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Organic carbon accumulation in modern sediments of the Angola basin influenced by the Congo deep-sea fan

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A B S T R A C T

Geochemical data (total organic carbon-TOC content, δ^{13}Corg, C:N, Rock-Eval analyses) were obtained on 150 core tops from the Angola basin, with a special focus on the Congo deep-sea fan. Combined with the previously published data, the resulting dataset (322 stations) shows a good spatial and bathymetric representativeness. TOC content and δ^{13}Corg maps of the Angola basin were generated using this enhanced dataset. The main difference in our map with previously published ones is the high terrestrial organic matter content observed downslope along the active turbidite channel of the Congo deep-sea fan till the distal lobe complex near 5000 m of water-depth. Interpretation of downslope trends in TOC content and organic matter composition indicates that lateral particle transport by turbidity currents is the primary mechanism controlling supply and burial of organic matter in the bathypelagic depths.

1. Introduction

Marine sediments represent the largest reservoir of organic carbon on earth and organic matter (OM) burial in marine sediments plays a key-role in the carbon cycle (Berner, 1982). The major part of OM in marine sediments derived from phytoplankton, although only a very small proportion of surface water primary production, reaches the deep ocean, owing to intense remineralization during settling of particles and at the seafloor. Moreover, the export and accumulation of marine OM in deep-sea sediments vary significantly from place to place (François et al., 2002; Jahnke, 1996; Seiter et al., 2004 among others). Marine OM concentration is generally higher along continental margins where nutrients are available, particularly in upwelling areas, and is lower in abyssal plains due to decreasing primary productivity with increasing distance from the coast and due to the longer transit time through water column because of larger water depth.

Terrestrial OM transported by rivers –and dust as a subordinate conveyor– also contributes to the burial of organic carbon in marine sediments (Bianchi et al., 2014; Blair and Aller, 2012; Dagg et al., 2004; Degens et al., 1991; Schlünz and Schneider, 2000). Although terrestrial OM is more resistant to remineralization than marine OM, it undergoes an intense recycling along the continental margins (Burdige, 2005). Most of the terrestrial OM preserved in marine sediments is stored in deltaic environments and the remainder is dispersed along continental margins and deep oceanic settings where it is mixed with autochthonous marine OM (Berner, 1982; Burdige, 2005; Hedges and Keil, 1995). Only rivers directly connected to the deep ocean by a submarine canyon may transfer high amounts of terrestrial OM into the abyssal plains.

This is the case of the Congo River, the second largest river in the world in terms of fluvial discharge (Kinga-Mouzeo, 1986), which exports large amounts of sediment to the eastern tropical part of the southern Atlantic Ocean, the Angola basin (Fig. 1). The influence of the Congo River for the OM export to the Angola basin has been recognized long time ago. However, previous studies suggested that only shelf and upper slope deposits in front of the Congo River have high continental-marine OM ratio (1:1) while sediments in water depths greater than 700 m contain predominantly marine OM (Mollenhauer et al., 2004; Müller et al., 1994; Seiter et al., 2004).

Since 1992, the Congo turbidite system was intensely studied by the

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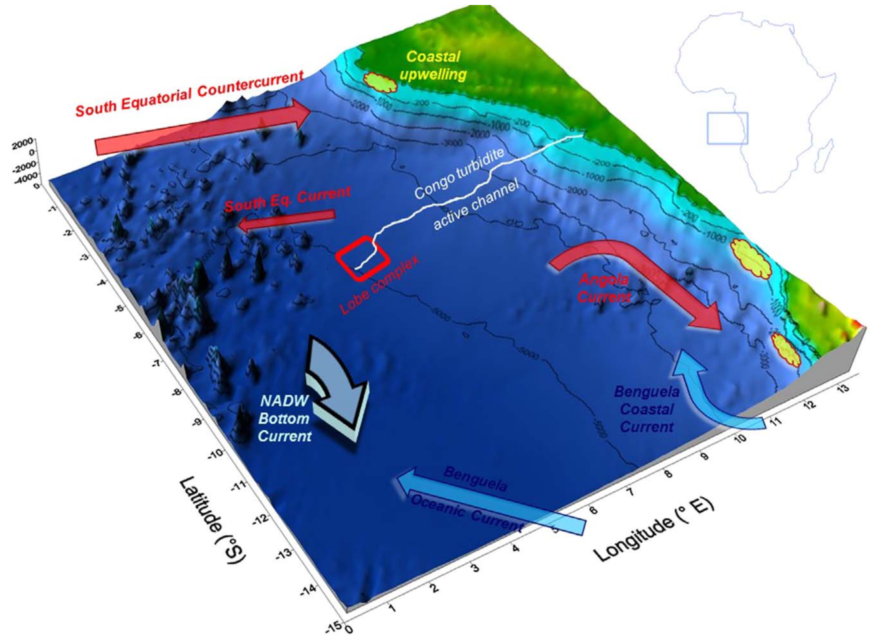

Fig. 1. 3D view of the bathymetry of Angola basin in the southeastern Atlantic Ocean with surface and bottom currents. The white line corresponds to the present-day active channel of the Congo deep-sea fan and the red rectangle encloses the terminal lobe complex.

