

New & recent publications

ISSN 0168-6208

Palaeoecology of Africa – and the surrounding islands (E.M.van Zinderen Bakker & J.A.Coetzee, eds. (1966–1986) & K.Heine, ed. (1987–))
1966–, 22 cm, c.250 pp., Hfl.125/\$60.00/£36 per volume
Annual publication. Comprehensive & up-to-date information on research in many different disciplines which give an overall insight into the environmental history of Africa. Volumes 1, 2, 3, 4 & 5 are out of print.
Volume 6 – Africa: 1969-71. 75 reports on non-palynological information. 1972, 312 pp., 0 86961 034 1.
Volume 7 – Africa: 1969-71. A.C.Hamilton: Pollen diagrams from E Africa & 17 reports. 1972, 222 pp., 0 86961 035 X.
Volume 8 – Proceedings of the Scientific Committee on Antarctic Research Conference on Quaternary Studies, Canberra, 9–12 August 1972. 1973, 208 pp., 0 86961 032 5.
Volume 9 – Africa: 1972–74. 36 reports & 4 articles. Central Sahara; Tropical forest biotopes; North Kenya Rift Valley; Palaeoclimates of S Africa; etc. 1976, 231 pp., 0 86961 082 1.
Volume 10 – Africa: 1975–77. 20 contributions on new research in S Africa. 1978, 200 pp., 90 6191 028 5.
Volume 11 – Africa: 1975–77. 23 contributions on northern & eastern Africa. 1979, 245 pp., 90 6191 037 4.
Volume 12 – Sahara and surrounding seas: Sediments and climatic changes (Proceedings of an international symposium, Mainz, 1–4 April 1979), edited by M.Sarnthein, E.Seibold & P.Rognon. 32 contributions on: Meteorology & climate; Indicators of climate on land; Indicators of climate in marine sediments; Reference sections on land. Editors: University Kiel & University Paris. 1980, 416 pp., 90 6191 050 1.
Volume 13 – 19 contributions on: The Sahara; The seas; Lakes from Mauritania to Rift Valley & Ethiopia to Malawi; Niger delta; Simen Mts.; etc. 1981, 290 pp., 90 6191 203 2.
Volume 14 – 16 contributions on: Glacial sequence of Mt. Kenya; Temperature changes & biogeography of the Sahara; Lake level changes in Ethiopia; Discharge of Senegal River & drought in Sahel; etc. 1982, 186 pp., 90 6191 204 0.
Volume 15 – Southern African Society for Quaternary Research, proceedings of the 6th biennial conference, Pretoria, 26–29 May 1981. (J.C.Vogel, E.A.Voigt & T.C.Partridge, eds.). 25 papers: Caves & fossil sites; Palaeoclimates; Cenozoic stratigraphy; Namib. 1982, 235 pp., 90 6191 257 1.
Volume 16 – 30 contributions on oceans & ocean margins; Sahara & West Africa; Kenya; Malawi; Southern Africa. Basic information on the parameters that determine the present. 1984, 488 pp., 1 color map, 90 6191 510 4.
Volume 17 – Southern African Society for Quaternary Research, Proceedings of the 7th biennial conference, Stellenbosch, 29 March–3 April 1985. (E.M.van Zinderen Bakker, J.A. Coetzee & L.Scott, eds.). Geology, geomorphology, palynology, palaeontology & archaeology in the fynbos region, southern-most Africa; Pans; Hist. biogeography. 1986, 272 pp., 90 6191 625 9.
Volume 18 – 32 contributions: Climatology; Oceanography; Palaeoenvironments of desert, East Africa, Central & West Africa, Southern Africa & the Islands; Anthropology; Archaeology. 1987, 486 pp., 21 photos (1 col.), 90 6191 689 5.
Volume 19 – Southern African Society for Quaternary Research, Proceedings of the VIIIth biennial conference, Bloemfontein, 20–24 March 1987. (J.A.Coetzee, ed.) Fluvial & lacustrine features in Southern Africa; Florisbad; Archaeology; Palynology; Coastal region; Palaeoclimatology; Biogeography; Geology/Geomorphol. 1989, c.360 pp., 90 6191 834 0.
Volume 20 – 14 contributions. Hydrology, palaeontology, pedology, sedimentology, glaciations, Holocene geomorphology, Plio/Pleistocene rift evolution in Sahara, Sahel, Kenya, Malawi & South Africa. 1989, c.400 pp., 90 6191 880 4

Matheis, G. & H.Schandelmeier (eds.) 90 6191 709 3
Current research in African earth sciences – Extended abstracts of the 14th colloquium on African geology, Berlin, 18–22 August 1987
1987, 25 cm, 504 pp., Hfl.135/\$70.00/£38.50
(90 6191 710 7, paper, Hfl.75/\$40.00/£21.50)
Continental basins; Precambrian evolution; Paleomagnetism & global tectonics related to Africa; Phanerozoic stratigraphy; Anorogenic magmatism; Hydrogeology & paleoclimatology; Remote sensing, metallogeny. 109 papers. Editors: Technische Universität Berlin, FR Germany.

