

THE SOUTHWESTERN ATLANTIC OCEAN: PRESENT AND PAST MARINE SEDIMENTATION

Roberto A. Violante ^{1*}, Leticia Burone ^{2*}, Michel Mahiques ^{3*}, José L. Cavallotto ^{1*}

¹ Servicio de Hidrografía Naval, Departamento Oceanografía, División Geología y Geofísica Marina. Montes de Oca 2124, Buenos Aires C1270ABV, Argentina. violante@hidro.gov.ar, jlcavallotto@hidro.gov.ar

² Universidad de la República, Facultad de Ciencias, Oceanografía y Ecología Marina, Grupo de Ciencia y Tecnología Marina (CINCYTEMA). Iguá 4225, Montevideo 11400, Uruguay. lburone@fcien.edu.uy

³ Universidad de San Pablo, Instituto Oceanográfico. Praça do Oceanográfico 191, San Pablo 05508-120, Brazil. mahiques@usp.br

* Guest Editors of the Special Issue: The Southwestern Atlantic Ocean: present and past marine sedimentation.

ARTICLE INFO

Article history

Received June 14, 2017

Accepted July 11, 2017

Available online July 12, 2017

Handling Editor

Ernesto Schwarz

PREFACE

Marine Geology is one of the most recently developed branches of the geological sciences, which began to actively evolve after the mid XX century when the “modern” research techniques for obtaining really trustworthy data from the ocean floor and subbottom appeared, such as high-resolution bathymetry, seismic, sea-bottom profilers, submarine photography and sea-floor sampling. In the Southwestern Atlantic continental margin the first great impulse occurred in the 1950’s and 1960’s by the agreement achieved between the Lamont-Doherty Earth Observatory (LDEO) of the Columbia University (USA) and the Argentina Hydrographic Survey (SHN). It was a pioneering work at a global scale as it represented a leading case for developing marine seismic technologies at sea useful for understanding the major oceanic sedimentary processes and the subbottom structure (e.g., Ahrens *et al.*, 1971). Also in the 1960’s, another major agreement between CONICET (Argentina) and Woods Hole Oceanographic Institution (USA)

allowed the acquisition by the Argentine government of the former research vessel Atlantis (later named, under Argentine flag, as “El Austral” and presently “Dr. Bernardo Houssay”), which was the first ship specifically built for oceanographic research and one of the most famous and internationally recognized because of its contribution to the knowledge of the ocean floors between 1939 and the latest 1950’s, including the findings that initially supported the continental drift’s theory. Following that, several national initiatives helped to advance in the development of marine geological sciences in the region. Among the most important we can mention: the REMAC Project in Brazil in the 1960’s and 1970’s -that allowed the participation of several Brazilian universities as well as North American research institutions-, the agreement between the SHN and the Uruguayan Oceanographic, Hydrographic and Meteorological Survey (SOHMA) in the 1970’s and 1980’s under the framework of the Administrative Commission for the Río de la Plata (CARP), the agreement between SOHMA and the Rio Grande do Sul University (URGS, Brazil) in the 1980’s and 1990’s, and the Projects MARGEN in Argentina and REVIZEE in Brazil - that began in the 1980’s-. The highly significant results that arose from those agreements and national projects impelled the Argentina-Brazil-Uruguay geological communities to focus on the importance of deeply studying the ocean environments in the region and the needs to organize working teams aimed at developing research programs on the subject.

A fundamental fact was the awareness of local

institutions, universities and national agencies for supporting research about the needs to financially support projects at sea and to promote scholarships and junior researcher's professional training on the subject. In the second part of the XX century the countries of the region already had their own research vessels, continuing the tradition of the respective Navies in their commitment to carry out scientific activities at sea. Later on, the co-organization of joint projects between institutions and researchers from Latin American and many of the world top-most European institutions dedicated to marine sciences began to come true. Many of these projects included campaigns in the region on board of some of the most modern research ships (from Germany, Spain, Italy, Russia, Brazil, etc.), which not only significantly improved the knowledge of the ocean environments but also allowed the on-board training of senior and junior researchers, as well as students, in the modern techniques of research at sea.

