Earth-Science Reviews 124 (2013) 184–201

Contents lists available at ScienceDirect

Earth-Science Reviews

journal homepage: www.elsevier.com/locate/earscirev

Miocene fluvial systems and palynofloras at the southwestern tip of Africa: Implications for regional and global fluctuations in climate and ecosystems

David L. Roberts [a,*], Lara Sciscio [b], Andy I.R. Herries [c], Louis Scott [d], Marion K. Bamford [e], Chiedza Musekiwa [a], Harilaos Tsikos [f]

[a] Council for Geoscience, PO Box 572, Bellville 7535, South Africa
[b] Department of Geology, University of Cape Town, Rondebosch, South Africa
[c] Australian Archaeomagnetism Laboratory, Department Archaeology, Environment and Community Planning, Faculty of Humanities and Social Science, La Trobe University, Melbourne Campus, Bundoora, 3086, VIC, Australia
[d] Department of Plant Sciences, University of the Free State, Bloemfontein, South Africa
[e] Bernard Price Institute for Palaeontology, School of Geosciences, University of the Witwatersrand, P. Bag 3, WITS 2050, Johannesburg, South Africa
[f] Department of Geology, Rhodes University, Grahamstown 6140, South Africa

ARTICLE INFO

Article history:
Received 25 April 2012
Accepted 9 May 2013
Available online 17 May 2013

Keywords:
Miocene fluvial deposition
Palaeontology
Palaeoclimate
South Africa

ABSTRACT

High amplitude climate fluctuations have been inferred from marine isotope data in the early Neogene, but few well documented terrestrial records exist from this era to gauge the effects of these high latitude events on continental climates and ecosystems. The extensive, three-dimensional exposures of Miocene fluvial and fluvio-lacustrine sediments in the Rondeberg clay pit near Cape Town provide a unique window on this era. Palaeomagnetic data suggests that the deposits accumulated over a period of <1 Ma. The presence of meso-megathermic palynoforms (Palmae, *Ilex*-type, *Euphorb*-type, Rhamnaceae) and mesothermic (*Podocarpus*-type) palynofloras suggests a humid subtropical/tropical climate. However, abundant charcoal, charred *in situ* tree stumps, overall poor preservation of organics, evidence for upward-drying lacustrine successions and an appreciable *fynbos* presence, point to cyclical periods of drought. We suggest that these climate fluctuations may have been influenced by the orbital pacing seen in the marine isotope record of the earlier Miocene, pointing to a high latitude link with mid-latitude terrestrial climate patterns. Earlier studies of pollen spectra from the nearby, slightly older Noordhoek deposits show cyclical alternations from tropical to cooler climates and more recent biogeochemical work has shown dramatic coincident fluctuations in depositional temperature. These vegetation changes were previously correlated with major global events embracing the entire Neogene from the Oligo–Miocene (late Oligocene to early Miocene) to the Pliocene. We offer a different interpretation, suggesting that the deposits represent a much shorter time interval in the earlier Miocene and that these climate fluctuations may have been influenced by orbital forcing evinced in the marine isotope record. Along the northern west coast, the Arrisdrift vertebrate fossil assemblage in Early–Middle Miocene terrace deposits of the Orange River indicate a tropical climate but possibly less humid than in the south, with more open vegetation patterns. The presence of pedogenic calcretes and gypcretes in the deposits suggests periodic extremes of aridity not seen in south; the current pronounced north-aridity gradient from humid temperate to hyper-arid may have had its inception in the earlier Miocene.

Contents

* Corresponding author. Tel.: +27 0219436731.
E-mail address: droberts@geoscience.org.za (D.L. Roberts).

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http://dx.doi.org/10.1016/j.earscirev.2013.05.001

1. Introduction

The dominant present day flora (Cape Floristic Region) at the south-western tip of Africa (Fig. 1) is characterised by summer-dry adapted maccia vegetation (*fynbos*). Modern extant families which typify this flora include Asteraceae, Ericaceae, Proteaceae, Restionaceae, Aizoaceae, Iridaceae, Rutaceae and Orchidaceae (Goldblatt and Manning, 2002). During the last few decades it has become apparent from palynological studies of onshore drill core that the *fynbos* was preceded by an early Neogene flora characterised by tropical/subtropical forest elements including palms. Many of these taxa are extinct in the region today and some are no longer found in Africa; overall the floras exhibit a distinct Gondwanan flavour, rooted deep in the past (Coetzee, 1978, 1980; Coetzee and Rogers, 1982; Coetzee, 1983a,b, 1986; Scott, 1995).

