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INTRODUCTION TO THE SPECIAL NUMBER (32.1) GOLFO SAN JORGE BASIN: THEMATIC SYNTHESIS, RECENT DEVELOPMENTS AND A LOOK FORWARD

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ABSTRACT

This contribution provides an overview of the content of this Special Number of the Latin American Journal of Sedimentology and Basin Analysis, which explores the geological evolution of the Golfo San Jorge Basin and the challenges it faces within the current context of hydrocarbon resource depletion and global warming. The Special Number comprises eight peer-reviewed articles synthesizing current knowledge across multiple disciplines. The topics covered include: (i) magmatic evolution (Navarrete); (ii) structural geology (Allard *et al.*); (iii) stratigraphy and provenance (Paredes *et al.*; Olazábal *et al.*; Foix *et al.*); (iv) paleosol development (Lizzoli and Raigemborn); and (v) Cretaceous biostratigraphy (Pérez Loinaze; De Sosa Tomas and Vallati). These contributions present recent advances in their respective fields and highlight critical unresolved questions that must be addressed to further our understanding of the geological evolution of the Golfo San Jorge Basin.

INTRODUCTION

The Golfo San Jorge Basin (hereafter referred as GSJB) is a dominantly extensional basin formed in response to the Gondwana breakup during the late Jurassic and early Cretaceous, and later modified by contractional deformation associated with the development of the Andes Cordillera since the late Cretaceous. The GSJB is located in the southern sector of Chubut Province and the northern sector of Santa Cruz Province (Argentina) covering an area up to 150,000 km^2 and totalizing up to 7000 m thick in the deepest depocenters. Since the oil discovery in 1907 in Comodoro Rivadavia, about 40,000 wells have been drilled in the GSJB with ~ 13,500 wells currently in production providing about 30% of the annual production of Argentina. Over the past decade, the geological knowledge of the GJSB has been synthesized in the Special Issue 72(1) of the Revista de la Asociación Geológica Argentina (2015), in the Special Issue entitled "Geological Evolution of the Golfo San Jorge Basin: Recent Advances" of the Journal of South American Earth Sciences (Paredes *et al.*, 2020), and in several chapters of the Relatorio de Geología y Recursos Naturales de la Provincia del Chubut (Giacosa, 2021). This Special Number of the *Latin American Journal of Sedimentology and Basin Analysis* consists of eight short papers that attempt to synthesize the current understanding of the multiple disciplines involved in the magmatic, structural, stratigraphic, and paleontological evolution of this sedimentary basin, which holds both academic and industrial significance. In this way, the contributions focus on recent advances in these disciplines and

the outstanding issues that still need to be addressed to enhance our understanding of the geological evolution of the Golfo San Jorge Basin, and future challenges in the current context of global warming.

CONTENTS OF THIS VOLUME

The first contribution (Navarrete, 2025) presents a groundbreaking overview of Late Triassic to Pleistocene magmatic events in the Golfo San Jorge Basin and its surroundings. The research provides a detailed analysis of geodynamic processes—such as flat subduction events, slab break-offs, ridge subduction, and mantle interactions— and their influence on the Patagonia's magmatic history. This contribution integrates geochronological, geochemical, seismic tomography, and tectonic modeling data, challenging conventional interpretations of magmatism in the region, particularly by reevaluating the origins of the Jurassic Chon Aike Silicic Large Igneous Province (SLIP). Rather than attributing it solely to crustal anatexis, the study proposes that slab break-off events and mantle-driven processes played a fundamental role in its formation. The study also brings new insights into Cenozoic intraplate magmatism, particularly the link between mantle transition zone dynamics and widespread basaltic volcanism in Patagonia. Navarrete (2025) suggests that subducted slabs reaching the mantle transition zone triggered mantle decompression, leading to large-scale magmatism and associated marine transgressions. Furthermore, the research highlights the tectonic significance of slab tears and slab windows, showing how these processes influenced magmatic activity and regional uplift, basin subsidence, paleoenvironmental changes, and reinterpreting key magmatic events.