Another significant advance was the involvement of many of those research teams in projects of the International Geological Correlation Program (IGCP N^{os} 61, 200, 274, 396, 437, 464, 495, 619, <http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/international-geoscience-programme/igcp-projects>), as well as in projects of the International Union for Quaternary Research (INQUA, <https://www.inqua.org>) and other European Projects focused on marine environments. Several research lines developed in the framework of those projects, such as Quaternary sea-level fluctuations, nearshore and deep-sea sedimentary processes, coastal and marine geomorphology, seismic-stratigraphy, ocean dynamics and related geological processes, marine geochemistry, marine neotectonics, construction and evolution of continental margins and paleoceanography. Many of the present-day senior researchers on Marine Geology in our regions gained expertise into the international marine community after their involvement in those projects, in some cases acting as project's proponents and leaders.

Starting at the 1990's, the research activities carried out in each country for the extension of the outer limit of the "Continental Shelf" under the rules imposed by the United Nations Convention on the Law of the Sea resulted in an impressive advance in the knowledge of the marine environment in the region (CIRM, 2006 -Brazil-; COALEP, 2009 -Uruguay-; COPLA, 2012 -Argentina-). Very recent

governmental initiatives such as Pampa Azul (Argentina), Amazonia Azul (Brazil), as well as a similar enterprise from the University in Uruguay (Science and Technology Laboratory, CINCYTEMA) open a promising stage in the definitive development of marine sciences. In recent years it has also been possible the co-participation of these countries in official proposals for the International Ocean Discovery Program (IODP) (Junium *et al.*, 2012; Baker *et al.*, 2016; Vannucchi *et al.*, 2016; Kulhanek *et al.*, 2016; Malinverno *et al.*, 2016; Wright *et al.*, 2016). This represents a highly significant and promising step ahead because of the possibility of performing deep-ocean drillings with high-quality scientific scopes aimed at bringing new data on diverse subjects such as the opening of the Atlantic Ocean, the construction of continental margins, sediments dynamics, paleoceanography, paleoclimatology, etc.

The importance of the Southwestern Atlantic, that justifies the international interest in its study and the imperative need of the countries in the region to put all the necessary scientific and economic efforts there, lies in the fact that the continental margin of eastern South America is one of the largest in the planet and richest in living and non-living resources. Based on its physical and biological characteristics, Bisbal (2005) considered the continental shelf of the region as a Large Marine Ecosystem. Moreover, in the framework of the global climatic-oceanographic coupling, the region represents a unique domain in the world ocean because of the particular interplay between Antarctic and Equatorial water-masses that produces a net exchange of heat between the Southern Ocean and tropical regions. As a result of that interoceanic interaction, particular morphosedimentary characteristics develop in the shelf and slope (e.g., Martins and Coutinho, 1981; Wefer *et al.*, 1996; ANCAP-Facultad de Ciencias, 2014; Nagai *et al.*, 2014; Violante *et al.*, 2014, 2017). The oceanographic background produces a marked thermohaline stratification in the water column, with interfaces between adjacent individual water-masses where high-energy processes occur. When those interfaces interact with the sea-floor a significant impact occurs, manifested as particularly energetic sedimentary processes. This partially explains the enormous amount of suspended sediments and the importance of nepheloid layers in the region, as generators of very large morphosedimentary features, like the huge Contourite Depositional System that

extends almost continuously from the central margin of Brazil to the circum-antarctic region (e.g., Viana, 2002; Hernández Molina *et al.*, 2009, 2015; Mutti *et al.*, 2014; Franco-Fraguas *et al.*, 2016; Violante *et al.*, this volume). Strong gravity-driven processes, both turbiditic currents and different kinds of mass-transport processes, are also significant as a response to the highly energetic environment. This interactive vision between sedimentary and oceanographic processes opens a new research line for the study of the margin evolution and resulting morphosedimentary features. Some updates of the advance in marine sciences in Argentina, Brazil and Uruguay have been published in recent years by Polejack (2010), Perillo *et al.* (2014) and ANCAP-Facultad de Ciencias (2014).

