# 4.4 Argentina

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## 1. Introduction

The coastline of Argentina is about 5,700 km long, with coastal landforms shown in (*Fig. 4.4.1*). The coastal geology ranges from a fairly stable area in the north to a generally rising area in Patagonia and tectonically-affected coasts in Tierra del Fuego. A continental shelf, in places, over 800 km wide, is covered by terrigenous sediment accumulated during Quaternary sea level oscillations.

Pebbles are a common component of Patagonian beaches, but sandy beaches are typical along the coast from Cabo San Antonio to Mar Chiquita lagoon, and along the southern Buenos Aires barrier coast. Salt marshes are present along the mostly macrotidal Patagonian coast, and on mesotidal areas, with extensive development in Bahía Anegada and Bahía Blanca, where freshwater influence is absent except for river outlets. Brackish marshes with freshwater mixing are found in the northeastern sector of Buenos Aires Province (Samborombón Bay, Mar Chiquita Lagoon). Cliffs are extensive on the Patagonian coast, but the Buenos Aires (Pampas) coastline alternates between low-lying and cliffed areas.

Evidence that the sea stood at higher levels during Pleistocene interglacial phases and the postglacial Holocene is seen on the Argentine coast as beach ridges, marine terraces and estuarine deposits, in most cases hosting a molluscan fauna which has enabled dating of the deposits. In many low-lying areas with marshes evidence of Quaternary emerged shorelines is found, and salt marsh development is strongly related to the postglacial sea level fluctuation.

The climate of the Argentine coast is cold and humid in Tierra del Fuego, arid and semi-arid from Rio Gallegos to Bahia Blanca and temperate-humid from there to the Paraná Delta. Predominant wave directions for the Argentine coast are S, SE and E, with wave periods between 6 and 16 s, the latter corresponding to ocean swell approaching from the south. There are stormy periods with waves up to 5 m high along the eastern Tierra del Fuego and on the Buenos Aires Atlantic coast.

Tides along the Atlantic coastline and on the Rio de la Plata are predominantly semidiurnal. Tide ranges are large (megatidal) on the east coast of Tierra del Fuego and along most of the Patagonian coast, with maximum spring amplitudes reaching more than 10 m at San Sebastian Bay (Tierra del Fuego), and about 10 m in Magellan Strait, at Rio Gallegos and at Punta Loyola (Santa Cruz province). Puerto Gallegos has 10.4 m, Puerto Santa Cruz 9.5 m, and Bahia Oso Marino 9.2 m. Mesotidal environments are present from the area north of the Rio Negro outlet (3.3 m at Punta Redonda) to Monte Hermoso, near Bahia Blanca. From there northward the coast is typically microtidal: Mar del Plata has 1.1 m and Buenos Aires 1.0 m.

Many storm surges have been recorded along the Argentine coast simultaneously with the northward travelling tidal wave. The duration of these storm surges ranges from a few hours up to 2 or 3 days. They are basically produced by the combined action of an anticyclone located to the west of Argentina (semi-permanent Pacific anticyclone) and a cyclone located over the Atlantic to the SE of Argentina, the latter moving towards the east or northeast. Because of this situation, strong winds from the south or southeast and high water levels affect the whole Argentine coast, as well as the Rio de la Plata shores.

Erosion is in progress on the sandy barriers of northern Argentina, particularly when a storm surge coincides with high spring tides. Storm surges are considered the most significant natural agent for coastal erosion on the eastern coast of Buenos Aires, and the Rio de la Plata area.

Historical mean sea level trends studied from tide gauge records (Lanfredi et al. 1998) show a rise of 1.6 ± 0.1 mm/year over 70 years at Buenos Aires, 1.4 ± 0.5 mm/year for Mar del Plata and 1.6 ± 0.2 mm/year for Quequén. Recent calculations for Buenos Aires and Mar del Plata over an extended period show a coincidental rise in sea level of ~1.6 mm/year (Pousa et al. 2007; D'Onofrio et al. 2008).

