# Recurrent Megaslides in the Foz do Amazonas Basin

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## Abstract

Mass-transport deposits are recurrent elements on the Middle-Miocene to Recent sedimentary architecture of the Foz do Amazonas Basin. Thick mobilized siliciclastic series (up to 1000 m) form huge megaslide deposits over areas up to 90000 km$^2$. The Pará-Maranhão Megaslide in the SE, shows a displaced block (>10$^4$ km$^2$) in association with large mass transport deposits covering an area of more than 10$^5$ km$^2$. The Amapá Megaslide Complex in the NW presents a series of recurrent megaslides in stratigraphic succession, bounded by listric normal faults and tear zones on the upper slope. Associated mobilized deposits extend for more than 300 km downslope, partially involving the upper channel-levee units of the Amazon Submarine Fan.

## Introduction

The Foz do Amazonas Basin on the Brazilian Equatorial Margin (Fig. 1) is a transform passive margin, strongly influenced by the immense sedimentary fluxes from the Amazon River, that contributes to seaward progradation of the margin and to the formation of the Amazon Deep-sea Fan. The submarine fan is a turbiditic complex, developed predominantly since the Upper Miocene, presenting thicknesses greater than 10 km (Silva et al. 1999). Deposition on the submarine fan took place mainly during low sea-level stands, channeled through the Amazon Canyon. Such a sedimentary context resulted in a rather smooth central basin, while to the NW and SE of the fan the margin is narrow and exhibits steep slope gradients.

Submarine mass movements and associated deposits are important elements in the sedimentary construction of the Foz do Amazonas Basin continental margin, mainly in the Quaternary section of the Amazon Deep-sea Fan. In this region, exceptionally high sedimentation rates can induce submarine failures and sediment fluxes contributing to the sedimentary evolution and architecture of the deep-sea fan (Damuth and Embley 1981; Damuth et al. 1988; Piper et al. 1997; Maslin and Mikkelsen 1997; Pirmez and Inram 2003; Maslin et al. 2005).

In this paper, we used regional seismic lines to investigate potential processes of gravitational collapse, focusing on mapping features and deposits that evidence episodes of mass transport since the Middle Miocene. We focused on the recognition and description of extensive megaslides on the continental margin NW and SE of the Amazon Deep-sea Fan.

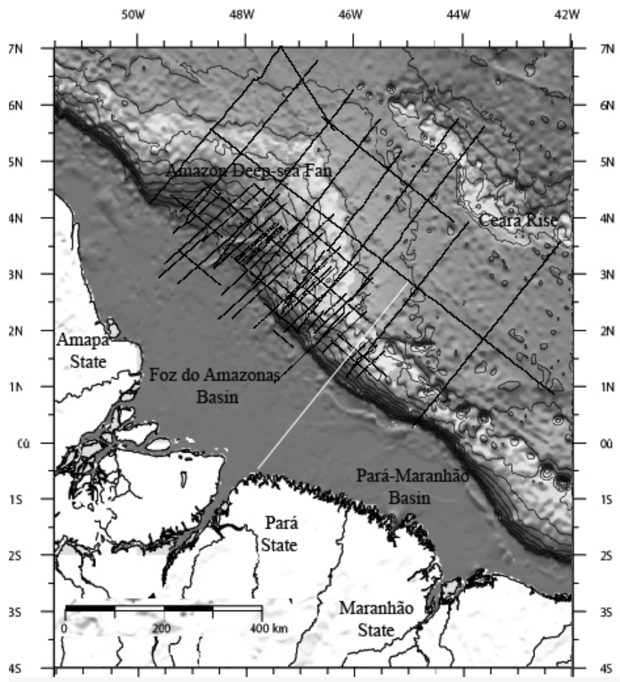


Fig.1. Location map. Regional bathymetry (100m and every 1000 m) and seismic dataset used.

## Database and Methods

Approximately 15000 km of 2D multichannel seismic reflection profiles (Fig. 1) were interpreted using SMT (8.0) Kingdom Suite Software. The data penetrates to a maximum of 13 seconds (TWT) and present 5 to 10 meters of vertical resolution. Seismic data was provided by the Brazilian Navy (LEPLAC Project) and by geophysical survey companies operating in Brazil (FUGRO and GAIA).

