contrast, maintainability is designed into a forager's weapon not so much to cope with the severity of the hunter's risk, but rather to buffer him against the erratic timing of the risks he faces (ibid: 63).

Tool Design Decisions Among Foragers and Collectors

At first glance, it appears that reliable tools would be more desirable to hunter-gatherers in all circumstances. However, reliable tools carry hidden costs: they are over designed, need extra care and require special spares. Some may be bulky or difficult to transport. Reliable tools really pay off for collectors dealing with clumped resources, long travel schedules, and little spare time. They pay off because they can be repaired at predictable times and cached (passive tools) for future use so they do not have to be schlepped with the equipment on duty (active tools). It is intuitively reasonable to assume that collectors will have very reliable weapons (Bleed 1986: 744-745). Good examples are the Nunamiut (Binford 1979: 268) who make elaborate tool preparations before long hunting trips (gearing up sessions), and the Ingalik whose elaborate technology focuses severely on reliable tools (Osgood 1940). Thus collectors ten to increase their overall investment in technology and also in the diversity and specialized nature of their tools (Torrence 1989: 60-61).

By contrast, foragers who are not under stress tend to invest in artifact designs without complex specialized tools. They are dependent on evenly distributed and more stable food supplies, and are more inclined to use maintainable implements and weapons (extractive tools) because tool failure is not so costly in terms of missed opportunities. There are no intense bursts of tool making because time is available almost every day (make and mend sessions) for maintaining and replacing tools (Silberbauer 1981: 243).

As most hunter-gatherers use a mix of both strategies, their tool kits should reflect a comparable mix of reliable and maintainable tools. Typical recent examples are the !Kung (Lee 1979: 128-144) and the G/wi (Silberbauer 1981: 206-209) who use both. It should be reiterated, however, that these are not discrete tool types. For example Torrence (1989: 63) suggests that all weapons, whether made by collectors or foragers, are basically maintainable, but the design of a collector's weapon will incorporate a higher degree of reliability whereas that of a forager will have less.

Kinds of Curation used by Foragers and Collectors

Bleed's (1986) reliable and maintainable tool design strategy can be merged with Binford's (1973, 1979) expedient/curated tool dichotomy. Curation, as a term in archaeological literature, has many different meanings (see below), but these two classifications seem to merge if we accept that the use of uncurated (expedient) tools is also a design goal. Curated tools could have either maintainable or reliable objectives in mind. Figure 106 suggests how a hypothetical tool's design might be fitted into a tri-polar diagram to reflect the appropriate mix of all three goals.

The term curation has come to mean either: (1) the tool was made long before it was used; (2) the tool was carried around and used for a long time; (3) the tool was regularly maintained during its life; (4) the tool was designed for many uses or; (5) the tool was reshaped for other uses (Bamforth 1986). Although there is some overlap, each is more usefully viewed as a distinct behavior set, driven by different needs. The first three variants deserve closer scrutiny because they articulate well with the collector/forager dichotomy explored in the previous chapter. The other two (multi-use and recycling) are more usefully linked to raw material distribution (Bamforth 1986).

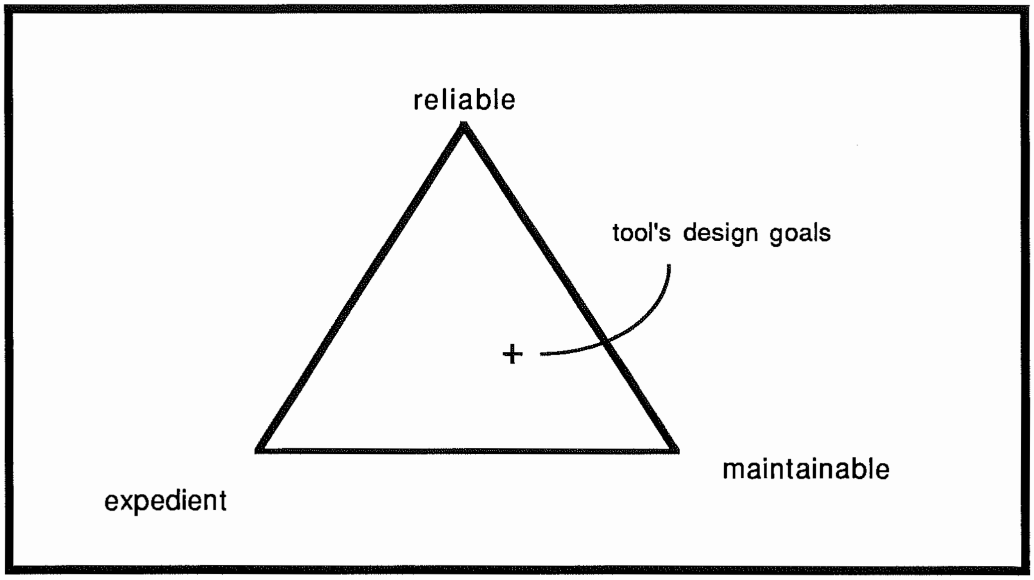

Figure 106. Tri-polar plot of a hypothetical tool's design goals plotted against three design qualities.

However, before turning to a discussion of curation, it is beneficial to look at the flip-side of curation: discard. In general tools may be discarded because of breakage during manufacture, expedient tools by definition are thrown away immediately after use, tools may break during use, tools may be lost during use or transport, tools may be cached but never retrieved, tools may be replaced if they appear to be near or at risk of failure, or tools may be discarded when exhausted and no longer maintainable (Kuhn 1989; Shott 1989; Tomka 1990). Reason for discard is inextricably linked with tool curation, and the two must be considered together.

(1) Tools Made Long Before Use: Foragers versus Collectors

Production in advance of use is promoted by what Torrence (1983: 11-13) calls "time stress" caused by scheduling conflicts. A typical scenario is the sudden arrival (and departure) of a migratory herd. There is no time to make more weapons, so they must be ready beforehand. Clearly, time stress promotes this kind of curation, which is practised vigorously by collectors, who are often faced with such situations.

How long it takes to make the tool may also determine how much time elapses between its manufacture and use. Yellen (1977: 76) and Lee (1979: 274-275) show that some !Kung tools take so long to finish that they are carried around in an unfinished state from site to site. This is quite different from time stress, a feature virtually unknown in !Kung daily life (Lee 1979: Tables 9.11 and 9.12) nor indeed in the lives of the rather more stressed G/wi (Silberbauer 1981: 243).

To generalize from these few examples: Collectors in higher-risk settings are more likely to carry around (or cache) finished, unused tools as a precaution; foragers in lower-risk habitats are likely to carry around unfinished tools that reflect little or no time stress. Discard due to this form of curation would be those tools broken during manufacture or those lost during transport.

(2) Tools with Long Use-lives: Foragers and Collectors

The best record of tool use-life for a forager band is that from the !Kung, whose shortest recorded tool use-life is five days and the longest is 16 years. It is not clear whether Lee (1979: 274-275) recorded details of shorter use-lives of real expediency tools. Roughly comparable data for a collector group come from the Ingalik that suggest shorter, not longer tool use-lives (Osgood 1940). Although the sample sizes for both data sets are limited and recording biases may have added more distortions, these are among the best published data available (Figure 107). Ingalik tools had an average use-life of 2.6±7.9 years while !Kung tools lasted on average 3.7±3.4 years.

Taken at face value, then, curation (meaning longer use-life, *sensu* Shott 1989) is more intensive for foragers than collectors and not the other way around, as predicted for other kinds of curation. One possible explanation is that collectors must keep their weapons in good working order at all times, and more frequently replace parts or even complete tools before they wear out (Kuhn 1989). Discard could occur because an artifact was lost or because of use-breaks, replacement before failure, or artifact exhaustion.

Also, it may be that the !Kung were in a position to use more durable, less brittle raw materials (eg. iron wire for arrow points) than the Ingalik, but ethnographic data (Lee 1979: Table 9.10, Osgood 1940) also includes skin artifacts that stay in use for longer periods of time than seemingly more durable materials like wood or stone (Tables 29 and 30). This is because the less durable artifacts are not being used as stressfully as many the more durable ones. Clearly, the intensity of use, not just the length of use must be considered also (Silberbauer 1981: 223-232).

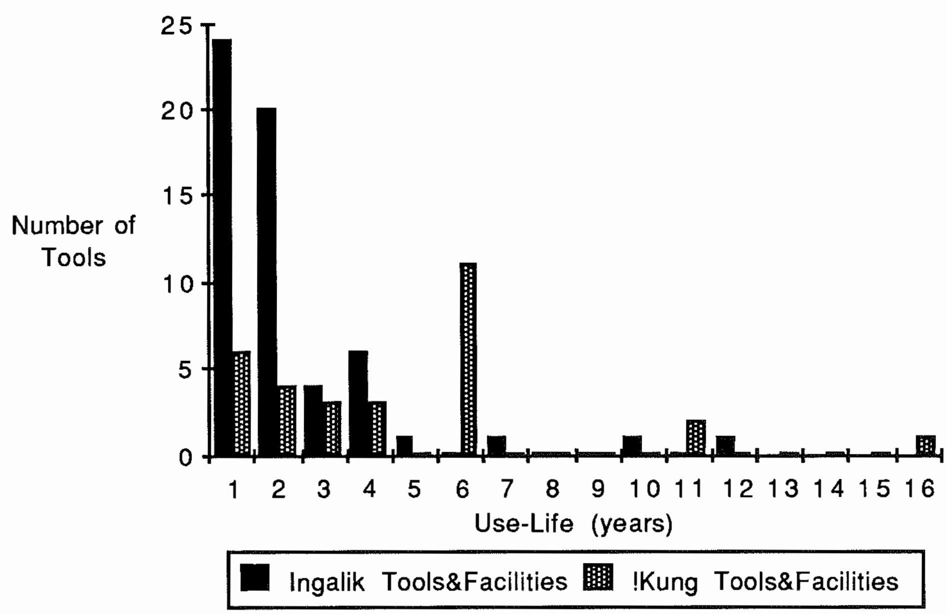

Figure 107. Histogram of Dobe !Kung and Ingalik artifact and facility active use-lives in years (data from Lee: 1979: Table 9.10 and Osgood 1940).

Table 29.--Average use-life, and production and maintenance costs of !Kung artifacts by material (data from Lee 1979: Table 9.10)

Artifact Materials	Average Manufacturing Time (min.)	Number of Maintenance Episodes	Average Total Maintenance Time (min.)	Total Costs (min./day)	Average Use-Life (day)
Ostrich Eggshell & Tortoise Shell	180	24	365	0.75	730
Skin (minus oracle disks)	397	33	1069	0.96	1528
Wood	359	64	1084	1.80	802
Metal	600	462	8303	4.44	2007
Other Plant Material	600	12	730	3.64	365

Table 30.--Average use-life, and production costs of hand-held Ingalik artifacts by material (data from Osgood 1940)

Artifact Materials	Average Manufacturing Time (day)	Average Use-Life (day)	N
Bone	1.3±0.7	2.3±2.2	7
Stone	3.4±1.0	1.4±1.1	5
Wood	0.9±1.1	1.4±2.2	16
Bark	1.9±2.2	1.9±1.5	4
Grass	1	1	1
Skin	3.3±4.6	2.4±1.3	4

Production Costs and Tool Use-life

Shott (1989) has argued that among foragers, use-life also increases with the effort and time invested in the tool's manufacture. He demonstrates this relationship with Lee's (1979) Dobe !Kung data, but he mixes multi-tool production costs with use-life measurements for single tools, which spoils the comparison for ostrich eggshell water containers. When this is corrected (Figure 108) the linear regression (r^2 = 0.47, p value = 0.005) suggests a moderately weak, although significant relationship between production time and use-life. Steel and flint fire kits, with very short use-lives, were omitted from the analysis on the grounds that they are not part of the indigenous kit. These are discussed later.

Among the Ingalik collectors, Shott (1989: 22) argues that there is no such relationship between tool production time and use-life, but he inexplicably omits 45 tools and facilities from his analysis. Furthermore, if a tool is periodically retired from use and cached, its time in cache as a passive tool should not be counted towards use-life. Only the active portion of a tool's use-life should be considered. Osgood's (1940) original Ingalik data lists the season(s) of use and, for many tools, the total number of seasons used. When active use-life is plotted (Figure 109) there is, after all, a weak linear regression (r^2 = 0.248, p value = 0.0001), implying a weak correspondence between production time and active use-life. This could be strengthened if two tools (bone wood scrapers and work boards) that have short production times and long use-lives were omitted from the analysis. Another item of this kind (ceremonial hats) with extremely long use-lives, was omitted from the analysis on the grounds that is not an adaptive part of the food quest. On the other hand, the correlation would be further strengthened if sleds, which have enormous production times invested in them, were included in the comparison.

When the !Kung and Ingalik data and regressions are combined on the same chart (Figure 110) it becomes clear that marked differences occur between the two. To generalize from this very limited sample, foragers and collectors may have different attitudes towards production time and use-life: foragers get much more use-life for their production effort, collectors do not appear to be terribly efficient overall.

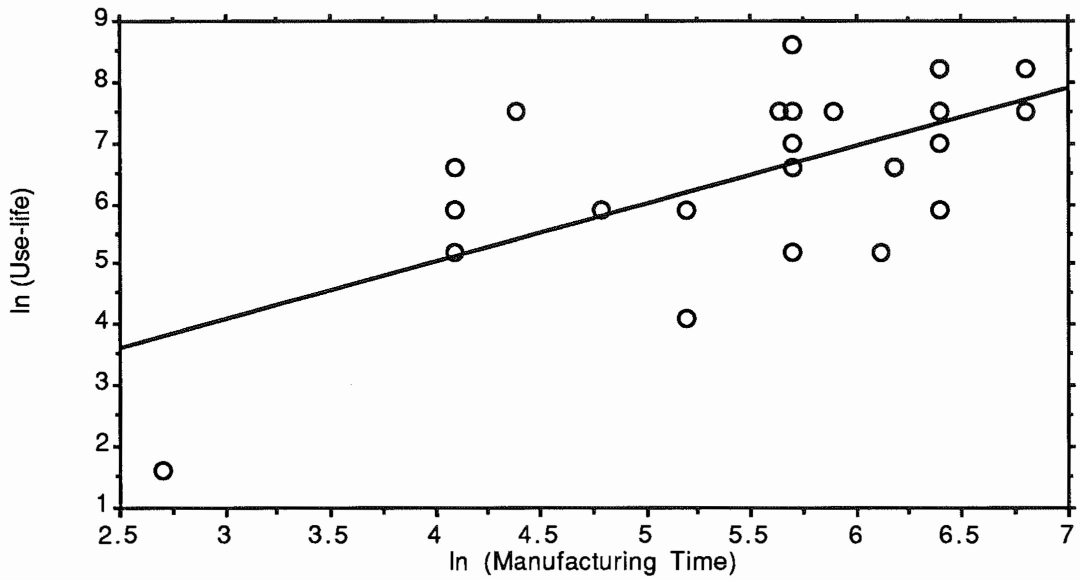

Figure 108. Linear regression between natural logarithm of use-life and manufacturing time for Dobe !Kung artifacts minus European clothing, r^2 =0.47 (data from Lee 1979: Table 9.10).

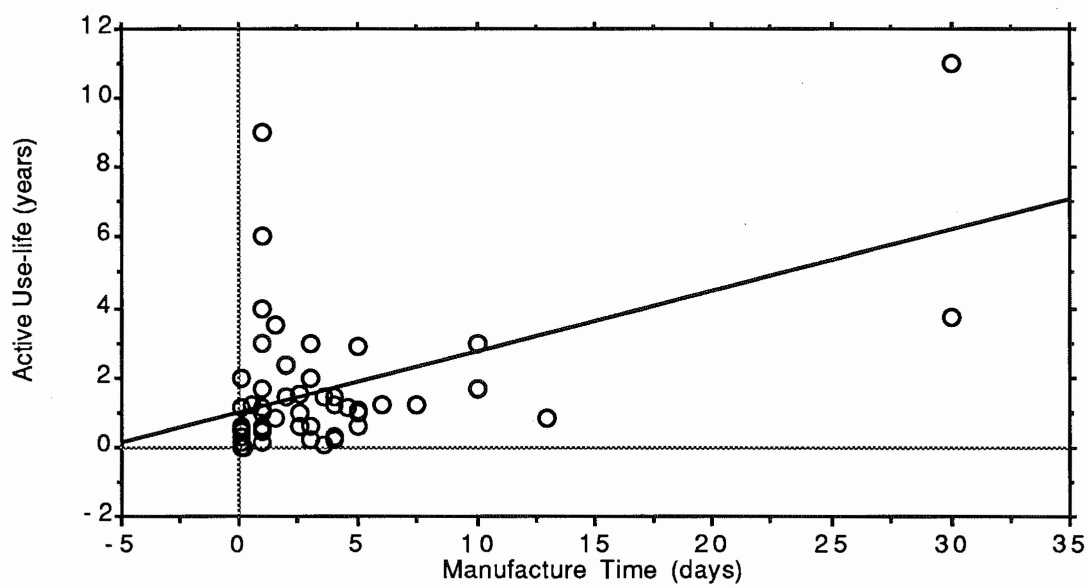

Figure 109. Linear regressions of Ingalik tool manufacturing time and adjusted use-life (data from Osgood 1940).

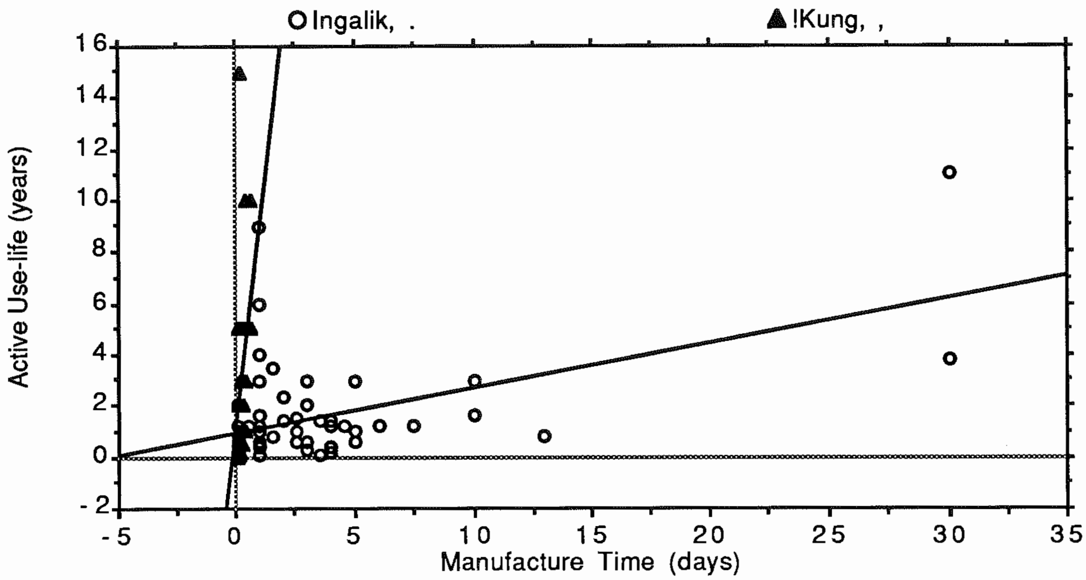

Figure 110. Linear regressions between manufacturing time and use-life for Dobe !Kung and Ingalik tools (data from Lee 1979 and Osgood 1940).

(3) Regularly Maintained Tools: Foragers and Collectors

The amount of time invested in a tool through repair and maintenance may also extend its use-life (Shott 1989). Unfortunately there are no data for the Ingalik, but the !Kung data (minus the European manufactured items) show a positive correlation (r^2 = 0.313) between total maintenance time and use-life (Figure 111). One of the omitted European items is of special interest here: the flint-and-steel fire kit is maintained almost every day, not because it wears out rapidly but rather out of fear that it might fail. This anxiety determines that it is kept in working order at all times (Kuhn 1989). It is an anxiety very similar to that which drives collectors to replace weapons more frequently, to assure fail-safe use at short notice at all times.

To generalize, again from very limited data, foragers in low-risk habitats may increase the maintenance of a tool to save the bother of making a new one. Collectors in high-risk settings may increase production/maintenance of a tool by replacing a part or the entire tool to avoid failure at a critical moment.

