Chapter 2
Mid to Late Quaternary Landscape and Environmental Dynamics in the Middle Stone Age of Southern South Africa

Andrew S. Carr, Brian M. Chase, and Alex Mackay

Abstract The southern Cape of South Africa hosts a remarkably rich Middle Stone Age (MSA) archaeological record. Many of the associated caves and rock shelters are coastal sites, which contain evidence for varied occupational intensity and marine resource use, along with signs of notable landscape, environmental, and ecological change. Here, we review and synthesize evidence for Quaternary landscape and climatic change of relevance to the southern Cape MSA. We seek to highlight the available data of most relevance to the analysis and interpretation of the region's archaeological record, as well as critical data that are lacking. The southern Cape MSA occupation spans the full range of glacial-interglacial conditions (i.e., 170–55 ka). It witnessed marked changes in coastal landscape dynamics, which although driven largely by global eustatic sea level changes, were modulated by local-scale, often inherited, geological constraints. These prevent simple extrapolations and generalizations concerning paleolandscape change. Such changes, including pulses of coastal dune activity, will have directly influenced resource availability around the region's archaeological sites. Evidence for paleoclimatic change is apparent, but it is scarce and difficult to interpret. It is likely, however that due to the same diversity of rainfall sources influencing the region today, compared to parts of the continental interior, the southern Cape climate was relatively equable throughout the last 150 kyr. The region's paleoecology, particularly in relation to the coastal plains exposed during sea level lowstands, is a key element missing in attempts to synthesize and model the resources available to occupants of this region. Technology, settlement, and subsistence probably changed in response to these paleoclimate/landscape adjustments, but improvements in baseline archaeological and paleoenvironmental data are required to strengthen models of ecosystem variation and human behavioral response through the MSA.

Keywords Archaeology • Coast • Sea level • Eolian • Chronology • Paleoenvironment • Palaeoclimate

Preamble

Recent findings have placed increased emphasis on the role of southern Africa – notably the southern Cape coastal region (Fig. 2.1) – in the story of the emergence of modern humans (e.g., Marean 2010; Parkington 2010). A combination of the region's unique environment, ecology, and oceanographic setting, along with a series of artifact findings suggestive of cognitively modern behavior (Henshilwood et al. 2002, 2004, 2011; Marean et al. 2007; Brown et al. 2009), have led to the proposition that this region represents an early habitat of modern humans, perhaps as long as ~165 ka (Marean et al. 2007; Marean 2010, 2011). Recent interpretations of archaeological records emphasize the unique environmental context and history of the southern Cape (Marean 2011; Compton 2011).

The southern Cape's Middle Stone Age (MSA; c. 280–30 ka) archaeological record primarily comprises a series of coastal cave occupations. These include Die Kelders Cave (c. 90 km east of Cape Town), Blombos Cave (near to Still Bay), Pinnacle Point (west of Mossel Bay), Nelson Bay

A.S. Carr (✉)
Department of Geography, University of Leicester, Leicester, LE1 7RH, UK
e-mail: asc18@le.ac.uk

B.M. Chase
Centre National de la Recherche Scientifique, UMR 5554, Institut des Sciences de l'Evolution de Montpellier, Université de Montpellier, Bat.22, CC061, Place Eugène Bataillon, 34095 Montpellier Cedex 5, France

A. Mackay
Centre for Archaeological Science, School of Earth and Environmental Sciences, University of Wollongong, Northfields Avenue, Wollongong, NSW 2522, Australia

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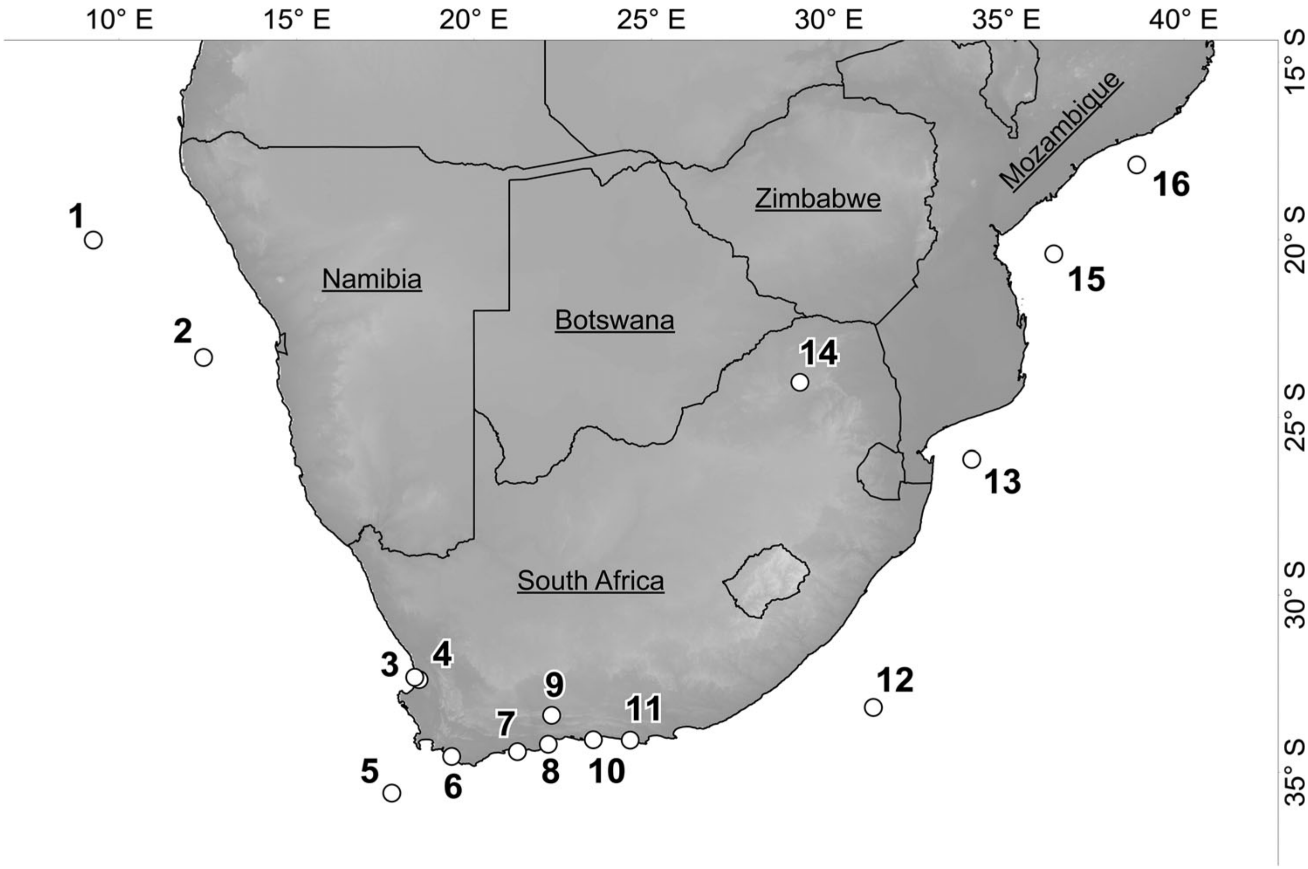

Fig. 2.1 Map of southern Africa with key marine and terrestrial paleoenvironmental sites and records. *Key 1* MD962094; *2* GeoB 1711-4; *3* Elands Bay Cave; *4* Diepkloof; *5* MD962081; *6* Die Kelders; *7* Blombos Cave; *8* Pinnacle Point-Crevice Cave; *9* Boomplaas Cave; *10* Nelson Bay Cave; *11* Klasies River; *12* MD962007; *13* MD962048; *14* Cold Air Cave; *15* MD79257; *16* MD79254

Cave (near Plettenberg Bay) and Klasies River (on the Tsitsikamma coast) (Fig. 2.1). A number of notable MSA sites on the west coast of South Africa are also situated on (e.g., Geelbeck [Kandel and Conard 2012] and Ysterfontein [Klein et al. 2004]) or relatively close (e.g., Diepkloof [Texier et al. 2010]) to the coastline. The significance of a dynamic coastal landscape for site formation, site preservation and in potentially explaining the occupational history of some sites has long been recognized (Tankard and Schweitzer 1976; Van Andel 1989). With the development of more robust chronologies for MSA occupations (Vogel et al. 1999; Feathers and Bush 2000; Feathers 2002; Jacobs et al. 2003, 2006, 2008, 2013; Tribolo et al. 2006, 2013; Jacobs and Roberts 2008; Jacobs 2010; Henshilwood et al. 2011) it is becoming possible to explore potential links between site occupation, human behavior, climate change, and landscape change in increasing detail (e.g., Cochrane et al. 2013).

This wider setting, comprising the regional landscape, climate, and ecology, their dynamism and influence on early human habitation, is the subject of this review. While the contemporary climatic and ecological conditions in the region are relatively well understood, evidence for paleoenvironmental change subsequent to the Last Interglacial (MIS 5e) remains limited and ambiguous (Chase and Meadows 2007; Chase 2010). New archaeological findings have made refining this record and unraveling its complexities a priority (Jacobs and Roberts 2008; Mackay 2011). An increasing pace of research, which includes several recent publications concerning local paleoclimate (Bar-Matthews et al. 2010; Chase 2010; Chase et al. 2013, 2015b; Quick et al. in press a, b) and landscape evolution (Bateman et al. 2011; Fisher et al. 2010; Cawthra et al. 2014) means that a regional-scale and holistic (re)consideration of paleoclimate and paleogeography is timely.

In this context, it is the purpose here to:

1. Provide an overview of the contemporary environmental setting of this region.
2. Synthesize newly published research concerning the geomorphic evolution of this coastal environment, highlighting the potential of these data to contribute to a holistic understanding of coastal landscape change.

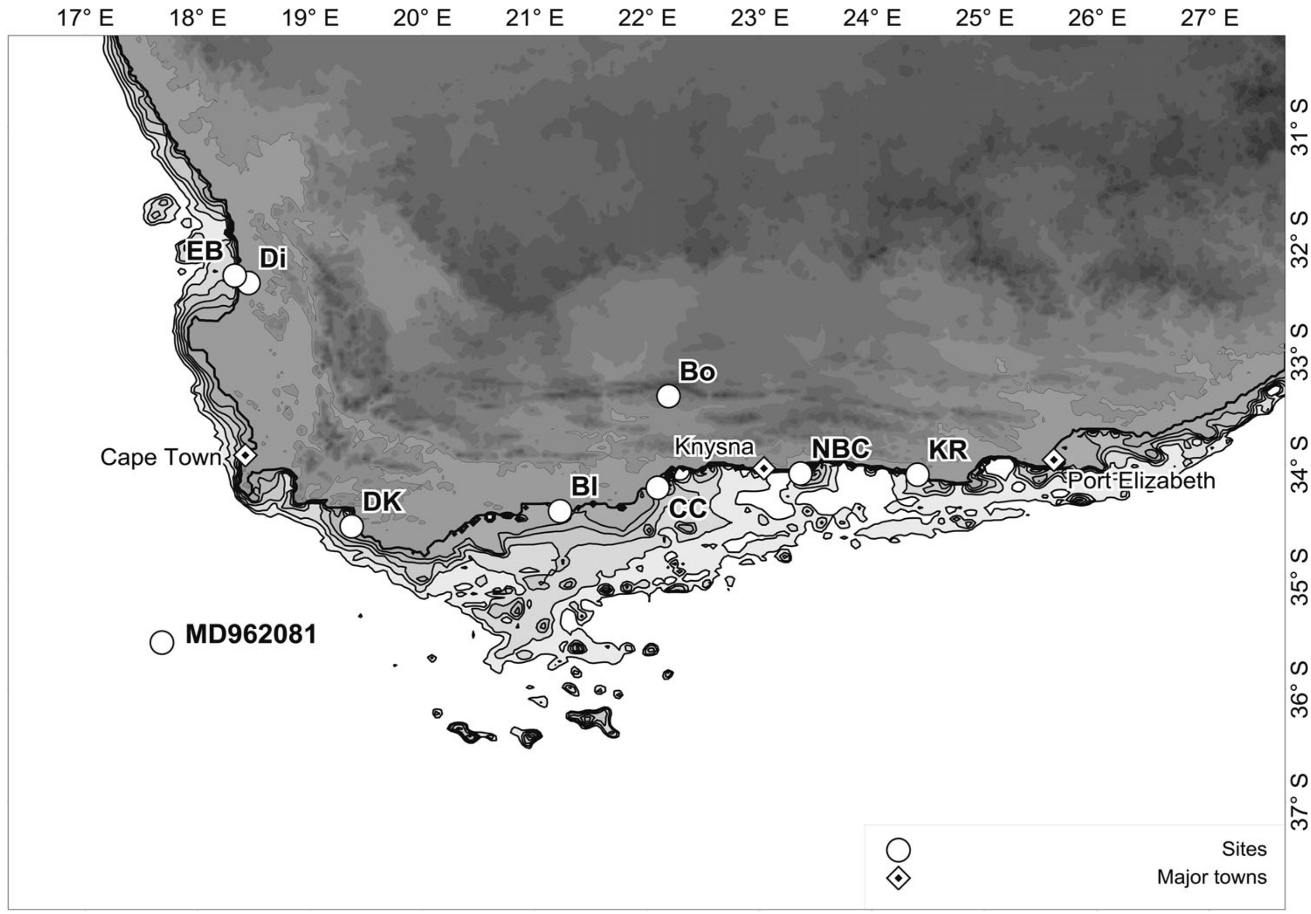

Fig. 2.2 Map of South Africa's southern Cape with regional paleoenvironmental and archaeological sites. Topographic contours are shown at 250 m intervals, while bathymetric contours are shown at 25 m intervals down to −125 m amsl, highlighting the extensive coastal plain that existed south of Cape Agulhas during the Last Glacial Maximum. EB = Elands Bay; DI = Diepkloof; CC = Crevice Cave; Bl = Blombos; Bo = Boomplaas; DK = Die Kelders; NBC = Nelson Bay Cave; KR = Klasies River

3. Analyze the currently available paleoclimatic data, and identify spatial, temporal, and interpretative gaps.
4. Consider, the relevance or potential relevance of points 2 and 3 for MSA archaeological research in this region.