The following article by Allard *et al.* (2025) provides an updated synthesis of the structural evolution of the Golfo San Jorge Basin (GSJB), offering significant contributions to the understanding of intracratonic basins in Patagonia. This work refines existing tectonic models by analyzing multiphase structural interactions, extensional tectonic events, and positive tectonic inversion processes. The article integrates regional geological data with advanced structural interpretations, shedding new light on the evolution of fault systems and basin-wide deformation patterns. The authors challenge traditional models that describe GSJB as a simple rift basin and, instead, they consider the basin a complex polyphasic history, demonstrating that reactivation of inherited faults and compressional overprints played a crucial role in shaping the basin's current architecture. The article analyzes the origin and onset of the San Bernardo Fold Belt, an intra-basin contractional structure associated with the selective tectonic inversion of inherited, extensional faults, contributing to the ongoing debate on the subjacent mechanisms and timing of positive inversion of the fold belt. Additionally, they explore the Western Flank, identifying zones of fault reactivation and highlighting the need for further investigation into the causes and extent of inversion-related deformation. As the GSJB is one of Argentina's most productive hydrocarbon basins, understanding the structural controls on basin evolution can improve exploration strategies and reservoir characterization. Areas of future research identified in this contribution include the role of deep lithospheric processes, far-field stress transmission, and the influence of inherited structures on fault kinematics, emphasizing the need to integrate high-resolution seismic data with field observations to refine structural models and improve tectonic reconstructions.

Paredes *et al.* (2025a) present a comprehensive and methodologically integrated analysis of the factors influencing the macro-architecture of the Chubut Group (Cretaceous) in the Golfo San Jorge Basin (GSJB). Their study focuses on allogenic controls—external geological forces that drive sedimentation and basin evolution—including tectonics, climate variations, and base-level changes. By integrating stratigraphic, sedimentological, and geochronological data, the research provides a refined understanding of how these factors interact to shape basin-scale depositional patterns. This work's key contribution is quantifying the relative importance of different allogenic controls at various temporal and spatial scales. The study highlights the control of extensional tectonics on basin subsidence, drainage reorganization, and sediment accommodation, particularly during the Barremian to Cenomanian-Turonian?. The evolution of fault systems and the uplift of structural highs played a significant role in shaping tectonically controlled sedimentary corridors and sedimentary facies. The detrital zircon ages and sandstone petrography analysis confirm shifts in sediment source areas, revealing the increasing influence of

Andean-derived sediments as orogenic processes intensified. Climatic interpretations are supported by paleosol analyses on floodplain deposits and paleo-hydrological reconstructions of fluvial channel belt deposits in the Bajo Barreal Formation, which, in conjunction, provides a mechanism to explain fluvial stacking patterns. The research suggests climate-driven changes in sediment supply and water discharge rates significantly influenced the development of high- and low-accommodation fluvial systems, particularly within the Bajo Barreal Formation. The study also acknowledges the role of base-level fluctuations in shaping lacustrine and fluvial sequences in the older units of the Chubut Group but calls for further research on the timing and extent of lake expansions and regressions in the basin.

The paper of Olazábal *et al.* (2025) summarizes the current understanding of the evolution of the source areas of the Chubut Group in the Golfo San Jorge Basin, with a focus on coeval tectonic processes and sediment source changes. The study integrates sedimentological, stratigraphic, and structural analyses to unravel how tectonic activity influenced sediment supply, accommodation space, and depositional environments over time. One of the central findings is the identification of tectonically controlled sedimentation patterns, particularly about Andean uplift phases, and processes of basin reorganization. By examining the petrographic composition of the Matasiete, Castillo, and Bajo Barreal formations, the authors demonstrate how shifts in Andean-derived sediments and local basement inputs reflect broader tectonic reorganizations in the basin. These results improve our understanding of paleogeographic reconstructions and how changes in climate and tectonics influenced basin infill and source areas.