Regional bathymetric data are from ETOPO1 (Smith and Sandwell 1997) and higher-resolution bathymetric data on the Upper to Middle Amazon Fan were compiled by the Brazilian Navy from different sources, including the

LEPLAC Project, Petrobras, the Geophysical Data System - GEODAS (www.ngdc.noaa.gov/mgg/geodas) and from the General Bathymetric Charts of the Oceans – GEBCO (www.gebco.net).

## Results

In the steep continental slope to the NW and SE of the Amazon Deep-sea Fan, mass transport mobilized thick siliciclastic series (up to 1,000 m) as megaslides deposits (Fig. 2) over areas up to 90000 km2.

To the SE of the deep-sea fan the upper slope gradients are in the order of 3 to 3.5°. An abrupt erosional scarp (maximum vertical relief of 1000 m), continuous along 180 km on the upper slope is the headwall scarp of megaslide deposits, which extends downslope for approximately 600 km with a maximum width of 200 km, covering an estimated area of 90000 $km^2$ and remobilizing a volume of 60000 $km^3$ of sediments. This megaslide was named (Araújo, 2008; Silva et al. 2008) the *Pará-Maranhão Megaslide* (Fig. 2). Large slided blocks departing from the headwall scarp are followed by chaotic-to-transparent allochtonous mass, suggesting debris flow, with internal preserved blocks (Fig.3). Distally, the megaslide is frontally and laterally confined, generating a series of reverse faults, detaching in levels progressively shallower and eventually reaching the seafloor developing pressure ridges (Fig. 4).

To the NW of the Amazon Deep-sea Fan the slope gradients attain circa 5.5°. A continuous erosive escarpment, as high as 1800 m, extends laterally in the upper continental slope for at least 120 km (Fig. 2). In this region a conjunction of several mass transport deposits encompassing the upper sedimentary section between 1800 to 2700 m thick present a total estimated area of about 80000 $km^2$, from the base of the slope (2600 m) to 4000 m below sea level. Each individual deposit can vary in thickness from approximately 300 to 700 m, and presenting variable extensions. This megaslide was named (Araújo, 2008; Silva et al. 2008) *Amapá Megaslide Complex* (Figs 2 and 5). This megaslide complex starts on a headwall scarp located on the upper continental slope, where a large displaced block moved along a basal sliding surface (Fig. 5). The distal domains of megaslides are still marked by prevalent, although discontinuous, layered reflectors deformed by thrusts related to frontal and lateral shortening.

## Discussion

The Pará-Maranhão and Amapá Complex megaslides deposits are located along steep continental slopes to the NW and SE of the Amazon Deep-sea Fan, indicating that higher slope gradients in areas of considerably lower sedimentation rates, as compared to the Amazon Deep-sea Fan, are prone to mega-events of mass wasting. These megaslides are considerably larger (several hundred kilometers long and a few hundred kilometers wide) and thicker (up to 1000 m) than the mass-transport deposits recognized by Damuth and Embley (1981) by Piper et al. (1997) in the Amazon Deep-sea Fan. Furthermore, the stratigraphic column in the Amapá and Pará-Maranhão Megaslides has recorded multiple events that, unlike in the Amazon Deep-sea fan are not restricted to the Upper Quaternary sedimentary section only as previously appointed by different authors on the Amazon Deep-sea Fan (Damuth and Embley,1981; Piper et al.,1997).

On the other hand, the Amapá Megaslide Complex differs markedly from the Pará-Maranhão Megaslide, because the entire sedimentary section (1800 to 2700 m) was affected by a succession of megaslides. Also the Amapá Megaslide Complex was influenced by the Amazon Fan sedimentation, as observed by the presence of numerous channel-levee systems, some of them partially mobilized by the mass-transport processes. This may be the cause of the observed differences in thicknesses and recurrence interval between the Amapá Megaslide Complex and the Pará Maranhão Megaslide. The thinner and more frequent episodes of mass-transport deposits that occurred in the Amapá Megaslide Complex, could result from higher sedimentation rates under stronger influence of the deposition of the Amazon sedimentary series.

One alternative hypothesis, not explored in this paper, is associated with tectonic reactivation inducing seafloor instabilities and mass wasting, as a consequence of strike-slip movements along fracture zones.

