Chapter 30
Mass Movements in a Transform Margin Setting: The Example of the Eastern Demerara Rise

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Abstract The eastern Demerara Rise located offshore French Guiana was surveyed in 2003 (GUYAPLAC cruise, part of the French EXTRAPLAC program) using multibeam bathymetry and imagery, 6-channel seismic data and 3–5 kHz echosounding. Analysis of seismic data shows that the flank of the Demerara Rise endures repetitive sliding of its Paleogene to Neogene sedimentary cover towards the ocean. Fluid escapes seem to be closely associated with the activity of those slides and deep faults

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seems to impact the location of the main headscarp. We suspect fluid overpressures and the specific architecture of transform boundaries ("free border") to be key parameters in the development of wide MTD's retrogressively eroding the eastern Demerara Rise.

Keywords Transform margin • MTD's • Demerara Rise • Fluid escapes

30.1 Introduction

Transform margins represent 30% of continental passive margins. Sediment mass movements in those geological settings has been poorly studied up to now even though these margins display many architectural elements that amplify the potential for mass failure. Such elements include:

– a steep (~20°) ocean-continent boundary inherited from the vertical transform fault along which opening occurred. Therefore the continental slope is subjected to erosional processes, the sediments being frequently mobilized by gravity instabilities at different scales (De Caprona 1992; Mosher et al. 2005; O'Regan and Moran 2007; Loncke et al. 2009).
– Syn or post-transform layers can outcrop along the ocean-continent transition and the post-transform unconformity is generally tilted landward or seaward depending on the marginal ridge development. This may favors the development of stratigraphic décollement layers

The objective of this work is to demonstrate the prominent role of mass transport processes along transform margins in the delivery of sediments to the deep ocean. The transform margin along Demerara Rise is used to typify this environment. In addition, controlling factors in mass failure that may be specific to this margin are presented.

30.2 Geological Setting

The study area is located on the French Guiana margin, in the western Equatorial Atlantic Ocean (Fig. 30.1a). There, the Demerara Rise prolonging the continental shelf. This rise is 380 km long and 220 km wide and delimited by a steep continental slope representing the continent to ocean transition.

This margin formed during two successive stages: (1) In the Early Jurassic, the opening of the central Atlantic created the western edge of the Demerara Rise as a divergent margin (Klitgord and Schouten 1986; Gouyet 1988; Unternehr et al. 1988); (2) at the end of the Early Cretaceous, during opening of the Equatorial Atlantic, the northern and eastern border of the Demerara Rise separated from the Guinea Rise in a strike-slip regime along a main transform zone (Gouyet 1988; Unternehr et al. 1988; Greenroyd et al. 2008) (Fig. 30.1a).

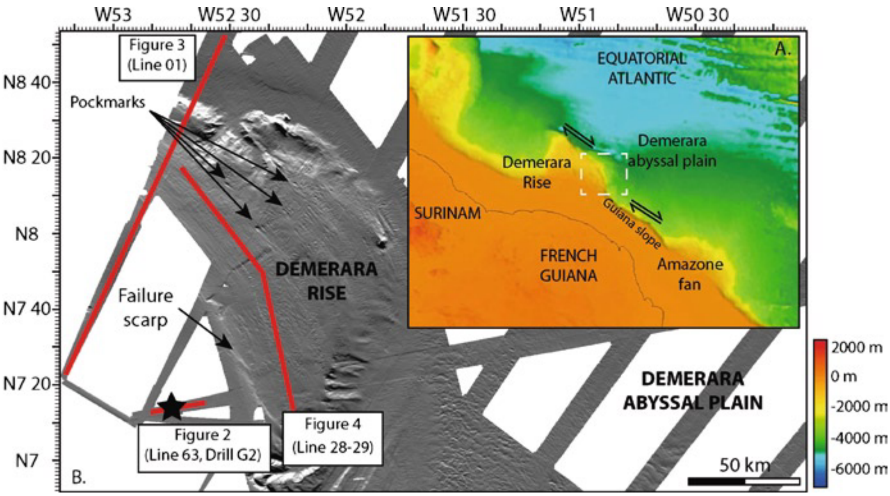

Fig. 30.1 (**a**) Location of the study area (*white dotted box*) in the western equatorial Atlantic ocean (**b**) Location of seismic lines profiles shown in Figs. 30.2, 30.3 and 30.5 and the G2 drill hole position