Spatial and Temporal Scope

We limit our discussion largely to the temporal framework established for this volume, which spans MIS 6-2 (190–12 ka). This is broadly commensurate with the latter half of the MSA in southern Africa (Lombard 2012). It also includes the occurrences of the Still Bay and Howiesons Poort industries (dating to ~73.5–70.5 ka and ~66–58 ka, respectively; Jacobs et al. 2008), which have attracted particular interest (Jacobs et al. 2008; Compton 2011; McCall and Thomas 2012; Sealy 2016). Geographically (Fig. 2.2), we focus on the southern South African coastline from Cape Town to Port Elizabeth, which incorporates a number of important environmental facets: (1) South Africa's winter rainfall zone (WRZ), which presents a climatic gradient from the winter rainfall dominated environs of Cape Town, through the year-round rainfall zone (YRZ) of the south coast, to the interface with the summer rainfall zone (SRZ) north of Port Elizabeth (i.e., "Axis B" of Chase and Meadows [2007]); (2) the extensive offshore Agulhas Bank, which was variously exposed as eustatic sea level changed throughout MIS 6-2; (3) the peri-coastal region subject to the climatic influence of the Agulhas Current and localized near-coastal seasonal upwelling systems (Cohen and Tyson 1995); (4) the southern section of the diverse Cape Floristic Region (CFR, Linder 2003). It is also the location of major archaeological sites relevant to current debates surrounding modern human origins: Die Kelders Cave, Blombos Cave, the Pinnacle Point complex and Klasies River cave system.

Context

Given long-standing attempts to consider aspects of hominin evolution in the context of global-scale climatic forcing, there remains an impetus to provide contextual environmental information for fossil finds or sites of human occupation. These may be variously derived from local proxy data (perhaps from the same strata as the fossil material) or archives of "global-scale" change, epitomized by marine and ice core archives (Behrensmeyer 2006; Kingston 2007; deMenocal 2011). The latter approach presents some fundamental difficulties; primarily the assumption of direct and meaningful linkages between "global" or "hemispheric" scale signals, and "local scale" environmental information within archaeological sequences or single site archives (Behrensmeyer 2006; Kingston 2007; Chase 2010). This "scale-gap" becomes increasingly intractable deeper in the geological past, where proxy records are more fragmentary and/or equivocal (Kingston 2007).

In a region like South Africa, which lacks detailed terrestrial paleoenvironmental archives, this issue presents a significant problem, even for the middle and late Pleistocene. In fact, this scale issue has been a point of contention for many years (cf. Butzer 1984). Notwithstanding this, considerable progress has been made since Butzer's (1984) work; both in terms of the number of published proxy records and associated chronological control (Chase and Meadows 2007; Jacobs et al. 2008; Mitchell 2008).

Archaeology and the Coastal Landscape

An additional aim here is to consider information pertaining to wider Quaternary *landscape* change. Such data reflect our improved understanding of coastal geomorphic responses to long-term global climate forcing. The southern Cape landscape changed radically throughout MIS 6-2, primarily in response to global eustatic sea level changes (Van Andel 1989; Butzer 2004; Fisher et al. 2010; Cawthra et al. 2014). Our understanding of the nature and effects of such changes is increasingly supported by developments in geochronology and geophysical surveying. With such information we can begin to develop hypotheses on the nature of long-vanished landscapes on the submerged continental shelf.

Given, their potentially equable and resource-rich (ecotonal) settings, coastal environments have been variously highlighted as "refugia" and "migrational routes" for ancient human populations (*inter alia*: Stringer 2000; Bailey and Flemming 2008; Finlayson 2008; Compton 2011; Lambeck et al. 2011). Several workers in South Africa have also emphasized this, and have highlighted the marine environment as a source of reliable food resources through the vagaries of Pleistocene climate. Such marine resource usage has also been considered to provide clues concerning human behavior (Parkington 2003; Marean et al. 2007; Marean 2010, 2011). This interesting issue is not entirely unique to the southern Cape record, and has also been considered in the context of Neanderthal behavior (Stringer et al. 2008). Notwithstanding this, shell middens along the South African coast are widely distributed, both within rock shelters and the wider landscape. Marked contrasts between MSA and Late Stone Age (LSA) midden compositions have been reported, and the significance of these differences has been debated (Parkington 2003; Klein et al. 2004).

In the African context, the specific role of the continental margins as "refugia" during periods of aridity within the continental interior has been highlighted in various studies (Walter et al. 2000; Faure et al. 2002; Hetherington et al. 2008; Compton 2011). However, with the exception of the environmental archives provided by the East African lakes (e.g., Scholz et al. 2007; Castañeda et al. 2009) the continental Quaternary paleoclimatic record is sparse and geomorphic evidence of paleo-aridity in particular has proved difficult to interpret (Chase 2009; Thomas and Burroughs 2012; Burrough 2016). Although blanket claims of "Quaternary aridity" or "glacial aridity" should be treated with caution, phases of enhanced late Quaternary aridity can be identified within the southern African interior (e.g., Chase 2009, 2010; Chase et al. 2009, 2011; Chevalier and Chase 2015; Collins et al. 2014; Dupont et al. 2011; Lancaster 2002; Partridge et al. 1997; Scholz et al. 2007; Shi et al. 2001; Stager et al. 2011; Stuut et al. 2002; Thomas and Burrough 2012; Truc et al. 2013). Such periods of interior aridity are not necessarily restricted to, or specifically characteristic of "glacial" periods, but an emerging theme in southern African research has been the hypothesis that the coastal margins may have been of increased importance for human habitation during periods of interior aridity (e.g., Morris 2002; Hetherington 2008; Parkington 2010; Compton 2011; Blome et al. 2012). In the southern Cape this idea, perhaps to some extent, reflects the relatively mesic conditions we see in this region today (notably in the Knysna area). However, today's largely aseasonal and relatively humid rainfall regime along parts of the southern Cape owes its existence to the balanced influence of temperate and tropical rainfall systems, and this scenario is almost certainly sensitive to perturbations in global and regional circulation systems (Stuut et al. 2004; Chase and Meadows 2007; Chase 2010; Chase et al. 2013).

Understanding human occupation of the coastal zone is a challenging and inherently interdisciplinary task. Westley and Dix (2006) emphasize that coasts may: (1) represent equable and stable habitats; (2) offer uniformity in environment along-shore; (3) offer diversity and productivity in terms of resources; and (4) offer simplified landscapes for migration and navigation. Yet, they also note that these propositions should not be assumed. Inferences to this effect, based on archaeological investigations at a single site should be treated with caution. All modern coastal landscapes are geologically young, and the nature of paleocoasts must be inferred from preserved geological and geomorphic evidence. Most interpretations are derived from fragmentary evidence sampled largely in the subaerial landscape. Evidence for landscapes on the submerged continental shelf has, for obvious reasons, been largely lacking. Recent geophysical surveying approaches suggest that there is potential to resolve this issue (Cawthra et al. 2014).

Contemporary Setting and Drivers of Change

Landscape

The landscape of the southern Cape is today dominated by two key elements: (1) the Cape Fold Belt Mountains; and (2) a coastal platform. The Cape Fold Belt formed from the orogeny of the Ordovician Table Mountain Group (TMG) sandstones during the late Paleozoic, and today the eroded remnants of these mountains form a series of broadly coast-parallel ridges separating the southern Cape from the continental interior (Deacon et al. 1992; Compton 2011). The breakup of Gondwana had a fundamental influence on the southern Cape coastline; it created an initial platform seaward of the Cape Fold Mountains (Partridge and Maud 1987; Marker and Holmes 2010) (Fig. 2.2) and, due to a series of half-grabens formed during the fragmentation, divided the continental margin into distinct sedimentary basins (Broad et al. 2006). This structural control produced a series of resistant TMG sandstone headlands separated by basins (today these broadly correspond to coastal embayments) containing Late Mesozoic clastic sedimentary infills (e.g., Enon and Kirkwood Formations), as well as Neogene and Quaternary eolian and marginal-marine sedimentary deposits (Malan 1990; Marker and Holmes 2010) (Fig. 2.2).

Coastal Geomorphology

The varied geological, geomorphic, and marine settings of the southern Cape provide a diversity of environments and habitats, with a notable dichotomy between the rocky headlands and open sandy beaches. The South African continental shelf widens substantially on the south coast, forming the Agulhas Bank (Fig. 2.2). The southern Cape experiences high open water wave heights (median heights ~2.5 m at Knysna; Whitfield et al. 1983) and swell directions are predominantly from the southwest (Davies 1980). Long-shore sediment fluxes are typically in an easterly direction (Martin and Flemming 1986) and tidal ranges are generally low. The combination of the high wave energies and the low tidal ranges means that the southern Cape is classed as a wave-dominated coastline (Davis and Hayes 1984). Thus, with the exception of rocky headlands the coastal geomorphology is dominated by "barrier" landforms, specifically, wave-deposited sediments and associated landforms (e.g., Davis and Hayes 1984; Roy et al. 1994). The refraction of incoming swell waves means that wave energy is generally concentrated at headlands, and the embayments are characterized by wide intermediate to dissipative beaches. Many embayment beaches are backed by extensive coastal dunes, which in a number of locations are currently active (Tinley 1985). Seawards-younging sequences of eolian deposits imply that this situation has persisted since the Pliocene (e.g., Roberts et al. 2008).

East of Cape Agulhas, notably in the Still Bay and Knysna areas, landwards dune migration is limited by abundant vegetation and during the Pleistocene parabolic dunes stacked upon one another to form large composite barrier dune systems (Roberts et al. 2008, 2009; Bateman et al. 2011). Submerged barrier features are present on the continental shelf, notably off the Wilderness coast and bear testament to the close links between dune formation and relative sea level change in this region (Martin and Flemming 1986; Cawthra et al. 2014).

The headlands bounding the half-moon bays are frequently rocky and represent impediments to longshore sediment transport. In some locations this is facilitated by headland-bypass dune systems (Tinley 1985). These are long-established landscape elements (Bateman et al. 2004, 2008; Carr et al. 2006a; Carr and Botha 2012).

