Landscape Evolution of Southern Patagonia

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ABSTRACT

Investigations have been focused on the glacial history and valley development in the region of the terminal basins Lago Argentino, Lago Viedma and the adjacent Río Santa Cruz and Río Shehuen Valleys, as well as on the stratigraphic classification and absolute chronology of Middle and Late Quaternary coastal deposits along the Atlantic coast of Patagonia from the Península Valdés in the north to the Bay of San Julián in the south. They indicate that characteristics of Late Miocene and Early Pliocene times were the deposition of the widespread Patagonian Gravel formation and the main epirogenic uplifting, as well as the fluvial incision down to ca. 110 m above the recent valley floors, and that the oldest Andean foreland glaciations extended to the east as far as the major Pleistocene ones. Along the Patagonian Atlantic coast, which is characterized by a slow uplift trend, coastal terraces of Middle and Late Quaternary age are preserved in different elevations, probably as results of eustatic sea-level oscillations.

RESUMEN

El área de estudio abarca la región de los lagos Argentino y Viedma, las cuencas fluviales de los ríos Shehuen y Santa Cruz, así como la costa patagónica atlántica desde Península Valdéz hasta Bahía San Julián. Los resultados obtenidos indican la existencia de glaciaciones terciarias (Mioceno tardío-Plioceno temprano) y de seis glaciaciones cuaternarias de piedemonte. Los rodados patagónicos son muy anteriores a los 3.5 Ma mientras que la incisión fluvial más importante se produjo durante el pulso de ascenso epeirogénico anterior al Plioceno tardío. Asimismo se encontraron diferentes generaciones de cuñas de hielo. En la costas, los sistemas de cordones litorales son el resultado de cambios eustáticos del nivel del mar con una moderada tendencia al levantamiento de la costa desde el Pleistoceno medio.

Introduction

■ The general knowledge of the Late Cenozoic landscape evolution of Southern Patagonia has recently been increased by more detailed morpho-, pedo- and chronostratigraphic investigations. Special emphasis was put on glacial history, valley development and stratigraphic classification as well as on absolute chronology of Middle and Late Quaternary coastal deposits along the Atlantic coast of Patagonia from the Península Valdés in the north to the Bay of San Julián in the south (Fig. 1). Details are published in SCHELLMANN (1998), RADTKE (1989), RUTTER et. al. (1990), TROMBOTTO (1998), WENZENS (1999).

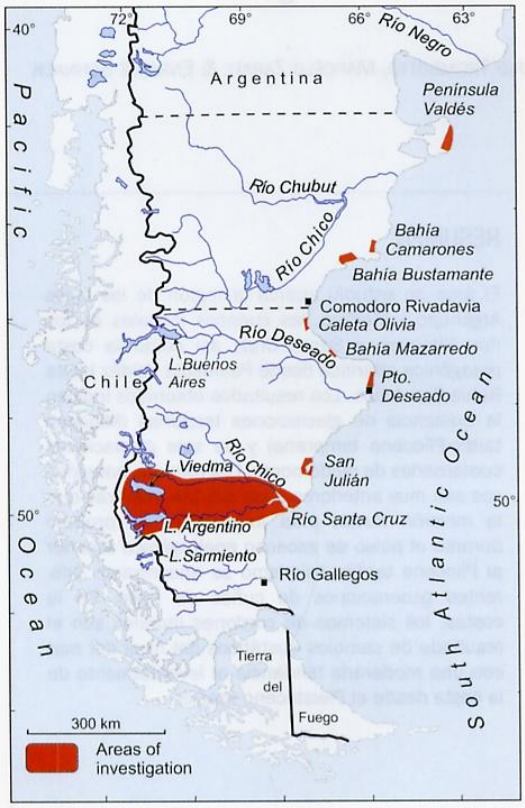


Fig. 1:
Areas of investigation.

General landscape evolution and glacial history east of the Southern Patagonian Andes since the Late Miocene

The study area covers the terminal basins of Lago Argentino and Lago Viedma and the adjacent Río Santa Cruz and Río Shehuen Valleys. Concerning the general landscape evolution and glaciation history of Southern Patagonia east of the Andes (Tab. 1), the following main conclusions can be drawn. The widespread deposition of the so-called Patagonian Gravel covering the mesetas on both sides of the Río Santa Cruz valley took place long before the Late Pliocene (before 3.5 Ma), but definitely after the deposition of predominantly fine-clastic molasse-sediments of the Late Middle Miocene Santa Cruz Formation (after 14 Ma). No evidence was found confirming either a fluvioglacial origin or a connection with an Early Pliocene pediment glaciation on the eastern Andean side.