Although the Miocene polleniferous organic sediments in the south-western Cape generally have fluvial and fluvio-lacustrine affinities, little attention has been paid to the sedimentation patterns of these depositional systems as a whole in elucidating palaeoenvironments. Fluvial depositional style reflects fluctuations in regional hydrology, climate, catchments, relative sea level and therefore, tectonics. We recognise three basic Miocene fluvial depositional styles along the west coast of South Africa (Models A, B and C; Fig. 2), whose deposits are characterised by a dominance of suspension load (fines) such as at the Rondeberg site north of Cape Town (Fig. 1), mixed load (coarse sands and fines) as at the Noordhoek site (Fig. 1) and bedload gravels at the Orange River site (Fig. 1), respectively. From these three models, we draw inferences concerning the parameters listed above. We focus on three sites in this region exemplifying these depositional models, namely the Orange River in the far north, Noordhoek and a new site (the Rondeberg clay pit), both of which are located near Cape Town in the south (Fig. 1). The inception of the present steep climate gradient along the South African west coast culminating in hyper-aridity around the Orange River in the north has been debated (Coetzee, 1978; Pickford and Senut, 1997) and we compare the Miocene terrace deposits of the Orange River and their diagenesis with their counterparts in the south to investigate this question.

Here we also provide an in-depth study of the Rondeberg clay pit (Model C), situated 60 km north of Cape Town, which offers extensive three-dimensional exposures of Neogene fluvial and fluvio-lacustrine fine sands, silts and clays, not previously reported in the literature. These exposures are complemented by information from a number of drill-holes designed to delimit the extent of the deposits, 10 of which are shown in Fig. 3. Organic-rich horizons have proved to be polleniferous and *in situ* preserved charred tree stumps yielded information concerning fire regime, taxonomy and plant growth patterns. Previous studies of the Neogene polleniferous successions of the south-western Cape were based on drillhole cores (Rogers, 1980, 1982). Importantly, the extensive exposures at Rondeberg allowed palaeomagnetic studies to be conducted, to independently constrain the age and time interval over which the Neogene deposits accumulated. Again, the exposures at Rondeberg provide a wealth of new data in this regard, not available for the vast majority of deposits which are confined to the subsurface. The Rondeberg clays are situated over a major terrain-bounding fault system and faulting observed in the deposits has shed further light on regional neotectonics.

The earlier work on the Neogene palynofloras, particularly at the Noordhoek site near Cape Town (Fig. 1) which hosts the longest and most complete record to date, also brought to light marked fluctuations in plant communities through time. These changes, which indicated alternating more tropical and cooler intervals (Coetzee, 1983a), were considered to embrace the entire Neogene from the Oligo–Miocene to the Pliocene and Quaternary and were correlated with major global events. These included the recovery from the Oligocene glaciation in the early Miocene, the Middle Miocene warm period and subsequent global cooling with increasing thermal isolation of Antarctica. A notable increase in *fynbos* taxa higher in the Noordhoek succession was considered to reflect the advent of the cooler/drier Pliocene climate as the Benguela Cold Upwelling System intensified heralding the transformation to the Quaternary dominance of *fynbos* encountered at the top of the succession (Fig. 1).

Subsequent to the major works of Coetzee (*e.g.* Coetzee, 1983a) on the Miocene palynofloras of the Western Cape, marine cores provided detailed information on global climate fluctuations during the Miocene (Prentice and Matthews, 1988; Zachos et al., 1992; Holbourn et al, 2007). Orbital (Milankovitch) forcing has been inferred from spectral analysis of the marine isotope data and both high frequency precession (23 ka) and obliquity (41 ka) bands are inferred, in addition to lower frequency eccentricity (100–400 ka) beats. The forcing is thought to have been amplified at high latitudes, but few well documented mid-latitude Miocene terrestrial records are available to