Late Quaternary environmental phases in the Eastern Cape and adjacent Plettenberg Bay-Knysna region and Little Karoo, South Africa

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ABSTRACT

Four major climato-environmental phases have been identified in the Eastern Cape, Plettenberg Bay-Knysna region and Little Karoo between somewhat before ~ 40 000 cal. a BP and the present: the *Birnam Interstadial* from before 40 000 cal. a BP until ~ 24 000 cal. a BP; the *Bottelnek Stadial* (apparently equating with the Last Glacial Maximum) from ~24 000 cal. a BP until before ~ 18 350 cal. a BP; the *Aliwal North* (apparently equating with the Late Glacial) from before ~ 18 350 cal. a BP until ~ 11 000 cal. a BP; the *Dinorben* (apparently equating with the Holocene) from ~ 11 000 cal. a BP until the present. The evidence for, and the characteristics of, these phases is briefly described.

Key words
Palaeoclimate. Southern Africa. Late Quaternary. Last Glacial Maximum. Late Glacial. Holocene.

1. Introduction

1.1. Purpose of this paper and use of proxy data

The purpose of this paper is to summarise the evidence for, and describe the characteristics of, the major climato-environmental phases that have occurred in the Eastern Cape and adjacent Plettenberg Bay-Knysna region and Little Karoo during the last ~ 40 000 a (Fig. 1). The age of these phases has been established mainly by radiocarbon dating. Events predating ~ 40 000 cal. a BP are effectively beyond the range of radiocarbon dating and are not considered in this paper. Explanation of the causes of climato-environmental phases, such as times of reduced obliquity (Chase and Meadows, 2007), are not discussed. The paper provides detailed information on climatic conditions, especially in the Southern (Eastern Cape) Drakensberg, during what appears to have been the Last Glacial Maximum (LGM), complementing and extending previous reviews of LGM conditions in southern Africa (Partridge et al., 1990, 1999) and extending the review of Lewis (2008a). Information from the Orange River Scheme, which is located within the Eastern Cape, (Sampson, 1967, 1968, 1970, 1972, 1974, 1988; Sampson and Sampson, 1967) has been excluded from the present study since that area is typical of the Highveld and Great Karoo, unlike the remainder of the study area.

Proxy data, much of which has been outlined in Deacon and Lancaster (1988), has been widely used in southern Africa to ascertain former climato-environmental conditions. Similar studies have been undertaken in many other parts of the globe, as indicated in many standard Quaternary environmental texts (e.g. Lowe and Walker, 1997; Williams et al., 1993; and Jones and Keen, 1993). Speleothems, that contain climatic signatures, have been analysed from the Cango Caves in Western Cape Province (Talma and Vogel, 1992), from Makapansgat in north-eastern South Africa (Holmgren et al., 1999), and from other areas in southern Africa (e.g. Holmgren et al., 1995). Palynological analyses, indicating former vegetation and hence suggesting former climatic conditions, were pioneered in southern Africa by Martin (1959) and by van Zinderen Bakker (e.g.1962) and are now commonplace (e.g. Scott, 1999). The isotopic composition of ground water, indicating former recharge temperatures, has been studied in the Eastern Cape (Heaton et al., 1986). Analyses of micro- and larger mammals, indicating conditions under which those creatures lived at various times in the past, has been pioneered in the Western and adjoining Eastern Cape (e.g. Avery, 1982; Klein, 1972,1978, 1980). Molluscan remains in coastal and archaeological contexts have also been examined and shed light on former environmental conditions, as exemplified by the work of Voigt (1982) at Klasies River Mouth. Many other techniques have been used, as in classic studies of sediments in the Pretoria salt pan crater (e.g. Partridge et al., 1993), to indicate, using proxy data, former environmental conditions. The present paper uses archaeological, geomorphological, isotopic, palynological and other proxy evidence to indicate climato-environmental changes during the last ~ 40 000 cal. a BP in the Eastern Cape and in the adjoining southern Cape coastlands and Little Karoo. In so doing, four distinct palaeo-climato-environmental time phases have been identified, as described and discussed in the remainder of this paper.

1.2.Present day climatic systems

The study area is influenced at present by two major climatic systems. The Indian Ocean Monsoon extends westwards in summer, bringing rainfall to eastern areas of the Eastern Cape. By contrast, western areas lie near the fringes of the South Atlantic anticyclonic gyre, which extends eastwards in winter, bringing enhanced precipitation to those areas (Preston-Whyte and Tyson, 1988; Meadows and Baxter, 1999). Between eastern and western (summer and winter rainfall) regions lies an area of year-round precipitation, centred on the Knysna region (Carr et al., 2006).

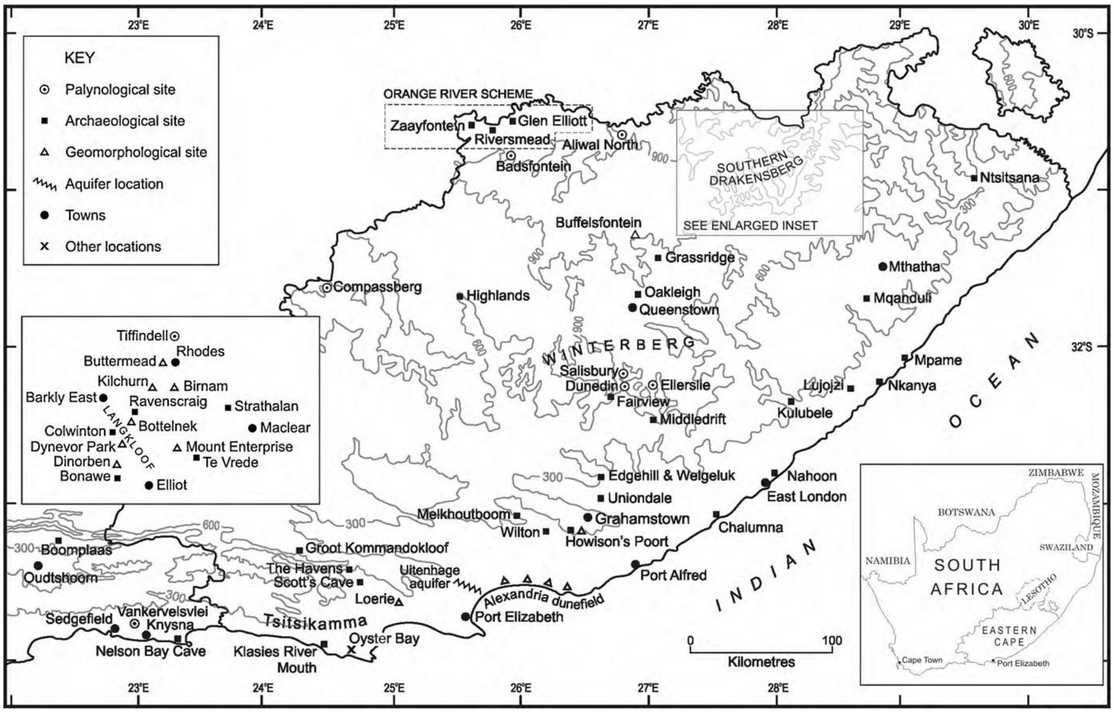

Fig. 1. The distribution and nature of radiocarbon and luminescence dated sites relevant to environmental phases during the last ~ 40 000 years in the Eastern Cape, Plettenberg Bay/Knysna area, and Little Karoo. Altitudes are indicated by generalised form lines at 300 m intervals. Latitudes and longitudes are shown along the margins of the Figure. (Based on Lewis, 2008a, with additions).

1.3. Absolute dating and other evidence

Martin (1959) provided the first radiocarbon dates from the study area. By the end of 2005 at least 113 relevant dates, calibrated using the Southern Hemisphere Atmospheric Calibration Curve of the Pretoria program (Talma and Vogel, 1993; updated 2000), from 53 different sites in the area, had been published (Lewis, 2002, 2008a). The radiocarbon dates in the present paper are calibrated dates from Lewis (2008a), except where stated otherwise. In order to aid the establishment of consistency when referring to ages (Rose, 2007), these calibrated radiocarbon dates are shown as cal. a BP. Radiocarbon dates that have not been calibrated are shown in this paper as 14C a BP. ‘a’ represents ‘years’ regardless of whether or not calibration has been undertaken. A few relevant optically stimulated thermoluminescence (OSL) dates have also been obtained, from sand deposits in the Buffelsfontein area, and are discussed in section 2.2.3.1. OSL dates have also been obtained from a shell midden near Sedgefield (section 2.4.4). OSL dates are expressed in this paper in ka, in conformity with the decision of the IUPAC-IUGS Task Group, 2006-016-1-200. In association with groundwater, sediments, landforms and artefacts, the overall dates evidence climatic and consequent environmental oscillations from the interstadial that began prior to 40 000 cal. a BP, through the stadial conditions of the LGM, followed by the Late Glacial and, finally, the Holocene. Appreciable climatic and environmental changes are hinted at during all of those phases. Furthermore, some areas experienced markedly different environmental conditions to others, even at the same time.

2. The major climatic and associated environmental phases

The main climatic phases are listed, with their type-sites, which provide lithostratigraphic and chronostratigraphic units, on Table 1. The *Bottelnek Stadial* appears to equate with the LGM, Chronozone Level 2, of Mix *et al*., (2001). None of these lithostratigraphic and chronostratigraphic units has yet been forwarded for formal accreditation.

