

# Chapter 11

## The Chuí Megaslide Complex: Regional-Scale Submarine Landslides on the Southern Brazilian Margin

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**Abstract** The Brazilian Continental Shelf Survey Programme (LEPLAC) identified the occurrence of large-scale mass-transport deposits on the southernmost limit of the Brazilian margin, based mainly on analyses of acoustic imagery. The mass-transport deposits, named the Chuí Megaslide Complex, comprise a stack of large translational slides that spread from the shelf break ~650 km downslope to ~4,900 m water depth, cutting into Pliocene-Quaternary sedimentary successions and strongly affecting both the margin morphology and regional depositional processes. The main headwall scarp is U-shaped, 400–500 m high, and extends *c.* 80 km downslope as a large elongated evacuated scar, 50–85 km wide. Outside this main failure scar, external scarps evidence a large area of erosion and faulted blocks, indicating ongoing retrogressive sediment disruption. Slide masses occur as a combination of variably deformed failed masses and debris flows, covering an area of ~150,000 km<sup>2</sup>. Main preconditioning parameters and the possible triggering mechanism for the Chui Megaslide Complex are likely a combination of a series of causative factors such as slope failure structurally-induced by gravity tectonics and high sediment influx into the shelf-edge and upper slope during the Early Miocene-Quaternary.

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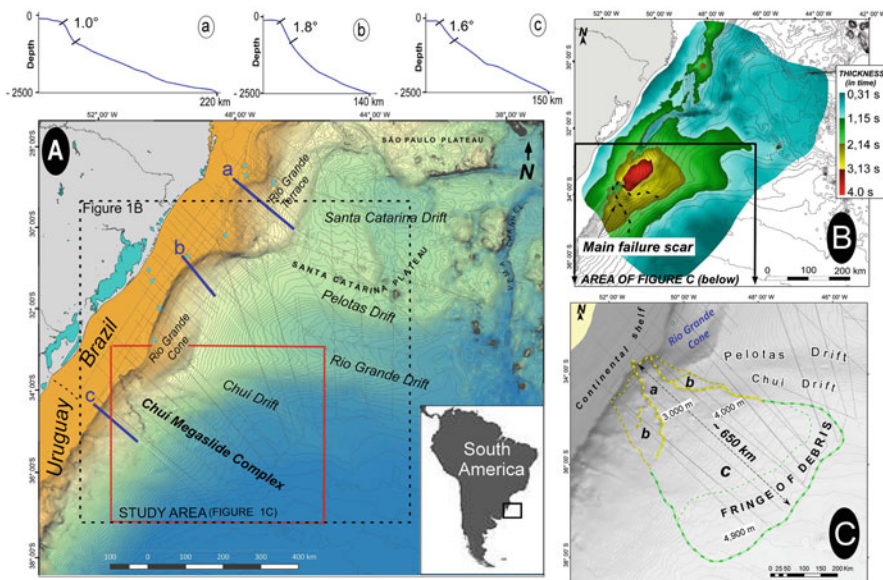
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G. Lamarche et al. (eds.), *Submarine Mass Movements and their Consequences*,  
Advances in Natural and Technological Hazards Research 41,  
DOI 10.1007/978-3-319-20979-1\_11

## 11.1 Introduction and Backgrounds

The continental slope of the Southern Brazilian margin (Pelotas basin) is interrupted by pronounced morphological features, as for example the Santa Catarina Plateau, the Rio Grande Terrace and the prominent Miocene–Quaternary sedimentary feature known as the Rio Grande Cone – a prograding sedimentary wedge deformed by gravity tectonics (Zálan 2005; Pereira et al. 2010) (Figs. 11.1a, b). The continental slope is also affected by erosion of contour currents that transport Antarctic Intermediate Water, Upper Circumpolar Deep Water, North Atlantic Deep Water and Lower Circumpolar Deep Water (e.g., Preu et al. 2013). Besides that, the southward flowing Brazil Current, which becomes gradually deeper (thicker) and stronger as it moves southwestwards, roughly follows the orientation of the shelf break-upper slope as a contour current (Stramma and England 1999). The deep-water setting is under the influence of the deep Antarctic Bottom Water circulation that comes freely as a bottom current from the south but is finally forced to form secondary currents and eddies in the water column across the Santa Catarina Plateau (Bassetto et al. 2000).

