24. Endrödy-Younga S. (1978). Coleoptera. In *Biography and Ecology of Southern Africa*, vol. 2, edit. M.J.A. Werger. Junk, The Hague.
25. Werger M.J.A. (1978). The Karoo-Namib Region. In *Biography and Ecology of Southern Africa*, vol. 1, edit. M.J.A. Werger. Junk, The Hague.
26. Ward J.D., Seely M.K. and Lancaster N. (1983). On the antiquity of the Namib. *S. Afr. J. Sci.* **79**, 175 – 183.
27. Kock C. (1962). The Tenebrionidae of southern Africa XXXI. Comprehensive notes on the tenebrionid fauna of the Namib Desert. *Ann. Transv. Mus.* **24**, 61 – 106.
28. Seely M.K. (1978). The Namib dune desert: an unusual ecosystem. *J. arid. Environ.* **1**, 117 – 128.

Dr Seely is director of the Desert Ecological Research Unit, P.O. Box 953, Walvis Bay.

Comments on the Namib's Past

C. K. Brain

Recent research on the sedimentary record, of marine cores, Antarctica and elsewhere, is helping to reveal the Namib's past.

In their recent publication, Ward, Seely and Lancaster[1] defined the Namib as that 'narrow tract of land, some 2000 km long and mostly less than 200 km wide, lying west of the Great Escarpment between the Olifants river (Cape Province, South Africa) and the Carunjamba river (Mocamedes District, Angola)'. As a discrete entity, the Namib came into being when the super-continent Gondwanaland started to break up early in the Cretaceous Period about 130 million years ago, the rift between the west coast of Africa and South America starting in the south and widening progressively as the South Atlantic came into being.[2] During this time, Africa was also drifting steadily northwards, through about 15° of latitude in the course of the Cainozoic Era, which in terms of Namib history means that the region has remained in those latitudes whose atmospheric circulation is dominated by anticyclones — cells of high pressure characterised by stable descending air. There appear to be two main reasons for the paucity of rain in the Namib, and both of them are related to the presence of anticyclones, positioned respectively over the South Atlantic and Indian Oceans. It is from the Indian Ocean that winds carry moisture to these latitudes of Southern Africa in summer, their passage in winter being frequently impeded by the presence of temperature inversion in the atmosphere over the east coast, below the level of the escarpment.[3] However, most of this moisture is lost as the winds penetrate westward, with the result that summer rain in the Namib is not only very sparse, but typically falls late in the season. This situation is likely to have pertained throughout Southern Africa's history as a subcontinent lying in its present latitudes, and bounded on east and west by the Indian and South Atlantic Oceans. For this reason it is not surprising that authors who have traced the geological history of the Namib[1] have found evidence of aridity in varying degree throughout the record.

There has, nevertheless, been a second aridifying influence in operation along the Namib coast and this too is mediated by the persistent presence of the South Atlantic anticyclone. South-westerly winds blowing around this high pressure cell are responsible for the Benguela Current and for the upwelling of cold, deep water that characterises it. The action of the wind close to the coast is to move the surface water westward, towards the centre of the high pressure cell, causing deeper, cold and nutrient-rich water to rise to the surface, although the movement pattern appears to be extremely complex.[4] As long ago as 1940, Taljaard and Schumann[5] demonstrated that, above the Benguela Current in the vicinity of Walvis Bay, a remarkably persistent temperature inversion is present in the atmosphere, so that between 2000 and 6000 ft (610 – 1830 metres) atmospheric temperature *increases* with altitude, above which it declines again. This feature appears to restrict the upper altitudinal limit of the moist fog so commonly found along the Namib coast. It also effectively inhibits the formation of rain-bearing clouds over the Namib.

So it is usually argued that, while the Benguela Current has been active, an additional aridifying influence has been in operation, transforming an already dry coastal environment into a really arid one. More than 40 years ago it was realised that the abundant beetle fauna of the Namib is not only very rich in endemic forms, but also in beetles highly adapted to their sandy habitats.[6] These observations stimulated the research of the late Dr Charles Koch, founder of the Desert Ecological Research Unit, who pointed out that in the tenebrionid, or tok-tokkie, beetle family alone, 200 endemic species, 30 endemic genera and two endemic tribes are to be found in the Namib.[7] On such grounds he suggested that the Namib might be regarded as 'the oldest desert in the world' — a changeless, antique sea of sand where evolution could take its steady course.

In recent years the concept of the Namib's great age has been questioned both on the composition of the beetle faunas[8] and on evidence from deep-sea sediments, especially those described by Siesser.[9] During 1975, cores were raised from the ocean bed through 1325 m of water from the western abutment of the Walvis Ridge off the Skeleton Coast. Various analyses were done on these by Siesser, including determinations of organic carbon content of the sediment, reflecting primary productivity of the sea associated with upwelling cold water. Other estimates were made of sediment accumulation rates and diatom abundances throughout the core. Siesser concluded that the cold, nutrient-rich northward moving system now known as the Benguela Current first began to develop in Oligocene times, about 30 million years ago, as had been suggested by van Zinderen Bakker,[10] and that from then until about 10 million years ago cold, upwelled water was weakly and spasmodically introduced into the system. After 10 million years ago a marked change is to be seen — there is evidence that the temperature of the sea along the west coast dropped and that its nutrient content increased sharply, a process that accelerated very greatly at the end of the Miocene, 5 million years ago.

