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Pollen distribution in the marine surface sediments of the mudbelt along the west coast of South Africa

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A B S T R A C T

The distribution of pollen in marine surface sediments offshore of the west coast of South Africa has been investigated to aid in the interpretation of marine pollen records of onshore vegetation changes. A transect of sediment surface pollen samples retrieved from the Namaqualand mudbelt from just south of the Orange River mouth (29°S) to St Helena Bay (33°S) indicates distinctive pollen spectra reflecting vegetation communities on the adjacent continent. Pollen concentration increases southwards, partly in relation to greater pollen productivity due to higher biomass and density of fynbos vegetation and of sedimentary processes and low pollen concentrations consequent to dilution with silt and clay from the Orange River. The distribution of specific pollen taxa suggests that the Orange River is a major contributor of pollen to the northern mudbelt declining southwards, while the pollen distribution in the central mudbelt is largely attributable to seasonal inputs of pollen from offshore berg winds and local ephemeral Namaqualand rivers. The typical fynbos elements dominate in the southern mudbelt indicating a pollen source mainly in the fynbos vegetation types. These conclusions support a companion analysis of fossil pollen records of two marine sediment cores from the northern and southern mudbelt respectively. This study demonstrates that pollen records from marine sediment cores in the Namaqualand mudbelt have the potential to be a tool to reconstruct palaeovegetation on the adjacent continent. However, to better reconstruct the palaeoclimate of South Africa and fully understand the relations between terrestrial and marine deposits, more marine surface sediments along the western coast of South Africa as well as more terrestrial surface sediments need to be studied.

1. Introduction

Palaeoenvironmental evidence based on terrestrial pollen records in a relatively dry region such as southern Africa is often difficult to obtain due to the paucity of lakes or swamps, although the palaeoenvironmental archive of rock hyrax middens is ideally suited to the reconstruction of dryland palaeoenvironments (Scott and Cooremans, 1992; Chase et al., 2012). Still, the terrestrial records are often discontinuous (Neumann et al., 2011), have a low temporal resolution (Meadows et al., 2010), cover short periods (Baxter and Meadows, 1994; Meadows et al., 1996; Stager et al., 2012), or are widely distributed over the continent with distinct local environment or have different proxies which generally lead to contradicted results or make them difficult for comparison even with long continuous records (Meadows and Baxter, 2001; Kristen et al., 2007; Baker et al., 2014; Neumann et al., 2014; Norström et al., 2014). Albeit less detailed, pollen preserved in undisturbed marine sediments has the potential to provide long continuous information integrating a large area of continental vegetation and climate developments (Dupont, 1999). Due to the large scale mixing possibility of pollen from diverse sources (Shi et al., 1998), checking whether or to what degree the sediments were disturbed is essential. The continental shelf off the west coast of southern Africa is a key region for palaeoenvironmental research and the understanding of climate change of southern Africa (Birch, 1977; Oboh-Ikuenobe and de Villiers, 2003; Herbert and Compton, 2007).

For the interpretation of sediment records of the continental shelf, it is crucial to characterize the source of its terrigenous sediments which would have been brought in mainly by the Orange

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River (Rogers, 1977; Rogers and Bremner, 1991). Much of the terrigenous sediment is redistributed in the high-energy coastal environment. The coarser fraction sand and gravel is transported northward by wave-induced littoral drift, and the finer fraction silt and clay (mud) is transported southward by the poleward countercurrent (Rogers, 1977; Nelson, 1989). The latter forms a Holocene mud deposit referred to as the Namaqualand mudbelt (Birch et al., 1991). However, the study of Mabote et al. (1997) revealed that the Orange River might be only a major source of sediments near the Orange River mouth, while further south along the mudbelt input of terrigenous sediments from both offshore berg winds and local ephemeral Namaqualand rivers becomes increasingly important.

Basically, pollen distribution in sediments is related to environmental and sedimentological factors including the vegetation composition, pollen production, dispersal, transportation (including fluvial, aeolian and ocean current transport), deposition and preservation. The mechanisms of pollen sedimentation on the Atlantic continental margin should be similar to the sedimentation processes of terrigenous fine particles (Heusser, 1983). This suggests that the marine pollen signal may indicate the source and transportation of fine-grained terrigenous sediments within which pollen is associated.

