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Morphological evolution of Cap Lopez Canyon (Gabon): Illustration of lateral migration processes of a submarine canyon

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ABSTRACT

Comparison of bathymetric data on short time scales (1959–2008) is used to provide new insights into the modern sedimentary dynamics of the Cap Lopez Canyon (Gabon, West Africa). The canyon head evolution is characterized by a north–eastward lateral migration of ~180 m between 1959 and 2008. The evolution of the coastline position over the same period highlights the strong relationship between the probable increase of the longshore transport, related to the smoothing of the coast and the morphological evolution of the canyon head. Lateral migration of the thalweg from the inner bend to the outer bend is estimated between 77 and 190 m (or between 1.6 and 3.8 m/year), leading to an increase of the sinuosity (from 1–1.5 in 1959 to 1.3–3.6 in 2008). The migration of the thalweg is associated with strong erosion on the outer bends (up to 60 m) and sediment deposition on the inner bends (up to 25 m). Both the absence of overbank deposits and the developing point-bar morphology may reflect that equilibrium flows are the most frequent flows encountered in the Cap Lopez Canyon. Although erosion of the outer bends is the result of slope failures and steady erosional processes, our study suggests that erosion related to the transit of sediment gravity flows would be the predominant process.

1. Introduction

Coastal submarine canyons incising a continental shelf are of particular importance to the continent-ocean sediment budget because they facilitate the transfer of sediment from terrestrial and coastal sources to the deep sea. In places where the longshore drift is captured by canyons, a large volume of sediments can be evacuated (Shepard and Dill, 1966; Burke, 1972; Paull et al., 2005; Covault et al., 2007; Smith et al., 2007). Sand, transported by wave-induced currents in the nearshore zone, is temporarily trapped in the head of the canyon, until it is transported suddenly down canyon (Mastbergen and Van Den Berg, 2003). In these types of environment, processes such as slope failures, channel erosion and deposition are significant.

Such sedimentary processes that shape submarine canyons may occur on very short time scales, as suggested by recent works on Monterey Canyon. Monitoring activities revealed the occurrence of numerous subannual transport events (Paull et al., 2003; Xu et al., 2004). Bathymetric comparison between 2002 and 2005 illustrated several significant morphological evolutions: active movement of crescent-shaped bedforms (Smith et al., 2005, 2007; Paull et al., 2010), oscillation of canyon-head rim position (Smith et al., 2007), high erosion on outer bends (Smith et al., 2007) or headward erosion of gullies (Smith et al., 2005).

The main objective of this study is to carry on those previous investigations and to bring complementary results about the sedimentary dynamics of submarine canyons on a short-time scale. Based on annual to multi-decadal bathymetric comparison of Cap Lopez Canyon (Gabon, West Africa), our work illustrates different examples of morphological evolution and evaluates the frequency of involved sedimentary processes. This study focuses more particularly on the interactions between the canyon head and the coastline and on the evolution of the thalweg position through time. Finally, we discuss the possible triggering mechanisms and the magnitude of flow events in the canyon.

2. Study area

The onshore part of the Gabon continental margin is drained by the Ogooué River which constitutes the third largest African fresh-water source into the Gulf of Guinea (Mahé et al., 1990). The river flows west–north–westward and discharges south of Port-Gentil, forming a large delta on both sides of Mandji Island (Fig. 1A). The Gabonese coast is essentially exposed throughout the year to southwesterly swells (Bourgoin et al., 1963; Actimar, 2004). The waves strike obliquely the coast and induce a northward longshore transport, first estimated between 300,000 and 400,000 m^3/year (Bourgoin et al., 1963, Fig. 1B). The

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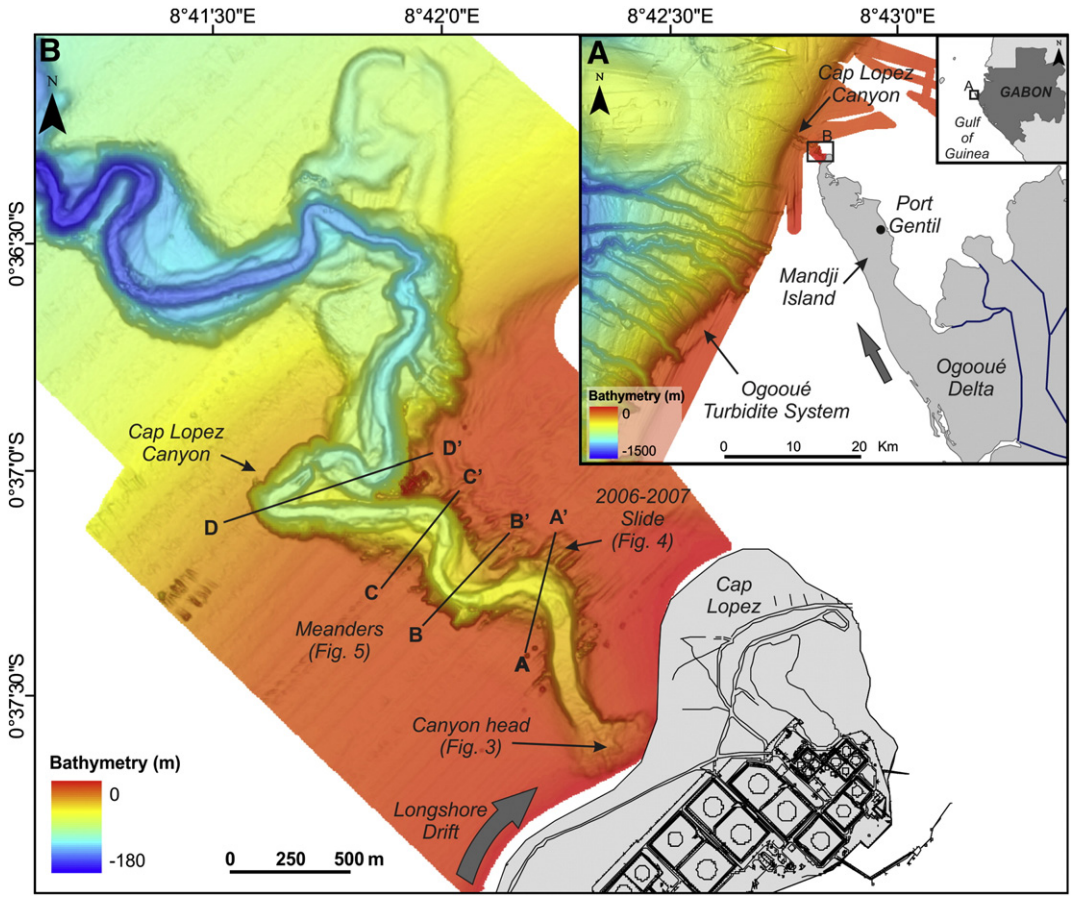

