Chapter 9

Late Quaternary Environmental Change and Human Occupation of the Southern African Interior

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Abstract The interior southern African basin (Kalahari) is a remarkable region, with a complex and dynamic environmental history and a long record of utilization by human populations during the late Quaternary. Paleoenvironmental reconstructions are beginning to provide a spatially detailed record of landscape and hydrological dynamics in the Kalahari, with a strong chronometric underpinning for records of environmental extremes. Theories concerning the distribution of early people in the landscape place great importance on the temporal dynamics of water availability, and may be particularly relevant in the Kalahari where there is significant evidence of hydrologic/climatic-driven landscape change. High amplitude environmental variability during MIS 6-2 is evidenced by periods of dune building within currently stabilized dunefields and the intermittent existence of large lacustrine systems such as Megalake Makgadikgadi that remain all but ephemerally dry under present-day conditions. That the wider Kalahari was, at times, a key resource for Stone Age populations is evident from the extensive occurrence of stone tools, most notably in association with the fluvial networks and lake basins of the Okavango-Chobe-Zambezi system. Today, these riparian corridors link the semiarid desert region to the southern subtropics and, in the past, drove environmental change in the Kalahari, potentially impacting the occupation and dispersal of hominins within the interior southern African basin.

Keywords Kalahari • Paleohydrology • Paleoenvironmental change • Dunes • Lakes • Stone Age archaeology

Introduction

Attempts to draw correlations between climatic events and trends and the African Stone Age archeological record are increasingly prevalent within the Quaternary literature (e.g., Scholz et al. 2007; Jacobs and Roberts 2009; Stager et al. 2011). These attempt to establish the causes of both behavioral changes by, and the geographical distribution of, early modern humans. Environmental contributions to hominin dispersal out of Africa are a particular point of interest (Maslin and Christiensen 2007). The influence of aridity on human resource use and mobility is often emphasized, though the spatial complexities of both landscape and climate dynamics are frequently overlooked (Thomas and Burrough 2012).

Within southern Africa, such human environment associations have been strongly focused on Middle Stone Age (MSA) technological change within coastal sites (e.g., Jacobs et al. 2008). Significantly less is known about early people in the southern African interior, despite the genetic and archeological evidence for sustained periods of regional occupation during the late Quaternary. The deficit of research is largely a consequence of the nature of the environment of the interior, which, by consequence of its geological history, offers few closed sites and, due to relatively arid conditions, preserves little organic material. Until recently, difficulties of paleoenvironmental reconstruction in present-day deserts have hindered our understanding of their long-term landscape evolution and environmental change. Technological and methodological advances, however, are now facilitating the development of robust records of Quaternary landscape dynamics: in the Kalahari, these records reveal environmental changes of significant amplitude and frequency during MIS 6-2. This chapter examines the potential consequences of this dynamic environmental history for early humans, the evidence for which is abundant but remains poorly investigated. Critically, however, no consideration of the dynamics of past climatic systems can be effectively conducted without assessing the nature and

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Sacha C. Jones and Brian A. Stewart (eds.), *Africa from MIS 6-2: Population Dynamics and Paleoenvironments*,
Vertebrate Paleobiology and Paleoanthropology, DOI 10.1007/978-94-017-7520-5_9

behavior of the climatic systems dominant in an area today, since past conditions are conventionally presented in terms of changes from the present. This chapter begins with a consideration of the controls on central southern African climate today, before reviewing the paleoenvironmental records derived from within the region itself.

Climate and Environment of the Kalahari Basin

The Kalahari basin, a region in excess of 2.5 million km^2 and comprising the largest continuous sand sea on earth (Thomas and Shaw 1991), dominates the southern African interior. The area north and west of the Okavango Delta is sometimes called the Northern Kalahari; the heart of the region, including the area occupied by the Okavango Delta and Makgadikgadi basin, the Middle Kalahari; and the remainder of the basin, the Southern Kalahari, following Passarge (1904). Geologically, it is characterized by Late Cretaceous and Early Tertiary sedimentary rocks, and overlain by unconsolidated sands, weathered and reworked from the underlying lithology during the Pliocene and Quaternary (Haddon 2005). This sand mantled landscape has been subsequently molded into a significant suite of depositional landforms dynamic over Quaternary timescales. These Kalahari sediments straddle a significant latitudinal climatic and environmental gradient ranging from the miombo and montane forests of Zambia and Angola (where mean annual precipitation [MAP] exceeds 1000 mm/year) to the arid deserts of southwest Botswana and the Northern Cape of South Africa (MAP < 200 mm/yr)