In a promising line of research, Lizzoli and Raigemborn (2025) provides a contribution to the understanding of paleoclimatic conditions during hothouse periods through the analysis of paleo-Ultisols from the Bajo Barreal Formation (Cenomanian-Turonian?) and Las Flores Formation (early Eocene) in the Golfo San Jorge Basin. The research highlights how Ultisols serve as key climate indicators, recording long-term chemical weathering processes and atmospheric conditions during these critical geological intervals. The study demonstrates that the Ultisols in both formations formed under temperate to tropical, humid conditions, with evidence of intense leaching, kaolinite accumulation, and horizon differentiation. These pedo-features contrast the basin's modern arid conditions, evidencing climate zone latitudinal shifts during the Cretaceous and early Eocene. By comparing these fossil soils with modern Ultisol analogs, the research reinforces the hypothesis that during past global warming events, warm-temperate zones extended much further poleward than today. The study integrates sedimentology, clay mineralogy, and geochemical proxies to assess past climate variability and validate global paleoclimate models, whose results contribute to ongoing discussions on latitudinal climate displacement and their impact on continental environments. Given current concerns about anthropogenic climate change, studying these ancient soils provides valuable comparative data for predicting future climatic trends.

The study of Foix *et al.* (2025) offers a detailed synthesis of the Cenozoic stratigraphic record of the Golfo San Jorge Basin, which holds the thickest sequence of Cenozoic deposits in extra-Andean Patagonia. The research provides a refined stratigraphic framework based on the development of three second-order transgressive-regressive (T-R) cycles corresponding to the Paleogene (Early Paleocene–Middle Eocene and Late Eocene-Early Miocene) and Neogene (Early–Middle Miocene) periods. The article compares the 2nd-order cycles, highlighting the differences in duration, climatic conditions, and depositional processes. The Paleogene cycle, spanning ~20-25 million years, recorded extensive pyroclastic input, strong climatic fluctuations, and a long-lasting fluvial and loess depositional environment. The following second-order cycle covers the late-Oligocene to early Miocene (~15 million years) and it is integrated by a shallow-marine formation preserved in the subsurface of the South Flank and pyroclastic continental deposits. The Neogene cycle, lasting only ~5 million years, was shaped by a single wet-to-dry climatic transition with a marine incursion followed by fluvial-eolian deposits. This article argues that Andean uplift, extensional tectonic reactivations, and mantle-driven subsidence significantly influenced accommodation space and sedimentary patterns through the Cenozoic. The manuscript also emphasizes the exceptional record of continental mammal faunas of the Paleogene

age, which are considered a key reference for South American biostratigraphy. A critical discussion of sea-level fluctuations, basin subsidence, and volcanic input sheds light on the complex interplay between internal (tectonic) and external (eustatic, climatic) factors shaping the basin's stratigraphy.

The last two articles of the Special Number address aspects related to the Cretaceous micropaleontology of the Golfo San Jorge Basin. The paper by Pérez Loinaze (2025) consolidates previous palynological research of the Las Heras Group in the Golfo San Jorge Basin (GSJB) while incorporating new taxonomic insights, refining the biostratigraphic interpretation of these Lower Cretaceous deposits. This overview improved our understanding of its chronostratigraphic framework and paleoenvironmental evolution through a detailed revision of palynological zones, which allows for more precise dating of the Las Heras Group. The study confirms that the unit does not extend beyond the Hauterivian in the northern and southern flanks, while in the western sector, its age reaches the Aptian. Fossil pollen assemblages reveal fluctuations between humid and semi-arid climates, with lacustrine and fluvial deposition cycles influenced by regional tectonics. Moreover, the study highlights the influence of marine incursions from the Pacific and the development of anoxic lacustrine environments with strong hydrocarbon potential eastward. While this research refines the stratigraphy of the Las Heras Group, it also highlights the need for additional multidisciplinary research to fully resolve uncertainties regarding stratigraphic unit correlations and depositional system evolution in the subsurface of the Golfo San Jorge Basin.