Throughout the Cenozoic, the persistent interplay between eustatic fluctuations and contour currents has significantly affected its architecture, as well the margin morphology (Pereira et al. 2010). As a result, drift deposits are ubiquitous across the entire margin, occurring either as large confined contourites, here named the Santa



**Fig. 11.1** (a) Study area location on the Southern Brazilian margin, also showing the grid of seismic data (gray lines), exploratory wells (blue dots) and morphological profiles *a*, *b* and *c*. (b) Time isopach map of the Lower Miocene–Quaternary stratigraphical succession. (c) Perspective bathymetric view with 50 m contour lines, showing morphological sectors *a*, *b* (limits represented in dotted yellow lines) and (c) (in dotted green line) of the Chuí Megaslide Complex

Catarina Drift, developed in the less subsided northern Pelotas Basin (Santa Catarina Plateau), or as gigantic elongated drifts across the southern Pelotas basin, which are deflected seawards as far as ~600 km perpendicular to the general lie of the margin, like the Rio Grande Drift, the Pelotas Drift (Pereira et al. 2010) and the Chuí Drift (Fig. 11.1a).

Only recently, during research projects within the scope of the Brazilian Continental Shelf Survey Programme (LEPLAC), features and deposits related to processes of slope disruption and mass-transport deposits were for the first time identified on the Southern Brazilian margin. These megaslides, grouped under the name of the Chuí Megaslide Complex, comprise a stack of large-scale submarine landslides (hereafter “landslides”) spreading across the southernmost margin limits (Fig. 11.1a).

In the present paper our main objective is to introduce the Chuí Megaslide Complex, focusing our attention on the description of its geomorphological features and seismic architecture, as well as on the analysis of associated depositional features. We also present possible preconditioning factors and triggering mechanisms involved in the initiation and evolution of the megaslide complex.

