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Chronology of bathymetric variations of the Pueyrredón-Posadas-Salitroso lacustrine system during the Late Pleistocene to Early Holocene

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ABSTRACT

The Pueyrredón-Posadas-Salitroso lacustrine system (PPS-LS) is located in the Andean Patagonia region of Argentina (47°22′28″S – 71°55′34″W) and represents a series of lakes formed as glaciers retreated during the late Pleistocene and early Holocene. These lakes began as proglacial lakes and later evolved into periglacial lakes. This research presents the chronological evolution of the PPS-LS bathymetric variations based on the analysis of stratigraphic profiles surveyed at different locations and the dates obtained from lake sediments. Four paleogeographic sketches representing the chronological evolution of the PPS-LS between 23,580 BP and 5208 BP have been developed based on the integration of these data.

1. Introduction

The chronology of climatic events during the late Pleistocene to early Holocene in Patagonian Argentina is of great importance for understanding global climate change during the late Quaternary (Porter, 2000; Luckman and Villalba, 2001; Jones and Mann, 2004; Sugden et al., 2005; Kaplan et al., 2008; Harrison et al., 2012). Present-day glaciers and periglacial lakes are the result of the most recent glaciation and subsequent deglaciation, and their dynamics reflect very specific climatic conditions (Fregenal Martínez and Meléndez, 2010). Patagonian lake level changes have been studied by different authors (Galloway et al., 1988; Stine and Stine, 1990; Tatur et al., 2002; del Valle et al., 2007; Isla and Espinosa, 2008; Bell, 2008; McCulloch and Morello, 2009; Ariztegui et al., 2010; Horta et al., 2011). In the case of General Carrera Lake in Chile (known as the Buenos Aires lake on the Argentine side), 100 km north of the Pueyrredón-Posadas-Salitroso lacustrine system (PPS-LS), lake levels fell from 650 m above sea level (masl) approximately 13,000 years ago to 201 masl (the current level) due to melting of the glacier damming the lake (Glasser et al., 2004). Delta fans were generated at different heights as a result of the different levels of the receding lake level (Bell, 2008, 2009).

Paleoenvironmental studies have been conducted by different authors at Cardiel Lake (Stine and Stine, 1990; Stine, 1994; Gilli et al., 2001; Ariztegui et al., 2010). Through the analysis of fluctuating lake levels using sedimentary and geomorphological data and ^{14}C dating, these studies determined that the highest level of the lake in the last 21,000 years, 55 m higher than the present day level (276 masl), occurred approximately at 9780 BP under more humid climatic conditions. These climate changes are in agreement with pollen studies conducted by Markgraf (1983, 1989). Between 9780 and 6700 BP, the level lake fall to 276 masl but around 5130 BP the coast line lake is located at 297.5 masl (Gilli et al., 2001). Horta et al. (2011) dated gastropods at 5208 BP on a lacustrine paleocoastline.

Hein et al. (2010) proposed a regional paleogeographic reconstruction of the ice distribution and extent of the PPS-LS between 28 and 15 ka. This reconstruction suggests that the lake system began to form between 16.5 and 15 ka. This proposal is supported by dates published by Horta et al. (2011) with slight differences. The lake level fluctuations 18,050 ± 350 BP indicate that the lakes are even more ancient.

During the last 25,000 years, there were changes in the levels of the PPS-LS. These fluctuations were primarily due to glacial retreat both during the formation of these lakes and evolution (Horta et al.,

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2011, 2013b). From this analysis, a chronology of changes from 25,000 BP to 5000 BP was established.

McCulloch et al. (2000) proposed two warming periods interpreted from pollen collected near the Ice North Field. The first one is around 14,335 BP. A second warming period around cal. 9500 BP was followed by stable climate conditions from Early to Middle Holocene.

2. Geographical location and general characteristics

The study area, centered at 47°22′28″S and 71°55′34″W, is located in NW province of Santa Cruz, Argentina. The area is composed of the Pueyrredón, Posadas and Salitroso lacustrine systems (Fig. 1). Pueyrredón Lake is shared with Chile and is known there as Cochrane lake. The average elevation ranges between 300 and 400 masl, and the maximum elevation is San Lorenzo Mountain, which reaches 3706 masl. Rainfall varies from 500 mm (in the Valle del Río Oro) to 200 mm in the east. The area is located in the ecotone between the shrub steppe in the east and the western edge of the forest on the border with Chile (Markgraf, 1983; Mancini, 1998).

3. Geomorphology

There is abundant evidence of the last glaciation in the study area (Glasser et al., 2004, 2008; Hein et al., 2009, 2010, 2011; Horta et al., 2013a), including glaciated valleys; hanging valleys; roche moutonnée; grooved and striated rocks; delta fans; delta-fluvial layers; and lacustrine, glaciolacustrine, and moraine sedimentary deposits (Fig. 1). The extent of the sedimentary deposits is restricted to protected areas. The end moraine systems are located to the east, and Pueyrredón and Posadas lakes are separated by a moraine. The Furioso River delta fan formed at the southern shore above of this moraine. Relict glaciers from the last ice age are located in the southwestern sector, the most significant of which are found near San Lorenzo Mountain (3706 masl, 47°35′S – 72°19′W). The main glaciated valleys are found in the SW sector (Fig. 1). Although some are also found in the northern sector, they are smaller in this region (Horta et al., 2013a).

4. Methodology

Lacustrine and glaciolacustrine deposits were found in 7 sectors at different levels (Fig. 1):

1 Nivel del Lago 400 (400 masl).
2 Cerro de los Indios (314 masl).
3 Perfil Río Camino (314 masl).
4 Milodón Norte 2 (300 masl).
5 Quebarada del Milodón (Two samples 5.1–180 masl. and 5.2–200 masl).
6 Alero Inclinado (180 masl)
7 Posadas Norte (190–198 masl).

