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Palynofacies reveal fresh terrestrial organic matter inputs in the terminal lobes of the Congo deep-sea fan

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ABSTRACT

The Congo deep-sea fan is directly connected to the Congo River by a unique submarine canyon. The Congo River delivers up to 2×10^{12}gPOC/yr, a part of which is funnelled by the submarine canyon and feeds the deep-sea environments. The more distal part of the Congo deep-sea fan, the terminal lobe area, has a surface of 2500 km^2 and is situated up to 800 km offshore at depths of 4750–5000 m. It is a remarkable place to study the fate and distribution of the organic matter transferred from the continent to the deep ocean via turbidity currents. Forty-two samples were analyzed from the terminal lobes, including sites from the active channel, one of its levees and an abandoned distal channel. Samples were collected using multitube cores and push-cores using a Victor 6000 ROV, which surveyed the dense chemosynthetic habitats that locally characterize the terminal lobes. Palynofacies reveal a remarkably well-preserved, dominantly terrestrial particulate organic matter assemblage, that has been transferred from the continent into the deep-sea by turbidity currents. Delicate plant structures, cuticle fragments and plant cellular material is often preserved, highlighting the efficiency of turbidity currents to transfer terrestrial organic matter to the sea-floor, where it is preserved. Moreover, the palynofacies data reveal a general sorting by density or buoyancy of the organic particles, as the turbulent currents escaped the active channel, feeding the levees and the more distal, abandoned channel area. Finally, in addition to aforementioned hydrodynamic factors controlling the organic matter accumulation, a secondary influence of chemosynthetic habitats on organic matter preservation is also apparent. Palynofacies is therefore a useful tool to record the distribution of organic matter in recent and ancient deep-sea fan environments, an important topic for both academic and petroleum studies.

1. Introduction

Downslope gravity flows may facilitate the rapid transport, deposition and burial of terrestrial and marine organic matter in deep-sea environments (Doust and Noble, 2008; Meyers et al., 1996; Peters et al., 2000), limiting the aerobic bacterial degradation of the organic matter in the oxygenated water column and/or at the sea-floor (Hedges and Keil, 1995). Indeed, turbidity currents are known to be important conveyors of terrestrial and marine organic matter to deep-water environments (Baudin et al., 2010; Biscara et al., 2011; Boulter and Riddick, 1986; Heezen et al., 1964; McArthur et al., 2016a, 2016b; Saller et al., 2006; Watanabe and Akiyama, 1998). This transported organic matter may locally constitutes as much as several weight% of the total organic matter delivered to the sea-floor (Baudin et al., 2010; Biscara et al., 2011) and submarine canyons acts as efficient conduits that can carry this organic matter downslope (Canals et al., 2006; Goni et al., 1997; Hedges et al., 1997; Heussner et al., 2006; McArthur et al., 2016a, 2016b; Sanchez-Vidal et al., 2012; Tesi et al., 2010).

The aims of this work are to assess the origin, distribution and preservation of particulate organic matter, by optical observations of the palynofacies of deep-sea turbidites. A near unique opportunity to investigate these questions is presented by recent high-resolution sea-floor data and shallow cores from the extremity of the active channel-levee system that is directly feeding the present-day Congo deep-sea fan. Investigation of the particulate organic matter preserved in modern deep-sea surface sediments in this area was carried out using palynofacies studies, complementing the previous and current studies on the lower channel-levee system located upstream from the distal lobe complex (Baudin et al., 2010) and on the distal lobes themselves (Baudin et al., 2017; Stetten et al., 2015). An attempt is made to

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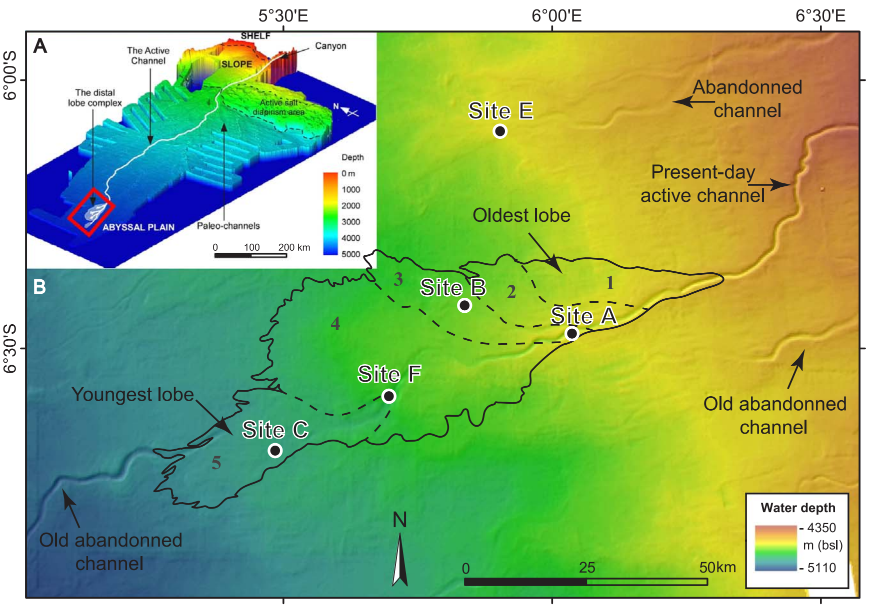

Fig. 1. A) Bathymetric map of the Congo deep-sea fan illustrating the active channel and the location of the distal lobe complex (reprint from Savoye et al., 2009). B) Bathymetric map of the distal lobe complex of the Congo deep-sea fan showing the location of the six sites explored during WACS and Congolobe campaigns. Subdivision of the lobe complex is simplified after Babonneau (2002).

document the particulate organic matter distribution in the depositional sub-environments (channel, levee and abandoned channel), to examine the possible local interactions between dense benthic communities and preserved organic matter at the sea-floor. This new data set was compared with the few previous studies that have used a similar approach in oceanic environments of this kind (Baudin et al., 2010; Biscara et al., 2011; Boulter and Riddick, 1986; Deniau et al., 2010; McArthur et al., 2016a, 2016b).