Vail, J.R. 90 6191 705 0
Lexicon of geological terms for the Sudan
1988, 25cm, 208 pp., Hfl.85/\$43.00/£24
Over 300 lithostratigraphic unit names; Reference list; Stratigraphic, location, & author index. Author: Head of Geology Department, Portsmouth Polytechnic, UK.

Mahaney, W.H.C. (ed.) 90 6191 794 8
Quaternary and environmental research on East African mountains
1989, 25 cm, 394 pp., Hfl.135/\$70.00/£38.50
This book is the culmination of over 25 years of environmental research on the East African mountains by a group of specialists, working in different disciplines, but with common interests in the Quaternary. Glacial history; Palaeoclimatology; Biogeography; Paleosol sequences; Ecosystem disequilibrium. 26 papers. Editor: York University, Toronto.

Lancaster, N. 90 6191 697 6
The Namib sand sea – Dune forms, processes & sediments
1989, 23 cm, 200 pp., Hfl.95/\$50.00/£27
Regional physiographic & climatic setting; Dune morphology & morphometry; Dune sediments; Dune processes; Controls of dune morphology; Accumulation of the sand sea. References; Appendices. Author: Arizona State Univ.

Dardis, G.F. & B.P.Moon (eds.) 90 6191 831 6
Geomorphological studies in Southern Africa – Proceedings of a symposium, Transkei, 8–11 April 1988
1988, 25 cm, 519 pp., Hfl.125/\$65.00/£36
Macromorphology; Arid & semi arid environments; Soil erosion & soil movement; Weathering & environmental change; Coastal & fluvial environments. Editors: Univ. Transkei, Umtata & Univ.Witwatersrand, Johannesburg.

Grove, A.T. (ed.) 90 6191 512 0
The Niger and its neighbours – Environmental history and hydrobiology, human use and health hazards of the major West African rivers
1985, 23 cm, 342 pp., Hfl.145/\$75.00/£41.50
Environmental setting; Physical evolution of the river basins; Water characteristics of Chari system & Lake Chad; Water quality & hydrobiology of Niger; Biology of river systems, particularly fishes; People & history; River control; Lower Volta; etc. Index. Editor: University of Cambridge, UK.

Klein, Richard G. (ed.) 90 6191 097 8
Southern African prehistory and palaeoenvironments
1984, 25 cm, 416 pp., Hfl.135/\$70.00/£38.50
A comprehensive survey: Late Cenozoic, from 14–15 million years ago to the time of European contact. Emphasis is on the last 2–3 million years during which people were present. Editor: University of Chicago. Authors: Scientists from USA, S Africa & UK who were invited to contribute.

PALAEOECOLOGY OF AFRICA

AND THE SURROUNDING ISLANDS

Established by E.M.van Zinderen Bakker Sr

KLAUS HEINE (editor)

Volume 19

SOUTHERN AFRICAN SOCIETY FOR QUATERNARY RESEARCH

Proceedings of the VIIIth biennial conference held at the University of Bloemfontein, 20-24 March 1987

SASQUA guest-editor:

J.A.COETZEE

OFFPRINT

A.A.BALKEMA / ROTTERDAM / BROOKFIELD / 1988

Southern African palaeoclimates 35-25 ka ago: A preliminary summary

K. HEINE

Universität Regensburg, FRG

ABSTRACT

A brief summary of southern African palaeoclimates 35-25 ka ago is presented. C. 35-33 ka more humid conditions characterized the central Namib Desert, the Namibian Highlands and, possibly, the Middle Kalahari. Between c. 32-28 ka several marked variations in humidity are observed in the Namib Desert that correlate with climatic variations recorded from different sites in both hemispheres. The phase c. 28-26 ka coincides with the changes to extremely arid conditions in the central Namib Desert but with fresh water lakes in the Ngami-Makgadikgadi area. An alternation of interglacial and glacial circulation patterns seems to be responsible for the described climatic record.

INTRODUCTION

During the period c. 35-25 ka most of Sweden and Canada was ice-free; according to $\delta^{18}\text{O}$ records and measurements of CO_2 from southern Greenland ice-cores, there is evidence of frequent climatic fluctuations on a time-scale around 2-3 ka (Weber & Flohn 1986). Between 40 and 20 ka the transition from the Middle Weichselian interstadial to the last glacial maximum occurred; since about 35 ka indicators from land, sea and ice sheet of the southern hemisphere point to a lowering of temperatures (Heine 1985).

Palaeoclimates are the most difficult to reconstruct. The following consideration involves examination not only of some new results from the Namib and Kalahari but also an estimate of published material on southern African palaeoclimates.