On the basis of the achieved knowledge about marine sedimentary processes in the region, it is considered that this is an appropriate time to edit a thematic volume on the matter. Stating this objective, this Special Issue of the Latin American Journal of Sedimentology and Basin Analysis aims to bring together some of the most recent advances in the research on part of the Southwestern Atlantic margin, both in littoral and deep-marine settings. Five papers are herein included. Some of them contain revisions on the advance in the knowledge on deep marine sedimentary processes (Violante *et al.* and Bozzano *et al.*). The rest of the papers contain details of specific areas of the slope (Franco-Fraguas *et al.* in the Uruguayan margin and Isola *et al.* in the central Patagonian margin) and the north-bonaerensian coastal plain (Gomez Samus *et al.*).

The paper by Violante *et al.* is an update of the knowledge on sedimentary processes in the Argentine margin. It highlights the fundamental change in the conception of the deep-marine processes that took place since the end of the XX century after the development of the modern techniques of research at sea, when it went from a model dominantly gravitational (across-slope) to one where the deep-marine currents parallel to the margin (along-slope) play a preponderant role. This change in the conception of the sedimentary processes arises from the recent results of research activities that enable to describe the huge contouritic sedimentary sequences that extend along the entire margin from mid to high latitudes. The strong interdependence between sea-floor sedimentary processes and ocean dynamics is

a novel aspect of marine geology, which is revealed in this work.

The paper by Bozzano *et al.* introduces into the knowledge of submarine canyons through an updated revision on the matter at a global scale. The different hypothesis about dynamic processes involved in canyon's genesis and evolution are presented. On the basis of this knowledge, the characteristics of the diverse canyon systems that cross the Argentine margin are discussed. Special focus is put in the better-known systems, like the Mar del Plata, Patagonian and Tierra del Fuego canyons, each of them dominated by diverse complex sedimentary processes in response to their location in different morphosedimentary settings.

The paper by Franco-Fraguas *et al.* describes the sedimentary processes at the head of a large submarine canyon dominated by megaslides in the continental slope of Uruguay, through a multidisciplinary approach that includes acoustic techniques with multibeam bathymetry, sub-bottom profiler, high-resolution seismic, sea-floor sampling (particularly the study of gravel deposits) and CTD measurements. The authors conclude that turbiditic flows and slides, possibly triggered by seismic activity in the framework of the high-energy processes imposed by the interaction between the Brazil Current and the Antarctic Intermediate water-mass, and the consequent influence of contouritic processes, play a role in the retrogressive erosion of the canyon.

The paper by Isola *et al.* is a new contribution to the comprehension of the sedimentary processes modeling the shallowest contouritic terraces in the slope at the southern end of the passive volcanic margin of Argentina (Terraces Nágera and Perito Moreno). Based on the interpretation of seismic sections, different stages of evolution are defined for the region. They are dominated by the interaction among the different gravitational and along-slope sedimentary processes and its relation to oceanographic factors, stressing the influence of the Almirante Brown Submarine Canyon on the contouritic processes modeling the terraces.

The paper by Gómez Samus *et al.* discusses, starting from a multi and interdisciplinary approach, the

sedimentological and mineralogical characteristics of the littoral facies associated to the Holocene Transgression in the Río de la Plata coastal plains surrounding the localities of La Plata, Berisso and Ensenada (Argentina). The work stresses the content, origin and transformations of iron minerals in the transgressive facies, discussing their paleoenvironmental significance and their importance in the regional evolution and pedogenetic processes.