2. General setting

The Congo deep-sea fan (Fig. 1) is located on the Congo-Angola passive continental margin (Savoye et al., 2009). The initiation of turbidite sedimentation began during the Oligocene, leading to deposition of a thick Cenozoic sedimentary succession up to 5 km in thickness (Ferry et al., 2004). Oligocene and Miocene turbidites are hydrocarbon reservoirs and have therefore been subjected to extensive studies. The present-day Congo canyon was established at approximately 5 at the Miocene to Pliocene transition (Ferry et al., 2004). From the Congo-Angola continental shelf (Fig. 1), the Congo deep-sea fan extends 750–800 km down to abyssal depths of 4700–5100 m (Rabouille et al., 2017; Savoye et al., 2009). The estimated surface area of the fan is 330,000 km^2 (Babonneau et al., 2002; Rabouille et al., 2017; Savoye et al., 2009). The active region of the Congo fan is located at the extremity of the single active distributary channel in water depth of 4750 m (Babonneau et al., 2002), where the channel-levee system feeds several distal lobes called the lobe complex (Rabouille et al., 2017) (Fig. 1). This region covers a surface area of 2500 km^2 and consists of five successive lobes that have developed 90 km south-westward from the channel-levee system (Dennielou et al., 2017). The initiation of this lobe complex started during the Upper Holocene 4 ka BP (Picot, 2015; Savoye et al., 2009). The lobes have been labelled 1–5 in a downslope, south-westward direction (Fig. 1), lobe 1 being the oldest and lobe 5 the youngest (Babonneau, 2002; Bonnel, 2005; Dennielou et al., 2017; Savoye et al., 2000). In this study, samples were examined from sites A, C and E (Fig. 1). Site A is located on a ~900 m-wide meander of the active channel, at water-depth between 4745 and 4790 m, immediately upstream of the mouth of the oldest part of the lobe complex (Rabouille et al., 2017, Fig. 1 and Fig. 2, Table 1). Site C is located in the active channel at ~4940 m water-depth in lobe 5, 65 km downstream from site A. Site E is located on an abandoned northern lobe complex, at ~4750 m water-depth, 45 km distant from the active channel (Figs. 1 and 2, Table 1). This northern lobe complex also developed during the Holocene, between 6 and 4 Ka B.P. (Picot, 2015).

The Congo deep-sea fan is a peculiar study site in that it has a direct and unique connection between the river and the Congo canyon, which has incised the shelf up to 30 km in the estuary and efficiently funnels the Congo River sediments into the deep-sea by turbidity currents (Rabouille et al., 2017; Savoye et al., 2009). Moreover, the Congo River carries up to 2×10^{12}gOC/yr (Coynel et al., 2005) and a large part of this organic carbon is directly transferred into the deep-sea (Stetten et al., 2015). Furthermore, this input of organic matter may locally sustains dense deep-marine ecosystems that are essentially composed of chemosynthetic vesicomyid bivalves and microbial mats, associated with methane-rich fluids seeping from the surface of these organic-rich sediments (Olu et al., 2017; Pastor et al., 2017; Pruski et al., 2017; Sibuet and Olu, 1998; Sibuet and Vangriesheim, 2009). Finally, the Congo deep-sea fan is a mud-rich system (Dennielou et al., 2017; Savoye et al., 2009) and it raises the question of the influence that particles size distribution in the system has on both the organic carbon transport and distribution from the Congo-Angola continental margin to the deep-sea setting.

3. Study material

Quantitative palynofacies data were obtained from selected samples collected from the so-called lobe complex area, during the West African Cold Seeps (WACS) and Congolobe cruises in 2011 (Olu, 2011; Rabouille, 2011). Samples were obtained from ship-operated multicores (MTB) and from Ifremer's Victor 6000 ROV operated push cores. The latter were collected at the sea-floor. Both MTB and push cores allowed the sediment-water interface to be preserved. Forty-two samples were collected at site A (from CoL-A-MTB2 and CoL-A-MTB3 multitubes), site C (from CoL-C-MTB10 multitube, CoL-C-PL491-CT14, CoL-C-PL491-CT1 and WACS-C-PL436-CT14 push cores), and site E (from CoL-E-MTB14 multitube) (Table 1 and Rabouille et al. (2017) for precise location). The selected samples allowed the palynofacies to be recorded from each of the various architectural elements in the two lobe complexes studied, namely the active channel (CoL-A-MTB3, CoL-C-MTB10, CoL-C-PL491-CT14, CoL-C-PL491-CT1, WACS-C-PL436-CT14), one of its levees (CoL-A-MTB2) and an abandoned channel (CoL-E-MTB14) (Table 1). Moreover, this sampling allowed estimation of the influence of dense chemosynthetic habitats on the organic matter preserved on the sea-floor (Olu et al., 2017; Sen et al., 2017). Indeed, CoL-C-PL491-CT1 and CoL-C-PL491-CT14 were collected in the adjacent sediment respectively inside and out of a dense aggregate of vesicomyid bivalves