Table 1.
The main climato-environmental phases in the Eastern Cape and Little Karoo during the past ~ 40 000 cal. a BP[1]

Name of phase	Type site	Probable age in cal. a BP	MIS[2]
Dinorben	Section I, Dinorben Spruit valley (Lewis, 2005)	~ 11 000 to present	1
Aliwal North	Core II, Aliwal North (Coetzee, 1967)	~18 350 to ~ 11 000	2
Bottelnek Stadial	In Bottelnek valley (Lewis and Hanvey, 1993; Lewis, 2008a)	~ 24 000 to ~ 18 350	2
Birnam Interstadial	Birnam, in Bokspruit valley (Hanvey and Lewis, 1990; Lewis, 2008a)	Before 40 000 until ~ 24 000	3

[1] Time units in this paper are stated as recommended by Rose (2007).
[2] The Marine Isotope Stages (MIS) are based on ages as given in Lambeck et al., 2002.
Note: the dates given under the column for 'Probable age' are those of the phase and not necessarily those of the type-site. The probable age for the Bottelnek Stadial, for example, is based on the age of an organic lens in what appear to be the basal sediments in rock glacier deposits in Bottelnek (~ 24 000 cal. a BP), and on the age of the lowest hearth at Melkhoutboom (~ 18 350 cal. a BP), as discussed in the text.

2.1. The Birnam Interstadial

2.1.1. Location of the evidence

The Birnam Interstadial is evidenced by organic lenses in what appear to be lacustrine (possibly ox-bow lake) deposits at Birnam, in the Bokspruit valley, near Barkly East (Fig. 2) (Hanvey and Lewis, 1990; Lewis and Hanvey, 1993; Lewis 2008a); by insect remains at Dynevor Park in the Barkly East area (Lewis and Hanvey, 1993; Lewis and Dardis, 1985; Lewis, 2002, 2005, 2008a,b); by archaeological remains (including bone, plant and pollen material) at Strathalan, near Maclear (Opperman and Heydenrych, 1990; Opperman, 1996; Lewis 2008a,b,c), at Grassridge (Opperman, 1987), Highlands (Deacon, 1976), Howison's Poort (Deacon, 1995; Lewis 2008c), Klasies River Mouth (Singer and Wymer, 1982; Klein, 1976; Voigt, 1982; Deacon, 1995), Nelson Bay Cave (Inskeep, 1965, 1987; Klein, 1971; Butzer, 1973; Fairhall and Young, 1973; Sealy, 1996) and Boomplaas (Deacon et al., 1984; Deacon and Brooker, 1976); by micromammalian and other mammalian remains at Boomplaas (Avery, 1982; Klein, 1978); and by organic matter at Vankervelsvlei (Irving and Meadows, 1997; Irving, 1998).

2.1.2. Length of the Birnam Interstadial

The Birnam Interstadial extended from before ~ 43 000 cal. a BP (the earliest dated evidence for Middle Stone Age (MSA) occupation in the study area, at Grassridge (Opperman, 1987; Lewis, 2008a), which provides a minimum age for the beginning of the Birnam Interstadial), until ~24 000 cal. a BP. By the latter date MSA foragers had abandoned Strathalan, in the Southern (Eastern Cape) Drakensberg (Opperman and Heydenrych, 1990; Lewis, 2008a, c), and a rock glacier in Bottelnek, near Barkly East (if the interpretation of sediments and landforms by Lewis and Hanvey (1993) is correct) overlay organic deposits dating to 23 982 cal. a BP (Lewis, 2005).

2.1.3. Environmental conditions during the Birnam Interstadial

In the Eastern Cape and Little Karoo conditions were apparently cool and moist, but there were appreciable environmental differences between the uplands of the Southern (Eastern Cape) Drakensberg, the coastal lowlands, and the Little Karoo. No evidence has been published of conditions in the area between Howison's Poort (Deacon, 1995; Lewis, 2008a, c), near Grahamstown and the inner edge of the present day coastal lowlands, and the foothills of the Southern (Eastern Cape) Drakensberg north of Queenstown (Fig. 1).

2.1.3.1. Environmental conditions in the Southern (Eastern Cape) Drakensberg during the Birnam Interstadial

Runoff (and hence precipitation) was enough for lakes to form in at least one valley in the Southern (Eastern Cape) Drakensberg: at Birnam in Bokspruit. At Birnam a lake apparently existed at ~ 41 500 cal. a BP, although the sedimentology of the site suggests that it was replaced by flowing water, with another lake existing at ~ 38 000 cal. a BP, and yet another at ~ 29 000 cal. a BP. These may have been successive ox-bow lakes (Fig. 2) (Hanvey and Lewis, 1990, with the addition of two previously unpublished dates).

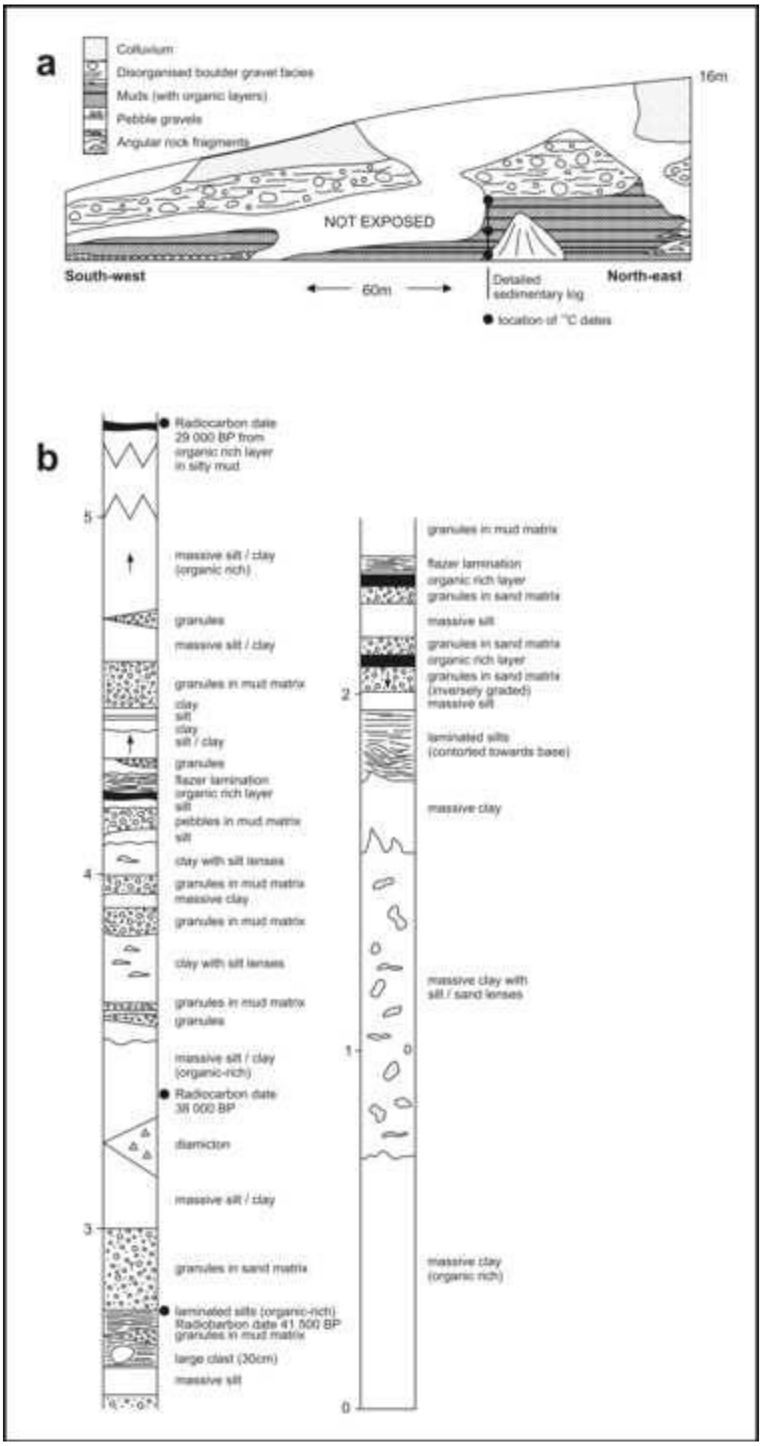

Fig. 2. The stratigraphic arrangement of unconsolidated deposits at Birnam, in the Bokspruit valley (A), and a sedimentary log indicating the detail of the silty mud sediment unit (B) and the calibrated radiocarbon ages BP of organic-rich units within the generally silty mud unit. (Based on Hanvey and Lewis, 1990, with the addition of two previously unpublished radiocarbon dates (Pta- 5263, 41 464 cal. a BP; Pta- 5246, 29 127 cal. a BP).