The papers included in this Special Issue were selected among the communications presented in the Special Session S2 “Quaternary sedimentation in coasts, shelf and slope”, organized during the XV Argentine Meeting on Sedimentology and VII Latin American Congress on Sedimentology held in Santa Rosa, La Pampa, Argentina, on 13-16 September 2016. The event was organized by the Asociación Argentina de Sedimentología, the Facultad de Ciencias Exactas y Naturales from the Universidad Nacional de La Pampa, and the Instituto de Ciencias de la Tierra y Ambientales of La Pampa (INCITAP-CONICET). The authors of this Preface, acting as Invited Editors of this Special Issue, who were also the conveners of the Special Session S2 in the above mentioned Congress, deeply thank the Editorial Team of LAJSBA, in particular Dr. Ernesto Schwarz and Dr. Diana Cuadrado, for inviting and encouraging the publication of this volume. We are also indebted to Dr. Gerardo M.E. Perillo for the critical review of this Preface and the comments that helped to improve its content. Special thanks are given to the different authors that decided to publish their papers in this Special Issue, as well as to the reviewers of those papers, who are mentioned in each case.

REFERENCES

- Ahrens, L.H., F. Press, S.K. Runkorn and H.C. Urey, 1971. *Physics and Chemistry of the Earth*, Vol 8. Pergamon Press, Londres, 333 pp.
- ANCAP-Facultad de Ciencias, 2014. *Uruguay, Margen Continental*. Zona Editorial, 383 pp.
- Baker, P., C. Silva, S. Fritz and T. Reis, 2016. Deep drilling of the Amazon continental margin: The evolution of Cenozoic neotropical biodiversity, climate, and oceanography. *IODP Full Proposal 859*.
- Bisbal, G.A., 2005. The Southeast South American shelf larger marine ecosystem - Evolution and components. *Marine Policy*, 19:21-38.
- CIRM, 2006. *The Brazilian submission to the Commission on the Limits of the Continental Shelf pursuant to article 76 of the United Nations Convention on the Law of the Sea*. Addendum to the Executive Summary dated 17 May 2004, 18 pp. http://www.un.org/Depts/los/clcs_new/submissions_files/submission_bra.htm
- COALEP, 2009. *Presentación de la República Oriental del Uruguay a la Comisión de Límites de la Plataforma Continental. Resumen Ejecutivo*. Comisión Asesora del Poder Ejecutivo para el Establecimiento del Límite Exterior de la Plataforma Continental, Montevideo, 11 pp.
- COPLA, 2012. *Límite Exterior de la Plataforma Continental Argentina, Resumen Ejecutivo*. Comisión Nacional del Límite Exterior de la Plataforma Continental, Buenos Aires, 224 pp.
- Franco-Fraguas, P., L. Burone, M. Mahiques, L. Ortega and A. Carranza, 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.
- Junium, C., J. Bidle, A. Sluijs, J. Moura, R. Pancost, S. Shah, V. Edgecomb, K. Billups, H. Christopher, C. Chessi and M. Arthur, 2012. Brazil-Argentina Margin, Black Shales and Microbiology. *IODP Pre-Proposal 801*.
- Kulhanek, D.K., R. Gerster, P. Kress, N. Bolatti, M. Ghidella, C.M. Paterlini, R. Meyer, C. Berndt, E. Schwarz, J.P. Pérez Panera, C. Heil, R.A. Violante, D. Ariztegui, M.C. Rondoni, B. Briggs, N. Riedinger, J. Kallmeyer, M. Prasad, T. Gorgas and T. Weber, 2016. Deep Drilling on the Argentine Passive Volcanic Continental Margin (APVCM): Exploring the Transition from Continental Breakup to Passive Margin. *IODP Pre-proposal 903*.
- Malinverno, A., F.S. Colwell, G.R. Dickens, V.B. Heuer, J.M. Ketzer, J.W. Pohlman, M.E. Torres and A.R. Viana, 2016. Carbon cycling in methane-charged continental margin sediments: Rio Grande Cone (Brazil). *IODP Pre-proposal 910*.
- Martins, L.R. and P.N. Coutinho, 1981. The Brazilian continental margin. *Earth-Science Reviews* 17:87-107.
- Mutti, E., R.S. Cunha, E.M. Bulhoes, L.M. Arienti and A.R. Viana, 2014. Contourites and Turbidites of the Brazilian Marginal Basins. *AAPG Annual Convention & Exhibition*, Houston, Search and Discovery Article #51069, 46 pp.
- Nagai, R., S.H.M. Sousa and M.M. Mahiques, 2014. The Southern Brazilian Shelf. In A.R. Chivas and F.L. Chiocci (Eds.), *Continental Shelves during Last Glaciation Cycle: Shelves of the World Reviews*. Final volumen Project IUGG-UNESCO-IGCP 464 “Continental Shelves during the Last Glacial Cycle”. Geological Society of London, Memoirs 41:47-54.
- Perillo, G.M.E., J.L. Esteves, F.I. Isla, G. Lovrich, M.C. Piccolo, M. Saraceno and P. Costilla, 2015. *Estado actual de las Ciencias del Océano en la Argentina*. Academia Nacional de Ciencias y Academia Nacional de Ciencias Exactas, Físicas y Naturales. Buenos Aires:307-348.
- Polejack, A., 2010. *Enhancing the policies in support of the marine sciences in Brazil*. The United Nations-Nippon Foundation Fellowship Programme 2010-2011. Division for Ocean Affairs and the Law of the Sea Office of Legal Affairs. The United Nations, New York, 41 pp.
- Vannucchi, P., T. Alves, F.H. Bezerra, H. Vital, F. Balsamo, C. Hensen, J.P. Morgan, C. Busby, E. Bongiolo, L. Gasperini, M. Praxedes Gomes, D. de Castro, D. Iacopini, P. Clift and C. MacLeod, 2016. Tectonics of the Brazilian Equatorial Margin (BEM): The Romanche Fracture Zone, from Cretaceous Birth to Neogene Rejuvenation. *IODP Full Proposal 882*.