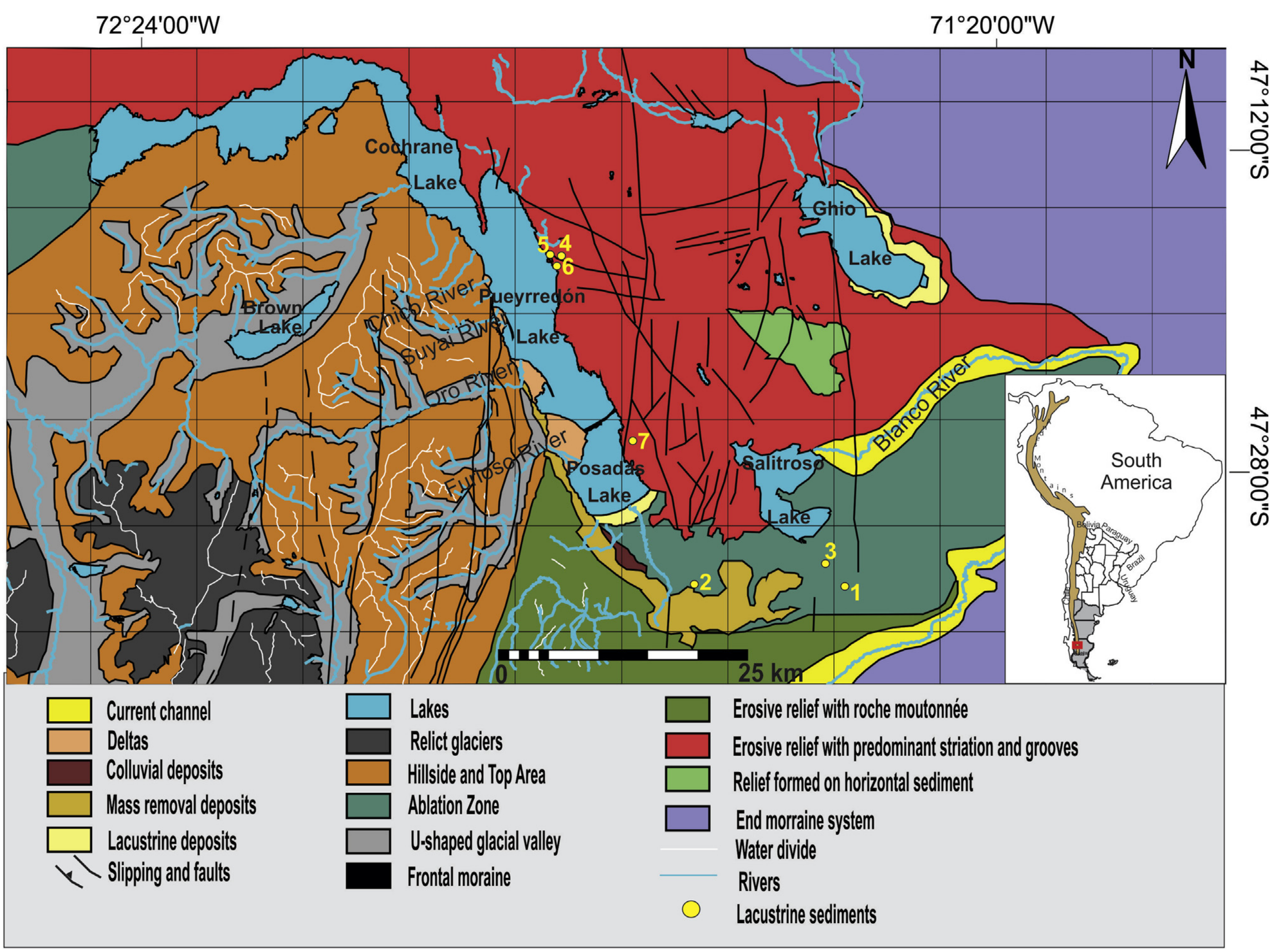

Fig. 1. Location map that includes the geomorphological characteristics of the study area. The dots correspond to locations where the stratigraphic profiles were surveyed and the lake levels were sampled: 1 – Nivel del Lago 400 (400 masl), 2 – Cerro de los Indios (314 masl), 3 – Perfil Río Camino (314 masl), 4 – Milodón Norte 2 (300 masl), 5 – Quebrada del Milodón (180 masl), 6 – Alero Inclinado (180 masl), 7 – Posadas Norte (190–198 masl) (Modified from Horta et al., 2013a).

The surveyed points were geo-referenced with a GPS GARMIN MAP and a Pretel barometric altimeter. The geomorphological map was developed with Landsat 7 ETM satellite images using the Ilwis Geographic Information System (ITC-International Institute for Geo-informatics and Earth Observation). A combination of bands 7, 4, and 1 in the RGB channels was used for mapping.

Current and past reliefs were analyzed from topographic features determined by digital elevation models (DEM) extracted from SRTM (Shuttle Radar Topography Mission) data. Paleocoastal levels of the lake system were also reconstructed. The organic matter of the sediment samples was analyzed using the Walkley-Black method (1934) to determine dating feasibility. The samples with higher percentages of organic matter were dated via radiocarbon at the LATYR (SHCal04), and samples low in organic matter and containing gastropods were dated via AMS at the NSF-Arizona AMS facility (tree-ring calibration curves are used to determine calendar ages).