Along Demerara Rise, the transform segments are NW-trending and the divergent segments are NE-trending (Fig. 30.1a). Transform activity ceased in the upper Albian and organic rich sediments deposited between the Turonian to Cenomanian (Gouyet 1988; Mosher et al. 2005) followed by deposition of a carbonaceous to clay rich sedimentary cover (Mosher et al. 2005). Sedimentation rates are low during the Cenozoic (in average less than 1 cm/ky) (Danelian et al. 2005). The eastern Demerara Rise seems to have been tilted seaward during the Paleogene and no clear marginal ridge could be observed (Maillard et al. 2010; Loncke et al. 2010). In the western Demerara Rise, giant slumps affect Oligocene to recent sediments (O'Regan and Moran 2007; Ingram et al. 2011).

30.3 Dataset

The French Guiana margin and the adjacent Demerara abyssal plain were surveyed in 2003 during the GUYAPLAC cruise onboard the R/V l'Atalante, as a part of the EXTRAPLAC French Program (Ifremer-IFP–SHOM-IPEV). The dataset comprises: (1) EM12-Simrad multibeam bathymetry and backscatter imagery, (2) 3.5 kHz echograms, (3) 6-channel seismic profiles. Bathymetric data were processed using CARAIBES software developed by IFREMER using a 100 m resolution grid. The combination of bathymetric and 3.5 kHz analyses allowed identification and characterization of the main recent sedimentary processes shaping the study area (Loncke et al. 2009; Gaullier et al. 2010).

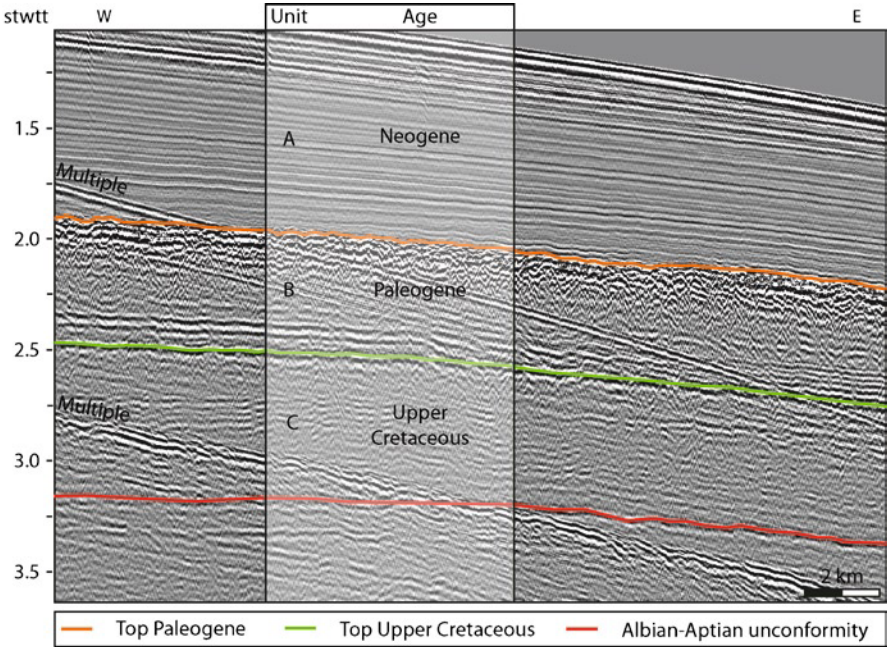

Fig. 30.2 Seismic units on seismic line Guyaplac 63 (Vertical Exaggeration: 4). The stratigraphy is correlated to drill hole G2 (Gouyet 1988). The *seismic line* is located in Fig. 30.1b

In this paper, we present mainly the GUYAPLAC seismic data calibrated by a correlation to the G2 industrial drill site presented by Gouyet (1988) (Fig. 30.2).