## 2. The Argentine Coastline

The southernmost coast of Tierra del Fuego (northern Beagle Channel coast and southern Atlantic coast) extends for 220 km from west to east. It is an indented rocky coastline with pocket gravel beaches in embayments.

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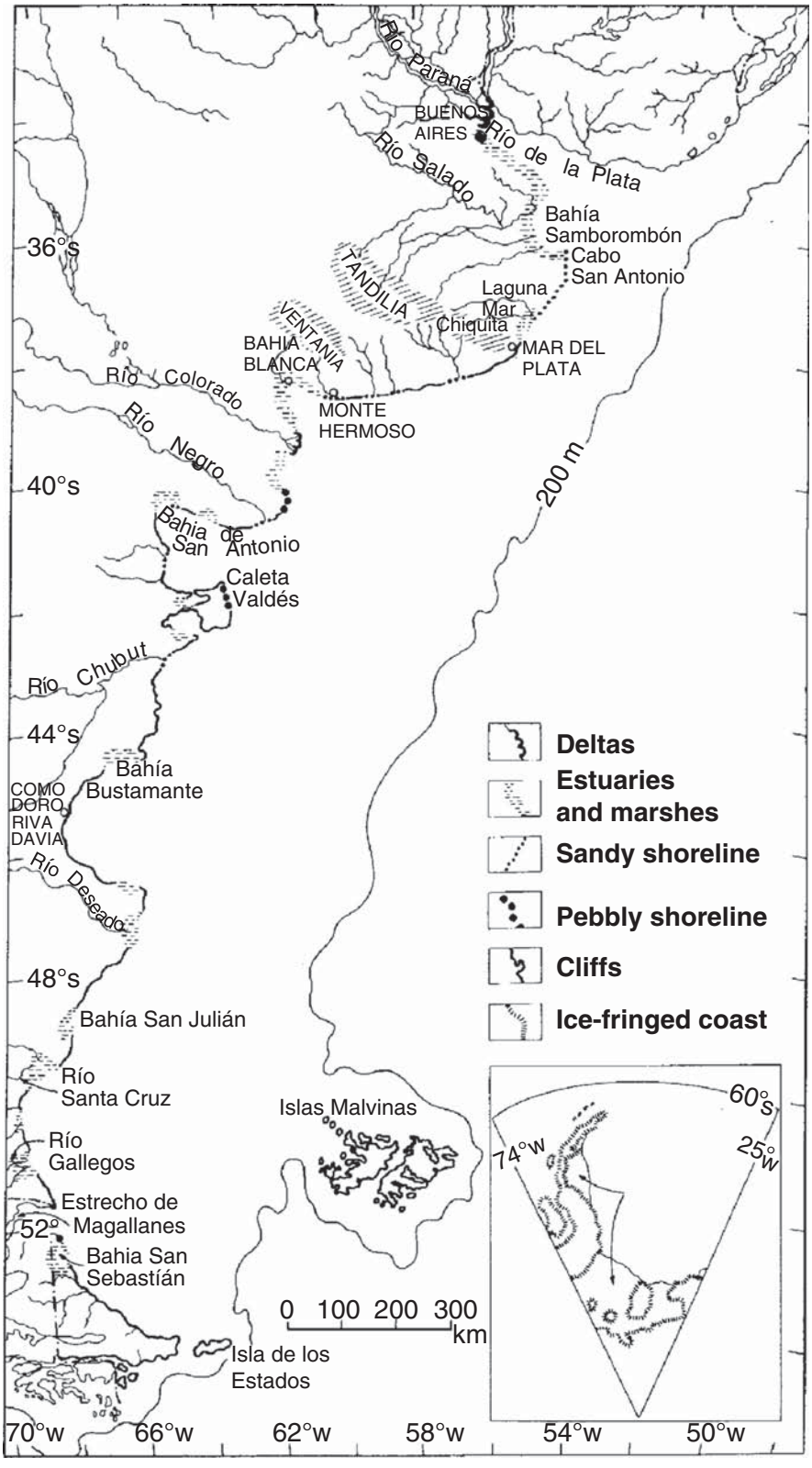


**Fig. 4.4.1**
**Predominant landforms on the Argentine coast.**

The channel is 5 km wide, its average depth between 100 and 450 m. Holocene raised beaches occur at various elevations along the southern coast.