A major epirogenic uplift of the eastern parts of the South Patagonian Andean foreland and of vast areas of the Atlantic coast occurred after the deposition of the Patagonian Gravel on the meseta plains and before the Late Pliocene (Tab. 1). During this time of uplift, the area experienced its main period of valley development and fluvial incision. Three and a half million years ago, the Río Santa Cruz was situated only 110 m above the recent valley floor. Thus, more than three quarters of the present valley depth is the result of fluvial incision before the Late Pliocene. Therefore, it is most likely that the preceding extensive deposition of Patagonian Gravel occurred in the early stages of the Early Pliocene, and during the Late Miocene.

Glaciogenic deposits of an early Late Pliocene or a Late Miocene/Early Pliocene piedmont glaciation are preserved in the upper Río Santa Cruz valley near Cóndor Cliff underlying 3.5 Ma old basalt flows (Tab. 1). These can be found on the uppermost parts of the valley slopes and more than 100 m below the adjacent meseta plains covered by the Patagonian Gravel. In the Lago Argentino and Lago Viedma area, Late Miocene/Early Pliocene glaciations extended to the East as far as the major Pleistocene glaciations.

K/Ar datings indicate that most of the basalt flows covering the meseta plains on both sides of the upper Río Santa Cruz valley, and some fluvial terraces near the valley floor date back to Late Pliocene times. In this area, the main period of basaltic volcanism was active around 2.5–3.5 Ma ago (Tab. 1). The eruption centers were located along NW–SE orientated fault zones. Tephra layers consisting of basaltic lapilli and interlayered between older Pleistocene glaciogenic sediments indicate that single eruptions happened here at least until the Early Quaternary.

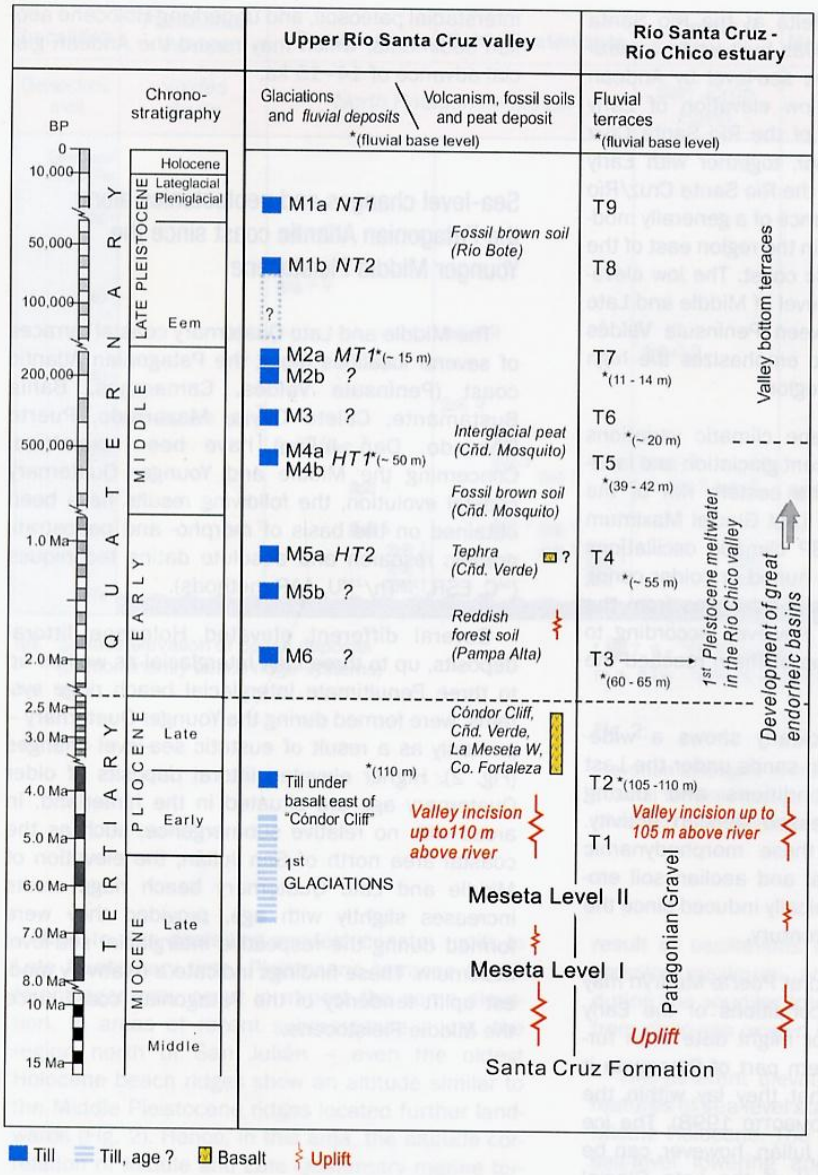


Table 1:

