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The long-term evolution of the Congo deep-sea fan: A basin-wide view of the interaction between a giant submarine fan and a mature passive margin (ZaiAngo project)

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ABSTRACT

We have integrated the relatively unknown distal domains of the Lower Congo basin, where the main depocenters of the Congo submarine fan are located, with the better-constrained successions on the shelf and upper slope, through the analysis of thousands of km of 2D seismic reflection profiles off-shore the Congo–Angola passive margin. The basin architecture is depicted by two ca. 800-km-long regional cross sections through the northern (Congo) and southern (Angola) margin. A large unit deposited basinward of the Aptian salt limit is likely to be the abyssal-plain equivalent of the upper-Cretaceous carbonate shelf that characterized the first post-rift deposits in West-equatorial African margins. A latest-Turonian shelf-deepening event is recorded in the abyssal plain as a long period (Coniacian–Eocene) of condensed sedimentation and basin starvation. The onset of the giant Tertiary Congo deep-sea fan in early Oligocene following this event reactivates the abyssal plain as the main depocenter of the basin. The time–space partitioning of sedimentation within the deep-sea fan results from the interplay among increasing sediment supply, margin uplift, rise of the Angola salt ridge, and canyon incision throughout the Neogene. Oligocene–early Miocene turbidite sedimentation occurs mainly in NW–SE grabens and ponded inter-diapir basins on the southern margin (Angola). Seaward tilting of the margin and downslope salt withdrawal activates the up-building of the Angola escarpment, which leads to a northward (Congo) shift of the transfer zones during late Miocene. Around the Miocene–Pliocene boundary, the incision of the Congo submarine canyon confines the turbidite flows and drives a general basinward progradation of the submarine fan into the abyssal plain The slope deposition is dominated by fine-grained hemipelagic deposits ever since.

Results from this work contribute to better understand the signature in the ultra-deep deposits of processes acting on the continental margin as well as the basin-wide sediment redistribution in areas of high river input.

1. Introduction

The Congo deep-sea fan is one of the largest submarine fan systems in the world and one of the most important depocenter in the eastern south Atlantic. The fan developed during the post-rift evolution of the continental margin of West-equatorial Africa, which was formed following early Cretaceous rifting. It is currently sourced by the Congo River, whose continental drainage area is the second largest in the world ($3.7{\cdot}10^6$ km^2) (Droz et al., 1996) (Fig. 1). Extending over 1000 km offshore the Congo–Angola continental margin, from the shelf up to the abyssal plain, this submarine fan covers a surface of about 300,000 km^2 (Savoye et al., 2000; Droz et al., 2003) and contains at least 0.7 M km^3 of Tertiary sediments (Anka and Séranne, 2004). The existence of a direct connection between the Congo River mouth and the submarine fan through an impressive submarine canyon is one of the most important characteristics of this system. The Congo canyon cuts across the margin, it is 950 m deep at the shelf-break and more than 1300 m at 100 km offshore the coastline (Babonneau et al., 2002). Thus terrigenous material coming from the continental drainage basin are transported through the canyon and directly transferred onto the abyssal plain, by-passing the shelf and upper slope (Droz et al., 2003; Turakiewicz, 2004).

Due to its economical relevance, the Lower Congo basin has been extensively studied since the sixties (e.g. Brognon and Verrier, 1966) until recent basin-wide initiative as the ZaiAngo project, a research collaboration between the Ifremer and Total. The continental margin architecture, as well as the stratigraphy of the proximal areas, has been rather well constrained due to the presence of numerous oil wells on the shelf and upper slope (e.g. Teisserenc and Villemin, 1989; Séranne et al., 1992; Meyers et al., 1996; Rasmussen, 1996; Nzé Abeigne, 1997;

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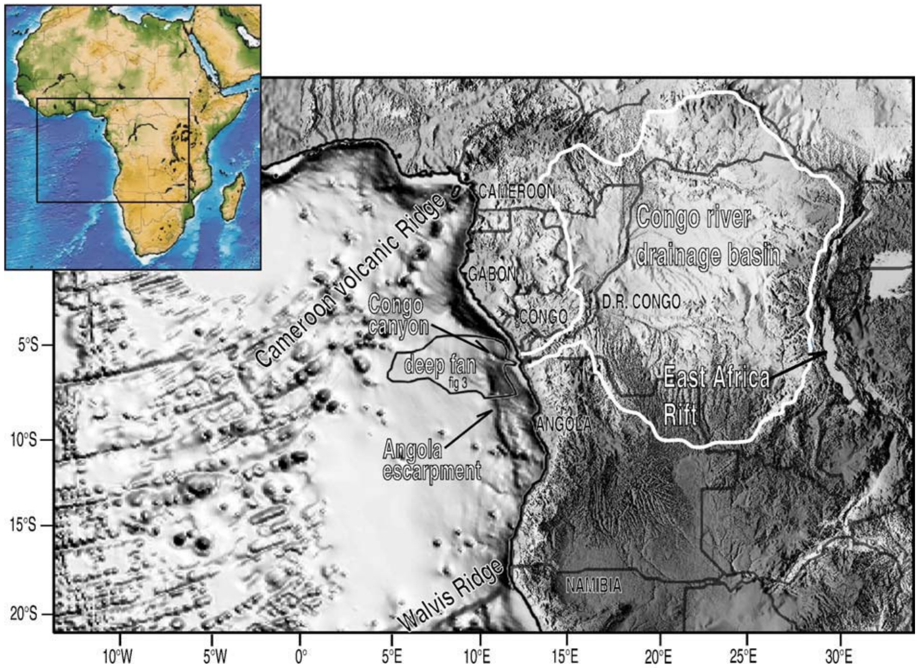