Selley (1979)-type profiles were drawn in eight (8) sectors (Fig. 2), at heights ranging from 180 to 400 masl. The profile description framework of Bossi et al. (1979) and the Rock-Color Chart Committee color table (1991) were used to survey the profiles at a 1:20 scale. Textures and sedimentary structures were described, and the presence of fossils was recorded. The profiles were then redrawn using Corel Draw (Fig. 2). Facies analysis was performed following the criteria established by Miall (1978, 1996): gravel facies (G), sand facies (S), and mud facies (F: silts; and C: clays).

5. Analysis and facies association

The paleoenvironmental interpretation of the deposits was conducted by analyzing the facies and facies associations (Table 1).

5.1. Nivel del Lago 400 (47°35′11″S – 71°32′33″W)

In this sector, conglomerate beds alternate with laminated pelitic beds (Figs. 2 and 3a,b,c). The Gms-c and Gms-f facies association represent till deposits, and in Gms-f, the sand lenses are

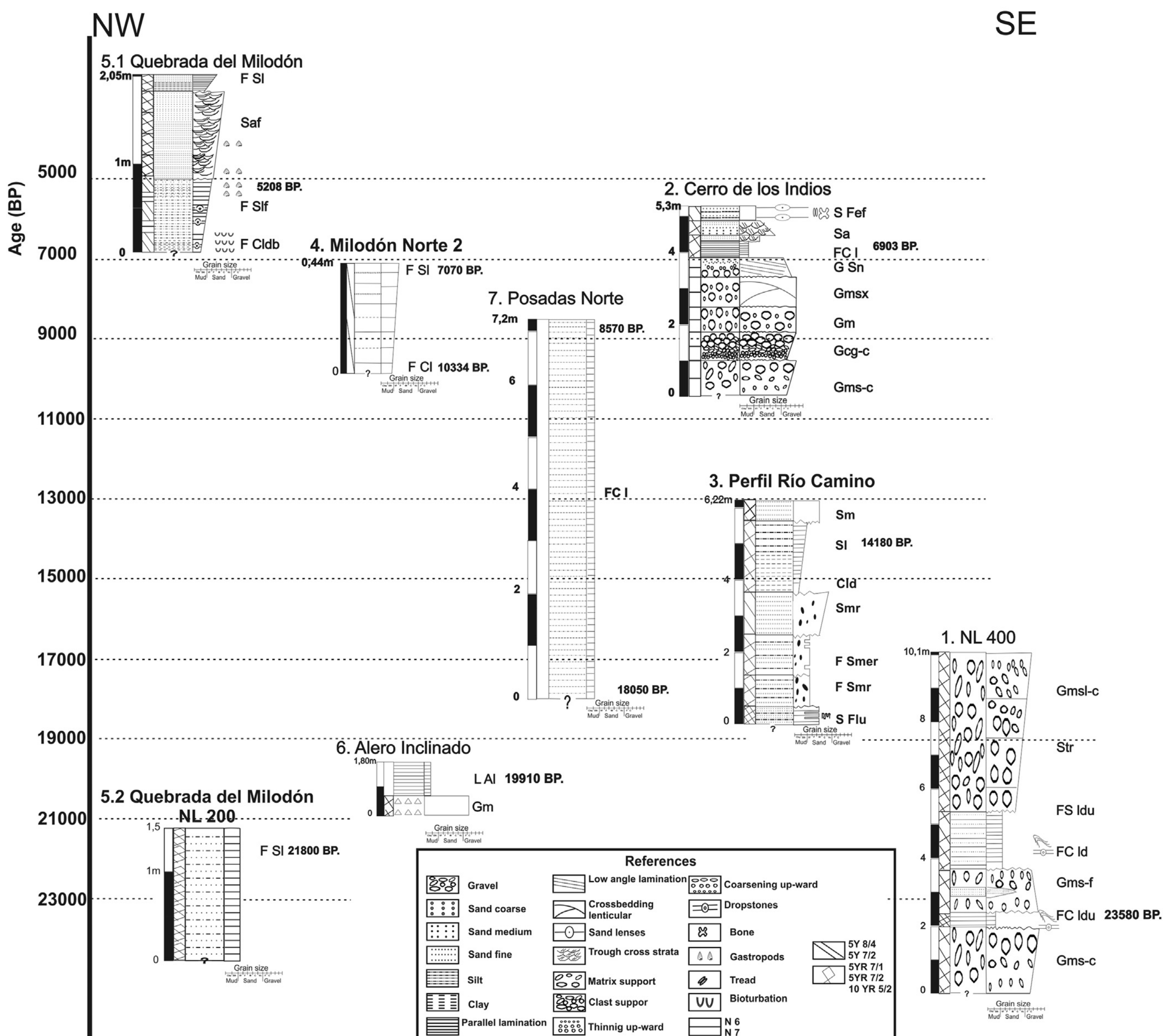

Fig. 2. Stratigraphic profiles surveyed in the different sectors (see Fig. 1). The facies and ages of the dated lake sediments are indicated. The references can be observed at the bottom right, and the orientation (NW–S) is indicated at the top.

Table 1
Facies descriptor codes.