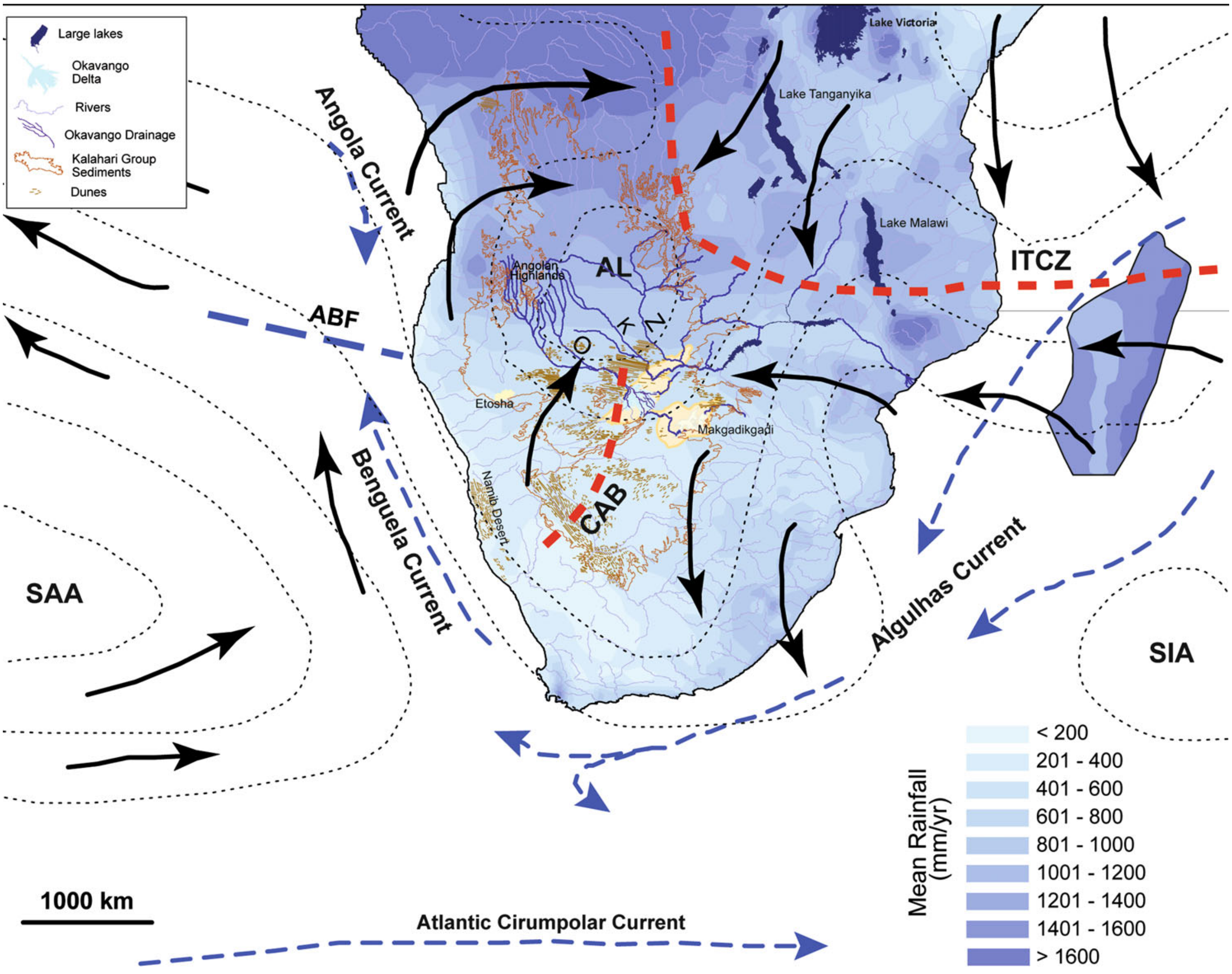

Fig. 9.1 Hydrological systems and dunefields of the Kalahari and the circulation systems affecting southern Africa (modified after Nicholson 1996; Gasse et al. 2008). *O* Okavango River; *K* Kwando River; *Z* Zambezi River; *SAA* South Atlantic Anticyclone; *SIA* South Indian Anticyclone; *AL* Angolan Low; *ABF* Angola-Benguela Front. The mean austral summer position of the ITCZ (Intertropical Convergence Zone) and CAB (Congo Air boundary) and major climatic regions (from Gasse et al. 2008) are indicated

(Fig. 9.1). This gradient can be measured not only in terms of mean precipitation amount but also in the length of the wet season (decreasing from northeast to southwest) and the degree of interannual variability (increasing from northeast to southwest). The Kalahari lies within southern Africa's semi-arid subtropical high-pressure belt, and is dominated by the Southern Hemisphere summer migration of the Inter Tropical Convergence Zone (ITCZ). This brings with it heavy convective rainfall between November and April, and migrates north of the equator in the austral winter allowing the dominance of high-pressure systems and dry conditions over the southern African interior.

In addition, synoptic conditions such as the presence of an eastern equatorial trough (Taljaard 1981) are responsible for low-level easterly moisture fluxes, originating from the Indian Ocean and facilitating the presence of unstable uplifting air via tropical-extratropical interactions. In the northern parts of the Kalahari, summer rainfall can occur in conjunction with recurved South Atlantic air, which enters the region from the Congo and Angola; while in the Middle and Southern Kalahari, easterlies blowing around the Indian Ocean high are a more likely source of rainfall (Thomas and Shaw 1991). In the southwestern Kalahari, the occasional passage of frontal systems associated with Atlantic westerlies that dominate the winter rainfall zone also makes a contribution to the annual rainfall during the winter season (Tyson 1986). The Indian Ocean is the major moisture source for most of the summer rainfall zone driving an additional zonal rainfall pattern that causes the eastern region of southern Africa to be wetter than the west. Within the Middle and Southern Kalahari, low annual precipitation and high rates of evaporation result in a region wide moisture deficit and a notable lack of surface water outside of the Okavango delta and its northerly perennial fluvial channels. It is the reorganization of these circulation systems that are frequently invoked to explain Quaternary climatic and environmental change in the Kalahari during MIS 6-2, typically characterized as regional transitions between humid and arid conditions, and, by implication, with important consequences for early human populations.

Wetlands in a Dryland: The Importance of Hydrology to Interior Southern Africa

The presence of surface water, in particular the hydrological systems fed by tropical rainfall that terminate in the Middle Kalahari, play a critical role in the survival of many species in the Kalahari, driving the migratory patterns of many large mammal and bird species. This area is primarily fed by the tropically-sourced Cubango and Cuito Rivers. These are the major tributaries of the endoreic Okavango River, the Kwando/Chobe drainage system and, prior to its Pliocene (Lister 1979) or Early-Mid Pleistocene (Bond 1975; Shaw and Thomas 1988) capture and coastal reorientation, the Upper Zambezi. Some surface water reaches the eastern part of the Middle Kalahari via small rivers sourced in western Zimbabwe, notably the Nata, which flows seasonally into Sua Pan, in the east of the Makgadikgadi system.

The northern rivers share a common source in the Angolan highlands, ~1000 km from the Middle Kalahari itself. The Lunda Divide forms a watershed on the Angola plateau and separates rivers, such as the Cuango, that flow north into the Congo River from those flowing in a southerly direction. A few tributaries join the Zambezi, but most, other than the Kwando, constitute the active catchment of the Okavango River. The Kunene also has its source in this region but takes a more westerly course toward the Atlantic. Other smaller rivers (*oshanas*) flow south forming the internal drainage of the Etosha Basin. Many of these rivers and streams are highly seasonal. For example, the tributaries of the Cubango remain completely dry for much of the year.