## Conclusions

Megaslide complexes remobilize huge allochtonous masses downslope the NW and SE slope segments of the Foz do Amazonas Basin, such as the Pará-Maranhão Megaslide and the Amapá Megaslide Complex. These megaslides have been recurrent events, not only restricted to the Quaternary section of the Foz do Amazonas Basin, but extending deeper into the sedimentary column. The mega-events were more frequent in the Amapá Megaslide Complex, probably because of higher sedimentation rates under the influence of the Amazon Deep-sea Fan

## Acknowledgments

We acknowledge financial support and scholarship during completion of this work from CNPq/CTPETRO, CAPES, COFECUB and the Brazilian Petroleum Agency, ANP. We also thank GAIA and FUGRO and the Brazilian Navy, for the availability seismic data and SMT Kingdom for the use of educational licenses of the software Kingdom Suite.

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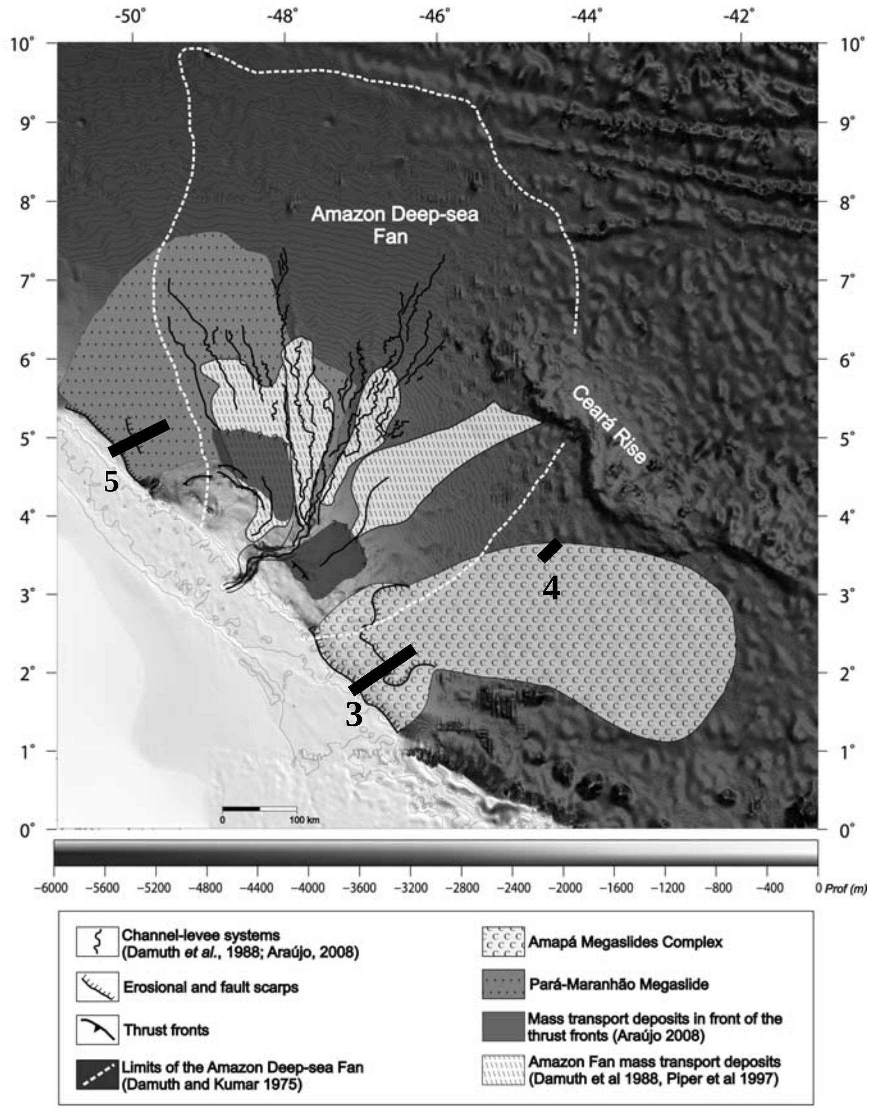


Figure 2 – Mass transport deposits and megaslides in the Foz do Amazonas Basin. Numbers indicate locations of figures 3 to 7 (Araújo (2008); Reis et al (submitted); Silva et al (submitted).

