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# Palaeoclimate in the Saharan and Arabian Deserts during the Middle Palaeolithic and the potential for hominin dispersals

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ABSTRACT

To disperse out of sub-Saharan Africa, it was necessary for hominins to cross the deserts of either the Sahara and/or Arabia. Thus, understanding the palaeoclimate of the Saharo-Arabian region is central to determining the role these deserts played in the peopling of the planet; when did they act as barriers and when were they more humid, opening dispersal routes across them? To address these questions we have conducted a temporal and spatial evaluation of dated sites from 20 to 350 ka using combined probability density function (PDF) and geographical Information System (GIS) analyses of all sites dated using uranium/thorium (U/TH) or optically stimulated luminescence (OSL) methods. Radiocarbon dates were not considered because of contamination problems in this time range. The results show that during MIS 2 there is little evidence for humidity in Arabia as would be expected during the height of the last glacial maximum, however, the Sahara shows a sharp rise in probability at the beginning of MIS 2, peaking near the boundary with MIS 3 at ~29 ka. There appear to be brief periods of humidity in MIS 3 and 6, though at different times in the Sahara (ca. 37, 44, 138, 154 and 180 ka) and Arabia (ca. 40, 54 and 163 ka). During MIS 5, both regions show much evidence for humidity, with PDF peaks corresponding to insolation maxima, though not all maxima are represented in either the Saharan or Arabian record. This situation can be explained by eccentricity-modulated precession: when eccentricity is strong, insolation is enhanced (but also more variable) and the desert climate is generally more humid, particularly at times of high insolation. The opposite happens when eccentricity is low, and deserts tend to be more arid, but local factors exert more of an influence on climate, affecting the timing and strength of the brief humid periods experienced, so that they no longer coincide with insolation maxima. The spatial distribution of humid sites is compatible with a number of different modern human dispersal theories. Southern Arabia experienced humid periods centred on 54 ka and 125 ka, and this could have facilitated dispersal from east Africa to southern Arabia and beyond via the Bab el Mandab. The Sahara shows considerable evidence for humidity during MIS 5 and may have had dispersal across its expanse at this time.



## 1. Introduction

It is becoming increasingly clear that the Saharan and Arabian Deserts were not always arid as they are today (Fleitmann et al., 2003; Drake et al., 2008; Petraglia et al., 2011, 2012), yet we are only just beginning to recognize the timing of these changes and their extent and consequences (e.g. Kuper and Kröpelin, 2006; Drake et al., 2011; Lézine et al., 2011). Understanding past climate change in these regions is important for: 1) determining when these areas were humid and when they were arid; 2) establishing the causes of these arid-humid fluctuations; 3) establishing when it was possible for hominins to occupy these regions; and 4) indicating how extensive this occupation could have been, thus elucidating the role the deserts played in forming barriers, or providing corridors, for the dispersal of hominins across them. The latter three questions are becoming increasingly important as archaeological and genetic evidence both suggest anatomically modern humans evolved in sub-Saharan Africa (e.g. McBrearty and Brooks, 2000; Barham and Mitchell, 2008; Tishkoff et al., 2009) and subsequently dispersed from Africa into adjacent continents. To occupy regions further afield they must have crossed either the Saharan or Arabian Deserts. A number of routes have been proposed, including the Nile corridor (Van Peer, 1998), the 'Green Sahara' route (Drake et al., 2011) and the coastal route, either around the Red Sea (Stringer, 2000), or across the Bab el Mandab

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(Kingdon, 1993) and then along the Arabian coast (Mellars, 2006). None of these routes are as yet well established.

Saharan and Arabian climate change and associated hominin dispersals are likely to have been important during the Middle and Upper Pleistocene as lithic artefacts from this period have been found dispersed throughout large areas of these deserts (e.g. Armitage et al., 2011; Drake et al., 2011; Petraglia et al., 2011, 2012; Rose et al., 2011; Groucutt and Petraglia, 2012). Furthermore, dispersal of modern humans out of Africa may well have occurred at this time, using one or more of the above-mentioned dispersal routes. Yet our understanding of climate changes in the Sahara and Arabia at this time is fragmentary. No integrated analysis has yet been conducted and thus our understanding of the synchronicity between Saharan and Arabian climate change has not been comprehensively evaluated. This could be an important issue for hominin dispersals as some of the proposed routes could have involved dispersal through both deserts (e.g. migrants using the Nile Corridor or the Green Sahara routes may then have crossed the Arabian Desert).

## 2. Saharo-Arabian climate and hypotheses explaining the causes of past climate changes

Our understanding of the causes and timing of Saharo-Arabian climate change are at present limited. There are two competing hypotheses on the causes of climate change in tropical deserts. The first is that the change is driven by high latitude processes, with humid periods during interglacials, arid ones during glacials and a cyclicity of roughly 100 ka (Cooke et al., 1993). The second hypothesis is that climate change is controlled by the enhancement and decline of the monsoon system, driven by the precession of the equinoxes, a process that manifests itself predominantly at low latitudes with a cyclicity of about 26 ka (Trauth et al., 2009).