Rather few marine palynological studies have been conducted on the marine surface sediments of this region (Davey, 1971; Davey and Rogers, 1975; Gray et al., 2000). Preliminary studies (Davey, 1971; Davey and Rogers, 1975) of palynomorphs in a traverse of the Orange River mouth region demonstrate the importance of turbulence of the Orange River in palynomorph deposition. Pollen analyses of two sediment cores from the Namaqualand mudbelt (Gray, 2009) show distinctive pollen composition, suggesting a major fluvial contribution near the Orange River mouth, while near the Buffels River mouth pollen elements originated mainly from the nearshore vegetation. Unfortunately, the interpretation of the data was hampered by inconsistencies in the chronology (Meadows et al., 1997, 2002; Gray et al., 2000; Gray, 2009). An accurate and detailed interpretation of regional marine pollen records, as well as other proxies, needs better data about the distribution and mechanisms of pollen transport in modern marine sediments of the mudbelt. In addressing this shortcoming, marine surface sediments (sampled by multicorer, which takes multiple cores at every deployment and is hydraulically damped enabling the samples tubes to be lowered gently sampling soft surface sediments with minimum disturbance) were obtained from the Namaqualand mudbelt (Fig. 1a, Table 1). Dating of four multicores in the mudbelt all suggest that the top samples are modern (Taylor, 2004; Leduc et al., 2010).

The primary aim of this study is to describe and explain the modern pollen distribution of the Namaqualand mudbelt, with the following specific objectives: (1) to characterize the pollen concentrations and distribution in the Namaqualand mudbelt surface sediments, (2) to determine the possible sources of mudbelt pollen, and to assess the degree to which the characteristic pollen concentrations and distribution reflect the adjacent continental vegetation, (3) to assess the significance of pollen preserved in mudbelt sediments during the Holocene as proxies of terrestrial palaeovegetation in the region and to assist in the interpretation of fossil pollen records.

2. Regional setting

The Namaqualand mudbelt (Fig. 1a) along the western coast of southern Africa extends from 20 km north of the Orange River mouth and 500 km to the south off St Helena Bay (Rogers and Bremner, 1991). This mudbelt is an inner continental shelf suite of generally fine-grained sediments lying in water depths of 80–140 m. The mudbelt is broadly cohesive, continuous and thicker in the Orange River prodelta area where it is dominated by laminated silt, while it tends to be thinner and consisting of homogeneous mud towards the south (Mabote et al., 1997; Meadows et al., 1997, 2002).

2.1. Oceanic circulation

Oceanographic conditions on the west coast of South Africa have been well described (Nelson and Hutchings, 1983; Nelson, 1989; Shannon and Nelson, 1996), which are dominated by the northward flowing cold Benguela Current (BC) (Fig. 1a). This current is induced by offshore prevailing southeast trade winds driving a coastal upwelling process especially during the austral spring and summer in the southern Benguela region. Below the BC, a poleward countercurrent (PCC) is positioned permanently south of 33°S while the northward boundary varies seasonally. In the southern boundary of the Benguela System, elements of the warm and saline Agulhas Current (AgC) water from the Indian Ocean are shed into the South Atlantic Ocean and filaments of AgC water enter the BC.

2.2. Climate and vegetation

In southern Africa, the climate is variable due to the alternating seasonal dominance of atmospheric and oceanic circulation systems across the region resulting in three main rainfall zones (Fig. 1a): winter rainfall zone (WRZ), year-round rainfall zone (YRZ) and summer rainfall zone (SRZ) (Tyson and Preston-Whyte, 2000; Chase and Meadows, 2007). During the austral summer, the WRZ is controlled by strong southeast trade winds inducing an intensive upwelling zone and low sea surface temperatures along the west coast, which minimizes summer precipitation over the west coast of southern Africa. The rainfall in the SRZ is mainly brought by warm and moist easterly winds associated with the South Indian

Table 1
Core sites, water depths, pollen sums and pollen concentrations of multicore top samples. (Core locations are shown in Fig. 1a)

Core name	Longitude (°E)	Latitude (°S)	Water depth (m)	Pollen sum	Terrestrial pollen sum	Pollen concentration (grains/cm^3)
GeoB8333-1	16.61	29.12	20	307	260	3962
GeoB8332-3	16.66	29.13	116	305	243	2314
GeoB8331-2	16.71	29.14	88	313	231	2011
GeoB8327-1	17.01	29.70	88	205	182	2762
GeoB8329-1	17.03	29.93	111	323	284	2792
GeoB8328-1	17.06	29.94	112	305	272	2710
GeoB8325-1	17.28	30.60	39	305	274	4310
GeoB8324-1	18.09	31.75	100	317	286	8816
GeoB8321-1	18.12	31.86	104	220	200	7571
GeoB8322-1	18.12	31.95	105	302	266	9594
GeoB8323-1	18.22	32.03	90	305	273	7686
GeoB8319-1	18.08	32.50	69	267	241	6760