Climate

The climate of the southern Cape is a function of: (1) the interplay between the South Atlantic and Indian Ocean high pressure cells, and the cyclonic westerly systems; and (2) its position relative to the warm Agulhas Current, which, in conjunction with heating contrasts between the land and ocean, enhances moisture delivery to the coast (Tyson 1986; Jury et al. 1993; Lindesay 1998). For the majority of southern Africa, the austral summer is the wet season. This is driven by the southward migration of the ITCZ and the

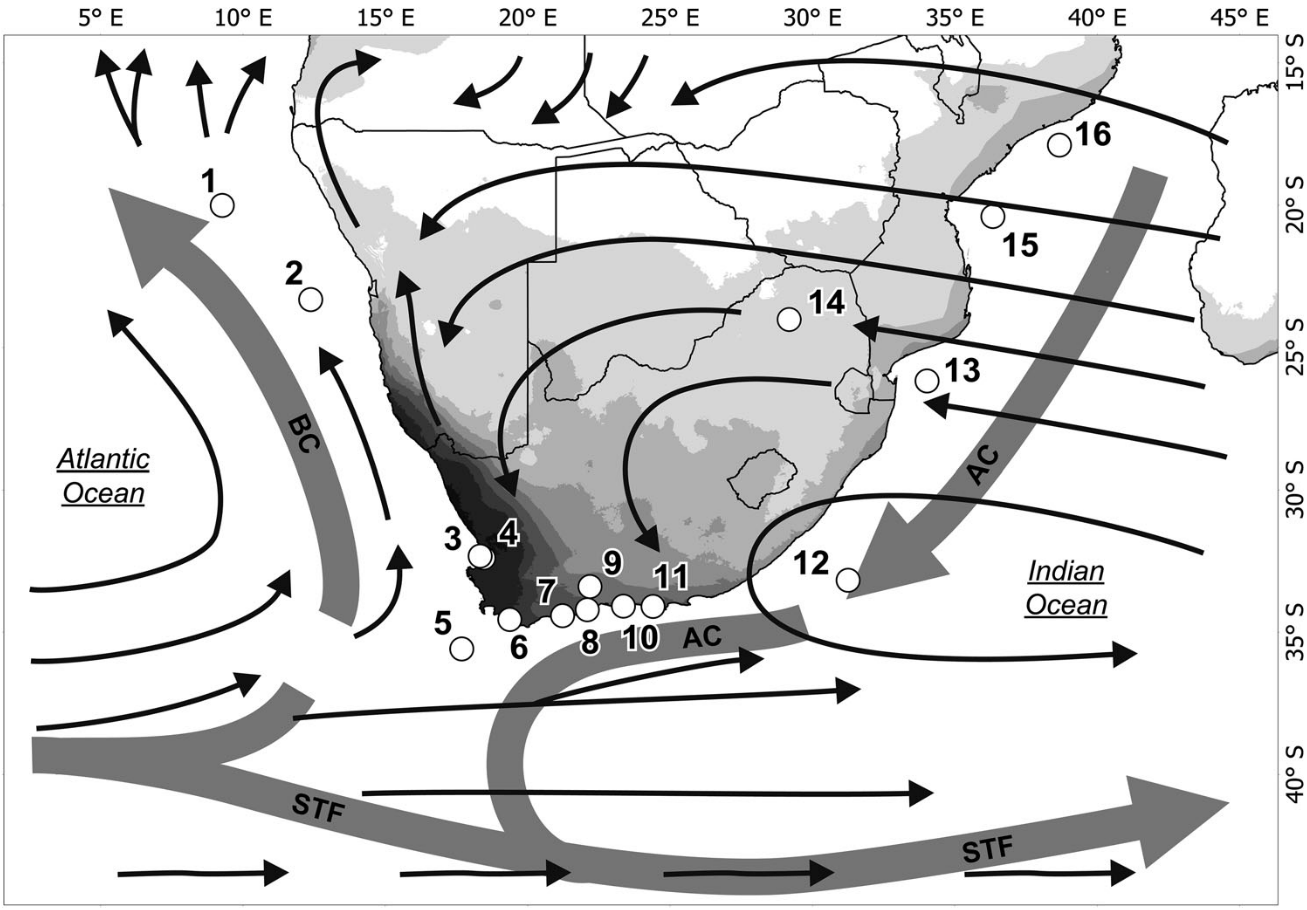

Fig. 2.3 Map of southern Africa with dominant atmospheric (*thin black arrows*) and oceanic circulation patterns (*thick gray arrows*). Major oceanic features include the Benguela Current (BC), the subtropical Front (STF), and the Agulhas Current (AC). Continental shading indicates the distribution of winter rain as a percentage of the annual total (darkest = 80%, lightest = 0%). Key marine and terrestrial paleoenvironmental sites and records are also shown: *1* MD962094; *2* GeoB 1711-4; *3* Elands Bay Cave; *4* Diepkloof; *5* MD962081; *6* Die Kelders; *7* Blombos Cave; *8* Pinnacle Point-Crevice Cave; *9* Boomplaas Cave; *10* Nelson Bay Cave; *11* Klasies River; *12* MD962007; *13* MD962048; *14* Cold Air Cave; *15* MD79257; *16* MD79254

influence of the tropical easterlies, producing a flux of moisture from the Indian Ocean. During the austral winter, the expansion of the circumpolar vortex causes the westerly cyclonic systems to track further north, bringing rain to the WRZ of the southwestern Cape (Fig. 2.3), while stable anticyclonic (dry) conditions prevail in the SRZ. The southern Cape represents a complex transitional zone between these regimes and large parts of it experience a year-round rainfall regime (YRZ) that derives moisture from both westerly systems and the Indian Ocean, along with more localized coastal disturbances (Tyson and Preston-Whyte 2000). Moving east of Cape Town, rainfall becomes less seasonal and shifts from a near semi-arid climate (~450 mm a^{-1} at Struisbaai) to a more temperate climate (~800 mm a^{-1} at Knysna).

It has long been argued that the positioning of the westerly cyclonic systems was a key driver of late Quaternary climatic variability in southwest Africa (van Zinderen Bakker 1967, 1976; Cockcroft et al. 1987). This has been linked to shifts in the position of the subtropical front (STF) (Fig. 2.3), which responds to the extent of Antarctic sea ice (van Zinderen Bakker 1976; Stuut et al. 2002, 2004; Chase and Meadows 2007; Chase 2010; Chase et al. 2013). These ideas are discussed further later in this review.

Ecology

The southern Cape lies largely within the Cape Floristic Region (CFR; Goldblatt and Manning 2002). The CFR comprises a number of separate biomes (Fig. 2.4), which are closely associated with specific soil types (Cowling and Holmes 1992; Low and Rebelo 1996). Fynbos ("*fine bush*") is characterized by small, needle-leafed ericoid shrubs, along with plants characterized by larger sclerophyllous leaves

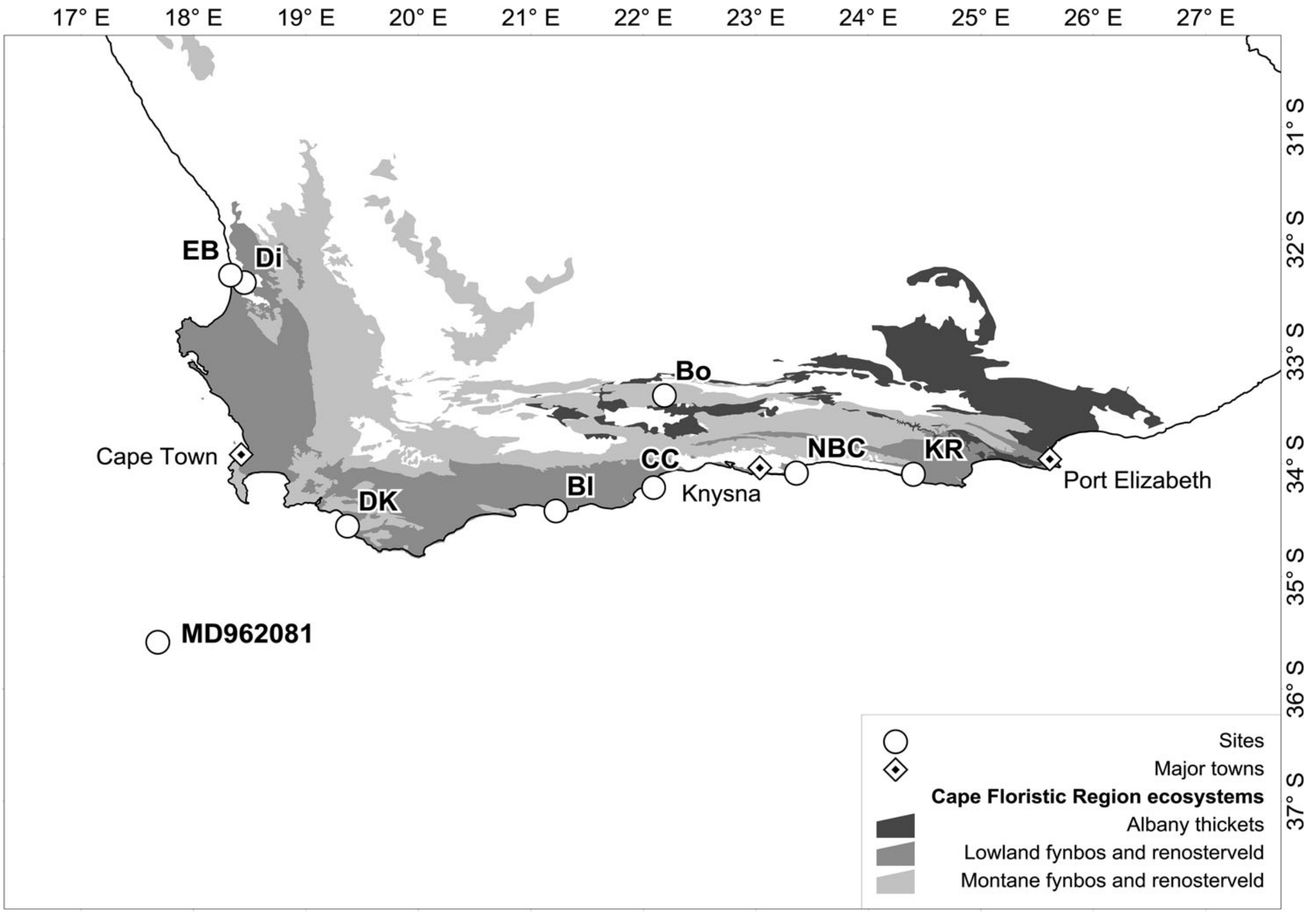

Fig. 2.4 Contemporary biomes of the southern Cape region. *EB* = Elands Bay; *DI* = Diepkloof; *CC* = Crevice Cave; *Bl* = Blombos; *Bo* = Boomplaas; *DK* = Die Kelders; *NBC* = Nelson Bay Cave; *KR* = Klasies River

(Cowling and Holmes 1992). Today it is dominated by plants using the C_3 photosynthetic pathway (Vogel et al. 1978).

Fynbos tends to be found as either upland Montane Fynbos, which is associated with the nutrient-poor sandy soils of the Cape Fold Belt or Lowland Fynbos, which is often associated with calcareous soils and dune sands. On finer-gained substrates (e.g., Bokkeveld Shale) *Renosterveld* is a common vegetation type, which, like fynbos, is broadly classed as a small-leaved shrub land (Cowling 1983; Cowling et al. 1988). It is often dominated by "Renosterbos" (*Elytropappus rhinocerotis*), and is associated with a higher proportion of grasses (including grasses using the C_4 photosynthetic pathway where more summer rains occur) and succulents (which will include CAM photosynthesis; *contra* Bar-Matthews et al. 2010). Its potential sensitivity to changing rainfall, in terms of the proportions of succulents and fynbos species has been noted (Cowling 1983; Low and Rebelo 1996), and possibly identified within the paleoecological record (Carr et al. 2006b; Quick et al. in press a, b). Thicket vegetation is associated with coastal dunes (Rebelo et al. 1991). A notable component of the southern Cape's vegetation is the afromontane forest of the Knysna area between Mossel Bay and Klasies River. This requires relatively humid year-round rainfall conditions and is relatively drought-sensitive (Cowling 1983), tending to be associated with ~800–1100 mm mean annual precipitation *and* low rainfall seasonality (a coefficient of variation of <17).

The responses of these vegetation communities during the Quaternary are poorly constrained. Evidence from the Cederberg in the Western Cape suggests that during the late Quaternary, Montane Fynbos was largely buffered from regional-scale climatic changes (Chase et al. 2015a, 2011) by the wide climatic tolerances of its plant genera, specific edaphic constraints (association with low nutrient sandstone substrates; Campbell and Werger 1988) and relatively reliable orographic rainfall (Cowling 1983; Meadows and Sugden 1993; Chase et al. 2011; Quick et al. 2011; Valsecchi et al. 2013). The paleoecology of the renosterveld (lowland fynbos, thicket and afromontane mosaic on the coastal lowlands), which is perhaps most relevant to the region's MSA archaeology, is discussed later, but is very poorly understood. Prior to the arrival of pastoralists and later, European colonists, a diverse range of fauna is thought to have occupied the southern Cape region (see Boshoff and Kerley 2001). In general, the large herbivores comprised of mixed feeders and browsers, including *inter alia*: African Elephant (*Loxodonta africana*), Cape Buffalo (*Syncerus caffer*), Red Hartebeest (*Alcephalus buselaphus*), Bontebok (*Damaliscus dorcas dorcas*), Quagga (*Equus quagga*), Blue Antelope (*Hippotragus leucophaeus*) and Cape Mountain Zebra (*Equus zebra zebra*).