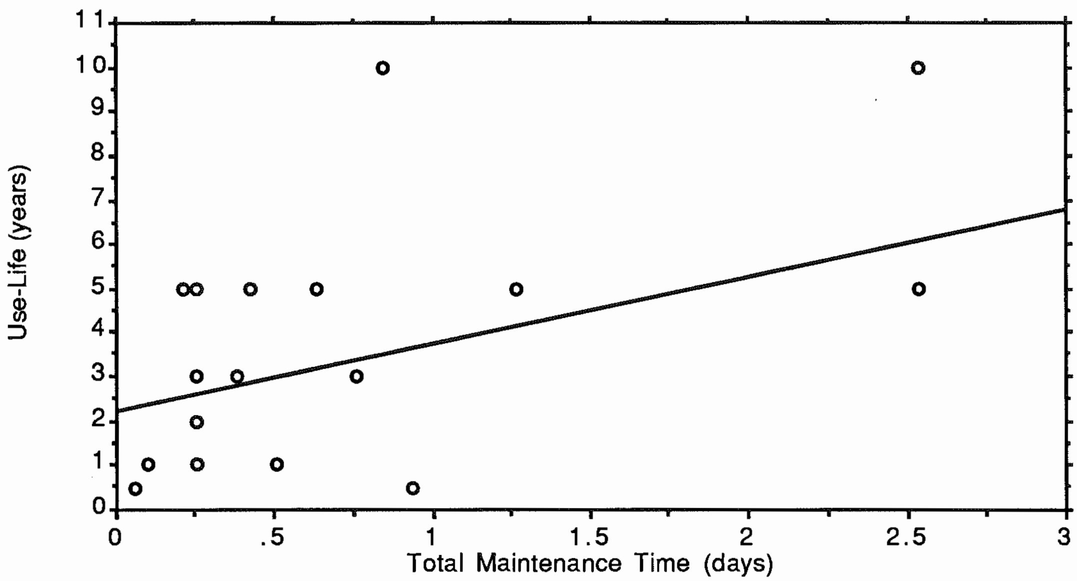

Figure 111. Linear regression between total maintenance time and use-life for Dobe !Kung artifacts minus European clothing and flint-and-steel fire kit, r^2 =0.313 (data from Lee 1979: Table 9.10).

Maintenance versus Production Costs

If collectors are more likely to use a reliable technology and foragers a maintainable technology (Bleed 1986) then it follows that combined production and maintenance costs for foragers should be equal to or possibly greater than production costs alone for collectors. If this is so, then combined !Kung production/repair time should be equal or greater than Ingalik production time alone. This is not the case (Figure 112, Table 31) because Ingalik production costs are much higher than combined !Kung costs. What is actually happening is that !Kung foragers keep production and maintenance (and transportation) costs down by making their tools last as long as possible and by discarding them only when completely worn out. Ingalik collectors are investing very heavily in the production of tools which they discard long before they are worn out (Kuhn 1989). Note that this result contradicts the expectations of Binford's (1973, 1977) original curation model.

Of course neither pattern is exclusive to foragers or collectors who both use a mix of the two patterns in ratios that seem to covary with the foraging/collecting mix in the individual bands mobility pattern. Thus the greater the emphasis on collecting and logistic mobility, the higher the likelihood that investment in tool production will increase and use-life will decrease, and vice versa.

Table 31.--Linear regression statistics for !Kung tool use-life by manufacture costs plus repair costs, and Ingalik tool use-life by manufacture costs

Group	Slope	Intercept	r2	p value
!Kung	1.436	1.843	0.352	0.0022
Ingalik	0.174	0.978	0.248	0.0001

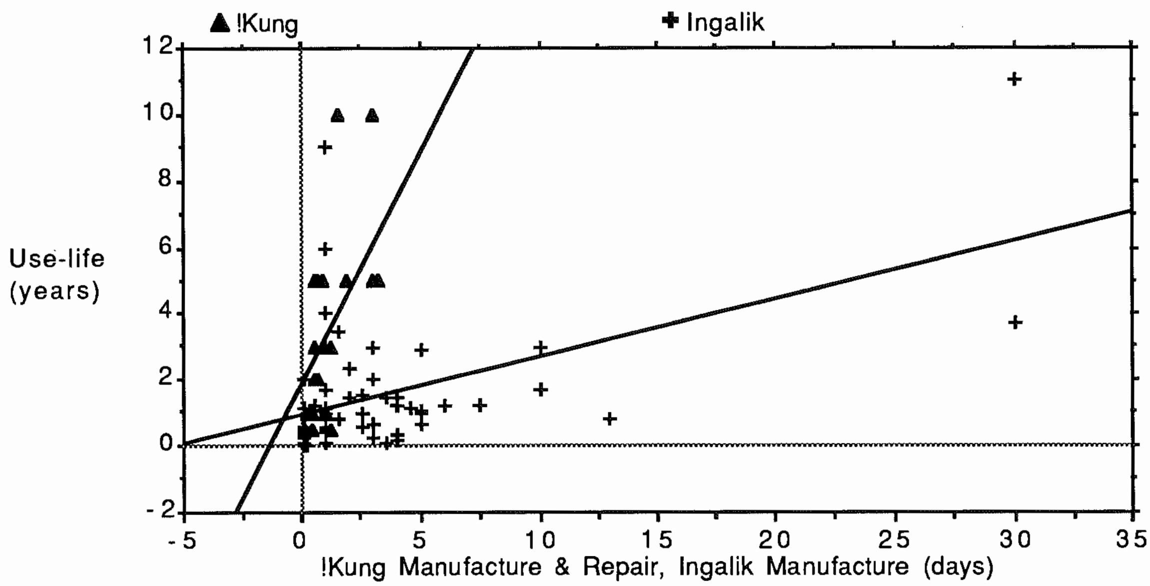

Figure 112. Linear regressions between total manufacturing and repair time by use-life for the !Kung tools and manufacturing time by use-life for Ingalik tools. Ceremonial hats and sleds were not included with the Ingalik data set. Flint and steel fire kits were omitted from the !Kung data. !Kung r^2 =0.352, Ingalik r^2 = 0.248 (data from Lee 1979: Table 9.10, and Osgood 1940).

The Use-Life of Repair Kits versus Tools and Weapons

Bleed's (1986) original dichotomy between maintainable and reliable tools was formulated for weapons only, not for the tools used to make and repair them. However, repair kits (maintenance tools) may not have been used and maintained in the same ways as implements and weapons (extractive tools). Also, foragers may not imbue them with the same relative worth as collectors do. This will be directly reflected in the use-life of repair kits versus implements and weapons. As usual, the available data are limited and there are some distortions. The Ingalik used more stone and bone, while the !Kung use more metal, probably inflating the use-lives of the latter's equipment in both classes. Nevertheless, Table 32 suggests that the hard-pressed collectors may take greater care of their repair kits and keep them longer, while the understressed foragers are more cavalier with their repair kits (including a greater use of expedient maintenance tools) but try to get their tools and weapons to last longer. A small number of ethnoarchaeological studies have documented the existence of expedient stone tool use (Binford 1986; Gould 1977; Gould et al 1971; Hayden 1979; Miller 1979; Sillitoe 1982; Strathern 1969; White 1968; White and Thomas 1972) including two cases from southern Africa (MacCalman and Grobbelaar 1965; Stow 1905: 66). In all cases the expedient tools are repair kit (maintenance) tools, and in each case lithic raw materials are readily available.

Table 32.--Extractive and maintenance tool mean use-life (years) for foragers (!Kung) and collectors (Ingalik). M/E Ratio equals maintenance tool use-life/extractive tool use-life

	Extractive Tool Use-life		Maintenance Tool Use-life		M/E Ratio
Foragers (!Kung)	4.2±3.2	(n=7)	3.3±2.5	(n=18)	0.79
Collectors (Ingalik)	1.4±0.3	(n=3)	1.7±2.0	(n=30)	1.21

Raw Materials and (4) Multi-Purpose or (5) Recycled Tools

For both foragers and collectors it is axiomatic that a scarcity of raw materials to make tool replacements will promote longer use-lives and repeated refurbishing. But scarcity will also promote multiple uses of the same tool, and even the recycling of broken parts or discarded tools (Bamforth 1986). Also, bits of raw material will be carried around from site to site (Kelly 1988; Parry and Kelly 1985). This applies with equal force to collectors or foragers so that a single band, of whatever mobility mix, will start practicing all the above saving behaviors each time they move into a portion of their range where the raw material in question is scarce or absent, or access to it may be unpredictable. As soon as they have ready access to the raw material, they will abandon these practices with alacrity.

Raw materials like stone (lithic resources) are not all acquired in the same way (procurement strategies). The hunter-gatherer may simply fetch some from an outcrop (direct procurement) as he/she passes by in the course of the seasonal or daily round (embedded strategy). Bands with very high mobility rates, particularly those with frequent camp moves as practised by foragers, will seldom if ever organize a long trip specifically to gather stone from a quarry. Although Gould and Saggars (1985) assert that this is not so, they do not develop their argument. Perhaps logistically organized bands, already inured to long expeditions, would be more readily inclined to make raw material trips. In this scenario, the distance that raw materials are transported between quarry and camp where the tool was discarded may not be a direct reflection of stone material scarcity (Binford 1979).

Another obvious way to acquire raw materials is through exchange (indirect procurement) where the hunter-gatherer gets it from somebody else who did the fetching (McAnany 1988). There is plenty of ethnographic evidence for this among the Kalahari San (see discussion on hxaro in Chapter XI and Lee 1979: 365-366;

Marshall 1976: 303-311; Silberbauer 1981: 239-242; Wiessner 1977, 1982) and many other groups. Other ways (indirect procurement) to acquire raw material include fetching it from a previously stored cache, or scavenging it from an old camp or other surface site.

Global Trends in Hunter-Gatherer Technology

The foregoing analyses suggest the presence of several interlocking trends in hunter-gatherer technology, all aimed at buffering risk. It follows that these same trends must articulate with the mobility pattern mix, which also aims to reduce risk. In the left column of Figure 113 an array of five hypothetical bands (A through E) are listed. The next column shows that they are arranged on a sliding scale based on their mobility pattern mix. As the number of annual camp-moves increases from bottom to top of the second column, so the annual number of long task-specific trips decreases. Each band is allowed a portion of the sliding scale, to signify that its mobility pattern mix is not rigidly fixed at a constant ratio.

By scanning the tops of the adjacent columns it emerges that the relatively stress-free forager bands A and B will make a smaller range of highly maintainable, general-use tools and weapons with longer use-lives. On average, they will get more use from a tool for the time and effort they invest in making it, even though they take their time to finish it. Thus they tend to carry around unfinished tools, and refurbish their completed tools frequently, to save the bother of making new ones. Consequently, their repair kits (maintenance tools) wear out quite rapidly and are often replaced. They seldom cache new, finished tools. Whenever and wherever raw materials become scarce, the tool(s) made of that material will be refurbished even more often. It will be used for various jobs and it may be recycled when broken.

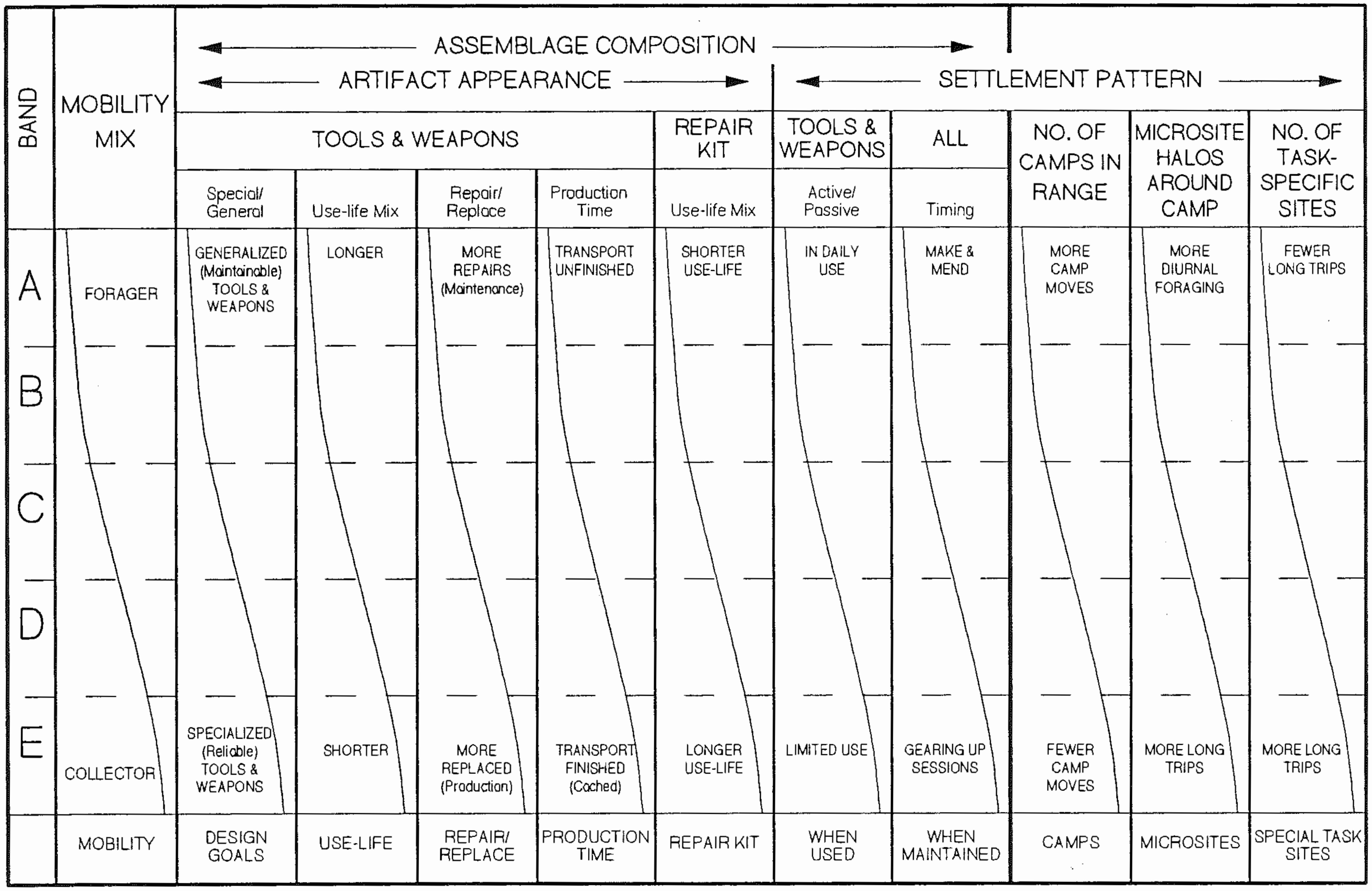

Figure 113. Assemblage composition and settlement pattern model for hypothetical bands.

When the base of Figure 113 is scanned it is apparent that they time-stressed collector bands D and E will make a greater variety of highly reliable, specialized tools and weapons with shorter use-lives. On average, they will get less use from a weapon for the time and effort they invest in making it, even though they finish it during limited, intense bouts of tool making. They seldom carry around unfinished tools and weapons, and replace completed ones frequently, rather than trying to maintain old ones. Consequently, their repair kits get light use and lasts longer. Not to overburden themselves, they tend to cache new, finished tools. When or where raw materials become scarce, the tool(s) made of that material will be refurbished rather than replaced. It may acquire various uses and it may even be recycled when broken.

Archaeological Implications

Different kinds of material culture fallout can be implied from groups of the above trends; there are trends affecting artifact appearance, trends that affect overall assemblage composition, and trends affecting between-assemblage comparisons. Also, the mobility pattern will directly affect the distribution of assemblages (settlement pattern) of the band.

Artifact Appearance

The appearance of a new tool or weapon is dictated by a number of factors; first by the physical properties of the raw material, then by the limits of it's makers technological know-how, then by his or her personal experience or skill, and finally by a set of culturally dictated values (style) to which the maker subscribes. However, the appearance of a tool or weapon by the time it enters the archaeological record is dictated by still more factors. Figure 113 regroups trends that dictate tool appearance. By scanning the tops of the adjacent columns, it emerges that the appearance of a specific tool or weapon made by members of the relatively stress-free forager bands A and B will have generalized design. Furthermore, most specimens will show signs of greater wear and refurbishment, likely resulting in alternations of shape. Tools from the repair kit may show less wear and tear before discard. There will also be some unfinished specimens that show no signs of maintenance.

At the other end of the scale, tools or weapons made by members of the time-stressed collector bands E and F are likely to betray a specialized design, and show fewer signs of wear or repair. Tools of the repair kit will be over-designed also, and tended to show signs of prolonged use before discard. Unfinished specimens, not broken during manufacture, will be very rare unless found in caches.

Assemblage Composition

The cluster of trends that dictate the range of tool types in the five bands is shown in Figure 113. The combined archaeological residues of forager bands A and B will yield relatively few, generalized types, mostly heavily used and repaired, plus some unfinished specimens of these types. Lightly used (expedient) repair kits will be quite common.

Combined artifact residues from collector assemblages produced by band E and F will contain a greater variety of clearly defined, finished types will little use-wear. Repair kit types will tend to be worn down (maintainable). Unfinished specimens will be rare.

Inter-Assemblage Comparisons

An assemblage recovered from one camp site within the range of forager band A will look pretty much like any other from the same range/territory. Only the size of the assemblage is likely to vary, depending on the popularity of the camping place. Very small assemblages with incomplete inventories may occur at task specific foraging areas. These will contain some of the same tools found in camp.

Although assemblages from collector camps like those in the range of band E will be quite similar to one another, the inventory of types will be incomplete. There will be rare, unused caches with very restricted inventories, possibly of types that occur only rarely in camp. There will be assemblages that reflect gearing up activities, in which fragments of replaced types occur. Some of the cached types will be found in broken or worn condition also concentrated at distant, task-specific areas that were repeatedly visited.

Distribution of Assemblages (Settlement Pattern)

Typically, the forager mobility pattern (Chapter XI) produces a residual pattern with numerous small/medium camp sites distributed widely across the range. There is a halo of small, task -specific foraging sites/areas within about 10km radius around each camp site. The reflect the accumulated residues of diurnal foraging from that camp. Specifically absent are caches and large, task-specific sites/areas remote from other camp sites.

Extreme collector mobility patterns generate a site distribution pattern with relatively few, large camp sites, without any 10km radius halos of micro-sites. Remote from these camps are several large sites/areas that denote intensive collecting tasks, such as frequently visited kill sites. Cache sites are present.

Again, these two extreme examples are at opposite ends of the forager-collector sliding scale. Most bands use a judicious mix of the two mobility patterns, and this means that both settlement patterns will be overlaid and mixed on the map of a single band's range. Any bias in favor of one mobility pattern, will be reflected in the band's site distribution map, however.

As was shown at the close of Chapter XI, a diagram like that in the Figure 113 can be converted so that it becomes applicable to regional data. In Figure 113 the layout is designed vertically to cover five, widely separated bands ranked from extreme collector mobility (bottom) to extreme forager mobility (top). It is converted for regional use by redesigning the vertical layout to represent the long term history of a set of adjacent bands in one region. In this layout, older is at the bottom and younger is at the top. In this scenario, a band cluster has experienced the whole gamut of global mobility changes. Although this is unlikely in any single site or even region, it is a useful device for modeling changes in the archaeological fallout resulting from such changes in the mobility mix of local hunter-gatherer residents.

Two portions of the diagram will be most useful for modelling purposes in the Blydefontein area during the late Pleistocene, Holocene and to recent times. The late Pleistocene roughly spans band F, and the remainder spans the upper part of band C up to the lower part of band A. This model predicts the appropriate risk-reducing technology used in the region under various habitat conditions.

CHAPTER XIII

BLYDEFONTEIN BASIN: A TEST OF THE NEW MODEL

Introduction

A first and partial test of the new model is attempted in this penultimate chapter. Although a full and comprehensive test must await new fieldwork on the huge Zeekoe Valley data base, some preliminary tests are possible now, even though they must be designed from the perspective of a single site. First, Blydefontein's habitat is fixed at appropriate points on the global hunter-gatherer ecological framework summarized in Figure 103.

Blydefontein's Place in the Ecological Model

The estimated percentage of hunted resources in the Blydefontein basin can be inferred from the local effective temperature and rainfall figures (Chapter XI). The (1962-1982) mean ET at Blydefontein is 14.2. By fitting this value to the curvilinear regression in Figure 92, we arrive at an estimate of 31 percent of hunted resources for the area (*Percent of hunted resources* = 214.481 - 21.196x + $0.584x^2$). Given Blydefontein's position on this curve, it would take a dramatic temperature increase (at least 4-5 ETs) before the percentage of hunted resources would start to climb. On the other hand, even slight reductions in mean ET would significantly increase the percentage of hunted resources. If temperatures during the Last Glacial Maximum fell as much as 5^{o}C (Vogel and Talma in Deacon and Lancaster 1988: 143) and the seasonal range remained the same as today, then the mean ET would be approximately 12.2 and the estimated hunted resources for Blydefontein equal 43 percent (Figure 114).

