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Variability of Holocene to Late Pleistocene Zambezi riverine sedimentation at the upper continental slope off Mozambique, 15°–21°S

Hartmut Schulz [a,*], Andreas Lückge [b], Kay-Christian Emeis [c], Andreas Mackensen [d]

[a] Department of Geosciences, Hölderlinstr. 12, D-72074 Tübingen, Germany
[b] Federal Institute for Geosciences, Stilleweg 2, D-30655 Hannover, Germany
[c] Institute for Biogeochemistry and Marine Chemistry, Bundesstr. 55, D-20146 Hamburg, Germany
[d] Alfred Wegener Institute for Polar Research (AWI), Am Handelshafen 12, D-27570 Bremerhaven, Germany

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ABSTRACT

Large rivers on continental margins play an important role as interfaces between land and ocean sedimentation. In many cases the modes and history of sediment dispersal, and the final deposition of the impressive volumes of terrigenous matter in the deep ocean remain poorly constrained by detailed sedimentary observations. The Zambezi River, by far the largest river of southeast Africa, discharges into the narrow, funnel-shaped Mozambique Strait between Africa and Madagascar. Here, we study the distribution of lithic grain sizes and major bulk fractions of biogenic and abiogenic components in core tops and long sediment cores off the Zambezi River, spanning the past ~60,000 years of the central and northern Mozambique continental margin. Due to the particular current regime, the modern Mozambique margin shows distinct sedimentation patterns not seen off most rivers of comparable size. Deposition is largely free of hiatuses, with high accumulation rates of fine-grained material, and only minor signs of erosion or sediment winnowing. Zambezi riverine detritus dominates the sedimentary facies between 20°S and 17°S from below the shelf break down to 2000 m water depth. However, a considerable fraction at present high sea level is deposited not directly downstream the Zambezi River mouth, but is dispersed to the northeast by along-shore transport, opposite to the mean flow within the Mozambique Strait. As a consequence, downslope transport today is highly unfocused and a canyon system at the upper slope is only poorly developed. We suggest that most of the riverine matter leaves the continental shelf ~200 km to the northeast of the present river mouth. Sediments took a more direct, chanellized path during the last glacial period of lowered sea level, which was confirmed by the reconstruction of Holocene and Late Glacial sedimentation rates in the area. In this regard, the Zambezi River–Margin sedimentary system stands for a margin with considerable temporal and spatial variabilities in downslope deposition on glacial-to-interglacial timescales.

1. Introduction

The transfer of materials from land to ocean basins is important to define the mass balance of the upper lithosphere (Burk and Drake, 1974), and the availability and biogeochemical cycling of elements on global scales (Wefer et al., 2003). Further, with continental erosion, extensive subaqueous reservoirs of hydrocarbons and minerals have accumulated in largely diverse upper continental margin settings due to rapid burial (Pratsch, 1978; Coster et al., 1989). Understanding of the mechanisms of submarine dispersal and deposition related to the large sediment volumes involved (Wetzel, 1993; McCave, 2003), and of the modification of the inorganic and organic matter entering the ocean (Jahnke et al., 1990; Walsh, 1991) is essential not only for the exploration of georesources, but also for the reconstruction of past climates from the sediment record. It appears that the exact relationship of downslope versus along-slope transport has to be studied on the basis of specific margins (e.g. Heezen et al., 1966). Large rivers play a key role in the processes of margin sedimentation with the world's 25 largest rivers, in terms of sediment and water discharge, accounting for approximately 40% of the fluvial sediments and 50% of the freshwater that enters the oceans (Milliman and Meade, 1983). Transport and transformation of the terrigenous particulate matter in these environments are not restricted to the near shore “estuarine” zone, but involves the upper continental margin with significant sorting and redistribution processes taking place below the outer shelf and on the upper slope (McKee et al., 2004).

The Zambezi River constitutes the longest and largest river system of eastern Africa with a drainage area of 1.4×10^6 km^2 and an annual runoff between 50 and 220 km^3 to the Indian Ocean (Gammelsrød, 1992; Fekete et al., 1999) (Fig. 1). With ten other large African rivers it discharges 290 million tons (mt) of sediment annually (Milliman and Meade, 1983) into the central part of the Mozambique Strait (MS)

* Corresponding author.
E-mail address: hartmut.schulz@uni-tuebingen.de (H. Schulz).

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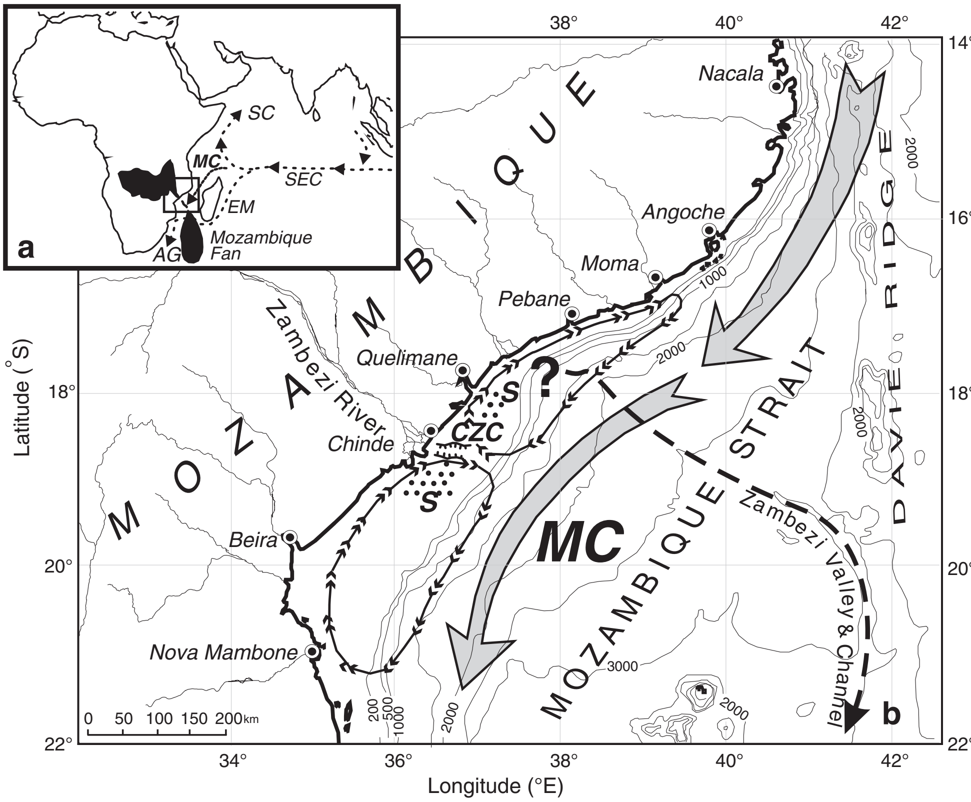