The Beagle Channel is a tectonic trough that was completely covered by ice during the Last Glaciation and occupied by a glacial lake at about 9,400 BP. It was invaded by the sea at about 8,200 BP and the marine environment was fully established along the channel by at least 7,900 BP, with a maximum sea level attained between 6,000 and 5,000 years BP (Rabassa et al. 2000; Bujalesky 2000).

The Beagle Channel is an estuarine (fiord) system controlled by significant and seasonal freshwater input and by tidal inflow from both west (Pacific) and east (Atlantic). The channel is microtidal with a semi-diurnal regime. Mean tide range is 1.1 m at Ushuaia and the tidal wave moves from west to east. The embayments of the indented rocky coastline of the Beagle Channel are related to tectonic alignments affected by successive glaciations, and are occupied by small gravelly pocket beaches.

Along the Beagle Channel Holocene raised beaches stand up to 10 m above mean sea level, and are often capped by anthropogenic shell middens. The oldest Holocene coastal deposits may be partly the result of isostatic recovery while the younger levels are due to recent tectonic uplift. The Bahía Lapataia-Lago Roca valley (20 km west of Ushuaia) is a palaeofjord that was occupied by a lateral and tributary valley glacier during the Last Glacial maximum (about 18,000–20,000 years ago). Well-rounded glacially moulded rocky hills (roches moutonnées), lateral moraines and kames are present in this area and Sphagnum peat bogs occupy the lowlands. Holocene marine depositst are scattered along Bahía Lapataia, Archipiélago Cormoranes, Río Ovando, Río Lapataia and the eastern coastline of Lago Roca, overlying glacial landforms and reaching a maximum altitude of at least 8.4 m above mean sea level (Bujalesky 2000).

The eastern (Atlantic) coast of Tierra del Fuego extends for 330 km from SE to NW. It is macrotidal to megatidal, and exposed to high energy waves and strong westerly winds. Extensive wide beaches are composed of gravel and coarse sand. Pleistocene glacial drift deposits form high cliffs in its northern section, and these and other submerged glacial deposits have supplied sediment to beaches. There are gravelly beaches and a narrow Holocene gravelly beach ridge plain (250 m wide) runs between Cabo Domingo and the Río Grande inlet, attached to the base of an Upper Pleistocene marine terrace.

In the northern part of the coast San Sebastian Bay is a semicircular embayment (55 km by 40 km) occupying a wide depression formed by glaciers during the Pleistocene and reshaped by the sea during the Holocene transgression. It includes a fossil marsh, the upper marsh, controlled by deflation and dominated by Salicornia sp. scattered on the mudflat, and Spartina grass progressively buried on the windward sides, gravel ridges and cheniers. The mudflat occupies much of the tidal flat. At low tide meandering tidal channels are seen. Península El Páramo is a 20 km long gravel spit barrier that partly shelters San Sebastián Bay.

Cliffs extend 40 km from Cabo Nombre (10 m high) to Cabo Espíritu Santo (90 m high) in the northern part of Tierra del Fuego. They are cut in glacial drift deposits and Tertiary silty sands. At Punta Sinaí is an extensive erratic boulder field, and erratics can be seen on the beaches.

In Patagonia most of the estuaries (with the exception of the Chubut, Negro and Colorado rivers) have low discharges, and tidal processes are very active at their outlets. Beaches are typically gravel-dominated, showing at times several ridges on the backshore and on the beach face (*Fig. 4.4.2*). In some protected embayments, the coarse substrate carries marsh vegetation (*Fig. 4.4.3*).

