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# A preliminary study of sediment cores from Lago Argentino and fluctuations of Moreno Glacier, Patagonia

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**Abstract**

Piston cores recovered from the southwestern arm (50°32.5′S, 72°52′W) of Lago Argentino allowed to study the behavior and timing of recent Moreno Glacier snout oscillations. Sedimentary signals were recognized, indicating floods which were related to ice-damming in the basin since 1917 due to small changes in the position of Moreno Glacier terminus. Also pyroclastic deposits assigned to three major Late Holocene volcanic events were identified. In spite of the preliminary sampling, there is palynologic evidence in the recent sediments, suggesting the late expansion of the lacustrine system and the decline of the forest during the current century.

## 1. Introduction

This research project is focused on the oscillations of Moreno Glacier snout by means of the sedimentary signals observed in the Brazo (Lago) Rico-Brazo Sur (BR-BS) lacustrine system, the southwestern branch of Lago Argentino (50°15′S, 72°30′W), southern Andean Patagonia (Fig. 1). Lago Argentino is a large glacier-fed lake located on the east side of the Southern Patagonia Icefield (SPI), at an elevation of about 180 m a.s.l. It drains into the South Atlantic Ocean through the Santa Cruz River. The BR-BS system is a relatively minor lacustrine basin, connected to the main lake body by a narrow channel, which is formed intermittently between the Magallanes Peninsula and Moreno Glacier (Fig. 1), according to the position of the glacier front.

Moreno Glacier, calving into Lago Argentino, is one of the major SPI outlet glaciers. It is well known for repeated impoundment of the BR-BS system by closing the channel between the Brazo Rico and Canal de los Tĕmpanos. The higher water level due to the ice-damming had caused floods in the catchment area of BR-BS, which were well documented since the beginning of the 20th century.

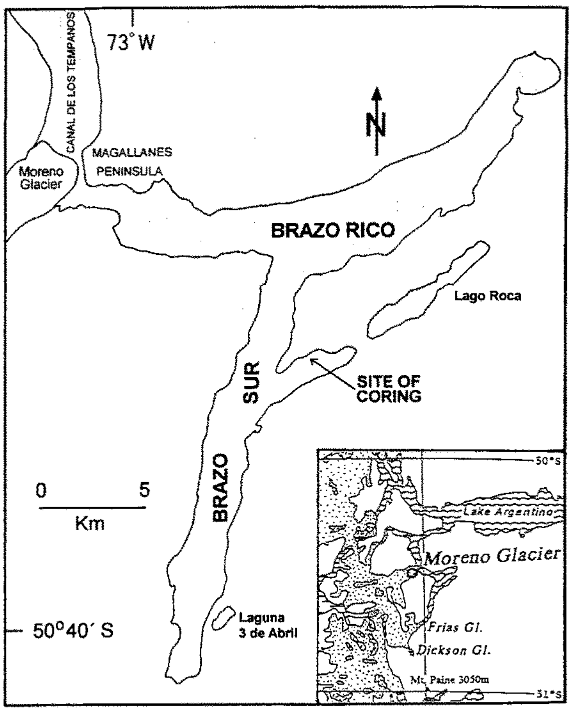


Fig. 1. Lago Argentino : Brazo Rico-Brazo Sur lacustrine system.

In 1899 the glacier front was located some 750 m off the Magallanes Peninsula (Heim, 1951; Nichols and Miller, 1952). Then the glacier started advancing and it was 1917 when the first ice-damming in the present century was recorded. Since 1917, the fluctuations of Moreno Glacier terminus have caused impoundment of the BR-BS lacustrine system at least 16 times (Nichols and Miller, 1952 ; Raffo *et al.*, 1953 ; Chiesa, 1994). Recently Aniya and Skvarca (1992) described in detail the variation of the glacier front between 1947–1986, based on aerial photographs and satellite imageries, concluding that the maximum terminus fluctuations during this 40 year period were about 500 m. Table 1 lists the recent main ruptures of ice-dams.

The normal sedimentary processes occurring in the BR-BS basin during the Late Holocene were intermittently interrupted during floods, producing a sequence of alternating normal-mud and flood-sediments with fine grains. Additionally, the sedimentary sequence accumulated in the BR-BS basin records the main changes that occurred in the Late Pleistocene scenario. The sediments contain also valuable information on the early formation of the lake, coincident with the main deglaciation in the region, and the Late Pleistocene-Holocene post-glacial fluctuations of Moreno Glacier.

