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GEOMORPHOLOGICAL AND SEDIMENTOLOGICAL CHARACTERIZATION OF THE URUGUAYAN CONTINENTAL MARGIN: A REVIEW AND STATE OF ART

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Abstract

The Uruguayan Continental Margin is located in a strategic location of great relevance to understand the dynamics of the regional and global climate and to study the sedimentary processes. The Río de la Plata represents the largest fluvial discharge of the Southwest Atlantic (23.000 m^3/s of water and 57.000.000 m^3/year of sediment for the South Atlantic Ocean). The sub-surface and deep circulation are characterized by the confluence of water masses with contrasting thermohaline characteristics that determine the formation of well-marked hydrological fronts. In the continental shelf, this characteristic is represented by the Subtropical Shelf Front, as a shallow extension of the Brazil-Malvinas Confluence that occurs in deep water off the shelf. Although the knowledge of the regional circulation is acceptable, there are significant gaps in the knowledge related to the influence of this complex hydrological system on sedimentation processes. The objective of this work is to synthesize the present knowledge about the morpho-sedimentary characteristics of the Uruguayan Continental Margin and the processes involved in its formation. It also aims to discuss some knowledge gaps that are the subject of current research in the region. The knowledge reflects the scientific-technological evolution at a global level that is translated in the increase of recent works on the continental slope. Nowadays, most of the available information is associated with the inner shelf and upper slope. Starting from the basis of the close relationship between bathymetry and sedimentological distribution it is clear that efforts should be concentrated on the better understanding of the interaction between the shelf and the slope. The scientific knowledge regarding sedimentology and geochemistry along the Uruguayan Continental Margin is still, scarce and heterogeneous. However, it indicates complexity in the sedimentary coverture present both in the continental shelf and slope. The Uruguayan Continental Margin can be considered as an *in situ* laboratory to improve the understanding of the influence of oceanic hydrodynamics on the margin configuration, a key point to achieve better paleoceanographic interpretations. In this sense, due to the complexity of both modern hydrology and morphological configuration of the margin, it would be interesting to understand the relative importance of the control of each environment on surface sedimentation. A better understanding of the processes that link the near bottom circulation and continental slope features is needed. At the same time, this will allow deepening a new field of research in Uruguay, considering the joint and interrelated vision between sedimentary and oceanographic processes.

Keywords: Sedimentology. Geomorphology. Surface sedimentation. Hydrology. Southwestern Atlantic.

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1. Introduction

1.1 Why study the Uruguayan continental margin?

The Southwest Atlantic comprises one of the largest continental passive margins in the world and is influenced by one of the most complex hydrological systems in global ocean dynamics. In addition, it is influenced by the freshwater discharge of the Río de la Plata (RdlP) which basin, located between latitudes 16°S and 34°S, has an area of 3.1 million km² representing the second river basin of South America.

The RdlP (Fig.1), limited by the coasts of Argentina (to the south) and Uruguay (to the north), represents the largest fluvial discharge of the Southwest Atlantic (23.000 m³/s of water and 57.000.000 m³/year of sediment for the Atlantic Ocean (Framiñan and Brown, 1996). The river forms a large-scale estuary characterized by a salt-wedge regime, a semidiurnal tide with low tidal amplitude (<1 m), a broad and permanent connection to the sea and a high connectivity to atmospheric forcing due to its large extension and shallowness (Guerrero et al., 1997). Although its internal sedimentary dynamics is known since the 1960s, the sediment dispersion system on the continental margin is still little known.

The sub-surface and deep circulation of the Southwest Atlantic contributes to the intrinsic complexity of surface hydrology related to the RdlP discharge. It is characterized by the confluence of water masses with contrasting thermohaline features determining the formation of well-marked hydrological fronts (Fig. 1; Ortega and Martínez, 2007).

In the continental shelf, this characteristic is represented by the Subtropical Shelf Front (STSF), a shallow extension of the Brazil-Malvinas confluence (BMC) that occurs in deep water off the shelf (Piola et al., 2000; Matano et al., 2010). Although the knowledge of the regional circulation is acceptable, there are significant gaps related to the influence of this complex hydrological system on sedimentation processes in the Southwest Atlantic.

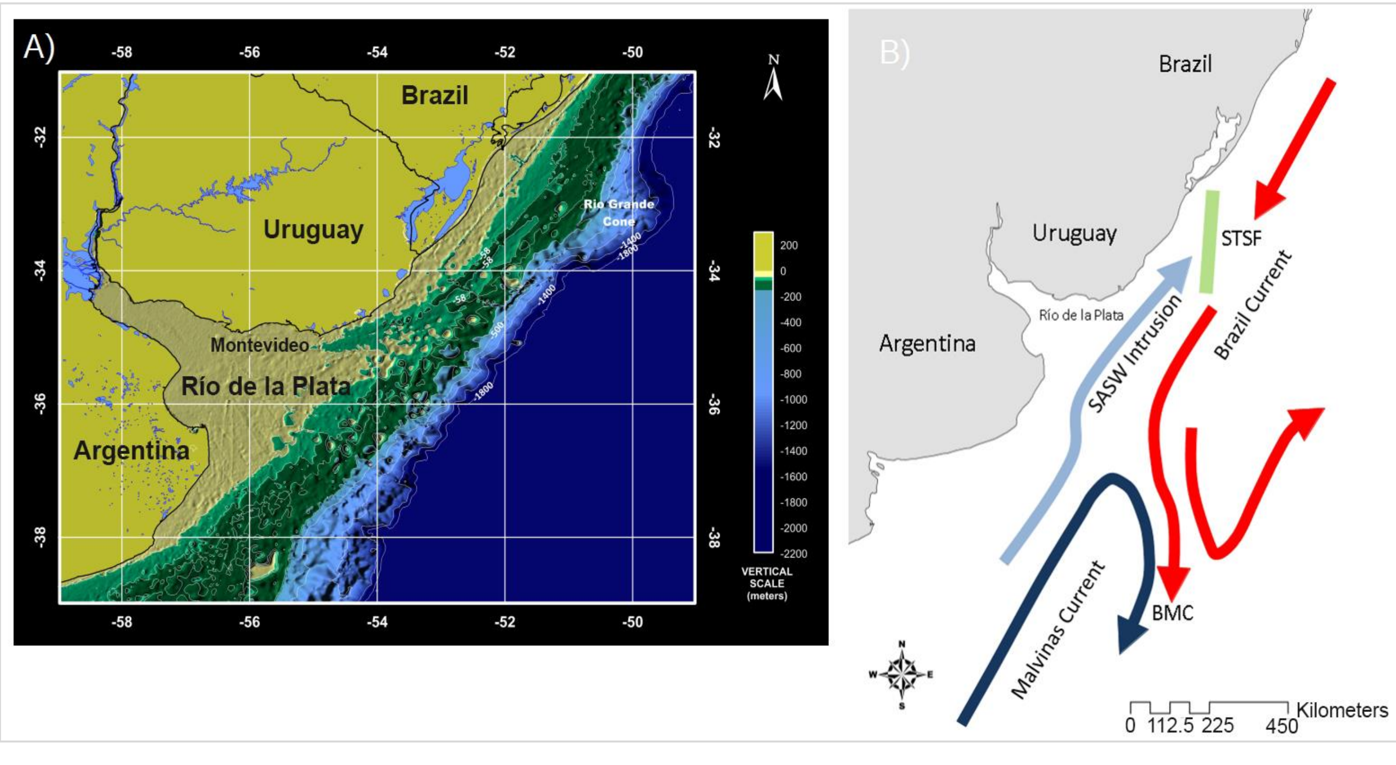

Fig. 1. Map Bathymetric map of the Uruguayan continental margin indicating major physiographic domains. Figure kindly provided by Professor Carlos María Urien (A). Scheme of the regional circulation of the Southwestern Atlantic continental shelf and slope re-drawn from Matano et al. (2010). SASW: subantarctic shelf waters; STSF: subtropical shelf front; BMC: Brazil-Malvinas confluence (B).