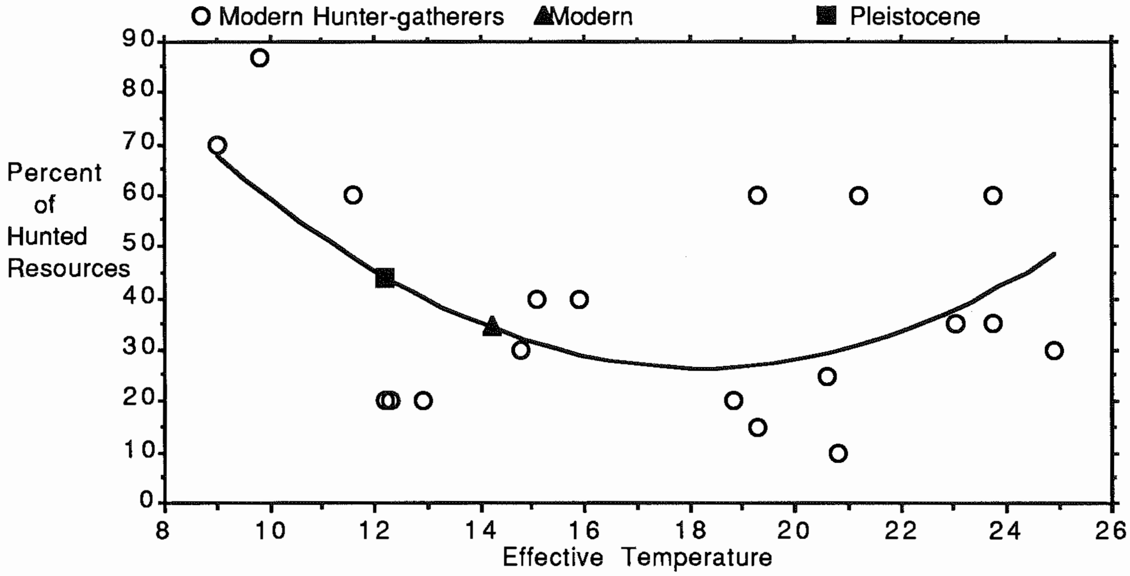

Figure 114. Modern and Pleistocene estimates of percent of hunted resources in diet at Blydefontein, based on estimated ET and curvilinear regression from Figure 92.

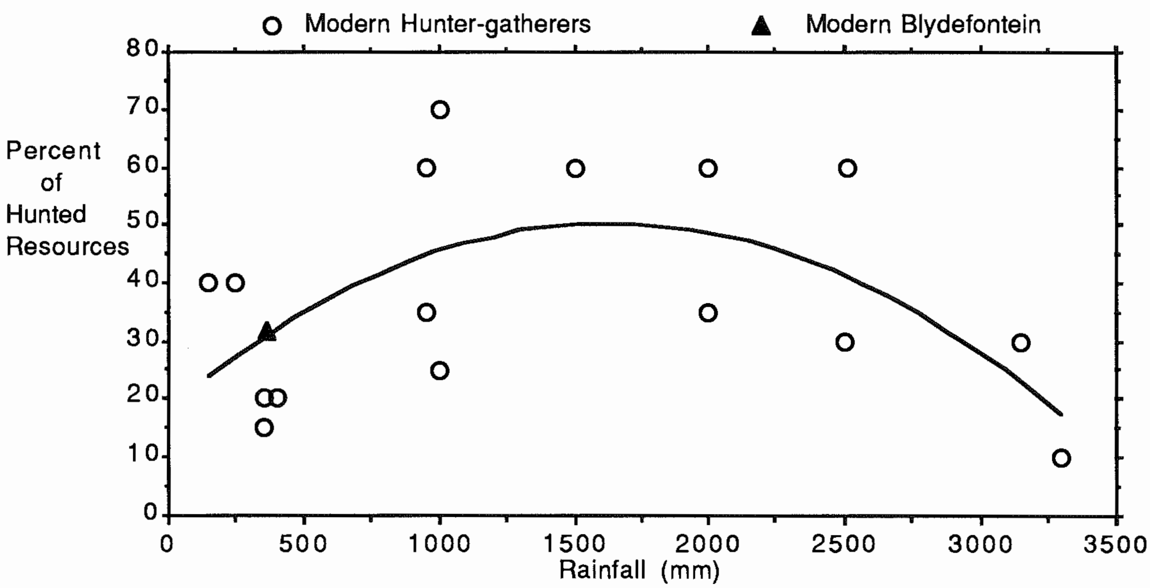

Figure 115. Modern estimate of hunted resources in diet at Blydefontein, base on modern rainfall and curvilinear regression derived from Figure 94.

Today's mean annual rainfall for Blydefontein is 366mm. When this figure is fitted to the regression curve in Figure 94, the estimated percent of hunted resources is 30.2. This is in close agreement with the estimate based on effective temperature given above. No reasonable estimates for Last Glacial Maximum rainfall is available so a plotting of a Pleistocene estimate is not possible as in Figure 114. Blydefontein's position on the curve shows that any slight increase or decrease in rainfall would significantly increase or decrease the percent of hunted resources (see Figure 115). Because Blydefontein is on the edge of the semi-desert Karoo shrubland and grassveld, more rain would increase the amount of grass cover, and this would certainly lead to increased densities of larger herbivores (see Chapter XI).

Changes in the Animal/Plant Food Mix in the Blydefontein Habitat

Temperature estimates were not used to estimate changes in the animal/plant food mix because their estimated variation was extremely low, which agrees well with the oxygen isotope temperature estimates from Cango Caves (Vogel and Talma in Deacon and Lancaster 1988: 144). However, the pollen-derived rainfall estimates (see Chapter VII) can be used to estimate the percent of hunted resources in the Blydefontein area. Because of possibly biases in alluvial and buried soil pollen sequences, only those estimates from Oppermanskop Midden, USP and BSM were used. Parenthetically, it is worth noting that the Southern, /Xam, and Mountain Bushmen also gave greater significance to rain (!khwa) in their mythologies and apparently in their paintings (Bleek 1933; Bleek and Lloyd 1912; Lewis-Williams 1981; Schapera 1930; Vinnicombe 1976). These estimates are only intended to suggest temporal patterns and should not be considered as exact estimates. Also one should remember that the pollen-derived rainfall estimates, at best, show general precipitation trends (averages) compared with the highly variable historic rainfall records (see Chapter VII), thus these estimated fluctuations in hunted foods are intended to reflect long-term (ca. 75-100 years or more) averages. Also, as shown in Chapter XI, the large herbivore biomass fluctuates as rainfall varies, and this provides the added animals that allow increased hunting. All the estimates of amount of hunted food fall between 29-36 percent of the diet.

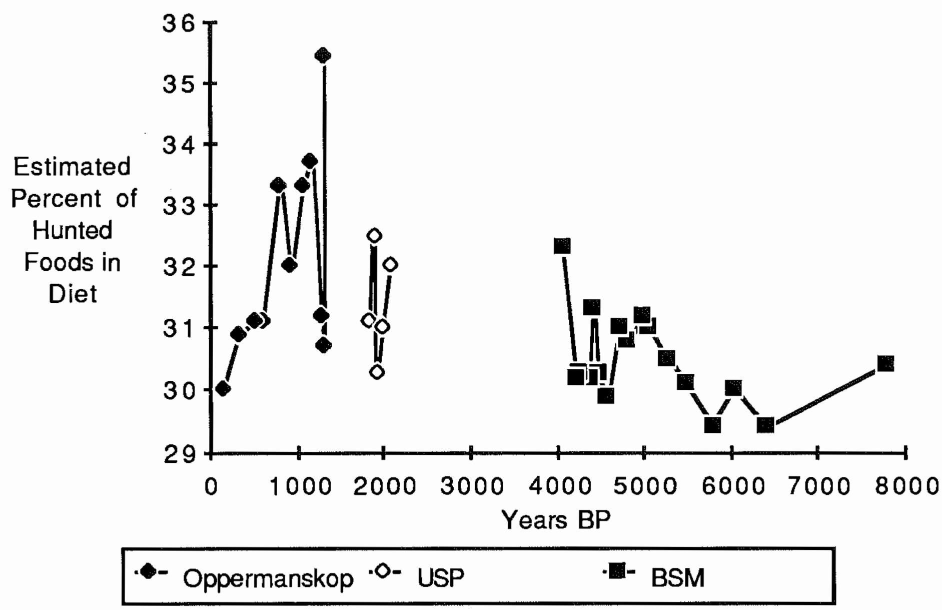

Figure 116. Changes in the amount of hunted resources in the Blydefontein diet, based on estimated changes in annual rainfall (see Figure 52).

As almost no plant food remains survived in neither the Blydefontein Rockshelter matrix (two *Diospyros* sp. seeds), nor the Meerkat Rockshelter deposits, a direct test of this portion of the model is not possible. Hunted resources are accessible through faunal analysis, but these data are not yet finalized (K. Cruze-Uribe, personal communication). The faunal analysis from Sampson's test excavation (Klein 1979: Table 3) indicates the range of hunted resources throughout the Interior Wilton occupations at Blydefontein Rockshelter. However, the sample is too small and the range is too large (about 16 different species) so that most cells in the table yield

MIND counts of 1-3 only. Consequently it is impossible to detect any significant changes in the frequency of species through time.

Ignoring for the moment the various shortcomings of MIND counts, Sampson's combined sample yields these estimates: 11 hares (*Lepus* spp.), two baboons (*Papio ursinus*), a fox (*Vulpes chama*), four yellow mongoose (*Cynictis penicillata*), two wildcat (*Felis libyca*), two rooikat/caracal (*Felis* spp.), a leopard (*Panthera pardus*), 17 hyrax (*Procavia capensis*), seven quagga (*Equus* cf. *quagga*), eight mountain reedbuck (*Redunca flulvorufula*), ten vaalribbok (*Pelea capreolus*), seven black wildebeest or red hartebeest (*Connochaetes gnou/Alcelaphus buselaphus*), three klipspringer (*Oreotragus oreotragus*), three steenbok (*Raphicerus campestris*) and two Cape buffalo (*Syncerus caffer*). No doubt changes in the frequencies of some species will become evident when the larger samples from my own excavations has been completed.

This is by no means the full range of meat in the hunter-gatherer diet, however. Large amounts of foraged meat is present in the Blydefontein sample, including a monitor lizard (Varanus sp.), abundant tortoises, amphibians, and crabs. Although micromammals were also present (Avery 1988: 341-342) it remains uncertain what proportion of these (if any) were acquired by humans. Barn owl pellets are assumed to be the major contributor of microfauna to the rockshelter matrix. Additional protein was obtained from ostrich eggs, and there are a few freshwater mussels also. There are no known fish bones in the sample and this is not surprising considering the small size of the local streams and the relatively high position of the rockshelters in the Oorlogspoort basin. This suggests that fishing played little or no part in the Blydefontein subsistence pattern, and any distortions to the model (see Figure 97) can be safely discounted, therefore. It seems likely that fluctuations in the frequencies of these foraged species can be expected, once the analysis is completed. A partial test of this portion of the model may eventually become possible by comparing the ratio of hunted to foraged meat in the diet at different layers in the two rockshelters.

Blydefontein's Range and Late Holocene Population Density

The (untested) assumption here is that Blydefontein is in the heartland of one band's range, and is not in a zone of territorial overlap between two or more bands. If so, then the ecological model predicts the relative changes in range size of hunter-gatherers who used both rockshelters. Range size fluctuations in accordance with the estimated amount of hunted resources (ultimately derived from the palynological rainfall estimates) and estimated changes in primary plant production (also originating from the pollen derived rainfall estimates using Rosenzweig's (1968) formula and estimates of primary production where *ln(primary production)* = ln(rainfall)*1.09 - 0.94, r^2 = 0.701, p value = 0.0001). The range sizes estimated from amount of hunted resources yields lower estimates for the drier periods because of presumed increased reliance on plant foods while the range size estimates derived from the primary production estimates yield larger range estimates for the dry periods because of reduced carrying capacities (Figures 117 and 118). These two separate estimates roughly overlap with each other, and they are well within the limits of known San range sizes (Figure 119). However, these estimates do not consider range constriction due to growing populations in the late Holocene. As I demonstrated in Chapter XI this is influential in controlling range size as well.

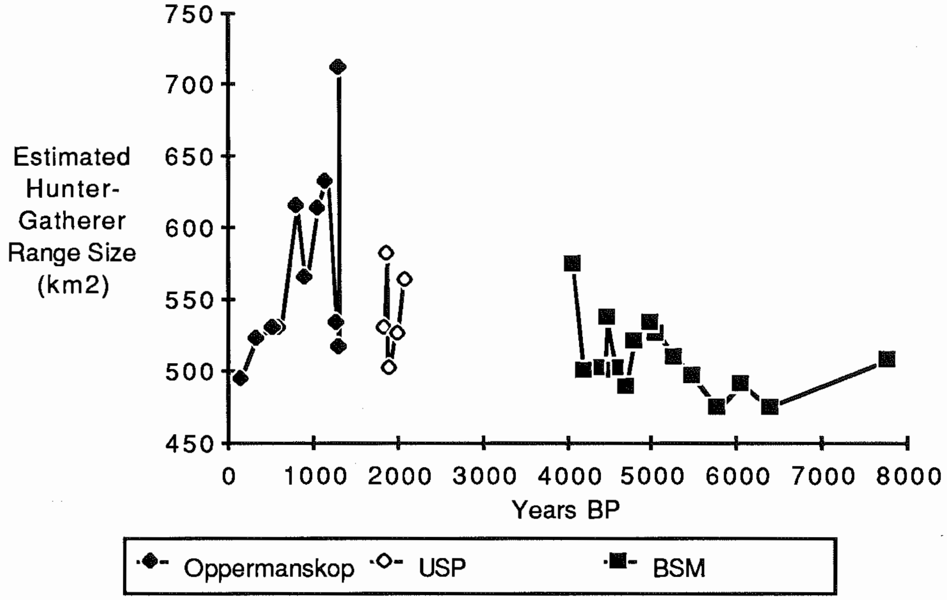

Figure 117. Hunter-gatherer range size estimated from amount of hunted resources in diet.

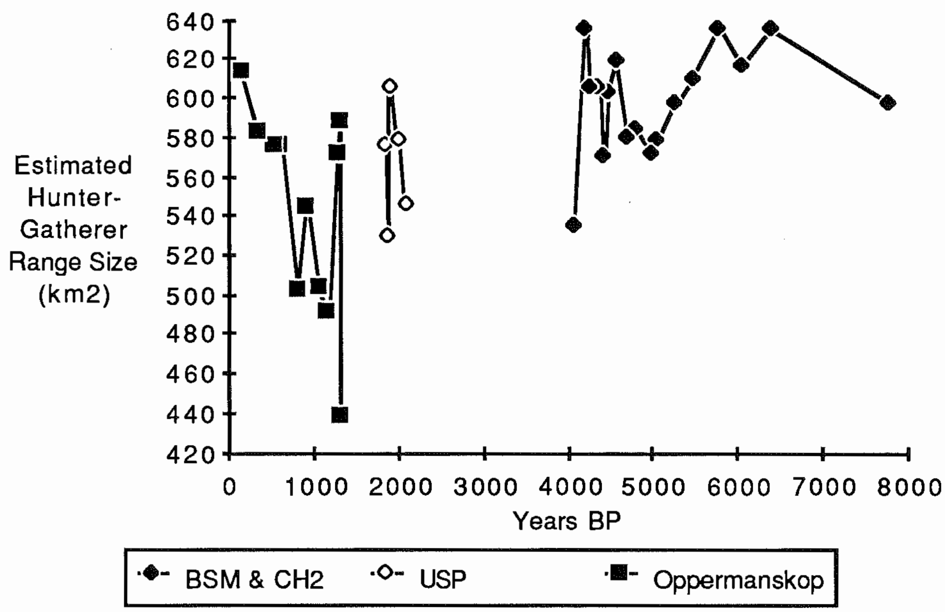

Figure 118. Changes in range size predicted by the ecological model for hunter-gatherers who incorporated Blydefontein within their subsistence round.

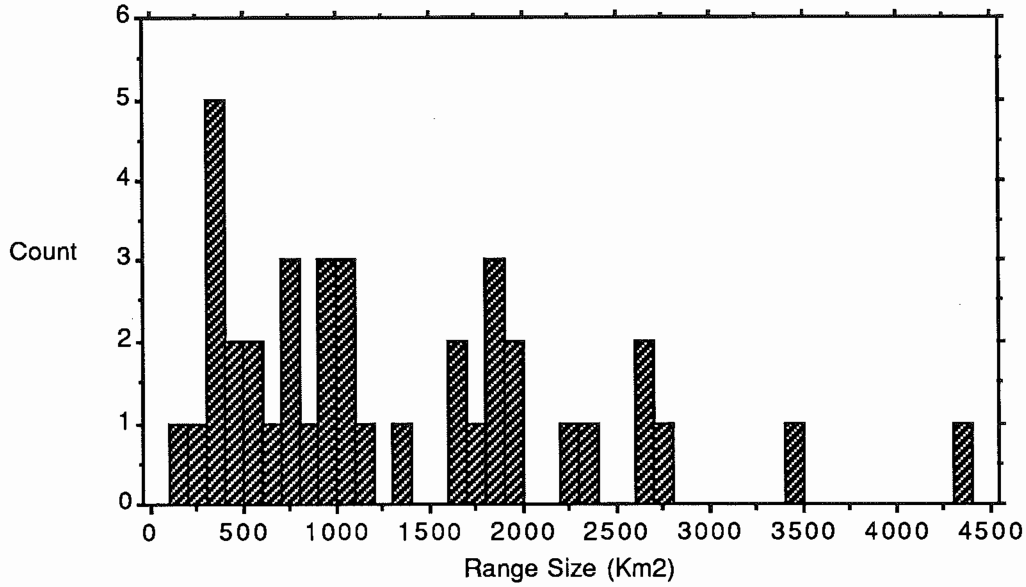

Figure 119. Histogram of recorded San ranges (see Figure 98).

Independent proxy evidence for population increase comes from the adjacent Zeekoe Valley where sub-recent (Smithfield) surface sites greatly outnumber later Holocene (Interior Wilton) surface sites (Sampson 1985). Finer time resolution for overall population increase during the last millennium is available for the upper Zeekoe Valley. There, sites with later ceramics (rocker-stamped wares) greatly outnumber those with the earlier (non-rocker) decorations (Sampson 1988; Sampson et al. 1989). Additionally the rarity of crescent dominated backed tool assemblages throughout the region points to low population densities in the early and mid-Holocene as originally suggested by J. Deacon (1974) using radiocarbon dates. As population rises to meet full carrying capacity, so territories shrink, with overall reductions in hunter-gatherer mobility. Thus the fluctuations in Figure 117 should be welded to a longer term trend towards smaller ranges during the later Holocene, in response to climbing population numbers. At present I am unable to provide a detailed model of these changes, however it is suggested that changes in carrying capacity as well as constrictions forced by by growing populations would be the most significant determinants of range size.

Test Implications

A sound test of this portion of the model may be possible with a spatial data base as large as that for the adjacent Zeekoe Valley (Sampson 1985), and any test derived from one or two sites is proportionally less sound. However, there are some test implications that can be built from local circumstances. Most of the stone used to make artifacts at Blydefontein is hornfels, but there are also rare specimens made of agate and jasper. These must have been obtained from the Orange River gravels at least 65km to the north. It is well known that agate or jasper tools decrease in frequency with distance from the Orange River (Humphreys 1972: 48-51; Sampson 1970: 97). While it is widely believed that adherence to a microlithic technology dictated the demand for agate and jasper, this is without foundation as all types of backed microliths, including all of the bifacial pressure-flaked tanged-and-barbed points, and pressure-flaked bladelets recovered from Blydefontein and Meerkat rockshelters are made of hornfels. It is far more likely that Orange River pebbles were acquired through contacts with local residents and, more significantly here, by personal visits to the Orange River valley. Dunn (1931) observed hunter-gatherers in Bushmanland, some 400km to the northwest, transporting stone as a matter of routine, and it is entirely possibly that this occurred in earlier times as well.

The implication is that the amount of agate and jasper in Blydefontein artifact assemblages is a direct reflection of the size of the inhabitant's range and overall mobility. At times when groups with small territories occupied the shelters, they did not have direct access to the Orange River gravels and even their indirect access would be reduced, consequently the amount of these rock types in the lithic debris would decrease. An increase in range size would bring them periodically closer to the gravels, and the amount of agate-jasper in the total assemblage would rise proportionally. This assumes also that risk-buffering gift exchanges (Wiessner 1977) between adjacent bands would increase during times of range increases. As the latter are modelled to occur during drought episodes, there are grounds for predicting an increase in overlap of territorial boundaries, more porous boundaries (Sampson 1988: Figure 1-11), and increased gift exchange. Orange River pebbles were potential gifts because of their attractive, colorful appearance and perhaps also because of the edge-holding qualities of the stone itself, certainly superior to that of the local hornfels. Estimates of real range sizes and boundary definitions are of course impossible from raw material ratios alone (pace Hester and Grady 1977; Schiffer 1975; Wilmsen 1973), and large amounts of spatial data (e.g. Sampson 1988) are needed before this becomes possible.