## 2. Methods

Four piston cores from Brazo Sur (50°32.5′S, 72°52′W) were recovered during a period from December 5 to 8, 1993. Of these, the Cores II (about 13 m long) and IV were selected to perform preliminary analyses.

The grain size and organic matter content are still being analyzed in order to characterize in detail the sediments. Searching for all the relevant geological and biological evidence, geochronological methods including paleomagnetism, tephrachronology, thermoluminiscense and radiocarbon dating are used ; also geochemical and micropaleontological methods such as detailed palinologic studies as well as pigments, ostracoda, chironomids, chrysophytae, diatoms and actinomycetes analyses are currently being performed. Four samples were selected to carry out radiocarbon ($^{14}C$) dating. The samples were sent to a conventional radiocarbon laboratory (Teledyne Brown Engineering). However, due to the small amount of carbon in the samples, the AMS method is recommended.

Photographic close-ups of the cores were enlarged to 13.5 cm×23.5 cm prints that were utilized to count varves and to measure their thickness. The clay layers were utilized to define the varve boundaries. Additional measurements using X-ray images of core sections were carried out. For statistical studies, the mean values of the upper part in Cores II and IV, where the lamination was best preserved, were used.

The final results will be published in the near future. Concerning the topics mentioned above, only the preliminary results are given in this paper.

## 3. General description of cores

The identification of the sedimentary signal in the upper part of the cores, indicating recent floods due to ice-damming, is an important step for this preliminary study (Fig. 2). The tentative correlation between the sequence of floods and the uppermost sediment sequence of the cores was examined, in order to identify the different sedimentary processes that occurred during the normal and flood periods (Fig. 3). The left part of Fig. 3 shows the vertical distribution of sediments accumulated approximately during the last 77 years ; the thin (1 mm) light-greenish layers intercalated with the normal rhythmites probably depict the sedimentation due to the major flooding. The series (Fig. 3) record only the major events ; some partial and/or minor impoundments of short duration (i.e. between 1966–1970) were caused by slight readvances of Moreno Glacier, with no significant floods (Chiesa, 1994).

Six palynologic samples from the upper 60 cm of

Table 1. Ruptures of ice-dams in BR-BS lacustrine basin*

| |
|---|
| 1917 : First documented ice-damming and rupture (Fig. 3) |
| 1935, 1940, 1942, 1947, 1952, 1953, 1956 : GROUP 2 (Fig. 3) |
| 1966, 1970, 1972, 1975, 1977, 1980, 1984, 1988, 1990? (last? ice-damming) : GROUP 3 (Fig. 3) |

*Compiled from Nichols and Miller (1952), Raffo *et al.* (1953), Aniya and Skvarca (1992), and Chiesa (1994).

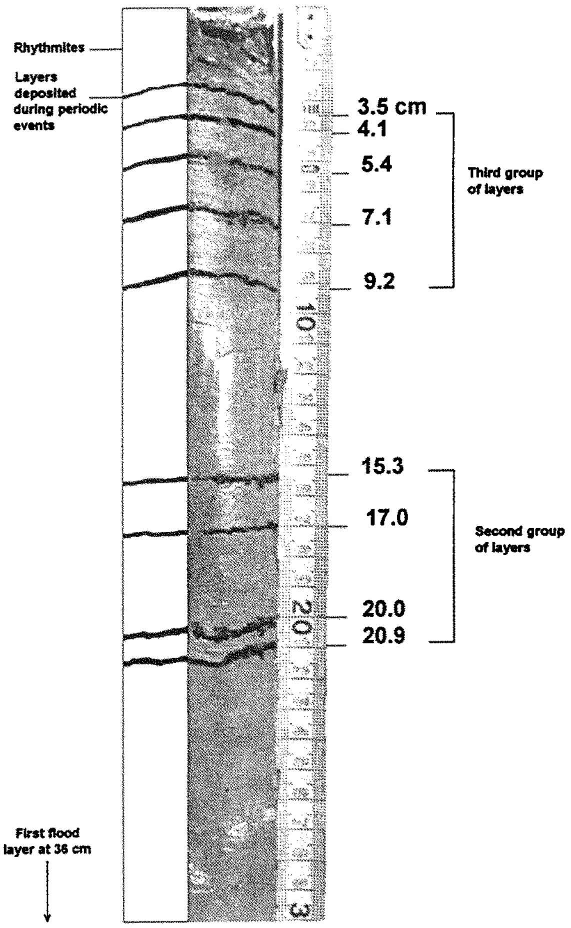


Fig. 2. Upper part of Core II from Brazo Sur, Lago Argentino.

