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Quantification of climate and vegetation from southern African Middle Stone Age sites – an application using Late Pleistocene plant material from Sibudu, South Africa

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ABSTRACT

In southern Africa numerous Middle Stone Age (MSA) sites document important steps in technological and behavioural development leading to significant changes in the lifeways of modern humans. To assess whether these cultural changes and developments may be related to environmental changes we need to ascertain past environments. To do this we apply a new quantitative method, the GIS-based Coexistence Approach (CA_{GIS}), on fossil plant material from the MSA site Sibudu, KwaZulu-Natal, South Africa. Previous qualitative environmental interpretations of the fossil fauna and flora of the site remain ambiguous. Because much of the material is anthropogenically introduced, it is difficult to distinguish between the effects of natural changes in the local vegetation and behavioural changes of the people that inhabited the shelter. CA_{GIS} can be applied to such biased assemblages and seems to be an adequate method to directly quantify palaeoclimate and vegetation parameters at an archaeological site.

The CA_{GIS} analysis shows that during the Howiesons Poort (HP) Industry winters were slightly colder and drier than present, whereas during summer, temperatures and precipitation were similar to today. Post-HP winters were drier and colder than present, presumably colder than during the HP. Summer temperatures remained the same, but summer precipitation decreased from the HP to post-HP. Vegetation cover was less than today, may be even less than during the HP. The late MSA was observably warmer than the older periods, especially during winter. At the same time summer precipitation slightly increased and vegetation became more dense, but still remained generally open similar to today's anthropogenic landscape.

Generally, climatic changes are most pronouncedly reflected in winter temperature parameters, especially in minimum winter temperatures, and to a lesser extent by changes in summer precipitation. The observed ecological trends seem to be affected mainly by variations through time in winter temperatures. This refinement of interpretation was not discernible using previous methods for analysing the Sibudu data.

1. Introduction

The challenge in reconstructing the Late Pleistocene climate of South Africa is that its isolated geographical situation makes it difficult to unravel the various parameters that influence regional climate. Chase and Meadows (2007), Holzkämper et al. (2009) and Chase (2010) discuss the issue in detail and conclude that southern African palaeoclimate does not respond to global climate change in a uniform way. Instead it is influenced by a variety of forcing mechanisms with different regional effects that do not allow the interpretation of local environments through correlation with global glacial/interglacial stages. Among the forcing mechanisms are changes in atmospheric circulation when the Westerlies transport moisture from the Atlantic Ocean onto the continent during winter, and when the easterly trade winds influence moisture transport from the Indian Ocean to eastern parts of southern Africa during summer. Changes in oceanic circulation are also important, in particular shifts of the Benguela and Agulhas Currents

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corresponding to changes in eustatic sea level and to shifts of the subtropical convergence (Chase, 2010). The absence of a clear response to these forcing mechanisms and a lack of linear correlation with Antarctic temperature records or other global archives (Chase, 2010; Caley et al., 2011), increases the importance and contribution of independent local data that provide direct information on the environment at specific times.

Another way to determine southern African past environments is to reconstruct vegetation cover and canopy density as measures of the general openness of the landscape and its changes in time. Methods available so far range from mainly qualitative, but widely used, interpretations based on mammal and plant communities, the proportion of arboreal vs. non arboreal pollen abundances (AP/NAP-ratio) when applicable (e.g. Scott, 1999), to a recently introduced quantitative method based on soil carbon isotopes applied presently only to eastern Africa (Cerling et al., 2011). Still, an objective method applicable to different kinds of environment to quantify and compare vegetation density from different sites is missing. One of the aims of this study is to test the applicability of a new approach to reconstruct vegetation density using plant fossils.

Fossil plant remains provide valuable information on past environmental conditions. Although few palaeobotanical data are available from southern Africa, some sites reveal rich and diverse fossil floras, most notably, Sibudu Cave, KwaZulu-Natal, South Africa, with its numerous fruits, seeds, pollen and charcoal flora. Such plant remains not only provide general information on past vegetation, but also serve as a sound base for the quantification of palaeoclimate and vegetation parameters.

Basically, there are two ways to quantify past environments from plant fossils: physiognomic, and nearest living relative approaches. Physiognomic approaches take advantage of empirical correlations between specific plant traits like leaf physiognomy (e.g., Wolfe, 1993; Wilf, 1997; Wiemann et al., 1998) or wood anatomy (e.g., Wheeler and Baas, 1993; Terral and Mengüal, 1999) and to a large extent they are independent of taxonomic determinations. A critical review of these methods is given by Wiemann et al. (2001).