Floods occurred in some valleys, as evidenced by palaeosols sandwiched between overbank flood deposits at Buttermead, near Rhodes in the Bell River valley (Lewis, 2008a), one of which dates to ~ 40 000 cal. a BP (Lewis, 1999). Fluvial sands and gravels underlie head at Dynevor Park in the Langkloof (Lewis and Dardis, 1985; Lewis, 2008b). Insect remains dated to ~ 37 000 cal. a BP underlie head at that site (Lewis and Hanvey, 1993; Lewis, 1999, 2002, 2005, 2008a, b) but their relationship to the adjacent fluvial deposits, which terminate ~ 11 m above the modern stream bed, has not been established: the fluvial deposits may be older or younger than the insect remains, which were too fragmentary to identify to species level. Nevertheless, the fluvial deposits, including some clasts deposited with their long axes aligned vertically, witness powerful stream flow in the Langkloof (possibly during floods) and infilling of the valley floor to form a flood plain at least 11 m above the bed of the present stream.

Foragers (i.e. hunter-gatherers), of MSA culture, occupied at least part of the Southern (Eastern Cape) Drakensberg, as evidenced by archaeological remains dating to between ~ 34 000 cal. a BP and ~ 24 000 cal. a BP at Strathalan (Opperman and Heydenrych, 1990; Opperman, 1996). That site is at an altitude of ~ 1300 m. The foragers ate plant food derived from *Watsonias,* as well as meat obtained from predominantly grazing animals (including blesbuck (*Damaliscus dorcas*), eland (*Taurotragus oryx*) and wildebeest (*Connochaetes gnou*), that probably migrated through the area seasonally. Palynological evidence (Hill, in Opperman and Heydenrych, 1990) shows that grassland was prominent in the Strathalan area at that time. The reduction in floral and faunal remains found on living floors dating to between ~ 26 000 cal. a BP and ~ 25 000 to 24 000 cal. a BP, compared with remains on older living floors (Lewis, 2008a) suggests that climatic conditions became colder towards the end of the Birnam Interstadial. However, there could have been other reasons for the reduction in remains, such as foragers then occupying the site less frequently, and/or for shorter periods, than previously. Strathalan was abandoned at an unknown date between ~ 25 000 cal. a BP and ~ 24 000 cal. a BP (Lewis, 2008c) and the Birnam Interstadial appears to have terminated by the latter date.

A number of archaeological sites have been excavated in the foothills of the Southern (Eastern Cape) Drakensberg, as at Grassridge (Opperman, 1987) and Highlands (Deacon, 1976). People of MSA culture occupied both sites, at least occasionally. The oldest dated occupation, at Grassridge (Opperman, 1987; Lewis, 2008a), took place by 42 913 cal. a BP and provides a minimum age for the beginning of the Birnam Interstadial (Lewis, 2008a).The foothills may have been essentially grassland areas, inhabited at least seasonally by predominantly grazing animals and their associates. More research is needed to verify whether that was, in fact, the case.

2.1.3.2. Environmental conditions in present day coastal areas during the Birnam Interstadial

In a present day coastal area, at Klasies River Mouth (KRM) in the Tsitsikamma region, MSA foragers introduced faunal remains including eland (*Taurotragus oryx*), the now extinct giant buffalo (*Pelorovis antiquus*), and grysbok (*Raphicerus melanotis*) (Klein, 1976) to the occupation site. They indicate that the surrounding area was probably vegetated with thick scrubby bush between ~ 36 000 cal. a BP and ~ 22 000 cal. a BP (Lewis, 2008a). The natural climax vegetation of the area at present is Afro-montane forest (Low and Rebelo, 1996), which requires more rainfall than scrubby bush. This suggests that rainfall was less in the Tsitsikamma area, during at least that part of the Birnam Interstadial, than at present.

The remains of marine foods introduced to the sites at KRM by humans: shellfish (Voigt, 1982), fish, seals and penguins (Deacon, 1995), may indicate that sea levels were not markedly below those of the present during the Birnam Interstadial, although, based on global findings as summarised by Waelbroeck et al (2002): (that sea levels during that Interstadial were ~ 74-106 m below those of the present); that is unlikely. Deacon has drawn attention to the steep nature of the coast at KRM and has suggested that even relatively low sea levels were unlikely to cause the shoreline to move more than ~ 10 km from the site, which is within forager range of the archaeological site at KRM. The 25 m isobath lies only ~ 2 km offshore, the 50 m isobath ~ 7 km offshore, and the 100 m isobath ~ 16 km offshore (SAN124). Birnam Interstadial sea levels, as indicated by deposits at KRM, thus remain in doubt.

Organic remains exist at Vankervelsvlei (VKV), in the coastal region near Sedgefield in that portion of the Western Cape that is near the political boundary of the Province of the Eastern Cape, some 70 km west of the Tsitsikamma. They indicate that appreciable forest cover existed in that area between ~ 40 000 cal. a BP and ~ 35 000 cal. a BP, succeeded prior to ~ 23 000 cal. a BP by vegetation indicative of drier conditions (Irving, 1998). The Birnam Interstadial in the Sedgefield region therefore seems to have been characterised by a moister climate and more forested environment prior to ~35 000 cal. a BP than after that date. Whether climatic and environmental conditions were the same temporally in the Sedgefield area as in Tsitsikamma is unknown, since there is a time difference between the dated evidence at KRM and at VKV.

Nelson Bay Cave (NBC), near Plettenberg Bay, was occupied, at least occasionally, by people of MSA culture during the Birnam Interstadial (Butzer, 1973) and MSA artefacts at that site have been dated to as far back as ~ 26 000 cal. a BP (Fairhall and Young, 1973). Although Butzer (1973) has suggested environmental conditions during the Birnam Interstadial at NBC, based on sedimentary analyses, faunal and other investigations are necessary to confirm (or otherwise) his suggestions. Mammalian remains investigated from NBC date to younger than ~ 22 000 cal. a BP (Klein, 1972; Sealy, 1996) and hence fall outside the time limits of the Birnam Interstadial which, as stated in section 2.1.2, terminated before ~ 24 000 cal. a BP.

On the inland margin of the present day coastal lowlands, a rock shelter at Howison's Poort, near Grahamstown, appears to have been occupied, at least occasionally, between ~ 23 000 cal. a BP and ~ 10 500 cal. a BP (Lewis, 2008c). Previous claims for earlier utilisation of the shelter (Deacon, 1995) are not supported by calibration of the existing radiocarbon dates (Lewis, 2008a) or by study of fluvial sediments and intercalated palaeosols on the floor of the Howison's Poort valley (Lewis and Illgner, 1998). There is therefore no published information from this site that definitely relates to the Birnam Interstadial.

Apart from KRM, NBC and VKV, no other sites in present day coastal areas of the Eastern and adjoining Western Cape, dating to the Birnam Interstadial, have been discovered and investigated.

2.1.3.3. Environmental conditions in the area between the present day coastal lowlands and the foothills of the Southern (Eastern Cape) Drakensberg during the Birnam Interstadial

Nothing is known of this vast area during the Birnam Interstadial.

2.1.3.4. Environmental conditions in the Little Karoo during the Birnam Interstadial

In the Little Karoo, at an altitude of ~ 800 m at Boomplaas, inland of Oudtshoorn (Deacon et al, 1984; Figure 1), MSA artefacts exist below a stratigraphic discontinuity that dates to between ~ 24 000 cal. a BP and ~ 17 000 cal. a BP (Lewis, 2008a). They indicate that foragers inhabited the Little Karoo during the Birnam Interstadial. Micromammalian remains at Boomplaas indicate that after ~ 38 000 cal. a BP and before ~ 24 000 cal. a BP there was ‘fairly extensive dense vegetation on [the] valley floor’, with a ‘grassy’ element on hillsides, as well as some semi-arid vegetation (Avery, 1982, 315). Examination of the remains of larger mammals (of the hartebeest tribe (Alcelaphini), grey rhebuck (*Pelea capreolus*) and grysbok species (*Raphicerus* spp.); Klein, 1978), dating to before ~ 24 000 cal. a BP, shows that there was a ‘significant browse component in the vegetation’ (Deacon et al., 1984, 342) prior to that date and that the vegetation ‘was broadly comparable to the historic one’ (Klein, 1978, 68).

By ~ 24 000 cal. a BP micromammalian evidence indicates that harsh cold conditions were replacing those of the interstadial (Avery, 1982), while remains of Equidae indicate that drier conditions, with grasslands, had replaced lusher interstadial vegetation in the Little Karoo by that date (Deacon et al., 1984). Deacon et al. (1984, 347) suggest that, when MSA foragers utilised Boomplaas between at least ~ 38 000 cal. a BP and ~ 24 000 cal. a BP, the habitat was ‘relatively productive’.

2.1.4. Summary, environmental conditions during the Birnam Interstadial

The Birnam Interstadial appears to have been relatively mild and moist, but was probably drier and cooler than the present. There were occasional floods, at least in valleys in the Southern (Eastern Cape) Drakensberg. They may have occurred under various climatic conditions. Regional variations in climate and environments occurred. They were related to locational variations in longitude, as outlined in section 1.1, which influenced the extent to which the area concerned came under the influence of the South Atlantic anticyclonic gyre, and hence the winter rainfall zone (Meadows and Baxter, 1999; Chase and Meadows, 2007), or the Indian Ocean Monsoon and hence the summer rainfall zone (Lewis, 2005), or the intervening year-round rainfall zone (Carr et al., 2006). Altitudinal variations in location were reflected in temperatures and other elements of climate.