Test

The test implication derived from the above hypothesis can be compared with the actual plot of agate-jasper in the lithic debris from Blydefontein (Figure 120). Meerkat Rockshelter is omitted from the test because samples are too small to be reliable. The Blydefontein sequence shows that the Early Microlithic assemblage in CAU9 has the highest frequency of all, and the Lockshoek in CAU8 has none. The remainder of the early Holocene and the first half of the mid-Holocene is represented here by the basal assemblage of the Interior Wilton sequence (CAU7), which has almost as much agate-jasper as the Early Microlithic, but there is a steady decline in the (always small) percentages thereafter. Similar declines are well known from sites closer to the agate-jasper source (Humphreys 1972: 48-51; Sampson 1967a:

157, 1967b: 79, 1970: 105; Sampson and Sampson 1967: 71) where the overall frequencies are higher. This is is a regional trend, therefore, not just a local one.

This late Holocene decline fits well with the new model's expectations of a gradual reduction in hunter-gatherer territorial sizes during the Interior Wilton and Smithfield industries. The fluctuations about this decline, due to habitat changes is not reflected, because of the coarse interval of time represented by the samples.

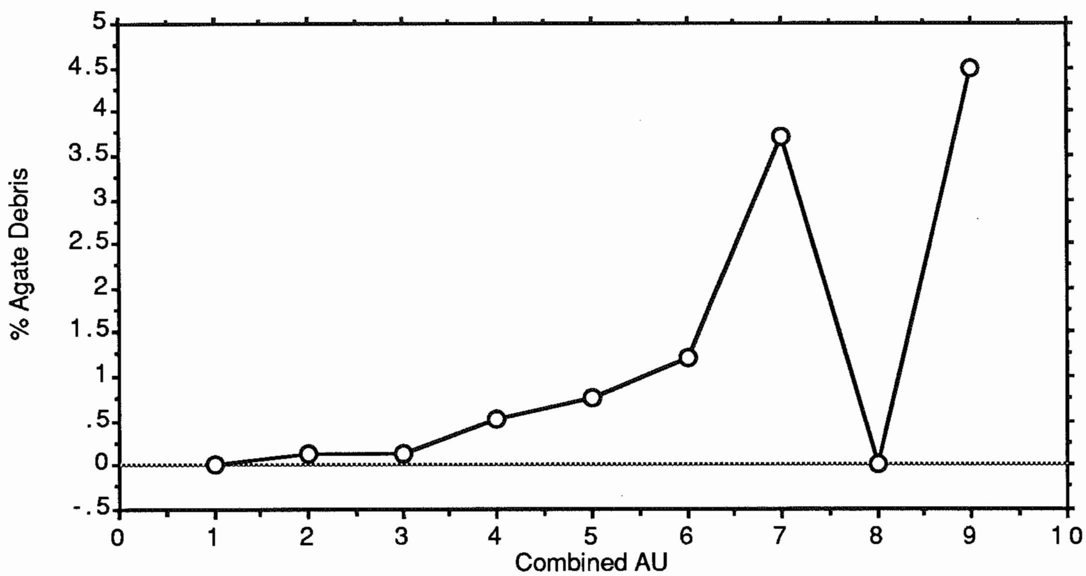

Figure 120. Percent of agate-jasper use through Combined Analysis Units.

Blydefontein Mobility in the Ecological Model

Obviously, a band's range size and its overall amount of mobility covary (see Figure 101 and 102). Another approach to calculating total mobility is to use the estimated amount of hunted food in the Blydefontein diet. Under modern conditions this is 30-31 percent and ranges between 29-36 percent for the Holocene (see above). When this is fitted to the regression curve in Figure 95, the resulting mobility score (number of camp moves X average length of logistic trip) is ca. 50, which is relatively low on the global scale. Any decrease in the frequency of hunted food at Blydefontein will produce almost no change in overall amount of mobility, but an increase of 15-20 percent of hunted foods could significantly raise the required mobility of the band.

Changes in the Blydefontein Collector/Forager Mobility Mix

The relative abundance of foraged meat in the Blydefontein fauna suggests strongly that it belongs on the forager-dominant end of the collector/forager scale. Most of the assemblages in the sequence would match somewhere along the gradient marked by hypothetical bands C-D-E in Figure 113. The only exception is the Early Microlithic (CAU9) that has no microfauna and is dominated entirely by large animals (R. Klein, personal communication). As the Early Microlithic assemblage was deposited during a time of more restricted environmental possibilities (see Chapter VII), it is reasonable to place this basal part of the sequence on the collector portion of the scale in the vicinity of band B in Figure 113.

A less intuitive fit can be achieved by looking at the number of camp moves as predicted by the percentage of the hunted food in the diet and calculating a linear regression. However, as Figure 121 shows a simple relationship does not exist. At approximately 45 percent of hunted foods in the diet residential camp moves either continues to increase or declines (presumably as the number of special task group trips, i.e. logistic mobility begins to dominate the mobility strategy. Given this split, a linear regression was calculated without the four (high percent of hunted foods and low number of residential camp moves) groups in the lower right hand corner (*number of residential camp moves* = -4.129 + 0.835 * percent of hunted resources). As the range of predicted hunted foods in the diet ranges between 29 and 36 percent, the span of

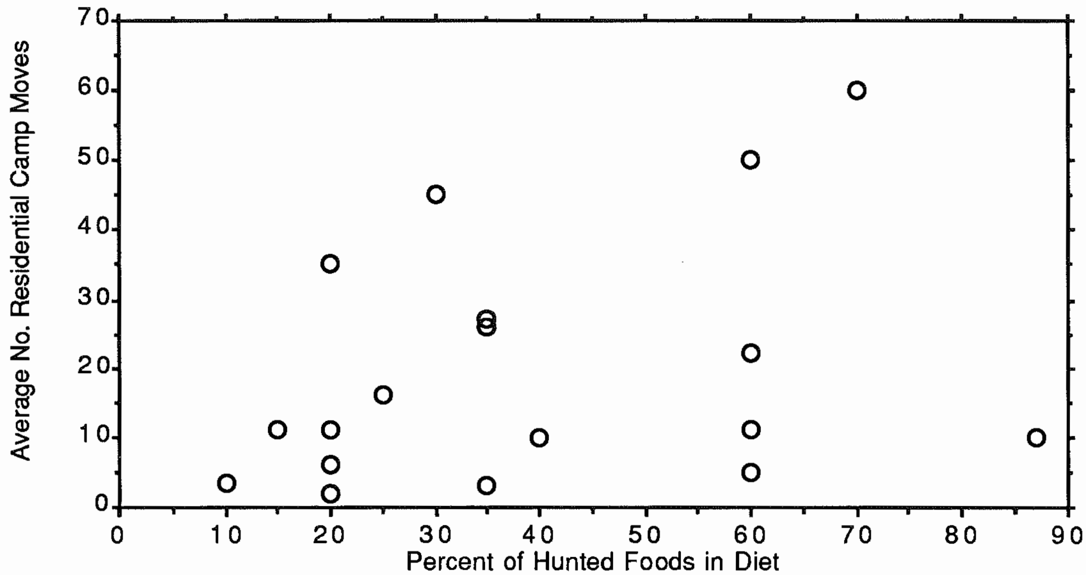

Figure 121. Scatterplot of percent of hunted foods in diet by average number of residential camp moves (data from Kelly 1983).

estimated camp moves falls between 20-26 moves. This is not a great deal of variation and it seems likely that for the entire Holocene the Blydefontein hunter-gatherers would be classified as foragers with slightly lesser or greater amounts of non-residential camp mobility.

Changes in Forager Mobility Predicted by Plant Productivity

The estimated primary production of plants for the individual pollen samples has been plugged into the formula for estimating number of camp moves (see Figure 92) and the resulting values are presented in Figure 122. These plant primary production estimates are based on the pollen-derived rainfall estimates, and again, I caution the reader that the actual historic rainfall variation was much greater than that estimated by the pollen and also that these are only estimates that I use for model building and not exact observational values. I expect that the actual range of camp moves by Blydefontein foragers would be greater than those predicted. Nevertheless the test implications for agate-jasper are the same as those for changes in range-size, so the test (Figure 120) is also the same. It is clear that the early and mid-Holocene foragers were highly mobile foragers and it is likely that reduced carrying capacities were the reason. Between 4000 B.P. and 900 B.P. reduced forager mobility appears to be a response to richer carrying capacities. The predicted rise in forager mobility does not show on the agate-jasper frequencies, possibly because population densities were then restricting mobility.

This figure suggests that the position of Blydefontein's forager/collector mix should be within the range of bands B and C in Figure 113. Further test implications for this segment of the model must be derived from its technological system, the components of which were reviewed in Chapter XII. As several aspects of decision-making in artifact design are intimately entwined with the forager/collector mobility mix, it is in the domain of artifact design that tests for the above prediction must be sought.

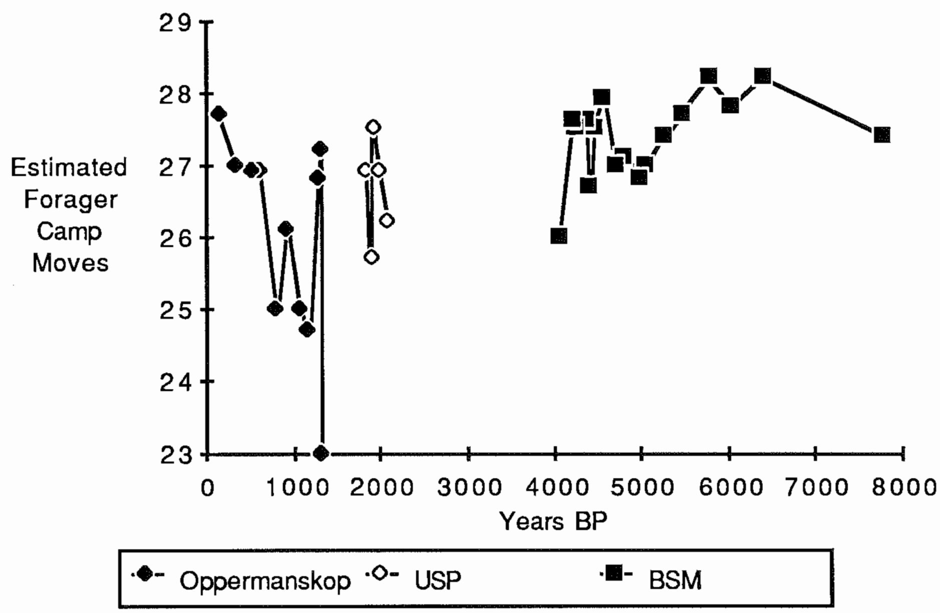

Figure 122. Estimated changes in the overall mobility of Blydefontein occupants based on estimates of plant primary production and correlation between plant primary production and forager camp moves (Figure 92).

Procedures for identifying the mix of maintainable/reliable design qualities (see Chapter XII) in a prehistoric stone tool are still in their infancy. Ethnoarchaeological studies of living stone toolmakers are not sharply focused on the problem, and only limited data for stone and bone tool use-life, manufacturing costs are available (see Table 30). To make matters worse these do not include detailed data for chipped stone tools. Replication/edgewear studies are mainly dealing with problems of usewear verification (Keeley 1980; Keeley and Newcomer 1977; Moss and Newcomer 1982) and these types of studies are just beginning to turn their attention to the question of tool efficiency (Keeley 1991). Dibble (1987) has shown that Middle Paleolithic scrapers, whether for working hides or wood, are essentially maintainable tools, and Barton (1990) has argued that almost all tools in Middle Paleolithic assemblages are really a single tool type used for many different tasks, each specimen being discarded at a slightly different stage of exhaustion. Thus tools classified as sidescrapers could be altered through intensive use to become transverse scrapers, concave scrapers, or sundry other types in the attribute-style approach developed in France (Bordes 1961), and elaborated and exported elsewhere (e.g. J. Deacon 1978; Sackett 1966).

Indeed Binford (1973, 1977) has argued that the Middle Paleolithic toolmakers were foragers who used, in his terminology, expedient (or non-curated) designs, such that tools would be discarded in a wide variety of shapes. One upshot of this is that assemblages from different sites would end up looking very different from each other. Binford further argues that the Upper Paleolithic toolmakers who followed used a collector mobility pattern that demanded curated tools. These would have standardized shapes that would not be altered before each tool was broken and discarded. In the latter scenario, assemblages from different sites would look very similar. Subsequent research (e.g. Dibble 1987; Hayden 1986; Marks 1988; Marks and Freidel 1978) has not supported the linkage between forager/expedient/Middle Paleolithic or collector/curation/Upper Paleolithic, but none of these tests of the model is particularly rigorous, and the results need not be taken to imply that the linkage never existed elsewhere or in other periods of prehistory.

Little has been done yet with the effects of mobility on the appearance of stone tools. Kelly (1988) suggests that highly mobile groups who were at the collector end of the forager/collector mobility scale carried bifacial cores about and used them for a relatively long time. He suggests that they were used also as tools that could double as raw material sources in areas and times when suitable rock sources were not available. In this case, bifacial cores in different assemblages from different sites would end up looking quite different from one another.

Stone Tool Design Decisions in the Later Stone Age

In South Africa, the lack of ethnographic stone tool makers is keenly felt. Almost all Bushmen now make metal arrowheads from fencing wire instead of stone, bone or wood (Lee 1979: 133, 277; Schapera 1930: 128-130; Silberbauer 1981: 206). The switch took place in the early 20th century when wire was still a scarce commodity. As the source became more abundant, so the switch to wire arrowheads became almost complete except where wire remains unobtainable (Wiessner 1983). This change does point up one apparent axiom about design efficiency, however. More durable and less brittle raw materials are at all times preferred. As access to these materials changed, so the frequency of tools in the assemblage changed according.

The role of raw material has been evoked repeatedly in the literature to explain changes in assemblage composition and stone tool design. In the interior plateau, the overriding assumption has been that siliceous rocks like agate and jasper are more flakeable, less brittle and have more durable edge-holding qualities than hornfels.

These differences have been used even to explain why there are no microliths in the Smithfield Industry: the knappers only used hornfels (Fagan 1965: 38). The underlying assumption is that assemblage composition is tied to the availability of suitable rock outcrops. A deeper assumption, nowhere made explicit in the South African archaeological literature, is that a group's access to suitable rocks is strongly linked to its mobility pattern mix and its range size. For example Parkington (1984: 128-131) suggests that the widely observed shift from an Early Microlithic (cf. Robberg) assemblage to the macrolithic (Oakhurst) assemblage was a response by resident hunter-foragers to a drop in the amount of available non-hornfels, but the implications for reduced range size and mobility are not spelled out. These controlling factors are given prominence in the technological system of the new model (Chapter XI) and are the target of the tests that follow.

Changes in Stone Tool Design Decisions at Blydefontein

The stone tool designs from Blydefontein that are most amenable to analysis are those with large enough sample from each of the CAU's in the sequence. These include the endscrapers, and the backed bladelets. Other items of technological interest are the bladelet debitage (and their parent cores) and the flake debitage.

End Scrapers

Later Stone Age endscrapers from the interior plateau have been long known to occur in a wide variety of forms (Goodwin and van Riet Lowe 1929). They have been extensively described from the Orange River Scheme area (Sampson 1970: 5-6; Sampson 1972: 259-261, 322-327, 376-381; Sampson and Sampson 1967: 6) and subjected to attribute and metric analysis at Highlands Rockshelter (H. Deacon 1976: 58-69). No systematic study of edgewear has been undertaken yet, although the potential clearly exists (Binneman 1981, 1983). The function(s) of the endscraper within the Later Stone Age adaptive system is still a wide open question, therefore. The only ethnoarchaeological research of immediate use is that on Ethiopian herdsmen who use hafted obsidian hide scrapers to prepare skins. From these studies (Clark and Kurashina 1981: 307-311; Gallagher 1977: 411-413) it is fairly clear that overall shape and size (especially length) directly reflects the intensity of use, and also whether the tool was hafted or not. Unremarkably, exhausted scrapers are shorter than new ones because they have been trimmed (resharpened) so many times. Also, hafted ones are shorter because one can still grip the tool long after an unhafted scraper has become too small to hold. The hafted ones are normally trimmed on their butts to improve their fit with the handle (Clark and Kurashina 1981: 309; Gallagher 1977: 410). Non-hafted scrapers are larger and have much less trimming (Clark and Kurashina 1981: 308). The motives for making hafted versus hand-held scrapers is not recorded, but the lack of suitable large flakes could be a limiting factor that might favor the use of hafted scrapers.

Short (Hafted) Endscrapers

Many analysts agree with Clark's (1959: 202, 232-234) suggestion that the differences between shorter (typically Wilton) and longer (typically Smithfield) endscrapers might be due to the former hafting their scrapers and the latter using hand-held scrapers (H. Deacon and J. Deacon 1980). Although hafted scrapers and/or adzes have been recovered from several coastal sites, usually embedded in a wad of mastic and attached to a wide variety of handles (Clark 1959: 232-234, H. Deacon 1966), there are few typical endscrapers in the sample. However, numerous short specimens with mastic adhering to the butts come from Melkhoutboom Cave (H. Deacon 1976: 58, H. Deacon and J. Deacon 1980), and it is now widely accepted that these were hafted and used for hide scraping.

These scanty and diverse scraps of data all converge to indicate that the short, hafted endscraper fits into the new model's technological system thus: it was designed with a balance (50-50) mix of maintainable and reliable qualities. It was designed also to have relatively long use-life and was refurbished rather than replaced. Discard occurred only when the bit was close to exhaustion. Note that there is no evidence for or against the replacement of LSA short endscraper bits. Production time was relatively costly because of the three materials that had to be gathered (stone, mastic, handle), so it is likely that it was carried about for some time before it was finished. There is no evidence of caches. It would have been in daily use at regular make-and-mend sessions. All of these qualities make it fit easily into the repertoire of a group with a forager-dominant mobility pattern (Figure 113). It misfits at one point in the system, however, because it falls squarely within the repair kit (maintenance tool) category, used to produce and repair other tools and weapons. The new model predicts that foragers have less regard for such tools and replace them often. Seen from this perspective, it would fit better with a collector's specialized repair kit, with a long use-life.

Long (Hand-Held) Endscrapers

The longer, unhafted endscraper fits more comfortably into the forager tool-making repertoire. Here the maintainable design qualities are utilized more often, with reliability of less concern. The unhafted endscraper is a very generalized, maintainable repair kit tool with a relatively short use-life (expedient tool), and soon discarded, well before exhaustion. It is also replaced when broken, which happens often. Endscraper tip fragments are a common occurrence. It is in active daily use at make-and-mend sessions. One residual doubt must be sounded, however. Kannemeyer (1890) observed Bushmen near Burgersdorp, only 120km from

Blydefontein, using unhafted stone tools called "Kuin" as skinning knives for antelope. His (albeit sketchy) illustration resembles an elongated "Smithfield" endscraper, but there appears to be heavy, adze-like retouch along the sides that is atypical. If endscrapers doubled as skinning (extractive) tools, they should have relatively longer use-lives among foragers.

Test Implications

It is reasonable to predict that abundant suitable rock will encourage the production of more hand-held, longer endscrapers, while a shortage of suitable stone will promote the more costly production of hafted, short endscrapers. Length here is considered to represent a rough index of remaining use-life. This is different from the Index of Reduction proposed by Kuhn (1990) who is attempting to measure the consumed portion of a scraper. However, Kuhn's procedure requires fairly standardized blanks for scraper use, and these are lacking in the artifact assemblages at Blydefontein. Viewed from a single site, a switch from abundance to scarcity of suitable rock can occur only when the occupant's range (and mobility) is curtailed so that they no longer have easy access to the right stone.

Test

The agate-jasper data support a model in which the Blydefontein occupants' range was gradually shrinking throughout the later Holocene (Figures 119 and 120). It follows that the test implications for endscrapers are that shorter, hafted endscrapers will proliferate with time. When mean endscraper lengths are plotted (with 1 standard deviation bars) the test fails (Figure 123). No endscrapers were recovered in the tiny Early Microlithic assemblage, and the single Lockshoek scraper in CAU8 is outside the range of the later samples and will not be considered further. Overall, endscrapers are smallest in CAU7 at the base of the Interior Wilton sequence, and increase in length through time. This implies that curation and hafting of endscrapers decreased, thus refuting the expectations of the model.