Patagonian gravels extend over the whole region. They have been reworked by marine action at various higher sea levels and are typical of the Pleistocene and Holocene raised beaches as well as the modern shore deposits, which contain varying proportions of sand. Much of the coast has cliffs (*Fig. 4.4.4*), cut in Tertiary continental and marine deposits and Jurassic volcanic rocks, and there are many embayments. Evidence of Pleistocene and Holocene high sea level stands extends along the coast, where six marine terraces, at least three of which are of Quaternary age, have been recognised. The most recent (Holocene) reaches an altitude of 8–12 m above mean sea level and extends from eastern Tierra del Fuego to northern Patagonia.

The coast of Península Valdés has cliffs and shore platforms cut in Miocene sedimentary rocks, and the Caleta Valdez lagoon is bordered by a series of Pleistocene emerged gravelly beaches (Schellmannn and Radtke 2003). Marshes are found in some protected low energy environments. Except for the northern (Río Negro-Bahia San Blas) marshes, which are mesotidal, the Patagonian wetlands are mostly macrotidal. They are present either in estuaries (Chubut, Deseado, Santa Cruz, and Gallego Rivers, and in NE coast Tierra del Fuego) or within sheltered coastal bays. Some of the marshes are eroding, exposing peaty microcliffs.

San Antonio Bay, which has a maximum spring tide range of 9 m, is bordered by pediments, hollows, Pleistocene and Holocene coastal and marine deposits and

**Fig. 4.4.2**
**Gravel beaches and berms near Bahía San Julián (Santa Cruz, Patagonia).**

**Fig. 4.4.3**
**Salt marsh vegetation on a gravelly beach near Bahía San Julián.**

marshy environments (Schnack 1985). Extensive sandy shoals are exposed at low tide at the outer part of the bay. There are slumping cliffs up to 8 m high in Miocene sediment at Las Grutas.

The coast from San Antonio Bay to the mouth of the Rio Negro has alternations of beach and dune-fringed low coasts and cliffs. The Rio Negro estuary has a mesotidal regime. Two shoals (Banco Miguel and Banco La Hoya)

**Fig. 4.4.4**
**Cliff and abrasion platform at Peninsula Valdés.**

form an ebb delta composed of well-sorted fine sand. The assymetry of the delta is mainly due to northward longshore drifting.

From the Rio Negro estuary to the Rio Colorado delta the coast is predominantly low-lying, except for cliffs immediately south of San Blas. Pebbly beach ridges of Holocene and Pleistocene age are also present near San Blas. The Rio Colorado is generally regarded as the northern limit of coastal Patagonia.

The south Buenos Aires (Pampas) coast extends from Bahia Blanca to the Paraná river delta. The mesotidal Bahía Blanca estuary is formed by several channels oriented NW-SE and separated by extensive tidal flats and islands.

The area between Bahía Blanca and Bahía San Blas may have formerly been part of the delta of the Río Colorado, and the tidal flats are derived sediment. Mesotidal beaches, typically sandy, extend from Monte Hermoso towards Miramar, alternating with cliffs (Isla et al. 1996). In low-lying areas, such as Claromecó and Quequén there is evidence of Pleistocene and Holocene high sea levels.

North and south of Mar del Plata high cliffs cut in Plio-Pleistocene sediment are retreating rapidly, at times reaching 1–2 m/year. At Mar del Plata the cliffs are in more resistant Lower Palaeozoic quartzites. From Mar Chiquita beach and tidal inlet north to Punta Rasa is a low-lying coastal plain, with dunes on a major coastal barrier. The geological substratum of this segment consists of Holocene estuarine and marine deposits, although evidence of former Pleistocene sea levels is also found. At Mar Chiquita these deposits are well developed, with shelly beach ridges and the lagoon marginal flat built on the estuarine deposits. Following a maximum sea level stand of about 2.5 m above present level about 6,000 years ago the sea fell, and a southward-prograding barrier enclosed the Mar Chiquita lagoon. The tidal inlet has shown northward migration interrupted several times by human intervention. Severe erosion is occurring at Mar Chiquita beach immediately south of the inlet. Extensive dunes along the coast north of Mar Chiquita are in many places fixed and urbanised.