Fig. 1. Geomorphologic and oceanographic features of the northern Mozambique coast and the north-western part of the Mozambique Strait. (a) Working area with schematic large-scale circulation patterns in the southwest Indian Ocean. Mozambique Current (MC); Somali Current (SC); South Equatorial Current (SEC); East Madagascar Current (EM); Agulhas Current (AC). Black areas show the catchment area of the Zambezi and the Mozambique Fan as the final depocenter of the erosional products; (b) Generalised oceanography of the northwest MS (modified after Saetre et al., 1984; De Ruijter et al., 2002). Chinde-Zambezi (CZC) paleo-Channel of the Zambezi River; Holocene cover sands of >2.5 m thickness (S) (Beiersdorf, et al., 1980). Note the distinct features of the Zambezi Valley and Zambezi Channel that can be followed upstream (dashed line) to about 1000 m water depth at 18°S, more than 200 km NE of the present Zambezi River mouth.

(100 10^6 t from the Zambezi) between 23°S and 18°S. The bulk of Zambezi River sediment load is channelled into the huge Mozambique deep sea fan (Kolla et al., 1980a, b). Another component of the sediment supply feeds extensive coastal mudflats and mangrove forests within the tidal and near shore regime (Massinga and Hatton, 1996). The shelf off the Zambezi River mouth is approximately 100 km wide and widens to 150 km off Beira. This wide margin section offshore central Mozambique contrasts with the narrow shelves and steep upper slopes to the northeast and to the southwest, which characterise the East African margin morphology. It has been demonstrated that the latter sections might show zones of sediment bypassing and starvation, with the resent sediments being scarce or even absent (Green et al., 2008). However, the patterns of dispersal and deposition of terrigenous sediments from the Zambezi River, and the transfer routes to the deep sea are poorly known.

Droz and Mougenot (1987) were the first to point out that the Mozambique margin and upper fan architecture may be different from most other river-dominated margins, whereby the Mozambique fan system appears to be characterised by a single and immobile deep sea feeder channel, the Zambezi Valley and Zambezi Channel (Fig. 1), and a mobile system of gullies and tributaries incising the outermost shelf and upper slope. This unstable upper margin part is lacking a distinct canyon and transfer path of the huge terrestrial sediment load of the Zambezi River to depth. The deep sea Zambezi Valley and Channel, together more than 2000 km in length, constitute well developed morphological units, suggesting recent activity. However, direct sampling of the valley floor and flank proved to be extremely difficult: two targeted DSDP sites were abandoned due to technical problems (Schlich et al., 1974). From the presence and geometry of the different channel systems identified in the deep sea by seismic profiles, Droz and Mougenot (1987) emphasised that the Zambezi River estuary may not have been stable, but was, and possibly still is, migrating. As a consequence, the paths of drainage from central East Africa may have been located further to the north, and, more recently, possibly to the south of the Zambezi Valley. In contrast, a map of Vanney and Mougenot (1986) (in: Droz and Mougenot, 1987) from the area to the N of the Zambezi River mouth shows numerous distinct channels with one channel below each larger East African river mouth, that deeply incise into the shelf break and upper slope, suggesting strong sediment focussing and channelised downslope transport, where the shelf and upper slope are rapidly bypassed.

Superposition of eustatic sea level change on the long-term, tectonically driven epeirogenic uplift (Nyblade and Robinson, 1994) of the Zambezi catchment complicates reconstructions of the sediment pathways. Glacial lowering of sea level by some 125 m below present level (Ramsay and Cooper, 2002) shifted the point of sediment delivery to near the shelf break. At the same time, the Zambezi River catchment, which today has a mean elevation of ~1 km (Summerfield and Hulton, 1994), appears to have risen. During the mid-Holocene, relative sea level in the region exceeded eustatic sea level (Fairbanks, 1989; Siddall et al., 2003) and was 2 to 3 m higher than today (Jaritz et al., 1977), causing coastal emergence after the last deglacial transgression. Significantly, this caused placer deposits to accumulate on the shelf (Beiersdorf et al., 1980).

The Zambezi shelf and continental slope are both a large and an atypical sedimentary system, and like most of the East African continental margin, it is poorly studied. A collection of the few available sedimentary data from the eastern African slope (Marchig, 1972; Reineck, 1973; Vincent, 1976; Beiersdorf et al., 1980; Kolla et al., 1980a,b; Flemming, 1981; Nehring et al., 1984) may be indicative of a