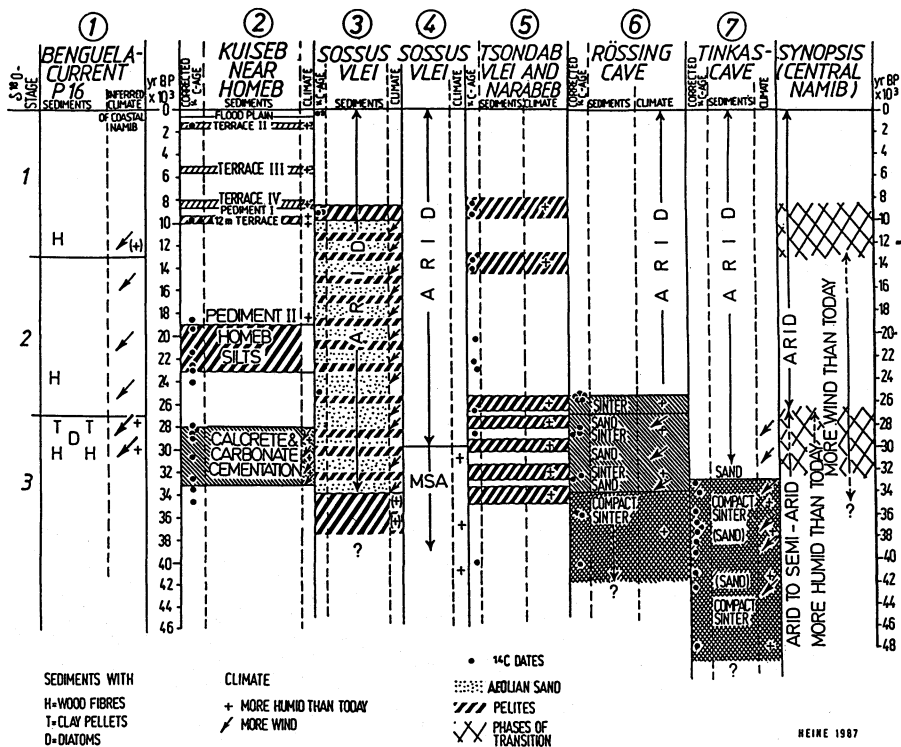


Figure 1. Late Quaternary sedimentary sequences of the Namib desert and adjacent areas. See Diester-Haass et al. (1988) for column 1; Vogel (1982), Vogel & Visser (1981) and Heine (1983) for column 2; Van Zinderen Bakker (1984a, b) and Heine (1987b) for columns 3 and 4; Teller & Lancaster (1986a) for column 5; Heine (1983, 1987b) for columns 6 and 7

THE NAMIB DESERT

Late Quaternary sediments from core PC 16 at the south-west African continental slope ($24^{\circ}04'17''S$, $12^{\circ}39'93''E$) give information on the history of the Benguela Current, on the influence of the near-coastal upwelling, and on the continental climate (Diester-Haass et al. 1988). During oxygen isotope stage 1 and 3 the Benguela Current turned to the west in the latitude of $24^{\circ}S$; during stage 2 there was a northward shifting of the area of west-turning of the Benguela Current. During stage 2 the local aeolian supply from the Namib Desert increased compared to stage 1 and 3. Wood fibres in stage 3 sediments (prior to 27 ka) point to an airborne origin from the desert (Fig. 1) and thus to a denser vegetation in the Namib in 24 to 22 kS.

The results from core PC 16 tie in with speleothem studies of some Namib

Desert caves (Heine & Geyh 1984). In the Rössing cave (30 km inland) and the Tinkas cave (70 km inland), speleothems, formed until about 34 ka, consist of massive calcite deposits (see columns 6 and 7, Fig. 1). Whilst the Tinkas cave remained without sinter formation since c. 34 ka, in the Rössing cave between c. 34 and 27 ka at least three noticeable climatic fluctuations on a time-scale around 2 ka occurred during which more humid conditions were replaced by more arid ones and vice versa; this is indicated by the intercalated sand/silt layers that are rich in palygorskite and kaolinite clay minerals which account for more windy climate with winds from NE to E directions. In the Rössing cave speleothems formed again 27-25.5 ka ago. The palaeoclimatic significance of speleothems is not quite clear, because speleothems are principally formed by two mechanisms (Atkinson 1981); the first requires a vegetation cover to produce the enrichment of CO₂ in the soil air. The second mechanism, the 'common ion effect' does not require a vegetation cover; if a water first becomes saturated with calcite, and then encounters either dolomite or a source of calcium sulphate, continued solution of the dolomite or CaSO₄ will force the solution to become supersaturated with calcite (Atkinson 1981). That means that the Namib speleothems indicate at least more precipitation during stage 3, although they must not be regarded as indicator for a dense vegetation cover during that time.