Uruguayan Continental Margin (UCM) is located in the transition zone characterized by the occurrence of the STSF, BMC and the RdlP discharge (Fig. 1).

Despite this strategic location of great relevance to understand the dynamics of the regional and global climate, the study of the sedimentary processes of the UCM is scarce (Burone et al., 2014). This knowledge is crucial to advance in the models of climate change, sustainable management of natural resources and in marine spatial planning (hydrocarbon industry, the fishing industry and other activities such as underwater cabling and maritime traffic; Marin et al., 2014).

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1.2 Evolution of geomorphological and sedimentological knowledge in the UCM

The pioneering works on sedimentology and geomorphology in the UCM were carried out during the decades from the 60s to the 80s (generally involving agreements with institutions from Brazil and Argentina) and are mainly descriptive. Most of them are based on the study of surface sediment samples and mostly restricted to the continental shelf, especially the inner and middle shelf (Ottman and Urien, 1965, 1966; Urien and Otmman,1971; Urien and Ewing, 1974; Urien and Martins, 1979; Urien et al., 1980a, b; Parker et al.,1985; López-Laborde 1987a,b, 1996, 1997, 1998, 1999; Ayup-Zouain et al., 1995; Martins and Ponzi, 1980; Martins, 1988). These authors have laid the foundations of the knowledge about the geological description of the region and the influence of relative sea-level changes and present hydrodynamics conditioned by the topography on the bottom sediments coverture.

Despite its descriptive nature, these works already suggested the great sedimentary and geomorphological complexity of the Uruguayan continental shelf. More recent works (Mahiques et al., 2008; Campos et al., 2008; Burone et al., 2013; Lantzsch et al., 2014) used modern geophysical and geochemical techniques, allowing performing a deeper interpretation of the environment based on modern conceptions of sedimentation. The pioneering works about the sedimentary coverture of the Uruguayan continental shelf were previously analyzed and discussed by Burone et al. (2014).

Only from the 90s, began the geochemical studies on the continental slope (Hensen et al., 2000; Benthien and Müller, 2000; Haese et al., 2000; Frenz et al., 2003). It should be noted that these works were carried out at the Atlantic Ocean scale while the sampling effort in the UCM was always scarce (i.e., few samples). These works cover topics such as lateral transport, nutrient flow, carbon accumulation, and organic and inorganic sedimentation. The lack of studies on the Uruguayan slope responds to the increasingly complex and expensive logistics as we move from the coast towards the offshore.

Since 2010, several works focused on issues such as sedimentary dynamics and associated submarine geo-hazards, bathymetry and geophysics were performed on the Uruguayan continental slope (Muñoz et al., 2010; Preu et al., 2010; Krastel et al., 2011; Henkel et al., 2011; Bender, 2012; Carranza et al., 2012; de Mello et al., 2014; Franco-Fraguas et al., 2014, 2016, 2017; Hernández-Molina et al., 2015, Ai et al., 2014). These studies used the modern conception of deep sedimentation, including contouritic and turbiditic processes and products, i.e., longitudinal and transversal sedimentary features associated with deep sea bottom currents (erosive - terraces and channels - depositional - drifts- and submarine canyons and gullies).

The objective of this contribution is to synthesize the present knowledge about recent sedimentary processes and geomorphologic characteristics of the UCM (from inner shelf to offshore; with special focus on the last years after the review carried out by Burone et al., 2014). It also aims to discuss some knowledge gaps that are the subject of current research in the region.

2. State of art

2.1 Geomorphologic characterization

The Southwestern Atlantic Margin (SAM) is a typical passive margin characterized by an extensive continental shelf (one of the widest in the world) that widens towards the south (Fig. 1). It was developed during the formation of the Atlantic Ocean during the Upper Cretaceous (Hinz et al., 1999; Franke et al., 2007). The UCM is a segmented, volcanic rifted margin where two main basins are recognized, with distinct Mesozoic and Cenozoic evolution; the Punta del Este Basin to the south, and the Pelotas Basin to the north (Soto et al., 2011). They are separated by a basement high, the so-called Polonio High, which played an important role as a sediment source area during the rift phase.

The morphology and sedimentary covertures of the UCM reflect the global climatic and oceanographic changes occurring along the Cenozoic, including successive regressions and transgressions of the coastline (Ottman and Urien, 1965, 1966; Urien and Ottman, 1971; Urien and Ewing, 1974; Urien and Martins, 1979; Urien et al., 1980a, b; Soto et al., 2011).

The continental shelf has a gentle slope and the shelf break occurs on average water depths of 160 to 200 m (Urien and Ewing, 1974; Muñoz et al., 2010; Lantzsch et al., 2014). The inner continental shelf is characterized by an elongated seafloor depression, which represents the RdlP paleo-valley (SW-NE direction and located 40 km from the Uruguayan coast; Urien and Ottmann, 1971; Urien and Ewing, 1974; Urien et al., 1980a, b; Laborde, 1999; Cavallotto et al. (2005); Lantzsch et al., 2014; Fig. 2). This depression was about 35 km wide and up to 50 m deep before it became partly filled by sediments since deglacial times (Lantzsch et al., 2014; Fig. 3). Its present-day seafloor physiography was described by Urien and Ottmann (1971), Urien and Ewing (1974), Urien et al., (1980a, b) and Cavallotto et al. (2005). South of this paleo-valley, the inner shelf shows relicts of complex barrier islands and sandbanks that constituted the major morpho-sedimentary features developed during the post- Last Glacial transgression (Fig. 2; Urien and Ewing, 1974; Urien et al., 1980a, b; Parker et al., 2008; Violante et al., 2010).

Whereas the outer- to mid-shelf display a relatively rough surface, the outermost shelf is characterized by a terrace-like shape and a smooth relief). The rough surface is the product of the differential exposure of sediments during Quaternary regressions and transgressions (Lantzsch et al., 2014).

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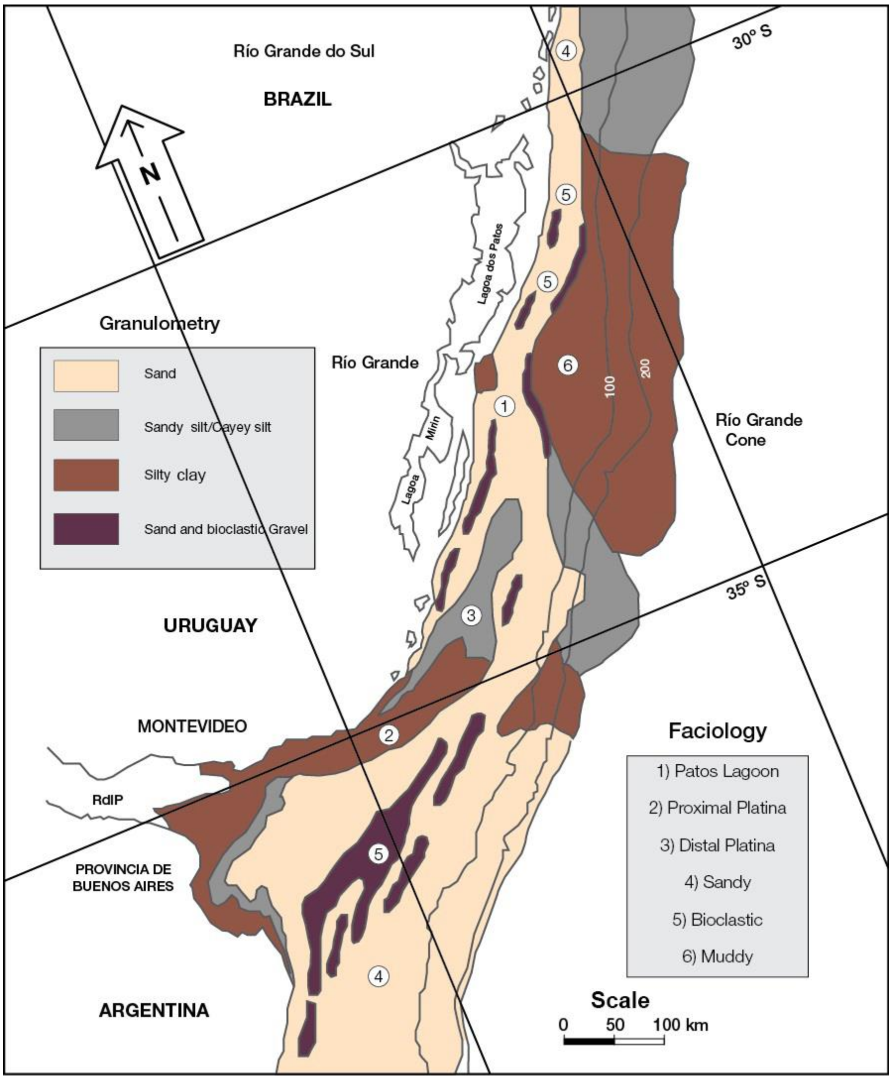