30.4 Results

30.4.1 Seismic Stratigraphy

The sedimentary cover along eastern Demerara Rise is deposited above the post-transform Albian-Aptian unconformity (in red on Fig. 30.2) that caps deformed upper-cretaceous and older rocks. The seismic stratigraphy of this sedimentary cover is divided into three main units:

– Unit C is poorly reflective, especially in its lower part where the transparent seismic facies corresponds to the Cenomanian-Turonian Black-shales. This unit is upper Cretaceous in age.
– Unit B is characterized by diffractions in the upper part, transparent seismic facies in the middle part, and a reflective lower part. This unit is Paleogene in age, with the base of Eocene located at the boundary between the transparent and reflective facies, and the base of Paleocene at the base of the reflective lower part.

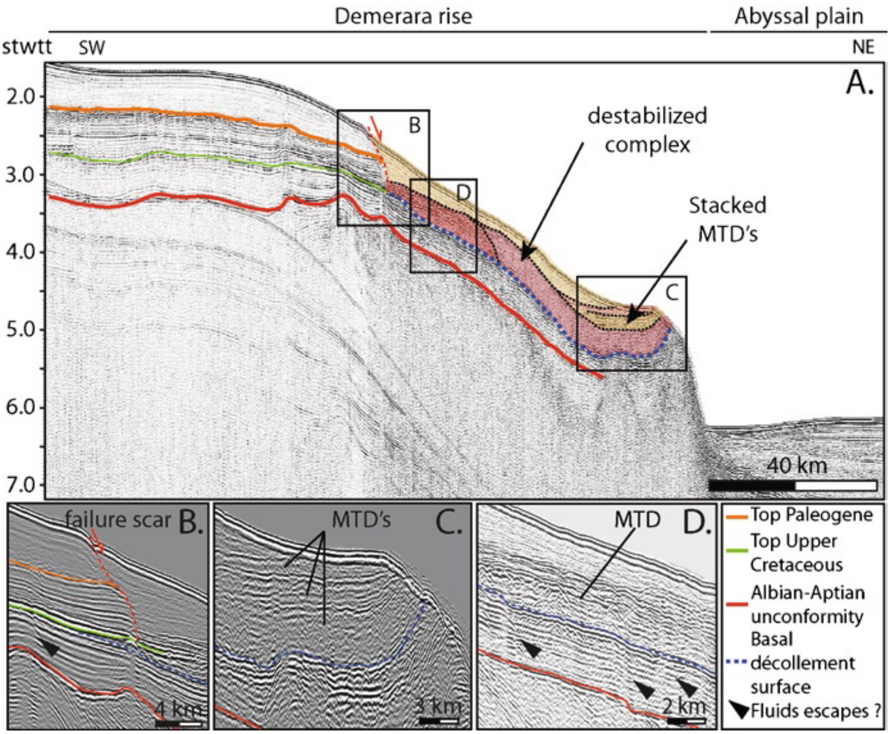

Fig. 30.3 Demerara Rise on seismic line Guyaplac 01 (see location Fig. 30.1) (Vertical Exaggeration: 5). The basal décollement surface is indicated by a *dotted blue line*

– The uppermost unit A shows reflections that are laterally continuous high amplitude reflections. This unit is Neogene in age, and its base fits with the base of Miocene.