- Viana, A.R.**, 2002. Seismic expression of shallow- to deep-water contourites along the south-eastern Brazilian margin. *Marine Geophysical Researches* 22:509-521.
- Violante, R.A., S. Marcolini, J.L. Cavallotto, C.M. Paterlini, I.P. Costa, C. Laprida, W. Dragani, S. Watanabe, V. Totah, E.I. Rovere and M.L. Osterrieth**, 2014. The Argentina Continental Shelf: morphology, sediments, processes and evolution since the Last Glacial Maximum. In A.R. Chivas and F.L. Chiocci (Eds.), *Continental Shelves during Last Glacioeustatic Cycle: Shelves of the World Reviews*. Final volumen Project IUGG-UNESCO-IGCP 464 "Continental Shelves during the Last Glacial Cycle". Geological Society of London, Memoirs 41:55-68.
- Violante, R.A., C. Laprida and N. García Chaporí**, 2017. *The Argentina Continental Margin: a potential Paleoclimatic-Paleoceanographic archive for the Southern Ocean*. Springer Briefs in Earth System Sciences, Springer International Publishing, Cham (Suiza), 117 pp. DOI 10.1007/978-3-319-04196-4.
- Wefer, G., W.H. Berger, G. Siedler and D.J. Webb**, 1996. *The South Atlantic, Present and Past Circulation*. Springer-Verlag, Berlin Heidelberg, 644 pp.
- Wright, J., J. Gruetzner, N. Slowey, D. Kulhanek, G. Uenzelmann-Neben, N. García Chaporí, S. Jaccard, N. Riedinger, G. Dickens, J. Hernández-Molina, J. Pérez Panera, R.A. Violante, E. Schwarz and N. Waldmann**, 2016. Argentine Margin Transects: Deciphering the Interactions among Southern Ocean Circulation, Climate, and Tectonics. *IODP Pre-proposal 911*.