Code	Facies
Gms-c	Matrix-supported gravel, coarsening upwards
Gms-f	Matrix-supported gravel, finning upwards
Gmsl-c	Laminated conglomerates, matrix supported, coarsening upwards
Gcg-c	Clastic conglomerates, matrix supported, coarsening upwards
Gm	Massive gravel
Gmsx	Matrix-supported gravel, with lenticular cross stratification
G Sn	Sandy gravel, with low-angle cross-stratification
Str	Sand with planar stratification with scattered pebbles
Sa	Sand with trough stratification
Sm	Massive sand
S Fef	Silty sand with sand lenses and fossils
S Flu	Silty sand with deformed parallel laminations
Smr	Massive sand with scattered pebbles
FS ld	Sandy silts, laminated with dropstones
FS ldu	Sandy silts, with deformed laminations and dropstones
FS l	Sandy silts with parallel lamination
F Slf	Sandy silts with parallel laminations and fossils
F Smr	Massive sandy silts with scattered pebbles
F Smer	Massive sandy silts with sand lenses and scattered pebbles
FC l	Clayey silt with parallel laminations
FC ldu	Clayey silt with deformed laminates and dropstones
F Cldb	Clayey silt with parallel laminations bioturbated with dropstones
Fcmb	Massive bioturbated silty clay
Fcmf	Massive silty clay with fossils
Fl	Laminate silts
Cld	Laminate clay with dropstone

attributed to a glaciofluvial sub-environment (Fig. 2). The FC l, FS ld and FS ldu facies association characterizes a glaciolacustrine sub-environment, and the Str and Gmsl-c facies association represents outwash deposits. These facies associations indicate glacial, proglacial (Woldstedt and Duphorn, 1974; Boulton and Deynoux, 1981: Wagenbreth and Steiner, 1982; Eyles, 1984;; Eyles and Miall, 1984; Smith and Ashley, 1985; Shaw, 1985; Edwards, 1986; Solari et al., 2012), lacustrine (FC l) and glaciolacustrine (FS ld and FS ldu) paleo-environments with abundant dropstones. The higher lake level deposits exhibit deformation due to outwash flow and slippage in some areas (Fig. 3a,c).

5.2. Cerro de los Indios (47°35′45″S – 71°43′2″W)

A stratigraphic profile of 5.3 m (Figs. 2 and 4) was surveyed at an elevation of 314 masl. The Gms-c and Gcg-c facies association corresponds to alluvial deposits and debris (Hooke, 1967; Gani, 2003), where Gms-c corresponds to the tail of the debris trace and Gcg-c corresponds to the front or head of the debris lobe. The Gm, Gmsx and G Sn facies association represents a fluvial bar (Allen, 1983; Gani, 2003; Bridge, 2006), where Gm is the base of the bar and Gmsx and G Sn represent the top of the bar. Above, the Fc facies corresponds to a lacustrine paleo-environment, which is overlain by the glaciofluvial Sa outwash facies (Sugden and John, 1988), followed by the S Fef lacustrine facies.

5.3. Río Camino stratigraphic profile (47°34′32″S – 71°33′43″W)

At 314 masl, a stratigraphic profile of 6.22 m (Figs. 2 and 5) was surveyed; where the S Flu, F Smr, F Smer and Smr facies association represents a glaciofluvial paleo-environment (Bristow et al., 1999; Perez-Arlucea and Smith, 1999; Bridge, 2003) in which S Flu represents paleo-beach deposits, F Smr and F Smer represent outwash deposits, and Smr represents levee deposits. The Cld and Ll facies represent a glaciolacustrine to lacustrine environment (Boulton and Deynoux, 1981; Eyles, 1984; Eyles and Miall, 1984; Smith and Ashley, 1985; Edwards, 1986; Solari et al., 2012), which transitions from a deeper zone (Ald) to a shallower zone (Ll). The Sm facies represents fluvial bar deposits.

5.4. Milodón Norte 2 (47°18′22″S – 71°53′55″W)

This sector is located at an elevation of 300 masl. Clayey silt and sandy silt beds were found beneath an archaeological excavation site (Fig. 2) at a depth of between 0.44 and 0.54 m; outcrops surrounded the excavation. The thickness of the clayey silt is at least 0.24 m, but the base was not reached. In this archeological excavation two facies were defined: in lower cross sections laminated clayey silts (Fc) and laminated sandy silts (F Sl) in the top the cross section. The Fc facies corresponds to deeper lacustrine beds transitional to the shallower F Sl lacustrine environment (Boulton and Deynoux, 1981; Eyles, 1984; Eyles and Miall, 1984; Smith and Ashley, 1985; Edwards, 1986; Solari et al., 2012).

5.5. Quebrada del Milodon

In this sector, two N–S stratigraphic profiles were surveyed in different sectors near Pueyrredón Lake. The elevation profiles varied between 180 and 200 masl (Figs. 2 and 7; Quebrada del Milodón, point 5.1, Quebrada del Milodón NL 200, point 5.2).

In the first profile (47°18′25″S–71°54′53″W), the facies analysis (Fig. 2) defined a lacustrine environment (Reading, 1986, 1996; Walker, 1992, Quebrada del Milodón, point 5.1), represented by the Fcmb, Fcmf, Fc and F Slf facies, where Fcmb, Fcmf, and Fc characterize deeper areas and F Slf characterizes mshallower areas. The Sm facies represents the bars at the mouth of the delta front in a deltaic paleo-environment (Postma, 1990). In the facies F Sl f, *Gastropoda succinea* gastropods were dated by AMS to 5208 BP.

The second profile (47°18′27″S–71°54′59″W) is composed of sandy silt sediments (Fig. 2, Quebrada del Milodón NL 200, point 5.2) at an elevation of 200 masl. The facies represent a lacustrine paleo-environment (Reading 1986, 1996; Walker, 1992) characterized by the shallow F Sl facies with an age of 21,800 BP. Thus, this profile is assumed to correspond to an eroded ancient paleo-shore.

5.6. Alero Inclinado (47°19′3″S – 71°54′12″W)

This profile is located at 190 masl and is a rock shelter open to the north (40 m long, 10 m wide, 5 m high; Fig. 2). Two facies are defined: massive subangular pebbles gravel (Gm) and laminated clayey silts (Fc), which correspond to till and lacustrine deposits, respectively. The Gm facies corresponds to till deposits (Boulton and Deynoux, 1981; Eyles and Miall, 1984) and the Fc facies corresponds to lacustrine deposits (Smith and Ashley, 1985; Reading, 1986, 1996; Walker, 1992).