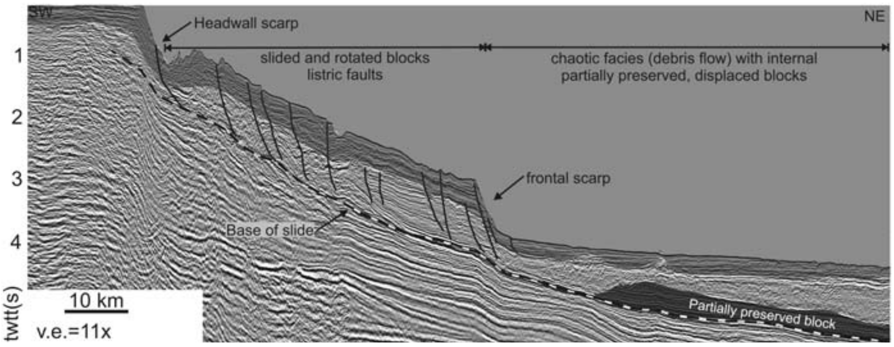


Figure 3 – Headwall scarp, displaced and rotated blocks, and debris flow deposits in the upslope portion of the Pará-Maranhão Megaslide. Silva et al ,submitted).

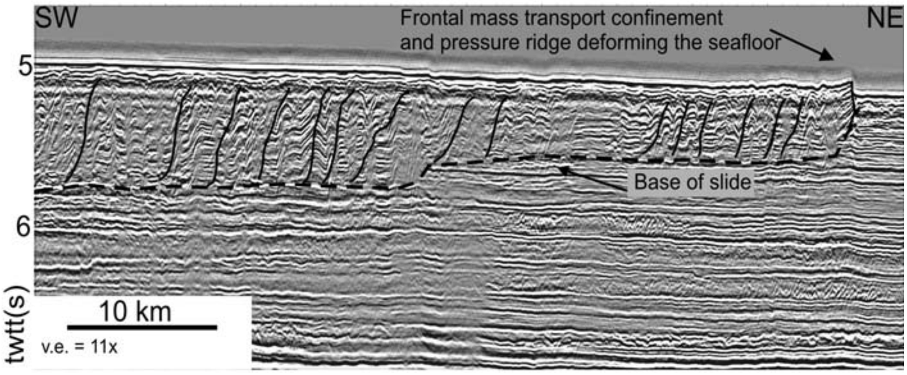


Figure 4 – Pará-Maranhão megaslide frontal confinement developing reverse faults and pressure ridge (Silva et al , submitted).

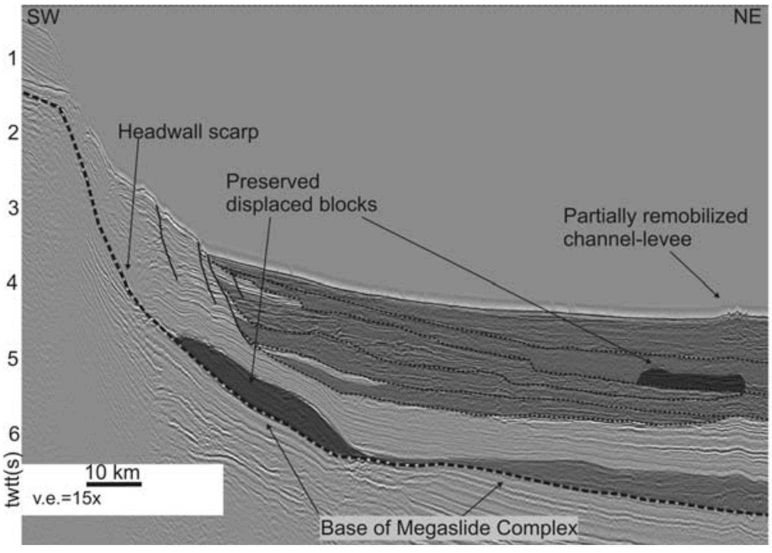


Figure 5 – Headwall scarp and upslope deposits of Amapá Megasilde Complex. Detachment surfaces (small dashed lines) and megaslide deposits (darker gray) (Silva et al., submitted).