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Late Holocene Neoglacial conditions from the Lesotho highlands, southern Africa: phytolith and stable carbon isotope evidence from the archaeological site of Likoaeng

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ABSTRACT

The late Holocene environmental history of the Lesotho highlands, southern Africa, is poorly understood with few detailed studies to date. At Likoaeng, Senqu Valley, Lesotho, a 3 m stratified sedimentary sequence from an open-air archaeological site records vegetation development for the period 3400–1070 cal. BP. Phytolith analyses and bulk sediment organic matter δ^{13}C indicate that C_4 grassland dominated the lower part of the sequence until approximately 2960 cal. BP when there was a switch to C_3 Pooid grassland (2960–2160 cal. BP). Also noted was a change from hunting mainly bovids to a dominance of fishing at the site. The change in grassland type and archaeological subsistence strategies corresponds with an episode of neoglacial cooling and the expansion of Alpine sourgrasses into lower altitudes. From 2160 to 1600 cal. BP grassland became a mix of C_3 and C_4 types and by 1600–1070 cal. BP there was a return to C_4 dominated grassland. During this latter phase there was a reversal from fishing to hunting again (and eventually some keeping of domestic livestock) at the site. These data outline the vegetation response to latitudinal shifts of frontal systems, and relatively strong atmospheric circulation variability, perhaps underpinned by variations of polar water into the Benguela Current during the late Holocene.

1. Introduction

The palaeoclimatic history of Lesotho is poorly understood when compared with other regions of southern Africa. Recent work has shown evidence for glaciation and periglaciation during the Late Pleistocene from the eastern high mountain region of Lesotho (Mills and Grab, 2005; Mills et al., 2009) along with Holocene Neoglacial episodes (Grab, 2000). Also within the eastern mountains, a series of Holocene sedimentary sequences have been described and dated but they lack any palaeobotanical evidence to underpin evidence for changing environmental conditions (Hanvey and Marker, 1994; Marker, 1994, 1995, 1998).

Holocene palaeoenvironmental records recovered during archaeological excavations from western Lesotho in 1988 and 1989 include charcoal assemblages, mammalian faunas and tooth enamel isotope studies in the Phuthiatsana Basin and Caledon Valley (Esterhuysen and Mitchell, 1997; Plug, 1997; Smith et al., 2002; Esterhuysen and Smith, 2003). More recently, Grab et al. (2005) studied a sedimentary sequence in the Tsoaing River valley, which spanned the period ca. 12 000–4000 years BP. The late Holocene record was not present in these sequences. Most late Holocene palaeoenvironmental evidence in Lesotho published to date therefore consists of inferences about possible past climatic situations from purely archaeological sites (Mitchell and Charles, 1996, 1998; Mitchell et al., 2006, 2008; Plug et al., 2003). This paper examines a Late Holocene palaeoenvironmental sequence from the Lesotho Highlands during the late Holocene, a period from which records exist.

Phytolith analysis offers an alternative technique from which palaeobotanical information can be derived, especially where conditions are not particularly favourable for pollen preservation. Phytolith analysis from environmental sequences and archaeological sites may be used to reconstruct both regional and local variations in climate and vegetation (Mercader et al., 2000; Ishida et al., 2003; Parker et al., 2004). The unique characteristics of phytoliths from soils and sediment deposits provide information about past vegetation, agriculture and human–plant relationships (Pearsall, 2000). Phytoliths, also called plant opals, or opaline silica, are solid deposits of SiO_2 ($SiO_2 \cdot H_2O$) that are produced in living

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plants and precipitated in and among their cells in organs such as stems, leaves, and inflorescences (Runge, 1999; Pearsall, 2000; Hodson et al., 2008). The silica that forms phytoliths is taken up from ground water as monosilicic acid (Hodson and Sangster, 1990). After the plant dies plant organic matter is decomposed but the silica bodies, which are chemically stable and resistant to decomposition, thus remain as microfossils in soils. Many phytoliths are morphologically distinctive, although some taxa have less distinctive masses that are difficult to characterise by shape and size. Unlike pollen analysis, phytolith analysis is particularly useful in identifying Poaceae to the sub-tribe level.

Whilst an increasing number of phytolith studies are becoming available from North Africa (Barton et al., 2008; Parker et al., 2008), East Africa (Alexandre et al., 1997; Bremond et al., 2008) and tropical Africa (Runge, 1999; Mercader et al., 2000), few records exist from southern Africa. Limited palaeobotanical studies have been undertaken in southern Africa as pollen preservation there is often poor. Environmental sequences in southern Africa from which phytolith analysis has been undertaken include the Pretoria Saltpan (McLean and Scott, 1999), Witpan (Telfer et al., 2009) and the Tsoaing River Basin, western Lesotho (Grab et al., 2005). However, the records from these sites all pre-date the Likoaeng sequence and the phytolith resolution in them is frequently poor.

