HỘI NGHỊ TOÀN QUỐC KHOA HỌC TRÁI ĐẤT
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Striations at the base of the paleo-fan and channel in offshore Cameroon revealed by 3D seismic data

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ABSTRACT

The 3D seismic data, offshore Cameroon, reveals the evidence of a Pliocene fan and a channel with a series of striations at their base. The fan and channel are developed in early Pliocene, characterized by high amplitude reflections with bi-directional downlap on the base of the Pliocene sequence, interpreted to be deep-water sand-rich fan, channel. Pliocene channel flows from east to west in the High Gradient Slope (HGS), whereas, the fan is extending from NE to SW on the Low Gradient Slope (LGS). Individual striations have been imaged that are 20 - 50 m wide, c. 10 - 20 km long and 4 - 8 m deep, trending NE – SW and E-W, slightly divergent patterns toward downslope. Striations are observed at the base of fan and channel suggest for the beginning of a period of unstable slope creating NE-SW slides in LGS and erosion in HGS, followed by the deposition of large scale fan deposits on the LGS and series of parallel aggradational channels in the HGS. The striated unconformity at the base of the Pliocene sequence is possible the result of a major tectonic uplift event or significant climate changes.

Keywords: Striation; Pliocene fan; Channel; Cameroon

1. Introduction

Submarine landslides are common features of ocean margin and play important role in the evolution of the ocean margins (Gee et al., 2007), capable of transporting sediment across the whole width of the continental rise to the abyssal plain (Hampton et al., 1996). Some of the largest known submarine landslides involving hundreds to thousands of cubic kilometers of material have been documented on Atlantic margins, which extend for > 700 km, such as the Saharan Slide (Embley, 1976) and the Storegga Slide (Bugge et al., 1988). Recent advances in three dimensional seismic techniques are allowing new insights into slope processes, improving our understanding of submarine landslide structure, flow mechanics and triggering (Gee et al., 2006). The term 'landslide' is used as a general term to describe a slope failure with no implication of specific process or geological setting (Gee et al., 2007). Submarine slides are common in five environments: (1) fjords, (2) active river deltas, continental margins, (3) submarine canyon-fan systems, (4) open continental slope, and (5) oceanic volcanic islands (Hampton et al., 1996).

The study of landslide and debris flow revealed the presence of an extensive shear layer underlying more than 450 km of the deposit, upon which the flow appeared to have gained enhanced runout (Masson et al., 1993, Gee et al., 2001). The mechanism of generation for this basal layer was speculated to have been erosion and shearing of the substrate by the overriding flow, resulting in the basal striations (Gee et al., 2006).

This paper describes a newly discovered Pliocene submarine fan and channels on the deep water slope of Cameroon (West Africa), using 3D seismic data. Detailed analysis is presented of the paleo submarine fan and channel with insight into their striated bases and possible triggering process.

2. Geological background

Located in Kribi-Campo sub-basin on the present day deep-water continental margin slope, the study area covers an area of 1500 km^2, and contains a sedimentary section up to 6.5 km thick, ranging in age from Upper Cretaceous to present (Fig. 1). This study is focused on the shallow section, from Pliocene to Pleistocene. The area is divided into a High Gradient Slope (HGS) and Low Gradient Slope (LGS) based on slope gradient. The high gradient slope dips to the west (3.4^o to 1.6^o), associated with the Kribi High; the low gradient slope (2^o to 0.7^o) dips southwest. These two geomorphic areas are separated by a line

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trending approximately NE – SW that varies slightly in location at different stratigraphic level but retains the same trend (Fig. 2).

The Kribi-Campo sub-basin is the northernmost of a series of salt basins on the West Africa margin. It is bounded to the east by Precambrian basement outcrops that occur close to the shoreline, the southern margin is limited by the Kribi Fracture Zone (KFZ) (Fig. 1), which separates the Kribi-Campo sub-basin from the Equatorial Guinea Rio-Muni basin. The northwest limit of the basin is bounded by another facture zone, and a further c. 100 km to the northwest is the Cameroon Volcanic Line (CVL), a NE – SW trending feature that extends onshore. The basin extends south offshore, across a shallow shelf into the deep water area of Equatorial Guinea.