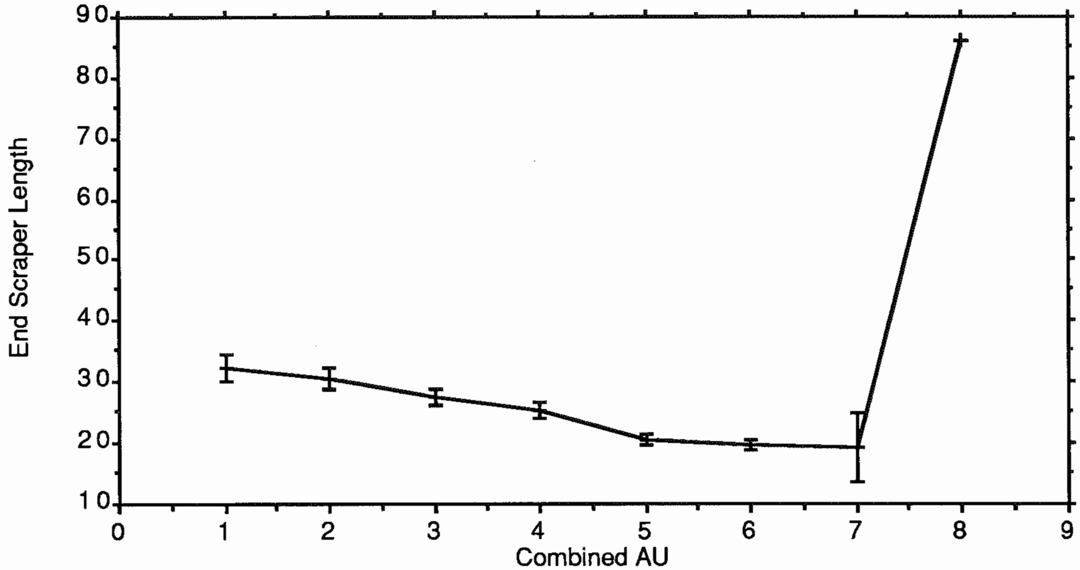

Figure 123. Mean endscraper lengths for Analytical Units at Blydefontein Rockshelter with one standard error bars. No end scrapers were recovered from CAU9.

If this trend towards increased use of hand-held endscrapers was dictated rather by a switch in the used of lithic materials to hornfels, as suggested by several authors, starting with Sampson and Sampson (1967), then the range hypothesis derived from the new model is redundant. However, Figure 124 plots the mean lengths of hornfels endscrapers only, and the trend is still present. The shift in endscraper raw material is too trivial at Blydefontein, and does not control the design change. Nor is it certain that a shrinking range would have made hornfels shortages inevitable for the Blydefontein occupants. In the adjacent Zeekoe Valley, hornfels outcrops are abundant and evenly distributed (Sampson 1984: 17, 1985: 81), and the nearest quarry to Blydefontein and Meerkat Rockshelters in only 5km away in the neighboring Hughdale basin.

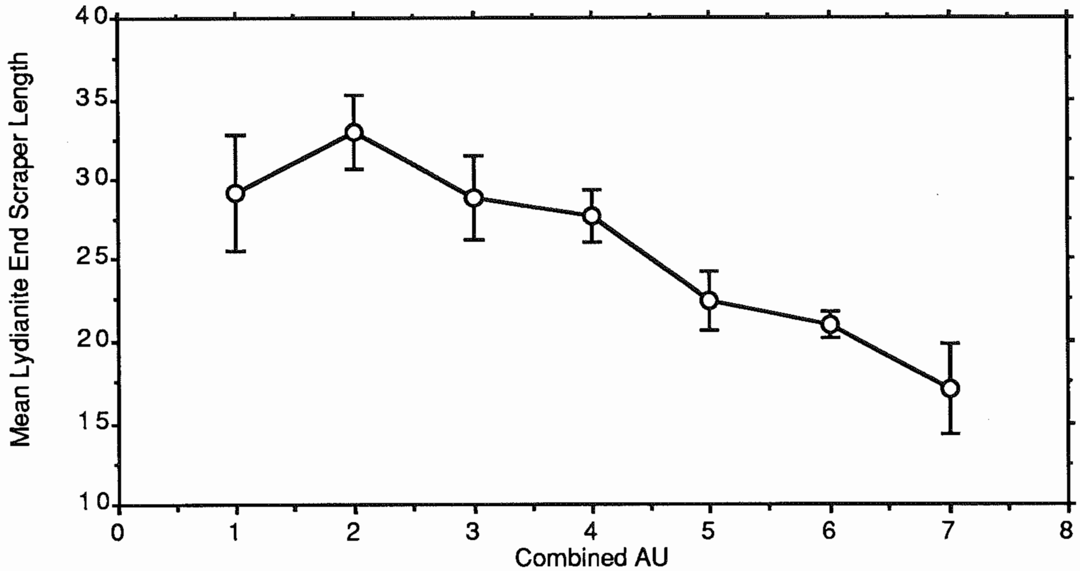

Figure 124. Mean lengths of hornfels endscrapers for Analytical Units at Blydefontein Rockshelter with one standard error bars. No end scrapers were recovered from CAU9 and standard errors should not be calculated for the two hornfels end scrapers from CAU8.

Obviously other factors are at work here, and rival hypotheses must be built and tested. Possibly the assumptions of similar use for hafted and hand-held scrapers is incorrect, and this can only be tested by extensive use-wear studies. Another testable scenario is that shrinking ranges made it more difficult to obtain mastic (tiny drops adhere to some Blydefontein tools although its source is unknown), while hornfels shortages were unlikely. The increasing risk of being caught short without mastic makes it more efficient to carry around (or cache at camps) a few large hornfels cores from which to strike suitable flake-blade blanks for hand-held endscrapers. This will require a study of local mastic sources, their distribution on the landscape and their fluctuations through time. If mastic sources prove to be rare, widely spaced and clumped on the the landscape, then the test implications would fit the endscraper data.

A final factor may be that a change in the mobility (from high to low) influences a band's ready access to lithic sources during work sessions. This is different from the first hypothesis. If a band is highly mobile it may be easier to use hafted, long use-life endscrapers in limited, more intensive work sessions when maintenance tools may be rapidly exhausted. In less mobile bands that work sporadically but often in make and mend sessions, raw materials may be obtained daily embedded in other foraging/hunting trips. Obviously more work is required before this issue will be settled.

Backed Bladelets

These tools are assumed, on limited grounds to have served exclusively as arrow armatures, either barbs or points. Clark (1977) describes a number of 19th century Bushmen arrows that have backed bladelets mounted in mastic as points. In 1872 Dunn (1880) observed an old woman in Botswana mounting two small triangular flakes in mastic to make an arrow point. Within the framework of the new model they should be viewed as artifacts to be replaced, rather than maintained. Their main design characters should be reliable rather than maintainable, and they will have relatively short use-lives, possibly with relatively long (passive) spells out of use. Collectors will replace them frequently in brief gearing-up sessions to buffer the risk of failure (Kuhn 1989). Foragers will replace them only when broken, and they will do this during daily make-and-mend sessions. If overall forager mobility is forced to increase, however, there may be a collateral increase in collector-like repairing, i.e. replace-before-failure.

A measure of replace-before-failure planning can be obtained by looking at the frequency of whole backed armatures versus broken fragments. Fragments are believed here to reflect replacement after breakage (see Keeley 1991 for intrasite discard patterns of this behavior). Whole arrow armatures may take the form of backed points, crescents, complete backed bladelets or complete bladelet blanks. Fragments including proximal, medial or distal pieces of any of the former. Note that manufacturing discards (proximal, medial and distal) are also present, but as most of these enter the archaeological record during production (H. Deacon 1976: 141-13; Movius et al. 1968: 50-51), they are not used in this test.

Test Implications

The implications for backed bladelets are that more whole specimens will occur in the shelter at times when overall mobility has increased, and also when the frequency of collector mobility patterns (task-specific trips) has increased. At times when forager mobility patterns (frequent camp moves) prevail, there will be more fragments, reflecting a more relaxed, fix-when-broken approach to arrowhead maintenance. Thus the relative frequencies will covary with the predictive curves shown for mobility in Figures 119 through 121.

Test

Only Blydefontein assemblages are considered as assemblages from Meerkat are too small for reliable comparisons. Table 33 lists all backed artifacts by CAU, and Figure 125 plots the percentages for the complete backed bladelets. The percentages suggests that complete backed tools occur in high frequencies in the the bottom of CY (CAU9), the upper portion of CY (CAU7), and lower portion of TG/CAC (CAU6). A working hypothesis can now be derived from these results: Interior Wilton hunters were discarding a number of complete tools and by implication using a significant amount of replace-before-failure planning in their arrowhead maintenance, a practice which they all but abandoned in the later Holocene. This fits well with the overall expectations of the shrinking-range hypothesis tested above. It would also fit well with the still-untested proposition that mastic became a scarcer commodity in the later Holocene--this could have inhibited frequent armature replacements as well.

Table 33.--Backed artifact discards, broken fragments and complete tools at Blydefontein Rockshelter. Percentages calculated for fragments and complete backed bladelets

Major CAU	Discards	Fragments	Complete Tools	Total	(- Discards)
1	1	0 /-	0 /-	1	(0)
2	4	7 /77.7%	2 /22.3%	13	(9)
3	8	27 / 81.8	6 /18.2	41	(33)
4	13	46 / 82.1	10 /17.9	69	(56)
5	5	24 / 82.6	5 /17.4	34	(29)
6	22	83 /72.8	31 / 27.2	136	(114)
7	1	7 /58.3	5 /41.7	13	(12)
8	-	-	-	0	
9	0	1 /33.3	2 / 66.7	3	(3)
Total	54	195	61	310	(256)

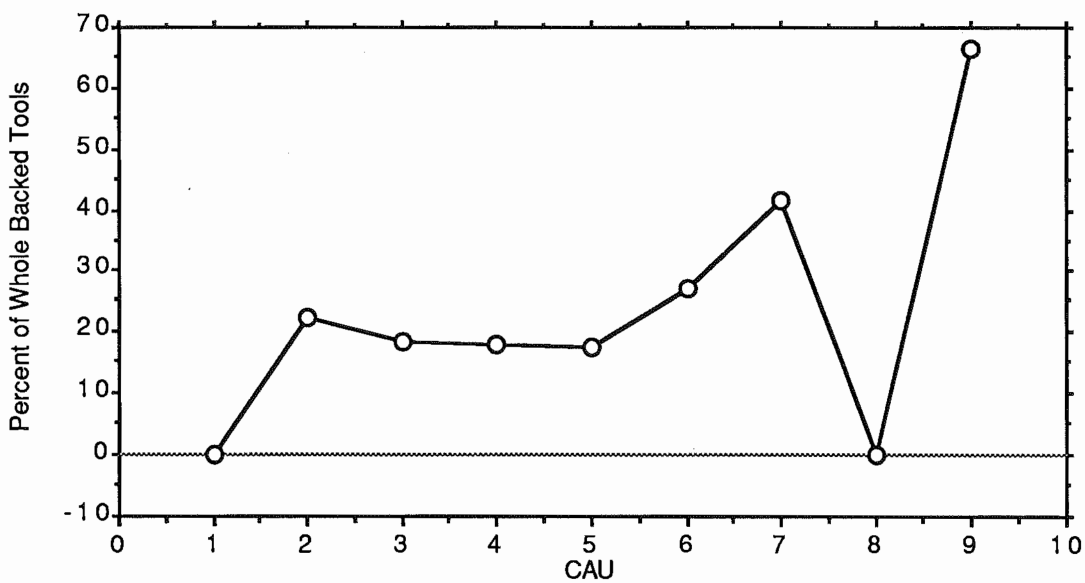

Figure 125. Percent of complete backed bladelet tools by Combined Analytical Unit at Blydefontein Rockshelter.

Bladelet Debitage and Bladelet Cores

If we cannot assume that hornfels shortages for the Blydefontein occupants were real during times of shrunken range and mobility (see caveat above), the model's expectation of more efficient use of raw materials (Kelly 1988: 719-721; Parry and Kelly 1987) may not apply in this case study. However, other related factors may come into play. If efficiency is defined as getting more cutting edge per weight of stone, then bladelet technology is a logical response to the need for more efficient use of stone (Bordaz 1970: 56-57; Clark 1976: 13; Leroi-Gourhan 1943; Mitchell 1988: 262-263).

Although range reduction and quarry losses may not be enough to induce more bladelet manufacture, the hypothesized decision to adopt more replace-before-failure planning in arrow maintenance will stimulate more bladelet production. Because bladelet shape and size can be better controlled during knapping than flake shapes and sizes, a greater proportion of pieces will be useable in any reliable technology that needs bladelet fitted parts like arrow armatures.

It follows that bladelet production is likely to play an important part in a replace-before-failure pattern of arrow maintenance, because the demand for armature blanks will be relatively great.

Test Implication 1

The hypothesis predicts higher bladelet production levels in mid-Holocene layers at Blydefontein and less during the later Holocene levels. The curve for changing bladelet frequencies in the Blydefontein sequence should resemble the curve for whole arrow armatures (see Figure 125).

Figure 126 plots the percentages of bladelets in the lithic debitage of each CAU at Blydefontein. The graph shows that bladelets were predictably common in the Early Microlithic (CAU9), and predictably rare in the Lockshoek (CAU8). However, the Interior Wilton in CAU7 has few bladelets. The frequency climbs to high levels on in CAU6 and it remains high through CAU4, after which it declines steadily. These results do not match with the frequency curve generated for the test implications above, so the test apparently fails to support the hypothesis.

When bladelet cores are plotted against flake cores (Figure 127) there is a rough covariance with the bladelet frequency curve (see Figure 126), but the high frequency is sustained through CAU3 although this and the following samples are very small. Nevertheless this curve also fails to covary with that for whole armatures.

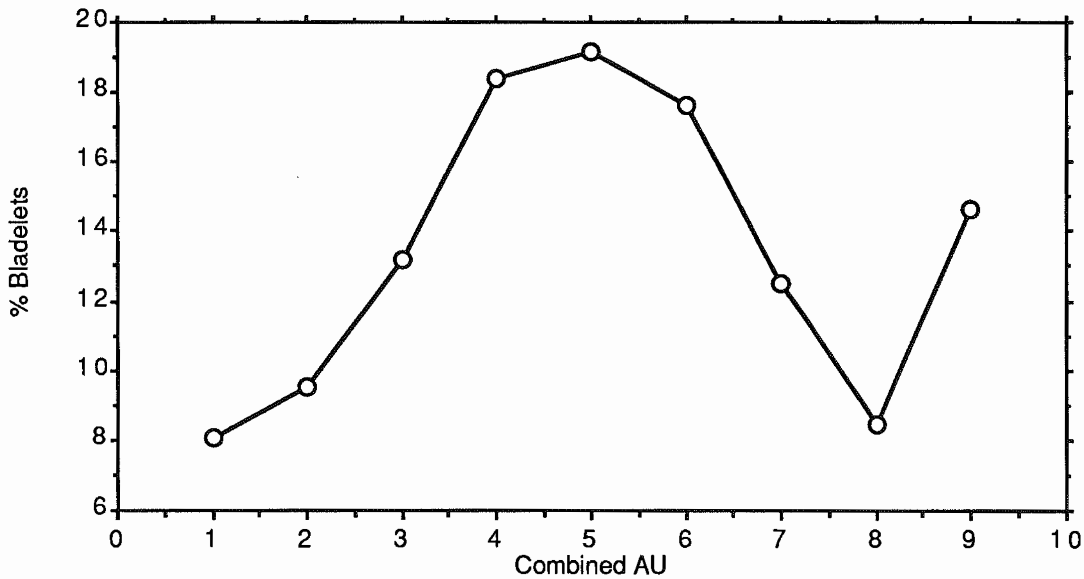

Figure 126. Percent of bladelets among lithic debris by CAU.

Thus bladelet production ratios are not linked to restricted access to quarries, nor are they determined by the amount of replace-before-broken planning in arrowhead maintenance schedule. A far more basic proposition is that the overall need for armature blanks, i.e. backed bladelets and their microlith variants, determined how often bladelets were produced. It is well known that the frequency of backed microliths is relatively low at the start of an Interior Wilton sequence, it peaks in the middle, then declines to near zero in the terminal (Smithfield) levels at the top of the sequence. This is demonstrated at several sites, and Blydefontein is no exception.

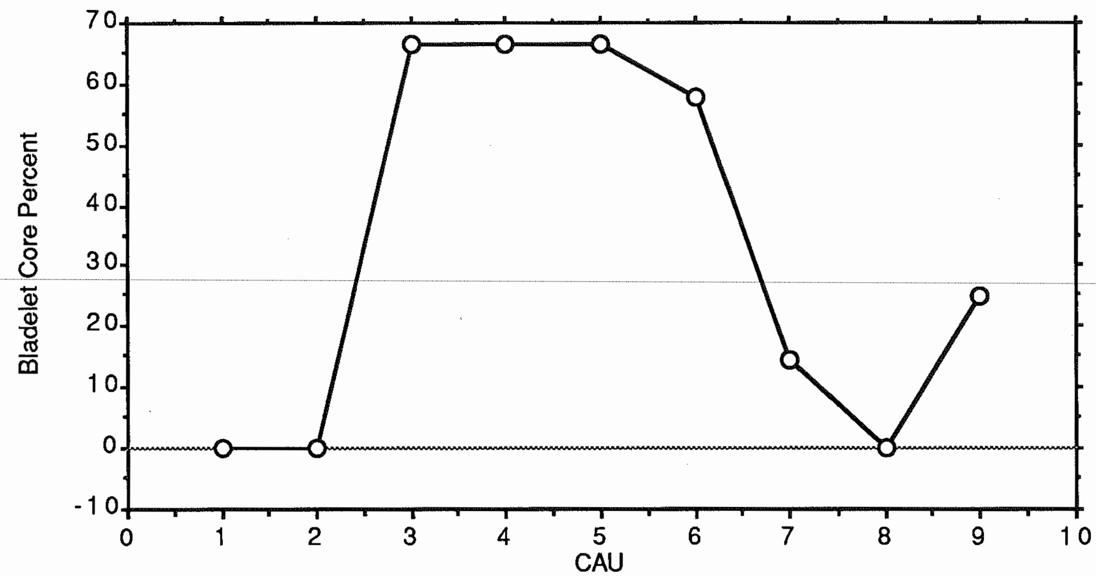

Figure 127. Percent of bladelet cores among lithic debris by CAU.

<u>Test Implication 2</u>

As the widespread trend bears a general resemblance to the bladelet curve in Figure 126 and the bladelet core curve in Figure 127, there are grounds for supposing they are linked. Thus the hypothesis states that there will be good correlation between the percentage backed bladelet tools in an assemblage and the percentage of bladelets in the debitage. Likewise there will be a similar correlation between the percentage of backed bladelet tools in the assemblage and the percentage of bladelet cores.

Test 2

A regression analysis displayed in Figure 128 demonstrates a clear relationship, and the hypothesis is supported. The rate of bladelet production is determined by the need for backed bladelets for arrow armatures and not by external factors. The early portion of the Interior Wilton sequence (CAU6-7) has more backed crescents that could have been made of small flake blanks. Reasons for this decline in backed armatures toward the end of the sequence is uncertain, but it has been linked at Glen Elliot Shelter to an increase in the use of cylindrical bone arrow points without armatures (Sampson 1967a). This relationship cannot be demonstrated at Blydefontein, however.

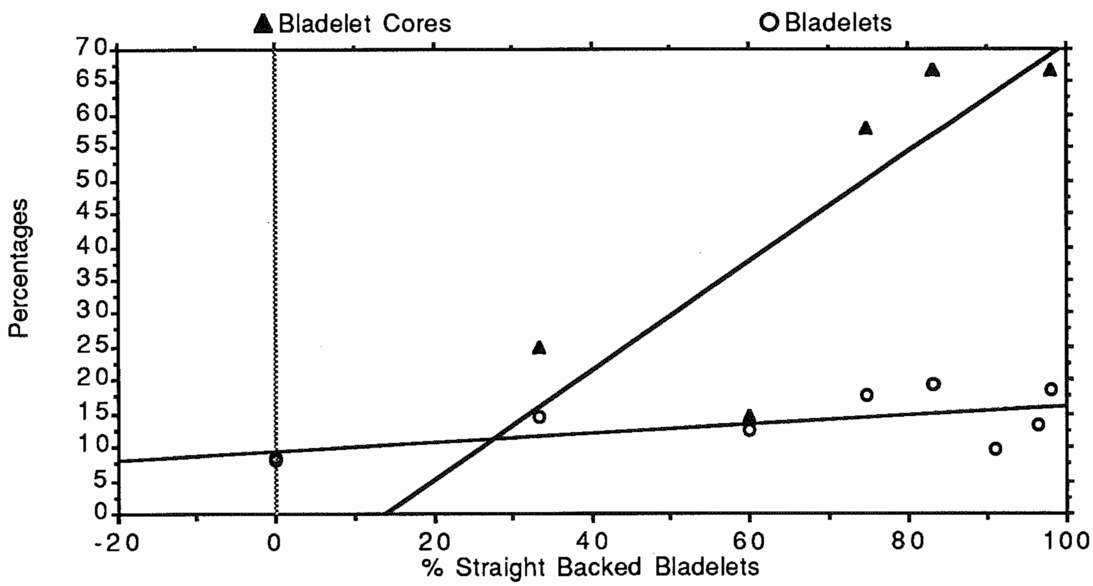

Figure 128. Scatterplot and linear regression between straight backed bladelets with bladelets (r^2 = 0.391, p = 0.072) and bladelet cores (r^2 = 0.673, p = 0.089).