Fig. 2. Faciology of the continental shelf (north of Argentina, Uruguay and south of Brazil) from Martins et al. (2003). RdlP: Río de la Plata.

On the continental slope, a well-developed Contourite Depositional System (CDS) exhibits both erosive and depositional features associated with the action of different Antarctic water masses and their interfaces (Fig. 4; Preu et al., 2013; Hernández-Molina et al., 2015; Soto et al., 2015). These features are well developed along the Argentinean margin and gradually disappear towards the study region, where across-slope (turbiditic) processes dominate (Hernández -Molina et al., 2009; Violante et al., 2010).

Submarine Canyons Systems (SCS) were first reported by Lonardi and Ewing (1971), between 35°S and 38°S (Fig. 3) and were recently described by Hernández-Molina et al. (2015) and Franco-Fraguas et al. (2014) (Fig. 4). These latest works are based on a new regional database comprising oceanographic, bathymetric, multi-channel 2D and 3D seismic reflection profiles and well data. Six large submarine canyons have been identified, namely from south to north: Río de la Plata SCS; Montevideo SCS; Piriápolis SCS, José Ignacio SCS, La Paloma SCS; Cabo Polonio SCS and Punta del Este SCS (Hernández-Molina et al., 2015; Fig. 5). These canyons reach widths of up to 6 km and incisions depths of up to 800 m. These systems do not connect to modern or ancient continental drainage channels, nor do they relate to paleo-fluvial incisions of the shelf (Hernández-Molina et al., 2015).

The Cabo Polonio Mega Slide spans more than 4000 km² and exemplifies large-scale features associated with downslope processes (Hernández-Molina et al., 2015; Fig. 4). Its head presents an amphitheater-like morphology and presents a wide sand lag-deposit in the southern flank (Franco-Fraguas et al., 2017). Its location coincides with the northernmost distribution of part of the Southwestern Atlantic Contourite Depositional System (CDS) and hence contrasting slope physiography and sedimentary regimes dominate to the south (contouritic slope) and north (progradational slope) of its location (Hernández-Molina et

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al., 2015). Seventeen submarine mounds with height of up to 24 m and diameter of 1200 m were identified by Carranza et al. (2012) at depths between 167 m and 330 m. In most of them coral reefs were observed indicating that they are calcareous mounds. Some mounds were observed at canyons head suggesting a relationship between hydrodynamics and sedimentological processes in the canyons.

From the Eocene–Oligocene boundary up to the present time, the long-term influence of water masses from higher latitudes, in combination with down-slope sedimentary processes have strongly controlled the overall margin morphology (Gruetzner et al., 2011; Henkel et al., 2011; Preu et al., 2012, 2013; García Chapori, 2015; Hernández-Molina et al., 2015). Most of the features described in the UCM were formed during the middle/late Miocene epoch due to paleoceanographic shifts that include the onset of Antarctic Intermediate Water (AAIW), in combination with Antarctic Bottom Water (AABW) (Hernández-Molina et al., 2015). Together with Quaternary climatic and eustatic changes in sea level, fluctuations of Brazil–Malvinas confluence during glacial and interglacial stages are recognized in the sedimentary features defined (Hernández-Molina et al., 2015; see item 2.2).

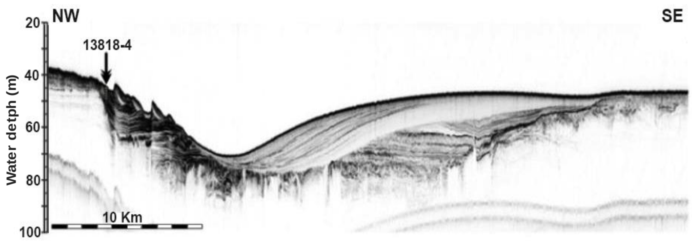

Fig. 3. Parasound acoustic profile of the inner shelf (paleo-valley) from Lantzsch et al. (2014).

2.2 Sedimentological characterization

The sediment distribution is closely associated with the regional circulation. Sandy sediments eroded from the Uruguayan basement distribute south of the RdlP paleo-valley (Urien et al., 1980a, b). Relict sand/shelly coverture dominates the continental shelf and was deposited and reworked under coastal (inner and middle shelf) and shelf (outer shelf) environments during Pleistocene transgressive-regressive events (Urien et al., 1980a, b; Lantzsch et al., 2014). Pyroclastic and volcanic sediments of Pampean-Patagonian origin distribute along the Argentinean margin up to the RdlP mouth transported by the northward displacement of Subantarctic Shelf Water (SASW) (Teruggi, 1954; Etchichury and Remiro, 1960, 1963; Mahiques et al., 2008; Bozzano et al., 2011; Lantzsch et al., 2014).

Recent studies indicate that these sediments that dominate mainly the outer shelf, are transported even during modern times, controlled by the STSF dynamic and are recognized in muddy sand depocenters located in the Uruguayan outer continental shelf (Lantzsch et al., 2014) and in an upper continental slope terrace (Bender, 2012). Here, Bender (2012), recorded sedimentation rates of ≈400 cm/ka for the upper Holocene and 50 cm/ka for the lower Holocene. This depocenter is further characterized by the highest content of organic matter registered along the continental slope and presumably coincides with the location of the contouritic terrace T1 (see below, Franco-Fraguas et al., 2016).

The RdlP buoyant plume is controlled by the dynamic of surface winds associated to the Subtropical Gyre. During austral winter, the buoyant plume is displaced towards the NE along the inner continental shelf. Large part of this continental discharge is deposited at the river mouth (i.e., turbidity front) and towards the NE along a clay-silty facies ("mud depocenter") covering the RdlP paleovalley (Urien and Ewing, 1974; López-Laborde, 1987; Martins et al., 2003; Burone et al., 2013; Lantzsch et al., 2014). This paleovalley was infilled during deglacial sea level rise where the modern facies (U1), deposited since 1.2–1.1 cal ka BP (Lantzsch et al., 2014), presents extremely high sedimentation rates (0.8 cm yr^{-1}) (Lantzsch et al., 2014; Pérez et al., 2016).

In the mud depocenter, Martins et al. (2003) and Campos et al. (2008) differentiated a proximal zone of present deposition of suspended sediments from the RdlP and a distal zone characterized by relict sediment (Fig. 2). These authors point out the influence of the STSF as a barrier to the current sedimentation of RdlP particles. However, studies in the Brazilian continental margin (Mahiques et al., 2004; Burone, et al., 2011; de Andrade, 2011; Nagai et al., 2014) suggest the influence of organic matter originating in the RdlP on the Brazilian continental shelf.