Unlike pollen, phytoliths preserve well under oxidising conditions including soils, colluvia and cave earths. However, of relevance with regards to palaeoenvironmental reconstruction, phytolith analysis allows (a) the distinction between forest and grassland ecosystems, and (b) the distinction between C_3 Pooidae (cool wet), C_4 Panicoideae (warm humid) and C_4 Chloridoideae (warm dry) grassland types (e.g. Barboni et al., 1999). The significance of the latter is that changing climatic conditions alter the proportion of C_3 and C_4 vegetation. C_4 plants can tolerate arid conditions, although high radiation and warm temperatures during the growing season are the primary controls on distribution of C_4 grasses (Ehleringer et al., 1997). C_3 plants prevail under cooler, more humid climates (Alexandre et al., 1997; Parker et al., 2004). Grasses serve as particularly good indicators of climate change as they generally have short life-cycles and can adapt quickly to rapid changes in environmental conditions. Variations in temperature, rainfall and ambient CO_2/O_2 ratios will alter the competitive balance between C_3 and C_4 proportions (Ficken et al., 2002) and thus may be used to infer changing climatic and environmental conditions.

Within southern Africa differing photosynthetic pathways predominate owing mainly to differences in annual rainfall regime, although temperature effects dominate at higher elevations in the Drakensberg Mountains (Vogel et al., 1978). Panicoid grasses (mainly C_4 malate forming types) predominate in mesic summer rainfall regions with more than 500–600 mm^{-1}, whilst Chloridoid grasses (C_4 aspartate forming types) preferentially occur in summer rainfall areas with less than 500–600 mm per annum. Arundinoidae (C_3) predominates in regions with more than 40% winter rainfall. Most Arundinoidae taxa have C_3 photosynthesis but the tribe Aristideae uses C_4 photosynthesis. Pooids, in southern Africa, tend to form a large component of the grass flora in the high altitude areas of Lesotho, the eastern and southwestern Cape, and along the southern Cape coast. This subfamily is absent from the warmer and drier regions (Gibbs Russell, 1986).

In addition to phytolith analysis, stable carbon isotope ratios from organic matter in soils and lake sediments reflect the isotopic composition of the dominant vegetation or succession of vegetation that produced it (Meyers, 1994; Olago et al., 1999, 2000). The C_3 and C_4 photosynthesis pathways lead to distinct $\delta^{13}C$ values that do not overlap (Smith and Epstein, 1971). Most plants photosynthesise by the Calvin–Benson or C_3 pathway. Relative to the atmosphere, terrestrial C_3 plants have bulk $\delta^{13}C$ values averaging about −26‰ (O'Leary, 1988), and include virtually all trees, most shrubs and herbs, and grasses and sedges in temperate regions. Plants following the Hatch–Slack or C_4 pathways occur in the tropics and sub-tropics with average $\delta^{13}C$ values of about −12‰, and include many tropical grasses, sedges and xeric herbs (O'Leary, 1981). The C_4 pathway is more efficient at conversion of CO_2, and because the sites of CO_2 capture and ultimate fixation to sugars by the RUBISCO enzyme are separated (Ehleringer et al., 1997), they conserve water more effectively.

The samples discussed in this paper come from the sediment sequence excavated at Likoaeng, an open-air Later Stone Age archaeological site in the Lesotho highlands of southern Africa (Mitchell and Charles, 1996, 1998; Plug et al., 2003; Mitchell et al., 2006, 2008; Mitchell, 2009) (Fig. 1). Results of phytolith analysis

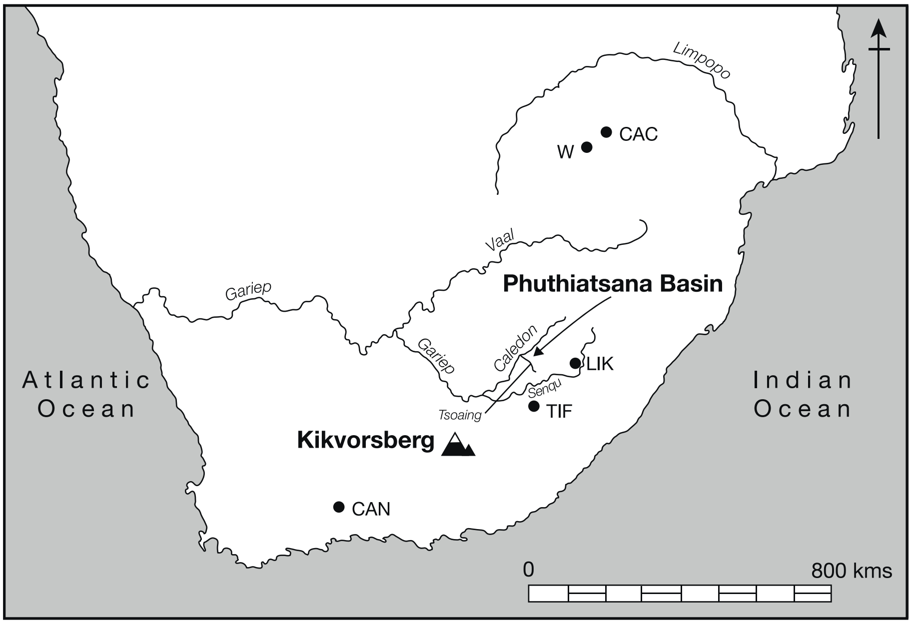

Fig. 1. Map of Lesotho and surrounding area showing the location of Likoaeng and other Later Stone Age sites (after Mitchell et al., 2006). CAC–Cold Air Cave, CAN – Cango Cave, LIK – Likoaeng, TIF – Tiffindell, W – Wonderkrater.