Many data on the evolution of the climate in the Namib have been published recently based on calcrete formation, river activity, palynology, palaeontology, archaeology, and sedimentary structures in dunes. These data are not repeated here. It can be concluded from this evidence that during the final stage 3 (35-25 ka) the central Namib Desert experienced an arid to semi-arid climate without marked changes in the vegetation cover, but with stronger winds from NE to E and with calcrete formation and recrystallisation of calcite in vlei sediments. The latter processes indicate alternating higher run-off from the Escarpment to the Namib and more windy conditions, leading to repeated inundation of vleis, river activity, calcrete formation, cementation of pelites, rise of ground water table, sinter formation, growth of reeds in Namib depressions and the possibility for MSA people to roam the central Namib Desert. In the central Namib a climatic regime entirely different from that of stage 2 and 1 existed; although the climate was arid to semi-arid, it was characterized by several climatic fluctuations with extremely windy and arid conditions on the one hand and semi-arid conditions with less frequent easterly winds of high velocity on the other hand (Fig. 1).

The so-called 'pluvial' or wetter periods of the Namib between c. 40-20 ka, mentioned by different authors (Teller & Lancaster 1986a, Heine & Geyh 1984), must have been arid to semi-arid as well. According to a re-evaluation of the Tsondeb and Sossus vlei sediments, the ¹⁴C ages of the pelites did not agree with the ages of accumulation of these sediments but they are respon-

sible for the ages of calcite recrystallisation in the pelites as a consequence of higher precipitation and run-off in the eastern highlands of SWA/Namibia (Teller & Lancaster 1986b, Heine 1987b). $^{234}\text{U}/^{230}\text{Th}$ dates and archaeological evidence refer to Middle Pleistocene pelite sedimentation in the vleis areas.

THE MIDDLE KALAHARI

Important new information of the late stage 3 lake-level fluctuations in the Ngami-Makgadikgadi area has become available recently (Cooke & Verstephen 1984, Shaw 1986, Shaw & Cooke 1986, Heine 1987a). The vast Ngami-Makgadikgadi area did not show synchronous fluctuations in lake-level; the Gidikwe Ridge west of the Makgadikgadi basin seems to be a geomorphic feature separating the old Makgadikgadi pans that existed at least since the Middle Pleistocene from the Ngami-Boteti area. The latter was flooded with brackish lakes up to the 936 m level before 30 and 25-14 (12) ka; during these periods the Makgadikgadi pans were not occupied by huge brackish water bodies (Fig. 2). Fresh water lakes existed c. 30-25 ka in the Ngami-Mababe-Boteti area as well as in the Makgadikgadi basin; because of lack of field evidence we cannot decide yet whether both areas were inundated by one huge lake or by two lakes with different lake levels. Other fresh water episodes occurred around 20-19 and c. 12 ka in the western Makgadikgadi basin. The Ngami-Mababe-Boteti area south-east of the Okavango Delta derived much of its water from the local and the Angolan catchment; therefore, fluctuating brackish high level lakes could even have existed during the late glacial maximum when most of the Makgadikgadi basin had dried up. The lacustrine landforms have attracted palaeoenvironmental interpretation in a wide range. The re-evaluation of Passarge's (1904) record of the Late Quaternary environmental conditions in the middle Kalahari (see Heine 1987a) may settle the controversy concerning the palaeoenvironmental reconstructions of the middle Kalahari since the concepts of very humid as well as of very arid Late Quaternary climates must be questioned. The middle Kalahari experienced semi-arid climates throughout the Late Quaternary but with gradual modifications to more humidity or more aridity. According to stratigraphic evidence (Fig. 2), brackish sedimentation and calcrete formation characterized the period prior to 30 ka. Between 30-25 ka (roughly) fresh water lakes are indicated by a dominance of freshwater species of ostracodes and diatoms (Heine 1987a) and by sedimentological data. Wind-blown sand was not deposited in the lake basin during this period.

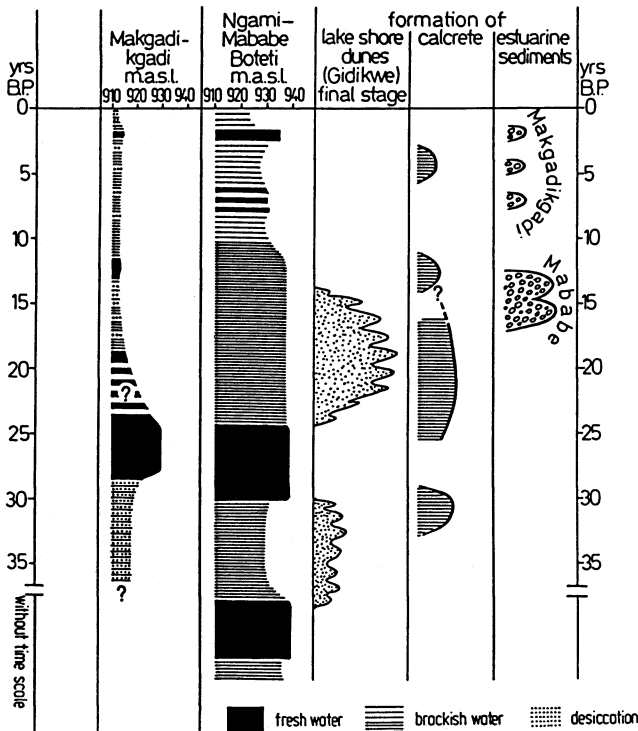


Figure 2. Late Quaternary lake-level fluctuations, dune formation, calcrete development, and deposition of estuarine sediments in the Ngami-Makgadikgadi area, middle Kalahari