During the austral summer, the RdlP buoyant plume is displaced towards the SW occupying surface waters of the continental shelf (and even the continental slope during el Niño events) in front of the estuary (Piola et al., 2000). Although the particles that make up this austral summer plume are distributed in a vast region, the dynamic and final destination is still not understand. Frenz et al. (2003), based on a south Atlantic large-scale study suggested that a relatively coarse lithogenic sediment tongue identified off the RdlP represent sedimentation of RdlP particles on the lower continental slope.

However, according to these authors, these data are insufficient to conclude the origin of these particles. On the other hand, recent research using Neodymium isotopes indicate that the RdlP do not contribute with lithogenic particles to the upper and middle Uruguayan continental slope (Franco-Fraguas et al., 2016). Instead, it fertilizes open waters with contributions consisting of mixed marine organic matter. However, there is recent clear evidence ($\delta^{13}C$ value of -28.68 and C/N of 17.41, unpublished results) that the RdlP is providing organic particles to the continental slope off Uruguay.

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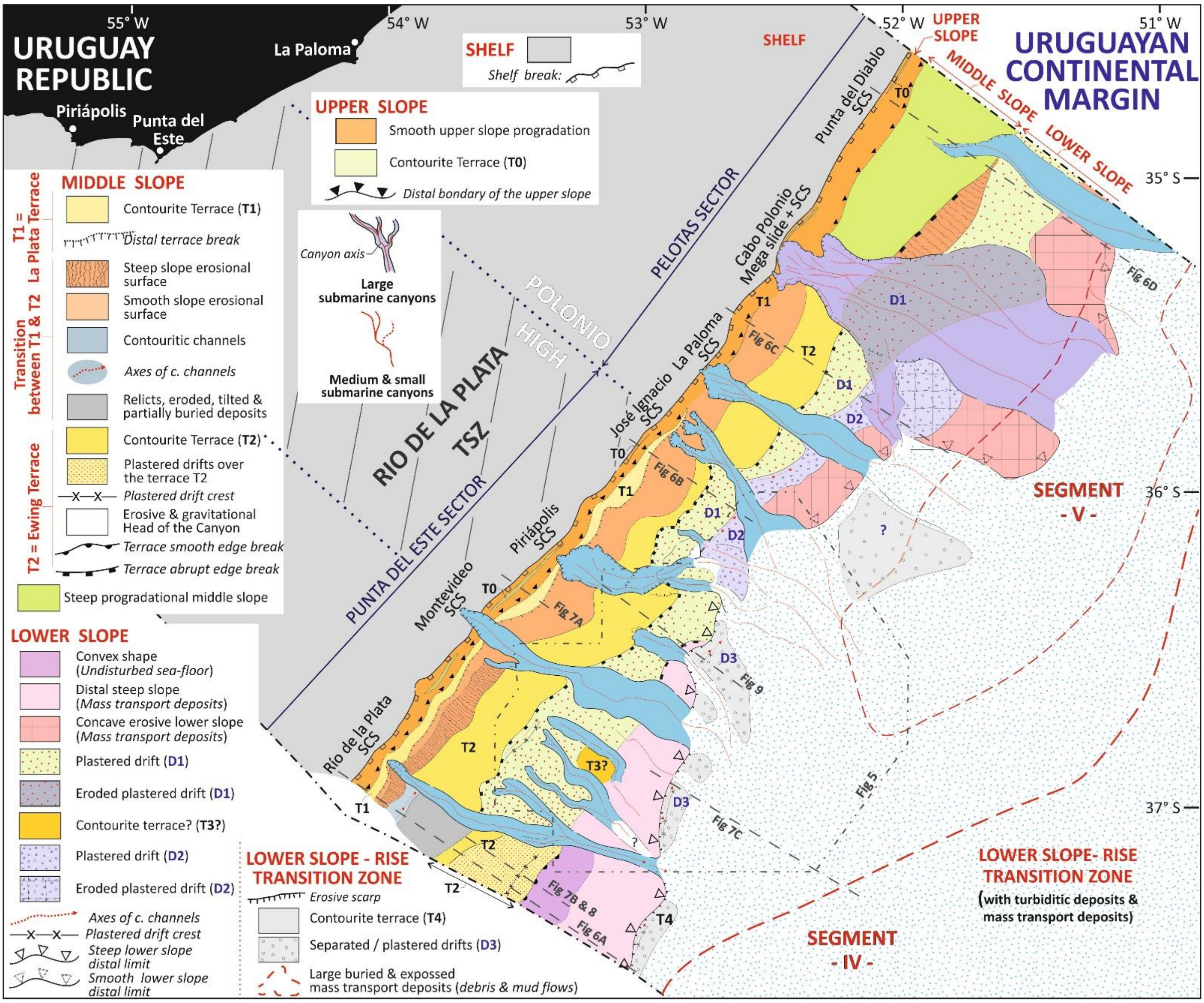

Figure 4

Fig. 4. Morphosedimentary map of the Uruguayan margin from Hernández-Molina et al. (2015). The map shows the interplay between down and along slope processes. Contourite depositional, erosional and mixed erosive-depositional features. Submarine canyon system (SCS) from south to north: Río de la Plata SCS; Montevideo SCS; Piriápolis SCS; José Ignacio SCS; La Paloma SCS; Cabo Polonio SCS; and Punta del Diablo SCS.

The influence of contouritic processes in the slope was recorded by Preu et al. (2011); Krastel et al. (2011); Hernández-Molina et al. (2015) and Soto et al. (2015) based on the analysis in seismic profiles as well as sedimentological samples. Hernández-Molina et al. (2015) proposed a morpho-sedimentary map of the Uruguayan slope (Fig. 4). This map illustrates the complex interplay between down- and along-slope processes and contourite depositional, erosional and mixed erosive-depositional features were indicated (i.e. contourite terraces, contouritic channels, and drifts) (Fig. 4). In addition, in the slope, models of modern sedimentary processes and the hydrological and geomorphological controls on surface sedimentation was recently developed based on high resolution data (Franco-Fraguas et al., 2014, 2016; Fig. 5). The distribution of surface sediment facies obtained in these models are strongly correlated with the distribution of morphosedimentary features (Hernández-Molina et al. 2015) indicating a strong morphological and hydrological control on sediment distribution. These include contouritic terraces in the south and a progradational slope in the north (Franco-Fraguas et al., 2016).

According to Hernandez-Molina et al. (2015), five contourite terraces are present in the Uruguayan margin and are formed in association with water mass interfaces. The T0 terrace coincides with the upper depth range of the SACW. The La Plata Terrace (T1) matches the depth ranges of the SACW and AAIW while the Ewing Terrace (T2) coincides

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with the AAIW- Upper Circumpolar Deep Water (UCDW) interface at a water depth range of 1.2 to 1.5 km. The disappearance of these terraces (T1 and T2) represents the imprint of the position of the BMC during large scale geological glacial times. The T3 terrace occurs very locally at about 2.5 km water depth on the southern sector but does not coincide with the present depth range of any specific water mass on the immediate study area. Nevertheless, the T3 terrace coincides with the depth of the UCDW- Lower Circumpolar Deep Water (LCDW) interface in the vicinity of the Argentinean margin (Hernández-Molina et al., 2009). The T4 terrace is presently under the influence of the Lower Circumpolar Deep Water (LCDW) but matches with the proposed depth range of the LCDW-AABW interface during past glacial periods (Preu et al., 2013). This indicates that this terrace was mostly formed during glacial phases. Contourite drifts D1 and D3 are extensive features (on the order of 100 km) that exhibit pronounced lateral continuity along the entire margin (see Fig. 4).

