Geomorphologic Map of North East Sector of San Jorge Gulf (Chubut Argentina)

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Abstract

This paper presents a geomorphologic map of the North East sector of San Jorge Gulf (Chubut Province) in Patagonia Argentina at 1:100,000 scale covering more than 1,000 km^2. It is derived from remote sensing data and validated by three field surveys, 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 a very low rates of dynamic landscape change allow the preservation of extensive past deposits and landforms, included those referable to sea-level variations. The relative change of seal level leaded the 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 a consequent beach progradation.

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 understating climatic changes and tectonic uplift history in this area (Feruglio 1950,Codignotto et al., 1992; Rutter et al., 1990; Rostami et al., 2000; Shellmann and Radtke, 2000; 2003; 2010; Pedoja et al., 2010; Ribolini et al. 2011).

The studied area covers in detail the coastal geomorphology of the north east sector of San Jorge Gulf (Chubut Province). It extends more than 1,000 km^2 between the mouth of Cañadón Linyera and the Caleta Horno. (W 66°.50'- W 65°47' longitude S 44°.54' and S 44°51' latitude Fig. 1)

Here, an outstanding successions of raised beach deposits is exposed for a total area of more than 500 km^2 , extending up to 10 km landward and reaching 90 m of height (a.s.l.). Past landforms and deposits are particularly well preserved because weathering processes are very limited .

In spite of these significant features, previous works provided only limited morphological sketch maps (Cionchi 1984, 1987, 1988; Shellmann 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 precipitations (Coronato et al. 2008). Constant dry wind blows in fact with great force from the west, particularly in the summer months, and eolian erosion shapes rocky outcrops and deflates loose sediments.

The low amount of precipitation (< 300 mm/yr) and the moderate thermal amplitude allow the growth of a barely grass cover and sparse shrubby vegetation, consistent with the semi-arid climate of Patagonia.

The oldest rocky substrate, Complejo Marifil, consists of Jurassic rhyolites, ignimbrites and volcaniclastic 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 (fig. 2).

Subordinate outcrops are made by the Paleocene marine deposits of the Formacion Salamanca and the Paleocene continental deposits of the Formacion Rio Chico (Lema et al. 2001, Sciutto et al. 2000)

Wave action is the most important morphoclimatic agent responsible for past and present landscape. The area is characterised by a high energy system with intense storms and a macrotidal regime. Unfortunately, tides data are not available, but a tidal range > 4m can be reasonably supposed as most of the Patagonian coast. This map is based on landforms recognition inferred from remote sensing analysis integrated by field surveys and ground points control. The landscape is dominated by the outcrops of marine deposits, prevalently organized in sandy to gravelly beach ridges series. They range from relatively small shore-parallel ridges tens of metres wide and a few meters thick to series of relict forms very large and thick. These latter may extend several kilometres inland rising to more than one hundred meters above current sea level. These deposits may occur as single form often dissected by fluvial erosion or as set characterised by crest located at the same elevation (fig. 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.

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

Hydrographic network represented, by several streams (locally named Cañadón or Zanjòn), has an ephemeral character consistently with the arid characteristics of the region (fig. 5).

The relatively flat landscape leads the streams to assume a meandering course, that becomes rectilinear and parallel to the coast in the terminal part, until an opening in the most recent beach ridges is reached, and the flow into the ocean is possible.

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

Marsh zones (fig. 8) are often present at the mouth of the main fluvial courses. From sedimentological point of view they are characterized by sandy silts and clays with high concentration of organic material. Generally they are covered by typical halophyte plants.

Methods

SRTM digital elevation model (DEM) 90 m spatial resolution (Shuttle Radar Topography Mission Nasa 2010), ASTER GDEM DEM 30m spatial resolution (Aster, 2010), optical satellite imagery Landsat7 ETM+ (30 m spatial resolution) and Quick Bird imagery (QB02 sensor and Pan_MS1 band, 60cm spatial resolution) were used.

Carta Topografica de la Republica Argentina maps 1:100,000 scale, were used for elevation points and toponyms. Each set of images was converted in the UTM projection, WGS 84 Datum, 20N zone.

Geomorphological features were digitally drawn in GIS environment analysing satellite images and shaded images derived from DEM.

Most of mapping was performed using high resolution Quick Bird images, while Landsat and shaded images were used only in case of cloudily cover because of their lower 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 great number of GPS control points were taken and the geomorphological interpretation from remote sensing data was verified and validated.

Data are organized in a database with different vector layers including seventeen polygon feature classes for areal features, i.e. bedrock outcropping or deposits, three feature linear classes, i.e. ridges and scarps, and one points feature class for elevation points. Generally each symbol is related to a specific form, but in some cases, forms with composite genesis are shown. It was not possible to determine the status of activity of the

geomorphological processes present in the area by remote sense analysis so no information is assumed on it. From a chronological point of view only a subdivision between Holocene and Pleistocene beach ridges has been possible. This distinction has been made by images interpretation and checked with chronological records from published (Shellmann and Radtke, 2000, 2003, 2010) and unpublished data obtained thanks to the funding of the University of Pisa (Progetto Ateneo 2007) and MIUR (PRIN2008).