French community. Several oceanographic campaigns were operated on this area: Guiness 1 and 2 (Cochonat, 1993; Cochonat and Robin, 1992), Zaïango 1 and 2 (Cochonat, 1998; Savoye, 1998), Zaïrov (Savoye and Ondreas, 2000), Biozaïre (Khripounoff, 2003; Sibuet, 2001a, 2001b), Reprezaï (Marsset and Droz, 2010), WACS (Olu, 2011) and Congolobe (Rabouille, 2011). Several thousands of kilometers of seismic lines, around 250,000 km^2 of bathymetric survey, moorings with sediment traps and current-meters, dives with submarine vehicles, core samplings and *in situ* geochemical measurements were acquired during these campaigns. A significant amount of data and samples was obtained which allows a good description and understanding of the whole Congo deep-sea fan (refer to Babonneau et al., 2004; Droz et al., 2003; Marsset et al., 2009; Migeon et al., 2004; Picot et al., 2016, and Savoye et al., 2009 with references therein). One hundred and fifty sediment cores were collected in different parts of the Congo turbidite system, from the canyon head to the terminal lobe complex, by ca. 5000 m of water-depth. The organic geochemical analyses of these cores significantly increase the available dataset of OM content in surface sediments along the Congo turbidite system and enable to refine the total organic carbon (TOC) map of the Angola basin, especially concerning the areal extent of the Congo influence. The present study reports the geochemical results obtained on 150 core tops, discusses the depositional patterns in OM along the Congo turbidite system and examines the downslope trends in TOC and OM composition in the Angola basin.

2. Study area

The Angola basin extends in the equatorial and tropical southeastern Atlantic Ocean between the Equator and 15°S and 0° and 13°E (Fig. 1). The surface water circulation in this basin is dominated by the Angola Current which forms the eastern branch of a large, cyclonic gyre in the Gulf of Guinea. It is formed by the southeast branch of the South Equatorial Countercurrent and the southward-turning waters from the north branch of the Benguela Oceanic Current. The modern distribution of primary production in this area is mainly characterized by oligotrophic waters in the southern part of the Angola basin with annual primary production less than 150 $g\,C\,m^{-2}$ (Antoine et al., 1996). By contrast, the northern part of the basin is characterized by higher primary production levels as the Congo River delivers large freshwater input with elevated nutrient concentration. The resulting plume extends in surface up to 800 km from the coastline (Cadée, 1984) and is deflected to the northwest by the South Equatorial Current. Annual primary production in this area may reach 400 $g\,C\,m^{-2}$ (Antoine et al., 1996). In addition, some wind-driven seasonal upwellings impact the local productivity along the coast with annual primary production levels up to 700 $g\,C\,m^{-2}$ (Antoine et al., 1996; Schneider et al., 1997).

The deep-water circulation in the Angola basin is dominated by the oxygen-rich North Atlantic Deep Water (NADW). NADW flows southward at depth along the western margin of South Africa (Reid, 1996).

Modern surface sediments in the Angola basin are classified as nannofossil oozes (Archer, 1996), with minor contributions of clay and siliceous microfossils. Clays are dominant below the calcite compensation depth (CCD), which presently lies at a depth of ca. 5000 m in the Atlantic Ocean (between 4800 and 5600 m in the Angola basin according to Jansen et al., 1984). Clayey and silty sediments are also associated to the mud-rich Congo deep-sea fan.

This Congo fan is developed on the adjacent continental margin off the mouth of the Congo River and is one of the world's largest active deep-sea turbidite systems, with a surface estimated to 330,000 km^2 (Savoye et al., 2000, 2009). The turbiditic activity results from the direct connection between the Congo River estuary and a canyon head that allows direct transfer of sediment into the deep-sea via a single channel. The presently active channel-levee system, which extends 760 km westward off the Congo River mouth, was subject of several detailed studies (Babonneau, 2002; Babonneau et al., 2002, 2010; Bonnel, 2005; Droz et al., 1996, 2003; Marsset et al., 2009; Picot et al., 2016; Savoye et al., 2000, 2009). Evidences for the occurrence of turbidity currents in the canyon/channel include submarine cable breaks (Heezen et al., 1964) and direct sampling of turbidity currents by current-meters and sediment traps between 2001 and 2004 (Khripounoff et al., 2003; Vangriesheim et al., 2009). The frequency of turbidity events is estimated at about 60 per century (Heezen et al., 1964). The slope of the channel floor decreases from 1.5 to 0.2% down channel. The channel is over-incised, with an incision depth ranging from 200 m at 3000 m-depth to 100 m at 4300 m-depth (Babonneau et al., 2002; Savoye et al., 2000). Though the base of turbidity currents remains confined within the canyon/channel, the upper part can overflow the channel flanks and build symmetric levees on both sides