Quaternary Coastal Dynamics

Quaternary Sea Level Change

Notable occupational hiatuses, particularly between MSA and LSA deposits, in the southern Cape coastal archaeological record have long been linked to eustatic sea level change(s) during MIS 5-2 (Van Andel 1989). Benthic oxygen isotope data imply 125–130 m of eustatic sea level change across glacial-interglacial cycles (e.g., Waelbroeck et al. 2002). Given the region's apparent tectonic stability (Roberts et al. 2012), this is probably a reasonable approximation for the southern Cape during the middle and late Quaternary (Ramsay and Cooper 2002; Compton 2011). Sea level change of this magnitude would have expanded the coastal platform by as much as ~50,000 km^2 during sea level lowstands (Fig. 2.2).

Sea Level Change, Site Formation and Site Occupation Evidence from the MSA deposits of Pinnacle Point Cave 13b implies that fluctuating marine resource use during MIS 6 was correlated with eustatic sea level fluctuations (Marean et al. 2007). Compton (2011) considered the significance of relative sea level change from a broader perspective, emphasizing its role in moderating resource availability, competition, hunting practices and population density as the exposed continental shelf expanded and contracted. He also emphasized the importance of sea level change in controlling migration (of humans and other fauna) to and from the continental interior via Cape Hangklip and Plettenberg Bay. Such routes would have avoided the Cape Fold Belt and the presumed arid Karoo, but are now on the submerged continental shelf (Fig. 2.2). Periods of potentially easier access to the southern Cape lowlands via these east and west routes occurred only when sea levels were at least 75 m below present. Similarly, Parkington (2010) noted the "pulsing of landscape availability" on the continental shelf in the face of proposed periods of aridity in the continental interior 160–125 ka and 80–60 ka.

Sea level highstands would have significantly reduced the extent of the coastal lowlands and directly impinged on some MSA occupations, with obvious implications for site formation, occupation, and preservation (Hendey and Volman 1986). In the middle to late Quaternary two significant highstands exceeded contemporary sea level reaching ~13 m and 6–8 m above mean sea level (amsl) (Roberts et al. 2012). Recent age constraints for the former suggest that it relates to MIS 11 (391 ± 16 ka; 370 ± 14 ka to 388 ± 14 ka) (Jacobs et al. 2011; Roberts et al. 2012). The Pinnacle Point Cave 13b excavation contains potential evidence for this highstand, with rounded boulders identified at the base of the western excavation (Karkanas and Goldberg 2010). These are overlain by a laminated facies, for which an average OSL age of 385 ± 17 ka has been reported (Jacobs 2010).

The 6–8 m highstand (Tankard 1976a; Marker 1987; Ramsay and Cooper 2002) holds interest for the archaeological community as it is close to the altitude of some coastal cave sites (Hendey and Volman 1986). Luminescence dating has recently confirmed that deposits of this altitude most likely relate to MIS 5e (127 ± 6 to 116 ± 9 ka) (Jacobs and Roberts 2009; Carr et al. 2010a; Roberts et al. 2012) (Fig. 2.5).

In terms of its impact on coastal archaeological sites, a 6–8 m MIS 5e highstand would not have flooded cave 13b at Pinnacle Point, nor Blombos Cave (Henshilwood et al. 2001; Marean 2010). At present, however, PP13b (15 m amsl) is the only major southern Cape coastal site unequivocally occupied during MIS 5e, although the exact timing in relation to the highstand is unclear (Jacobs 2010). The densest occupation of the site seemingly occurred *after* MIS 5e, between 100 and 90 ka (Jacobs 2010). Pinnacle Point Cave 9 is much closer to sea level (c. 8–12 m amsl), but is protected by more recent rock fall debris (Marean et al. 2004). The exposure of this cave to the elements prior to the rock fall may explain the more limited archaeology it contains (Marean et al. 2004). The most recent ages from Blombos Cave (34 m amsl) constrain the MSA occupation to between 101 ± 4 ka and 68 ± 4 ka (Henshilwood et al. 2011), which therefore postdates the MIS 5e highstand. The reliability of a previously published age for the M3 phase of 143 ± 6 ka (Jacobs et al. 2006) is now questioned (Henshilwood et al. 2011).

There are as yet no published MSA records unequivocally relating to MIS 5e at Die Kelders or Klasies River. Die Kelders lies relatively close to the shore and the MIS 5e highstand would likely have significantly impacted the site. The base of cave sequence is only ~2 m above modern sea level (Tankard 1976b; Hendey and Volman 1986), implying that it was uninhabitable until MIS 5d. Currently published OSL ages provide a broad estimate of 80–60 ka for the MSA occupation, which as might be expected, postdates MIS 5e (Feathers and Bush 2000). The habitability of Klasies River during and after MIS 5e has been debated (Hendey and Volman 1986; Deacon and Lancaster 1988). The basal LBS Member overlies beach deposits at c. 8 m amsl (Deacon and Lancaster 1988; Deacon and Geleijnse 1988) and the faunal assemblages in the LBS are reportedly not dissimilar to

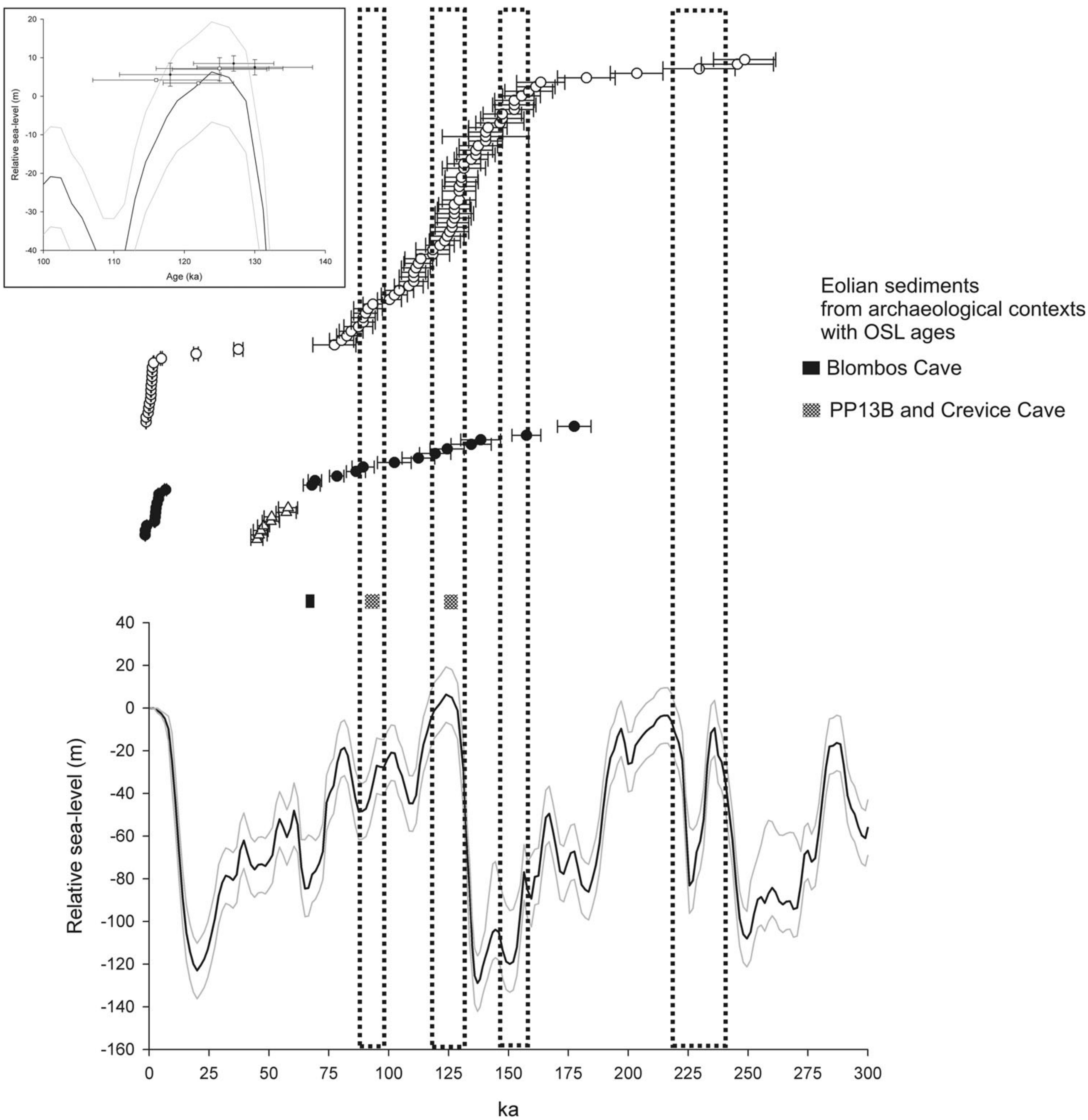

Fig. 2.5 Main Diagram: Distribution of optical luminescence ages (plotted in rank order) for eolian sediments along the southern Cape coastline, plotted relative to the eustatic sea level curve of Waelbroeck et al. (2002). *Open circles* are ages from the Wilderness Barrier dune systems (Bateman et al. 2011). *Filled circles* are OSL ages from the Agulhas Plain and Still Bay regions (Bateman et al. 2004, 2008; Carr et al. 2006a; Jacobs et al. 2003; Roberts et al. 2008). *Triangles* represent ages from pan-fringing lunette dunes on the Agulhas Plain (Carr et al. 2006a). The *dashed boxes* represent phases of eolian activity identified from statistical analysis of the Wilderness barrier dune OSL chronology (Bateman et al. 2011). Age ranges for eolian sediments within Blombos Cave (Jacobs et al. 2003), Pinnacle Point Cave 13b and Crevice Cave (Bar-Matthews et al. 2010; Jacobs 2010) are marked (*shaded boxes*). *Inset* The timing and magnitude of the southern Cape MIS 5e sea level highstand (Carr et al. 2010a; Roberts et al. 2012) relative to Waelbroeck et al.'s (2002) curve

Holocene ones (Deacon 1995) implying that the site was most likely occupied not long after MIS 5e – probably ∼110 ka (Deacon 1995). More recent quartz OSL and feldspar IRSL ages of 110–115 ka (UW282) for the LBS in Cave 1 support this notion (Feathers 2002). The LBS is overlain by the Rock Fall Member, the SAS member and the Upper Member (which contains Howiesons Poort artifacts). Single grain OSL ages now suggest that these were deposited between c. 72 and c. 58 ka (Jacobs et al. 2008; Jacobs and Roberts 2008). Significant truncation of the Klasies River deposits was caused by the mid-Holocene sea level highstand (Deacon 1995), emphasizing the vulnerability of low altitude coastal sites to marine erosion. Mid-Holocene sea level probably peaked at 2–3 m amsl between 7500 and 6000 cal BP (Compton 2001).

Landscape Responses to Sea Level Change: Some Generalizations

While simple comparison between site altitude, global eustatic sea levels, and/or geological evidence for the magnitude of interglacial sea level highstands provides some basic context for the occupational records of specific sites, the response of wider sedimentary systems (and thus, the coastal *landscape*) to Quaternary sea level change is more complex, particularly within the embayed sections of the southern Cape coastline. Due to the region's tectonic stability, middle, and late Pleistocene sea level highstands reached similar points in the landscape, often reworking significant volumes of poorly lithified calcareous sediments within embayment fills (Roberts et al. 2008; Bateman et al. 2011).

Coastal responses to sea level change will comprise both the large-scale lateral translation of the shoreline across the continental shelf, as well as more subtle secondary effects, which confound simple interpretations of paleocoastal conditions and form. The lateral (onshore-offshore) response is a function of various factors; viz., sediment supply, accommodation space and continental shelf gradient (e.g., Storms et al. 2002; Cattaneo and Steel 2003). In addition, alongshore sediment fluxes, induced by waves approaching the shore obliquely, will respond to both changing wave energy and incident wave angle (Ashton et al. 2001). At large temporal and spatial scales the former will alter in response to wave attenuation (controlled by offshore bathymetry), while the angle of wave approach will respond to regional swell-wave conditions, as well as local wind systems and/or adjustment in the coastal plan-form itself (i.e., feedback response; Ashton et al. 2001). All are mediated by inherited geological characteristics (Roy et al. 1994).