Late Cenozoic landscape development in the Lago Argentino – Río Santa Cruz area – a stratigraphical overview (modified after SCHELLMANN 1998).

All the glacial landforms known in the study area are younger than the Late Pliocene volcanism and its widespread layers of basaltic flows. During the last 2.5 million years, at least six distinctive and extensive piedmont glaciations took place (Tab. 1) with their oldest and most extensive reaching as far as 83 km east of the Last Glacial terminal basin of Lago Argentino. The glacier catchment areas were located not only in the Southern Patagonian Cordillera but also in the sub-Andean mesetas and sierras with altitudes of more than 1,400 m above sea-level. The different extent and ranges of Pleistocene piedmont glaciations can be explained by the general increase of fluvial erosion and glacial broadening of the Lago Argentino terminal basin. Furthermore, the larger expansion of the Early Pleistocene piedmont glaciations might have been a result of more humid climatic conditions. According to paleopedological and palynological findings at least the Early Quaternary interglacial intervals were more humid and probably warmer than the recent interval.

In the Quaternary, the delta at the Río Santa Cruz/Río Chico confluence was built up to a maximum height of 75 m above sea-level by Andean meltwaters. The relatively low elevation of Early Pleistocene fluvial terraces of the Río Santa Cruz above the recent valley floor, together with Early Quaternary river deposits in the Río Santa Cruz/Río Chico delta (Tab. 1) are evidence of a generally modest rate of Quaternary uplift in the region east of the Andes and up to the Atlantic coast. The low elevation above the modern sea-level of Middle and Late Quaternary coastlines between Península Valdés and Bay of San Julián, also emphasizes the high neotectonic stability of the region.

Late Glacial and Holocene climatic variations have controlled the most recent glaciation and landform development along the eastern rim of the Andes since the end of the Last Glacial Maximum (LGM). Since ca 14,000 BP climatic oscillations including either some more humid or colder conditions induced different glacial advances from the South Patagonian Icefield. However, according to the present knowledge, none of them reached the Andean foreland.

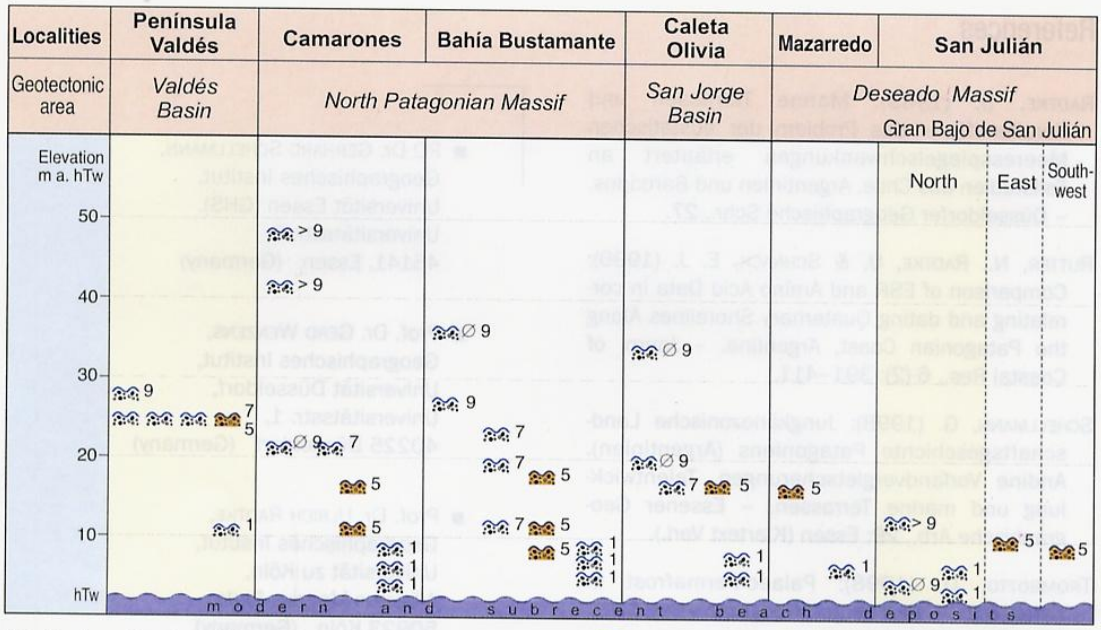
Paleopedological data clearly shows a widespread deposition of aeolian sands under the Last Pleniglacial cold arid conditions and during Holocene phases of increased aeolian activity. Further intensification of these morphodynamic activities, in terms of fluvial and aeolian soil erosion, has been anthropogenically induced since the beginning of the twentieth century.