At 18° S, the Okavango, Kwando, and Zambezi Rivers reach the tectonically active zones of the Gwembe Trough and Okavango Depression (Thomas and Shaw 1991). Here, the Okavango terminates in an alluvial fan, known as the "the Okavango Delta" – a "wet zone" in a dryland region, now internationally renowned for its rich biodiversity. The morphometry and hydrology of this alluvial fan is dominated by two major conjugate faults: a larger north easterly striking "half-graben," which holds the Delta; and a smaller north westerly striking faultline (Gumbricht et al. 2001) occupied by the Panhandle (Scholz et al. 1976; McCarthy and Hancox 2000). The total catchment of the Okavango River basin is approximately 530,000 km^2. Under present-day conditions, however, 95% of the Okavango's flow is contributed from an area of only 135,000 km^2, situated within Angola (Andersson et al. 2003). The easterly catchment (Cuito River) responds to instabilities in tropical lows in the Indian Ocean easterlies, while the western catchment (Cubango River) is more strongly influenced by variability in the Atlantic equatorial westerlies (McCarthy et al. 2000). Approximately 450 mm/yr (or 5×10^9 m^3) of local precipitation falls annually over the delta itself (McCarthy and Hancox 2000). This is usually confined to the period between December and February compared to a mean annual inflow into the fan of 11×10^9 m^3 (Ellery and McCarthy 1998). The majority of surface water takes months to arrive from its northerly source and peaks as a flood wave during the winter dry season. Critically then, the hydrological regime of the Middle Kalahari, and the functioning of much of its biodiversity, is principally controlled by the climatology of the tropics at 12° S rather than locally in the region of the Okavango fan (~18°–21° S).

The common catchment region of the Zambezi, Kwando, and Okavango Rivers means that changes in their hydrological regimes are likely to co-vary over time. Mazvimavi and Wolski (2006) demonstrated that the average annual discharges of the Okavango and Zambezi Rivers are closely related, with a correlation coefficient of 0.70. This has important implications for flood regimes of the southern African interior, both under contemporary conditions and in relation to past Quaternary environmental change. The Kwando is connected to the Okavango system via the Makwegana (Selinda Spillway), but today diverts east to the Zambezi via the Linyanti and Chobe Rivers, forming ephemeral connections between these three substantial river systems (Fig. 9.3). The Mambova Falls marks the Chobe-Zambezi confluence where the rivers flow east across a Karoo basalt ridge along a north-south-oriented fault line. During peak flows, the impediment of the ridge results in an annual backflood up to 20 km westwards along the Chobe (Thomas and Shaw 1991). Evidence for periods of extreme flooding during the Quaternary is derived from erosional notches cut along the hill slope at 935 m above mean sea level (amsl), from calcretized alluvial terraces at 932–934 m amsl (Shaw and Thomas 1988), and from shorelines bounding the backflooding zone (Burrough and Thomas 2008). It is hypothesized that Zambezi flow made a significant contribution to the surface water of the Middle Kalahari during these periods of high discharge and back-ponding (Shaw and Thomas 1988; Burrough and Thomas 2008), providing an important link between these two sizeable hydrological systems during the Quaternary.

Quaternary Environmental Dynamics in the Kalahari

The magnitude of past environmental changes within the Kalahari has left a strong signature in the landscape that has been recognized and documented for more than 100 years (Livingstone 1858; Passarge 1904; Grove 1969; Thomas and Shaw 2002). Shifts in landscape processes in response to prevailing climatic events and trends have been encoded into a range of archives including extensive now largely inactive dunefields, speleothems, fluvial channels, and today's predominantly dry lake systems. Such juxtaposed signals of extreme "wet" conditions and extreme "dry" conditions testify to the amplitude of environmental change in the southern African interior. The drivers of large-scale landscape and environmental shifts remain poorly understood, but hypotheses regarding spatial reorganizations of climate and their causal mechanisms have been put forward by a number of researchers. These can be summarized as: (1) the latitudinal displacement of major circulation features; (2) intensification or weakening of major circulation features; and (3) longitudinal displacement of circulation features (c.f. Tyson 1999; Chase and Meadows 2007; Singarayer and Burrough 2015).

Dryland landscapes are particularly challenging environments in which to assess the nature of past climate changes. Regions such as the Kalahari, one of the driest parts of Africa, are often devoid of, or have only limited, biological and geochemical proxies or closed sites. This restricts their potential for paleoenvironmental reconstructions. The reliance on spatially diverse and fragmentary records has resulted in contradictory, and often oversimplified, explanations of climatic change that fall short of providing the precision with which to adequately test the climatic hypotheses described above. More recently, marked advances in the ability to establish, and date, suitable proxy records from such areas, have enabled significant steps to be made toward the reconstruction of a more detailed picture of environmental dynamics (Drake and Bristow 2006; Burrough et al. 2009a) and a necessary reevaluation of the interpretation of these data. These geoproxy records constitute an important facet in the understanding of Late Pleistocene dynamics of the Kalahari. Their interpretation is considered below. Following this, the relationships between archaeology and paleoenvironments are examined. This examination integrates other, limited-occurrence paleoenvironmental proxies from specific site associations, though it is the picture of past landscape dynamics as a whole, including the spatial variance of environmental conditions, that generates the perspective that is necessary to understand hominin usage of the Kalahari environment.

Kalahari Dune Archives

Dunefields dominate large areas of the Kalahari. These in turn are primarily composed of linear sand dunes that, unlike more mobile transverse and barchans dunes, have a greater propensity to accumulate and store sand over time, due to their formative mechanism (see, for example, Thomas 1992; Lancaster 2011). They are therefore potentially important archives of past environmental conditions, and have been analyzed in this way in the Kalahari since Flint and Bond (1968). Following technological and methodological developments, more than 200 luminescence ages for dunefield activity have been produced in the last 20 years providing information on dune activity that extends back to 185 ka. However, far from increasing the certainty with which we are able to interpret the environmental change occurring in MIS 6-2, the growing body of luminescence ages has destabilized initial interpretations (e.g., Stokes et al. 1997) and is difficult to interpret when synthesized as a regional body of data (Thomas and Burrough 2013). Recent analyses