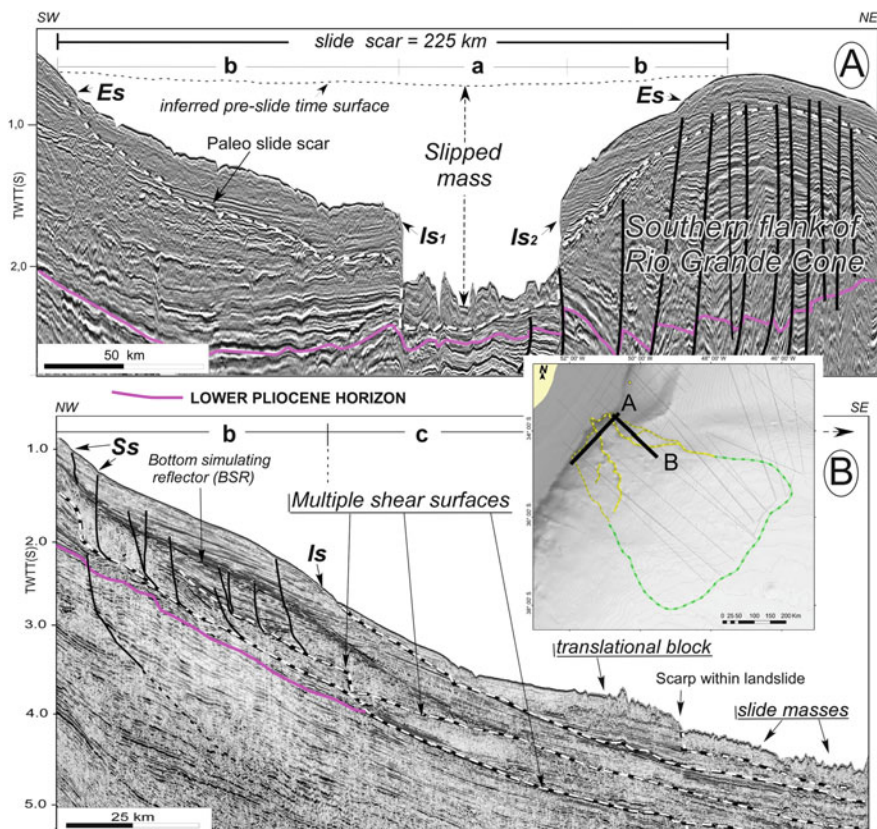
## 11.2 Data and Methods

This study has been conducted using primarily three kinds of dataset: Along-track swath bathymetry, 3.5 kHz sub-bottom profiles and multichannel and single channel seismic data collected during LEPLAC (first and second phases). Extra data include 2D seismic lines made available by the Brazilian National Oil and Gas Agency (ANP), together with chronostratigraphic data from nine exploratory wells (Fig. 11.1a). Regional bathymetry was built by LEPLAC based on the compilation of information from various sources, including collected bathymetric data (swath and conventional bathymetry), the General Bathymetric Charts of the Oceans – GEBCO ([www.gebco.net](http://www.gebco.net)), PETROBRAS, and the Geophysical Data System – GEODAS ([www.ngdc.noaa.gov/mgg/geodas](http://www.ngdc.noaa.gov/mgg/geodas)).

## 11.3 Results and Discussions

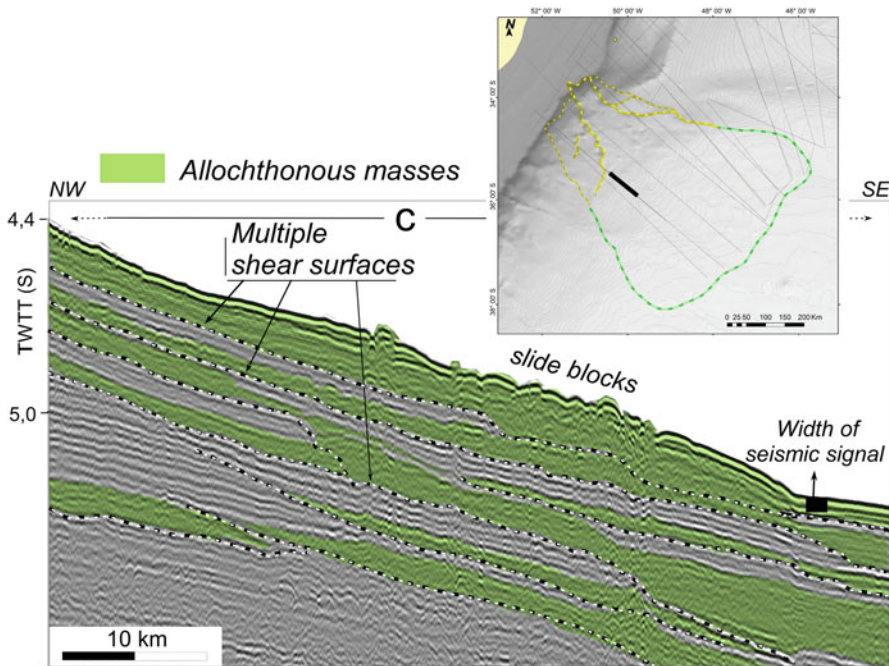
### 11.3.1 *Geomorphological Characterization*

MTDs on the southern Brazilian margin are located on the southern flank of the Rio Grande Cone, spreading from the shelf break ~650 km downslope (Figs. 11.1b, c). Seabed features related to mass-transport processes can be divided into three main morphological sectors (**a**, **b** and **c**, in Fig. 11.1c), each one characterized by distinct morphologies and processes (Figs. 11.2 and 11.3).