The response of coastal locations at spatial/temporal scales relevant to the occupation of specific archaeological localities (scales of km and temporal scales of 10^2–10^3 years) is hard to assess. At this scale, noteworthy alterations of coastal environments need not occur in response to major environmental perturbations (e.g., Cooper et al. 2007). Variability in coastal environments reflects a subtle interplay of sediment supply, wave energy, and alongshore wave energy gradients, tidal currents, storm activity, and geological constraints. Understanding and predicting coastal sedimentary responses to sea level change, even over decadal and centennial timescales, is therefore a huge challenge (Cooper and Pilkey 2004). Hints of local-scale change (albeit over longer timescales) within the southern Cape geomorphic record are apparent. For example, at Cape Agulhas there was seemingly a shift from a rocky shore to a sandy shore setting *within* MIS 5e (Carr et al. 2010a). While at Pinnacle Point, which is presently rocky headland, the archaeological record contains evidence of eolian dune formation during MIS 5, which in-filled and sealed caves (Marean 2010). These dunes would undoubtedly have required a sandy beach as a sediment source; implying wave energy was less focused on this section of coast, allowing beach, and dune formation. Such changes imply that in headland locations accommodation space and/or sediment supply all respond to major sea level perturbations. Thus, models of coastal landscape based on modern bathymetry provide a useful means by which to consider the position of the coastline and the likely access to resources (i.e., site to shore distances) (Fisher et al. 2010), but the complexity of coastal sedimentary systems and their potential to respond to relatively subtle changes in climate, sea level, and sediment supply should be remembered, as should the uncertainties associated with eustatic sea level estimates derived from locations distant from southern Africa.

Landscape Responses to Sea Level Change: Coastal Eolian Systems

Our understanding of the timing and mechanisms of coastal dune formation on the southern Cape has grown considerably (Vogel et al. 1999; Shaw et al. 2001; Bateman et al. 2004, 2008, 2011; Carr et al. 2007, 2010a; Roberts et al. 2008, 2009). Some of this work was specifically motivated by reports of eolian sediments within cave sequences and shell middens within dune fields, but ultimately, it speaks more broadly to wider questions of coastal landscape adjustment and evolution.

A synthesis of some 104 coastal dune OSL ages from the southern Cape illustrates the drivers of eolian sediment accretion and preservation over glacial-interglacial timescales in what are presently subaerial environments (Fig. 2.5). The record suggests that dune formation was strongly mediated by eustatic sea level change, with dune activity broadly associated with periods of relatively high sea level (i.e., MIS 1, MIS 5e, and MIS 7). This is consistent with mechanisms of contemporary dune formation, whereby parabolic dunes do not migrate far from their primary sediment source, the modern shoreline. During sea level regressions eolian activity tracked the receding coastline across the Agulhas Bank, evidence for which is preserved in numerous coast-parallel dune ridges identified at depths of −40, −50, −65 to −70, and −80 to −90 m (Birch et al. 1978; Flemming et al. 1983; Martin and Flemming 1986) and at −33, −42, −77, −93, −97, −103, −108 and −115 m in the Wilderness embayment itself (Cawthra et al. 2014). The orientation of modern parabolic dunes and analysis of bedding in Quaternary dunes is consistent with south-westerly to north-westerly formative winds, implying an association with winter cyclonic systems (Flemming et al. 1983; Carr et al. 2006a; Roberts et al. 2008) and more specifically, that wind strength and sediment supply, rather than seasonal aridity, were/are the key factors mobilizing coastal dunes along the southern Cape.

In evaluating the response of coastal eolian systems over finer timescales, such as MIS 5e through to MIS 5a (Bateman et al. 2004: Fig. 9) identified separate phases of coastal eolian activity associated with MIS 5e, MIS 5c, and MIS 5a. The current synthesis (Fig. 2.5), comprising far more OSL ages from a longer stretch of coastline, suggests that such a separation is less clear at regional scales. Analysis of the OSL age distribution for the Wilderness Embayment barrier dunes reveals clusters of activity centered at c. 87–92 ka, 120–130 ka, 143–159 ka, and 221–241 ka (Bateman et al. 2011). Perhaps more important for the interpretation of single archaeological sites, the same study demonstrated that stratigraphic records at single sections of coastline (i.e., spatial scales of a few km) can differ significantly. This could be explained by recourse to the local bathymetry, which modulates the dune accumulation history of a particular locale by determining the duration over which the site was close to its beach sediment source (Bateman et al. 2011). The southern Cape geomorphic record thus demonstrates both large-scale/long-term drivers of coastal geomorphic change (glacial-interglacial sea level change), as well as local-scale variations in coastal response, driven by sediment supply and inherited geological constraints (e.g., bathymetry). These impart site-specific variation in the preserved coastal stratigraphic record.

The presence of eolian sediments within coastal rock shelters is abundantly clear at sites, such as Blombos Cave and Pinnacle Point. So far, published OSL ages for Pinnacle Point sites show good correspondence with the wider eolian geomorphic record (Fig. 2.5). For example, the LC-MSA (Upper) at Pinnacle Point 13b preserves evidence for a large dune that sealed the cave at 93 ± 4 ka (Jacobs 2010). Similarly, the Crevice Cave site indicates dune formation at 90 ± 2 ka (Bar-Matthews et al. 2010). These are both associated with the cluster of dune ages in the regional eolian record associated with MIS 5b (87–92 ka) (Bateman et al. 2011) (Fig. 2.5). At Blombos, new OSL ages, as well as previous TL ages and U-series dating constrain the M3 phase to 97.0 ± 2.7 ka (MIS 5c), the M2 phase to MIS 5a (weighted mean 82 ± 2 ka [MIS 5a]) and the M1 phase to 73 ± 3 ka (MIS 4/3; Henshilwood et al. 2011). Subsequent to the M1 Phase at 69 ± 4 ka, the cave was sealed by a coastal dune (BBC Hiatus) (Henshilwood et al. 2001; Jacobs et al. 2003; Henshilwood 2005), commensurate with the MIS 4 sea level regression. What happened at Blombos during and around MIS 5e is unclear at present, but to the east of Still Bay, a major phase of (eolian) barrier dune construction occurred between 140 ka and 121 ka, followed by later phases of barrier accretion at 114 and 90 ka (Roberts et al. 2008). The ages of the dune sands preserved in the cave (BBC Hiatus 69 ± 4 ka) and the eolianite remnants surrounding the cave (70 ± 4 ka and 71 ± 3 ka; Jacobs et al. 2003) are thus relatively young compared to both the eolianite east of Still Bay, and the synthesis from the Wilderness Embayment (Bateman et al. 2011), both of which imply that eolian activity was much reduced after c. 90 ka. Thus, although the occupations of Blombos and Pinnacle Point were seemingly influenced by coastal dune formation, there is apparent variation in the extent to which these phenomena reflect regional scale climatic/sea level changes (e.g., PP13b), as opposed to local geomorphic, geological, or preservational factors.

Sea Level Lowstands: Paleolandscapes and Paleohydrology

The bathymetry of the shelf is such that the area of landscape exposed off the southern Cape during MIS 5-3 was substantially less than that exposed relatively briefly during MIS 2 (Van Andel 1989) (Fig. 2.2). For instance, at Pinnacle Point the shoreline between MIS 5e and MIS 3 was between 0 and 37 km south of the modern coast, extending to more than 90 km at the Last Glacial Maximum (Fisher et al. 2010). This reflects the relatively steep shelf gradients close to the shore and a much flatter profile at depths below ∼ −80 m (Dingle and Rogers 1972; Fisher et al. 2010).

The contemporary coastal platform, which lies between the Cape Fold Belt and the modern shore, is therefore relatively narrow compared to most of the Pleistocene. Today this lowland landscape represents an "unusual" topography and ecology (compared to the sandstone and fynbos vegetation of the Cape Fold Mountains), but it would have comprised a more substantial component of the landscape during the last glacial cycle. Dingle and Rogers (1972) note a distinct contrast in geological substrates between the western and the central/eastern areas of the Agulhas Bank. The coastal margin between Cape Town and Cape Agulhas is substantially rockier (pre-Mesozoic) to greater depths compared to areas east of Cape Agulhas. Recent sediment wedges are usually localized and the outer boundary of the rocky inner shelf extends to the 140 m isobath (Rogers 1985; Gentle 1987). Compton (2011) argued that this rocky terrain (especially between Cape Hangklip and Danger Point) would have been a major impediment for travel between the coastal lowlands and the interior of the Western Cape for all periods in which relative sea level was between 0 and 75 m below modern levels.

Given the strong edaphic controls on the region's vegetation communities, the ecology of the continental shelf during lowstands may have been strongly influenced by bedrock geology. The vegetation on rocky continental shelf regions around the Cape Peninsula and Cape Hangklip may not have been too dissimilar to modern fynbos vegetation. To the east, however, such quartzite exposures are limited more to headlands and few assumptions concerning substrates on the central and eastern Agulhas Bank can be made. It has been proposed that they may have included include finer grained, more nutrient-rich soil derived from Cretaceous clays (Dingle and Rogers 1972; Compton 2011). On the modern coastal platform today such finer grained soils are not associated with fynbos vegetation and potential modern analogues for such vegetation communities are more likely to lie (for example) in the Bokkeveld shale communities (e.g., the Agulhas Plain), which are associated with Renosterveld vegetation; Cowling et al. 1988) or Albany Thicket (Compton 2011). Renosterveld contains a grass component, which will contain greater or lesser proportions of C_3 and C_4 taxa depending on the annual distribution of rainfall (Mucina and Rutherford 2006), and its periodic occurrence in what are now offshore regions may offer some explanation for the fluctuating proportions of grazing and browsing fauna in the archaeological record (Deacon 1978; Klein 1976, 1983; Faith 2011a, b). At present such inferences are rather speculative. The complex sedimentary dynamics associated with sea level transgressions and regressions, this time across the continental shelf, will impart spatial variability in substrate composition, exposure, and preservation, irrespective of the temporal vegetation dynamics driven by climatic changes during the same periods. Notwithstanding, efforts are underway to model the "palaeoscapes" of the now submerged continental shelf (Marean et al. 2015).

Pleistocene Paleoenvironments and Paleoecology

Various attempts have been made to synthesize paleoenvironmental evidence from the southern Cape (Deacon and Lancaster 1988; Partridge 1990; Meadows and Baxter 1999; Partridge et al. 1999). Even more recent reviews are, however, significantly limited by a lack of reliable data (Chase 2010; Chase and Meadows 2007; Lewis 2008). There are, fortunately, a wide range of research initiatives underway, the findings of which (in contrast to many of the older records) will be independent of material within archaeological sequences. Here, we review the likely drivers of southern Cape climatic variability, which we consider in the context of recent terrestrial proxy records and marine proxies.

East of Still Bay, the southern Cape exists within what is largely a year-round rainfall zone (YRZ). This year-round precipitation is a function of moisture derived from temperate, tropical, and local storm systems (Fig. 2.3). Given these multiple controls, each of which influenced by different elements of the global oceanic-climate systems, it is likely that this is an ephemeral climatic regime. However, such diversity in potential moisture sources may have buffered the region from the more extreme climatic variability seen in the continental interior (e.g., Scholz et al. 2007).

Rainfall Regime Configurations During the Pleistocene

Colder conditions during the Pleistocene have often been closely linked with enhanced aridity throughout southern Africa, including the south coast (Partridge et al. 1999). A conceptual model of southern African climatic variability, in which there is an anti-phase relationship between the summer and winter rainfall systems of southern Africa, has been applied to interpretations of Pleistocene climatic variability (Tyson 1986; Cockcroft et al. 1987). From this it has been argued that when tropical systems intensify, the influence of the westerly storm systems declines, and vice versa (Tyson 1986; Cockcroft et al. 1987; Chase and Meadows 2007). These adjustments reflect latitudinal shifts in westerly storm tracks in response to changing hemispheric temperature gradients, Antarctic sea ice extent and the positioning of the subtropical front (STF), in addition to changes in the positioning and seasonal movements of the Atlantic and Indian Ocean subtropical high pressure systems.