Ice wedge casts identified at Puerto Madryn may represent extremely cold conditions of the Early Pleistocene "Initioglacial" or might date even further back, but in the northern part of Patagonia it can definitely be stated that they lay within the Patagonian Gravel (e.g. TROMBOTTO 1998). The ice wedge casts of Puerto San Julián, however, can be assigned to the Pleniglacial of the Late Glacial (Pleniglacial of the last glaciation, LGM). Based upon their stratigraphical, morphological and sedimentological characteristics, they correlate very well with those found at Holdich – Pampa del Castillo (Chubut) and at Las Heras, Kensel and Romberg in northern Santa Cruz (46 °S approx.). Whereas at Romberg one generation of ice wedge casts can be assigned to the Pleniglacial of 18–20 ka (to be confirmed by absolute datings), an even older generation is found below under a solifluction layer. Various profiles exhibit a solifluction layer overlying the Pleniglacial ice wedge casts and an interstadial paleosoil, and underlying Holocene aeolian sediments, which may record the Andean glacial advance of 14–15 ka.

Sea-level changes and neotectonics along the Patagonian Atlantic coast since the Younger Middle Pleistocene

The Middle and Late Quaternary coastal terraces of several localities along the Patagonian Atlantic coast (Península Valdés, Camarones, Bahía Bustamante, Caleta Olivia, Mazarredo, Puerto Deseado, Dan Julián) have been examined. Concerning the Middle and Younger Quaternary coastal evolution, the following results have been obtained on the basis of morpho- and pedostratigraphic research and absolute dating techniques (^{14}C, ESR, $^{230}Th/^{234}U$, AAR methods).

Several different elevated Holocene littoral deposits, up to three Last Interglacial as well as up to three Penultimate Interglacial beach ridge systems, were formed during the Younger Quaternary – primarily as a result of eustatic sea-level changes (Fig. 2). Higher elevated littoral deposits of older Quaternary age are situated in the hinterland. In areas with no relative submergence, such as the coastal area north of San Julián, the elevation of Middle and Late Quaternary beach ridge crests increases slightly with age, provided they were formed during the respective interglacial sea-level maximum. These findings indicate a relatively modest uplift tendency of the Patagonian coast since the Middle Pleistocene.



Surface elevation of beach deposits (predominantly beach ridge systems)

1, 5, 7, 9 - $^{16}O/^{18}O$ stages
m a. hTw - meters above highest tide water level

Fig. 2:

Elevation and ages of Middle and Late Quaternary coastal terraces along the Patagonian Atlantic coast (modified after SCHELLMANN 1998).

Due to this prevailing modest coastal uplift in Late Quaternary time, Pleistocene terraces of different ages may occur in almost the same elevation. In areas of recent submergence – e.g. the region north of San Julián – even the oldest Holocene beach ridges show an altitude similar to the Middle Pleistocene ridges located further landwards (Fig. 2). Hence, in this area, the altitude correlation of Middle and Late Quaternary marine terraces is even less viable than in tectonically more stable areas of the Patagonian coast further north.

Sea-level oscillations during Holocene, Last Interglacial and Penultimate Interglacial highstands and regression phases created several beach ridge systems of decreasing ages and elevations. Because of the low temporal resolution of ESR and Th/U dating methods on fossil mollusc shells it cannot be determined whether the Late and Penultimate Interglacial beach deposits are the result of oscillations during the regressive transgression maximum, or whether they were formed during the younger Interglacial submaxima, known from deep-sea oxygen isotope curves.

The different elevated Holocene shorelines are features of sea-level stability periods since the Early Middle Holocene. The general tendency of relative sea-level lowering apparently lasting up to the recent past, was interrupted by at least one short phase of relative sea-level rise during the older Subatlantic period.

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