**Fig. 11.2** Strike (a) and dip (b) seismic lines illustrating morphological features and seismic facies of the head area of the Chuí Megaslide Complex. *a*, *b* and *c* are morphological sectors across the submarine landslide complex; *Is* Internal scarps, *Ss* Secondary scarps

Morphological sectors **a** and **b** comprise the upslope erosive head area (Fig. 11.1c). Headwalls consist of multiple scarps which separate different levels of failure features between morphological sectors **a** and **b** (Fig. 11.2a). Morphological sector **a** is the main and deepest slide scar. It is a U-shaped failure scar with an along-slope orientation, extending ~180 km to ~3,000 m water depth, constituting a large morphological corridor some 50–85 km wide. Upslope it is bounded by internal scarps (*Is*), as high as 400–500 m, strongly affecting the margin morphology (Fig. 11.2a). Internal scarp *Is*<sub>2</sub> lies in vertical continuity with listric faults that compose the gravity system of the Rio Grande Cone, thus constituting a lateral fault scarp (Fig. 11.2a). Downslope, relief of internal scarps is reduced to *c*. 100 m high (Fig. 11.2b). Morphological sector **a** is not totally devoid of displaced sediment and slide blocks, but its quite deep erosive depression (up to 1,100 m high) attests to a somewhat evacuated corridor that is obviously the main erosive area from which all MTDs are sourced from multiple-failure events (Fig. 11.2a). The morphological



**Fig. 11.3** Dip-oriented seismic line showing internal features and architectural elements of the Chuí Megaslide Complex

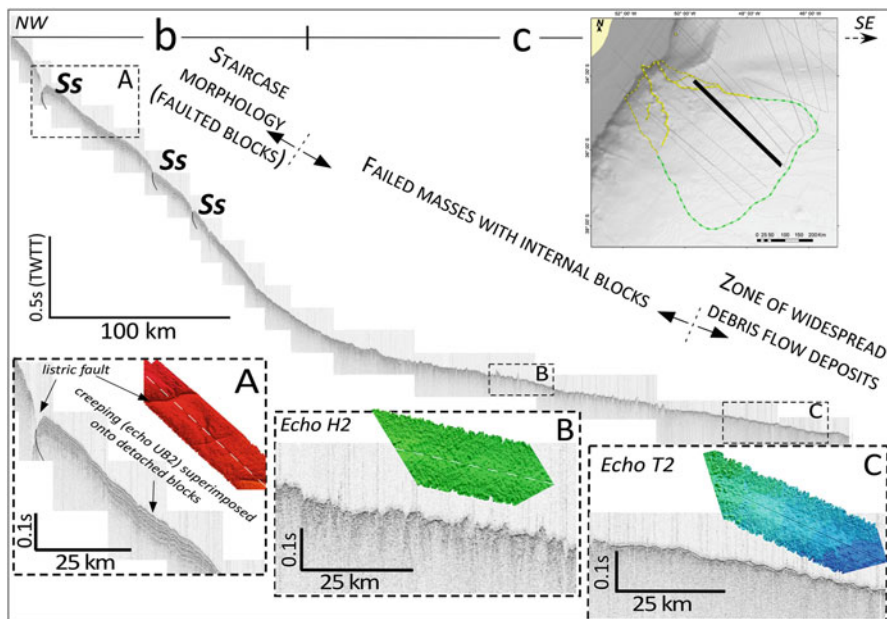
sector **b**, in its turn, comprises two separated areas: one along the northern flank of the main topographic low (sector **a**) and the other one along its southern flank (Figs. 11.2a, b). In both settings, sector **b** is bounded by external scarps (**Es**), located outside the main evacuated **a** slide scar, which exhibit reduced relief, as high as 100 m. A series of secondary inner scarps (**Ss**), up to *c.* 80 m high, give the sea-floor a general staircase appearance across sector **b** (Figs. 11.2b and 11.4a).