Although – or perhaps because – these models were based on contemporary/historical climatic variability (Cockcroft et al. 1987) it has proved difficult to test such ideas in the proxy record. However, there are now a growing number of records derived from marine environments, which span the last 125 kyr or more and indicate significant, and often regionally unique, responses to global forcing mechanisms. Key among these records are: (1) marine records relating to position of the STF (Peeters et al. 2004; Bard and Rickaby 2009); (2) records indicative of changes in the character and flow of the Agulhas Current (Bard et al. 1997; Sonzogni et al. 1998; Peeters et al. 2004; Caley et al. 2011); and (3) records indicative of changes in the west coast Benguela upwelling system (Little et al. 1997a, b; Stuut et al. 2002; Pichevin et al. 2005). While these marine records do not necessarily directly reflect changes in terrestrial systems, they do indicate, at least in a general sense, variations in the underlying climate systems. Thus, they can be used to explore hypotheses of causation. For instance, Stuut et al. (2002) hypothesized that increased humidity on the western margins of Namibia during periods of relative global cold was the result of increased winter rainfall. This hypothesis finds support in the significant correlation between their record

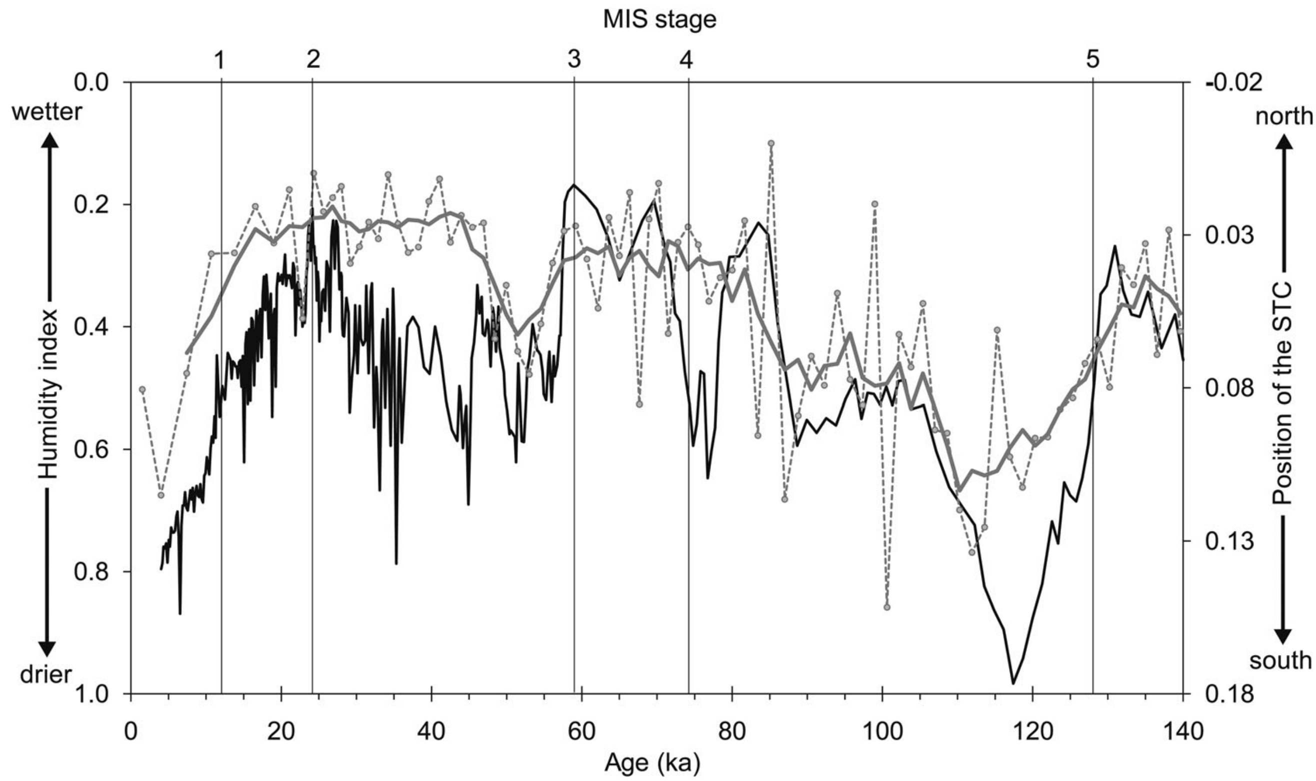

Fig. 2.6 Stuut et al.'s (2002) record from MD962094, which is interpreted as indicative of the significance of winter rainfall along the Namibian coastline (*Black solid line*). This is compared to Peeters et al.'s (2004) record (*dotted line*) indicative of the position of the STF (derived from the ratio: *Globorotalia truncatulinoides*/(*Neogloboquadrina pachyderma* (dex.) + *Globorotalia inflata* + *G. truncatulinoides*). The light *gray line* is the 7 point moving average for this dataset

and migrations of the STF (Peeters et al. 2004) (Fig. 2.6). Concerning tropical moisture systems, a pollen record reflecting conditions in the Limpopo Basin (Dupont et al. 2011) shows similarities with SSTs in the Mozambique Channel over the last 300 ka, as do several sites in northeast South Africa during the last 45,000 years (Chevalier and Chase 2015; Truc et al. 2013), implying a link between SSTs and continental humidity in the proximal summer rainfall zone. This link is seemingly less strong, however, in central South Africa, where variation in westerly systems also contributed to overall rainfall variability (Chevalier and Chase 2015).

Paleoclimatic Insights from MIS 2 and MIS 1

As previously reported (Chase and Meadows 2007), the MSA predates the majority of the region's terrestrial paleoenvironmental evidence (particularly evidence independent of archaeological/anthropic deposits). We can, however, consider evidence for terrestrial climate change during the last 25 kyr to illustrate potential paleoclimatic scenarios, and the responses of the driving systems. The late Pleistocene-Holocene transition (18–11 ka) and the mid- to late Holocene demonstrate the potential diversity of climatic configurations and the complexity of interpreting such changes based on proxy data (Figs. 2.3, 2.7).

The Late Pleistocene-Holocene Transition

As argued by Chase (2010) for MIS 4 it is possible to envisage scenarios within which both temperate and tropical moisture sources intensify at the same time (cf. Cockcroft et al. 1987). On the southern Cape the terminal Pleistocene, between 17.0 and 14.0 cal kBP, is potentially an example of this. Evidence from Boomplaas Cave (Fig. 2.1) indicates that this period witnessed the highest effective precipitation of the last c. 80 kyr (Scholtz 1986). In contrast, much of this period (including "Heinrich stadial 1" (HS-1)) was notably drier throughout parts of the Afro-Asian Monsoon region (cf. Stager et al. 2011, and reference therein). The early onset of warming in the Southern Hemisphere (Blunier et al. 1998; Pedro et al. 2011) becomes apparent in southwest Indian Ocean SSTs at ~17 ka (Sonzogni et al. 1998; Dupont et al. 2011). These warmer SSTs would have invigorated summer rainfall systems during the early parts of the glacial-interglacial transition, and evidence for this is seen in the increase of forest taxa in the Limpopo Basin (Dupont et al.

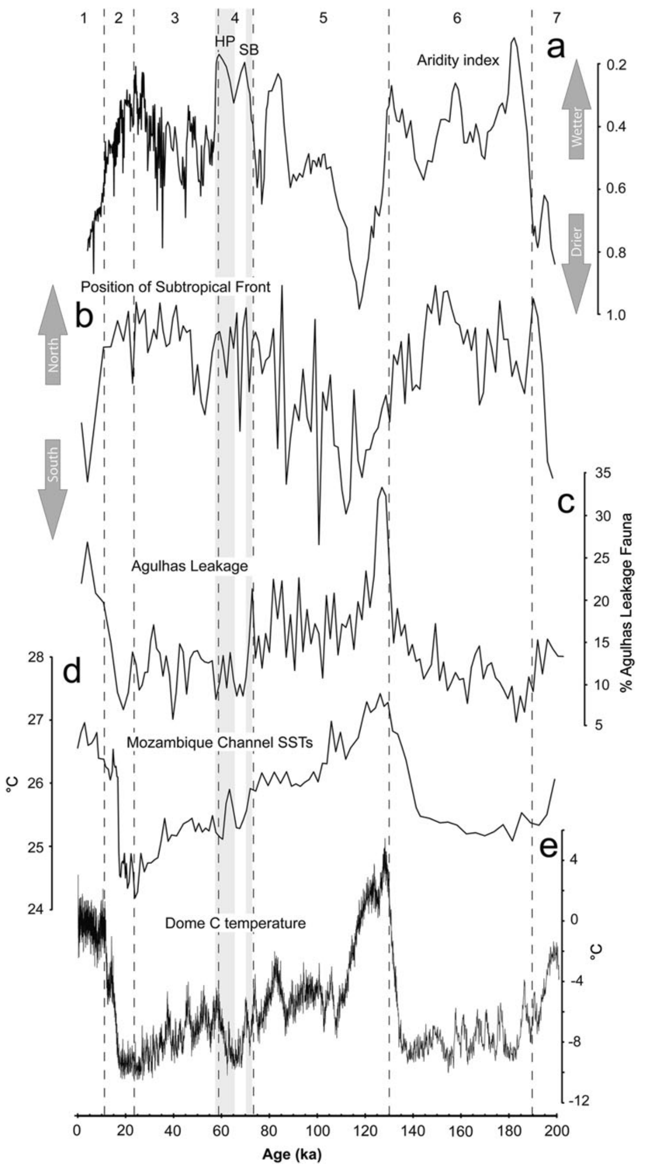

Fig. 2.7 Comparison of the key paleoclimatic records from southern Africa and Antarctica discussed in the text: **a** MD962094 (Stuut et al. 2002); **b**, **c** MD962081 (Peeters 2004); **d** MD79257 (Bard et al. 1997); **e** Antarctica Dome C (Jouzel et al. 2007). *Dotted vertical lines* delimit MIS 1-6. Shaded zones indicate the ages of the Howiesons Poort (HP) and Still Bay industries (as per Jacobs et al. 2008)

2011). The influence of these easterly systems appears to have extended across the southern continental interior (cf. Chase et al. 2015b), and more humid conditions in the Cederberg Mountains of the southwestern Cape during HS-1 have been attributed to increases in summer rainfall (Chase et al. 2015a). Furthermore, it would seem that there was no significant poleward shift in the STF (Peeters et al. 2004) until the beginning of the Holocene (~11 ka) indicating that little or no decline in winter rainfall had occurred. Thus, particularly humid conditions on the southern Cape from 17 to 14 ka can perhaps be explained as the combined influence of winter and summer rainfall (Chase and Meadows 2007).

The Mid- to Late Holocene

During the mid-Holocene (c. 7300–4500 cal BP) the drought-sensitive afromontane forest, which currently occupies the heart of the YRZ in the Knysna area (Fig. 2.4), was more restricted than today (Martin 1968; Scholtz 1986), while evidence for more arid mid Holocene conditions is also observed at Still Bay to the east (Quick et al. in press a). In detail, recent evidence from high-resolution rock hyrax midden records from Seweweekspoort in the Groot Swartberg mountains (170 km northwest of the Knysna area) suggest a distinct period of aridity 7–5 ka, which is coeval with anomalies in Antarctic sea ice extent. This is interpreted as good evidence for the role of the westerly systems (Chase et al. 2013) in driving variability in southern Cape climatic conditions. A subsequent period of drier climate and reduced forest cover also seems to have occurred between 2700 and 1300 cal BP (Scholtz 1986; Carr et al. 2006a, b; Quick et al. in press a). In this case, the underlying mechanisms are less straightforward, but a similar pattern of increased aridity at Cold Air Cave (Lee-Thorp et al. 2001) suggests that this could also reflect a reduction in summer rainfall (increasing southern Cape rainfall seasonality), perhaps due to lower Agulhas Current sea surface temperatures (Sonzogni et al. 1998), which would have promoted drier conditions on the south coast (Chase and Meadows 2007; Quick et al. in press a, b).