Dorsal Cortex on Debitage

The amount of cortex on the dorsal surface of debitage is a rough measure of the degree to which cores have been reduced (Ahler 1989; Butler and May 1984; Collins 1975; Henry 1989; Johnson and Morrow 1987; Muto 1971; Vehik 1985). Factors controlling the amount of core reduction are many, and not all of these are connected to the size and quality of the original block or nodule. One factor of immediate interest is the effect of source-to-site distance on the amount of core reduction found at a site. All things being equal, the farther the core must be carried, the more material the knapper will try to get from it. If quarries at great distances from the site are being exploited, then cores from those quarries will be more heavily reduced and less cortex from those cores will occur in the debitage. As hunter-gatherer mobility, either number of camp moves or length and distance of task group trips, increases the amount of dorsal surface cortex will decline. Implicit in this scenario is the naïve assumption that nodules/blocks were not decorticated at the source.

Test Implication

The model predicts reduced amounts of cortex on the dorsal surface of debitage in mid-Holocene Interior Wilton and Early Microlithic assemblages when mobility levels are thought to be higher.

Test

All lithic debris was classified into six cortex categories and ranked: zero percent cortex = 0, one to twenty-five percent cortex = 1, twenty-six to fifty percent cortex = 2, fifty-one to seventy-five percent cortex = 3, seventy-six to ninety-nine percent cortex = 4, and one-hundred percent cortex = 5. Simple averages of the cortex ranks were calculated for all flakes and bladelets over 10 mm in length. This eliminated the very small resharpening flakes produced by the retouching of scrapers and other tools. Figure 129 is a line graph of the resulting mean cortex rank for flakes and bladelets from each of the nine Blydefontein Rockshelter assemblages.

There is high cortex retention in the Early Microlithic of CAU9, and a significant drop in CAU8. Cortex retention again peaks in CAU4-5, and then steadily declines to CAU1. These results are virtually opposite to those expected. For example the very low retention in the Lockshoek sample of CAU8 appears to be anomalous because cortex on Lockshoek scrapers is so common that it is a hallmark. This case points up one flawed assumption mentioned above: that cores were not decorticated at the quarry. Hundreds of Lockshoek (Goodlands) quarries are known from the middle Orange River (Sampson 1972) and from the Zeekoe Valley (Sampson 1985). One notable feature of these quarries is that large, hand-sized flakes were struck directly from the bedrock outcrops. If these were carried away as raw material, they would retain cortex only on the dorsal surface, thus cutting in half the potential amount of cortex removed from the quarry. The smaller flakes were converted directly into typical macro-scrapers, while the larger ones were removed and further reduced as cores.

By contrast, the many Interior Wilton sources recorded from the Zeekoe Valley are usually weathered rubble cobbles in terrace gravels or outcrop scree fans. Refitting of bladelets and flakes on the original cores demonstrates that the flat oblong rubble cobbles make perfect pre-formed blanks for bladelet removal. Typical Interior Wilton flaking debris at these sources includes tested cores and some decortification flakes, but all indications from both quarries and other sites suggest that small cobbles were taken away whole, and with most of their original cortex surface intact after only a few test flake removals (Sampson 1985: 29, 57).

Instead, there is an obvious resemblance between the cortex retention curve and that for bladelet production rates (see Figure 126). It is reasonably to suppose, therefore, that cortex retention is determined indirectly by technical production decisions, rather than by any external factors. The use of weathered rubble as a ready-formed source for bladelets simply produces more cortex on debitage than the use of large flakes struck from bedrock outcrops. At Blydefontein, the cortex retention curve does not conform to the predicted correlation with the overall mobility curve, so the test fails to support the hypothesis that cortex retention reflects range/mobility.

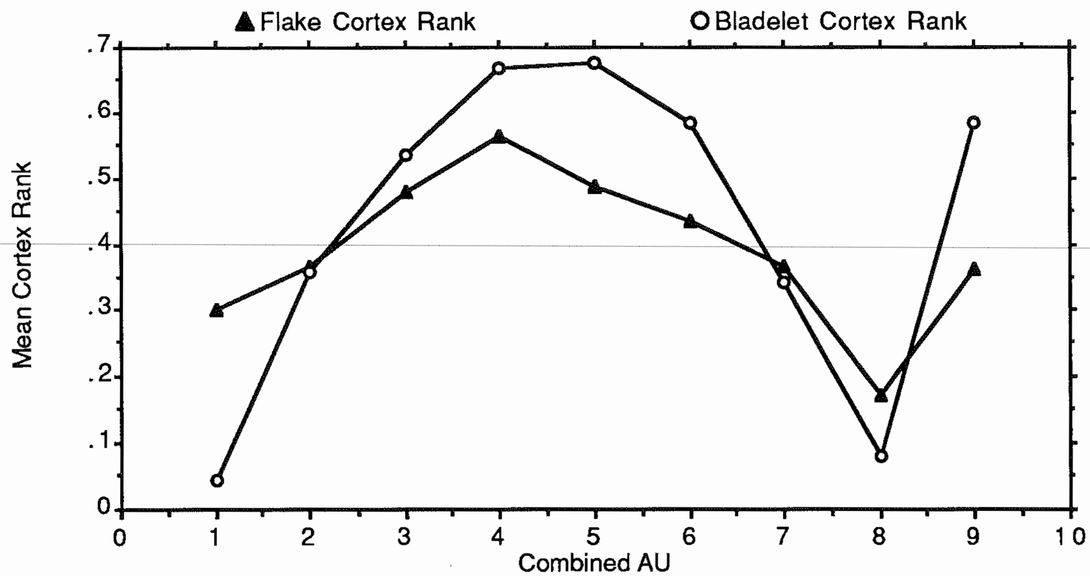

Figure 129. Mean cortex rank for flakes and bladelets in Combined Analytical Units.

Isolation of the Variables that Reflect Curation Decisions

It is now apparent that an interlocking cluster of technological variables is running interference with the continued testing of the new model. Before proceeding, it is necessary to isolate this cluster from the other variables so that interrelationships between the latter can be put in sharper focus. Thus far, each of the above test compared only a pair of trends at a time. However, the results have revealed similarities between more than just two pairs. In order to tease out more complex, combined relationships between these trends, all the above data were subjected to a factor analysis. Factor analysis assumes that the combined trends are controlled by one or more variable, called factors, for which no direct observations exist. Then, assuming linear relationships, the factor analysis attempts to identify the underlying controlling variable(s) and to determine which of the documented variables are influenced by them.

In this analysis, only the assemblages from the Interior Wilton sequence at Blydefontein Rockshelter (CAU7 through CAU2) were used, as there are missing data from all the others. Unfortunately bladelet cores had to be dropped from this test because of small samples in CAU2 and CAU3. Two factors were identified (Table 34), and an orthogonal varimax solution was used. The same factors composed of the same artifacts were identified by oblique methods as well.

The first factor is an uni-polar factor with significant factor loadings (i.e. greater than 0.5 or less than -0.5) that were only positive values. Not surprisingly, Factor 1 had significant loadings on percent of bladelets, flake cortex rank and bladelet cortex rank. This effectively isolates the bundle of trends controlled by technological forces of the bladelet core reduction sequence. No doubt the trend for bladelet cores would be controlled by Factor 1.

The second factor is bipolar, with significant positive loadings for complete backed tools and percent of agate-jasper debitage. Factor 2 also has significant negative loading for mean endscraper length. These are the variables that are more likely to be determined by the various kinds of curation decisions discussed above. These in turn are controlled by larger adaptive forces like mobility, and range size, which are in their turn acted upon by carrying capacity and population density.

Table 34.--Factor loadings and proportion of artifact type variance (communality) explained by factor analysis. Factor Analysis uses Principal Components and varimax orthogonal rotation. Also listed are proportion of common or explained variance for each factor, and variable complexity. Variable complexity indicates how many factors account for variable's (artifact type) communality. Significant loadings underlined

Artifact Type	Factor 1	Factor 2	Communality	Variable Complexity
Complete Backed Bladelets	-0.437	<u>0.863</u>	0.935	1.481
% Agate-Jasper Lithic Debris	-0.263	<u>0.949</u>	0.970	1.153
Mean End Scraper Length	-0.387	-<u>0.892</u>	0.954	1.363
Mean Flake Cortex Rank	<u>0.864</u>	-0.312	0.844	1.257
Mean Bladelet Cortex Rank	<u>0.977</u>	-0.208	0.997	1.090
% Bladelets	<u>0.974</u>	0.186	0.984	1.073
Proportion of Common Variance	0.539	0.461		

Factor analysis also measures, through the use of scores, the contribution of each CAU assemblage to the factor analysis. These scores are plotted in Figure 130, and this clearly shows that Factor 1 has a very similar pattern to the bladelet percentages and the mean cortex retention patterns. While this resemblance is gratifying, it is the scores for Factor 2 that are of outstanding interest. The scores decrease from the bottom to the top of the sequence in a very regular exponential (decay) manner. These results fit extremely well with the expectations of the model: the combination of stone tool curation strategies is being gradually altered as an ongoing adjustment to gradually shrinking range size and mobility due to increasing population density.

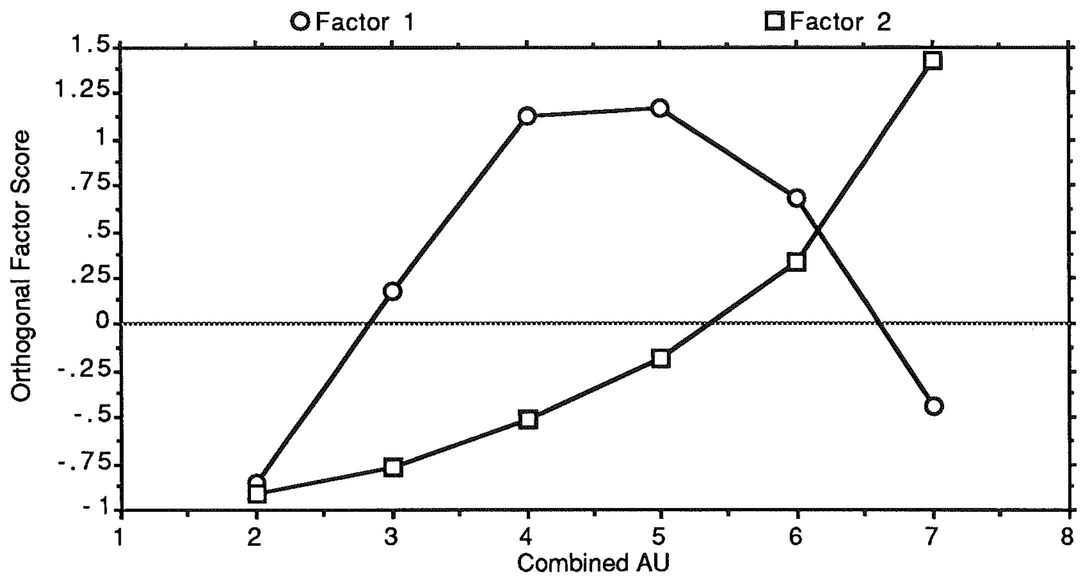

Figure 130. Factor 1 and Factor 2 Scores for assemblages from Combined Analytical Units.

<u>Comparisons between Tool Design and Paleoenvironment Change</u>

A detailed comparison (using individual AUs) between the paleoenvironmental record as measured by the ostrich eggshell $\delta^{13}C$ values and non-local raw material percentages shows that the high resolution situation is complex, but as the environment becomes drier (and presumably carrying capacity drops) hunter-gatherers use more non-local raw materials (Figure 131). This pattern is especially strong for the older portion of the record (AU10 to AU24) when I believe that population densities are low, but a response clearly occurred for the drought at 2000 B.P. in AU6 even though at this time I believe that populations have grown enough to constrict population ranges. It is possible that the increased use of agate and jasper in AU4-6 is due to increase exchange (gift-giving) as a response to greater risks and stress as environmental productivity dropped rather than significant increases in range size.

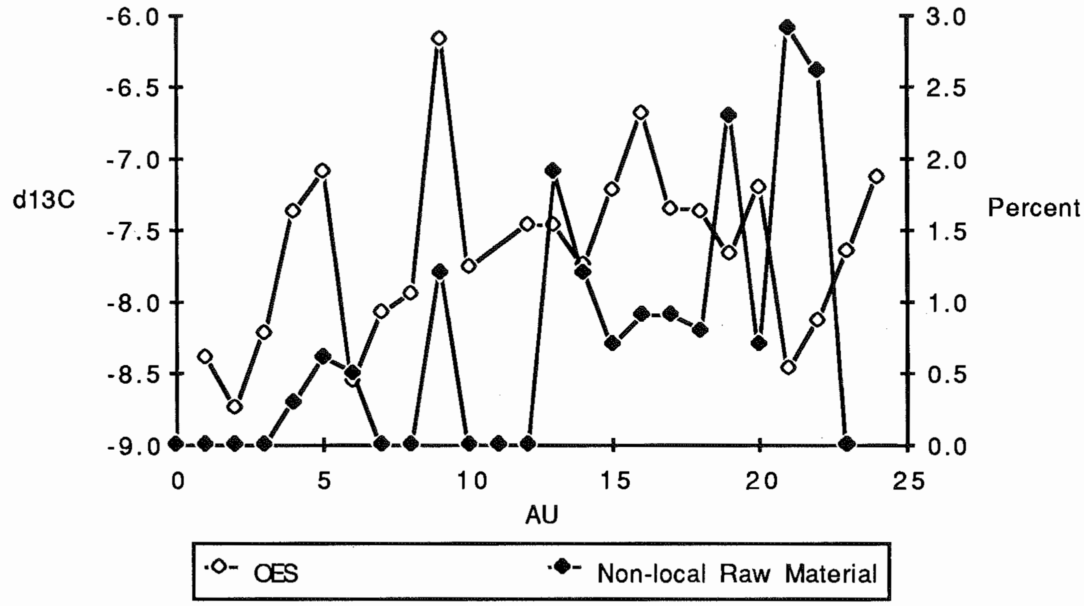

Figure 131. Ostrich eggshell stable isotope curve and agate-jasper percents for individual Analytical Units at Blydefontein Rockshelter.

A similar comparison between the ostrich eggshell stable isotope curve and endscraper lengths shows that endscrapers are short between AU24 and AU13 (the relatively large endscraper measurement in AU21 is a single specimen) (Figure 132). This is a period when population appears to be increasing, but territories are believed to be large. Between AU1 and AU13 populations are probably dense enough to constrict hunter-gatherer ranges, and it is at this point that environmental change and endscraper lengths becomes more tightly linked although there is a lag response between environmental change and endscraper lengths. In general as the environment becomes wetter and less stressful and with limited risks, endscraper lengths become longer due to less intensive use. When droughts occur, such as at 2000 B.P. in AU6, endscraper lengths drop, an indication of more intensive use and greater curation.

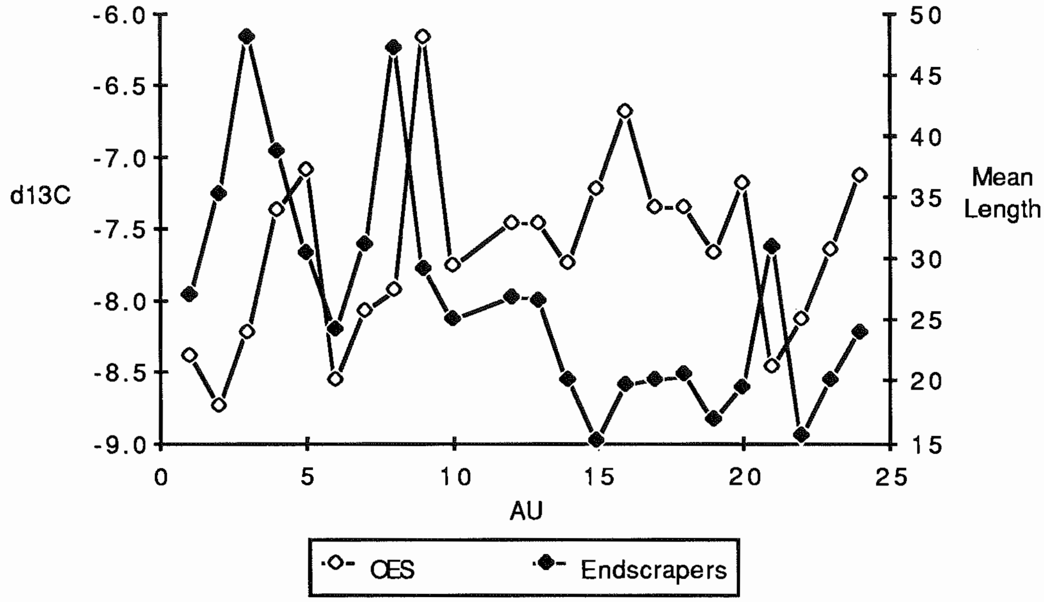

Figure 132. Ostrich eggshell stable isotope curve and endscraper mean lengths for individual Analytical Units at Blydefontein Rockshelter.

Conclusions

Clearly, not just one set of factors will control the observable patterns recognized in lithic assemblages in southern Africa. It has been argued above that population density, range size, settlement mobility, tool design strategy, variations in core reduction, and the nature and size of raw materials can influence the well known patterns recognized as characteristic of the Later Stone Age in the eastern Karoo. Stylistic changes in lithic artifacts, at least as defined by Wiessner (1983, 1984) may be particularly difficult to identify, and making assumptions that morphological variation equals stylistic variation results in incorrect conclusions. In reference to Wiessner's usage of style, it is clear that style, either assertive or emblemic, requires visual comparison, and many of the artifacts most commonly used for stylistic analysis are tools that would be obscured from view, thus making comparison impossible. However it is possible that hafts had stylistic designs (Clark 1959; H.

Deacon 1966), and it is possible that as hafts changed stylistically the manner in which stone tools were affixed also changed.

CHAPTER XIV

SUMMARY AND CONCLUSIONS

In this dissertation I undertook three objectives. The first was to reconstruct a radiocarbon-calibrated record of Holocene climate change for my research area: a small portion of the South African interior plateau. Because this semi-desert region is littered with (mainly lithic) residues of ancestral Bushmen hunter-gatherers, and because it is well known that their stone tools gradually changed shape and frequencies throughout the Holocene, my second objective was an obvious choice. I would have to explain <u>why</u> these changes occurred if I was to avoid merely describing another artifact sequence. Furthermore, I would need an ecological-adaptative model that went well beyond the limited cultural-stylistic causes already put forth to account for Later Stone Age tool design changes. While building the model, I took advantage of a variety of recent data on living hunter-gatherer ecology, and tool-making/using strategies. Having built a climate-driven model and integrated Binford's (1979) notion of hunter-gatherer managed technologies with it, my third task was to test the model. This I did by comparing trends in stone tool designs and frequencies recovered from my own excavations with the climatic/ecological changes I had already extracted from the parallel geological sequence.

Holocene Paleoecology

Blydefontein basin in the Kikvorsberg Range has a restricted outlet that created a sediment trap during the terminal Pleistocene and Holocene. Recent down cutting has exposed a long sequence of sediments that reflect changing climatic episodes. Hillwash and alluvial sediments interfingered with with humic-rich vlei deposits from which radiocarbon, pollen, and stable carbon isotope samples could be extracted. Rare pond deposits, yielding diatoms, pollens, and molluscs, intercalated with other valley fills. Several exposures were studied and correlated with the help of seventeen radiocarbon dates. The basal Older Fills, mainly dorbank deposits, were undatable, but contained isolated Late Pleistocene extinct mammal remains. The Younger Fills span most of the Holocene, and are correlated with the Blydefontein Rockshelter sequence, from which another nine radiocarbon dates were obtained. Stable carbon isotopes from ostrich eggshell in the Blydefontein Rockshelter sequence were correlated with those from the radiocarbon dated humate samples. Abundant faunal remains from the Rockshelter are still under analysis, and could not be used in the reconstruction. The last 1200 years of the archaeological record is poorly represented at Blydefontein Rockshelter, but this span is represented well at nearby Meerkat Rockshelter. Three further radiocarbon dates in this second rockshelter sequence allow a tight correlation. Better still, two finely stratified, pollen-rich hyrax dung middens are correlated with the last 1300 years of the sequence by means of five more radiocarbon dates.

