Puglia 2003 - Final Conference
Project IGCP 437

Coastal Environmental Change
During Sea-Level Highstands:
A Global Synthesis with implications
for management of future coastal change

Otranto / Taranto - Puglia (Italy) 22-28 September 2003
Quaternary coastal morphology and sea level changes

Project 437

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Aeolianite and Barrier Dune Construction Spanning the Last Two Glacial-Interglacial Cycles from the Southern Cape Coast, South Africa.

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Keywords: *Coastal barrier dunes, aeolianites, sea-level, luminescence dating, palaeoenvironments*

Introduction

The coastal aeolianites and barrier dunes found on the tectonically stable southern Africa represent the largest Southern Hemisphere continental record of this type of deposit outside Australia (Brooke 2001).

They are extensive in the southern Cape region of South Africa which is at the current interface of the southern African winter and summer rainfall zones and is particularly sensitive to changes in the upwelling regimes on the eastern Agulhas Bank due to the convergence of the Benguela and

Agulhas ocean currents and its location adjacent to the extensive but currently submerged Agulhas plateaux (Figure 1). Past changes in the strength and position (which will be affected by relative sea-level change) of the Agulhas current coupled with variability in wind direction/strength will have had a significant influence on moisture and sediment supply to coastal terrestrial environments.

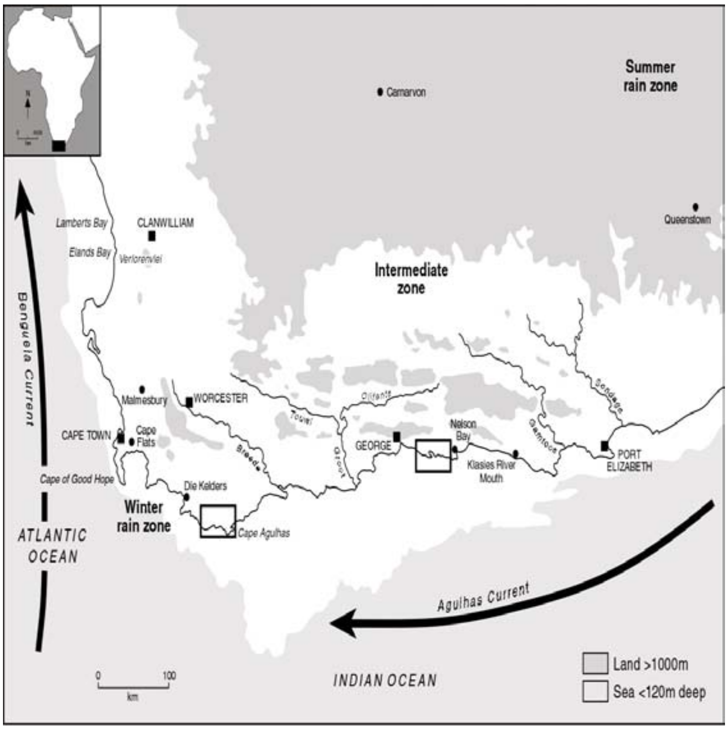

Figure 1. Location map of the Southern Cape coastline of South Africa with boxes showing Wilderness Cordon dune and Agulas aeolinate study areas.

The Southern Cape coastline has a spatially extensive and diverse range of Pleistocene aeolian deposits from which regional palaeoenvironmental conditions can be deduced.

These include 200 m high barrier dunes and spatially diverse aeolianite deposits up to 100m thick. However, as the review of Brooke (2001; p.141) illustrated the temporal control on African aeolianites is extremely poor.

The aims of this paper are firstly to investigate the development of the Southern Cape coastal deposits, with high resolution well dated, site-specific studies on the Wilderness seaward cordon dune and aeolianite sites from the Cape Agulhas area. Second, to revisit the question of dune formation in relation to sea-level oscillations during the Upper Pleistocene.

Chronology

The new optical luminescence chronology for the Wilderness seaward cordon and Agulhas aeolianites shows some synchronicity along the coastline and considerably extends the aeolianite record back in time to include the penultimate interglacial.