The basin was initially a rift branch of the proto-Atlantic, which includes the Rio-Muni, North Gabon (West Africa), and Sergipe-Angolas (Brazil) (De Matos, 1992, Davison, 1997). During the laterpassive margin phase, the basin experienced several additional regional tectonic events resulting in inversion and folding in the Santonian, and gravity sliding during Early/Mid/Late Tertiary time. These events are marked by major unconformities including the Albian-Aptian break up unconformity (115 Ma), middle Cretaceous (Santonian - ~ 85 Ma), late Cretaceous (K/T boundary - ~ 70 Ma) and mid-Oligocene (~ 30 Ma), mid-Miocene (~ 15 Ma) and late Tertiary event (~ 5.3 Ma) (Fig. I.5) (Turner, 1995, Lawrence et al., 2002, Brownfield and Charpentier, 2006)

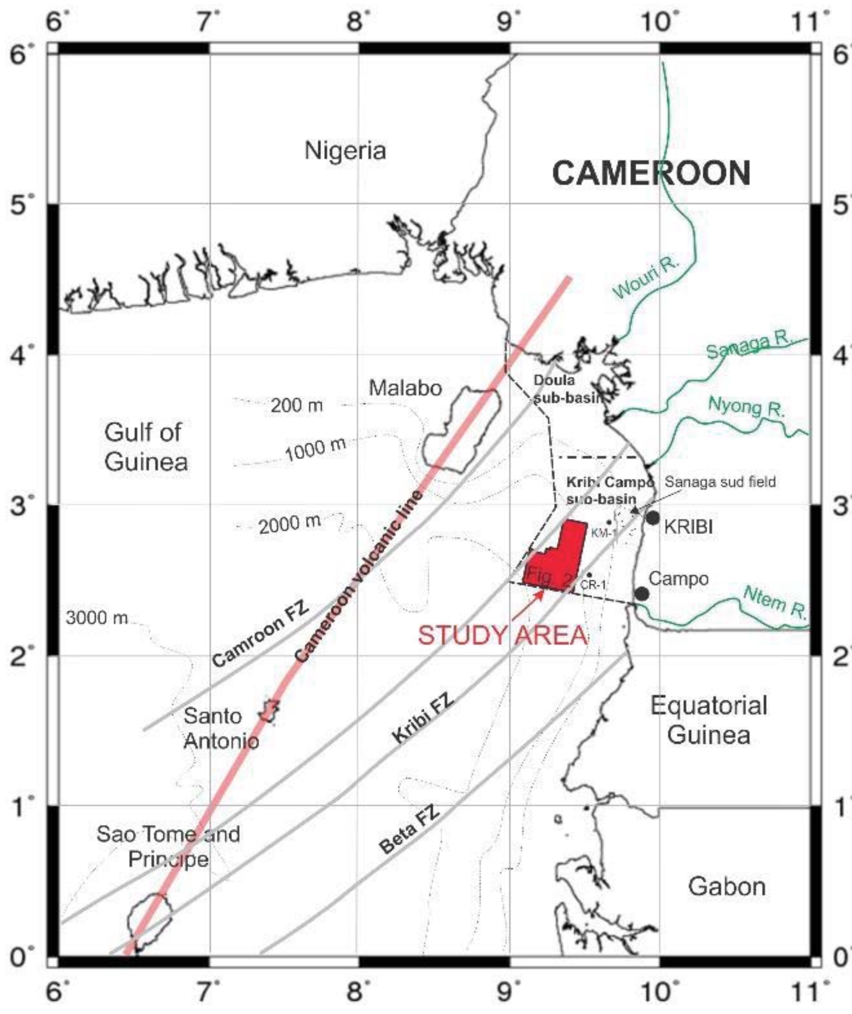

Figure 1. Bathymetry map of the continental slope on the Cameroon margin. It shows the location of the study area, the two wells that have been drilled within the basin (Pauken, 1992), and the location of the fracture zone system (Meyers et al., 1996). The coastline and river system is extracted from the National Geophysical Data Centre (NGDC) (http://rimmer.ngdc.noaa.gov/mgg/coast/getcoast.html).