Current across-margin transport of sediments occurs from the shelf to the upper and middle slope probably associated to the STSF dynamic (Bender, 2012; Franco-Fraguas et al., 2014, 2016) as well as assisted by the physiography of submarine canyons heads (Hernández-Molina et al., 2015; Franco-Fraguas et al., 2017). Small-scale gravitational processes promote the lateral flow of organic matter (Hensen et al., 2000) from the Argentine shelf towards the lower slope. Sand spillover and slumps from the upper slope dominate the progradational slope, and this modern sedimentation presumably suffered a southward shift in relation to the distribution of glacially-controlled contouritic terraces T1 and T2 (Franco-Fraguas et al., 2016).

The Cabo Polonio mega slide canyon edge (Fig. 4) is dominated by patchy outcrops of Pleistocene mass deposits and contouritic sediments transported from the continental shelf and from the south by Antarctic water masses during glacial times, respectively. Retrogressive erosion dominates the head of the mega slide canyon presumably assisted by modern highly energetic conditions related to the Brazil current and its interaction with Antarctic Intermediate Water Contouritic (Franco-Fraguas et al., 2017). Modern mass gravity processes in the middle and lower continental slope (Krastel et al., 2011; Ai et al., 2014) are associated with seismic movements in a fracture zone (Ai et al., 2014; Henkel et al., 2011). Krastel et al (2011) described a headwall scarps originally created by slope failures which direct and focus contour currents along the scarps, hence enforcing the formation of contour-parallel channels and mounded depositional structures. They concluded that despite the widespread occurrence of landslide deposits, their geohazard potential is considered to be low. Most events are relatively small and occur in water depths >1,500 m; the tsunami risk for such slides would be small.

3. Discussion and perspectives

The knowledge of the UCM reflects the scientific-technological evolution at a global level that is translated in the increase of recent works on the continental slope. As in other continental margins the evolution of knowledge occurs from the coast to the offshore. This is consequence of the advance of technology that allows reaching unexplored depths. An area that was previously considered as homogeneous (i.e., continental slope; Stow et al., 2002) is now known to be extremely dynamic and heterogeneous, with great potential both for the scientific community (i.e, paleoceanographic and paleoclimatic studies; physical - sedimentological linkages) and for the exploration of hydrocarbons and gas hydrates (Hernández-Molina et al., 2015).

The pioneering works focused on the UCM have appointed enormous information regarding marine geological processes. However, the combined use of high-resolution technology (i.e., seismic, bathymetric, hydrological, sedimentological, biological) together with biogeochemical proxies in recent studies have allowed to discovery key seafloor features (i.e., submarine canyons, contouritic features, mounds, outer shelf depocenters, sediment facies, margin physiography, etc), and infer processes involved in their formation. It is of great importance to continue these studies mainly along the continental shelf and lower slope and rise of the UCM (see below).

In general, the initial works included the Uruguayan shelf and slope in large-scale studies (considering the UCM as part of a larger system, the SAM) but recently both regions became the focus of investigation of more detailed studies. Recent investigations indicate that the strategic location of the UCM along the southwestern Atlantic margin in terms of regional hydrology can be translated to the seafloor. This is especially evident in the continental slope.

The UCM includes the disappearance of the enormous contouritic structures developed along the Argentinean margin (in the south) and the marked change to a progradational margin (in the north) associated to the glacial BMC position. For the authors of this work, this is an extremely interesting feature of potential information of both past and present sedimentation. We estimate that future high-resolution studies will bring comparable novel information regarding the continental shelf and its relation to the STSF. Thus, it is necessary to improve the knowledge of the seabed of the UCM through basic research that contributes to the hydrological-sedimentological coupling, and to the better exploitation of mineral and fisheries resources (Burone et al., 2014; Marin et al., 2014).

In the continental shelf, although several morpho-sedimentary structures have been identified (i.e., barrier islands, Martins et al., 2003), both their characterization and distribution are based on low resolution studies. Hence, their

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small-scale morphological characteristics have yet to be explored as well as its relation with regional sedimentation and hydrography. Studies considering the interaction between the coast and inner shelf in different timescales must be carried forward. High resolution seismic profiles may help to understand how previous paleo-relieves, determined by continental or coastal processes, influences the shelf roughness and morphology, which affects present hydrographic and sedimentary thickness in the continental shelf during the Holocene.

There is an important difference between the spatial coverture of studies focused on surface sedimentation along the shelf and slope in the UCM. This lack of information does not allow the integration of knowledge about the sedimentary dynamics and sediment transport that occurs through the shelf break. Besides, there is still no consensus about the influence of the sediments from the RdlP on the continental margin sedimentation, both in the present and along the Holocene.

Due to the effects that this process has on the sediment accumulation rate, carbon flux, organic matter supply and, therefore, in the biological communities distribution, it is essential to understand the influence of the sediments supplied by the RdlP as best as possible.

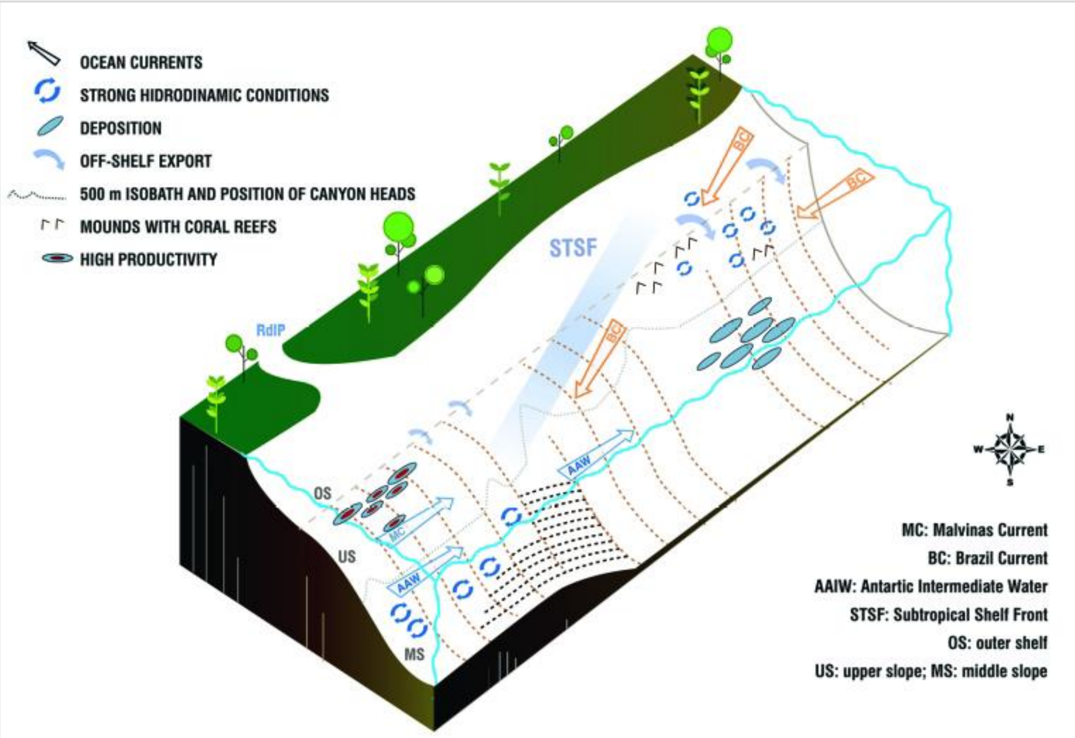

Fig. 5. Schematic diagram from Franco-Fraguas et al. (2014) showing the sediment dynamics and sedimentary processes associated to the regional hydrology and morphology (upper and middle slope; northern Uruguayan continental margin).

