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Geomorphologic Map of Northeastern Sector of San Jorge Gulf (Chubut, Argentina)

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Abstract

This paper presents a 1:100,000 scale geomorphologic map of the Northeastern sector of San Jorge Gulf (Chubut Province) in Patagonia, Argentina, covering more than 1,000 km^2. Derived from remote sensing data and validated by three field surveys, it has been compiled in order to understand the past and recent evolution of the area with particular reference to sea-level oscillation studies, for which this map is the basic tool. The very low human impact and rates of dynamic landscape change allow the preservation of extensive palaeo deposits and landforms, including those indicative of sea-level variations. The relative change of sea level dominates landscape evolution, allowing the formation of widespread marine and lagoon deposits often interfingering with fluvial deposits and reworked by aeolian process in the framework of consequent beach progradation.

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1. Introduction

The Patagonian coast of Argentina preserves impressive traces of sea-level oscillations represented by marine deposits and erosional forms of high scientific value for understanding climatic changes and tectonic uplift history in this area (Feruglio, 1950; Codignotto et al., 1992; Rutter et al., 1990; Rostami et al., 2000; Schellmann and Radtke, 2000; 2003; 2010; Pedoja et al., 2010; Ribolini et al., 2011). The studied area covers in detail the coastal geomorphology of the northeastern sector of San Jorge Gulf (Chubut Province). It extends over more than 1,000km^2 between the mouth of Cañada del Linyera and the Caleta Horno (66°50'W – 65°47'W longitude and 44°54'S – 44°51'S latitude; Figure 1).

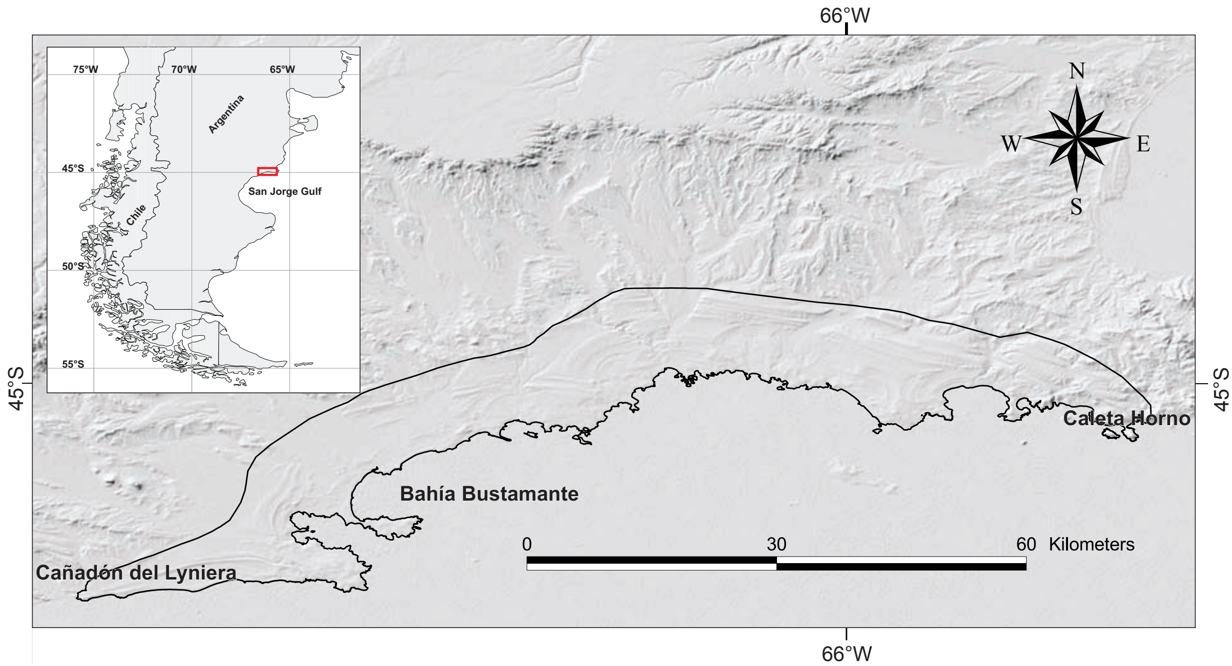

Figure 1. Location of the study area.