Vegetation varied from predominantly grassland in the Southern (Eastern Cape) Drakensberg to scrubby bushland/grassland in the Tsitsikamma area, with better developed forest further west in the Sedgefield region (although it may be that the scrubby bushland dates from more recent times than the apparently better developed forest of the Sedgefield area, and reflects the existence of drier climatic conditions in the later than in the earlier part of the Birnam Interstadial). Vegetation in the Little Karoo was not markedly different from that of the present, but may reflect drier, and increasingly colder, climatic conditions towards the end of the Birnam Interstadial. Nothing is known of the vegetation between the present day coastal belt and the foothills of the Southern (Eastern Cape) Drakensberg during the Interstadial.

The larger mammals throughout the greater Eastern Cape appear to have been predominantly grazers, possibly with an increase in browsers in the drier area of the Little Karoo. The giant buffalo (*Pelerovis antiquus*) existed in present day coastal areas, at least west of Port Elizabeth, where it may have been suited to the scrubby woodland/grassland environment that seems to have existed at least during the latter part of the Birnam Interstadial. Nothing is known of coastal areas east and north of Port Elizabeth, or of the area between the present day coastal belt and the foothills of the Southern (Eastern Cape) Drakensberg during the Interstadial.

Foragers, of MSA culture, were widespread, but, as the limited number of living sites discovered suggests, probably few, in the Eastern Cape and Little Karoo during the Birnam Interstadial. Their remains are obvious in the Southern (Eastern Cape) Drakensberg and its foothills, the Little Karoo, and in present day coastal areas west of Port Elizabeth. Nothing is known of foragers in the intermediate inland regions, or in present day coastal areas east and north of Port Elizabeth. Further research is needed to establish whether or not these areas were occupied during the Interstadial.

2.2. The Bottelnek Stadial (Last Glacial Maximum)

2.2.1. Location of the evidence

Landforms exist in Bottelnek, a valley near Barkly East, that Lewis and Hanvey (1993) interpreted as the remains of rock glaciers (Fig. 3). Boelhouwers and Meiklejohn (2002, 51) believe that these deposits '…lack any diagnostic features of such forms and are most likely debris flow deposits (Shakesby, pers. comm.)'. Lewis and Hanvey (1993) argued that they were of rock glacier origin on the basis that their location, morphology and stratigraphy, resembles that of modern rock glaciers. These contentious deposits were laid down by, or soon after, ~ 24 000 cal. a BP, which is the age of an organic lens in the lower part of the sediments (Lewis, 2005, 2008b).

A cirque moraine exists at Killmore, in a tributary valley of the Bokspruit valley (Fig. 4) (Lewis, 1994, 1996, 2008a, d). Other moraines and protalus ramparts are located below Mount Enterprise, under the Drakensberg escarpment (Lewis and Illgner, 2001, Lewis, 2008a, d). Although no absolute dates exist for these moraines and protalus ramparts, their pronounced morphology indicates that they can be no older than the Late Quaternary. At least some of them may date to the Aliwal North (Late Glacial).

Boelhouwers and Meiklejohn (2002, 52) state that: 'field investigations do not support the presence of glaciers in southern Africa during the Quaternary'. Osmaston and Harrison (2005) echoed the same conclusion, however, Mark and Osmaston (2008, 604) accepted that evidence exists in the Eastern Cape for the former presence of: '…very limited cirque glaciers at the highest elevations'. Mills et al. (2009a, b) have shown conclusively that niche glaciers existed in the Drakensberg of Lesotho during the Late Quaternary. The statement of Boelhouwers and Meiklejohn (2002) predates the publications by Mills et al. (2009a, b), and was most likely written before the publication by Lewis and Illgner (2001), and is consequently regarded as outdated.

Head deposits, thought to result largely from gelifluction (Lewis, 2008b), occur at many locations above ~ 1800 m in the Southern (Eastern Cape) Drakensberg (Lewis, 2008a, b). They are younger than ~ 40 000 cal. a BP at Buttermead (Lewis, 1999), ~ 37 000 cal. a BP at Dynevor Park (Lewis and Hanvey, 1993; Lewis, 1999, 2002, 2005, 2008a) and ~ 26 000 cal. a BP at Birnam (Hanvey and Lewis, 1990; Lewis, 2008a): they probably formed subsequent to ~ 26 000 cal. a BP.

The rock glacier, moraine, protalus rampart and head deposits, assuming that is what they are, testify to the former existence of periglacial and glacial conditions in the Southern (Eastern Cape) Drakensberg. They provide evidence of climatic conditions during their formation. Grab's argument (2000): that the evidence is too contentious to be used for that purpose; predates more recent publications and is therefore considered outdated.

Fig. 3. A debris lobe, terminating at an altitude of ~ 1930 m, believed to be the remains of a talus rock glacier that extended onto the floor of the Bottelnek valley on Rose Hill farm, near Barkly East (Lewis, 2008a).

Fig. 4. Different aspects of the Killmore moraine:

A. View along the clast-strewn trough between the moraine (on the left) and the vegetated talus slopes and cliffs of the backwall (on the right). Scale is provided by the person (arrowed) standing on the inner side of the moraine.
B. The Killmore moraine seen in cross-section near its southern terminus, where it was cut by a melt-water channel. Scale is provided by the person (arrowed) standing near the inner side of the moraine. (Lewis, 2008d, courtesy of NISC).

Aeolian deposits, luminescence dated to between ~ 24 and 18 ka, forming lunette and stabilised climbing dunes, exist near Buffelsfontein farm in the Stormberg, north of Queenstown (Fig. 1; Marker and Holmes, 1993, 1995; Thomas et al., 2002). Although dunes may reflect windy rather than dry conditions (Chase and Meadows, 2007), the Buffelsfontein deposits probably evidence windy conditions during their formation, possibly with seasonal precipitation succeeded by dune development in the dry season. These conditions apparently occurred when periglacial and glacial environments existed in the Southern (Eastern Cape) Drakensberg at that time (Lewis, 2008a).

Archaeological evidence for the abandonment of the Southern (Eastern Cape) Drakensberg by hunter gatherers, from between ~ 25 000 cal. a BP and ~24 000 cal. a BP until ~ 12 000 cal. a BP, exists at Strathalan, near Maclear (Opperman and Heydenrych, 1990), and Ravenscraig, near Barkly East (Opperman, 1987; Tusenius, 1989; Lewis, 2005). In conjunction with palynological and other evidence, including charcoal (Hill, in Opperman and Heydenrych, 1990; Opperman, 1987; Tusenius, 1989; Lewis, 2005, 2008a), human abandonment of the uplands seems to have coincided with the initiation of cold, dry, harsh climatic conditions, with reoccupation taking place when grasslands re-established during the Late Glacial (Lewis, 2008a).

At lower altitudes, evidence of forager occupation exists at Howison's Poort, at ~ 600 m, between at least ~ 23 000 cal. a BP, and ~ 22 000 cal. a BP, but none thereafter until ~ 13 000 cal. a BP (Deacon, 1995; Lewis, 2008a, c). There is no evidence of occupation at KRM between ~ 22 000 cal. a BP and ~ 14 000 cal. a BP (Singer and Wymer, 1982; Lewis, 2008a). At NBC archaeologically sterile deposits and an erosional unconformity immediately underlie evidence of occupation at ~ 22 000 cal. a BP. Beneath the unconformity lie MSA artefacts dating as far back as at least ~ 26 000 cal. a BP (Fairhall and Young, 1973; Lewis, 2008a). The unconformity may reflect abandonment of NBC after ~ 26 000 cal. a BP, with reoccupation before ~ 22 000 cal. a BP. Boomplaas, in the Little Karoo, was occupied more frequently by foragers immediately prior to ~ 24 000 cal. a BP than between then and ~ 17 000 cal. a BP, when it was used by 'relatively mobile groups' (Deacon et al., 1984, 346). Melkhoutboom, some 80 km west of Grahamstown, was occupied by hunter-gatherers by somewhat before 18 350 cal. a BP, as evidenced by a hearth resting on bedrock (Deacon, 1976; Lewis, 2008a). Whether it was occupied earlier is unknown.

Groundwater isotopic evidence exists from the Uitenhage aquifer, near Algoa Bay, for colder temperatures between ~ 28 000 14C a BP and ~ 15 000 C14 a BP than between ~ 13 000 14C a BP and 0 14C a BP (Heaton et al., 1986), but these dates are uncalibrated.

2.2.2. Length of the Bottelnek Stadial

The Bottelnek Stadial extended from ~ 24 000 cal. a BP, as judged by the age of organic deposits in the lower layers of rock glacier sediments in Bottelnek (Lewis, 2005), evidence of abandonment of the Strathalan archaeological site (Opperman and Heydenrych, 1990; Lewis, 2008c), the oldest date for dune deposits at Buffelsfontein (Thomas et al., 2002), and the youngest date for organic deposits beneath head at Birnam (Hanvey and Lewis, 1990), until somewhat before ~ 18 350 cal. a BP: the date of the oldest hearth at Melkhoutboom (Deacon, 1976; Lewis, 2008c); vide 2.3 for evidence of temperate conditions post dating the hearth).