In final editing polygons and lines vectors representing landforms were draped on shaded images derived from SRTM DEM.

Conclusion

A strong interpretation of satellite images allowed to draw an extensive (more than 1,000 km^2) detailed geomorphological map of the northern S. Jorge Gulf sector. Three field surveys validated the images interpretation allowing to produce a final confident representation at 1:100,000 scale. The most widespread elements are marine deposits, organized in beach ridges sets and spaced out by lagoon remains. Fluvial, lagoon and marine deposits are often mixed forming complex systems, locally covered by current aeolian deposits. This area, thanks to the arid climate and a low dynamic landscape evolution, preserves a very wide evidence of sea level oscillations and the detailed mapping of these features represents a basic tool for further works focussed on paleogeographic reconstruction of this sector of Patagonian coast, driven by palaeoclimatic variations, in a context of a moderate coastal uplift and anthropogenic forcing. The approach followed to realize this map looks suitable for geomorphological mapping in remote wide areas where vegetation covers are rare and scattered and where the classical approach would be too long and expensive to be followed.

Software

Shaded relief of Digital elevation models and digitalization of features were performed using Esri products (arcGis ArcVew). Topographic maps were georeferenced using Terra Nova ShArc, Satellite images were processed using ENVI 3.6, while conversions between different projections were carried out using Global Mapper 10 software.

Polygons and lines vectors 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 Arc map 10

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Map Design

For better show the morphology of the area, polygons and lines vectors representing landforms were draped on shaded image derived from SRTM DEM and pictures showing the main morphologic features are included.