Fig. 1. Location of the study area. A) General bathymetric map showing the Ogooué turbidite system, Mandji Island and the Cap Lopez Canyon. Inset indicates the location of the Mandji Island on the Gabonese margin. B) Detailed bathymetric map of the upper part of the Cap Lopez Canyon obtained from multibeam echo-sounding. A–A', B–B', C–C' and D–D' are the locations of the bathymetric sections through the canyon meanders (Fig. 4). Grey arrows indicate the direction of longshore drift in the main figure and inset.

longshore transport is responsible for the formation of the Mandji Island, a sandy spit of 50 km long and 1–7 km wide located at the northern end of the Ogooué Delta (Fig. 1A & 1B). Sediment samples collected along the west coast of the Mandji Island are composed of well sorted fine to medium sand. Particles <63 μm are rare (<3%). Fine sedimentation is more present in the bay of Port Gentil (up to 20% of silty clay sediment; Artelia, 2012a).

Based on directional wave statistics and numerical simulations, recent work on the study area provided more detailed information about longshore transport (Artelia, 2012b). First, offshore wave data were obtained from the WANE2 wave database between 1999 and 2006 at the geographic point no. 25918, located 90 km south–westward from Cap Lopez (900 m water depth, Fig. 2). A second dataset, made up of in-situ measurements near Cap Lopez between 10 and 45 m water depth, was used to complete wave observations on the coast. This dataset covers short period (up to 4 months) between 2008 and 2010. Statistical analysis of offshore wave conditions shows a predominant direction between N190° and N200° (85%, Fig. 2). 70% of wave conditions are characterized by a peak period between 9 and 13 s and 17% show a peak period greater than 14 s. More than 90% of significant wave height ranges between 0.75 m and 2 m. 100-Year extreme sea waves simulated on a study area located ~20 km south of Cap Lopez at 12 m water depth show a significant wave height and a peak period around respectively 3.8 m and 15.8 s (Actimar, 2004). A wave refraction model of the dominant swells was calculated by wave propagation on the coast (Artelia, 2012b). Different results were highlighted: 1) swells tend to rotate around the Cap Lopez and especially as the peak period increases, 2) because of bathymetric effects, swells are gradually attenuated northward, 3) the Cap Lopez Canyon favours the local strengthening of swells south of the canyon and their attenuation in and just north of the canyon. Dominant wave statistics and simplified wave rays from wave refraction model are illustrated in Fig. 2.

Using the wave propagation model, the longshore sediment transport along the Mandji Island was calculated with the CERC formula (Artelia, 2012c, Fig. 2). South of Cap Lopez, longshore sediment transport is estimated between 670,000 and 1,120,000 m^3/year (Fig. 2). Refraction effect on the swells then increases northward, leading to a lower longshore transport compared to the south (mean 630,000–675,000 m^3/year). In the vicinity of the canyon head, transport efficiency becomes considerably weak (60,000–100,000 m^3/year), indicating that the canyon head capture a major part of the longshore transport. Finally, north of the canyon head, the change of orientation of the coast conduces to a local intensification of the longshore drift (90,000–150,000 m^3/year). Longshore transport estimates along the coast are synthetized in Fig. 2.

The strong sediment accumulation at the extremity of the Mandji Island is thought to have led to the formation of the Cap Lopez Canyon by retrogressive erosion (Le Fournier, 1972). The deep incision of the continental shelf by the canyon head (Fig. 1) combined with longshore drift favours the capture of sandy sediment by the canyon (Reyre, 1984).

3. Data acquisition and analysis

Annual oceanographic surveys on the Cap Lopez Canyon were performed by the IOTA SURVEY Company between 2004 and 2008. Bathymetric data were collected with Odom Echotrac DF3200 MKII and 320M Knudsen single beams. Acquisition of bathymetric data for year 1959 and 1982 was performed by the French Navy and the