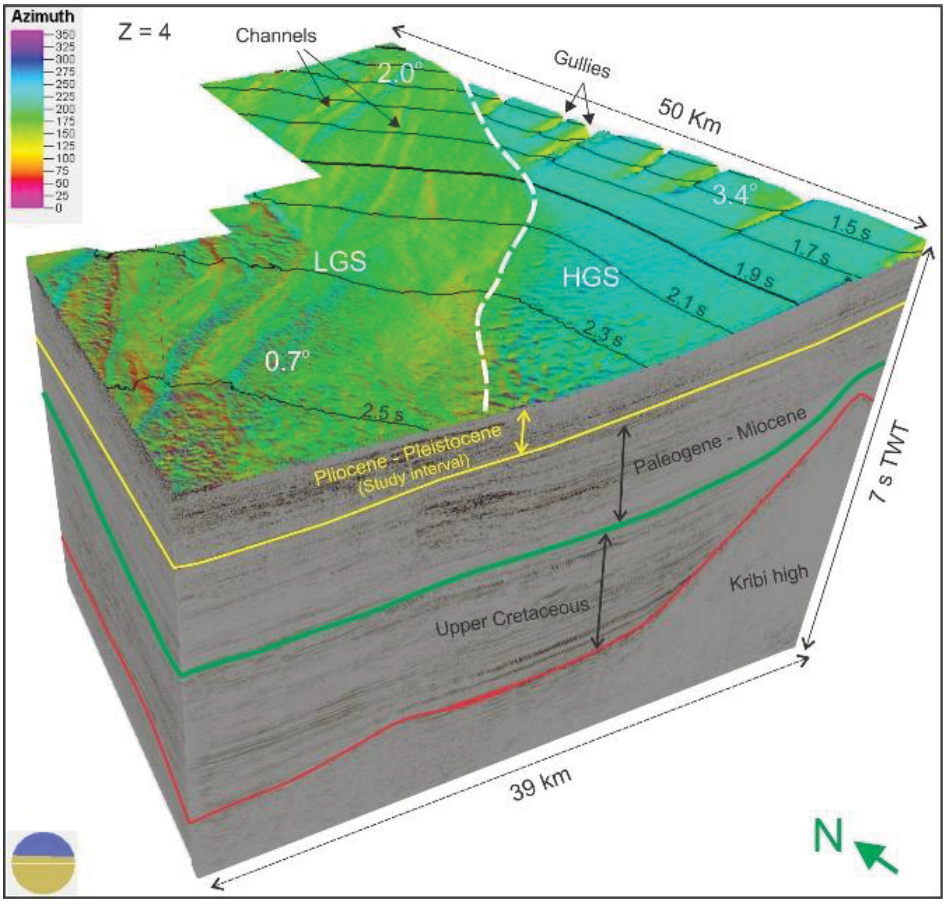

Figure 2. The figure showing a 3D view of the study area, which is located in a water depth ranging from 1.4 to 2.6 s TWT. The slope area is divided into two slopes, a High Gradient Slope (HGS) dipping southeast (3.4^o down to 1.6^o) and a Low Gradient Slope (LGS) dipping west (2^o down to 0.7^o). Seafloor is imaged by an azimuth attribute map, showing a number of gullies derived from the east northeast. The basin fill sequence is divided into three mega sequences; Upper Cretaceous, Paleogene-Miocene and Pliocene-Pleistocene (focus of this study).

3. Dataset and Methodology

The data used for this study comprises a high-resolution 3D seismic dataset, covering an area of 1500 km^2 (Fig. 1 & 2). It includes c. 1581 inlines and 2051 crosslines with a line spacing of 25 m, and a record time of 6.6 s TWT. The study interval ranges Pliocene to Pleistocene in age. Standard seismic processing was applied to the data provided by Sterling Energy Company (and no further processing has been attempted as part of this study). The seismic data is zero-phase, and displayed in this study such as red, yellow or orange corresponds to positive polarity and light blue to negative polarity.

Due to the lack of well data in the basin, depth conversion assumes a similar lithological composition to the Rio-Muni basin, and a Vp velocity of 1850 m/s has been used for the Tertiary sediments (Turner, 1995). That velocity and the dominant frequency of 45 Hz in the Tertiary give a vertical resolution ($\lambda/4$) of ~10 m. The interpretation of the seismic data has primarily used the Schlumberger™ Petrel software. Interpretation has been carried out using a manually picked fine interpretation grid; followed by auto-tracking where there is a good quality surface.