Depression **a** is open at its SE boundary and connects downslope with an unconfined slope area (sector **c**) dominated by an irregular rugged morphology up to tens of meters high, that tends to smooth downslopes (Fig. 11.1c). Sector **c** comprises a large area of MTDs with variable degrees of disruption, which spreads down to ~4,900 m water depth (sector **c** in Figs. 11.2b, 11.3 and 11.4b, c). The MTDs together make a total area of ~150,000 km<sup>2</sup> (Fig. 11.1c).

### 11.3.2 Seismic Architecture and Depositional Features

Failed masses move downslope along multiple flat-lying bed-parallel basal shear surfaces, indicating the occurrence of translational slide masses (Figs. 11.2b and 11.3). However, MTDs in different locations involve shear surfaces that follow





**Fig. 11.4** Dip-oriented 3.5 kHz profile, coupled with extracts of along-track swath bathymetry, across the Chuí Megalide Complex, showing the variable nature of mass-transport deposits as indicated by varying echofacies across the morphological sector *a*. *Ss* Secondary scarps; *a* and *c* are morphological sectors across of the submarine landslide complex

different stratigraphic horizons. Besides that, shear surfaces often step down the stratigraphy to create a series of staircase-like geometries, pointing to the creation of new décollements at depth and to incremental incorporation of new material during the emplacement of sediment slides (Fig. 11.3). MTDs are stacked either directly one on the top of the other, or separated from each other by continuous units of strong plan-parallel reflectors, acoustically interpreted as a combination of turbiditic and hemipelagic deposition. Failed masses can also be interbedded with well stratified uniform lens- or wedge-shaped strata, previously interpreted in the area as contourite deposition (Pereira et al. 2010). These architectural elements evidence the occurrence of multiple and complexly-interbedded landslide events and/or failed masses, all of them sourced from the main failure scar (sector *a*) and spreading for hundreds of kilometers downslope (Figs. 11.1c, 11.3 and 11.4b, c). For these reasons, all MTDs were grouped under the designation of the Chuí Megalide Complex (CMC), which consists of a stack of 8–12 large-scale landslides, depending on the area considered and on the resolution of the available data, cutting into Pliocene-Quaternary sedimentary successions (Figs. 11.2 and 11.3). The MTDs were classified as megalides due to their extension (hundreds of km large) and thickness (individual thickness up to *c.* 400 m; considering a value of stacking layer velocity of 2,000 m/s).

On both seismic and 3.5 kHz lines, the shallow stratigraphy across sector **b** appears as uniformly-bedded truncated layers, comprising large extensional zones of closely-spaced faulted-detached blocks with small runouts, replaced downslope by failed masses (Figs. 11.2b and 11.4a). Such structural features allow us to interpret morphological sector **b** as consisting of zones of mainly retrogressive slide experiencing ongoing seabed disruption to give rise to downslope mass-transport processes.

However, dip-oriented seismic and 3.5 kHz profiles across depositional area **c** can show variable seismic facies and features depending on the region considered, as well as on the seismic resolution involved. Seismic facies vary from disrupted masses containing large internal blocks (up to several kilometers across) to dominant cohesive mass flows. Owing to the relatively limited seismic resolution, failed masses are seen mostly as transparent to chaotic in seismic profiles, with individual blocks resolved only by their rough morphology (Fig. 11.3). On the other hand, on 3.5 kHz lines and on along-track swath bathymetric profiles two distinctive seafloor textures can be seen within the landslide deposits (Fig. 11.4): (i) a very rough sea-floor texture depicts rather irregular hyperbolic echoes (our echo type H2 in Fig. 11.4b) indicating the occurrence of large zones of failed masses containing internal preserved blocks, extending in downslope continuity to sector **b** down to c. 4,600 m water depth; this area being followed by (ii) a smoother seafloor dominated by continuous transparent layers (our echo type T2 in Fig. 11.4c), interpreted as a distal fringe of dominant debris flow deposits, according to its dominant transparent seismic facies that can be traced further down to a water depth of ~4,900 m (Fig. 11.1c). The mechanism involved in the downslope physical transformation of the failed masses remain unclear in the area.