Fig. 1. Location of the Congo deep-sea fan complex in the context of the South Atlantic and the West African margin. The fan is currently sourced by the Congo River whose drainage basin (white line) is about 3.7 × 106 km^2. There is a direct connection between the river mouth and the fan through the Congo submarine canyon, so terrigenous sediments bypass the shelf and slope, and are directly delivered to the abyssal plain, basinward of the Angola escarpment (sea-floor bathymetry and land topography DEM from Gtopo30).

Uenzelmann-Neben et al., 1997; Karner and Driscoll, 1999; Anderson et al., 2000; Lavier et al., 2000; Marton et al., 2000; Rosendahl and Groschel-Becker, 2000; Valle et al., 2001; Ardill et al., 2002; Lucazeau et al., 2003; Robin et al., 2005; Petzet, 2007). In addition, some regional works provided some hints on the regional significance of the distal provinces and an idea of the deep fan size (Emery et al., 1975a,b; Uchupi, 1989; Uchupi, 1992). More recently, other studies have provided a better understanding of the stratigraphy and evolution of the abyssal plain, where the main fan depocenters are located (Anka, 2004; Anka and Séranne, 2004). Nevertheless, a comprehensive integration of proximal and distal domains, assessing a global basin-wide view of the fan evolution is yet to be carried out.

This contribution complements previous work done in the abyssal plain of the Lower Congo basin and addresses questions regarding the sediment partitioning between the deep-sea fan and the continental margin, its timing and controlling factors. We focus on analysing how different processes known to affect the margin, such as submarine erosions, salt tectonics, basin tilting, and continental uplift, are recorded in the distal deposits of the lower slope and abyssal plain, and to what extent they control the submarine fan deposits. We present the results from analysis of 2D seismic reflection data on the slope north of the Congo Canyon that, once correlated to wells in the shelf domain and integrated to the distal seismic, allow to (1) re-interpret and better age-constrain the relatively unknown distal units deposited onto the oceanic crust, (2) analyse the possible interactions between the salt tectonics and the fan depocenter location/migration, and (3) reconstruct the basin-wide architecture proposing a long-term evolution for the Congo deep-sea fan.

2. Geological setting

The Congo–Angola passive margin results from Neocomian rifting of Gondwana followed by oceanic accretion (Rabinowitz and Labreque, 1979). Although no magnetic anomaly is found in the Lower Congo basin, the age of the oldest oceanic crust is interpreted to be close to Chron M0 (118.7 Ma), that is Aptian (Nürnberg and Müller, 1991) or even older: Barremian (Marton et al., 2000). Moreover, a literature review reveals that the estimated ages in this area range from 127 to 117 Ma (Teisserenc and Villemin, 1989; Guiraud and Maurin, 1992; Karner and Driscoll, 1999; Jackson et al., 2000). The precise location of the Continent–Ocean boundary (COB) is rather unknown, but it would correspond to a narrow transition zone between extended continental crust and normal oceanic crust, located few kilometres landward of the Angola escarpment (Fig. 1) (Moulin, 2003; Contrucci et al., 2004; Séranne and Anka, 2005).

Following the continental break-up, a transgressive clastic succession, from fluvial sandstones to lagoon shales, accumulates in the basin (Fm. Chela, Fig. 2). They are overlain by a thick evaporitic level deposited in restricted marine conditions during late Aptian (Fm. Loeme, Fig. 2) (Emery et al., 1975a,b; Teisserenc and Villemin, 1989). This layer, composed mostly of massive halite topped by anhydrite, is the detachment level of the widespread salt tectonics that affects overlaying post-rift sequences (Duval et al., 1992; Lundin, 1992; Vendeville and Jackson, 1992; Gaullier et al., 1993; Spathopoulos, 1996; Cramez and Jackson, 2000; Fort et al., 2004; Jackson and Hudec, 2005; Hudec and Jackson, 2007).

During the Albian, shallow carbonate accumulations (the Pinda Group) built up an aggrading ramp-profiled shelf. As sea-floor spreading goes on, open marine conditions establish and carbonate production is halted. In consequence, from the Cenomanian to the Eocene the sedimentation is characterized by the mudstones and marine siliciclastics of the Iabe/Landana Groups (Fig. 2) and depositional rates remain very low throughout this time span (Anderson et al., 2000; Valle et al., 2001).

The early Oligocene is characterized by a major submarine erosion that removed as much as 500 m of sediments of the outer shelf (Nzé Abeigne, 1997; Lavier et al., 2000). This event is linked to the so-called "Oligocene unconformity" identified throughout the West African margin (Teisserenc and Villemin, 1989). Early Oligocene is also a time of a widespread stratigraphic reorganization along the margin, expressed by a generalized turn-over in the depositional pattern from aggradation to progadation deposits (Séranne et al., 1992). An important increase in terrigenous supply is also registered at this time, which is evidenced by the development of the massive Congo deep-