THE SOUTHERN KALAHARI

In the south-western Kalahari, dunes were fixed by vegetation between 32-28 ka and organic soil horizons formed in interdune areas (Heine 1982). At Wonderwerk Cave, on the south-eastern margins of the Kalahari, cave sediments suggest a moist and cold climate from 35-24 ka with frost shattering in very cold conditions prior to 30 ka (Butzer 1984, J. Deacon et al. 1984). The record from the Gaap Escarpment is similar, with colder conditions from 35-30 ka; although dating is uncertain there may have been tufa deposition in wetter climates from 30-25 ka ago (Butzer et al. 1978, J. Deacon et al. 1984).

NAMIBIAN HIGHLAND

¹⁴C dates on calcretes, chalks, etc. document stages of landscape evolution in Etosha, SWA/Namibia, induced by environmental changes. The time ranges 33-28, 22-18 and 10.5-9 ka were periods of geomorphic stability, whilst at Enguruvau (west of the Great Escarpment, eastern Namib), 32-28 ka ago a period of morphodynamic activity occurred (Rust 1984, 1985). The climatic conditions during morphodynamically stable periods must have been characterized by fundamentally different precipitation regimes, either more precipitation and/or more regularly distributed precipitation (Rust 1984). In contrast, in the Enguruvau desert environment more rainfall would mean a geomorphic active phase.

Investigations of landform evolution, carried out by the author, reveal that after a period with limnic accumulation prior to c. 32 ka a phase of calcrete formation is documented by a number of ¹⁴C dates that cluster around 30 ka (e.g. in the area of Bullspout and Henkries). At Bullspout the calcretes are covered by limnic stratified silty calcareous clays of late glacial maximum age; the sequence suggests a semi-arid regional climate with fluctuations in humidity during the late oxygen isotope stage 3 and the last glacial maximum. Near Henkries in the arid lower Orange River area, after the calcrete formation about 30 ka ago only arid geomorphic processes are recorded in the sedimentologic sequences, although sheetflood sediments indicate fluvial erosion presumably during late glacial maximum times.

EASTERN SOUTH AFRICA

Pollen data from Wonderkrater in the Transvaal indicate relatively moist but only slightly cooler conditions associated with expanded forest during most of stage 3, with drier conditions developing before the onset of stage 2 (Scott 1982, J. Deacon et al. 1984). Speleothems and spring tufas in Transvaal caves are interpreted as the result of a humid to subhumid and cooler than present climate (J. Deacon et al. 1984). In the eastern interior, Butzer (1984) adds data of frost action processes to the palaeoclimatic history at the end of stage 3.

THE CAPE AND COASTAL SECTOR

Oxygen isotope temperatures derived from a Cango Cave speleothem indicate colder conditions in the southern Cape at 30 ka (Talma & Vogel 1986, cited in Tyson 1986), followed by an abrupt warming at 29 ka; after 25 ka temperatures began to decline steadily. Between 28-25 ka, surface temperatures were about 5-5.5°C lower than during the Holocene (Heaton et al. 1986,

Tyson 1986). Along the Indian Ocean, the results from different cave sequences suggest cool and drier conditions around 30 ka (J. Deacon et al. 1984). In the Boomplaas sequence an abrupt decline in diversity of all biological indicators is dated between 30-25 and 17 ka (H.J. Deacon, J. Deacon et al. 1984) and the relevant final Middle Stone Age occupation, dated to some 32 ka, is the richly organic BP stratigraphic unit (H.J. Deacon & Thackeray 1984). The change from an *Olea* woodland (browsers) to a scrubland (grazers) after c. 32 ka indicates a cooler and drier climate (J. Deacon et al. 1984).

CONCLUSIONS

The interval between 35 and 25 ka seems to be a unique Late Quaternary climatic phase without any parallel situation since about stage 5 until today (Heine 1983). The climatic oscillations, deduced from cave sinters and vleisequences of the Namib and, to a certain degree, from lake-level fluctuations of the middle Kalahari, are well correlated with worldwide documented climatic oscillations, e.g. the oxygen isotope profile from Camp Century between about 33-27 ka (De Q. Robin 1983), the CO₂-concentration and ¹⁸O/¹⁶O ratio at Dye 3 (southern Greenland) (see Flohn 1986, Weber & Flohn 1986, Oeschger et al. 1983), the Grand Pile pollen diagram between 34-28 ka (Woillard & Mook 1981), lake-level fluctuations of the Searles Lake, California (Smith 1976), lake-level and diatom fluctuations of Lake Abhé, central Afar (Gasse & Delibrias 1976), oscillating changes within the vegetation of the area of Lake Abijata, Ethiopia (Bonnefille 1985), oscillating lake levels 35-25 ka ago in the Tchad basin (Baumhauer 1986), and the transition of Lake Qarhan (northern margin of Qinghai-Xizang Plateau/China) from a freshwater to a slightly saline stage (pre-evaporitic) under a relatively humid climate (Chen Kezao & Bowler 1986), and in Australia a phase 36-25 ka ago with lake-level oscillations during drastic changes of fluvial, lacustrine and aeolian environment (Bowler & Wasson 1984).