5.7. Posadas Norte (47°28′3″S – 71°47′33″W)

The area known as Posadas Norte is between 190 and 200 masl, 18 km southeast of Alero Inclinado. Laminated clayey silts are found in this location (Figs. 2 and 6a,b) represent a lacustrine paleo-environment (Smith and Ashley, 1985; Reading, 1986, 1996; Walker, 1992).

6. Chronology and paleogeographic reconstruction

Paleogeographic reconstructions were made based on the analysis of the profiles surveyed. Ages obtained from the lake levels at different sampling points were linked by their respective heights (Table 2). In addition, the correlation of these levels was established based on the development of fan-deltas found on the southern shores of the PPS-LS and terraced levels (Horta et al., 2013b). Four

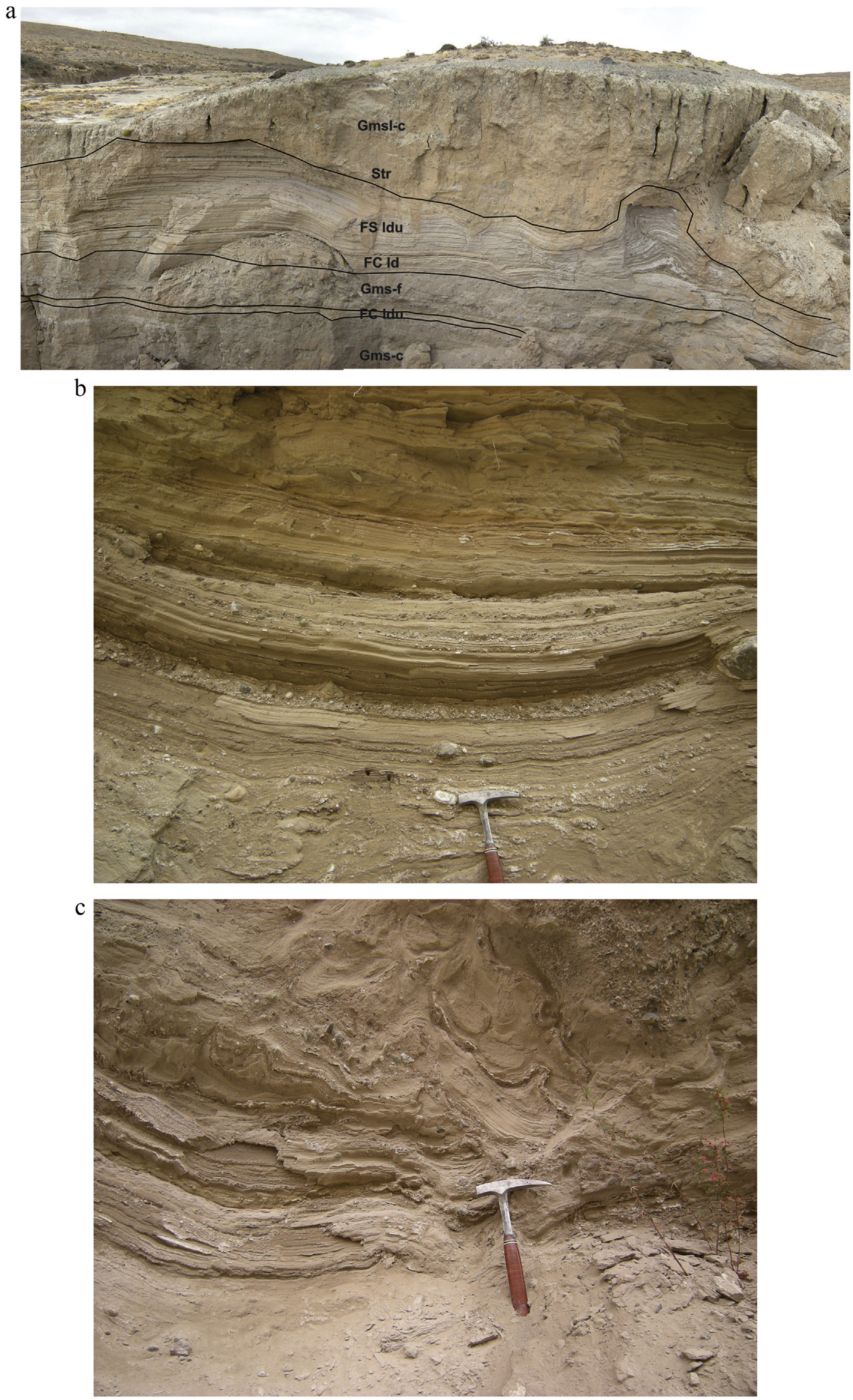

Fig. 3. a: Panoramic view of the northeast sector. Contacts are highlighted in black, and the facies are indicated. b. Abundant dropstones are found in the upper glaciolacustrine beds. c. Northeast view of glaciolacustrine beds deformed by outwash flow.

Fig. 4. Panoramic view south from the area where the profile was surveyed in Cerro de los Indios. The contacts are highlighted in black, and the facies are identified.

paleogeographic reconstructions with ages ranging from 23,580 ± 200 BP to 5208 ± 180 BP were constructed (Fig. 7, Table 2).