Recent research indicates that both these hypotheses could play a role in Saharo-Arabian climate change because the desert climate is controlled by two sources of rainfall. Southern regions receive monsoonal rainfall and northern parts obtain precipitation from North Atlantic and Mediterranean Westerlies. Each of these rainfall sources is controlled by a different hypothesis outlined above. The monsoon moves north, and the Saharo-Arabian Deserts contract, at times when precession produces higher solar insolation over the deserts. Monsoon enhancement occurs because increased solar radiation strengthens the thermal contrast between the land and the ocean, causing the monsoon to move northwards, further into the desert belt (Kutzbach and Liu, 1997). The factors that control the location of the mid-latitude Westerlies are less well understood but recent research appears to show that they vary with global temperatures (Toggweiler and Russell, 2008; Blome et al., 2012), strengthening and contracting towards the poles during warm periods (interglacials), or conversely decreasing in strength and expanding towards the equator during colder periods (glacials). Thus the Saharo-Arabian Desert can be expected to contract due to the southward movement of Westerlies when a ‘goldilocks scenario’ prevails whereby the global climate is cool enough to keep the Westerlies in a southern position, but not too cool to make them so weak they do not have enough strength to bring rainfall into the desert.

Given these two opposing climate mechanisms, there could be times when the Westerlies and monsoons converge and the deserts become green, forming dispersal routes across them. We hypothesise that this is likely to occur in the earlier stages of interglacial periods when insolation is high but the Earth is still relatively cool.

## 3. Aims and objectives

This paper reports a temporal evaluation of dated Saharan and Arabian ‘humid deposits’ during the Middle and Upper Pleistocene (from 350 to 20 ka) to evaluate our understanding of climate change in the context of human evolution. Information on sediments deposited during humid periods was compiled from the HOPE ENV Arabian palaeoenvironmental database (Parker and Rose, 2008; Parker, 2009) and from an equivalent database of Saharan data produced by Drake and Breeze (in press) that is broadly analogous to that recently published by Smith (2012), though with a series of statistical filters and selection criteria applied (see below). From these data, probability density function (PDF) curves were calculated for both regions in order to determine humid periods, and to permit cross-region comparisons of the timing of pluvial periods, whilst also accounting for the errors associated with the dates. These PDF curves were compared to each other and to select marine records (oxygen isotopes and aeolian dust) and orbital parameters (eccentricity and insolation). Doing this provides not only a comparison of Saharan and Arabian terrestrial palaeoclimate records but also an assessment of land and ocean records. Finally, in order to determine the region that the curves represent during each of the identified humid periods the location of the samples were mapped using ARC GIS, and the spatial distribution of the dates was evaluated.

## 4. Materials and methods

### 4.1. Data sources

The databases of Parker (2009), and Drake and Breeze (in press) have assembled published data from deposits representative of humid conditions within the respective regions, and record (amongst other parameters) spatial and temporal information associated with dated samples, lab identification codes, and parent publications. Deposits utilised as evidence for humidity were dated lacustrine and fluvial deposits, palaeosols, calcretes, speleothems, and tufas, travertines and sinters. Quaternary hydrothermal travertines from the northern Sahara in Morocco have not been included as pluvial proxies, as Akdim and Julia (2005) assert that travertine formation in this region is likely due to an interplay of hydrothermal activity and precipitation, resulting in a lag between precipitation and travertine formation (Weisrock et al., 2008).

### 4.2. Probability density function analyses

Probability density function (PDF) analyses have increasingly been used as a method to identify clustering of dates with errors during large-scale regional assessments, such as reconstructions of European Holocene fluvial geochronology (Macklin et al., 2006, 2010) and of global loess accumulation phases (Singhvi et al., 2001). PDF analyses have formerly been applied in an Arabian context to Pleistocene alluvial fan geochronology (Blechschmidt et al., 2009) and aeolian deposition studies in the Wahiba sands (Preusser, 2009) and to regional palaeoenvironmental summaries including radiocarbon dates (Glennie and Singhvi, 2002; Parker and Rose, 2008; Parker, 2009). Within North Africa PDFs have also been used to assess Holocene fluvial activity in Tunisian floodplains (Zielhofer et al., 2008) and to evaluate Saharan paleoclimate (Smith, 2012).

PDF analyses were applied to the Saharan and Arabian humidity datasets for the period from 350 to 20 ka. Samples were included in the analysis if data points came from within today’s desert proper (here regarded as regions with average rainfall below 200 mm), as well as those from surrounding semi-arid areas. The latter regions were included as at times during the Middle and Upper Pleistocene, when the Saharan and Arabian Deserts were larger, they would have become deserts. But also, conversely, when these desert fringe areas were humid but the desert proper still arid, the source