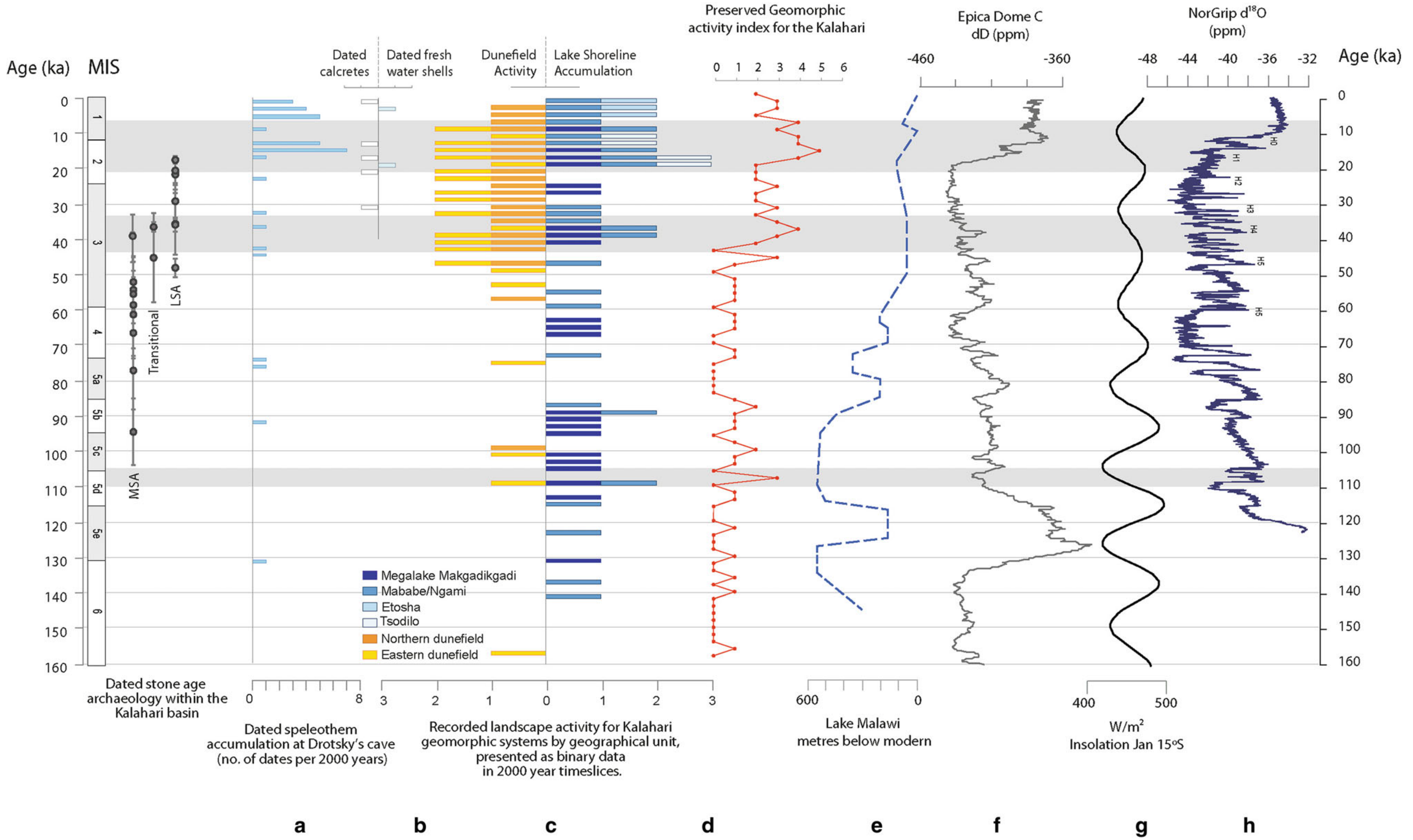

Fig. 9.2 Paleoenvironmental records from the Kalahari in the context of regional and global records. **a** Dated speleothem accumulation shown as number of dates per 2000 year time slice at Drotsky's cave (interpreted as indicative of wetter periods) (Cooke and Verhagen 1977; Shaw and Cooke 1986; Brook et al. 1996); **b** Dated calcretes and fresh water shells from the Middle Kalahari (Shaw 1985; Shaw and Thomas 1993); **c** Summary of geoproxy records (active dunefields and lake highstands) within the Kalahari region; **d** Preserved geomorphic activity index, i.e., total number of geographical units preserving a record in each 2 ka time slice (Thomas and Burrough 2012); **e** Lake Malawi lake level status derived from the synthesis of sediment core paleoclimate indicators with observations from seismic reflection records (Scholz et al. 2011); **f** EPICA Dome C Ice Cores Deuterium Data (Jouzel et al. 2007); **g** Insolation at 15° S (Berger 1992); **h** NorGRIP d^{18}O record (NorGRIP members 2004). Archaeological dates relating to the MSA/LSA transition (Feathers et al. 1997; Barham 2000; Robbins et al. 2000; Brook et al. 2008; Ivester et al. 2010) are shown for comparison

suggest that in the driest parts of the interior, particularly in the southwest Kalahari, the landscape lies close to mobility thresholds such that for dune ages used as proxies, short-term multiyear drought events may be indistinguishable from significant arid episodes (Thomas and Burrough 2012; Bailey and Thomas 2014). Combined with the issue of discontinuous preservation, current analyses propose that these records should be viewed in the context of regional landscape activation and transition rather than in simple terms as evidence of "arid" (Stokes et al. 1997) or "windy" (Chase and Thomas 2006) periods.

By contrast, dunefields from more northerly or easterly areas of the Kalahari, which lie wholly within the range of the annual ITCZ-induced wet season and that are often heavily wooded today, are likely only to become mobile during extremely prolonged periods of dryness sufficient to see significant die-off of vegetation. Even allowing for the potential for incomplete preservation of sediments from past dune building events (due to their potential for reactivation during later periods of dune dynamics), these features are paleoenvironmentally more significant than their more southerly counterparts. While they are less sensitive to short-term episodic activation, they provide a more significant proxy for Precipitation-Evaporation (P-E) deficits in the context of large-scale Quaternary environmental change. Theoretical studies suggest that the greatest preservation potential for accumulation phases of linear dune proxies is the transition period out of a mean dry or windy phase (Kocurek 1998; Telfer et al. 2010), though not all transitions may be preserved if further periods of aeolian activity are severe enough to remobilize entire dunes. The effect of preservation potential on the production of a robust record of past dune activity can also be enhanced by the intrinsically unsystematic sampling of dunefields. This arises from sampling individual dunes as representative landforms of a large area and can to some extent be removed by combining data from individual sample locations and reducing a data set to a binary record of "switched on" or "switched off" state at the dunefield-scale (Fig. 9.2).