Nearest living relative approaches rely on the close relationship between modern and fossil plants. For the Quaternary especially, it can be assumed that environmental requirements of plants have not changed significantly. Taxa with known climatic requirements that occur together in one fossil flora therefore are likely to have lived under the climatic conditions indicated by their overlapping climatic ranges. First approaches using this method were applied only on selected key taxa (Iversen, 1944; Hintikka, 1963; Grichuk, 1969; Zagwijn, 1996). Later, increasing sophistication of computer facilities allowed all available information to be included and common climatic ranges for all taxa were determined (Kershaw and Nix, 1988; Mosbrugger and Utescher, 1997; Fauquette et al., 1998; Klotz, 1999; Kühl et al., 2002; Kou et al., 2006).

Such methods are based on the taxonomic composition of the assemblages and so can generally be applied to all categories of plant material, such as pollen, wood, fruits, seeds and leaves. Because the methods depend on taxonomic determination, the more precise the identification, the more accurate and precise are the results. Thus, macrobotanical material, which often can be determined to species level, provides better results than pollen data that usually are determined to genus or family level.

As a result, some methods take advantage of empirical correlations between the composition of surface pollen spectra and climatic conditions and combine those data to increase the climatic resolution by restricting the applicability of the method to pollen floras (Guiot et al., 1989; Fauquette et al., 1998). However, in their

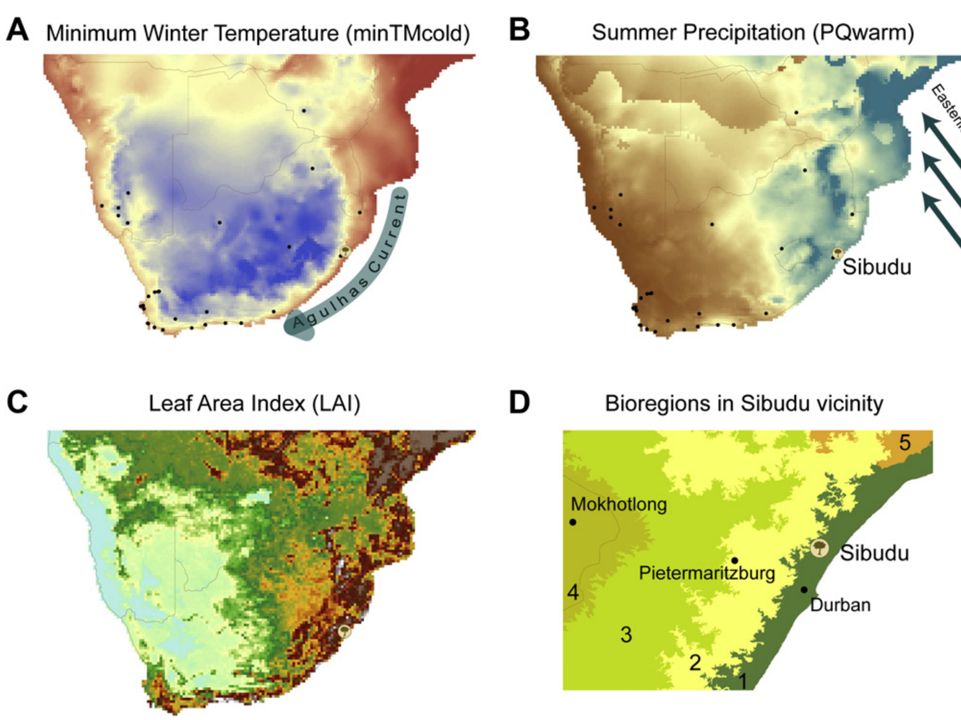

Fig. 1. Geographic position of Sibudu Cave and other MSA sites (black dots) in Southern Africa. The colour scale for map A with minMTcold range from (blue) −5.4 °C to (red) 17.5 °C, and for map B with QPwarm from (brown) 3 mm to (blue) 1142 mm. Map C shows the distribution of LAI values (based on Masson et al., 2003) ranging from zero (light blue) in the west to 5.43 (dark brown and grey) in the east. Map D gives a detail of the vegetation map of Mucina and Rutherford (2006) with bioregions, 1: Indian Ocean Coastal Belt, 2: Sub-Escarpment Savanna, 3: Sub-Escarpment Grassland, 4: Drakensberg Grassland, 5: Lowveld (from Mucina and Rutherford, 2006).