2.2.3. Environmental conditions during the Bottelnek Stadial

Assuming that the landform interpretations of Lewis and his co-workers were correct (see section 2.2.1), glacial and periglacial conditions prevailed, at least above ~1800 m in the Southern (Eastern Cape) Drakensberg. At about that altitude, Mean Annual Air Temperatures (MAAT) in shaded places were probably no higher than -2 ^{o}C (the highest MAAT at which rock glaciers normally occur; Humlum, 1998) and precipitation at rock glacier sites (including snow blow, as shown on Fig. 5 and discussed in section 2.2.3.1) may have been of the order of 540 mm of water equivalent (Lewis, 2008c). Conditions were less severe at lower altitudes, as in the present day coastal lowlands west of Port Elizabeth and in the Little Karoo. Little is known of conditions between Grahamstown and the Southern (Eastern Cape) Drakensberg, (apart from Marker's (1986) suggestion that periglacial conditions existed in the Amatola and other uplands), or of conditions in the Transkei.

2.2.3.1. Environmental conditions in the Southern (Eastern Cape) Drakensberg during the Bottelnek Stadial

Rock glaciers normally form within the zone of continuous permafrost, when MAAT is below – 6.5^{o}C, although some occur in the discontinuous permafrost zone, where MAAT may be as high as – 2^{o}C (Humlum, 1998). According to Lewis and Hanvey (1993), rock glaciers existed in the Southern (Eastern Cape) Drakensberg. Lewis (2005, 2008b) maintains that they were active, at and above ~ 1800 m, at ~ 24 000 cal. a BP. Consequently, MAAT in shaded areas of the mountains at and above that altitude, at that time, were unlikely to have been above ~ -2^{o}C. They may have been much lower. At least discontinuous permafrost existed in suitable sites and, based on the standard continental geothermal gradient of 0.0033 ^{o}C m^{-1} (Kappelmeyer and Haenel, 1974), may have been at least 60 m deep at rock glacier sites. Permafrost may have been non-existent at less shaded localities. If MAAT was -8^{o}C, permafrost, based on the geothermal gradient of Kappelmeyer and Haenal (1974), may have penetrated the ground to a depth of ~ 240 m, although no evidence for such deep penetration has been discovered in southern Africa. (Grab (2002) considered, on the evidence of relict sorted circles in the high Drakensberg, that permafrost formerly occurred in areas above 3400 m altitude, although this was contended by Sumner (2004), to whom Grab (2004) replied). Mean Annual Precipitation (MAP), including snow that drifted or otherwise accumulated on the rock glaciers, may have been of the order of 540 mm of water equivalent at rock glacier sites at ~ 24 000 cal. a BP, which is just under 80 % of MAP at Barkly East over the period 1939-45 (Fig. 5) (WB 40; Lewis, 2008b).

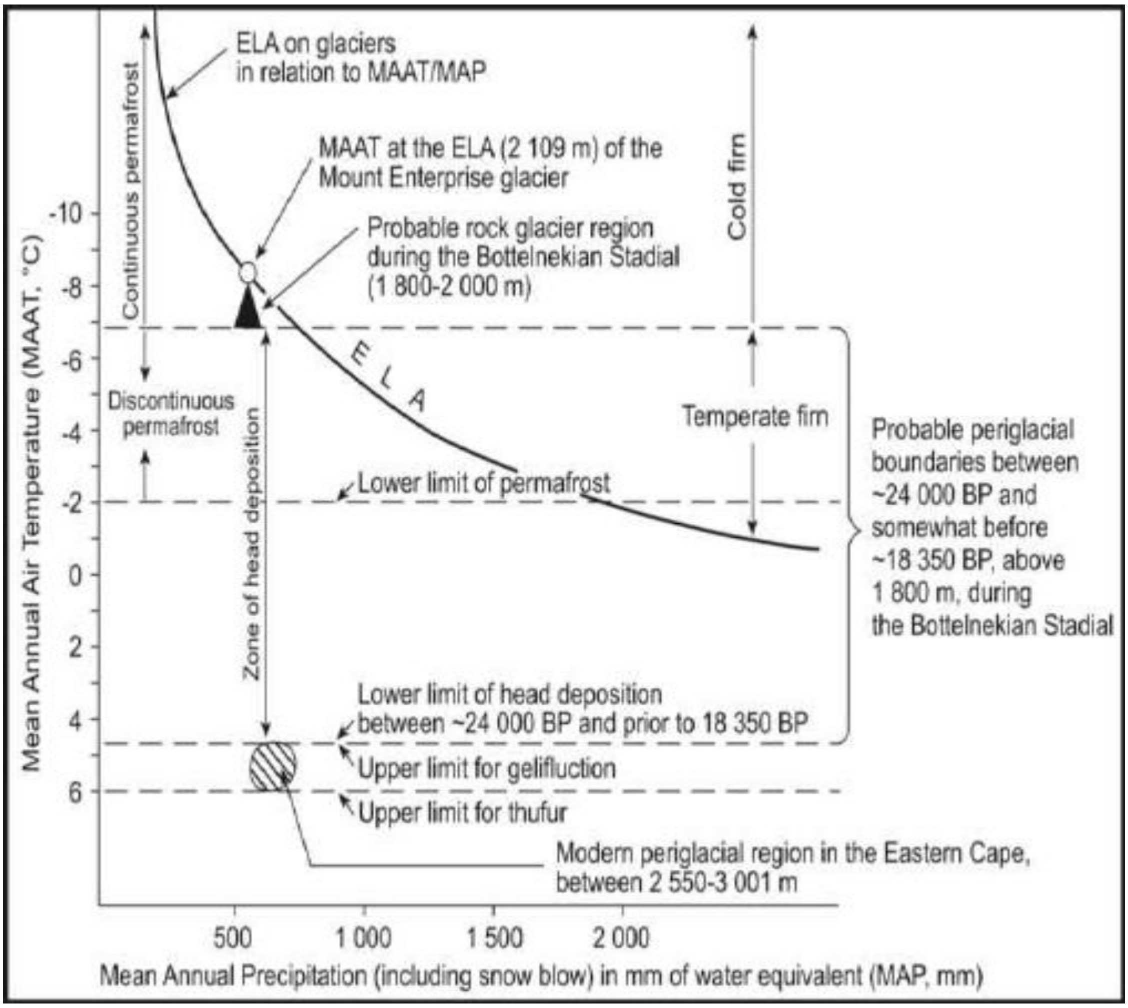

Fig. 5. Climatic conditions at various altitudes in the Southern (Eastern Cape) Drakensberg during the Bottelnekian Stadial (~ 24 000 cal.a BP to before ~ 18 350 cal. a BP). Based on radiocarbon dates as discussed in the text, glacial and periglacial landforms and deposits, and on global climatic parameters pertaining to permafrost, firn and the Equilibrium Line Altitude (ELA) on glaciers as given by Humlum and Christiansen, 1998. (This Figure has been revised from that of Lewis, 2008b, to take account of the radiocarbon date from the lowest hearth at Melkhoutboom, and the arguments (presented in the text) pertaining thereto).

The Equilibrium Line Altitude (ELA) for the glacier at Mount Enterprise, when the inner moraine was being deposited at that site, was ~ 2 100 m (Lewis and Illgner, 2001; Lewis, 2008d). The ELA for the Killmore cirque glacier (Lewis, 2008d) was at a similar altitude. These ELAs correlate with a MAAT of ~ -8^{o}C, and a MAP of ~ 500 mm of water equivalent (Fig. 5; Humlum and Christiansen, 1998; Lewis, 2008d). The MAAT was calculated by Lewis and Illgner (2001) according to Sutherland's formula (1984) for computation of the mean summer air temperature (MSAT). Lewis (2008b) used the MSAT in conjunction with data in Humlum (1998, Fig. 9) to establish the mean annual precipitation in mm of water equivalent (MAP mm w.e.). He then used the MAP mm w.e. to establish the MAAT based on further information in Humlum (1998, Fig. 10).

Since the computation of MAP disregarded snowblow, MAAT at the ELA on the Mount Enterprise and Killmore glaciers may have differed from that indicated on Fig. 5. Assuming that glaciers were active at the same time as rock glaciers, environmental conditions in the Southern (Eastern Cape) Drakensberg at ~ 24 000 cal. a BP may have been extremely harsh, with MAAT in shaded areas at and above 1800 m as low as -8^{o}C, with MAP (including snow blow) of ~ 500 mm. Permafrost may have been ~ 240 m thick, if the standard continental geothermal gradient (Kappelmeyer and Haenel, 1974) applied in that area. Further research is needed to establish whether these low temperatures and deep permafrost penetrations actually occurred. Research is also needed into the onshore effects of possible oceanic upwelling off the coast of the Eastern Cape during the Bottelnek Stadial. Upwelling presently occurs off the Port Alfred region and has been known to reduce sea surface temperatures by over 11^{o} C compared with the temperature of 'surface water in the core of the [adjacent] Southern Agulhas Current', from in excess of 26^{o} C to below 15^{o} C (Lutjeharms, 2006, 132).

Aeolian (dune) deposits in the Stormberg, luminescence dated to between ~ 24 and 18 ka (Marker and Holmes, 1993; Thomas et al., 2002), indicate that windy conditions existed in the vicinity of the Southern (Eastern Cape) Drakensberg at that time. They may have resulted from strong anticyclonic circulation, at least over the Karoo (Thomas et al., 2002). This supports the rock glacier and glacier evidence from the Southern (Eastern Cape) Drakensberg: the regional climate was evidently cold and windy, and may have been semi-arid.