Kalahari Lake Archives

In addition to dune mobilization, another important regional proxy is the suite of shoreline deposits associated with the, now-dry, paleolake Makgadikgadi system at the terminal sump of the Okavango. These landforms have undergone detailed mapping, surveying, and investigation for many decades, and the recognition of the former presence of a large lake system was the subject of numerous publications (e.g., Cooke and Verstappen 1984; Shaw 1985; Shaw and Cooke 1986; Shaw and Thomas 1993). It is only recently that a systematic dating program has enabled a detailed analysis of the timing of lake highstand events to be established (Shaw et al. 2003; Burrough et al. 2007, 2009a; Burrough and Thomas 2008). Like Kalahari dunes, these landform proxies should be interpreted with care. Two of the basins that make up the paleolake system (Mababe and Ngami) are fed directly by tributaries from the Okavango delta and can become partially decoupled from regional environmental change, responding instead to avulsion within the Okavango fan (Fig. 9.3). To the southeast of the fan, a horst feature separates the delta domain from the Makgadikgadi Depression (Haddon 2005). These are connected by the down-cutting of the Boteti River, which acts much like an overspill valve. The conservative record of lake highstand phases is thus more robustly derived from the shorelines of the Makgadikgadi sump basin. Highstands in this basin are usually referred to as "megalake" events, since the implication of shoreline construction here is the existence of a 66,000 km^2 lake, similar in size to Lake Victoria in East Africa, the world's largest tropical lake.

Like linear dunes, these sandy lake shorelines appear to be compound features and accumulated over multiple lake highstand events punctuated by more seasonal conditions that facilitated the formation of pedogenic and non-pedogenic calcretes (Nash and McClaren 2003). Like dunes, these geoproxies offer a discontinuous snapshot into the past enabling us to place the transitions from the extremes of regional environmental conditions within the context of global change, but offer little information about the subtleties of intervening gaps in the record (c.f. Burrough et al. 2009a).

Dating suggests that megalake Makgadikgadi highstands were centered on 131 ± 11 ka; 105 ± 4 ka and 92 ± 2 ka with subsequent paleolake transgression phases occurring between 66 ± 5 ka and 62 ± 8 ka; 40 ± 4 ka–37 ± 5 ka and 28 ± 2 ka–25 ± 3 ka (weighted means of these high phases are centered on 64 ± 2 ka; 39 ± 2 ka and 27 ± 1 ka, but do not preclude significant fluctuation of lake levels within each phase) (Burrough et al. 2009a). A very distinct high lake level phase also occurred at 17 ± 1.5 ka (between 19 ± 2 ka and 15 ± 2 ka). What remain poorly understood, however, are the specific drivers of these hydrological changes and whether high lake phases occurred when *local* climates were wetter, drier, or comparable to those of today. Simply invoking local climate change alone is oversimplistic: it has long been suggested that the magnitude of sustained rainfall increase over the lake itself required to fill the basin is so high to be improbable (Cooke and Verstappen 1984; Shaw 1985; Burrough et al. 2007). The key to filling the extensive Kalahari lake systems lies in understanding its relationship to the rivers flowing from the north with tropical sources. The driving force of these major hydrological excursions is thus relevant to understanding the occupation and mobility of hominins in the Kalahari, in as much as it determines the wider geographical pattern of water availability in the southern African interior.

The persistent dominance of easterly wind systems during the Quaternary is evidenced by the orientation of shorelines (wave-built shorelines are found on the western boundaries of Kalahari lake basins). However, both Nash et al. (2006) and Burrough et al. (2009b) note the possible role of recurved Atlantic moisture in driving hydrological change via increases in P-E balance in the upper western catchment. The long latitudinal extent of the hydrological system that feeds the paleolake could, theoretically, enable a tropical wet pulse to be imported into a dry Kalahari. While this implies a possible decoupling from local environmental conditions and the feasibility of large lakes in a dry environment, HADCM3 coupled ocean atmosphere model simulations suggest that the very large lake surface area of a full Makgadikgadi system (66,000 km^2) would have had a significant feedback effect on the local and regional climate (Burrough et al. 2009b). These simulations predict a resultant increase in the local P-E balance (i.e., in effective rainfall) by up to 15%, with associated changes in vegetation (Burrough et al. 2009, 2012). Biophysical feedbacks, which are often insufficiently considered in paleoenvironmental reconstructions, render our ability to distinguish between the drivers and responses of environmental change very challenging. In this case, they imply that even if large lake systems could exist under arid conditions in the Kalahari, an important consequence would be the localized environmental and ecosystem modification toward conditions more amenable to both humans and animals alike.

Together, these geoproxy records suggest that, far from the largely geomorphologically inactive landscape that characterizes much of the Kalahari under contemporary conditions, the region is, in fact, extraordinarily dynamic over long timescales and has repeatedly experienced both extreme water deficits and excesses with significant implications for both hominins and other taxa. The resolution of these geoproxies is highly influenced by preservation and is currently often insufficiently fine-scale to allow unpicking of discrete wet or dry “events”. Vitally, however, in the absence of high-resolution biological proxies, these geoproxies do capture a major, and often ignored, component of environmental dynamics, namely *variability* (Thomas and Burrough 2012). This would have played a crucial role in driving innovation, survival, and the capacity of hominins to move successfully (Maslin and Christensen 2007). Detectable periods of extreme climatic variability/change resulting in significant landscape activity are highlighted in Fig. 9.2. These suggest that the relative amplitude and frequency of preserved change was particularly marked on the cusp of the transitions into and out of the last glacial period at ~110 ka and 19–12 ka, respectively, and during MIS 3 at 40–36 ka. Further evidence from the Stampriet Aquifer in the southwest Kalahari (Stute and Talma 1998) suggests that at least the later transition, a period for which we have a suite of paleoenvironmental records, was also a time of marked temperature change. This additionally drove competition between plant species (Scott et al. 2008, 2012), and resulted in significant changes to prevailing vegetation assemblages. Transitional periods in the Kalahari during MIS 6-2, characterized by large-scale landscape and ecosystem change, are thus likely to have been testing times for humans and animals alike requiring a significant level of adaptive capacity in the form of innovation and/or mobility.