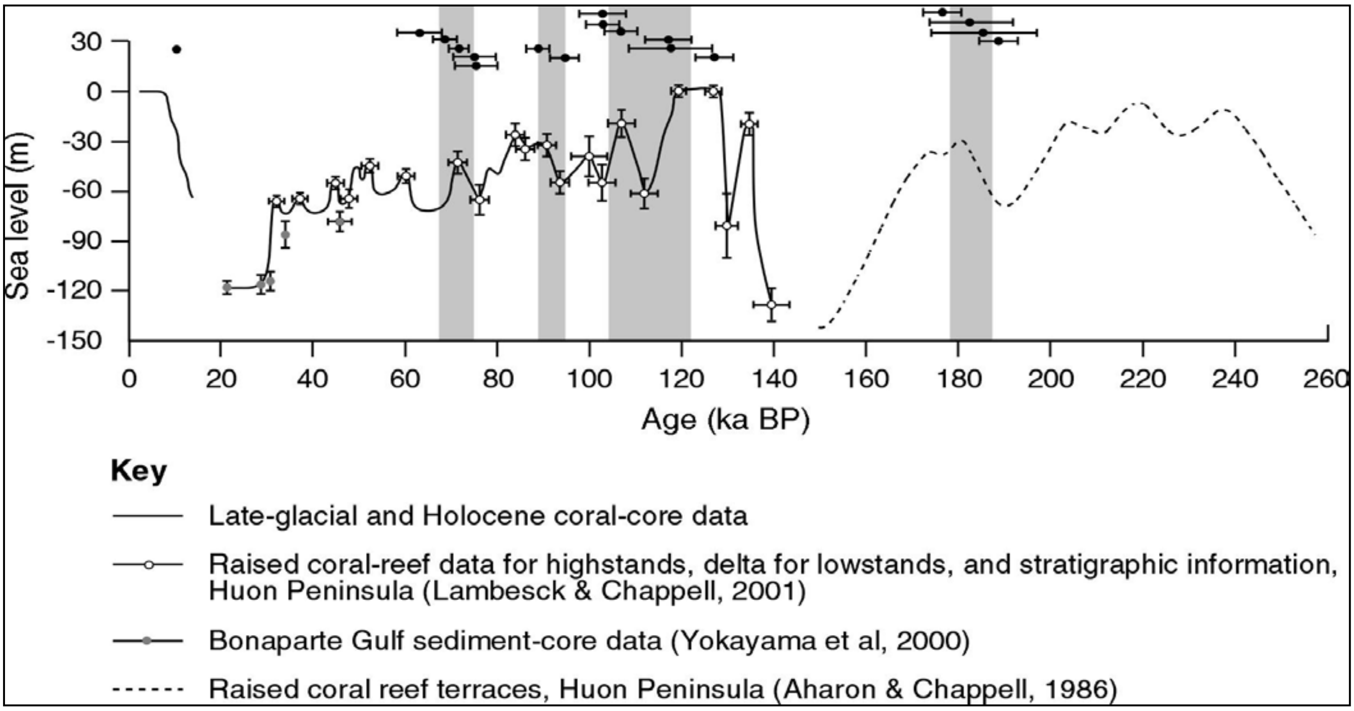

Figure 2. Ages from aeolian sediments on the Southern Cape, South Africa compared to The relative sea-level curve for the penultimate and last glacial cycle. Shading relates to mean ± 1 standard deviation of clusters of ages.

All the aeolianites are older than 60 ka and can be clustered into 5 phases *c.*68-75, 89-95, 104-122, 178-188 and >200 ka before the present (Figure 2).

Provenance

Both the Agulhas aeolianites and the aeolianite found in the core of the seaward cordon at Wilderness are carbonate rich (50-80% and 20-25% respectively). The dispersion of this carbonate throughout the sediments makes a pedogenic origin for these carbonates unlikely. All three Agulhas aeolianite sites exhibited shell fragments within the aeolianites and shells and commuted shell fragments within the aeolianites reported from elsewhere appear relative common (e.g., Malan 1989). The occurrence of foraminifera tests and other marine shells (Siesser 1970) all point to a marine source for the aeolianites. Sediments from the upper sand unit on the Wilderness cordon dune and many of the most recent coastal dune systems are carbonate poor.

As there is no evidence for carbonate leaching, this lack of carbonate may reflect a change in sediment provenance or changes in offshore carbonate production for these more recent (<75 ka) sediments. Increased fluvial discharge of terrigenous clastic sediment would have reduced the off-shore production of Heterozoan carbonate. However, currently the Southern Cape coast is classified as sediment-starved, with only 17.9% of sediment supplied to the continental shelf coming via rivers (Dingle et al., 1987).

Additional changes to carbonate production could have been caused by changes in the relative strength and position of the confluence of the Benguela (cold) and Agulhas (warm) ocean currents which supply nutrients and high carbonate-producing biota respectively.