In the continental slope, the knowledge of hemipelagic, contouritic and turbiditic processes (Preu et al., 2010; Krastel et al., 2011; Franco-Fraguas, et al., 2014, 2016; Hernández-Molina 2015; Cibils, 2016) along the continental slope needs further studies. These processes still must be studied from the sedimentological point of view for a more detailed understanding. The recent integration and coupling of results based on between 2 and 3D seismic surveys, and modern sedimentation have yield important information (Franco-Fraguas et al., 2016). Yet, a profound exploration is needed in order to obtain a better understanding of the sedimentary processes at different time scales. The lower continental slope and rise are still unexplored. Therefore, the study of these regions is urgent.

4. Conclusion

After the enormous information on marine geological processes gathered in the pioneer works on the UCM, recent studies focused on the UCM and based on high resolution technology have provided an important step forward in the scientific knowledge. The approaches used in these studies are evidently complementary. For example, the horizontal and vertical distribution of sediments was analyzed using different methodologies (i.e., seismic, long corers, surface) and interpreted together with the analysis of morphologic (i.e., bathymetry) and hydrologic information. The coupling and joint analysis of these results can potentially contribute with enormous information and is hence, especially highlighted in this contribution.

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The UCM can be considered as an *in situ* laboratory to improve the understanding of the influence of oceanographic hydrodynamics on the margin configuration, a key point to achieve better paleoceanographic interpretations. Due to the complexity of both modern hydrology and the morphological configuration of the UCM margin, the relative control of each environment on surface sedimentation and the processes that link the near bottom circulation and continental slope features is needed. This will allow deepening a new field of research in Uruguay, considering the joint and interrelated vision between sedimentary and oceanographic processes.

This knowledge in turn will allow the evaluation of natural resources, whose future exploratory stage should consider multi and interdisciplinary aspects such as knowledge of types and mobility of marine sediments, longitudinal processes (contouritic) and transverse (gravitational), sedimentary dynamics in the bottom ocean and in water masses, areas of instability of soil and subsoil, deep currents and their action on the bottom, as well as their physical properties (velocity, temperature, salinity, density). Also, with direct application in the field of geological risk in the marine environment.

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References

Ai, F., Strasser, M., Preu, B., Hanebuth, T.J.J., Krastel, S., Kopf, A., 2014. New constraints on oceanographic vs. seismic control on submarine landslide initiation: a geotechnical approach off Uruguay and northern Argentina. Geo-Marine Letters 34, 399-417. https://doi.org/10.1007/s00367-014-0373-3

Ayup-Zouain, R.N., Fachel, J., Weschenfelder, J., Zomer, S., Souto, R., 1995. Analise multivariada estadística aplicada ao reconocimiento da evolucao paleogeografica da plataforma continental adjacente ao Río de la Plata. VI Congreso Latinoamericano de Ciencias del Mar, COLACMAR 56.

Bender, V.B., 2012. From shelf dynamics to shelf export: evidences from sedimentologic and palaeoceanographic slope record. PhD Thesis, Uuroprox, University of Bremen, Germany.

Benthien, A., Müller, P.J., 2000. Anomalously low alkenone temperatures caused by lateral particle and sediment transport in the Malvinas Current region, western Argentine Basin. Deep-Sea Research 47, 2369-2393. https://doi.org/10.1016/S0967-0637(00)00030-3

Bozzano, G., Violante, R.A., Cerredo, M.E., 2011. Middle slope contourite deposits and associated sedimentary facies off NE Argentina. Geo-Marine Letters 31: 495-507. https://doi.org/10.1007/s00367-011-0239-x

Burone, L., Centurión, V., Cibils, L., Franco/Fraguas, P., García-Rodríguez, F., García, G., Pérez, L. 2014 Sedimentología y Paleoceanografía. *In*: Uruguay, Mar Territorial / Programa oceanográfico de caracterización del margen continental de la Republica Oriental del Uruguay, ANCAP, Facultad de Ciencias, Montevideo, pp. 54 – 56.

Burone, L., Ortega, L., Franco-Fraguas, P., Mahiques, M., García-Rodríguez, F., Venturini, N., Marin, Y., Brugnoli, E., Nagai, R., Muniz, P., Bícego, M., Figueiras, R., Salaroli, A., 2013. A multiproxy study along the transition between the Río de la Plata and the adjacent Southwestern Atlantic inner Shelf to assess the sediment footprint of river vs. marine influence. Continental Shelf Research 55, 141–154. https://doi.org/0.1016/j.csr.2013.01.003

Burone, L., Sousa, S.H.M., Mahiques, M.M., Valente, P., Ciotti, A., Yamashita, C., 2011. Benthic foraminiferal distribution on the southeastern Brazilian shelf and upper slope. Marine Biology 158, 159-179. https://doi.org/10.1007/s00227-010-1549-7

Campos, E.J.D., Mulkerherjee, S., Piola, A.R., de Carvalho, F.M.S., 2008. A note on a mineralogical analysis of the sediments associated with the Plata River and Patos Lagoon outflows. Continental Shelf Research 28, 1687-1691. https://doi.org/10.1016/j.csr.2008.03.014

Carranza, A., Muñoz-Recio, A., Kitahara, M., Scarabino, F., Ortega, L., López, G., Franco-Fraguas, P., de Mello, C., Acosta, J., Fontan, A., 2012. Deep-water coral reefs from the Uruguayan outer shelf and slope. Marine Biodiversity 42 (3), 411–414. https://doi.org/10.1007/s12526-012-0115-6.

Cavallotto, J.L., Violante, R., Colombo, F., 2005. Evolución y cambios ambientales de la llanura costera de la cabecera del río de la Plata. Revista de la Asociación Geológica Argentina 60(2), 353-367.

Cibils, L., 2016. Productividad marina en el el Margen Continental Uruguayo – Atlántico suroccidental: Un análisis multiproxie. Tesina de Grado. Licenciatura de Biología, opción Oceanografía. Universidad de la Republica, Uruguay. 88p

de Andrade, P.C., 2011. Variações de paleoprodutividade na plataforma continental interna ao largo de Itajaí-SC (26°59´16.8´´S - 048°04´33.6´´W) durante o Holoceno: uma abordagem de multi-indicadores. MsD Thesis, Universidade de São Paulo, São Paulo, Brazil.

de Mello, C., Burone, L., Ortega, L., Franco-Fraguas, P., Lahuerta, N., Mahiques, M., Marin, Y., 2014. Benthic foraminiferal distributions on the Uruguayan continental margin (South-western Atlantic) and controlling environmental factors. Journal of Marine Biology 91, 120-133. https://doi.org/10.1016/j.csr.2014.08.006

Etchichury, M.C., Remiro, J., 1963. La corriente de Malvinas y los sedimentos pampeano–patagónicos. Revista del Museo Argentino de Ciencias Geológicas I.

Etchichury, M.C., Remiro, J.R., 1960. Muestras de fondo de la plataforma continental comprendida entre los paralelos 34° y 36°30 de latitud sur y los meridianos 53°10 y 56°30 de longitud oeste. VI Revista del Museo Argentino de Ciencias Naturales, Bernardino Rivadavia 4, 1–70.

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (4): 253-264. October-December, 2018
doi: 10.12957/jse.39150

Framiñan, M.B., Brown, O.B., 1996. Study of the Río de la Plata turbidity front Part I: spatial and temporal distribution. Continental Shelf Research 16, 1259–1282. https://doi.org/10.1016/0278-4343(95)00071-2

Franco-Fraguas, P., Burone, L., Goso, C., Scarabino, F, Muzio, R., Carranza, A., Ortega, L., Muñoz, A., Mahiques, M., 2017. Sedimentary processes in the head of the Cabo Polonio Mega Slide Canyon (Southwestern Atlantic Margin off Uruguay). Latin American Journal of Sedimentology and Basin Analysis 24 (1), 31-44.

