Quaternary Science Reviews 80 (2013) 29–46

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Invited review

Central southern Africa at the time of the African Humid Period: a new analysis of Holocene palaeoenvironmental and palaeoclimate data

S.L. Burrough[a,b,*], D.S.G. Thomas[a,c]

[a] School of Geography and Environment, University of Oxford, South Parks Road, Oxford OX1 3QY, UK
[b] Long Term Ecology Laboratory, Department of Zoology, University of Oxford, UK
[c] Department of Environmental and Geographical Science, University of Cape Town, South Africa

ARTICLE INFO

Article history:
Received 8 February 2013
Received in revised form
28 July 2013
Accepted 7 August 2013
Available online 27 September 2013

Keywords:
African Humid Period
Central southern Africa
Kalahari
ITCZ
CAB
Holocene

ABSTRACT

The Holocene African Humid Period (c 14.8–5.5 ka) is now recognised in high-resolution records from western Africa as well as in tropical Africa north of the equator. Establishing a clear picture of Late Quaternary, including Holocene, environmental changes in central southern Africa is proving both difficult and contentious. This is because in dryland systems in particular it can be difficult to distinguish the effects of sub-millennial scale regional climatic variability from those of major externally-forced global climate changes, and because it is essential to distinguish records of environmental drivers from those of environmental responses. We analyse and review existing records for central southern Africa, and neighbouring areas affected by the same climate systems, to understand the primary controls of regional hydrological systems during the Holocene. We then present new data from Makgadikgadi basin barchan dunes that indicate mid-late Holocene aridity following a period of marked hydrological dynamism extending from the early Holocene. We suggest that present-day conditions in central southern Africa are relatively stable compared to the early and mid-Holocene and infer that this period of relative stability in the landscape has occurred since ca 2 ka. We explain Holocene hydrological changes through analysis of changing zonal climatic influences linked to Congo Air Boundary (CAB) and Intertropical Convergence Zone (ITCZ) dynamics, the effects of which filter into the region via complex drainage basin dynamics. It is proposed that, *sensu stricto*, the AHP was *not* a spatially uniform feature of early Holocene central southern Africa.

1. Introduction

The African continent is now providing a suite of continuous and often high resolution records of environmental change that span the late Quaternary period (e.g. Tierney et al., 2010, 2013; Sinninghe Damsté et al., 2011; Ivory et al., 2012), allowing a much improved understanding of low latitude responses and relationships to global and regional scale forcing events (e.g. Tierney et al., 2011a).

Relative 'stability' characterised high latitudes during the Holocene (11.7 ka – present; Walker et al., 2012), but much of present-day arid and semiarid Africa north of the equator underwent major Holocene climatic and environmental shifts. Most notable is the African Humid Period (AHP), attributed to a stronger West African monsoon. The AHP, c 14.8–5.5 ka (DeMenocal et al., 2000; but with timing differing slightly between key studies: for example, see Ritchie et al., 1985), is well-documented from a range of proxy records from the Sahara, Sahel, and western tropical Africa that indicate higher lakes and major ecosystem changes including greening of the Sahara/Sahel belt (e.g. Kutzbach and Street-Perrott, 1985; Lézine et al., 1990; Gasse, 2000; Prentice et al., 2000). The West African monsoon is widely viewed as sensitive to climate changes in the northern high latitudes (DeMenocal et al., 2000) as well as equatorial Atlantic sea surface temperatures (Weldaeb et al., 2005). Marine core records (for example, from the Gulf of Guinea (1 in Fig. 1) (Weldeab et al., 2007) have been interpreted to show a dominant northern high latitude summer insolation forcing of monsoon dynamics at millennial timescales, and associate the AHP with a strengthened and more northerly average position of the Intertropical Convergence Zone (ITCZ).

The model of insolation influence on the ITCZ predicts 'anti-phase' drier conditions in southern hemisphere Africa during the AHP, as the average position of the ITCZ moves away from the southern subtropics and the southern hemisphere summer ITCZ

* Corresponding author. School of Geography and Environment, University of Oxford, South Parks Road, Oxford OX1 3QY, UK.
E-mail address: sallie.burrough@ouce.ox.ac.uk (S.L. Burrough).

0277-3791/$ – see front matter
http://dx.doi.org/10.1016/j.quascirev.2013.08.001

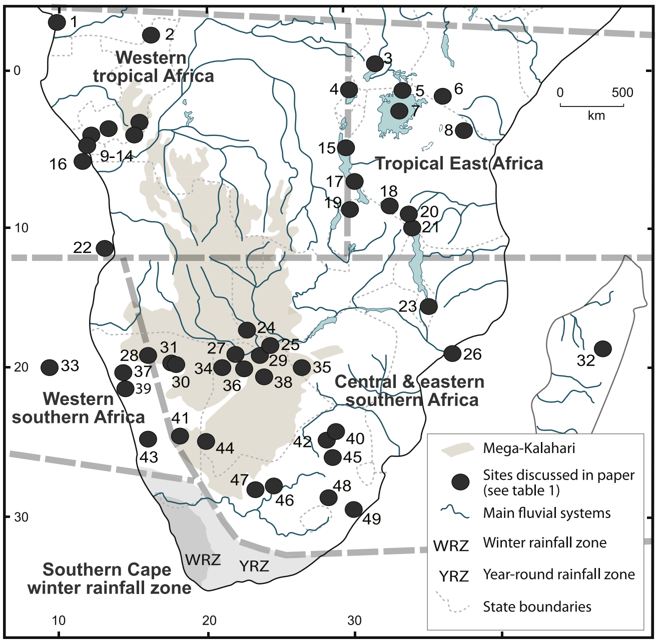

Fig. 1. Location of sites referred to in the text and in other figures (key to sites shown is in Table 1). Climatic sub-regions described in the text are indicated (c.f. Gasse et al., 2008) by the wide dashed lines. The extent of the Mega-Kalahari is shown, the region within central and eastern southern Africa is the key focus of this paper. It should be noted that some records refer to regional-scale landscape features (e.g. #24) and therefore the location of some sites is schematic. We do not consider the southern Cape region affected by the Winter Rainfall Zone (WRZ, YRZ) indicated by the shaded region.