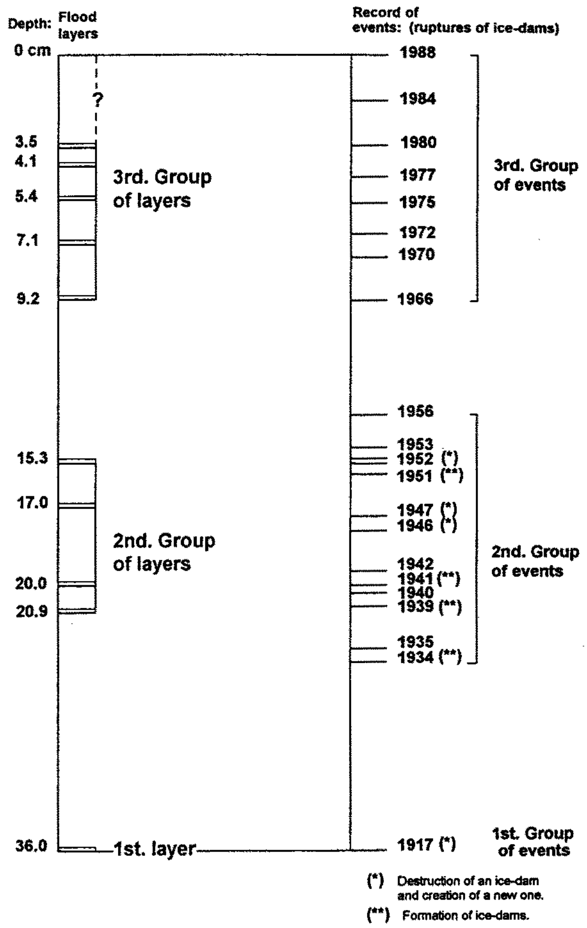


Fig. 3. Correlation between flood layers and sequence of events by Core II.

the Unit 1 (Fig. 4) representing a period of ca. 120 years were analyzed ; low to moderate pollinic concentrations were found and evidences of reworking are shown by most of the grains. The pollinic spectra are dominated by *Nothofagus*, indicating the abundance of this genus in the region. Two palynologic zones are being determined from these analyses : 1) The upper 20 cm are dominated by *Nothofagus* (20–30 %) and *Poaceae* (up to 25 %). Other frequent taxa are *Euphorbiaceae* and *Rosaceae*, which represent the vegetation abounding in the current gramineous steppe with patchy bushes. *Rumex* is also present (15 %) jointly with *Brassicaceae* in the upper sample (10 cm) indicating that the sediments had been disturbed. 2) *Nothofagus* increases (up to 84 %) and *Poaceae* declines (14 %) between 30–50 cm, suggesting that the forest was continuous in the region during the end of 19th century.

## 4. Stratigraphy of Core II

Core II was selected as the reference core for the area, since it shows longer and more complete stratigraphic sequence (Fig. 4) than Core IV. Four main units were recognized in the core (from top to bottom) :

1) Unit 1 (0–6.82 m) : Rhythmites

The rhythmites forming most of this unit are thin (3.5–7.1 mm), regularly bedded and contain no current structures. Regularly alternating light green silty clay beds (3 mm in mean thickness) and dark green clay laminae (>1 mm in thickness), form the bulk of this section. At least ten thin (1 mm) layers composed of light greenish clay are intercalated in the upper 36 cm of the "normal" rhythmic sequence. Three thin (0.5–12 cm) graded tephra beds are inter-