Palynological research at Strathalan (Hill, in Opperman and Heydenrych, 1990), taken in conjunction with mapping by Low and Rebelo (1996), suggests that by ~ 24 000 cal. a BP the vegetation belts in the Southern (Eastern Cape) Drakensberg had moved downwards, altitudinally, by some 1200 m, and that alpine vegetation had replaced grassland at ~ 1300 m. Whether the vegetation belts moved lower after ~ 24 000 cal. a BP, and whether the Southern (Eastern Cape) Drakensberg became unvegetated after that date, is unknown. No evidence of organic deposition has been found in that area of the Drakensberg and its immediate vicinity for the time period between ~ 24 000 cal. a BP (the age of a thin organic lens in Bottelnek: Lewis and Hanvey, 1993; Lewis, 2005, 2008a) and ~ 15 000 cal. a BP (the age of the lowest organic material discovered at Aliwal North: Coetzee, 1967).

No faunal evidence has, as yet, been discovered in the Southern (Eastern Cape) Drakensberg for the time period between ~ 25/24 000 cal. a BP, when faunal and floral remains were deposited on an occupation floor at Strathalan (Opperman and Heydenrych, 1990; Lewis, 2008a), and ~ 12 000 cal. a BP, when faunal remains were deposited at the archaeological site at Ravenscraig (Opperman, 1987; Tusenius, 1989; Lewis, 2005, 2008a, c).

Archaeological evidence, summarised in Lewis (2008a, c), indicates that humans abandoned the Southern (Eastern Cape) Drakensberg between ~24 000 cal. a BP and ~ 12 000 cal. a BP: environmental conditions were presumably too harsh for human survival in those mountains during that time period.

2.2.3.2. Environmental conditions in the present day coastal belt during the Bottelnek Stadial

The rock shelter at Howison's Poort, near the inland margin of the present day coastal belt, was occupied by human foragers during the earlier part of the Bottelnek Stadial, between ~ 23 000 cal. a BP and ~ 22 000 cal. a BP (Deacon, 1995; Lewis, 2008a, c), but no faunal or floral information has been presented from that site. The shelter was apparently not occupied again until ~ 13 000 cal. a BP, after the rigours of the Bottelnek Stadial had been replaced by less harsh conditions. The present flood plain and river terrace deposits on the floor of Howison's Poort had not yet been emplaced by the latter date (Lewis and Illgner, 1998; Lewis, 2008a). Angular clasts in deposits on the floor of the rock shelter, dated to between ~ 23 000 cal. a BP and ~ 10 500 cal. a BP (Deacon, 1995; Lewis, 2008c), may reflect frost action during the Bottelnek Stadial, or be of other origins: frost occurs during winter in Howison's Poort at present. Flood plain deposition on the floor of the Poort, evidencing appreciable runoff rather than cold, essentially dry, stadial conditions, predates ~ 11 000 cal. a BP, although the date of flood plain initiation remains unknown (Lewis and Illgner, 1998; Lewis, 2008a). Very little is therefore known of environmental conditions in Howison's Poort during the Bottelnek Stadial.

No evidence of environmental conditions during the Bottelnek Stadial has been presented from the Tsitsikamma coastal belt. KRM, the only site examined in detail in the Tsitsikamma, contains no dated evidence of human occupation between ~ 22 000 cal. a BP and ~ 14 000 cal. a BP (Singer and Wymer, 1982; Lewis, 2008a), neither does it provide dated evidence of environmental conditions in that time period. The absence of dated evidence of occupation is discussed below, under NBC.

In the Plettenberg Bay area, near the edge of the western margins of the Tsitsikamma, faunal remains at NBC, dated to between ~ 22 000 cal. a BP and ~ 20 000 cal. a BP, included those of African buffalo (*Syncerus caffer*), eland (*Taurotragus oryx*), blesbok/bontebok (*Damaliscus* cf. *dorcas*), grysbok/steenbok (*Raphicerus* sp.), roan (*Hippotragus* spp.), red hartebeest (*Alcelaphus caama*), springbok (*Antidorcas* cf *marsupialis*) and wildebeest (*Connochaetes* cf *gnou*), as well as rock hyrax (*Procavia capensis*) (Klein, 1972; Lewis, 2008a). They indicate that the vegetation of the Plettenberg Bay region at that time, during the Bottelnek Stadial, was open country grassland with some shrubland, unlike the present climax vegetation of closed evergreen forest (Low and Rebelo, 1996). Consequently, there was probably less precipitation in the vicinity of NBC during the Bottelnek Stadial than at present (Lewis, 2008a). Some of the animals, whose remains date to ~ 21 500 cal. a BP, ate a mixture of C^3 and C^4 grasses (Sealy, 1996). This suggests that the area experienced year-round rainfall at that time and hence atmospheric circulation similar to that of the present. As stated by Lewis (2008a), this conflicts with the existing conceptual atmospheric models for that area, during 'glacials', of Heine (1982), Cockcroft et al. (1987), and Chase and Meadows (2007): that the winter rainfall zone extended across this region during 'glacials', rather than that the area lay between the summer and winter rainfall regions, and was dominated by neither.

Klein (1972, 138) suggested that the 'near absence of sea creatures' in the deposits at NBC dating to between at least ~ 22 000 cal. a BP and ~ 14 000 cal. a BP, implies that sea levels were low in that period, which accords with global findings as summarised by Waelbroek et al. (2002), and with discoveries further west along the southern coast of South Africa (Fisher et al., 2009). Klein (1972, 138) postulated that, due to reduction in sea level, the shoreline may have lain some 75-80 km distant from NBC during that period: 'far greater than the regular distance that hunter-gatherers could be expected to travel from home base to food source'. This may also have been the case at KRM and may explain the lack of dated human occupation there between ~ 22 000 cal. a BP and ~ 14 000 cal. a BP.

Lewis (2008a) hypothesised that the reason why the Plettenberg Bay region was apparently drier between ~ 22 000 cal. a BP and ~ 14 000 cal. a BP than at present, may have been because land extends seaward at times of low sea level, as during the cold conditions of the Bottelnek Stadial. Consequently, moisture carried by cold fronts brushing the coast then, as at present, failed to be carried inland to the vicinity of NBC in such quantities as at present.

Isotopic analyses of gas from groundwater in the aquifer that runs from the vicinity of Uitenhage to Coega, has shown that 'earth temperatures at the base of the unsaturated zone north of Uitenhage increased by an average of 5.5^{o} C from the last glacial maximum to Holocene times' (Heaton et al., 1986, 85). Since the average was based on two 13 000 year periods: 28 000 to 15 000, and 13 000 to 0 14C a BP; it is of limited value and is unlikely to indicate the extent to which MAAT might have dropped in the area at and immediately after ~ 24 000 cal. a BP, when MAAT may have been well below the 28 000 – 15 000 14C a average. The statement that 'There is no dissolved gas evidence for major temperature variations in the period 28, 000 to 15, 000 yr [uncalibrated] BP' (Heaton et al., 1986, 85) is not proof that major temperature variations did not occur.

In summary: during the Bottelnek Stadial, the present day coastal area of the Eastern Cape, at least west of Port Elizabeth, lay further from the shore than at present, due to reductions in sea level exposing areas now inundated by the sea. Faunal remains indicate that the vegetation was predominantly open grassland with some bush. This indicates that the climate in this region was drier than at present. Isotopic examination of bone remains indicate that at least the Plettenberg Bay region experienced year round rainfall at ~ 21 500 cal. a BP, as at the present day. Atmospheric circulation may therefore have resembled that of the present, with reduction in precipitation being due to increased distance from the shore, rather than to any appreciable atmospheric perturbation. MAAT, as indicated by isotopic analyses of groundwater, was apparently lower than at present.

Nothing is known of present day coastal areas east and north of Port Elizabeth, or of the interior of Transkei, during the Bottelnek Stadial.

2.2.3.3. Environmental conditions in the area between the present day coastal belt and the foothills of the Southern (Eastern Cape) Drakensberg during the Bottelnek Stadial

The only published dated evidence of environmental conditions in the above area, from 24 000 cal. a BP until and including ~ 18 350 cal. a BP, comes from Melkhoutboom, an archaeological site at an altitude of ~ 650 m, some 80 km west of Grahamstown (Fig. 1). At Melkhoutboom, a hearth, resting on bedrock and associated with Later Stone Age (LSA) tools of the Robberg industry (Deacon and Deacon, 1999), dates to ~ 18 350 cal. a BP (Deacon, 1976; Lewis, 2008a, c). Carbonised seeds from sediments overlying the hearth, dated between ~ 18 350 cal. a BP and ~ 12 250 cal. a BP, indicate that 'patches of climax temperate ever-green forest' (Deacon, 1976, 109) existed in kloofs (hillside valleys) in the vicinity of the archaeological site between those dates. Faunal remains from those sediments indicate that grassveld animals occupied the Melkhoutboom area during that ~ 6 000 year period, but fail to indicate environmental conditions prior to ~ 18 350 cal. a BP, when conditions, at least in the Southern (Eastern Cape) Drakensberg, were cold, windy, probably semi-arid, and inhospitable.