4. Results

Striations are observed on the basal surface of the Pliocene sequence, on both the HGS and LGS (Fig. 3). Individual striations can be imaged that are c. 50 m wide, c. 30 -50 km long and 5 – 30 ms TWT deep. Striations developed at the base of the NE-SW Pliocene fan (Fig. 3a) and E-W trending channel (Fig. 3c) (see more disciptions of the channel and fan in Le, 2016).

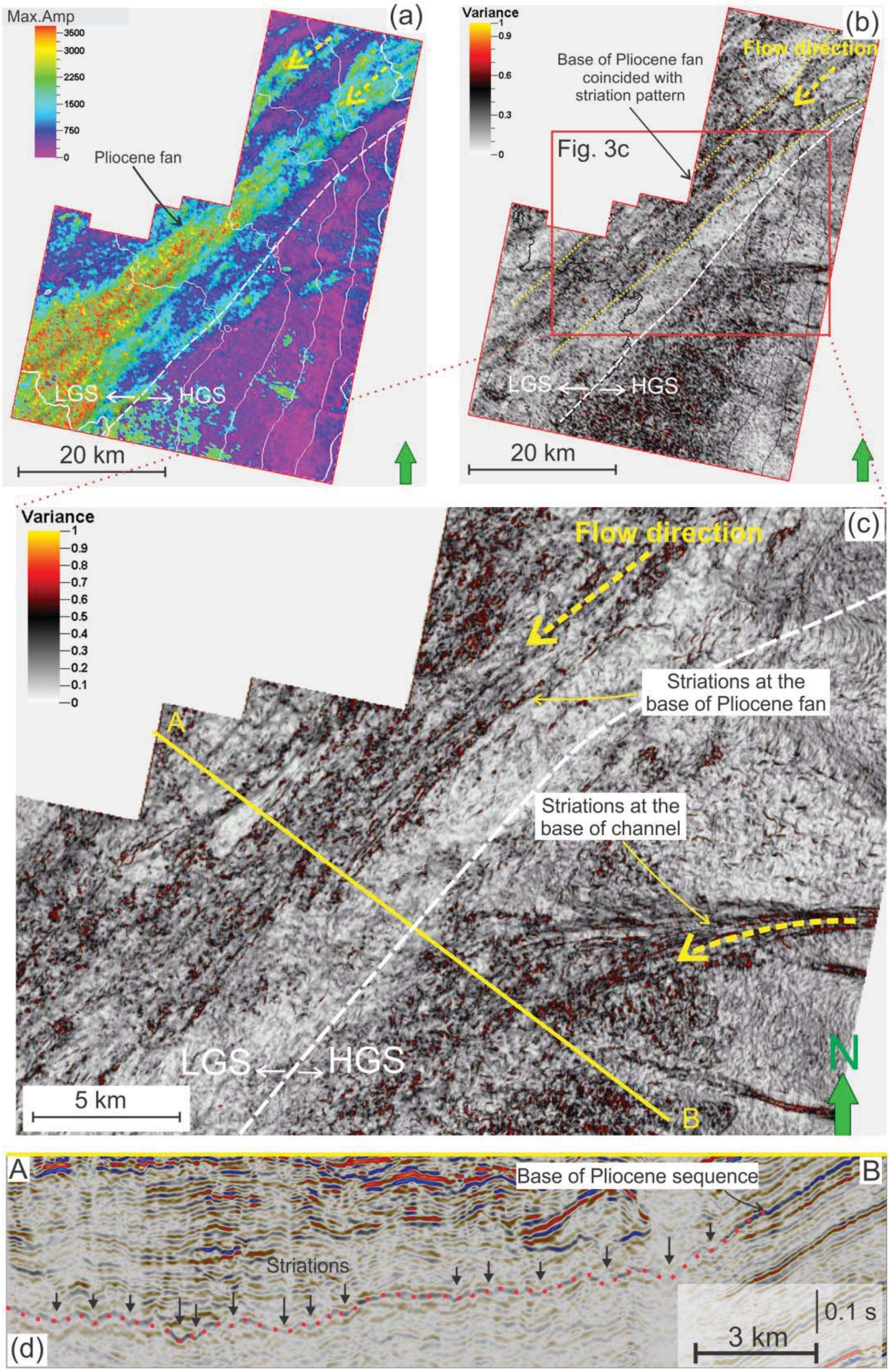

Figure 3. (a) Maximum amplitude map of 300ms above the Pliocene base showing deep water fan. (b) Variance map of base Pliocene showing the coincidence of fan and striation location. (c) Variance map of base of Pliocene sequence showing a series of striations at the base of a fan deriving from NE and a W-flowing channel. Striations are associated with the pattern of the Pliocene fan and at the base of E-W trending channel. (d) Striations are shown on seismic cross-section.

4.1. Striations at base of Pliocene fan in the LGS

High amplitude reflections observed in early Pliocene correspond to areas with increased thickness downslope. Its dimensions range from c. 2 – 15 km wide, 60 km long, and up to 250 ms TWT thick (Fig. 3a). Internally it is composed of low to high amplitude, continuous upward convex reflections, which bi-directional downlap onto the base of Pliocene sequence. Widen high amplitude pattern downslope and bi-directional downlap which characterized the feature suggests for the interpretation of submarine fan deposits. The variance map at the base of the Pliocene surface reveals a series of striations at the base of a fan deriving from NE. Individual striations can be imaged that are 20 - 50 m wide, c. 20 km long and 4 - 8 m deep, trending NE – SW, slightly divergent patterns toward downslope. In cross-section this reflector marks the base of a mixed low to high amplitude, bi-directional downlap reflection package (Fig. 3d). The origin of the striations is interpreted to be a catastrophic slope failure event, in which sliding was the main process.

4.2. Striation at the base of the Pliocene channel in the HGS

In the HGS, series of concave features are observed trending E-W (Fig. 3b). In cross-section, these concave features are characterized by an alternation of aggradational low to high amplitudes, onlapping onto the flanks. High amplitude reflections have linear patterns in map view and are interpreted E-W channels (Le et al., 2015). This is similar to the observation of Pilcher and Argent (2007) and Jobe et al. (2011) of data from a similar setting in Gabon and Equatorial Guinea. Among those channels, at the base of the largest channel, striations are observed. They have similar dimentions to the striations at the base of the Pliocene fan but shorter. Individual striations can be imaged that are 20 - 50 m wide, c. 10 km long and 4 - 8 m deep. There is no obvious divergence in the striation patterns.