Franco-Fraguas, P., Burone, L., Mahiques, M., Ortega, L., Carranza, A., 2016. Modern sedimentary dynamics in the Southwestern Atlantic Contouritic Depositional System: New insights from the Uruguayan margin based on a geochemical approach. Marine Geology 376, 15-25. https://doi.org/10.1016/j.margeo.2016.03.008

Franco-Fraguas, P., Burone, L., Mahiques, M., Ortega, L., Urien, C., Muñoz, A., López, G., Marin, Y., Carranza, A., Lahuerta, N., de Mello, C., 2014. Hydrodynamic and geomorphological controls on surface sedimentation at the Subtropical Shelf Front–Brazil–Malvinas Confluence transition off Uruguay (Southwestern Atlantic Continental Margin). Marine Geology 349, 24–36. http://dx.doi.org/10.1016/j.margeo.2013.12.010.

Franke, D., Neben, S., Ladage, S., Schreckenberger, B., Hinz, K., 2007. Margin segmentation and volcano-tectonic architecture along the volcanic margin off Argentina/Uruguay, South Atlantic. Marine Geology 244, 46-67. http://dx.doi.org/10.1016/j.margeo.2007.06.009.

Frenz, M., Höppner, R., Stuut, J.B.W., Wagner, T., Henrich, R., 2003. Surface sediment bulk geochemistry and grain-size composition related to the oceanic circulation along the South American Continental Margin in the Southwest Atlantic. In: Wefer, G., Mulitza, S., Ratmeyer, V. (eds), The South Atlantic in the Late Quaternary: Reconstruction of Material Budgets and Current Systems. Springer-Verlag Berlin Heidelberg New York Tokyo, pp 347-373 https://doi.org/10.1007/978-3-642-18917-3_17

García Chapori, N., 2015. Reconstrucción paleoceanográfica del talud bonaerense a partir de testigos cuaternarios. PhD Thesis, Universidad de Buenos Aires, Argentina, 203 pp. (not published).

Gruetzner, J., Uenzelmann-Neben, G., Franke, D., 2011. Variations in bottom water activity at the southern Argentine margin: indications from a seismic analysis of a continental slope terrace. Geo-Marine Letters 31, 405–417. http://dx.doi.org/10.1007/s00367-011- 0252-0.

Guerrero, R.A., Piola, A.R., Boschi, E.E., 1997. Masas de agua en la plataforma continental. El Mar Argentino y sus Recursos Pesqueros. Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Mar del Plata. A. R. 1, pp. 107-118.

Haese, R.R., Schramn, J., Rutgers van der Loeff, M.M., Schulz, H.D., 2000. A comparative study of iron and manganese diagenesis in continental slope and deep-sea basin sediments of Uruguay (SW Atlantic). International Journal of Earth Sciences 88, 619-629. https://doi.org/10.1007/s005310050292

Henkel, S., Strasser, M., Schewenk, T., Hanebuth, T.J.J., Hüsener, J., Gail Lee, A., Winkelmann, D., Formolo. M.J., Tomasini, J., Krsatel, S., Kasten, S., 2011. Sediment and por water data of five cores from the continental slope off Uruguay. PANGEA. https://doi.org/10.1029/2011GC0036669.

Hensen, C., Zabel, M., Schulz, H.D., 2000. A comparison of benthic nutrient fluxes from deep-sea sediments off Namibia and Argentina. Deep-Sea Research 47, 2029-2050. https://doi.org/10.1016/S0967-0645(00)00015-1

Hernández-Molina, F.J., M. Soto, A.R. Piola, J.B.P., Tomasini, P., Thompson, G., Badalini, A., Creaser, R.A., Violante, E., Morales, M., Paterlini, H., de Santa Ana, 2015. A contourite depositional system along the Uruguayan continental margin: Sedimentary, oceanographic and paleoceanographic implications. Marine Geology 378, 333-349. https://doi.org/10.1016/j.margeo.2015.10.008

Hernández-Molina, F.J., Paterlini, M., Violante, R., Marshall, P., de Isasi, M., Somoza, L., Rebesco, M. 2009. Contourite depositional system on the Argentine Slope: An exceptional record of the influence of Antarctic water masses. Geology 37(6), 507-510. https://doi.org/10.1130/G25578A.1

Hinz, K., Neben, S., Schreckenberger, B., Roeser, H.A., Block, M., Souza, K.G.D., Meyer, H., 1999. The argentine continental margin north of 48°S: sedimentary successions, volcanic activity during breakup. Marine and Petroleum Geology 16, 1–25. http://dx.doi.org/10.1016/S0264-8172(98)00060-9

Krastel, S., Wefer, G., Hanebuth, T.J.J., Antobreh, A.A., Freudenthal, T., Preu, B., Schwenk, T., Strasser, M., Violante, R., Winkelmann, D. 2011. Sediment dynamics and geohazards off Uruguay and the de la Plata River region (northern Argentina and Uruguay) M78/3 shipboard scientific party. Geo-Marine Letters 31 (4), 271-283. https://doi.org/10.1007/s00367-011-0232-4

Lantzsch, H., Hanebuth, T.J.J., Chiessi, C.M., Schwenk, T., Violante, R.A., 2014. The high-supply, current-dominated continental margin of southeastern South America during the late Quaternary. Quaternary Research 81, 339-354. https://doi.org/10.1016/j.yqres.2014.01.003

Lonardi, A., M. Ewing, 1971. Sediment transport and distribution in the Argentine Basin. *In*: Ahrens, L.H. Press, F. Runkorn S.K., Urey H.C. (Eds.), Physics and Chemistry of the Earth. Pergamon Press, London, 8, 253-264.

López-Laborde, J., 1999. Sand deposits on the outer shelf of the Río de la Plata and adjacent continental shelf. In: Martins, L.R. Santana, C.I. (eds), Non living resources of the Southern Brazilian Coastal Zone and Continental Margin, OAS/IOC-UNESCO/MCT., Special Publication, Porto Alegre, Brasil, pp. 80-91.

López-Laborde, J., 1998. La delimitación de la Plataforma Continental Uruguaya según el artículo 76 -parrafo 4 -literal a) -inciso i). Tareas a desarrollar. Informe interno. Departamento de oceanografía, División Geología Marina. SOHMA.

López Laborde., J., 1997. La delimitación de la plataforma continental uruguaya y el articulo 76-parrafo4-literal a)-inciso i) criterio del espesor de sedimentos. Informe interno. Departamento de oceanografía, División Geología Marina. SOHMA.

López-Laborde, J., 1996. La convención de las naciones unidas sobre los derechos del mar y la delimitación de la plataforma continental Uruguaya. Informe interno. División Geología Marina. SOHMA.

López-Laborde, J. ,1987a. Distribución de sedimentos superficiales de fondo en el Río de la plata exterior y plataforma adyacente. Investigaciones Oceanológicas 1, 19-30.

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (4): 253-264. October-December, 2018
doi: 10.12957/jse.39150

López-Laborde, J., 1987b. Caracterización de los sedimentos superficiales de fondo del Río de la Plata exterior y plataforma adyacente. 2do Congreso Latino Americano sobre Ciencias del Mar.

Mahiques, M.M., Gaeta Tassinari, C.C., Marcolini, S., Violante, R.A., Lopes Figueira, R.C., Almeida da Silveira, I.C., Burone, L., Sousa, S.H.M., 2008. Nd and Pb isotopes signatures on the southeastern south America upper margin: implication for sediment transport and source rocks. Marine Geology 250, 51-63. https://doi.org/10.1016/j.margeo.2007.11.007

Mahiques, M.M., Tessler, M.G., Ciotti, A.M., da Silveira, C.A., Sousa, S.H.M., Figueira, R.C.L., Tassinari, C.C.G., Furtado, V.V., Passos, R. F., 2004. Hydrodynamically driven patterns of recent sedimentation in the shelf and upper slope off Southeast Brazil. Continental Shelf Research 24, 1685-1697. https://doi.org/10.1016/j.csr.2004.05.013

Marin, Y., Chocca, J., González, B., Beathyate, G., 2014. Interacción entre diferentes actividades antrópicas. In. Uruguay Margen Continental. Programa oceanográfico de caracterización del margen continental uruguayo. Zona Económica Exclusiva. Ancap-Facultad de Ciencias, Zona Editorial, 383 pp.