Finally, De Sosa Tomas and Vallati (2025) summarize the current understanding of the micropaleontology and paleoecology of the Chubut Group in the Golfo San Jorge Basin, offering new insights into past climatic and environmental conditions supported by continental microfossils. The contribution emphasizes on the Pozo D-129 Formation (late early Aptian) and the Lago Colhué Huapi Formation (late Maastrichtian), summarizing the knowledge of the remaining formations of the Chubut Group. The Pozo D-129 Formation contains charophytes, palynomorphs, and primitive angiosperm pollen, evidencing freshwater lakes developed under semi-arid conditions. In contrast, the Lago Colhué Huapi Formation is characterized by aquatic ferns and megaspores, reflecting a humid and warm climate with rich freshwater ecosystems. The research improves the biostratigraphic framework of the basin, identifying key floristic transitions during the Cretaceous: the presence of transitional taxa, including austral and paleotropical species, suggests that Patagonia underwent dynamic climatic shifts influenced by global paleogeographic changes. These findings establish new correlations between Patagonian and global floras, contributing to understanding continental biogeographic connections during the Cretaceous. In addition, the authors identify potential future lines of research, including high-resolution palynological analyses, stable isotope studies, and paleoclimate modeling, which will elucidate vegetation and climate evolution in southern South America during the Cretaceous.

PERSPECTIVES

Recent contributions on the geology of the Golfo San Jorge Basin (Paredes *et al.*, 2020; Giacosa, 2021) and this volume show mature lines of research on several topics regarding the geological evolution of the basin but also show that more research is needed to understand sedimentation patterns and links between sub-crustal, geodynamic processes and basin reorganization at multiple scales. Many of these aspects influence sedimentary and paleontological evolution at regional scale conforming non-linear, dynamic systems, within the context of dynamic complex systems analysis (Thurner *et al.*, 2018) whose uniqueness challenge understanding and predictions using knowledge derived from single disciplines.

Many of these topics indirectly impact the development, preservation, and quality of hydrocarbon reservoirs, whose industries currently motorize the productive developments in the Santa Cruz and Chubut provinces, although evidencing a declining activity trend. However, the massive availability of recent technological developments and their use in outcrop and subsurface databases (UAV, machine learning, AI tools) anticipate renovating efforts to maximize the use of underutilized and currently available resources in pursuit of improving process efficiency in the hydrocarbon industry, which could enhance and revitalize the basin's extractive activities.

On the other side, a significant challenge for the future generations of geologists in the Golfo San Jorge Basin is expected to be closely linked to the principle of sustainable development and management of water resources from the Senguerr River basin, on which communities in much of southern Chubut and northern Santa Cruz depend. Although this topic has not been explored in this special volume, the current context of climate change, marked by rising temperatures and decreasing snowfall-derived precipitation, is causing recurrent water crises associated with ENSO cycles and anthropic water use. In a climate scenario that sets the background conditions, the increasing demand for water for human consumption, agriculture, and industry is drastically altering environmental conditions, as exemplified by the recent desiccation of Lake Colhué Huapi (Paredes *et al.*, 2025b). Over the next decade, efforts to maintain quality-of-life standards will collide with climate signals, urging us to adopt a more efficient use of natural resources. These challenges will require optimizing historically wasteful processes, such as traditional flood irrigation of agricultural areas, or specific measurements to reduce the water abstraction from Musters Lake and water consumption in urban centers. These topics will require the training of geologists interested in enhancing the understanding of the complex interrelationship between internal geological processes, hydrological response to climate change, and the impact of human actions on ecosystems—a challenge that will demand paradigm shifts in education and new points of reference.

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