This rich, composite record reveals that terminal Pleistocene conditions were colder and drier than the semi-desert, summer-rainfall, cold-winter pattern of today. The Pleistocene plant communities have no modern analog. The early Holocene saw a warming trend, but with continued dryness. Modern Karoo plant communities (as defined by my new quantified analysis) began to establish themselves, but the typical montane C_4 grasses of the area had not yet appeared. After about 6500 B.P. all pollen spectra are comparable to modern plant communities, i.e. combinations of semi-desert scrub and grasses. There was a prolonged, major drought episode between 6500-5500 B.P. that was probably drier than the current dry conditions. Thereafter conditions improve, and the C_4 grasses appeared at about 5000 B.P.

Another extended, extreme dry spell occurred between 5000-4000 B.P. This equates well with the Cango Cave speleothem temperature record that shows a 2°C drop between 5000-4300 B.P, rising rapidly to 4000 B.P. Thereafter, rainfall levels were higher than present for the rest of the late Holocene, except for several short drought episodes. Cool-dry conditions occurred around 3200 B.P.; warm-dry conditions at 2000 B.P.; and cool-dry once again at about 1300 B.P. The late Holocene period of sustained high rainfall ends in the later part of the 19th century, and the 20th century is warm-dry. Modern conditions may not be as severe as the two mid-Holocene drought episodes, but over-grazing has distorted the pollen record so that direct comparisons produce blurred results.

This record has been used to test computer simulations of regional climate changes based on orbital forcing mechanisms. Although the simulations lack the fine detail of the Blydefontein record, the overall fit is good. Thus the reconstruction conforms with current models of circulation systems, and a major regional gap in southern Africa climatic history has been filled. Although archaeological research has been conducted in the upper Karoo for 25 years, only hints have emerged of a major mid-Holocene dry spell, derived from radiocarbon dates (J. Deacon 1974) and micromammal studies (Avery 1988). That episode is now verified and fixed in the radiocarbon time scale as a two-phase event of which the second phase was apparently cool-dry. The later Holocene is also established as a relatively wet episode with oscillations, culminating in modern dry conditions. No other Karoo record is this detailed, so well calibrated at multiple points of time, nor is any other record so thoroughly cross-checked by multi-disciplinary methods. It provides an important baseline from which to judge prehistoric shifts between hunting and gathering, and the raising of domestic stock (Sampson, personal communication), it is supported by new paleoenvironmental research efforts in the area (Scott and Cooremans 1990), and it hopefully will help stimulate future paleoenvironmental research in this largely ignored region of southern Africa (Hubbard, personal communication). Of wider significance, this dissertation represents an early use of hyrax dung middens as a potent source of paleoclimatic data from the last millennium and more (Scott 1988a; Scott and Bousman 1989), and the continued analysis of hyrax dung middens will probably alter our current views of past environments dramatically.

The Model

Current models purporting to explain changes in stone tool design during the Later Stone Age use too few processes to be at all convincing. In this climate-driven model, carrying capacity and population density are prime movers. Ecological data from over a dozen hunter-gatherer ethnographies in different habitats are ordered according to each group's level of risk associated with the food quest. The axis of the model is a sliding scale of mobility options used to reduce that risk. At one end of the scale are mobility patterns that used frequent camp moves to secure enough food. These are called forager patterns. At the opposite extreme are settlement strategies in which camps are seldom moved, but long, task-specific trips are taken to secure food by smaller groups, which is often cached or stored. These are collector patterns.

Most hunter-gatherers use a mix of both patterns. The chosen balance is determined by the spacing and seasonal timing of foodstuffs in the habitat. Collectors live in habitats with clumped erratic sources; foragers operate in habitats with dispersed continuous food supplies. One crude measure of the mobility mix employed by a group is the amount of hunted food in the group's diet, versus plant foods. If the average temperature and rainfall of the group's habitat is known, the percentage of hunted foods in their diet can be statistically predicted from the ethnographic data. Armed with this figure, it becomes possible to predict the collector/forager mobility mix chosen by the group, as well as the total annual mobility of the group. Percentage of meat in the diet also makes it possible to predict the size of the group's range/territory, which in turn allows a prediction of the amount of between-band reciprocity.

The mix of collector/forager mobility choices employed by the band has a profound impact on the way its member's design their tools. Again, ethnographic data can be ranked to show that groups with strong collector patterns make a wider range (relative to forager toolmakers) of specialized, reliable tools and weapons which they keep in top condition by frequent replacement of parts. Such artifacts tend to have short use-lives but are likely to be cached. Repair kits are carried around and have longer use-lives. At the opposite extreme, foragers make fewer, more generalized tools and weapons, with longer use-lives. They are casually maintained on the move, and unfinished tools are carried around. The repair kit has no great value and is soon discarded.

The Test

The stone artifacts from Blydefontein Rockshelter were used as a first and partial test of the model. At the base of the sequence is a very small sample of Early Microlithic (cf. Robberg *sensu lato*) followed by a small Lockshoek sample. This is followed by a mid-Holocene decline in occupation. Thereafter the accumulation begins again with a dense and apparently continuous accumulation of Interior Wilton. These occupations span most phases of the originally described local sequence. Unlike many other rockshelter accumulations in the region, the terminal Later Stone Age phase (Smithfield) is poorly represented.

When the ecological components of the model are applied to Blydefontein, computations predict that the percentage of hunted food in the diet was 30-35 percent, under modern conditions. On the sliding scale of collector-forager mobility, this would place the Blydefontein occupants firmly in the class of forager-dominated mobility patterns, with 20-30 camp moves per year (one of which involved Blydefontein, itself). There would be some long, task-specific (collector) trips also, and these would occasionally include Blydefontein as well. Under modern conditions the band's range size is estimated at 600km^2 with moderate reciprocity and gift exchange between bands.

Under cold-dry terminal Pleistocene and early Holocene conditions, the Early Microlithic probably had around 40-45 percent hunted food in their diet, with fewer camp moves, more collector trips and a much larger range. The high frequency of macrofauna in the layer gives a subjective hint that these were mainly game hunters without the generalized, microfaunal component in the diet that appears later. The range would have been considerably larger than under present conditions.

Early Holocene conditions are estimated to have approached modern circumstances, so that at ca. 8500 B.P. the Lockshoek diet, mobility mix and range would be comparable to the figures given above for today.

Population decline marks the earliest Interior Wilton occupations during the mid-Holocene major drought episode. Dramatically reduced carrying capacities forced a near abandonment of the region, and the few remaining Interior Wilton groups would have used much larger ranges, greater overall mobility, possibly tethered to dependable waterholes, and a more intensive use of collected (versus hunted) foods.

After the mid-Holocene reduction in occupations, the Interior Wilton sequence dramatically increases at Blydefontein around ca. 4300 B.P. under cool-dry conditions. The model predicts increased hunted food in the diet over modern conditions, with more collector trips and fewer camp moves per year. Range size is larger than modern. Thereafter, three millennia of generally wetter conditions induce a marked population growth. During this time span, late Holocene population density becomes the prevailing force. Increased density drives down range size and reciprocity to an all time low at the end of the sequence at ca. 700 B.P. While the minor drought episodes centered on ca. 3200 B.P., 2000 B.P. and 1300 B.P. should have expanded the range size, the model predicts that there would have been relatively minor impacts on the dietary and mobility mix. Population growth dominates the minor setbacks induced by these oscillations.

Range size and reciprocity changes can be inferred from changing frequencies of agate-jasper found in the Blydefontein sequence. These came from sources at least 65km distant and are a measure of contact with remote quarters of the landscape. Agate-jasper percentage is highest in the Early Microlithic, drops to zero in the Lockshoek, starts high at the base of the Interior Wilton, and declines at ever slower rates to zero by ca. 700 B.P. This is an excellent fit with the expectations of the model, and a high resolution test with the ostrich eggshell stable carbon isotopes shows that increased use of agate-jasper occurs in association with drought episodes at ca. 2000 B.P. and 1300 B.P., but not 3200 B.P. This last drought episode was the only late Holocene dry phase that could not be demonstrated with more than one line of paleoenvironmental evidence, so its accuracy may be questioned.

Habits of composite arrowhead maintenance are a good reflection of the way hunters approach risk. The typical collector pattern is to replace whole microlithic armatures frequently to keep arrowheads in top working condition in case a suitable quarry is encountered. Typical forager patterns evince less anxiety because suitable quarry are encountered more frequently, and a few missed opportunities will not spell disaster. Armatures are repaired only when they are broken. Thus the percentage of whole microliths in the camp residues will increase in periods when quarry encounters diminish. Declines in encounters are induced by drought. In the

Blydefontein sequence, whole armatures are at record frequencies in the Early Microlithic. There are no data from the Lockshoek, presumably because microlithic armatures were not in use then. When the Interior Wilton occupies the shelter, whole armature percentages are again high, then they decrease sharply to ca. 3200 B.P. Thereafter, percentages are relatively stable until the most recent portion of the sequence, with a hint of increase at the end. Overall, this fits well with the expectations of the model, but poor dating resolution and small sample sizes do not allow me to test the potential effects of the three late Holocene droughts, although the terminal rise might be associated with one of these droughts.

Endscrapers afford bigger samples throughout the late Holocene sequence, so these should be more sensitive indicators still. Short hafted, and often trimmed endscrapers are maintenance-and-repair tools that require three different materials (handle, mastic and stone bit) to construct. They are relatively costly to produce and will not be discarded frequently. This design conforms well with the model's requirements of a typical collector's repair kit. Long unhafted endscrapers perform similar functions but could double as knives, and are more generalized tools, therefore. They cost very little to produce, are ill cared for, often break, and are quickly discarded. This fits well with the model's requirements for a typical forager's repair kit tool.

At Blydefontein, small hafted endscrapers predominate during the more stressful conditions at the start of the Interior Wilton sequence, but decline once conditions improve. Hand-held endscrapers increase rapidly in frequency after conditions improve. Also, they increase gradually in average length throughout the sequence. There is a decrease in both frequency and average size at the end of the sequence. The overall fit with the expectations of the model are good, and a high resolution comparison with the ostrich eggshell stable isotope record suggests that the predicted changes associated with the three late Holocene droughts occur as predicted as well.

Another set of tests designed around the frequency of microblade production and cortex retention failed outright, and further analysis suggested strongly that bladelet production may have been an independent technological variable, driven by mechanisms not accounted for by the model. Collectors replace arrow armatures more often than is absolutely necessary, so they should need more bladelet blanks. However, bladelet production frequencies failed to covary through time with whole microlith frequencies, so it cannot be demonstrated that bladelet production is tied to the needs of collectors. Nor can it be demonstrated that flake production (and cortex retention) increased as they switched from hafted to unhafted endscrapers. Evidently the models needs to be modified further to take into account the changing role played by informal tools (untrimmed flakes) in the overall tool-management strategy.

Throughout, these tests have been bedeviled by small sample sizes which force the collapsing of short-term units into larger ones. This has robbed the tests of the kind of chronological resolution needed to provide adequate rigor, but the overall trends revealed thus far are encouraging, to say the least. The multi-causal nature of the model's design makes it easily adaptable to other local sequences from southern Africa with good parallel climatic records. This model holds out the first real possibilities for explaining some of the subcontinent-wide trends in Later Stone Age tool design that have been observed by many researchers, but not adequately explained by them. With judicial care the general model might be used for other periods such as the Middle Paleolithic and Howiesonspoort, where significant changes in tool design strategies are evident. For example the largely untrimmed Orangian assemblages contrast sharply with the heavily retouched scrapers and points from Florisbad, and these two assemblages may represent expedient and maintainable technologies while the backed crescents in the Howiesonspoort seem to be an early production of a reliable tool. If the Howiesonspoort does represent the production of reliable technologies then the organizational abilities of Middle Stone Age groups may be more complex than Binford (1984) seems willing to accept. Further applications to Acheulian (largely maintainable) and even Oldowan (expedient) assemblages await consideration.

Blydefontein in the Prehistory of the Interior Plateau

A more sharply focussed picture of Later Stone Age hunter-gatherers in the interior plateau is beginning to emerge. This picture begins with a somewhat clouded view, but Blydefontein offers the only available glimpse of very thinly scattered groups of Early Microlithic hunter-gatherers in the late Pleistocene. They evidently ranged over large areas and exploited the larger, more mobile herd animals. These Early Microlithic groups appear to have employed collector-dominant strategies or they even may have been serial specialists [in Binford's (1979) sense] in that their own movements could have been planned around the predicted movements of migrant herds. The little artifactual data that were recovered from Blydefontein Rockshelter suggest that projectile point armatures were replaced with a before-failure strategy, and nonlocal knappable stone frequencies suggest that large territories were travelled by these groups. It is likely that bladelet technology and core transport were used to insure a regular supply of flakeable stone.

Roughly coeval pollens from the Older Fills suggest that plant communities were most similar to those of the higher Drakensberg ranges. Other coeval pollen spectra (Coetzee 1967; Scott and Cooremans 1990) hint at numerous abrupt and rapid fluctuations between Karoo scrub and grassland communities. It may emerge with more research that such fluctuations created such unstable and unpredictable habitats in much of the upper Karoo, that it was virtually abandoned by these Early Microlithic hunters. When enlarged, Blydefontein will provide the only sealed assemblage with which to compare the many reported "Driefontein" surface sites in the adjacent Zeekoe

Valley (Sampson 1985: 75). Most of these are ephemeral middle (cf. Developed) Wilton chipping stations, but some are suspected to be Early Microlithic in age.

Blydefontein has provided the first associated radiocarbon date with a Lockshoek assemblage, thus settling various long standing arguments about the nature and age of the industry. It is indeed the local expression of the Oakhurst macrolithic complex in southern Africa. At the start of the Holocene, there appears to have been a significant increase in population, assuming that most "Driefontein" sites are later than Lockshoek. Early Holocene pollens from Channel 2 suggest that conditions were wetter and possibly more stable than Early Microlithic times. This seems likely, as the adjacent Zeekoe Valley, the middle Orange River Valley, and Blydefontein basin, itself, all indicate that Lockshoek hunter-gatherers were widespread throughout the region, as well as in the type area of the western Orange Free State (Goodwin and van Riet Lowe 1929). Lockshoek territories probably were fairly small, and there may have been a dietary shift towards a more generalized diet focussing on nocturnal animals, diverse microfauna and more plants. Although Blydefontein will afford the first glimpse of the Lockshoek diet, an expanded sample is needed for a better view. The Lockshoek groups employed typical forager technology focussed on quick production of rapidly made knives and scrapers that were resharpened but not to the point of exhaustion, and soon discarded. Projectile armatures are missing, and may have been made of wood or bone. Expansion of the sample by further excavation should help determine whether or not backed microliths persist in very low frequencies in Lockshoek assemblages. The present sample is too small to settle this question, nor can chronological markers for the Lockshoek be determined yet. Note, however, that the Blydefontein sequence, along with others (Mitchell 1988) refutes Parkington's (1984) model in which the Early Microlithic and the Lockshoek are aspects of the same group's technological response to differences in the quality and size of locally available flakeable stone. They clearly are of different ages.

The mid-Holocene is poorly represented at Blydefontein Rockshelter, and three other rockshelters in the adjacent Zeekoe Valley have yielded gaps at this time (Sampson, personal communication), although details have still to be worked out. The pollen from BSM indicates a two-phase drought episode (6500-5000 B.P. and 5000-4300 B.P.), but rockshelter evidence cannot corroborate this. Nevertheless, these combined results lend strong support to J. Deacon's (1974) hypothesis for a mid-Holocene population decline. Clearly rockshelters were seldom in use, and the very thin but present mid-Holocene occupations at Blydefontein show that this is not a completely missing segment of the record. Presumably drier conditions would have stimulated more intensive use of plant foods, and lower carrying capacities would have forced hunter-gatherers to range over large areas, although probably not as large as those of Early Microlithic bands. This contrasts sharply with relatively dense rockshelter occupations dating between 7000-5000 B.P. in the Drakensberg and Winterberg Ranges east and south of the Karoo rim only 150km away from Blydefontein (Hall 1985: 1-50; Opperman 1987).

Occupation intensity of Blydefontein Rockshelter dramatically increased at ca. 4300 B.P., and comparable dates have been obtained for the first Interior Wilton occupations from two rockshelters in the adjacent Zeekoe Valley. Five other rockshelters in the valley were first occupied at about the same time (Sampson, personal communication). There can be little doubt that improving conditions stimulated population growth and possibly even influx at the start of the late Holocene. Interior Wilton site counts in the adjacent Zeekoe Valley are far in excess of Lockshoek site numbers, and there is a marked switch in settlement patterns away from spring-eye focus (Lockshoek pattern) to hillsides near springs (Interior Wilton pattern).

Conditions remained favorable except for the three brief drought episodes at ca. 3200 B.P., 2000 B.P. and 1300 B.P. Sustained high carrying capacity led to further population growth which led in turn to constriction of bands with even smaller territories. Artifact design strategies responded to these changes in range size and overall mobility. Maintenance of projectile armatures shifted from a replace-before-failure to a fix-when-broken strategy. Also, armatures changed shape and form with relative rapidity, and there may be some covariance with the short-term climatic oscillations. For instance the appearance of pressure-flaked bifacial projectile points corresponds with the 1300 B.P. drought. After this, there is a notable decline in the overall frequency of backed microlith production. Many other factors may be involved here, such as penetrations of ancestral Khoi herders into the area, and/or the introduction of arrow poison on the bone projectile point. Hafted endscrapers were gradually replaced by hand-held ones used in a wider range of tasks.

The last several hundred years of these long-term trends in tool design strategies are scarcely represented at Blydefontein Rockshelter and the sample from Meerkat Rockshelter is too small to throw much light on the terminal (Smithfield) phase of occupation. By this time hand-held endscrapers and poison-covered bone arrow points appear to have become standard equipment. Possibly population constriction prompted the kinds of social interactions that stimulated more group signals through artifact design (heavier stylistic loads). This would have involved increased production of ostrich eggshell water beads, decorated ceramics, shell pendants, engraved ostrich eggshell water containers, and other perishable items. On the other hand, many other design changes that culminated in the Smithfield can be traced back to the beginnings of the Interior Wilton, and these two entities appear to be linked in a developmental sense. Although no systematic comparison has been made yet, the differences between the coterminous phase of the Coastal Wilton and the Interior

Wilton may be equal to or greater than the differences between the later phases of the Interior Wilton and the Smithfield. Unless a chronological break between the two can be established there is no cause at present to regard the Smithfield as a separate prehistoric entity in the sense of a culture, people, or industry. No break has been established yet, although the reasons why Blydefontein Rockshelter (and Riversmead Rockshelter on the middle Orange River) were not occupied in Smithfield times remains enigmatic. For the present, the Smithfield is an historically established field label, best used to describe a terminal phase of Interior Wilton development.

APPENDIX 1

Seasonal Rainfall and Temperature Correlations

The three atmospheric circulation systems that influence the modern climate of southern Africa, also drive the local climate of the Blydefontein region. A formal proof of this is presented here in the form of two factor analyses. The data are seasonal mean temperatures from Grootfontein and seasonal rainfall from Grapevale between 1963 and 1981.

By running two factor analyses each season can be associated with its previous season. As the Southern Hemisphere, summer is December through February, December from the previous year was combined with the following year's January and February to comprise a single season summer. Also, within a single calender year spring follows winter. Thus to investigate spring-summer relationships, a previous year's spring was matched with the following year's summer, fall and winter.

Two factor analyses were run on this data set. The first factor analysis uses a seasonal progression that begins in summer and ends in spring, here called the Winter-Spring Factor Analysis (Table 35). The second factor analysis uses a seasonal progression that begins in spring and ends in winter, and this analysis is called the Spring-Summer Factor Analysis (Table 36). Both factor analyses produced three factors. It is worth noting that droughts (mid 1960s) and wet years (early 1960s and mid 1970s) are represented (see Figure 17), and thus a reasonably full range of short term climatic conditions are present in the data.