The Melkhoutboom hearth indicates that the Bottelnek Stadial probably ended before ~ 18 350 cal. a BP, by which date Melkhoutboom was inhabited by hunter-gatherers. Temperate forest and grassland apparently colonised the area after that date. Evidence from Howison's Poort, east of Melkhoutboom and near the inland edge of the presently coastal belt, suggests that hunter-gatherers abandoned the Poort after ~ 22 000 cal. a BP, when roof spalls suggest that cold, frosty, conditions occurred, and did not reoccupy it until ~ 13 000 cal. a BP (Deacon, 1995; Lewis, 2008 a, c). Melkoutboom may also have been abandoned when environmental conditions were particularly harsh, to be reoccupied by ~ 18 350 cal. a BP, when they ameliorated. Since the dated hearth lies on bedrock, it is unknown whether there was earlier human occupation.

Scree tongues that exist at altitudes between ~ 1860 and 1550 m on south facing slopes, near Queenstown and the Hogsback, may indicate the former existence of periglacial conditions (Marker, 1986). They may have formed during the Bottelnek Stadial, but have not been dated. No further evidence of environmental conditions during the Bottelnek Stadial has been published for the extensive area between Melkhoutboom and the Southern (Eastern Cape) Drakensberg, and further research in that area is desirable.

2.2.3.4. Environmental conditions in the Little Karoo during the Bottelnek Stadial

Archaeological evidence from Boomplaas (Figure 1) indicates conditions in the Little Karoo during the Bottelnek Stadial. Boomplaas was occupied by hunter-gatherers throughout the period between ~ 24 000 cal. a BP and ~ 17 000 cal. a BP, when it was used by 'relatively mobile groups' (Deacon et al., 1984, 346). The site was occupied more frequently immediately before ~ 24 000 cal. a BP than during the period between ~ 24 000 cal. a BP and ~17 000 cal. a BP, which suggests that the Little Karoo was less densely populated during the Bottelnek Stadial than previously.

Examination of micromammalian remains at Boomplaas (Avery, 1982) indicates that the vegetation in the area was fairly open between ~ 24 000 cal. a BP and ~ 17 000 cal. a BP, being grassy on hillsides, and of semi-arid type on valley floors. Charcoal analyses (Scholtz, 1986) indicate that woodland was virtually absent from the Cango valley, adjacent to Boomplaas, between ~ 24 000 cal. a BP and ~ 17 000 cal. a BP, although shrubland had existed in the area previously, at least as far back as ~ 38 000 cal. a BP, when 'climatic conditions were neither as dry or as cold as at the last Glacial Maximum' (Deacon et al., 1984, 345).

The most common faunal remains at Boomplaas (Klein, 1978; Brink (unpublished) as reported in Deacon et al., 1984) during the period from ~ 24 000 cal. a BP until ~ 17 000 cal. a BP were of the hartebeest tribe (Alcelaphini), horses, eland (*Taurotragus oryx*) and klipspringer (*Oreotragus oreotragus*). They evidence grassy habitats in the area at that time. The high frequency of alcelaphini remains dating to the same period indicate that the climate was drier at that time than during the previous interstadial, when it was less cold but moister than at the Last Glacial Maximum (Deacon et al., 1984,). There appears to have been 'a major episode of large mammal extinctions' in the Boomplaas area at ~ 17 000 cal. 14C yrs BP, after which there is no evidence of giant buffalo (*Pelerovis antiquus*) and giant hartebeest (*Megalotragus priscus*) (Klein, 1978, 70). The reasons for these extinctions remain unclear, but may have been associated with climatic amelioration and associated changes in vegetation.

2.2.4. Summary, environmental conditions during the Bottelnek Stadial

The Bottelnek Stadial was very cold, arid to semi-arid, and probably windy at high altitudes in the Southern (Eastern Cape) Drakensberg, where rock glaciers and glaciers apparently existed and MAAT in shaded locations was not higher than -2^{o}C and may have been as low as -8^{o}C. Permafrost may have been up to 240 m thick at and above 1800 m, if the standard continental geothermal gradient of Kappelmeyer and Haenel (1974) applied in this low latitude and high altitude area. MAP (including snow blow) at ~ 1800 m, where rock glaciers existed, may have been of the order of 540 mm of water equivalent. The area may have been dominated by anticyclonic conditions. Floral and faunal evidence has not been discovered from the Southern (Eastern Cape) Drakensberg, apart from a thin organic lens in Bottelnek dating to ~ 24 000 cal. a BP. There is no evidence of human occupation of the Southern (Eastern Cape) Drakensberg during the Bottelnek Stadial.

Conditions at lower altitudes, in the present day coastal belt, were less severe than in the Southern (Eastern Cape) Drakensberg, but were drier and colder than in the previous Birnam Interstadial. Sea levels were lower than at the present and the shoreline in the Plettenberg Bay district may have been 75-80 km distant from the present coast (Klein, 1972). Atmospheric circulation probably resembled that of the present, with reduced precipitation on the present day coastal belt being due to greater distance from the shore than at present.

Vegetation in the NBC region was predominantly open grassland with some bush. Nothing is known of the vegetation elsewhere in the present day coastal belt. In the Little Karoo the vegetation was grassy on hillsides and of semi-arid type on valley floors: trees were absent. Nothing is known of the vegetation, or fauna, between the present day coastal belt and the Southern (Eastern Cape) Drakensberg until after ~ 18 350 cal. a BP, by which time the Bottelnek Stadial appears to have terminated.

The fauna of the present day coastal belt is known only from NBC and, apart from rock hyrax (*Procavia capensis*), is known to have consisted essentially of grazers, some of which, including the African buffalo (*Syncerus caffer*), needed bushy shade. Humans only occupied NBC occasionally, possibly because an important source of their food was the sea and shore, which was too distant for them to use NBC more frequently. The fauna of the Little Karoo was similar to, but more restricted than, that of the present day coastal region near Plettenberg Bay.

The Little Karoo fauna included Saunder's vlei rat (*Otomys saundersae*) as the dominant rodent (Avery, 1982). This animal at present lives in cold conditions at high altitudes in southern Africa, indicating that conditions in the Little Karoo during the Bottelnek Stadial were harsh, cold and dry (Deacon et al., 1984). Environmental conditions were, however, much less severe than in the Southern (Eastern Cape) Drakensberg, where small glaciers existed, and where faunal evidence is apparently absent, perhaps because conditions in those mountains were too inhospitable for faunal survival.

Although people occupied the present day coastal belt, at least occasionally, and the Little Karoo, there is no evidence that they were present in the Southern (Eastern Cape) Drakensberg or in the vast area between those mountains and the present day coastal belt during the Bottelnek Stadial.

2.3. The Aliwal North (Late Glacial)

2.3.1. Palynological evidence from the Southern (Eastern Cape) Drakensberg and the Winterberg during the Aliwal North

Organic deposition, evidencing amelioration of climate, took place in the vicinity of the Southern (Eastern Cape) Drakensberg, at Aliwal North, following the Bottelnek Stadial, by ~ 15 000 cal. a BP. Core II from Aliwal North (Coetzee, 1967) is here designated as the type site for the Aliwal North since it provides the longest palynological record (age-wise) yet known from the Eastern Cape for that climato-environmental phase. In the Winterberg, the oldest radiocarbon dated organic deposits also yielded an age of ~ 15 000 cal. a BP (Meadows and Meadows, 1988). At Aliwal North there were relatively moist and cool conditions between ~ 14 000 and 12 000 cal. a BP, when climate became relatively dry and Karoo-type vegetation invaded the area. Between ~ 12 000 and 11 500 cal. a BP the Aliwal North area was invaded by grassland under relatively moist conditions, although Karoid vegetation, indicating the resumption of dry and warm conditions, reasserted itself between ~ 11 500 and 10 000 cal. a BP. In the Winterberg, grassland was widespread soon after organic sedimentation began.

2.3.2. Human reoccupation of the Southern (Eastern Cape) Drakensberg in the Aliwal North

By ~ 12 000 cal. a BP foragers of LSA culture resumed utilisation of the Southern (Eastern Cape) Drakensberg, as evidenced by use of a rock shelter at Ravenscraig at an altitude of ~ 1850 m. They hunted hartebeest/wildebeest (*Alcelaphus/Connochaetes*) and other animals that were grazers, indicating that grassland existed in the Ravenscraig area, at altitudes around 1850 m, at that date (Opperman, 1987; Tusenius, 1989; Lewis, 2005, 2008a).

2.3.3. Spread of grassveld (grasslands) between the Southern (Eastern Cape) Drakensberg and the present day coastal lowlands in the Aliwal North

At lower altitudes, in the vicinity of Melkhoutboom at ~ 650 m, temperate evergreen forest established itself in kloofs (hillside valleys) after ~ 18 350 cal. a BP, while grassveld spread over surrounding lowlands and was grazed by migratory grassveld animals that included red hartebeest (*Alcelaphus* cf. *caama*), blesbok/bontebok (*Damaliscus* cf. *dorcas*), blue antelope (*Hippotragus* cf. *leucophaeus*) and quagga (*Equus* cf. *quagga*) (Deacon, 1976). These resources fed 'a stable [human] population' (Deacon, 1976, 117) from some 18 000 cal. a BP until historic times.