The history of the Benguela Current cannot be dissociated from that of the southern oceans and Antarctica. In regard to oceanic cooling and the build-up of ice on Antarctica, I will outline first the 'conventional' reconstruction[11] and then mention some doubts and reservations which very recent evidence has occasioned.

A 'conventional' reconstruction

About 55 million years ago, at the beginning of the Eocene, surface sea temperatures in high southern latitudes were comparatively high — about 20°C according to Shackleton and Kennett[12] on the basis of oxygen isotope ratios in the calcareous tests of foraminifera found in deep-sea cores. However, these temperatures declined pro-

Dr Brain is director of the Transvaal Museum, P.O. Box 413, Pretoria 0001, South Africa.

gressively with the passage of time, to reach an extreme low point at the end of the Miocene 5 million years ago. This long-term cooling trend is thought to have been brought about by the gradual thermal isolation of Antarctica, following the northward drift of Australia and the opening of the Drake Passage. After these events, a deep seaway surrounded Antarctica, allowing the development of the circum-Antarctic current which has been flowing for the last 25 – 30 million years. It is well known that temperatures, averaged over the whole year in the interior of Antarctica, are 11 – 12°C colder than those in the Arctic.[13] So it appears that as Cainozoic cooling progressed, a marked asymmetry developed in respect of polar temperatures, with ice sheets forming in the Antarctic long before they did so in the Arctic.

The Antarctic ice sheet may be divided into two principal but unequal portions. In East Antarctica there is currently about 10.2 million km^2 of ice grounded largely above sea-level, while the much smaller West Antarctic ice sheet, covering about 1.6 million km^2, is grounded mainly below sea-level and possesses floating ice-shelf extensions into both the Ross and Weddell seas.[14] It is assumed that by Mid-Miocene times substantial ice sheets were developing in East Antarctica, discharging ice through gaps in the southern Transantarctic Mountains into an open Ross Sea, but that at this stage the West Antarctic ice sheet was not yet present.

There is a variety of evidence[11] to suggest that, at the end of the Miocene between 6.5 and 5 million years ago, global temperatures dropped abruptly, leading to the rapid build-up of the West Antarctic ice sheet[15,16] and to the sudden lowering of world sea-level, which in turn contributed to the Messinian salinity crisis in the Mediterranean.[17] It seems possible that it was this abrupt cooling, representing the Terminal Miocene Event, that strongly activated the Benguela Current and accentuated the aridity of the Namib.

Some doubts and reservations

It often happens in science that when an interpretation looks clear and firmly based, renewed doubts and uncertainties suddenly appear. Thus things in regard to the history of Antarctica and the Namib may not be as they seem. The whole concept of progressive Cainozoic cooling in high southern latitudes is now being questioned on the basis that recrystallization of calcium carbonate in foraminiferal shells from older deep-sea cores may have altered the oxygen isotope compositions used to reconstruct past sea temperatures and global ice volumes.[18] In addition to this, the concept of an ice-free Cretaceous Period with little temperature zonation from equator to pole has been questioned by climatologists,[19] while Matthews and Poore[20] maintain that there is evidence for the presence of significant quantities of land-based ice at intervals *throughout* the Cainozoic Era. Finally, Keller and Barron[21] have shown that a series of breaks or hiatuses in the deep-sea sedimentation record represent cold phases occurring at intervals back to 23 million years ago.

In view of such evidence, the concept of the Terminal Miocene event being a unique episode which triggered both the first build-up of the West Antarctic ice sheet and the first major activation of the Benguela Current, with resulting aridification of the Namib, may need to be reconsidered. Such cold episodes may have occurred many times in the course of the last 30 million years. In fact, in a recent paper, Mercer[16] presented a variety of evidence to suggest that the West Antarctic ice sheet was present very much earlier than visualised in the 'conventional' scenario considered earlier. Such evidence comes from the study of volcanic rocks, known as hyaloclastites, which were apparently erupted beneath a major ice sheet and which have led to the conclusion[22] that the 'West Antarctic ice sheet formed during middle Oligocene time or earlier on a flat, prevolcanic subaerial erosion surface that has since been fragmented by block faulting'.[23]

Finally, in their important paper on the antiquity of the Namib, Ward, Seely and Lancaster[1] conclude that 'although not well-dated, the Tsondap Sandstone Formation, and its probable arenaceous equivalents, strongly suggest the existence of a major Early to Middle (possibly Late) Tertiary desert sand sea in the Southern and Central Namib, at least, which was more extensive than the current main Namib Sand Sea. These fossil-dunes were deposited by a dominant southerly palaeo-wind regime which was similar to the present wind system. Significantly, these early sand accumulations pre-date the full development of the Benguela Current in Late Miocene times.'