Paleoclimates During the MSA: MIS 5b-3 (95–60 Ka)

The waxing and waning influence of the major moisture-bearing systems was specifically considered by Chase (2010) in a review of MSA climates during MIS 4 and the Howiesons Poort (HP) and Still Bay (SB) industries (~74–58 ka [Jacobs et al. 2008; Jacobs and Roberts 2008; Bar-Matthews et al. 2010; McCall and Thomas 2012]). This review of proxy data from multiple southern African archaeological sites (e.g., Klein 1976, 1983; Tankard 1976b; Butzer et al. 1978; Avery 1982; Butzer 1984; Deacon et al. 1984; Klein and Cruz-Uribe 2000) concluded that during MIS 4 overall conditions were relatively cool and moist compared to the present (Chase 2010). Such findings imply that southern African climate systems did not follow apparent global trends during this period and it was suggested, based on records of variation in the westerly systems (Stuut et al. 2002) the STF (Peeters et al. 2004; Bard and Rickaby 2009), the Agulhas Current (van Campo et al. 1990; Peeters et al. 2004) and the influence of orbital obliquity on hemispheric temperature gradients, that MIS 4 was relatively humid as a result of increased contributions from both winter and summer rainfall systems (Chase 2010). New SST records from the southwest Indian Ocean (Caley et al. 2011) modify this hypothesis to some extent, but the basic premise still pertains, with periods of relatively elevated Indian Ocean SSTs combining with a more northerly position of the STF to enhance both summer rainfall and westerly derived rainfall, generating relatively wetter conditions across southern Africa. While more data will be required to verify this hypothesis, this scenario is comparable with that outlined for the late glacial and early Holocene. Recent findings from Sibudu Cave in KwaZulu-Natal (SRZ) imply summer rainfall comparable to the present during the HP, with the subsequent post HP period being relatively drier (Bruch et al. 2012).

More recently, there has been an attempt to directly consider high-resolution paleoenvironmental data for the southern Cape, although the link between the paleoenvironmental record and underlying processes is difficult to decipher. The Crevice Cave speleothem record from the Pinnacle Point excavations (Bar-Matthews et al. 2010) provides a high-resolution record of stable carbon and oxygen isotope variations for the period 90–53 ka (MIS 5b-MIS 3). Fluctuations in $\delta^{13}C$ within the record are interpreted as reflecting the relative abundance of C_3/C_4 grasses. In turn, this is interpreted as indicative of the degree of winter rainfall, which, gives the strong linkage between C_3 vegetation and the winter rainfall zone (i.e., growing season temperature), is how most records of this nature have also been interpreted (e.g., Lee-Thorp and Beaumont 1995; Scott and Vogel 2000). The $\delta^{13}C$ record shows some marked shifts, with periods of increased (open?) C_4-dominant vegetation inferred for 75–70 ka and 65–60 ka. Additionally, a period of rapid variation in the $\delta^{13}C$ signal at 65–70 ka is interpreted as a period of marked climatic/ecological instability between the SB and HP Industries. The mechanisms behind this are unclear.

Bar-Matthews et al.'s (2010) interpreted changes in vegetation type are not inconsistent with some long-standing ideas that suggest grassier environments probably existed on the continental shelf during periods of relative cold (and low sea level), explaining the increased prominence of grazing fauna in many MSA assemblages (e.g., Klein 1972). Although Rector and Read (2010) caution that it should not be assumed that such coastal plain grasses were C_4, proposing that complex mosaics of C_3 grasses and Fynbos, would also have been able to support grazing communities.

Despite a detailed analysis, the Crevice Cave record defies easy interpretation in some respects. The $\delta^{18}O$ record (interpreted as reflecting the seasonality of rainfall) shows little correlation with regional records of winter rainfall intensity, the position of the STF, or with data indicative of Agulhas Current flow and temperature (Stuut et al. 2002; Peeters et al. 2004; Caley et al. 2011). Counter to previous models (van Zinderen Bakker 1967, 1976; Cockcroft et al. 1987; Tyson 1999a, b; Chase and Meadows 2007) periods of *cooling* (through correlation with remote records from the EPICA ice core and an SST record from the Chatham Rise, New Zealand) are associated with *increases* in *summer* rainfall (lower $\delta^{18}O$) and the expansion of C_4 vegetation (higher $\delta^{13}C$). By way of perspective, it is important to note that the nearby (85 km north) Cango Cave speleothem record shows markedly different trends (de Wit et al. 2009). In the Cango record, variation in $\delta^{13}C$ shows strong correlations with changes in the strength of Agulhas flow along the south coast (Peeters et al. 2004), most notably including relatively enriched $\delta^{13}C$ values (more C_4) prior to MIS 4, and then a shift to more depleted values (more C_3) at $\sim$70 ka implying increased winter rainfall during MIS 4. Similarly, the Holocene portion of the Cango Cave record (6000 cal BP to present) contrasts with the MIS 2 section of the record, with the former period exhibiting markedly higher $\delta^{13}C$ than the latter (Talma and Vogel 1992). Here, an interpretation concerning "interglacial" verses "glacial" vegetation, based on $\delta^{13}C$, would imply that the "glacial"/ "cooler" conditions were associated with *more* C_3 vegetation – the opposite of what is seen in the Crevice Cave scenario.

The discrepancies between the Cango and Crevice Cave records may relate to the fact that while the Cango Cave speleothem was recovered from a deep cave complex the Crevice Cave speleothem was recovered from a wave-cut crevice, which began to form after the hollow was sealed by coastal dunes c. 90 ka. The context for this speleothem record is therefore quite unusual. At present it is not entirely clear to what depth the cave was buried, and to what extent it was ventilated during formation. The latter aspect can have a substantial impact on isotopic equilibrium due to de-gassing effects in areas (or periods) of greater ventilation, creating variability unrelated to the inferred climatic parameters (Talma and Vogel 1992; Mickler et al. 2004; Tremaine et al. 2011). Some data (from two laminae) are presented concerning this nonequilibrium precipitation issue ("Hendy tests"), but these issues warrant further investigation. In the case of both the Cango and Crevice cave records, neither considers (or is easily able to consider) the influence of CAM plants, which are common at both sites. These may display a range of $\delta^{13}C$ values (Rundel et al. 1999), and may influence $\delta^{13}C$ signals in some paleoenvironmental archives in this region (Carr et al. 2010b).

Southern Cape Paleoecology

Aside from the aforementioned Crevice Cave record, paleoecological data for the MSA are largely restricted to faunal remains recovered from archaeological sites. Broadly speaking, there appears to be a significant correlation between glacial periods and increased numbers and diversity of grazing animals (Klein 1972, 1976, 1978, 1983; Klein and Cruz-Uribe 2000; Faith 2011a, b; Rector and Reed 2010). Based on these data, the inference has long been that glacial periods supported more open, grassier environments. Recent faunal evidence from PP13b, notably the Upper Roof Spall layer dating to 98–91 ka, has been interpreted as indicative of more open, mosaic habitats (Rector and Reed 2010), while data for the periods 134–94 ka and 102–91 ka were also thought to be suggestive of relatively open conditions, as well as moist ("vlei") conditions (Rector and Reed 2010). Nelson Bay Cave on the Robberg Peninsula is one of the few coastal archaeological sites with a faunal record crossing the Pleistocene-Holocene transition and a clear switch from dominantly grazing to dominantly browsing fauna seems to have occurred during the period 12,000–9,000 ^{14}C BP (Deacon 1978).

While the relationship between grazers and open, grassier environments is clear, it does not follow that this was the result of drier climates. Presently, the southern Cape coastal plain hosts a complex variety of vegetation types, and the shrubby renosterveld vegetation that would dominate parts of the coastal plain (were it not for modern land use practices) is on the drier end (250–550 mm a^{-1}) of the climatic continuum. It is only with increased humidity (500–750 mm a^{-1}) that grasses become a more important component of the vegetation (Cowling 1983).

Unfortunately, aside from the aforementioned speleothem records, there are very few data available that can assist in the interpretation of fluctuations within these faunal assemblages. Botanical remains are often poorly preserved in archaeological contexts, and there are few suitable and adequately studied wetlands in the region. At present only three lake sediment records extend beyond the Holocene (Fig. 2.1): (1) Voëlvlei and Soetendalsvlei from the Agulhas Plain (Carr et al. 2006b); (2) Rietvlei near to Still Bay (Carr et al. 2010c; Quick et al. in press a); and (3) Vankervelsvlei near to Knysna (Irving and Meadows 1997; Irving 1998; Quick et al. in press b). Voëlvlei and Soetendalsvlei have relatively coarse chronological control. However, Rietvlei and Vankervelsvlei are the subject of recent studies and provide detailed multi-proxy records spanning the last ~35 kyr (Quick et al. in press a) and 140 kyr (Quick et al. in press b), respectively.

At the Voëlvlei site modern vegetation is heavily modified by human activity, but the natural vegetation was probably renosterveld. The pollen records, derived from pan sediments, have limited chronological control. However, in conjunction with the surrounding geomorphic evidence they suggest a period of relative humidity, probably within MIS 3 (ages span >48,000–33,000 cal BP). The pollen spectra are rich in both fynbos pollen and characteristic renosterveld pollen. Grass pollen is also present, but not markedly abundant (Carr et al. 2006b). A core from the margins of nearby Soetendalsvlei dating to 14,400–13,300 cal BP produced pollen spectra similar to the modern limestone fynbos around the site, implying a comparable situation to the present (Carr et al. 2006b). Thus, evidence for significant reorganizations of the Pleistocene Agulhas Plain vegetation communities is rather equivocal, although coastal Fynbos was clearly present at Cape Agulhas from 14,000 cal BP. Further to the east, in the year-round rainfall zone, the Vankervelsvlei record spans ~140 kyr. The site is located within the drought-sensitive afromontane forest of the Knysna area (see section "Landscape Responses to Sea Level Change: Coastal Eolian Systems"), and like the Holocene records discussed above (e.g., Scholtz 1986) shows clear fluctuations in the extent of afromontane forest. MIS 2 is associated with increases in the relative significance of fynbos pollen, perhaps implying a decrease in humidity and/or increased rainfall seasonality (Irving 1998). Recent work has extended this record back to 140 kyr using luminescence dating (Quick et al. in press b). This study reveals distinctly warmer temperatures during MIS 5d compared to later MIS 5, MIS 4, and MIS 3. Evidence for increased summer rainfall during MIS 5d is also identified, but importantly although there is some evidence for increased rainfall seasonality from ~96 kyr onwards, significant reductions in overall humidity did not seemingly occur during MIS 4 and MIS 3, perhaps implying that reductions in (summer) rainfall were offset by lower evapotranspiration due to cooler temperatures. East of Still Bay, the Rietvlei wetland dates back to at least 35,000 cal BP (Carr et al. 2010c; Quick et al. in press a). Additional evidence suggests a persistent wetland of some form was present as early as MIS 5e (Roberts et al. 2008). Nearby MIS 5e eolianites contain trace fossils revealing a diversity of mammal fauna in the immediate area, suggesting that animals congregated here. The site is perhaps analogous to the coastal "vlei" environments inferred by Rector and Reed (2010). The Rietvlei record itself shows evidence for relatively humid conditions during MIS 3, but also distinct evidence for arid phases within this period. A clear contrast between relatively humid early Holocene and more arid mid Holocene conditions is also apparent.

Fundamentally, the nature of the vegetation on the continental shelf remains a critical unresolved element for interpretations of both the human and faunal records in this region (Rector and Reed 2010). Aside from the poorly defined nature and distribution of continental shelf substrates, the unknown hydrology of continental margin is a complicating factor. It is of specific relevance to models of coastal-zone habitability (Parkington 2003). The "coastal oasis" model argues that during sea level regressions steeper peri-coastal water table gradients increased the hydraulic head on continental aquifers, promoting spring activity and primary productivity on the continental margins (Faure et al. 2002). This potentially increased availability of water and biomass would have rendered the continental shelves more attractive environments for both grazing fauna and human occupation (e.g., Compton 2011). At present there is a little specific evidence to support this hypothesis on the southern Cape, although there is some limited geomorphic evidence for an adjustment in the southern Cape coastal hydrology in the Agulhas Plain salt pans (Carr et al. 2006a). These became inactive after c. 45 ka, as they ceased to intersect the water table, implying a response to sea level change consistent with that envisaged by Faure et al. (2002).

Summary: Integrating Human Occupation and Subsistence with Paleolandscape and Paleoclimates

A full understanding of the human story during the MSA requires an integration of the archaeological record with data pertaining to the landscapes and environments at that time. Linking specific aspects of human development such as stone tool industries or technocomplexes to environmental change is fundamentally difficult and contentious. For example, McCall (2007) argues for a direct correlation between the HP and colder temperatures during late MIS 4 (see also Ambrose and Lorenz 1990). Jacobs et al. (2008) argue that there can be no such association given that global temperatures at this time exhibit a *warming* trend. Hiscock et al. (2011) argue that the HP is a response to this warming. All of these arguments use global temperature data to model environmental change, and none is able to make significant use of local paleoenvironmental records that directly reflect subsistence conditions. As paleoenvironmental and paleogeographic evidence accrues, however, we can begin to offer a guide to some of the (potentially) most relevant facets of the environment for the region. We attempt to summarize these linkages in Fig. 2.8. Many elements of this diagram might be considered as generic, but based on the preceding we can highlight how they are uniquely manifested on the southern Cape.