Populations and Paleoenvironmental Change in the Kalahari

Regional Records

Whether seasonal or on longer timescales, current geoarchaeological theory attaches great importance to the role of climatic and environmental change in providing environmental constraints and opportunities for movement, dispersal, and adaptive resource use by humans. Like modern populations in southern Africa, Late Pleistocene groups would have been strongly dependent on surface water availability, particularly during times of increased aridity, and, as today, would have been vulnerable both to extreme floods and droughts (Flint 2006). The migratory patterns of many species, particularly ungulates, within the continental interior are highly dependent on the dynamics of the Okavango flood pulse. Historically, animals have moved from dry season permanent water bodies to temporary water holes in the wet season grasslands including millions of springbok and wildebeest that moved from the central Kalahari to the southwest and hundreds of thousands of zebra and wildebeest that seasonally migrated from the Boteti River to wet season pools in the Makgadikgadi grasslands (Bartlam Brooks et al. 2011). Until the development of modern economies in the Kalahari from the mid-twentieth century onwards, mobility, both by hunter-gatherers and pastoralists, had also been a widespread practice (e.g., Sporton and Twyman 2002; Hitchcock 2002) as a legitimate resilience strategy to resource fluctuations.

Brooks (1984) investigated the varying seasonal landscape use by modern Juc’hoansi (!Kung) San in the northwest Kalahari and found that dispersed and highly mobile wet season groups aggregate near water during the dry season. It is these aggregation camps, at resource-rich sites, that are occupied for longer periods and leave a visible record of usage. If these patterns hold for prehistory, archeological visibility in the landscape should strongly correlate with areas where water is available during Late Pleistocene dry phases. In Zambia, investigations at sites such as Kabwe, Kalambo Falls, Twin Rivers and in particular at Mumbwa Caves have demonstrated marked changes in archeological visibility through time (Barham 2000). This has led to hypotheses that fluvial systems may have formed key refugia at times of regionally dry conditions during the Pleistocene, when occupation of sites distant from water sources was absent or limited (Barham 2001; Avery 2003). Taking these interconnected systems as a whole, the North-South fluvial corridors of the interior that bring flood pulses from the tropics, together with the basin sumps in which these systems terminate, are likely to have been critical as the last vestiges of perennial food and water at times of regional water deficit.

Whether or not such mobility is visible in the archeological record of the drier Kalahari zone has yet to be systematically tested. Despite the depth of Kalahari prehistory, a general consensus that the region was "a backwater of archaeological interest" (Walker 1998: 67), has led to a dearth of archeological investigations. The lack of closed, stratified sites has greatly contributed to the continued deficit of regional Stone Age archeological research. As a consequence, with the exception of the sites of Tsodilo Hills and ≠Gi, little is known about the archaeology of the African subcontinental interior, particularly when compared to the major advances made in the last two decades in regions to the south and north.

Stone Age archeological assemblages, however, are numerous and are frequently noted within the gray literature. The site register of the National Museum of Botswana records 15 sites with tool typologies designated as Early Stone Age (ESA), more than 50 MSA archeological occurrences and more than 100 Late Stone Age (LSA) sites (*National Sites Register*, National Museum of Botswana). Many of these are based on observed surface finds related to impact assessments for infrastructure development, and few receive any formal excavation. Figure 9.3 illustrates the location of some of these sites (where their specific locations are recorded and published) and their relationship to the hydrological system of the Middle Kalahari.

The greatest concentration of reported ESA sites is found in the hardveld fluvial channels in southeast Botswana. Here, Wayland identified a total of 36 sites in the vicinity of the Taung, Ngotwane, and Limpopo Rivers (Cooke 1979; Thomas and Shaw 1991), and Ebert et al. (1976) reported the location of more than 400 Acheulean artifacts at Serowe. Further north, ESA sites maintain a strong fluvial association. *In situ* sites are reported by Aldiss (1987) from the