Aeolian Record and Sea-levels

Globally, the exact association between barrier dune and coastal aeolianite formation on the one hand, and sea-level and coastline fluctuations on the other is still subject of debate (e.g. Brooke 2001).

The data outlined above begins to address this problem for South Africa.

The chronometric framework established above and previously published coastal aeolian dates from the region (Roberts and Berger 1997, Vogel et al.1999, Hensilwood et al. 2002, Shaw et al.2001; Ramsey and Cooper 2002) were overlain on the relative sea-level curve for the Huon Peninsula over the penultimate and last glacial cycle (Aharon and Chapell 1986, Lambeck and Chappell 2001).

This was supplemented with observations from Bonaparte Gulf, Australia (Yokoyama et al. 2000) (Figure 1). Although hampered by the level of precision associated with the chronology, two observations can be made of the apparent relationship of aeolianite deposition to sea-level. Firstly, it is clear that a significant amount of aeolian deposition occurred after the high-sea stand associated with the Eem but not during full glacial times.

Secondly, dunes and aeolian sediments appear to have been deposited when sea-levels were rapidly transgressing or regressing.

That aeolian sedimentation occurred during periods post-dating interglacials also explains why many of the aeolianites and cordon dunes found on the present-day coastline are being eroded, as sea-levels would have been marginally lower than the present-day whilst they were being deposited.

The great thickness of the Southern Cape aeolianites may in part be attributed to them containing older deposits as yet undated.

It may also be explained by examination of the effects of sea-level fluctuations on the Southern Cape coastline. Barrable *et al.* (2002), using present day topography and bathymetry, showed that at the Last Glacial maximum (LGM) lower sea-levels would have exposed the Agulhas Bank, placing the coastline approximately 80 km further south than the present-day Cape Agulhas. As soon as sea-levels rose above -75 m the exposed coastal shelf was reduced in width by at least two-thirds (van Andel 1989). Sea-levels in the period 70-95 ka were nowhere near as low as at the LGM and included within this period are a number of interstadials in which sea-level rose to be relatively close to that of the present day.

This would have been particularly the case east of the Agulhas plateau where the coastal platform initially shelves more quickly (Dingle and Rogers 1972a).

The effect of such rises means that the sea would have returned to within a few kilometres of the present-day coastline on a number of occasions (van Andel 1989) allowing sediment accretion to repeatedly occur at these same localities. Further evidence for cordon dune construction only near the littoral zone comes from the reporting of a complex of submarine barrier-like dune ridges found off the Southern Cape coast.

These occur between -130 to -112 m coincident with where sea-levels would have been for a considerable period of time during the last glacial maximum low-stand (van Andel 1989).

Other submarine dune complexes have been reported off the Wilderness area coastline at -40 m and -50 m (van Andel 1989), which again could relate to dune construction associated with other interstadial sea-level high stands within OIS 3 in which sea-levels transgressed but not sufficiently high enough for aeolian sediments to be recorded at the present-day coastline.

Conclusions

The OSL dating has established for the first time a regional chronology for the coastal aeolianites of the Southern Cape, which spans two glacial-interglacial cycles and redresses the lack of chronological control for the African aeolianite as reviewed by Brooke (2001).

The majority of the sedimentary record examined relates not to deposition during interglacial highstands but to post-interglacial periods (interstadials) when sea-levels were fluctuating and climatic conditions were cooler and wetter, and therefore more conducive to cementation/preservation.

The chronostratigraphy of the Southern Cape aeolianite record appears to be similar to that found in other major aeolianite localities, e.g. South Australia, Bermuda and Barbados. The lack of carbonate found in sediments at the transition of OIS 1/2 and OIS 4/5 is not due to leaching.

It may reflect increased terrestrially derived quarzitic material and/or changes in the positions and strengths of the Benguela and Agulhas currents dampening carbonate production in the near-shore zone from which the sediment for the dunes is sourced.

The presence of such a thickness of aeolianites is partly interpreted as showing that palaeo wave energy levels on the Southern Cape coast have been high, building up littoral sediments and that on-shore winds have been significant over the long-term. It is also suggested that Late Quaternary sea-level oscillations have repeatedly caused the driving onshore of carbonate rich sediments. Where the coastal platform shelves gently and there are no other topographical obstructions this has lead to the formation sheet-like aeolianites. Elsewhere, where the coastal platform shelves steeply away from the present-day coastline, sea-level fluctuations repeatedly moved sediment close to the same localities allowing the building up of cordon dunes.

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