The general picture of the 35-25 ka palaeoenvironments confirms that during this phase the transition from the Middle Weichselian (stage 3) interstadial to the last glacial maximum occurred (see Heine 1985). An abrupt cooling is deduced about 40 ka ago from regression of ¹⁸O/¹⁶O values (‰) and corresponding CO₂-concentrations in a Greenland ice-core (Weber & Flohn 1986); several frequent fluctuations which were not strictly periodic are derived from the ice-core for the time 37-27 ka. In southern Africa, data on climatic abrupt changes between 35-25 ka are very limited and conclusions on palaeoclimatic models are based on heterogeneous evidence.

The global climatic trend seems to be documented by the palaeoenvironmental history of the Namib Desert. To the east this global trend is masked by

regional trends that originate in a number of different factors. In tropical southern Africa maximum humidity (high fresh water lake levels) occurred during ice-growth phases and may support theories that call for control of precipitation intensity by orbitally modulated rhythms in insolation (see Pokras & Mix 1985, Sellers 1984). During stage 3, the climate of southernmost subtropical South Africa seems to be linked to that of the higher latitude Antarctic ice sheets.

Tyson (1986) describes a model of an atmospheric circulation over southern Africa modulating wet and dry spells; this model may be used for palaeoclimatic implications. According to Tyson (1986), two circumstances must, therefore, be distinguished: 1. southern Africa might have been wetter in the past owing to an increase of winter rainfall associated with enhanced northerly penetration of temperate westerly perturbation; 2. summer rainfall may have been increased in the past as a consequence of enhanced occurrence of tropically-induced disturbances. The former would have been associated with lowered and the latter with raised temperatures. Both sets of palaeoenvironmental conditions undoubtedly prevailed at one time or another (Tyson 1986).

In the light of Tyson's model, at the time of the last glacial maximum the present-day dry-spell analogue would have prevailed. During the period 35-25 ka perhaps the dry, cool and windy intervals may indicate atmospheric circulation conditions of the present-day dry-spell type or: of last glacial maximum analogues. On the other hand, the mechanisms which are responsible for the 35-25 ka wet, relatively warm and less windy intervals are poorly understood.

Among the most remarkable features of air-sea interactions in equatorial latitudes and in the north Atlantic off Greenland are the exchange processes of CO₂ and H₂O, strongly varying between 'normal' upwelling and El Niño (downwelling) in the tropics (Flohn 1986, Weber & Flohn 1986, Newell & Hsiung 1984). In upwelling areas, warm/wet and cold/dry phases have been recorded. During cold/dry phases the increase of the atmospheric CO₂ content is significantly lower than during warm/wet phases. Simultaneously the H₂O exchange through evaporation drops in upwelling areas to 20-25% of its normal value in tropical oceans (Weber & Flohn 1986). Since both gases are responsible for the natural greenhouse effect, these fluctuations control global temperatures and atmospheric circulation (Weber & Flohn 1986, Schlesinger 1986, Broccoli & Manabe 1987). The observed facts about climatic fluctuations 35-25 ka ago in the Namib, the Kalahari and in different sites of South Africa suggest a climatic feedback mechanism between bottom water of the oceans, upwelling, downwelling, sea-surface temperatures, and atmospheric flow patterns. The warm and 'wet' intervals of late stage 3, especially of the Namib area, that have had no analogues since about 25 ka, may be related to decreased upwelling processes (El Niño occurrence) off the

south-west African coast, which caused solar radiation to heat the water locally (see Morley & Shackleton 1984). The consequence of these events may have been an abnormal weak latitudinal temperature gradient and more precipitation in the Namib Desert may be the consequence thereof. It remains to be determined in what way these rather complex mechanisms operated.

ACKNOWLEDGEMENTS

I thank M.A. Geyh for ^{14}C age determinations; P. Rothe and L. Diester-Haass for clay mineral analyses and useful discussions, the DFG for financial support of the field work and J.A. Coetzee for critical comments.