### ***11.3.3 Possible Preconditioning Parameters and Triggering Mechanisms***

Slope angle may have an important impact on slope instabilities but it is not always considered as a good indicator of susceptibility to landsliding (e.g., Migeon et al. 2006). Accordingly, slope angle alone does not seem to have played a significant role in inducing slope failure on the South Brazilian margin. The MTDs that compose the CMC were all developed along the southernmost margin where the slope is inclined at  $\sim 1,6^\circ$ , but similar gradients occur across the continental slope of the entire southern margin (profiles a, b and c in Fig. 11.1a). Nonetheless, we do not exclude the action of contour current erosion in contributing to the local over-steepening of the slope around the outreach of the Rio Grande Cone.

On the other hand, structural features and the stratigraphy provide hints at other preconditioning parameters and triggering mechanisms that may have played a most significant role in the area, such as: (i) structures of thin-skinned tectonics

affecting the Rio Grande Cone (Zalán 2005) seem to have played a major role in the initiation of slope failures. The high angle fault plane across scarp **Is<sub>2</sub>** points to a clear causal relation between block slump-off and the gravity-related listric faults (Fig. 11.2a). Actually, mass-wasting induced by gravity tectonics has also been identified in other segments of the Brazilian margin (e.g., the Amazon fan; Reis et al. 2010); (ii) the main slide scar (sector **a**) flanks the thickest Early Miocene-Quaternary depocenter of the entire southern Brazilian margin, which extends across the shelf edge into the Rio Grande Cone (Fig. 11.1b). Higher sedimentation rates related to the deposition of the Rio Grande Cone would possibly have induced pore pressure elevation in the upslope area of the megaslides occurrence (as required to initiate landslides). Equally, high sedimentary influx into the area has also provided enough sediment to partially refill the failure scar and to the successive reconstruction of the shelf edge-upper slope. Actually, the occurrence of landslides on the flanks of major submarine fans has been recurrent on various continental margins, as for instance the Amazon fan (Silva et al. 2010).

## 11.4 Conclusions

The combination of a diversified geophysical dataset provides insights into the slope failure processes that occur in the Southern Brazilian Margin. Results lead us to the following main conclusions:

1. The Chuí Megaslide Complex stands out as a regional-scale megaslide complex within the context of a margin largely dominated by sediment drifts;
2. The megaslide complex, composed of 8–12 large MTDs, affects significantly both the margin morphology and sedimentation across a large area (~150,000 km<sup>2</sup>), extending from the shelf-break ~650 km downslope to ~4,900 m water depth;
3. Active gravity tectonics has to be assumed as the probable major mechanism inducing slope failures, since the main upslope slide scar seems likely to have been initiated by movements of gravity-related structures;
4. Preconditioning for the submarine mass-wasting process may also have been favoured by rapid sediment accumulation in the head area of the slide complex, together with the erosive action of contour currents around the Rio Grande Cone.

**Acknowledgements** The authors wish especially to thank the *Executive Committee of the LEPLAC PROGRAMME* for permission to publish the acquired geophysical data. We would also thank the Brazilian National Oil and Gas Agency (ANP) for supplying extra seismic and well data. We are also very grateful to reviewers Sébastien Migeon and Nathalie Babonneau for their constructive suggestions while revising the paper. Special thanks are due to Seismic Micro-Technology Inc. (SMT) for the use of the educational licenses of the software Kingdom Suite®. Finally, we thank the Brazilian National Research Agency (CNPq) for providing research grants for the first and second authors.



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