1) The oldest of these levels located between 23,580 and 21,800 BP, when the PPS-LS would have reached an elevation of approximately 450 masl (Fig. 7a). reconstructed based on the lacustrine and glaciolacustrine deposits found in the Nivel del Lago 400 area with alternating diamicton deposits, which are interpreted to represent a series of ice advances and retreats (Figs. 1, 2 and 7a. point 1 and Fig. 8). The result was this alternating sequence of lacustrine and diamicton beds, with a higher conglomerate bed interpreted as a glaciofluvial outwash. The lower lake level was dated by AMS, yielding an age of 23,580 BP. To reconstruct the paleogeography, lacustrine levels were correlated with the apex of the fan-delta of the Furioso River and

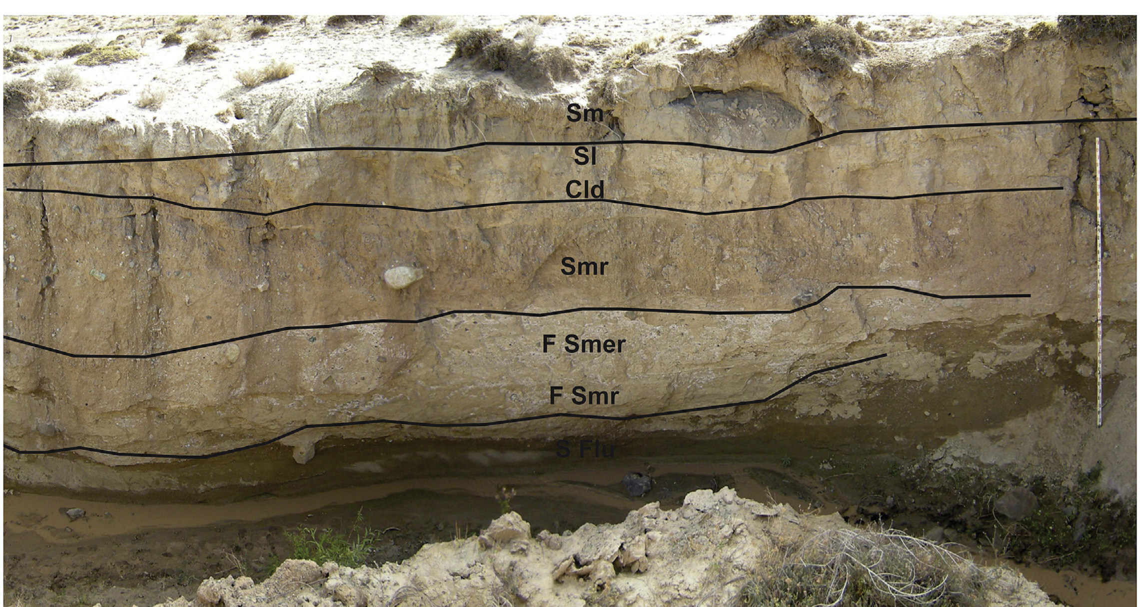

Fig. 5. View to the north of Río Camino stratigraphic profile. The contacts are highlighted in black, and the facies are identified.

Fig. 6. a. Detailed image of laminated clayey silts deposits; b. view to the northeast in the rock shelter where the deposits were found.

with the terraced levels (Horta et al., 2013b). This process resulted in a paleogeographic model of the flooded area at an elevation of 450 masl (Fig. 7). This reference level was calculated by estimating 50 m of water above the clay-rich silt with abundant dropstones, and the paleoenvironment was determined to be a proglacial paleolake. The limit of the ice was located in the Quebrada del Milódon according to the lake level of 200 m at 21,800 BP (Fig. 7a. point 5.2). The diamicton deposits below this level could correspond to tills of the Last Glacial Maximum, which occurred at approximately 27–25 ka (Hein et al., 2009), represented by the Blanco River moraine systems and the diamicton deposits from glacial advances that occurred about at 23–22 ka (Hein et al., 2010).

2) Between 21,800 and 14,180 BP, the level of the lacustrine system fell from 450 masl to 360 masl (Fig. 7b), when the Oro River fan-delta began to form (Horta et al., 2013b). This paleogeography is reconstructed taking into account the lacustrine sediment records found in Alero Inclinado (19,910 BP, Fig. 7b. point 6) and in Posadas Norte (18,050 BP Fig. 7b. point 7) and the presence of glaciolacustrine sediments of the Perfil Río Camino (point 3 Fig. 7b–d) that transition into lacustrine deposits dated 14,180 BP.
3) Between 14,180 and 6903 BP, the level of the lakes system fluctuated between approximately 360 masl and 300 masl (Fig. 7c). The paleogeography is reconstructed from lacustrine sediment records at Perfil Río Camino (14,180 BP Fig. 7b–d. point 3), Milodón Norte 2 (10,334 BP for the lower level and 7070 BP for the upper level Fig. 7b–d. point 4), Upper Posadas Norte (8570 BP Fig. 7b–d. point 7), and Cerro de los Indios (6903 BP Fig. 7b–d. point 2).
4) Between 6903 and 5208 BP, the height of the PPS-LS fell from 300 to 180 masl (Fig. 7 d), as evidenced by the *Gastropoda*