2.3.4. Extinction of the giant buffalo and vegetation changes in the present day coastal lowlands during the Aliwal North

In the present day coastal region, increasingly bushy vegetation appears to have replaced grassland around NBC by ~ 14 000 cal. a BP and the giant buffalo (*Pelerovis antiquus*) became extinct, while bush-loving reedbuck (*Redunca arundinum* and *Redunca fulvorufula*) and grey rhebok (*Pelea capreolus*) were increasingly common. A marked increase in bone remains of the Cape fur seal (*Arctocephalus pusillus*) in archaeological deposits argues for sea level rise by ~ 14 000 cal. a BP, bringing the shoreline into human foraging distance of NBC (Klein, 1972). By ~ 13 500 cal. a BP there had been further environmental changes, and the vegetation probably consisted of open woodlands with good grass cover (Lewis, 2008a). By ~ 12 000 cal. a BP, as evidenced by the large quantities of marine shells of that date in NBC, sea level seems to have risen so that littoral areas were within easy human foraging distance of the site (Klein, 1971).

2.3.5. Recolonisation of the Little Karoo by trees during the Aliwal North

The Little Karoo, judging from evidence from Boomplaas, experienced recolonisation by trees after ~ 18 000 cal. a BP, initially by *Olea* and *Rhus* spp (shrubs or small trees normally under 8 m in height) but, after ~ 14 800 cal. a BP, by *Acacia karroo* that is frost and drought resistant (Deacon et al., 1984). Between ~ 14 800 cal. a BP and ~ 10 200 cal. a BP there were numerous climatic fluctuations and a rapid rise in temperatures, evidenced by micromammals (Avery, 1982). The Little Karoo, judging by evidence from Boomplaas, was occupied by foragers throughout the Aliwal North (Late Glacial) and 'The best developed trace of human occupation in the Boomplaas archive' (Deacon, 1995, 123) took place between ~ 18 000 cal. a BP and ~ 14 800 cal. a BP, before the spread of *Acacia karroo* indicates the existence of frost and droughts.

2.3.6. Length of the Aliwal North

The recolonisation of the Little Karoo by trees, and the spread of grassveld in the area between the Eastern Cape Drakensberg and the present day coastal belt, which took place at ~ 18 000 cal. a BP (see 2.3.3 and 2.3.5) indicate that amelioration of climate took place at about that date, which is taken as the beginning of the Aliwal North. The date of termination is less clear, since there is no clear correlation throughout the area of the rapid climatic oscillations that are its characteristic. For the purposes of this paper, the termination date is considered to be ~ 11 000 cal. a BP.

After that date flood plain deposition was widespread, as geomorphic adjustment of landscapes took place as a result of what appear to have been conditions of increased stream flow (Lewis, 2005). The Aliwal North therefore extended from ~ 18 000 cal. a BP until ~ 11 000 cal. a BP.

2.4. The Dinorben (Holocene)

2.4.1. Type site and age of the Dinorben

The Dinorben is named after flood plain sediments containing palaeosols that have been radiocarbon dated at Sections I and II in the Dinorben Spruit valley, which is a tributary of the Langkloof drainage system near Barkly East (Lewis, 2005, 2008a). Section I (Lewis, 2005, Fig.5) is here designated as the type-site for the Dinorben. The oldest palaeosols, which formed within flood plain deposits, pre-date ~ 10 000 cal. a BP, which is taken as the minimum age for the initiation of the Dinorben, which is marked by the dominance of fluvial processes. These processes still continue in the study area, so that the Dinorben extends to the present day.

2.4.2. Climatic and environmental conditions in the Southern (Eastern Cape) Drakensberg during the Dinorben

The palaeosols beside the Dinorben Spruit, at Sections I and II, formed within flood plain sediments from somewhat before ~ 10 000 cal a BP. The associated flood plain/s were transformed into river terraces after ~ 8000 cal. a BP. The older palaeosols, overlain by flood plain deposits, contain charcoal and what appear to be reed fragments. This suggests that droughts in the Early Dinorben, associated with veld fires, were followed by heavy rainfall events, or snow melt, causing floods. Semi-arid conditions with limited fluvial activity characterised the Mid Dinorben in the Southern (Eastern Cape) Drakensberg after ~ 7 000 cal. a BP. They were succeeded by moister conditions with alternating flood plain erosion and deposition after ~ 3200 cal. a BP (Lewis, 2005). Faunal and charcoal remains left by human foragers in Ravenscraig and in Colwinton rock shelters in the Barkly East area, reflecting the composition of the former fauna and flora (Opperman, 1987; Tusenius, 1989; Lewis, 2005), generally support the geomorphic evidence. They indicate relatively moist conditions in the Early Dinorben followed by a long dry and warm phase when a Karoo plant (*Euryops)* dominated the charcoal assemblage, and, finally, relatively moist conditions.

2.4.3. Climatic and environmental conditions in the area between the Southern (Eastern Cape) Drakensberg and the present day coastal lowlands during the Dinorben

At Howison’s Poort, near the inner margin of the coastal lowlands, flood plain deposition began before ~ 10 750 cal. a BP, as slope and fluvial processes reworked weathered deposits that had accumulated on the valley sides. Flood plain deposition was succeeded by fluvial erosion and transformation of flood plain deposits into river terraces subsequent to 4870 cal. a BP, probably due to climatic change and an increase in fluvial energy (Lewis and Illgner, 1998; Lewis, 2008a; Hattingh, 2008). Similar readjustments took place elsewhere as moister Dinorben (Holocene) climates replaced cooler and drier Aliwal North (Late Glacial) conditions.

Although Howison's Poort appears to have been relatively moist from before ~ 10 750 cal. a BP, the nearby Fish River basin appears to have been too dry for human occupation until after ~ 6300 cal. a BP: the earliest occupation site being of approximately that date (Hall, 1990). Palynological research suggests that the Winterberg was also drier in the early Dinorben (Holocene) than subsequently (Meadows and Meadows, 1988). There has thus been appreciable environmental variation, spatially and temporally, even over small distances, in the Eastern Cape during the Dinorben.

2.4.4. Conditions in the present day coastal lowlands during the Dinorben

Present day coastal areas west of Port Elizabeth appear to have been occupied by hunter gatherers throughout the Dinorben. By ~ 1300 cal. a BP Iron Age farmers were moving south into Transkei and, since they grew tropical cultigens (Maggs, 1980), climatic conditions there at that date were presumably suited to such crops (Feely, 1987; Vogel and Fuls, 1999; Binneman, 1996; Prins, 1993; Cronin, 1982; Lewis, 2008a). Presumably Transkei then, as now, lay within the summer rainfall (Indian Ocean monsoon) region of southern Africa. Iron Age farmers apparently failed to penetrate further south than the vicinity of East London, suggesting that climatic conditions further south and west were unsuited for their crops.

Along the present day coast, especially between Oyster Bay and East London, extensive headland bypass dunefields and accretionary dunefields accumulated during the Dinorben (Illenberger and Burkinshaw, 2008). They indicate the existence of relatively strong winds and plentiful supplies of sediment during that time. OSL dates from a shell midden at Sedgefield, at the western extremity of the study area, suggest that dune accumulation continued into the last 2000 cal. a BP (Bateman et al., 2008).

2.4.5. Environmental conditions in the Little Karoo during the Dinorben

The Little Karoo was settled throughout the Dinorben (Holocene) and by ~ 1600 cal. a BP herders, who kept sheep, utilised Boomplaas, replacing hunter gatherers in the occupation record at that site (Deacon et al., 1984). Hunter gatherers continued to occupy valleys in the adjacent mountains between the Little Karoo and the Algoa Basin (e.g. Binnemann, 1997, 1999, 2000). The remains of their food hoards suggest that there was little difference in the environment of that region throughout the Dinorben.

3. Conclusion

There have been four major environmental phases during the last ~ 40 000 cal. a BP in the study region:

i) an interstadial from before 40 000 cal. a BP until ~ 24 000 cal. a BP, in which relatively mild conditions existed,

ii) a stadial between ~ 24 000 cal. a BP and before ~ 18 350 cal. a BP, equating with the LGM, in which rock glaciers and at least small glaciers apparently formed in the Southern (Eastern Cape) Drakensberg and in which MAAT was remarkably low in the uplands, possibly -8^{o} C at 1800 m in shaded areas during the harshest of that stadial. MAP (including snow blow) at that time in the same uplands was apparently 80 % or less than the MAP (excluding snow blow) of the present day,

iii) a time of considerable climatic oscillation after ~ 18 350 cal. a BP until ~ 11 000 cal. a BP as readjustment took place from LGM stadial to Post Glacial conditions,

iv) finally, the present interglacial.

There appear to have been remarkable environmental variations between the Southern (Eastern Cape) Drakensberg and the present day coastal lowlands. These were partly due to altitudinal differences between the two areas, partly to their differing distances from the Indian Ocean and precipitation bearing winds, and possibly due to inversion effects, probably associated with anticyclonic conditions over the Southern (Eastern Cape) Drakensberg and high interior, affecting adiabatic lapse rates. Little is known of the area between the present day coastal lowlands and the Southern (Eastern Cape) Drakensberg, and virtually nothing is known of environmental conditions in Transkei prior to the movement of Iron Age farmers into the coastal and river valleys of that area after ~ 1300 cal. a BP.

There is pressing need for further research throughout the Eastern Cape to:

i) establish the details of environmental change while that area has been under human occupation and

ii) provide environmental managers with the basic information on temporal and spatial environmental changes that is necessary for sympathetic environmental management based on firm scientific foundations.

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