REFERENCES

- Atkinson, T.C. 1981. Uranium series dating of speleothems and their palaeoclimate significance. *Newsletter (Quat. Res. Ass., UK)* 35: 30-31.
- Baumhauer, R. 1986. Zur jungquartären Seenentwicklung im Bereich der Stufe von Bilma (NE-Niger). *Würzburger Geogr. Arb.* 65: 1-235.
- Bonnefille, R. 1985. Evolution of climate in the dry intertropical zone of Eastern Africa over 50 000 years BP. In R. Fantechi & A. Ghazi (eds.), *Environment and quality of life* (First R & D programme in the field of climatology): 53-59.
- Bowler, J.M. & R.J. Wasson 1984. Glacial age environments of inland Australia. In J.C. Vogel (ed.), *Late Cainozoic palaeoclimates of the southern hemisphere*: 183-208. Rotterdam: Balkema.
- Broccoli, A.J. & S. Manabe 1987. The influence of continental ice, atmospheric CO_2 , and land albedo on the climate of the last glacial maximum. *Climate Dynamics* 1: 87-99.
- Butzer, K.-W. 1984. Late Quaternary palaeoenvironments in South Africa. In J.C. Vogel (ed.), *Late Cainozoic palaeoclimates of the southern hemisphere*: 235-264. Rotterdam: Balkema.
- Butzer, K.-W., R. Stuckenrath, A. Bruzewicz & D.M. Helgren 1978. Late Cenozoic palaeoclimates of the Gaap Escarpment, Kalahari margin, South Africa. *Quat. Res.* 10: 310-339.
- Chen Kezao & J.M. Bowler 1986. Late Pleistocene evolution of salt lakes in the Qaidam Basin, Qinghai Province, China. *Palaeogeogr., Palaeoclim., Palaeoecol.* 54: 87-104.
- Cooke, H.J. & H.Th. Verstappen 1984. The landforms of the western Makgadikgadi Basin in northern Botswana, with a consideration of the chronology of the evolution of Lake Paleo-Makgadikgadi. *Z. Geomorph. N.F.* 28: 1-19.
- Deacon, H.J., J. Deacon, A. Scholtz, J.F. Thackeray, J.S. Brink & J.C. Vogel 1984. Correlation of palaeoenvironmental data from the Late Pleistocene and Holocene deposits at Boomplaas cave, southern Cape. In J.C. Vogel (ed.), *Late Cainozoic palaeoclimates of the southern hemisphere*: 339-351. Rotterdam: Balkema.
- Deacon, H.J. & J.F. Thackeray 1984. Late Pleistocene environmental changes and implications for the archaeological record in Southern Africa. In J.C. Vogel (ed.), *Late Cainozoic palaeoclimates of the southern hemisphere*: 375-390. Rotterdam: Balkema.
- Deacon, J., N. Lancaster & L. Scott 1984. Evidence for Late Quaternary climatic change in

- southern Africa. In J.C. Vogel (ed.), *Late Cainozoic palaeoclimates of the southern hemisphere*: 391-404. Rotterdam: Balkema.
- De Q. Robin, G. 1983. The climatic record from ice cores. In G. De Q. Robin (ed.), *The climatic record in polar ice sheets*: 180-195. Cambridge: Cambridge Univ. Press.
- Diester-Haass, L., K. Heine, P. Rothe & H.-J. Schrader 1988. Late Quaternary history of climate and surface currents off SW Africa. *Palaeogeogr., Palaeoclim., Palaeoecol.* (in press).
- Flohn, H. 1986. Treibhauseffekt und Klima. Stand und Perspektiven. *Energiewirtschaftliche Tagesfragen* 12: 3-8.
- Gasse, F. & G. Delibrias 1976. Les lacs de l'Afar Central (Ethiopie et TTAI) au Pléistocène supérieur. In S. Horie (ed.), *Palaeolimnology of Lake Biwa and the Japanese Pleistocene* 4: 529-575.
- Heaton, T.H.E., A.S. Talma & J.C. Vogel 1986. Dissolved gas palaeotemperatures and ^{18}O variations derived from groundwater near Uitenhage, South Africa. *Quat. Res.* 25: 79-88.
- Heine, K. 1982. The main stages of the Late Quaternary evolution of the Kalahari region, Southern Africa. *Palaeoecol. of Africa* 15: 53-76.
- Heine, K. 1983. Preliminary reconstruction of the Late Quaternary climatic history of the central Namib desert, SW Africa, based on new ^{14}C dates. In S. Horie (ed.), *Palaeolimnology of Lake Biwa and the Japanese Pleistocene*: 41-54.
- Heine, K. 1985. Jungquartäre Klimaschwankungen auf der Südhalbkugel. *Zbl. Geol. Paläont. Teil I*, 11/12: 1751-1768.
- Heine, K. 1987a. Zum Alter jungquartärer Seespiegelschwankungen in der mittleren Kalahari, südliches Afrika. *Palaeoecol. of Africa* 18: 73-101.
- Heine, K. 1987b. Jungquartäre fluviatile Geomorphodynamik in der Namib, Südwestafrika/Namibia. *Z. Geomorph. Suppl. Bd.* 66: 113-134.
- Heine, K. & M.A. Geyh 1984. Radiocarbon dating of speleothems from the Rössing cave, Namib desert, and palaeoclimatic implications. In J.C. Vogel (ed.), *Late Cainozoic palaeoclimates of the southern hemisphere*: 465-470. Rotterdam: Balkema.
- Morley, J.H. & N.J. Shackleton 1984. The effect of accumulation rate on the spectrum of geologic time series: evidence from two South Atlantic sediment cores. In A.L. Berger, J. Imbrie, J. Hays, G. Kukla & B. Saltzman (eds.), *Milankovitch and climate*. Part I: 467-480. Dordrecht: Reidel.
- Newel, R.E. & J. Hsiung 1984. Sea surface temperature, atmospheric CO_2 and the global energy budget: some comparisons between the past and present. In N.-A. Mörner & W. Karlén (eds.), *Climatic changes on a yearly to millennial basis*: 533-561. Dordrecht: Reidel.
- Oeschger, H., J. Beer, U. Siegenthaler, B. Stauffer, W. Dansgaard & C.C. Langway 1983. Late-glacial climate history from ice cores. In A. Ghazi (ed.), *Palaeoclimatic research and models*: 95-107. Dordrecht: Reidel.
- Passarge, S. 1904. *Die Kalahari. Versuch einer physisch-geographischen Darstellung der Sandfelder des südafrikanischen Beckens*. Berlin: Reimer. 822 pp. + Maps.
- Pokras, E.M. & A.C. Mix 1985. Aeolian evidence for spatial variability of late Quaternary climates in tropical Africa. *Quat. Res.* 24: 137-149.
- Rust, U. 1984. Geomorphic evidence of Quaternary environmental changes in Etosha, South West Africa/Namibia. In J.C. Vogel (ed.), *Late Cainozoic palaeoclimates of the southern hemisphere*: 279-286. Rotterdam: Balkema.
- Rust, U. 1985. Die Entstehung der Etoschapfanne im Rahmen der Landschaftsentwicklung des Etoscha Nationalparks (nördliches Südwestafrika/Namibia). *Madoqua* 14: 197-266.