The type of factor analysis used was a Statview 512+ principal components varimax oblique rotation method so that the factors would not necessarily be independent. Three factors were identified in each run, and the factor loadings for each season's temperature and rainfall are presented in Tables 35 and 36. The factor loadings for each factor can be used to identify the variables that contribute the most to the patterns isolated by the factor analysis. If a variable's loading was 0.5 or greater, then that variable was considered a significant component of the factor. All six factors represent bipolar relationships, i.e. variables with high positive and high negative loadings. If a factor has high loadings in seasons that are not adjacent (i.e. summer and spring in Table 35, or winter and spring in Table 36), then that factor is not considered further. In the second factor analysis, Factor III has high loadings only on winter temperature and rainfall, but in the first factor analysis, Factor II indicates that winter temperature and rain, and the following spring temperatures comprise a more complete association. A full complement of factors are obtainable by using Factor I and Factor II from the Spring-Summer factor analysis (Table 35), and Factor II from the Winter-Spring factor analysis (Table 36).

There are obvious relationships between temperature and rainfall within the same season caused by the interplay between rainfall, cloud cover and temperature, but these analyses suggest that different, more complex types of interactions are in effect. Winter-Spring Factor 2 has high positive loadings for winter and spring temperatures, while winter rainfall has a high negative loading (Table 35). Temperature and rainfall are inversely related, and in this pattern as winter rains increase winter and spring temperatures decrease or vice versa. In Spring-Summer Factor I, fall temperature has high negative loadings, and summer and fall rainfall have high positive loadings. Thus as summer and fall rains increase (decrease), fall temperature decrease (increase). In Spring-Summer Factor II, spring and summer temperatures have high positive loadings, and spring rainfall has a high negative loading. Spring temperatures appear to be the most complex variable as it is controlled by two factors (Winter-Spring Factor II and Spring-Summer Factor II).

It can be argued that two summer patterns are represented by Spring-Summer Factor I and Factor II, and that Winter-Spring Factor II represents a winter pattern. Spring-Summer Factor I may be linked to increased strength of the South East Trades, and Spring-Summer Factor II might correspond to variations in convectional and thunderstorm activity. Correlations of all three factors with annual rainfall and average temperature (Table 37) show that Spring-Summer Factor I has the strongest correlation with annual rainfall, but Spring-Summer Factor II has no clear

Table 35.--The Winter-Spring Factor Analysis. Factor loadings and proportion of a individual variable's variance (communality) explained by factor analysis. Factor Analysis uses Principal Components and varimax oblique rotation. Also listed are proportion of common or explained variance for each factor, and variable complexity. Variable complexity indicates how many factors explain a variable's communality

season	Factor 1*	Factor 2	Factor 3*	Communality	Variable Complexity
summer temp.	-0.074	0.122	-<u>0.9060</u>	0.816	1.050
fall temp.	-<u>0.898</u>	-0.120	0.0004	0.848	1.036
winter temp.	-0.494	<u>0.628</u>	0.0040	0.562	1.895
spring temp.	0.091	<u>0.720</u>	-0.3930	0.707	1.584
summer rain	<u>0.789</u>	-0.310	<u>0.5790</u>	0.841	2.101
fall rain	<u>0.869</u>	-0.167	0.1970	0.729	1.180
winter rain	0.025	-<u>0.910</u>	-0.0930	0.834	1.022
spring rain	<u>0.533</u>	0.231	<u>0.6460</u>	0.674	2.209
Proportion of Common Variance	0.425	0.304	0.276		

* Factor not used because significant seasons are not adjacent.

Table 36.--The Spring-Summer Factor Analysis

season	Factor 1	Factor 2	Factor 3*	Communality	Variable Complexity
spring temp.	0.396	0.536	-0.108	0.451	1.935
summer temp.	-0.274	0.856	0.117	0.836	1.243
fall temp.	-0.825	-0.350	0.154	0.828	1.428
winter temp.	-0.377	0.189	-0.627	0.544	1.851
spring rain	-0.069	-0.805	0.206	0.682	1.146
summer rain	0.860	-0.207	0.163	0.799	1.191
fall rain	0.879	-0.014	0.209	0.802	1.113
winter rain	-0.067	0.001	0.894	0.808	1.011
Proportion of Common Variance	0.441	0.320	0.272		

* Factor not used because full temporal sequence of seasons not available.

associations. As the greatest contribution to a year's rainfall occurs during the summer and fall the strong association of annual rainfall with Spring-Summer Factor I is no surprise. It is also clear that it is the South East Trades that delivers the moisture to the interior during these seasons (Tyson 1986).

A comparison of factor scores for individual years, and sea surface temperature (SST) anomalies from the Peruvian coast provide a visual comparison between the three factors and the Walker Circulation (Table 37). High SST measurements are correlated to the Low Phase of the Walker Circulation, when reversed wind directions reduce the amount of convectional uplift over the interior. The SST measurements were gleaned directly from Barber and Chavez (1983: Figure 7), and can only be considered approximate estimates of this phenomenon. The closest correspondence of SST anomalies was to Winter-Spring Factor II scores ($r^2 = 0.273$), and it suggests that as SST temperatures increase so do Winter-Spring Factor II scores (Figure 133).

Locally this means that a shift to the Low Phase of the Walker Circulation appears to cause warmer winters with less rain which are followed by warm springs. Rasmusson and Wallace (1983) provide information which can be used to suggest that the mechanism is complex and involves the Westerlies and its semi-stationary meanders. Comparisons of the SST anomaly, and Spring-Summer Factor I and Spring-Summer Factor II scores show no associations with the SST anomaly, but it appears that other climatic elements are associated with those factors as discussed above.

Table 37.--Correlations (r^2) between factor scores and climatic variables

Factor	Annual Rainfall	Average Temperature	SST Anomaly
Winter-Spring Factor II	-0.130	0.429	0.273
Spring-Summer Factor I	0.656	-0.319	-0.079
Spring-Summer Factor II	-0.120	0.341	0.077

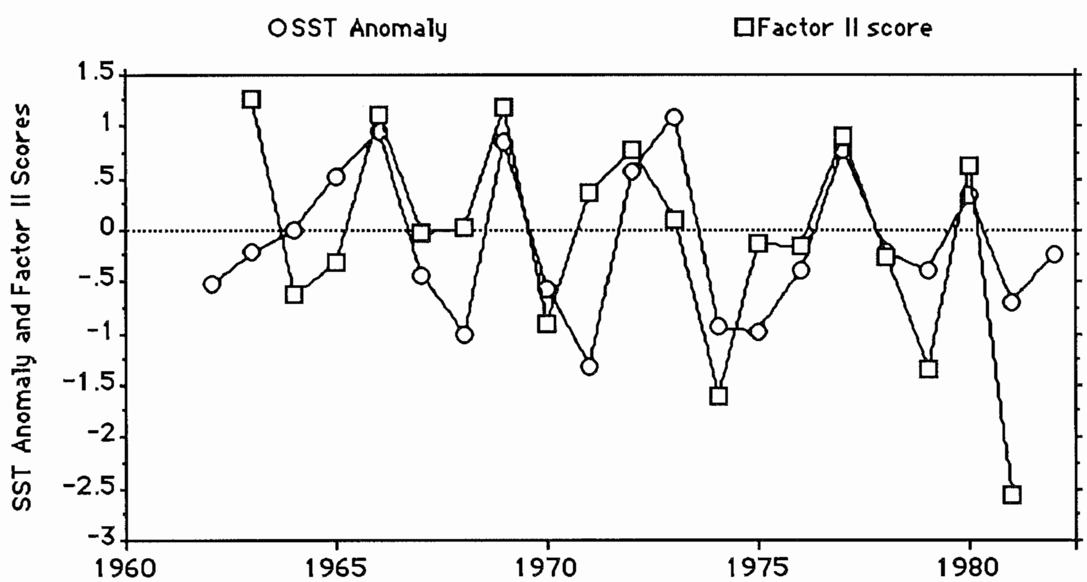

Figure 133.--Factor II scores for each year from the Winter-Spring factor analysis, and SST anomalies from Peruvian coast.

These analyses suggest that two summer systems and a winter system are in operation. The information presented on general circulation systems in Chapter III can be used to suggest that the summer system represented by Spring-Summer Factor I is linked to tropical circulation patterns and the Southeastern Trades, while the winter system is associated with the Walker Circulation. The second summer system is tentatively linked to convectional activity. Yearly fluctuations of trough and ridge positions, including the ITCZ, are clearly linked to seasonal changes in solar radiation, and changes in solar radiation, on an annual or seasonal basis, could alter the position and/or strength of the circulation systems.

APPENDIX 2

BLYDEFONTEIN ROCKSHELTER AND MEERKAT ROCKSHELTER

ARTIFACT TABLES

The tables that comprise this appendix provide the raw artifact data on which the archaeological analyses are based. The artifacts were classified by Sampson's (1974) system, and presented by Analysis Unit for each site.

Table 38.--Blydefontein Rockshelter, Block B Artifacts.

A. U.	End Scrapers	Side Scrapers	Circular Scrapers	Scraper Frag.s	Backed Bladelets	Adzes	Notches	Backed Borers	T/U Flake or Bladelet	Flake or Bladelet w/ Wear	Outils éscaillés	Cores	Core Frag.	Core Hammers
1	5	-	-	-	-	-	-	-	-	-	-	-	-	-
2	2	-	-	-	2	-	2	-	6	-	-	-	-	-
3	8	-	-	-	8	-	1	-	3	-	-	-	1	-
4	9	-	-	-	18	1	1	-	6	-	-	1	-	-
5	18	1	-	3	25	4	1	2	6	-	-	4	-	-
6	19	1	-	-	20	2	3	2	6	1	1	2	-	-
7	8	-	-	2	16	1	-	1	3	-	1	1	-	-
8	10	-	-	4	22	2	1	1	11	-	-	2	-	-
9	21	2	-	1	29	2	3	4	5	-	-	6	1	1
10	7	1	-	-	10	1	1	-	3	-	2	2	-	-
11	16	1	-	2	19	3	4	2	8	-	-	5	-	1
12	7	-	1	1	7	-	1	-	3	-	1	3	-	-
13	4	-	-	-	-	-	-	-	3	-	2	-	-	-
14	1	-	-	1	8	-	-	-	-	-	2	-	1	-
15	-	-	-	-	2	-	-	-	-	-	1	2	-	-
16	1	-	-	2	2	-	-	-	1	-	-	1	-	-
17	4	-	-	-	-	-	-	-	-	-	-	-	-	-
18	1	-	-	-	1	-	-	-	-	-	-	-	-	-
19	-	-	-	1	-	-	-	-	-	-	-	1	-	-
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	1	1	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	141	6	1	17	195	17	18	12	64	1	10	30	3	2

Table 38.—Continued.

A. U.	Burins	Grind-Stones	Reamer	Palattes	Ceramics	Bone Points	Other Worked Bone	Ostrich Eggshell Beads	Ochre	Whole Lithic Debitage	Total
1	-	-	-	-	7	-	-	-	-	108	121
2	-	1	-	-	10	1	1	1	-	323	349
3	-	1	-	-	6	1	-	1	-	439	469
4	-	-	-	2	2	-	1	4	-	491	536
5	-	-	-	-	-	-	1	3	-	615	683
6	1	-	-	-	-	-	-	-	-	500	558
7	-	-	-	-	-	-	1	-	-	466	500
8	-	-	-	-	-	2	1	-	-	545	601
9	-	2	-	-	-	1	-	-	-	521	599
10	-	-	-	-	-	-	1	-	1	291	320
11	-	-	1	-	-	-	-	-	1	420	483
12	-	1	-	-	-	-	-	-	-	302	327
13	-	-	-	-	-	-	-	-	-	21	30
14	-	-	-	-	-	-	-	-	-	117	130
15	-	-	-	1	-	-	-	-	-	99	105
16	-	-	-	-	-	-	-	-	-	32	39
17	-	-	-	-	-	-	-	-	-	24	28
18	-	1	-	-	-	-	-	-	-	42	45
19	-	1	-	-	-	-	-	-	-	14	17
20	-	-	-	-	-	-	-	-	-	8	8
21	-	-	-	-	-	-	-	-	-	9	11
22	-	-	-	-	-	-	-	-	-	10	10
Total	1	7	1	3	25	5	6	9	2	5397	5969

Table 39.--Blydefontein Rockshelter, Blocks C-D Artifacts.

A. U.	End Scrapers	Side Scrapers	Transverse Scrapers	Scraper Frag.s	Backed Bladelets	Adzes	Notches	Backed Borers	T/U Flake or Bladelet	Flake or Bladelet w/ Wear	Outils éscaillés	Cores	Core Frag.	Core Hammers
1	3	-	-	1	1	-	-	-	3	-	-	-	-	-
2	8	3	-	-	-	-	1	-	4	-	-	-	-	-
3	1	-	-	-	1	-	1	-	-	-	-	-	1	-
4	7	-	-	2	2	-	1	-	5	-	-	-	-	-
5	3	1	-	-	-	-	-	1	-	-	-	-	-	-
6	7	-	-	3	6	-	4	1	4	-	-	-	-	-
7	6	1	-	-	6	-	2	1	6	1	-	-	-	-
8	3	1	-	3	8	-	2	1	14	-	-	1	-	-
9	14	1	-	3	11	-	1	-	1	-	-	1	1	-
10	4	-	-	1	7	-	1	-	2	-	-	2	-	-
11	-	-	-	-	2	-	-	-	1	-	-	-	-	-
12	4	-	-	1	4	-	-	-	1	-	-	-	-	-
13	6	1	-	-	1	-	-	-	1	-	-	-	-	-
14	9	1	-	1	12	3	-	-	7	-	1	12	1	-
15	8	1	-	2	5	3	1	1	5	-	-	4	-	-
16	11	4	-	1	5	2	1	-	2	-	-	1	-	-
17	17	1	-	4	5	2	2	1	1	-	-	4	-	-
18	10	-	1	3	8	1	2	1	2	-	-	1	-	-
19	5	-	1	-	4	1	-	-	1	-	-	2	-	-
20	8	1	-	2	2	2	2	-	4	-	-	2	-	1
21	2	1	-	1	6	-	-	1	2	-	-	2	-	-
22	3	-	-	-	1	-	-	1	3	-	-	-	-	-
23	1	-	-	1	2	-	-	-	-	-	-	-	-	-
24	1	-	-	-	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	1	-	-	-	1	-	-	-	1	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	-	-	-	1	-	-	-	-	-	-	-	-	-	-

Table 39.—Continued.

A. U.	End Scrapers	Side Scrapers	Transverse Scrapers	Scraper Frag.s	Backed Bladelets	Adzes	Notches	Borers	T/U Flake or Bladelet	Flake or Bladelet w/ Wear	Outils éscaillés	Cores	Core Frag.	Core Hammers
30	-	-	1	-	-	-	-	-	-	-	-	1	-	-
31	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	-	-	1	-	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	1	-	-	-	-	-	-	-
34	1	-	-	1	-	-	-	-	1	-	-	2	-	-
35	-	-	-	-	1	-	-	-	-	-	-	1	-	-
36	-	-	-	1	-	-	-	-	-	-	-	-	-	-
37	-	-	-	-	-	-	-	-	-	-	-	1	-	-
38	-	-	-	-	-	-	3	-	2	-	-	2	-	-
Total	143	17	4	32	101	14	25	9	73	1	1	39	3	1

Table 39.—Continued.

A. U.	Bifacial Points	Grind-Stones	Painted Rock	Palattes	Ceramics	Bone Points	Other Worked Bone	Ostrich Eggshell Beads	Ochre	Whole Lithic Debitage	Total
1	-	-	-	-	5	-	-	-	-	169	182
2	-	-	-	-	14	-	1	2	-	251	284
3	1	-	-	-	1	-	-	-	-	59	65
4	-	-	-	-	4	-	-	3	-	302	326
5	1	3	-	-	-	1	3	2	-	155	170
6	-	1	-	-	1	-	1	2	2	434	466
7	-	-	-	-	1	-	-	1	-	198	223
8	-	2	-	-	1	-	-	1	-	290	328
9	-	-	-	-	-	-	-	2	-	334	368
10	-	1	-	-	-	-	1	1	-	215	235
11	-	-	1	-	-	-	-	2	-	69	75
12	-	-	-	-	-	-	-	-	-	69	79
13	-	-	-	-	-	-	-	-	-	103	112
14	-	3	-	-	-	-	1	1	-	430	482
15	-	3	-	-	-	-	-	-	1	280	314
16	-	2	-	-	-	-	-	-	-	233	262
17	-	-	-	-	-	1	-	-	-	220	259
18	-	-	-	-	-	-	-	-	-	241	270
19	-	1	-	1	-	-	-	-	-	133	148
20	-	-	-	-	-	-	-	1	-	151	176
21	-	-	-	-	-	-	1	-	-	105	121
22	-	-	-	-	-	-	-	-	-	77	85
23	-	1	-	-	-	-	1	-	-	21	27
24	-	-	-	-	-	-	-	-	-	9	10
25	-	-	-	-	-	-	-	-	-	1	1
26	-	-	-	-	-	-	-	-	-	23	26
27	-	-	-	-	-	-	-	-	-	6	6
28	-	-	-	-	-	-	-	-	-	11	11
29	-	-	-	-	-	-	-	-	-	19	21

Table 39.—Continued.

A. U.	Bifacial Points	Grind-Stones	Painted Rock	Palattes	Ceramics	Bone Points	Other Worked Bone	Ostrich Eggshell Beads	Ochre	Whole Lithic Debitage	Total
30	-	-	-	-	-	-	-	-	-	31	32
31	-	-	-	-	-	-	-	-	-	13	14
32	-	-	-	-	-	-	-	-	-	10	10
33	-	-	-	-	-	-	-	-	-	5	6
34	-	1	-	-	-	-	-	-	-	16	22
35	-	-	-	-	-	-	-	-	-	18	20
36	-	-	-	-	-	-	-	-	-	9	10
37	-	-	-	-	-	-	-	-	-	21	22
38	-	-	-	-	-	-	-	-	-	14	21
Total	2	18	1	1	27	2	9	18	3	4745	5289

Table 40.--Meerkat Rockshelter Artifacts.

A. U.	End Scrapers	Side Scrapers	Scraper Frag.s	Pressure Flaked Points	Backed Bladelets	Adzes	Notches	Borers	Trimmed Flake or Bladelet	Flake or Bladelet w/ Wear	Outils éscaillés	Cores
1	1	-	-	-	-	-	-	-	-	-	-	-
2	3	-	-	-	-	-	1	-	-	-	-	-
3	6	-	-	-	-	-	1	1	1	-	-	2
4	2	-	-	-	-	-	-	-	-	-	-	-
5	8	-	-	-	-	-	-	1	3	1	-	-
6	4	-	-	-	-	-	-	1	1	-	-	-
7	2	-	1	-	-	1	-	-	2	-	-	-
8	8	-	1	-	-	-	-	-	2	1	-	-
9	3	-	1	-	-	-	1	1	1	1	-	-
1 -	8	1	1	1	-	1	-	-	-	1	-	2
11	-	-	1	1	2	1	-	1	2	-	-	1
12	4	-	1	-	7	1	1	-	3	-	1	1
13	4	-	1	-	4	2	-	-	-	1	-	1
14	1	-	1	-	-	-	-	-	-	-	-	-
15	6	-	-	-	3	1	-	-	-	-	-	1
16	-	-	-	-	3	-	-	-	2	-	-	1
17	2	1	-	-	3	-	-	-	2	1	-	-
18	-	-	-	-	1	-	-	-	-	-	-	-
Total	62	2	8	2	23	7	4	5	19	6	1	9

Table 40.—Continued.

A. U.	Grind-Stones	Palattes	Ceramics	Bone Points	Other Worked Bone	Bone Beads	Ostrich Eggshell Beads	Mussel Shell Pendant	Whole Lithic Debitage	Total
1	-	-	1	3	-	-	3	-	55	63
2	1	1	3	1	2	-	-	-	101	113
3	2	-	5	-	2	-	3	-	124	147
4	-	-	5	1	1	-	-	-	56	65
5	1	-	5	-	1	1	33	1	174	229
6	2	-	7	-	1	-	28	-	85	129
7	-	-	4	-	-	-	2	-	62	74
8	-	1	8	1	-	-	11	-	199	232
9	1	-	1	-	1	-	2	-	89	102
10	2	-	3	2	1	-	4	-	154	181
11	1	-	3	-	-	-	2	-	85	100
12	2	-	3	2	2	-	2	-	211	241
13	7	-	-	-	-	-	2	-	123	145
14	-	-	-	-	-	-	-	-	22	24
15	1	-	-	-	3	-	1	-	166	182
16	-	-	-	1	2	-	-	-	79	88
17	-	-	-	-	-	-	1	-	66	76
18	-	-	-	-	-	-	-	-	35	36
Total	20	2	48	11	16	1	94	1	1886	2227

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