Wave energy generally diminishes along the coast from Mar del Plata to San Clemente del Tuyú, but at Punta Médanos larger waves are due to the nearshore presence of linear sand ridges oriented SSE 30° to the coastline, which concentrate wave energy. These ridges continue south beyond Pinamar. At Mar de Ajó mean wave heights are 0.68 m, whilst maximum annual wave heights are 1.31 m.

Erosion has lately dominated the Buenos Aires coastline northward to the Mar Chiquita lagoon. The southern beaches (Mar del Plata, Santa Clara, Mar de Cobo) are typically reflective, while the beaches at Villa Gesell, Pinamar and Partido de la Costa generally have a dissipative profile with the development of sand bars. In those areas where there is no human pressure, as in Mar Azul (south of Villa Gesell), or where sediment transport is blocked by a hydraulic barrier, as at San Clemente del Tuyú, beaches are accreting with backshore dunes (*Fig. 4.4.5*). At Mar del Plata and other sites, the emplacement of sea walls, jetties and piers is responsible for erosion along the littoral drift direction.

Dune fixation by vegetation, traditionally considered beneficial, has been claimed to be responsible for alteration of the sediment supply to the beach.

A transitional zone extends for more than 100 km at Samborombón Bay, in the central part of the Salado depression and part of the Río de la Plata system. The hinterland is a low-lying portion of the Pampas Plain, occupied by Pleistocene and Holocene coastal and marine deposits. At Samborombón Bay a brackish marsh is present behind an extensive mudflat. From Punta Piedras to Buenos Aires the Río de la Plata coast runs SE-NW and the coastal plain is up to 8 km wide. rising to about 5 m.

**Fig. 4.4.5**
**Stable or accreting beach on the NE barrier of Buenos Aires at Mar Azul, south of Villa Gesell.**

**Fig. 4.4.6**
**Storm surge damage at Mar del Tuyú.**

It formed during the mid-Holocene maximum sea level stand around 6,000 years BP (Cavallotto et al. 2005) and the subsequent emergence.

The coastal plain is composed of Holocene beach ridges, marshes and fresh-water wetlands, with a levee of estuarine sediment on the coastal fringe. It is backed by a high terrace on continental sediment, mainly loess-like silts. The inner boundary of the coastal plain is the mid-Holocene high sea level coastline.

The Río de la Plata has an area of about 35,000 sq km and a drainage basin (Paraná and Uruguay Rivers) of more than 3 million sq km. The estuary receives large amounts of dissolved and suspended solids and organic carbon. The sediment is largely from the Paraná River, mainly as suspended load but also as bed load, and forms a delta of 18,000 sq km. The sediment in the estuary consist mainly of silty clays with some sand from the Paraná river, while the yield From the Uruguay River is sandy.

Coastal plain flooding due to storm surges can be particularly destructive in areas where topographic gradients are extremely low, as on the Río de La Plata shores and in the Salado basin. Storm surges are regarded as the most important morphodynamic factor in coastal development along this area (*Fig. 4.4.6*).

It is widely accepted that a global sea level rise is causing impacts on coasts, and an accelerated sea level rise would certainly exacerbate coastal erosion and flooding in Argentina. The most vulnerable areas are the Río de la Plata, including the Paraná delta and the estuarine coastal plain, already exposed to frequent storm surges, and the sandy coastline extending from Mar del Plata to Punta Rasa, close to Samborombón Bay, where there is already severe erosion. It is likely that other areas such as Samborombón Bay and some estuaries would be affected by an increasing sea level, depending on its magnitude and the interaction with other, human and climatic variables.

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