Figure 1 - Location of the study area

Figure 2 - Rocky shore platform in the *Peninsula Gravina*

Figure 3 - Holocene Beach ridge series in *Peninsula Aristizabal*

Figure 4 - *Salitral* near the Bahia Bustamante pueblo

Figure 5 - Section in marine deposits along the *Cañadón Malaspina*

Figure 6 - Stabilized dune covers fluvial deposits in *Cañadón Restinga*

Figure 7 - Dunes in *Cañadón del Linyera*

Figure 8 - Tidal area at *Cañadón Restinga* mouth

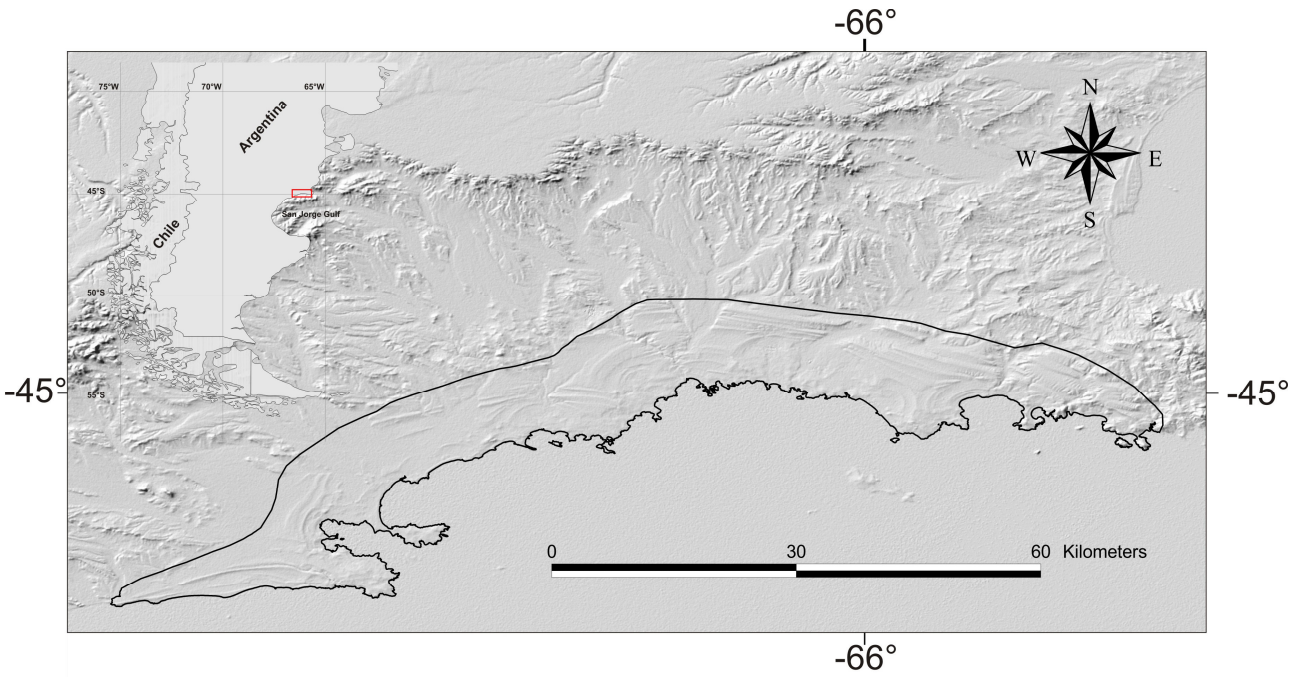

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

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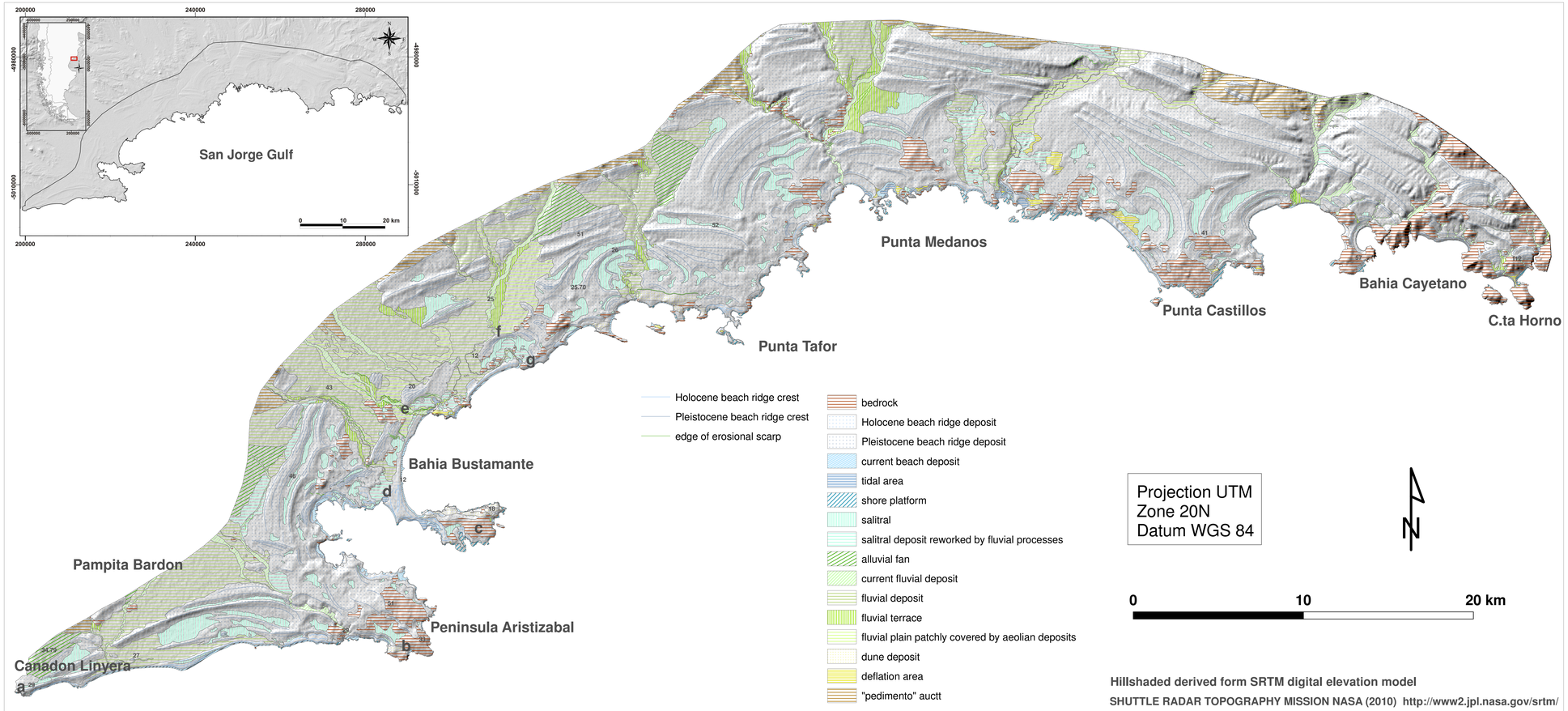
a - Holocene beach ridge series in Peninsula Aristizabal

b - Dunes in Peninsula Aristizabal



c - Rocky shore platform in the Peninsula Gravina

d - Salitral near Bahia Bustamante Pueblo

e - Section in marine deposits along the C. Malaspina

f - Stabilized dune covers fluvial deposits in C. Restinga

g - Tidal area at C. Restinga mouth

Founded by the University of Pisa (Progetto Ateneo 2007, Leader G. Zanchetta) and MIUR (PRIN2008, Leader G. Zanchetta).