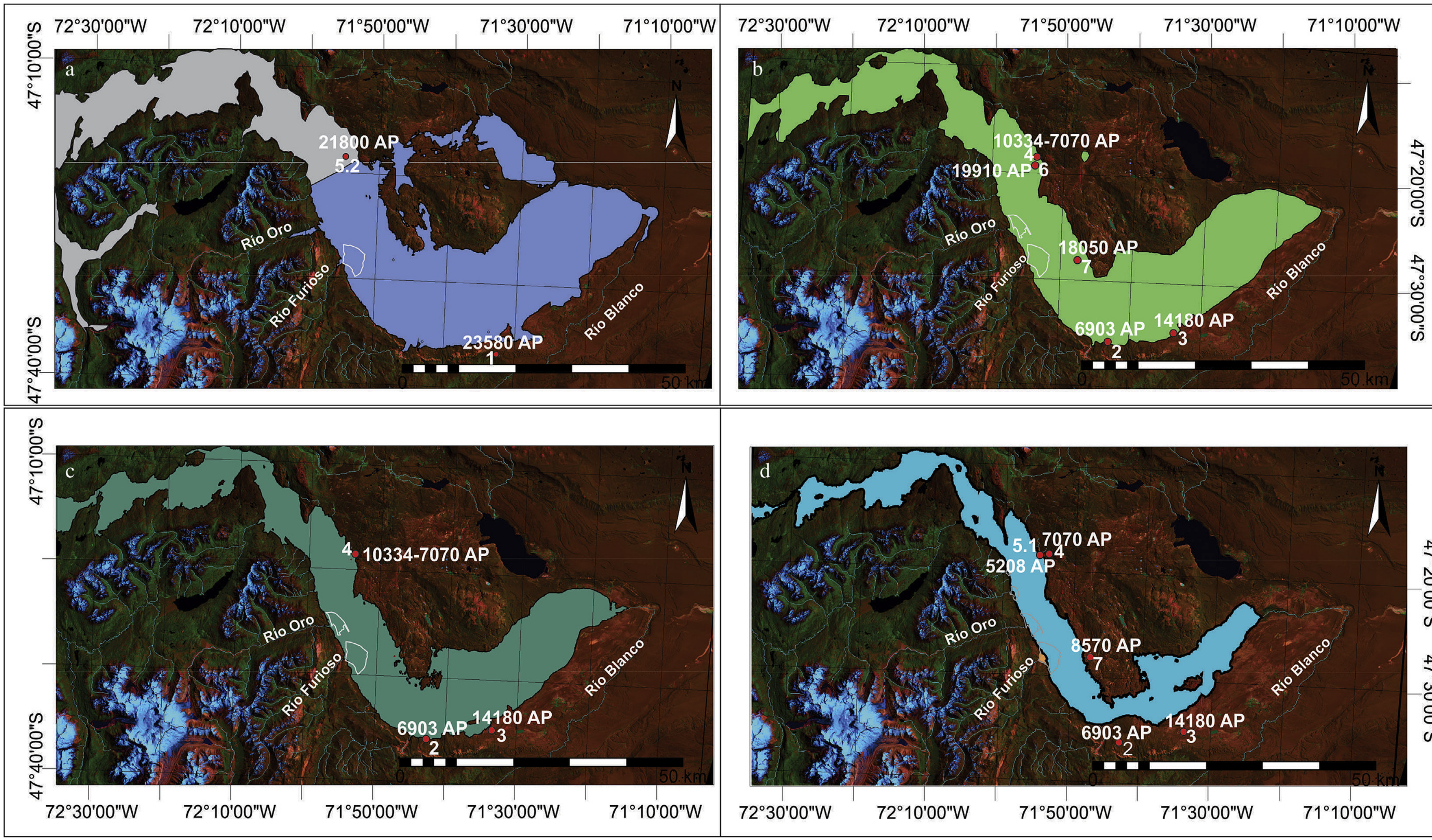

Fig. 7. Landsat 7 satellite images. a) Surface flooded to a height of 450 masl in dark blue and gray in glaciated sectors. Points 1 and 5.2 correspond to lacustrine deposits, and their ages are indicated. The Furioso River fan-delta is also highlighted in gray; its subaqueous section is beginning to form. b) Flooded to a height of 360 masl. This image shows the relationship between the lacustrine levels found at points 2, 3, 4, 6, and 7 and fan-detla of the Furioso and Oro River c) Paleogeographic reconstruction, Flooded area at an elevation 300 masl. This image shows the relationship between the lake levels found at points 2, 3 and 4 and fan-delta of the Furioso and Oro Rivers d) The flooded surface at an elevation of 190 masl. This image shows the relationship between the lacustrine levels found at points 2, 3, 4, 5.1 and 7, the Furioso River (the subaerial section is highlighted in brown) and the Oro, Suyai and Chico fan-deltas. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 2
Sampling points and sampled lake levels from Fig. 1, with age, elevation, coordinates and material dated.

Point	Sample	Age	±	Elevation	Coordinates	Material dated
1	Nivel del Lago 400	23,580	20	400	47°35′11″S – 71°32′33″W	Lacustrine sediments
2	Cerro de los Indios	6903	78	314	47°35′45″S – 71°43′2″W	Lacustrine sediments
3	Perfil Río Camino	14,180	150	314	47°34′32″S – 71°33′43″W	Lacustrine sediments
4	Lower Milodón Norte 2	10,334	60	300	47°18′22″S – 71°53′55″W	Lacustrine sediments
4	Upper Milodón Norte 2	7070	120	300	47°18′22″S – 71°53′55″W	Lacustrine sediments
5.1	Quebrada Milodón	5208	38	180	47°18′25″S – 71°54′53″W	Shell
5.2	Nivel del Lago 200	21,800	190	200	47°18′27″S – 71°54′59″ W	Lacustrine sediments
6	Alero Inclinado	19,910	310	180	47°19′3″S – 71°54′12″ W	Lacustrine sediments
7	Lower Posadas Norte	18,050	350	190	47°28′3″S – 71°47′33″W	Lacustrine sediments
7	Upper Posadas Norte	8570	170	198	47°28′3″S – 71°47′33″W	Lacustrine sediments

succinea gastropods dated to 5208 BP at the Quebrada del Milodón site. These fossils indicate coastal levels at this site at this time (Fig. 7 d, point 5.1) (Horta et al., 2011). During this period, in the southern shore of Pueyrredón Lake, two new fan-deltas were developing; the first one corresponds to the Estancia Suyai River and the other grew at the River Chico mouth (Fig. 1). This assumption is supported using the altitude of the apical area and the areas of these fan-deltas. The connections amongst the Pueyrredón-Posadas-Salitroso lakes were maintained until 5208 BP.