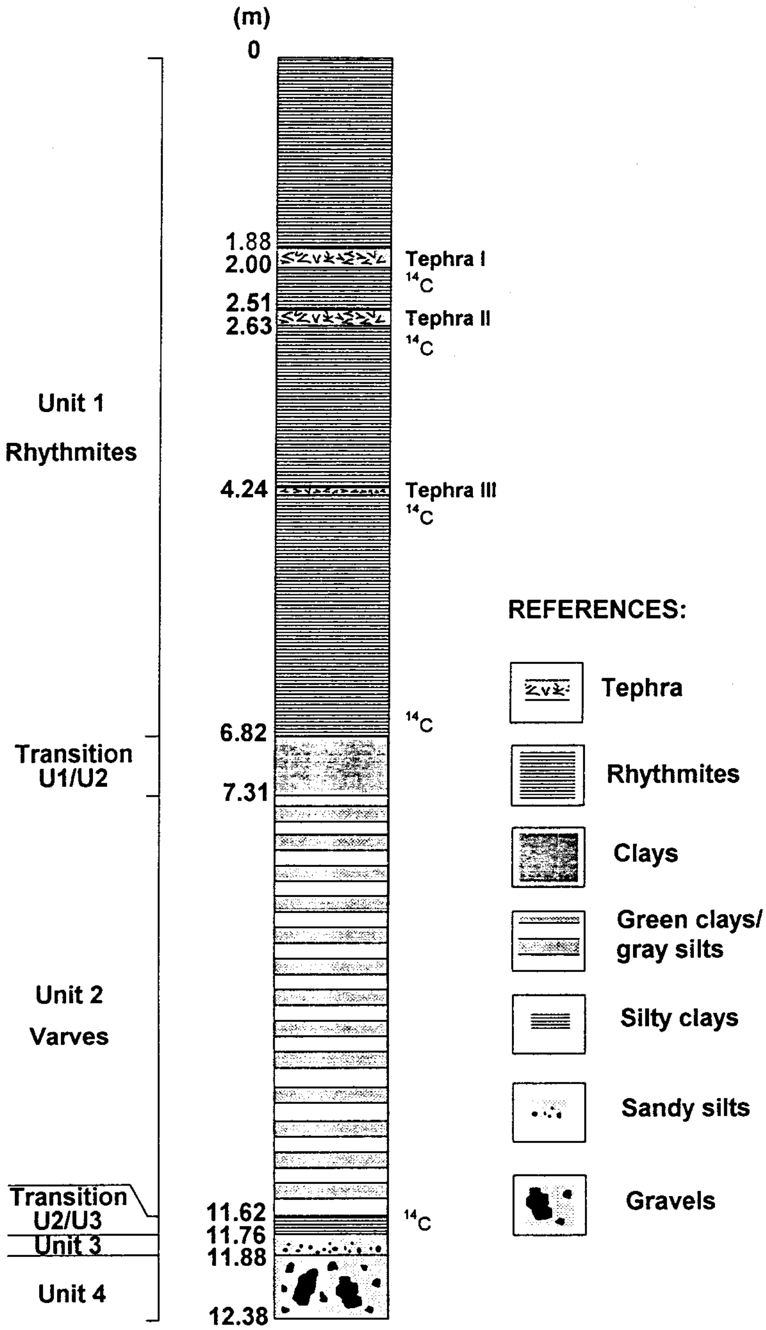


Fig. 4. Stratigraphy of Core II from Brazo Sur.

calated with the rhythmites at 2 m (Tephra I), 2.63 m (Tephra II) and 4.24 m (Tephra III). The grain size of the pyroclastic fragments forming Tephra I and Tephra II vary between 0.5 mm and the silt fraction, while in Tephra III the silt fraction is dominant. Occasionally light brown clay rich laminae (weathered tephrae) are also present (*i.e.* at 18, 19 and 210 cm). There are no other conspicuous tephra layers in the core.

2) Unit 2 (6.82−11.62 m) : Light-gray silty clay/Greenish clay (varves)

Thick (mean : 3.5 cm) light-gray silty clay layers (97 beds) irregularly alternated with also thick (mean : 2.5 cm) greenish clay layers (78 beds) form this unit of classic varved appearance. Lebensspuren abound in both the light and the dark layers ; irregular and inclined small (0.3 mm in diameter) empty burrows meander within the silty light-gray layers, being horizontal at the upper part of the green layers. Additionally in the upper third of the light-gray muddy layers, casts of small bivalves are also present. The existence of white calcareous minute laminae (14 in total), bounded by gray clay layers, is another conspicuous feature in the lower part of this Unit.

Between 6.82−7.31 m, a structureless zone, entirely composed of dark gray clay, indicates the transition between Unit 1 and Unit 2.

3) Unit 3 (11.62−11.88 m) : Dark gray clays

Dark gray clays which are virtually structureless form this unit. Occasional and isolated pebbles (up to 0.5 cm in long diameter) grading to granules are present in the lower part (11.76−11.88 m) of this section ; but they are rather scarce in the upper half (11.62−11.76 m), which is considered as the transition between Unit 3 and Unit 2.

4) Unit 4 (11.88−12.38 m) : Till

Angular pebbles and cobbles (up to 10 cm in diameter) in a very poorly sorted sandy−pelitic matrix form this matrix supported gravel.

## 5. Preliminary results and discussion

The persistence of the similar sedimentary features in the rhythmites in Unit 1 suggests that the present environmental conditions have been almost continuous during most of the Holocene. Virtually no turbidites were accumulated in the sampling sites during this period.