- Schlesinger, M.E. 1986. Equilibrium and transient climatic warming induced by increased atmospheric CO₂. *Climate Dynamics* 1: 35-51.
- Scott, L. 1982. A late Quaternary pollen record from the Transvaal Bushveld, South Africa. *Quat. Res.* 17: 339-370.
- Sellers, W.D. 1984. The response of a climate model to orbital variations. In A.L. Berger, J. Imbrie, J. Hays, G. Kukla & B. Saltzman (eds.), *Milankovitch and climate*. Part II: 765-788. Dordrecht: Reidel.
- Shaw, P.A. 1986. The palaeohydrology of the Okavango delta – some preliminary results. *Palaeoecol. of Africa* 17: 51-58.
- Shaw, P.A. & H.J. Cooke 1986. Geomorphic evidence for the late Quaternary palaeoclimates of the middle Kalahari of northern Botswana. *Catena* 13: 349-359.
- Smith, G.I. 1976. Palaeoclimatic record in the upper Quaternary sediments of Searles Lake, California, USA. In S. Horie (ed.), *Palaeolimnology of Lake Biwa and the Japanese Pleistocene* 4: 577-604.
- Teller, J.T. & N. Lancaster 1986a. Lacustrine sediments at Narabeb in the central Namib desert, Namibia. *Palaeogeogr., Palaeoclim., Palaeoecol.* 56: 177-195.
- Teller, J.T. & N. Lancaster 1986b. History of sediments at Khommbabes, central Namib desert. *Madoqua* 14: 409-420.
- Tyson, P.D. 1986. *Climatic change and variability in Southern Africa*: 1-220. Cape Town: Oxford Univ. Press.
- Van Zinderen Bakker, E.M. 1984a. A late- and post-glacial pollen record from the Namib desert. *Palaeoecol. of Africa* 16: 421-428.
- Van Zinderen Bakker, E.M. 1984b. *Palynological evidence for late Cenozoic arid conditions along the Namibia coast from holes 532 and 530 A, Leg 75*. Deep Sea Drilling Project 75: 763-768. Washington D.C.: US Government Printing Office.
- Vogel, J.C. 1982. The age of the Kuisieb river silt terrace at Homeb. *Palaeoecol. of Africa* 15: 201-209.
- Vogel, J.C. & E. Visser 1981. Pretoria radiocarbon dates II. *Radiocarbon* 23: 43-80.
- Weber, K.-H. & H. Flohn 1986. Oceanic upwelling and air-sea-exchange of carbon dioxide and water vapor as a key for large-scale climatic change? In H. Flohn (ed.), *Tropical rainfall anomalies and climatic change*: 73-107. Bonner Meteorol. Abh. 31.
- Woillard, G.M. & W.G. Mook 1981. Carbon-14 dates at Grande Pile: correlation of land and sea chronologies. *Science* 215: 159-161.