7. Discussion and conclusions

Climatic events during late Pleistocene to early Holocene in Patagonia were key for the evolution of the Patagonian lakes, although these occurred gradually over time. In the case of the PPS-LS, the maximum level of approximately 450 masl occurred at 23,580 BP. Thus, the water level was 300 m above the present level (150 masl). In comparison, the level of General Carrera Lake fell from 650 masl (at approximately 13,000 years ago) to its present level of 201 masl (Glasser et al., 2004). In the PPS-LS, delta fans were generated at different levels and resulted from the different pulses (Bell, 2008, 2009).

Based on paleogeographic reconstructions performed via dating glacial moraines, Hein et al. (2010) proposed that the lake system began to form between 16.5 and 15 ka. Horta et al. (2011) found evidence that supported a lacustrine system before 18,050 BP. New field evidence and seven AMS dates allow us to extend the span of the PPS-LS as a unique lacustrine system from 23,580 BP until 5208 BP.

The PPS-LS bathymetric variations were related to glacier fluctuations during the Late Pleistocene and Early Holocene. A clear example of this relationship can be observed in the Nivel del Lago 400 profile where tills dating from 27 – 25 ka and 23 – 22 ka (Hein et al., 2009, 2010) alternate with lacustrine beds. The lower level of these beds was dated to 23,580 BP. Another prime example is Alero Inclinado, where lacustrine beds (19,910 BP) were found above till deposits. The two warming stages proposed by McCulloch et al. (2000) at the 14,335 BP and cal. 9500 BP could relate to our PPS-LS fluctuations recorded between 360 and 300 masl.

The Cardiel Lake level rose to 331 masl around 9780 BP (Stine and Stine, 1990; Stine, 1994; Gilli et al., 2001; Ariztegui et al., 2010), after that several fluctuations are recorded between 6700 and 5130 BP. These changes are coincident with fluctuations recorded on PPS-LS between 6903 and 5208 BP, in this case the coastline generally fell (with some small rises) from 300 masl to 180 masl and later the fall continued until the nowadays level (150 masl). The facies associations demonstrate the influence of ice masses in the evolution of the paleoenvironment with alternating glacial and proglacial environments. Important deposits include tills, glaciolacustrine/lacustrine deposits, glaciofluvial/fluvial deposits, outwash/alluvial fans, and deltaic deposits.

Together with dating, the integration of the interpretations made from the stratigraphic profiles, taking into account the heights of the lake levels at different sampling points, allowed for the determination of a chronological evolution represented by four paleogeographic stages between 23,580 and 5208 BP:

1. The lake level at 450 masl was dated to 23,580 ± 200 BP.
2. The lake level at 360 masl dated between 21,800 ± 190 and 14,180 ± 150 BP, with the start of development of the Furioso River delta fan.

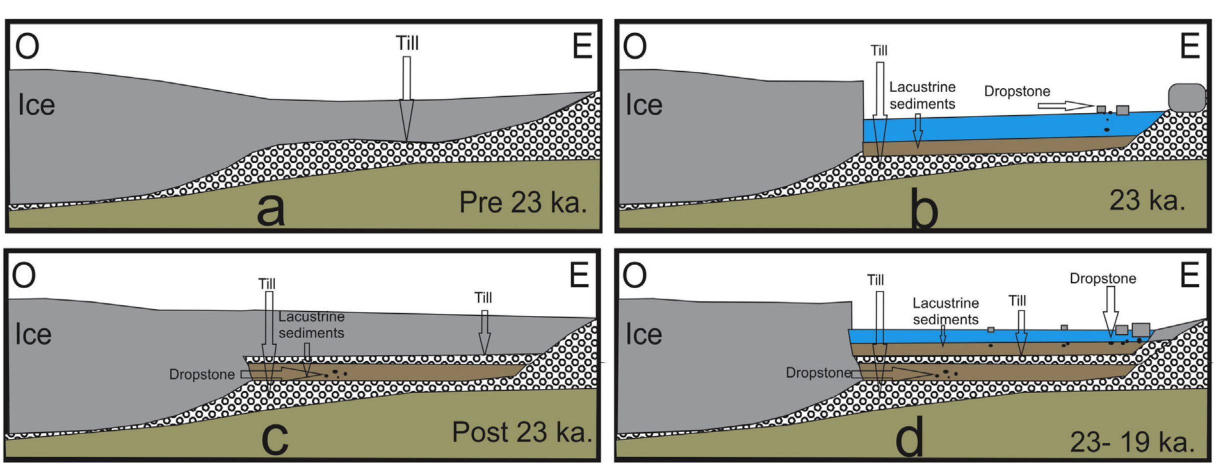

Fig. 8. Paleogeographic schematic generated from the interpretation of the profile Nivel del Lago 400 (dot 1, Fig. 1), representing the stages that led to the deposition of the surveyed sedimentary sequences. a) The first panel represents the ice advance prior to 23 ka, which resulted in the diamicton deposit. b) Ice retreat, generating a proglacial lake with glaciolacustrine deposits. c) New ice advance generating the diamicton deposits above the glaciolacustrine deposits. d) Ice retreat with new generation of lacustrine deposits.

3. A fall in the lake level to approximately 300 masl occurred between 14,180 ± 150 and 6903 ± 78 BP, with the development of the Oro River delta fan and the growth of the Furioso River delta fan.
4. The lake level at approximately 200 masl between 6903 ± 78 and 5208 ± 38 BP, which featured the presence of *Succinea* gastropods in the sandy sediments of the deltaic body and the formation of the deltaic fans of the Suyai and Chico rivers.

The present extension of lacustrine complex occurred after 5208 ± 38 BP, and the coalescence of the Furioso River alluvial fan with a frontal moraine separated the Pueyrredón and Posadas lakes.

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