Landscape Factors

Landscape factors are a function of geology and relative sea level change. Sea level change, mediated by local-scale geological control, has operated as an overarching driver of

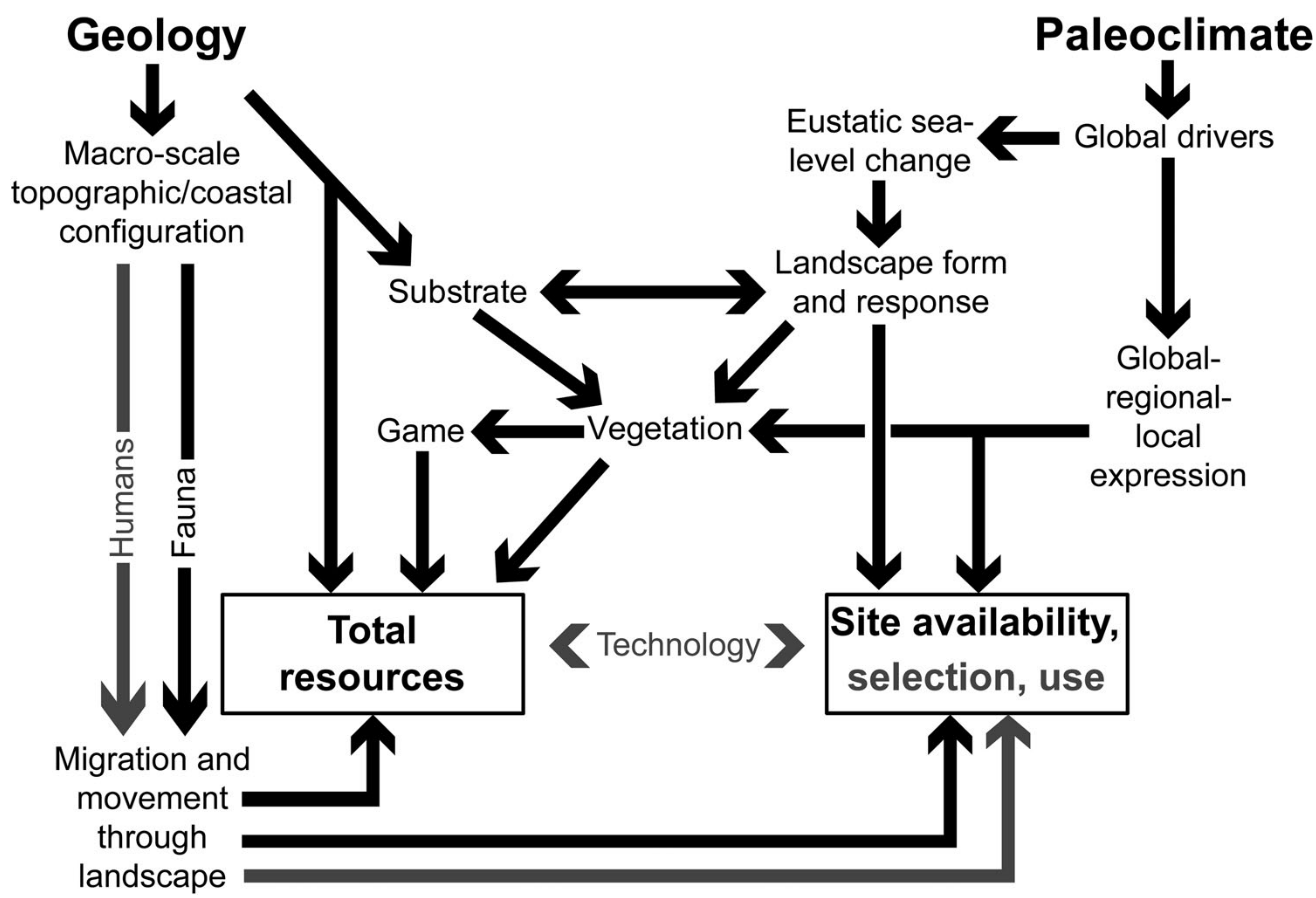

Fig. 2.8 A schematic representation of the interactions between landscape, palaeoclimate, resource availability (including fauna), and human behavior. The primary purpose is to summarize potential interconnections identified in this review, not to provide a prescriptive framework. The diagram highlights the role of (inherited) characteristics (e.g., geology) in mediating local responses to global-scale forcers of landscape and climate change

landscape dynamism and resource availability throughout the Pleistocene. It is a global-scale pacemaker (eustatic sea level change) mediated by (inherited) local geological control (e.g., Compton 2011). Landscape factors are somewhat interrelated, but are significant in terms of:

1. *Geological constraints act on landscape structure and topography*. They control coastal landscape configuration both locally (bays and headlands, sandy/rocky shores) and regionally (continental shelf topography). As a result they influence site to shore distance, marine resource availability, and site selection. Through the topography of the continental shelf they also determine local sensitivity to eustatic sea level changes. Regional geological structures might have presented impediments to migration between the interior and margins of South Africa. Periodic isolation of communities and fauna is a possible outcome (Compton 2011).
2. *Sea level constraints on coastal landscape, landscape dynamism and site occupation*. Eustatic sea level is a global signal but it is moderated at both local and regional scales by geological constraints. In coastal locations, sea level influences site access, habitability, and preference (i.e., occupational hiatuses), both directly through flooding/inaccessibility during sea level highstands (e.g., De Kelders during MIS 5e), and indirectly via local and regional-scale pulses of coastal eolian activity (Pinnacle Point, Blombos). The relative availability of marine food resources will have been directly influenced by most of these factors, as will the availability of fresh water (e.g., Avery 1974; Faure et al. 2002; Carr et al. 2006a).
3. *Soils, vegetation, and game resources*. Soil properties – largely a function of geology – control the distribution of the major vegetation types in this region. The vegetation on the exposed continental shelf during the Pleistocene was probably also strongly influenced by this phenomenon. It is potentially a key driver of habitat extent and heterogeneity, and thus, game resources (e.g., the extent of grazing). Habitat extent and heterogeneity will have been affected by relative sea level change. It remains a critical unresolved issue.

In considering these landscape factors the present evidence implies that caution is required when applying regional-scale trends at local (site) scales. Uncertainties in sediment supply/accommodation space and the absolute magnitude of relative sea level change remain (note that in southern Africa we are largely applying eustatic records derived from distant locations). Overinterpretation in the absence of stratigraphic evidence should be avoided.

Paleoclimatic and Paleoecological Factors

Paleoclimatic and paleoecological factors are not independent of our basic geological and sea level framework. They however are fundamentally related to *terrestrial and shore-margin ecosystem productivity*. In terrestrial environments, the availability, density, and type of water and food resources available are directly relevant to issues of population density, settlement organization, and technological change (Mackay 2009). They can be summarized as follows:

1. *The diversity of climatic drivers*: The southern Cape climate is a function of several components of the global climate circulation. This results in a diversity of moisture-bearing systems, which combine to create a variable, but resilient resource base. While the amount and seasonality of surface-available fresh water varied through the late Pleistocene, it is unlikely that the region was ever truly arid or “harsh”.
2. *The complexity of vegetation response*: The available evidence suggests that the delivery of moisture to this region did vary, but the specific impacts on the region’s vegetation communities, mediated by substrate type and availability (exposure), are difficult to resolve. Weak knowledge of the region’s lowland and continental shelf paleoecology is a critical issue, particularly concerning the significance of “grassier” communities and the drivers of such structural changes in the region’s vegetation. At present we have insufficient evidence to disentangle the role of paleoclimate (moisture source/seasonality) from substrate and as drivers of vegetation change on the coastal lowlands.
3. *Local mediating factors, which are difficult to predict*: As with landscape controls, local-scale controls will serve to buffer/mask the effects of global scale “climate deteriorations” through the influence of (for example) soil substrate patterns, marine resource availability and local hydrology (e.g., coastal springs).

Human Interaction and Subsistence

Human subsistence behavior is structured by the spatial and temporal distribution of key resources, principally water, food, and shelter (Kelly 1995). The effects of these factors are mediated by changes in mobility, settlement systems and prey choice; technology likely responds to all three.

Shelter selection on the south coast is likely to have been influenced by a combination of sea level and inherited (contingent) local responses. The appearance and disappearance of springs, shifts in beach ridges and dunes, and the reconfiguration of shore lines will all have influenced the ways in which sites were used and indeed whether they were used at all. That the operation of these factors is difficult to predict may provide some explanation for the limited temporal overlap or nonoverlap in relatively proximate south coast MSA sequences (e.g., Blombos, Klasies River, Nelson Bay Cave and Pinnacle Point). Such local controls, along with the small sample of well-resolved south coast sites, makes attempts to correlate periodicities of site usage with population fluxes problematic. Local resource availability and landscape configuration likely exert stronger control than absolute population size. As noted, proximity to shoreline will have influenced the viability of marine resource use, with implications for shelter use (e.g., Marean et al. 2007). Beyond this, however, shifts in the availability of marine resources may have affected patterns of mobility and technological systems, the former with potential impacts on duration of site occupancy. Sessile marine resources provide a reliable food source, which can be harvested with minimal technological constraint. Many marine resources can withstand longer and more intensive harvesting than can their terrestrial equivalents (Binford 2001; Kelly 1995). Proximity of marine resources may thus have allowed periods of extended occupancy within a regime of diminished residential mobility at near-shore sites during high-stand periods (though note Borrero and Barbarena 2006).

In a similar vein, shifts between seasonal and aseasonal moisture regimes resulting from changes in the relative strength of summer and winter rainfall systems can alter patterns in the organization of landscape use. Surface water availability has a structuring effect on mobility; with diminished surface water, a greater frequency of movements involving entire groups is expected (Kelly 1995; Read 2008). Conversely, extended residential occupation of sites becomes more viable with greater water availability (Mackay 2009). Due to attendant local resource suppression resulting from extended occupancy, a shift in the configuration of mobility from residential to logistical is plausible (cf., Binford 1980; Kelly 1983). Such a shift may have occurred during relatively humid phases, potentially explaining the large assemblage sizes in MIS 4 at many south coast sites (Mackay 2009). Greater incorporation of small game might be expected to follow local resource suppression under such circumstances.

A secondary effect of shifting seasonality may have been on the complexity of technological systems deployed. Ethnographic data suggest that length of growing season affects technological complexity (Bousman 1993; Collard et al. 2005; Read 2008; Torrence 1983). Shorter or less predictable rainy seasons would have operated to increase subsistence risk. A second controlling factor here, however, is effective temperature, which is difficult to model at the local scale with available data. Expanded grasslands may have supported large herds of grazers, potentially generating a stronger hunting-resource base, but fynbos is notably resilient and supports both browsing game and a rich suite of edible floral resources including tubers (Marean 2010; Parkington 1977). We might anticipate that changes in the past composition of floral communities in the southern Cape are likely to have influenced technological systems. Data from the LSA suggest that reductions in grasslands around the transition from MIS 2 to MIS 1 were associated with a shift from microlithic to macrolithic technologies (Deacon 1984). Without proposing a direct relationship we might expect to see technological changes of some kind tracking earlier shifts in southern Cape flora. As we discussed above, however, such vegetation responses are presently difficult to model, emphasizing the need for local archives.

Conclusions

The southern Cape hosts a remarkable archaeological record; the significance of which is steadily being revealed. Here we have sought to summarize the environmental facets most relevant to the interpretation of these archaeological findings. In doing so, we emphasize the legacy of geological controls in influencing both macro and meso-scale landscape responses to environmental change. The region's climate presents both challenges (complexity of interpretation) and opportunities (relevance to synoptic scale climatic controls), but it is likely that regional climates were never sufficiently "harsh" to fully prevent occupation of the southern Cape. Although the specific composition of south coast ecosystems during the late Quaternary remains unclear, the potential combination of mosaic-like vegetation communities and marine food resources implies a relatively diverse and resilient, if variable, resource base. Taken as a whole, the occupational record for the southern Cape probably spans much of the period 170–50 ka, the full range glacial-interglacial conditions. Systems of technology, settlement, and subsistence undoubtedly changed through this period and we have attempted to highlight some of the relevant factors and linkages, and how they may be operationalized. Improvements in baseline archaeological and paleoenvironmental data are now required to strengthen our modeling of ecosystem variation and human behavioral response through the MSA.

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