30.4.2 Seismic Analysis

A regional seismic line across the eastern Demerara Rise shows that the Albian-Aptian unconformity and the Cenozoic sedimentary cover are dipping seaward (Fig. 30.3). Where the plateau is tilted seaward, the post-transform sedimentary cover is clearly affected by numerous mass transport deposits (MTD's) (Fig. 30.3a). Those initiate far inboard on the Demerara rise along a failure scarp that is clearly visible on bathymetry (Fig. 30.1b). There, a near vertical normal fault affects recent sediments (Fig. 30.3b). This fault seems to connect to a deeper fault slightly offsetting the Albian unconformity (Fig. 30.3a, b). Going downslope, the slide complex evolves into stacked disorganized bodies where seismic reflectors are sparse. At least four different successive events are identified (Fig. 30.3c). The oldest one is sealed by

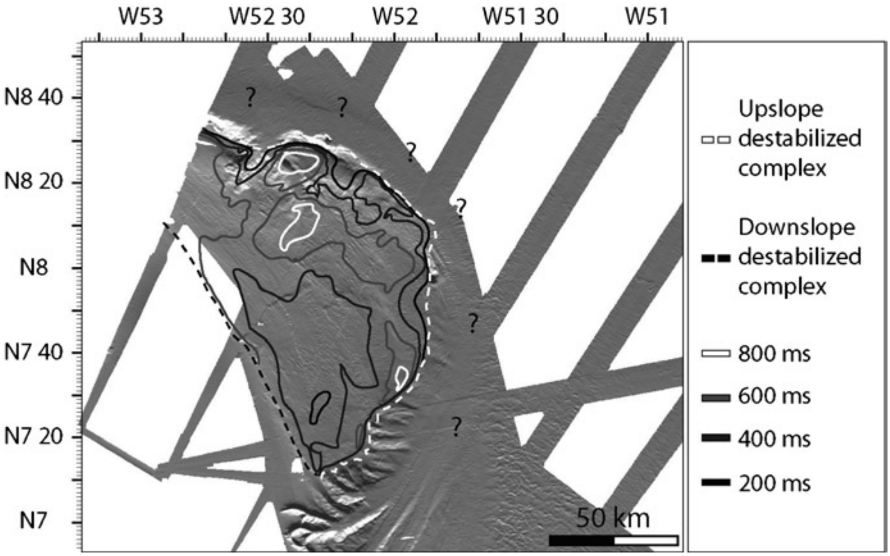

Fig. 30.4 **Isopach contour map (in ms) of the destabilized complex**. The distal termination of the oldest slides is questionable (*?* on figure) since no age calibration exist in the Demerara abyssal plain

non-remobilized Paleogene sediments (Fig. 30.3b). The youngest one is late Neogene to recent. The basal décollement layer (in dotted blue in Fig. 30.3a.) seems to follow the main stratigraphic horizons. No clear compressional deformations have been observed in the distal tip of sided masses (Fig. 30.3c). The termination of those MTD's is sharp approaching the Demerara steep border (Figs. 30.3a and 30.4).

The total thickness of this destabilized complex was mapped (Fig. 30.4) in order to better quantify the cumulative importance of those events. This slide complex, about 10.521 km² in area shows variable thicknesses. The MTD's thickness is 800–900 ms towards the NE border of the plateau. Towards the east, thicknesses decrease (200 ms). Maximum thicknesses are observed along the Demerara NE border. Some MTD's likely extend onto the abyssal plain (Fig. 30.4). The lack of drill data prevents any accurate correlations of MTD's recognized in the abyssal plain with Demerara Rise MTD's.

Bellow the MTD's, Cretaceous to Paleogene sediments appear highly faulted by sub-vertical faults or crossed by vertical pipes. These pipes may have been may generated by fluid escapes (Figs. 30.3d and 30.5). The faults occur in two different directions seismic lines with similar wavelength (2 km). Therefore, we interpreted those as polygonal faults (Fig. 30.5). This evidence past or even recent dewatering processes (some polygonal faults reach the seafloor upslope the failure scarp). This polygonal fault interval mainly affects unit B (Paleogne) but faults frequently propagate more or less in units A and C. Under the destabilized complex, they even affect Cretaceous sediments and root on the Albian-Aptian unconformity (Fig. 30.5).