5. Discussion

Striations base of Pliocene sequence are interpreted to be the result of a catastrophic slope failure event, in which sliding was the main process. They are all large scale, very straight trending northeast to southwest and east to west. This suggests a period of major failure, possibly associated with high energy and high sedimentation rate with sediment sourced from the NE and East.

Deposition of Pliocene sequence begins with a period of unstable slope deposits characterized by NE-SW slides in LGS and erosion in HGS, followed by the deposition of large scale fan deposits on the LGS and series of parallel aggradational channels in the HGS. The lithology is significantly different in both slopes; the LGS it is dominated by high amplitudes associated with channels and fan-lobes, interpreted to be a deep-water sand-rich fan system and in the HGS low amplitude reflections are associated with polygonal faults, interpreted to be a mud-rich system. The unconformity at the base of Pliocene sequence is striated and overlain by a large scale fan suggests a period of slope failure and high sediment which is possibly the result of a major tectonic uplift event or significant climate changes.

6. Conclusions

There are two sets of striations are observed in the study area, on the unconformity surface defined the base of the Pliocene sequence. Striations are coincided with the area of the Pliocene fan in LGS and large scaled-channel in HGS. They developed at the base of Pliocene fan and channel. Under the Pliocene fan, the striations have longer length (up to c.20 km) compared with the triations underneath the large scaled-channel (upto c.10 km). Individual striation can be imaged that are 20 - 50 m wide and 4 - 8 m deep. The occurrence of striated unconformity at the base of the Pliocene sequence and overlain by a large scale fan and channel suggests a period of slope failure and high sedimentation rate which is possibly the result of a major tectonic uplift event or significant climate changes. The area was supplied by two sediment sources, from NE and east.

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