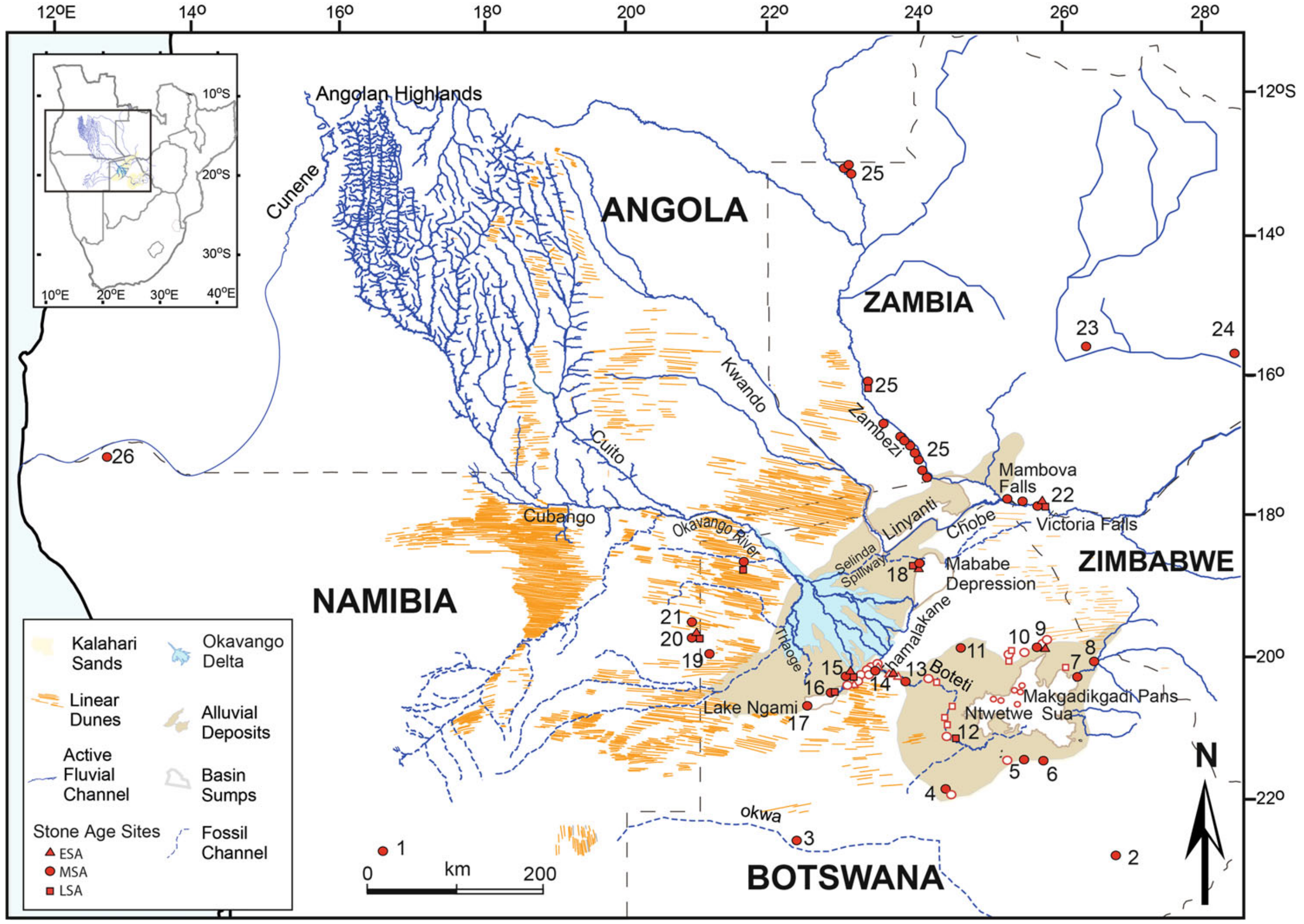

Fig. 9.3 Kalahari Stone Age sites reported in the literature (see Table 9.1). Closed symbols are those sites published in academic journals. Open symbols include sites reported in gray literature including archeological impact assessments where specific locations are given

Okwa Valley, and by Yellen (1971) in the Quangwa Valley. In addition to the numerous ESA handaxes found with the Nchabe, Thamalakane and Boteti Rivers (Campbell 1988), a transitional ESA/MSA factory site remains intact at Samedupe Drift (Wayland 1950), one of several localities where silcrete outcrops along the Boteti River. None of these sites have been dated, and their integration with the paleoenvironmental record from MIS 6-2 remains unknown.

MSA sites are more numerous, though most are still characteristically open in nature. Specifically, the region surrounding the Thamalakane, the Boteti, and the Makgadikgadi basin seems to have been an important locality for early humans. The basin floor of Makgadikgadi itself, in particular that of Ntwetwe Pan, is also yielding extensive suites of MSA artifacts. These tools are generally made from locally formed silcrete and are similar in nature to those noted from Kudiakam Pan, also within the Makgadikgadi basin. Robbins (1987) notes that these artifacts are relatively fresh and characterized by well-made unifacial and bifacial points, notched pieces, denticulates, and a number of small handaxes, some of which were found embedded on their edges suggesting erosion *in situ*. Levallois cores at both pans are a significant component of the debitage. Within Ntwetwe, an additional component of the archeological assemblage includes some extraordinarily large and unusual artifacts (Fig. 9.4). Like the ESA sites, these assemblages remain unsystematically investigated and without chronological control, making their integration into the record of paleoenvironmental change currently unattainable.

There are very few well-dated archeological assemblages within the interior of southern Africa. ≠Gi, an open site associated with permanent water and a well-developed MSA industry characterized by a variety of retouched points, is associated with extinct large *bovids* dated to 77 ± 11 TL kBP (Brooks et al. 1990). A bracketing ostrich eggshell, dating to 34 ± 1 ^{14}C kBP, has also been obtained from the transition pan margin sediments that separate the MSA from the LSA blade industries (Brooks et al. 1990). At Tsodilo, the MSA spans the range from ~90–50 ka at White Paintings rock shelter (Robbins et al. 2000, 2016; Ivester et al. 2010), with a dramatic increase in stone artifacts during the MSA levels at c.35 ka, and indications of long-term reoccupation of the shelter (Robbins and Murphy 1998). Recent work has also yielded a date of 52 ± 7 OSL kBP for a low-density MSA artifact scatter exposed in a modern quarry on the shores of Lake Ngami (Brook et al. 2008).

The transition to microlithic industries and the emergence of the LSA in Botswana appears to have taken place between 40 and 30 ka (Fig. 9.2), although the association of microlithic assemblages with fish fossils at White Paintings rock shelter in the Tsodilo Hills suggests this transition may have taken place earlier (Robbins et al. 2000).

While Walker (1998) notes that the strong association of Stone Age sites with the Kalahari's hydrological systems may partly be a function of archeological visibility, the role of water availability within this environment most likely was, and still is, extremely important to the survival of all species. The dynamics of the hydrological system during

Fig. 9.4 Stone tools made on local silcrete and found in the Ntwetwe Pan, Makgadikgadi found eroding out of the pan floor. The age and functionality of these tools remains unknown. Use as cores, bifacial tools, and/or symbolic artifacts have all been suggested (K. Kuman personal communication)

Table 9.1 Reported Stone Age sites in the Kalahari (see Fig. 9.3)