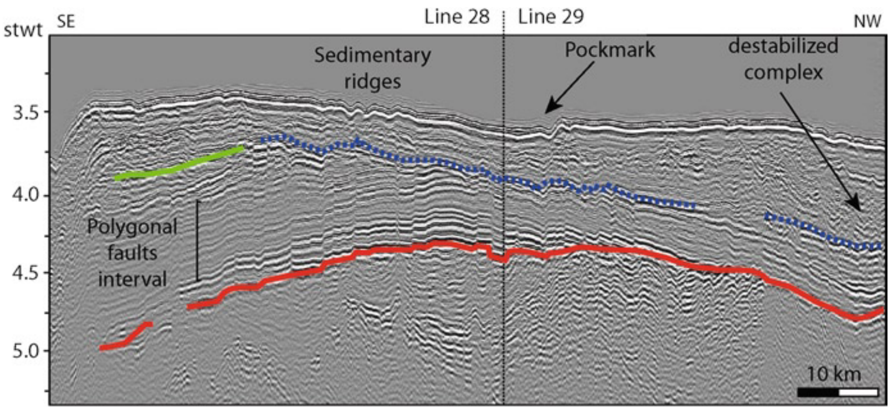

Fig. 30.5 Polygonal faults on seismic line Guyaplac 28–29 (see location Fig. 30.1) (Vertical Exaggeration: 5)

On surface data (bathymetry and imagery) numerous giant pock-marks (Figs. 30.1 and 30.5), reaching 1–2 km in diameter, affect the Demerara Rise seafloor. These pock-marks appear on the surface of MTD's but are difficult to image to depth on seismic data.

We suspect that this faults interval may allow fluid transfer between pre-Albian deformed sediments and Neogene sediments and MTD's (see vertical pipes) and plays a role in the triggering of the observed mass movements.

30.5 Discussion – Controlling Factors

The eastern Demerara Rise endured significant and repetitive mass movements during the Cenozoic. These mass failures initiate far inboard on the Demerara Rise where slope gradients are low, suggesting a structural control and/or retrogressive evolution of slides from the steep continental slope to the inner rise through time. The basal décollement layer seems to follow stratigraphy and outcrops along the continental slope. The MTD's dislocate polygonal fault intervals and are systematically associated with fluid escape structures on the seafloor (giant pockmarks).

These observations suggest that: (i) fluid overpressures could play a role in initiating some of those slides in weakening some stratigraphic horizons, (ii) the structure of the margin is a key parameter in allowing massive sliding of the Cenozoic sedimentary cover towards the ocean by localizing failure scars (above deep faults) and creating a "free border" towards the ocean.

Recent experimental models applied to natural slides in New-Zealand have shown that the combination of a free border (post-albian sediments outcrop on the slope) and fluid overpressures can be extremely favorable for triggering massive retrogressive slides (Lacoste et al. 2011).

During the ODP leg 207, Mosher et al. (2005) described erosion events in late Miocene along the western Demerara Rise. O'Regan and Moran (2007) even estimated that 220 m sediment was removed during this slide. It has been shown also that Cretaceous deposits are overpressured (O'Regan and Moran 2007). The mass movement and erosion defined by O'Regan and Moran (2007), could be an equivalent of the described destabilized complex on the eastern Demerara Rise.

Alternatively, some authors (Ingram and Wise 2006; Ingram et al. 2011) proposed that the western Demerara slide could relate to massive hydrate dissociation. The ice-house to green-house transition (Eocene-Oligocene transition; Seranne et al. 1999) could be an excellent candidate for causing such events. Those hypothesis are still to investigate more in details and probably need additional dating and numerical/experimental modellings.

Finally, the lack of present seismicity supports the hypothesis of over-pressure or climatic initiation but we can not exclude that a Cenozoic seismic event could have occurred, as proposed on the western Demerara Rise (Ingram et al. 2011).

30.6 Conclusions

The western Demerara Rise is a rather poorly sedimented passive transform margin where important slides were not expected. Our analysis show at the contrary, that slides are massive (10.521 km^2) and repetitive through time. We suspect that fluid overpressures combined with outcrop of potential décollement layers (free border effect) are key parameters in the development of wide mass movements retrogressively eroding the Demerara Rise. Climatic and other structural controls can however not be excluded in controlling the development of those destabilized complexes. Further analysis is necessary to better investigate those possibilities.

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