weakens (e.g. Partridge et al., 1997). In East Africa however, as far as ~10° south, a humid period, coeval with the AHP, has been identified (e.g. Haberyan, 1987; Stager, 1988; Vincens et al., 2005). Mechanistically, this has been attributed to an orbitally-induced increase in easterly moisture-bearing trade winds off the Indian Ocean. The interpretation is that the contrast between seasonal hemispheric insolation gradients is at a maximum: an increase in either total annual rainfall (Verschuren et al., 2009) or shortening of the dry season (Tierney et al., 2011a) occurred. It has also been suggested that enhanced convergence associated with the Congo Air Boundary (CAB) may have increased precipitation in western East Africa (Tierney et al., 2011b). Emerging analyses of high resolution proxy data have also hypothesised that the AHP extended as far south as 23°S in western southern Africa (Chase et al., 2009).

Given these recent studies, this paper analyses the evidence for major Holocene climate changes in central southern Africa, particularly addressing the issue of whether the African Humid Period (AHP) occurred in the region. We define central southern Africa as broadly coincident with the ‘Mega Kalahari’ region (Thomas and Shaw, 1991; Fig. 1) and justify its assessment because it is the southern hemisphere equivalent, in aridity terms if not in circulation dynamics, of the broad dryland region of Africa north of the equator in which the Holocene AHP has been widely identified. Our discussion and analysis draws, when relevant, on data from peripheral regions, as these are influenced by the dynamics of the same climate systems and possess important, recently analysed, proxy records (Fig. 1).

First, we outline the context of central southern African precipitation dynamics and their controls, and models of Holocene African climate change drivers. Second, we analyse critical issues regarding proxy data availability and use in the region, which impact on how Holocene environmental dynamics might be perceived. We then present new evidence of Holocene landscape dynamism in central southern Africa, interpreting it in the context of other regional and sub-continental records of environmental change and an hypothesis of regional moisture controls. This allows the question of the AHP occurrence in central southern Africa to be addressed, and the causes of apparent record contradictions in complex datasets to be explained. Following Gasse et al. (2008) and to aid subsequent discussion of regional data, we subdivide southern Africa into five major climatic regions (Fig. 1): i) Western tropical Africa, dominated by moisture from the equatorial Atlantic. This region is directly affected by the West African monsoon; ii) Western southern Africa, which today includes the driest parts of the subcontinent, where the influx of moist tropical easterly air is restricted by the flow of dry air from the Atlantic coastal zone,; iii) Tropical East Africa, affected by the East African Monsoon and convergence along the Congo Air Boundary, particularly in western East Africa; iv) Central and eastern southern Africa, principally influenced by tropical easterlies bringing moisture from the Indian Ocean during the southern hemisphere summer; and v) the Southern Cape winter rainfall zone affected by rainfall carried by austral westerlies (not considered in this paper).

2. Precipitation controls in central southern Africa

Rainfall patterns in central southern Africa are dominated by the influence of two major convergence zones, the ITCZ and CAB, which generate unstable convective air and associated seasonal rainfall, and influence environmental and ecosystem gradients in the region (Thomas and Shaw, 1991). The ITCZ defines the large scale vertical motion of the equatorial Hadley cells, migrating north–south over an annual cycle and bringing moisture to central southern Africa between October and May. The CAB, a humid, unstable air confluence with seasonal zonal movement, separates the easterly trade winds from West African monsoonal wind systems, forming the northeast to southwest confluence of moisture flux from the Atlantic with that derived from the Indian Ocean (Nicholson, 1996). Westerly winds bring (predominantly winter) frontal rainfall to areas further south (i.e. the South African Cape region), parts of the southwestern coast, and occasional frontal rain to the southern interior. Expansion of the westerlies across central and eastern Africa has been proposed as a mechanism both for decreased and increased moisture signals in the interior (e.g. van Zinderen Bakker, 1976; Cockcroft et al., 1987; Chase and Meadows, 2007) during glacial maxima. There is currently little evidence that this system has played a dominant moisture-control role in central southern Africa (c.f. Lee-Thorp and Beaumont, 1995; Gasse et al., 2008; Burrough et al., 2009b; Collins et al., 2013) particularly during interglacials. As such it is not considered further in this analysis of Holocene interior moisture controls and patterns.

On annual and interannual timescales, meridional migration determines the timing and duration of rainfall seasons. On much longer timescales the average latitudinal position of these convergence zones has become the focus of Quaternary climate analyses in Africa (e.g. Tierney et al., 2011a,b). This has marked significance for the assessment and explanation of palaeoenvironmental data from the region. Superimposed on convergence zone impacts, subtropical southern Africa experiences the additional precipitation influences of both Atlantic and Indian Ocean sea surface temperatures (SSTs). Modulation of trade wind strengths and the advection of moisture on to the continent can therefore be influenced by global scale phenomena, including high latitude-induced ocean circulation changes in the Atlantic, and zonal circulation shifts in the Indian Ocean related to the El Nino Southern Oscillation, and the Indian Ocean Dipole.