Location	Site description	References
1. Windhoek	MSA at spring	Fock (1954), Clark (1982)
2. Serowe	ESA on terrace of Metsemasweu River	Ebert et al. (1976)
3. Okwa Valley	ESA on river terraces	Aldiss (1987)
4. Kedia	MSA hunting camp on edge of pan	Cooke and Patterson (1960b)
5. Orapa	MSA factory site on beach ridge	Cohen (1974)
6. Lethakane Well	MSA/LSA site on pan edge	Cooke and Patterson (1960b)
7. Nata	LSA/MSA hunting camp on lake shoreline	Bond and Summers (1954)
8. Nata	MSA site on Nata river	Cooke (1967)
9. Ngxaishini pan	ESAR and MSA site with fossilized faunal remains	Robbins and Murphy (1998)
10. Makgadikgadi	ESA site	McFarlane and Segadika (2001)
11. Kudiakam pan	MSA at Kudiakam pan	Robbins (1987)
12. Toromoja/Gwi	LSA site on Boteti	Denbow and Campbell (1980), Helgren (1984)
13. Maklamabedi Drift	MSA in bed of Boteti river	Van Waarden (1988)
14. Samedupi drift	ESA quarry site on banks of Boteti	Wayland (1950), Cooke (1979)
15. Nhabe river	ESA to LSA sites	Campbell (1988), Robbins et al. (2008)
16. Lake Ngami	MSA and LSA at Toteng	Cooke (1979), Robbins (1984), Brook et al. (2008)
17. Lake Ngami	MSA factory site on southeast shore	Cooke and Patterson (1960a)
18. Savuti	MSA factory site along base of outcrops; ESA on raised beaches; LSA and rock paintings	Hitchcock (1982), Campbell (1970), Robbins (1987)
19. Dobe valley	ESA to LSA and dated MS/LSA site at #Gi pan edge	Yellen (1971), Brooks and Yellen (1977), Helgren and Brooks (1983), Brooks et al. (1990)
20. Xai Xai	LSA site at pan edge	Yellen (1971), Wilmsen (1978)
21. Tsodilo	MSA and LSA rock shelter sites	Junod (1963), Denbow and Campbell (1980), Robbins et al. (2000)
22. Victoria Falls	ESA to LSA at on terraces	Clark et al. (1950), Clark (1975)
23. Mumbwa	MSA cave site	Barham (1996, 2000)
24. Twin Rivers	MSA cave site	Clark and Brown (2001)
25. Upper Zambezi	MSA to LSA sites along river	Phillipson (1978)
26. Cunene	MSA site on banks of river	Nicoll (2010)

MIS 6-2 must therefore be considered critical to understanding the regional dynamics of hominin populations.

Subcontinental Records

With the exception of Drotsky's Cave, where speleothem growth has been dated by radiocarbon and U/Th techniques (Cooke and Verhagen 1977; Shaw and Cooke 1986; Brook et al. 1996) and the sporadic occurrence of datable freshwater shells and calcretes (Cooke and Verstappen 1984; Shaw 1985; Shaw and Thomas 1988; Shaw et al. 1992), there are almost no long records with which to tie in the environmental record of landscape and hydrological change in the Kalahari for the duration of MIS 6-2. Attempts to place the record of hydrological change within the context of concurrent continental-scale change are hampered by poor resolution. Though at the broadest scale, "wet" phases can be related throughout MIS 6-2 in both the northern and southern hemispheres of Africa (Burrough et al. 2009a, b). Recently published records from lake Malawi suggest a significant divergence in lake conditions between lake Malawi (which is subject to "megadrought" conditions during 115–95 ka) (Scholz et al. 2007, 2011) and the Middle Kalahari, where megalake Makgadikgadi is at least sporadically high during MIS 5d-5b (Fig. 9.2). On more recent timescales, however, better chronological resolution enables some analysis of regional leads and lags within paleoenvironmental records to be ascertained.

An interesting spatial divergence between patterns of environmental change in the equatorial tropics and the southern African tropical-subtropical zone (cf. Partridge et al. 2004; Gasse et al. 2008; Burrough et al. 2009a; Thomas et al. 2009) can be observed during the most recent post-glacial period. For example, Gasse et al. (2008) note that the major shift in P-E balance toward wetter conditions in the southern tropics occurred at 18–16 ka and continued until 13–12.5 ka. This contrasts with the later, and more stepwise, response of the equatorial tropics where major monsoonal reactivation occurred at 15–14 and 11.5–10.5 ka (Gasse et al. 2008), and seems to have been driven by strong teleconnections with the northern hemisphere high latitudes (Gasse 2000; Stager et al. 2011). Further, late glacial aridity, reported for the equatorial tropics (Stager et al. 2011) is not widespread through the southern hemisphere tropics and subtropics, where at the very least contemporaneous pockets of increasing wetness were experienced (Thomas et al. 2012; Singarayer and Burrough 2015).

Mechanistically, this may be related, via teleconnections, to the effect of major high latitude events, including meltwater discharge, on the extent of the seasonal migration of the ITCZ (and associated CAB) (e.g., Tierney et al. 2011). Coupled ocean-atmosphere-sea ice GCM simulations have been used to examine East African water balance responses to high latitude North Atlantic meltwater pulses. These experiments demonstrate the potential for a stronger southern ITCZ, leading to wetter surface conditions over southern Africa and southern areas of East Africa, and drier conditions in northern East Africa (Thomas et al. 2009). Causal mechanisms, however, remain notoriously difficult to test, and cannot be examined robustly beyond the last glacial/interglacial transition, without a substantial increase in the quantity and precision of Quaternary environmental data from the southern African summer rainfall zone (Burrough et al. 2009a). Nonetheless, the regional divergence of environmental conditions during periods of rapid transition holds strong potential as a driver of population movements during the late glacial, particularly during times of catastrophic equatorial drought as has been suggested by Stager et al. (2011).

Conclusion

The drivers of climatic change during MIS 6-2 in the semi-arid southern African interior remain a significant challenge to Quaternary science, especially to developing hypotheses regarding the climatic mechanisms that drove environmental changes in the region. Despite this, a much better and more sophisticated understanding of paleoenvironmental records, and their implications in terms of environmental dynamics relevant to human behavior, is emerging. This is due in no small part to approaches that seek to find the appropriate interpretation of the growing body of geoproxy records, which in central southern Africa is critical, as these records dominate data sources in this dryland region. In the context of past population dynamics, overarching climatic theories remain largely irrelevant, since it is regional environmental (rather than climatic) variability to which hominins are likely to have responded. In the Kalahari, this variability is driven largely by the availability of surface water and as Walker (1998) notes, it was (and is) reliability, rather than quantity, of rainfall that was the critical factor in the development of biological and cultural systems.

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