Martins, L.R., Martins, I.R., Urien, C.M., 2003. Aspectos sedimentares da plataforma continental na área de influencia de Río de la Plata . Gravel 1, 68-80.

Martins, L.R. ,1988. Conhecimento atual da geologia costeira e marinha da região sul da América Latina. Informe UNESCO sobre Ciencias del Mar 47, 1-21.

Martins, L.R., Ponzi, V.R.S., 1980. Aspectos texturais e mineralógicos dos sedimentos superficiais da plataforma continental brasileira. Notas Técnicas 2, 33-151.

Matano, R.P., Palma, E.D., Piola, A.R., 2010. The influence of the Brazil and Malvinas Currents on the Southwestern Atlantic Shelf circulation. Ocean Science 6, 983–995. https://doi.org/10.5194/os-6-983-2010

Muñoz, A., Fontan, A., Marin, Y., Carranza, A., Franco Fraguas, P., Rubio, L., 2010. Informe de Campaña Uruguay 0110. Buque de Investigacion Oceanografica y Pesquera Miguel Oliver (SGM).

Nagai, R.H., Ferreira, P.A.L., Mulkherjee, S., Martins, V.M., Figueira, R.C.L., Sousa, S.H.M., Mahiques, M.M., 2014. Hydrodynamic controls on the distribution of surface sediments from the southeast South American continental shelf between 23°S and 38°S. Continental Shelf Research 89, 51-60. http://dx.doi.org/10.1016/j.csr.2013.09.016.

Ortega, L., Martínez, A., 2007. Multiannual and Seasonal Variability of Water Masses and Fronts Over the Uruguayan shelf. Journal of Coastal Research 23, 618-629. https://doi.org/10.2112/04-0221.1

Ottmann, F., Urien, C.M., 1966. Sur quelques problèms sédimentologiques dans le Río de la Plata. Revue de Géographie Physique et de Géologie Dynamique 8, 209-224.

Ottman, F., Urien, CM., 1965. Observaciones preliminares sobre la distribucón de los sedimentos en la zona externa del Río de la Plata. Academia Brasileira de Ciências 37, 284-289.

Pérez, L., García-Rodríguez, F., Hanebuth, T.J.J., 2016. Variability in terrigenous sediment supply offshore of the Río de la Plata (Uruguay) recording the continental climatic history over the past 1200 years. Climate of the Past 12, 623–634. https://doi.org/10.5194/cp-12-623-2016

Parker, G., Violante, R.A., Paterlini, C.M., Costa, I.P., Marcolini, S.I., Cavallotto, J.L. 2008. Las secuencias depositacionales del plioceno-cuaternario en la plataforma submarina adyacente al litoral del este bonaerense. Latin American Journal of Sedimentology and Basin Analysis 15(2), 105-124.

Parker, G., Marcolini, S., Cavallotto, J.L., Martínez, H., López, M.C., Ghiorzo, D., de León, A., Maza, M.T., Ayup, R.N., López Laborde, J. 1985. Distribución de sedimentos en lasuperficie del fondo. Estudio para la Evaluación de la Contaminación en el Río de la Plata SHIN – SOHMA, (División Geología Marina).

Piola, A.R., Campos, E.J.D., Moller, J.R.O.O., Charo, M., Martinez, C., 2000. Subtropical shelf front off Eastern South America. Journal of Geophysical Research 105, 6565-6578. https://doi.org/10.1029/1999JC000300

Preu, B., Hernandez-Molina, F.J., Violante, R., Piola, A., Paterlini, C.M., Schwenk, T., Voigt, I., Krastel, S., Spiess, V., 2013. Morphosedimentary and hydrographic features of the northern Argentine margin: the interplay between erosive, depositional and gravitational processes and its conceptual implications. Deep-Sea Research Part I: Oceanographic Research Papers 157–174. https://doi.org/10.1016/j.dsr.2012.12.013

Preu, B., Schwenk, T., Hernández-Molina, F.J., Violante, R., Paterlini, M., Krastel, S., Tomasini, J., Spieß, V., 2012. Sedimentary growth pattern on the northern Argentine slope: The impact of North Atlantic Deep Water on southern hemisphere slope architecture. Marine Geology 329–331, 113–125. http://dx.doi.org/10.1016/j.margeo.2012.09.009.

Preu, B., Schwenk, T., Hernández-Molina, F.J., Strasser, M., Huppertz, T., Hanebuth, T., Violante, R., Krustel-Gudegats, S., Henrich, R., Lindhorst, K., Meyer, M., Spieb V., M78/3 shipboard scientific party, 2010. Interaction between a Contourite depositional system and the Mar del Plata canyon off Argentina and Uruguay. Geo-Temas 11, 139-140.

Soto, M., Morales, E., Hernández-Molina, F.J., Veroslavsky, G., Tomasini J., de Santa Ana, H. 2015. Procesos sedimentarios en el talud continental de Uruguay: una síntesis actualizada. In: Goso, C. (Ed.), Nuevas miradas a la problemática de los ambientes costeros, Sur de Brasil, Uruguay y Argentina. 1aed. DIRAC. 14 pp. Montevideo.

Soto, M., Morales, E., Veroslavky, G., de Santa Ana, H., Ucha, N., Rodríguez, P., 2011. The continental margin of Uruguay: crustal architecture and segmentation. Marine and Petroleum Geology 28, 1676–1689. http://dx.doi.org/10.1016/j.marpetgeo. 2011.07.001.

Stow, D.A.V., Faugères, J.-C., Howe, J.A., Pudsey, C.J., Viana, A.R., 2002. Bottom currents, contourites and deep-sea sediment drifts: current state-of-the-art. In: Stow, D.A.V., Pudsey, C.J., Howe, J.A., Faugères, J.-C., Viana, A.R. (Eds.), Deep-Water Contourite Systems: modern drifts and ancient series, Seismic and Sedimentary characteristics. The Geological Society of London, Memoir 22, 7-20.

Teruggi, M.E., 1954. El material volcánico-piroclástico en la sedimentación pampeana. AAS Revista 9, 184–191.

Urien, C.M., Martins, L.R., Martins, I.R., 1980a. Evolução geológica do Quaternário do litoral atlântico uruguaio, plataforma continental e regiões vizinhas. Notas Técnicas 3, 7-43.

Urien, C.M., Martins, L.R., Martins, I.R., 1980b. Modelos deposicionais na plataforma continental do Rio Grande do Sul (Brasil), Uruguai e Buenos Aires. Notas Técnicas 3, 13-25.

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
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doi: 10.12957/jse.39150

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Urien, C.M., Martins, L.R., 1979. Sedimentación marina en América del Sur Oriental. Memorias del seminario sobre ecología bentónica y sedimentación de la plataforma continental del Atlántico Sur. Parte 1: Geología y Sedimentación. Unesco. Oficina regional de Ciencia y Tecnología para América Latina y el Caribe, pp. 43-66.

Urien, C.M., Ewing, M. 1974. Recent sediments and environment of southern Brazil, Uruguay, Buenos Aires, and Rio Negro continental shelf. In: Burk, C.A., Drake, C.L. (eds), The Geology of Continental Margins, New York, N.Y., Springer, pp. 157-177.

Urien, C.M., Ottmann, F., 1971. Historie del Río de la Plata au Quaternarie. Quaternaria 14, 51-59.

Violante, R.A., Hernández-Molina, F.J., Paterlini, C.M., Bozzano, G., Krastel, S., Hanebuth T., Preu, B., Laprida, C., 2010. Contouritic terraces on the Northern Argentina middle continental slope (southwestern Atlantic). Geo-Temas 11, 183-184.