Here, an outstanding succession of raised beach deposits is exposed for a total area of more than 500 km^2, extending up to 10 km landward and reaching 100 m of elevation (a.s.l.). Past landforms and deposits are particularly well preserved because weathering processes are very limited.

In spite of these significant features, previous work has provided only limited morphological sketch maps (Cionchi, 1984; 1987; 1988; Schellmann and Radtke, 2000; 2003; 2010), and an extensive geomorphologic map is still lacking.

According to its latitudinal location and to the presence of the Andean Cordillera, the climate of Patagonia is characterized by two main meteorological elements: very strong winds and low precipitation (Coronato et al., 2008). Constant dry winds blow with great force from the west, particularly in the summer months, and aeolian erosion shapes rocky outcrops and deflates loose sediments.

The low amount of precipitation (<300 mm/yr) and moderate thermal amplitude allow the growth of a sparse cover of grass and shrubby vegetation, consistent with the semi-arid climate of Patagonia. The oldest rocky substrate, Complejo Marifil, consists of Jurassic rhyolites, ignimbrites and volcanoclastic conglomerates. It is often covered by thin to very thick debris deposits and crops out basically in current and paleo rocky shore lines, islands and cliffs (Figure 2).

Figure 2. Rocky shore platform in the Península Gravina.

Subordinate outcrops are represented by Paleocene marine deposits of the Formación Salamanca and the Paleocene continental deposits of the Formación Río Chico (Lema et al., 2001; Sciutto et al., 2000). The landward part of the area is characterized by the outcrop of a pediment surface covered by rounded volcanic pebbles and gravels in a sandy matrix, occasionally strongly cemented by carbonate.

Wave action is the most important morphoclimatic agent responsible for the past and present landscape. The area is characterised by a high-energy system with intense storms and a macrotidal regime. Unfortunately, tidal data are not available, but a tidal range >4 m can be reasonably assumed for most of the Patagonian coast.

This map is based on landform recognition via remote sensing analysis, supplemented by field surveys and ground control points. The landscape is dominated by outcrops of marine deposits, predominantly organized as series of sandy to gravelly beach ridges. They range from relatively small shore-parallel ridges tens of metres wide and a few metres thick to series of relict forms that are very large and thick. These latter may extend several kilometres inland rising to more than one hundred metres above current sea level. These deposits may occur in singular form often dissected by fluvial erosion, or as sets characterised by crests located at the same elevation (Figure 3). Their curvature varies from almost straight (in the higher and older forms) to very curved, tracking the variation of the shoreline geometry in time.

Figure 3. Holocene Beach ridge series in Península Aristizábal.

Marshes or swales generally separate ridges or sets of ridges. These depressed areas lying in a back-beach ridge position are characteristic elements of this region. They are remnants of old coastal lagoons locally known as “salitrales” (Figure 4) formed in dry evaporative environments by sandy silt and clay deposits including mineral deposits, such as gypsum, that locally form crusts. All these deposits are often reworked and dissected by fluvial activity.

The hydrographic network has an ephemeral character consistent with the arid characteristics of the region (Figure 5). The relatively flat landscape leads the streams to assume a meandering course that becomes rectilinear and parallel to the coast in the terminal sector, until an opening in the most recent beach ridges is reached, through which flow into the ocean is possible.

Fluvial deposits are widespread, and locally one or more terracing orders are present. Continental and marine deposits are often mixed, forming complex systems, and are locally covered by active aeolian deposits or pure dunes (Figures 6 and 7).