### *5.1. Flooding*

Ten thin (1 mm) conspicuous light greenish clay layers alternating with rhythmites represent sedimentary events relating to the intermittent floods. In the BR-BS basin, the first ice-dam was formed in 1917 and the last one during 1990, with almost immediate formation of the ice-tunnel through which water of the BS was drained. Since 1917, three main periods of floods (Fig. 3) can be recognized (Table I). This sequence of events may be correlated with the vertical distribution of the ten thin layers which were taken as sediments due to the flooding as shown in Fig. 3. Most of the weak sedimentary signals produced by the minor floods were not identified in the cores due to the preliminary stage of the research.

### *5.2. Tephras*

Three major volcanic episodes are recorded in the Unit 1 (Fig. 4). The older eruption formed a single thin (0.5 cm) fine grained pyroclastic layer (Tephra III). Three thin (<5 cm) pyoclastic beds (Tephra II) alternated with lacustrine rhythmites were accumulated during the second volcanic episode, and during the younger volcanic event a coarse grained pyroclastic sequence (Tephra I) was formed, suggesting relatively long range intermittent eruptions. The lithological composition of the bulk of the pyroclastic materials is dominated by dark basaltic glass, indicating the subsilicic character of the eruptions. An important lithological change occurs in the lower part of Tephra I, where a conspicuous white pyroclastic layer is present. The mineralogical composition of this layer is dominated by crystalline shards (amphiboles, pyroxenes, feldspars) and accidental rock fragments, mainly metamorphics, with small amounts of white pumice pyroclasts. All these characteritics indicate explosive eruptions producing large amounts of basaltic ash.

Three ash bands melting out on the ablation areas at the ice margins of some glaciers are a very distinctive feature of the SPI. Satellite images show these ash bands on almost all major outlet glaciers draining the northern SPI. To the south they are still clearly visible even on Upsala Glacier. These bands were described by Lliboutry (1956, 1957) as melt borders of volcanic ash and are due to the volcanic activity of Volcán Lautaro (3380 m), located on the northwestern part of the SPI, at 49°S ; 73°30′W. The ash layers, buried in the accumulation areas of the icefield represent important reference horizons for any future stratigraphic studies (Skvarca, 1993).

The three unique, distinctive pyroclastic beds present in the Unit 1 could be attributed to the Lautaro volcanic events. Whether or not these tephra layers correspond to the ash bands on the glaciers is a matter of further research. The geochemical analyses of samples collected recently from the three ash bands on Viedma Glacier may help to solve this question when compared with the analyses of the core tephras. The radiocarbon dating of the core samples taken immediately below each tephra layer will also provide a valuable information on establishing the chronology of these volcanic events.

### *5.3. Palynology*

The complete period (1917–1990?) of floods in the BR-BS basin was covered by the preliminary micropaleontologic study of cores. There is no evidence in the palynologic spectra, indicating fluctuations in the lake level except for the increasing *Cyperaceae* and *Poaceae* in the upper (10 cm) sample. Since these taxa are related to the present peat bogs located near the lake, the increase of both of them in the upper part of the cores suggests the late expansion of the lacustrine system. This evidence is accompanied by a significant increase in *Tubulliflorae* and *Rosaceae*, which represents the bushes growing in the surroundings. The decline of the forest during the current century probably relates to the human colonization in the region ; however the influence of environmental changes cannot be excluded.

### *5.4. Varves*

The layers in the Unit 2 are unlike those of the Unit 1. The differences in thickness of layers, bedding, bioturbation, paleontology, *etc.*, suggest that they were accumulated under different environmental conditions. The sediments forming the Unit 2 are clastic varves poor in organic matter (about 2 %) that are thought to be accumulated in proglacial lacustrine environments during the Early Holocene and/or the Late Pleistocene postglacial times.

### *5.5. Formation of the BR-BS system*

The gray clays forming the Unit 3 were deposited during the beginning (Late Pleistocene?) of the lacustrine environment (proglacial lake) in the BR-BS area. The early proglacial lake was formed when the glacier definitely receded from the BR-BS area during the postglacial times.

A glacial environment is inferred from the lowermost part of the cores (Unit 4). The transition zone (11.62–11.76 m) between the Unit 2 and Unit 3 indicates the end of the glacial accumulation in the BR-BS area and the beginning of the lacustrine environments. The deglaciation, indicated by the sharp boundary between till (Unit 4), and the proglacial clays (Unit 3), was rapid. Since the retreat of Moreno Glacier, the ice has never reached again the Brazo Surarea.

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