Recent and exciting evidence on the history of the Antarctic ice sheets may tend to indicate that the Benguela Current has had periods of activity more intense and ancient than previously visualised. In fact, future research on Antarctic glacial history is likely to have very important implications for the interpretation, not only of Namib history, but of past African environments in general.

1. Ward J.D., Seely M.K. and Lancaster N. (1983). On the antiquity of the Namib. *S. Afr. J. Sci.* **79**, 175 – 183.
2. Smith A.G. and Briden J.C. (1977). *Mesozoic and Cenozoic Paleocontinental Maps.* Cambridge University Press, Cambridge.
3. Tyson P.D. (1969). Atmospheric circulation and precipitation over South Africa. Witwatersrand Univ. Environmental Studies Occasional Paper no. 2, Johannesburg.
4. Boyd A.J. (1983). Intensive study of the currents, winds and hydrology at a coastal site off central South West Africa, June/July 1978. *Investl. Rep., Sea Fisheries Research Institute, S. Africa,* **126**, 1 – 47.
5. Taljaard J.J. and Schumann T.E.W. (1940). Upper air temperatures and humidities at Walvis Bay, South West Africa. *Bull. Am. Meteorol. Soc.* **21**, 293 – 296.
6. Gebien, H. (1938). Die Tenebrioniden (Coleoptera, Heteromera) der Namib Wüste in Süd-westafrika. *Abh. Nat. Ver. Bremen* **30**, 20 – 107.
7. Koch C. (1962). The Tenebrionidae of Southern Africa XXXI. Comprehensive notes on the tenebrionid fauna of the Namib desert. *Sci. Pap. Namib Desert Res. Stat.* **5**, 61 – 106.
8. Endrödy-Younga S. (1982). The evidence of Coleoptera in dating the Namib Desert re-examined. *Palaeoecology of Africa and the Surrounding Islands* **15**, 217 – 223.
9. Siesser W.G. (1978). Aridification of the Namib Desert: evidence from oceanic cores. In *Antarctic Glacial History and World Palaeo-environments,* edit. E.M. van Zinderen Bakker, pp. 105 – 113. Balkema, Rotterdam.
10. Van Zinderen Bakker E.M. (1975). The origin and palaeo-environment of the Namib Desert biome. *J. Biogeogr.* **2**, 65 – 73.
11. Brain C.K. (1981). The evolution of man in Africa: was it a consequence of Cainozoic cooling? *Alex. L. du Toit Memorial lecture, 17, Trans. Geol. Soc. S. Africa.* Annex to Vol. LXXXIV: 1 – 19.
12. Shackleton N.J. and Kennett J.P. (1975). Paleotemperature history of the Cenozoic and the initiation of Antarctic glaciation: oxygen and carbon isotope analyses in D.S.D.P. sites 279, 277 and 281. *Initial Repprts of the Deep Sea Drilling Project* **29**, 743 – 755.
13. Flohn H. (1978). Comparison of Antarctic and Arctic climate and its relevance to climatic evolution. In *Antarctic Glacial History and World Palaeoenvironments,* edit. E.M. van Zinderen Bakker, pp. 3 – 13. Balkema, Rotterdam.
14. Drewry D.J. (1978). Aspects of the early evolution of West Antarctic ice. In ref. 9, pp. 25 – 32.
15. Mercer J.H. (1978). Glacial development and temperature trends in the Antarctic and South America. In ref. 9, pp. 73 – 93.
16. Mercer J.H. (1983). Cenozoic glaciation in the Southern Hemisphere. *Ann. Rev. Earth Planet Sci.* **11**, 99 – 132.
17. Adams C.G. *et al.* (1977). The Messinian salinity crisis and evidence of Late Miocene eustatic changes in the world ocean. *Nature* **269**, 383 – 386.
18. Kerr R.A. (1983). Early climate data questioned. *Science* **220**, 807.
19. Barron E.J., Thompson S.L. and Schneider S.H. (1981). An ice-free Cretaceous? Results from climate model simulations. *Science* **212**, 501 – 508.
20. Matthews R.K. and Poore R.Z. (1980). Tertiary ^{18}O record and glacio-eustatic sea level fluctuations. *Geology* **8**, 500 – 514.
21. Keller G. and Barron J.A. (1983). Paleooceanographic implications of Miocene deep-sea hiatuses. *Geol. Soc. Am. Bull.* **94**, 590 – 613.
22. Le Masurier W.E. and Rex D.C. (1982). Volcanic record of Cenozoic glacial history in Marie Byrd Land and western Ellsworth Land: revised chronology and evaluation of tectonic factors. In *Antarctic Geoscience,* edit. C. Craddock, **89**, 725 – 734. Univ. Wisconsin Press, Madison (not seen, quoted by Mercer, 1983).
23. Mercer J.H. (1983). Ref. 16, p. 112.