Marsh zones (Figure 8) are often present at the mouth of the main fluvial courses. From a sedimentological perspective they are characterized by sandy silts and clays with

Figure 4. Salitral near the village in Bahía Bustamante.

Figure 5. Section in marine deposits along the Cañadón Malaspina.

high concentration of organic material. Generally they are covered by typical halophyte plants.

Figure 6. Stabilized dune covers fluvial deposits in Cañadón Restinga.

Figure 7. Dunes in Península Aristizábal.

2. Methods

Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) at 90 m spatial resolution (NASA, 2010), ASTER GDEM DEM 30 m spatial resolution (ERSDAC, 2010), optical satellite imagery Landsat 7 ETM+ (30 m spatial resolution) and Quick Bird imagery (QB02 sensor and Pan_MS1 band, 0.6 m spatial resolution) were used as primary data sources.

Figure 8. Tidal area at Cañadón Restinga mouth.

Carta Topográfica de la República Argentina maps (1:100,000 scale) were used for elevation points and toponyms. Each set of images was converted to the Universal Transverse Mercator (UTM) projection (WGS 84 Datum, 20N zone). Geomorphological features were digitally drawn in a geographical information system (GIS) environment by analysing satellite images and shaded images derived from DEMs. Most of the mapping was performed using high resolution Quick Bird images; Landsat and shaded DEM images were used only where cloud cover intervened due to their low spatial resolution. Landforms were initially mapped at the maximum resolution allowed and then shown to a scale of 1:100,000 for printing.

Field surveys were carried out during January 2009, February 2010 and 2011. During these surveys a large number of global positioning system (GPS) control points were taken and the geomorphological interpretation from remote sensing data verified and validated.

The data are organized in a database with different vector layers, including 17 polygon feature classes for areal features (e.g., bedrock outcropping or deposits), three feature linear classes (e.g., ridges and scarps) and one point feature class for elevation points. Generally, each symbol is related to a specific form, but in some cases, forms with composite genesis are shown. Except for the evidently relict landforms (i.e. old beach ridges, elevated shore platforms), the state of activity of most of the features is uncertain due to the intermittence of processes and the difficulty of evaluation (even qualitative) via remote sensing analysis. For this reason, we decided not to indicate the state of activity on the geomorphological map. From a chronological perspective only a subdivision between Holocene and Pleistocene beach ridges has been possible. This distinction has been made by image interpretation and checked with chronological records from published (Schellmann and Radtke, 2000; 2003; 2010) and unpublished data.

Finally, edited polygons and vector lines representing landforms were draped on shaded images derived from SRTM DEM.

3. Conclusions

A thorough interpretation of satellite images allowed us to compile an extensive (more than 1,000 km^2) detailed geomorphological map of the northern San Jorge Gulf sector. Three field surveys validated the image interpretation, allowing us to produce with confidence a final landscape representation at 1:100,000 scale. The most widespread elements are marine deposits, organized as beach-ridge sets and spaced by lagoon remnants. Fluvial, lagoon and marine deposits are often mixed, forming complex systems, and are locally covered by active aeolian deposits. Owing to the arid climate and a low dynamic landscape evolution, this area preserves wide-ranging evidence of sea-level oscillations. The detailed mapping of these features represents a basic tool for further work focussed on paleogeographic reconstruction of this sector of the Patagonian coast, driven by palaeoclimatic variations, in a context of moderate coastal uplift and minimal anthropogenic influence. The approach adopted is transferrable to remote areas where vegetation cover is sparse and where the classical approach would be too long and expensive to be followed.

Software

Shaded relief of digital elevation models and digitization of features were performed using ESRI ArcGIS. Topographic maps were georeferenced using Terra Nova ShArc, satellite images were processed using PCI Geomatica, while conversions between different projections were carried out using Global Mapper 10. Polygons and lines representing landforms reduced on 1:100,000 scale were draped on shaded images derived from SRTM DEM. The final editing of the map was performed using ESRI ArcMap 10.

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