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Chronostratigraphic and Palynozone chronosequences charts of Napostá Grande Creek, Southwestern Buenos Aires Province, Argentina.

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ABSTRACT: Changes in Late Pleistocene and Holocene vegetation, including sea level fluctuations in the Middle Holocene, were detected by means of pollen analysis and marine palaeomicroplankton of three sediment profiles from the Napostá Grande creek and one profile from layer with the 'fossil footprints' at Monte Hermoso I, southwestern Buenos Aires Province. Changes in sedimentary facies associated with changes in pollen assemblages allowed the inference changes in depositional environments and climate. Fifteen pollen zones and four subzones (one interval zone) were determined. Arid to semiarid climatic conditions were inferred for the Late Pleistocene (Profile 1) represented from the abundance of Chenopodiaceae-Amaranthaceae, and Asteraceae (Compositae) or Cruciferae + Chenopodiaceae-Amaranthaceae in Profile 2. Both zones are overlain by truncated palaeosoils followed by erosion. The early Holocene interval (Profile 4: Monte Hermoso I), dominated by Chenopodiaceae-Amaranthaceae, and Gramineae is dated at 7125 ± 75 and 7030 ± 100 ^{14}C yr BP. This vegetation community is characteristic of coastal dunes associated with lacustrine conditions, with slight marine influence suggests the existence of local humid conditions. The Middle Holocene is palynologically barren in Profile 1. While the Pollen Zone Chenopodiaceae-Amaranthaceae, Gramineae (presence), of Profile 3, dated at 6000/5580 ± 100 ^{14}C yr BP, reflects the destruction of the littoral environment by the rise of the sea level as evidenced by appearance of dinocysts and acritarchs. Between 3560 ± 100 yr BP and 3000 yr BP, grass steppe replaced the littoral environment. The uppermost levels dated at 2610 ± 60 ^{14}C yr BP are dominated by Chenopodiaceae-Amaranthaceae, Cruciferae, Compositae and Gramineae, reflecting semiarid conditions comparable to the present ones.

RESUMEN: Se han detectado cambios en la vegetación del Pleistoceno tardío y Holoceno, incluidas las fluctuaciones del nivel del mar en el

Holoceno medio, a través del análisis de polen y el microplancton marino de tres perfiles sedimentarios y un perfil del nivel con pisadas fósiles en Monte Hermoso I, en el Sudoeste de la provincia de Buenos Aires. Cambios en las facies sedimentarias asociados a cambios en conjuntos polínicos permitieron inferir cambios en ambientes depositacionales y clima. Se determinaron quince zonas polínicas y cuatro subzonas (una zona de intervalo). Se infirieron condiciones climáticas áridas a semiáridas para el Pleistoceno tardío (Perfil 1) representadas por la abundancia de Chenopodiaceae-Amaranthaceae y Asteraceae (Compositae) o Cruciferae + Chenopodiaceae-Amaranthaceae en el Perfil 2. Paleosuelos truncados seguidos de erosión sobreyacen ambas zonas. El intervalo Holoceno temprano (Perfil 4: Monte Hermoso I), dominado por Chenopodiaceae-Amaranthaceae y Gramineae está datado en 7125 ± 75 y 7030 ± 100 ^{14}C años AP. Esta comunidad vegetal es característica de las dunas costeras asociadas con condiciones lacustres con escasa influencia marina, que sugiere la existencia de condiciones locales húmedas. El Holoceno medio es palinológicamente estéril en el Perfil 1. Mientras la Zona polínica Chenopodiaceae-Amaranthaceae, Gramineae (presencia) del Perfil 3, datada en 6000/5580 ± 100 ^{14}C años AP, refleja la destrucción del ambiente litoral por el ascenso del nivel del mar, tal como lo evidencia la aparición de dinocistos y acritarcos. Entre 3560 ± 100 años AP y 3000 años AP, la estepa de gramíneas reemplazó el ambiente litoral. Los niveles superiores datados en 2610 ± 60 ^{14}C años AP están dominados por Chenopodiaceae-Amaranthaceae, Cruciferae, Compositae y Gramineae, lo cual refleja condiciones semiáridas comparables a las actuales.

1 INTRODUCTION

The present paper attempts to improve the knowledge of the stratigraphy and palaeoenvironments of the Late Pleistocene and Holocene of southern Buenos Aires province, Argentina, based on the analysis of pollen grains, spores and marine microplankton.

The aim of this work is the recognition of plant communities, their fluctuations through time and the specification of pollen assemblage zones. This paper also purports to determine the space-time correlation of the recorded events (chronosequences chart) and how changes of the vegetation interact with palaeoclimatic fluctuations.

The studied area (Fig. 1) comprises the Napostá Grande creek basin (Profiles 1, 2 and 3) and the layer with 'fossil footprints' at Monte Hermoso I (Profile 4). Deposits are distinctly continental (fluvial, lacustrine and aeolian) or transitional and marine.

Previous palynological research in southern Buenos Aires province are those of Guerstein & Quattrocchio (1984), Quattrocchio et al. (1988,

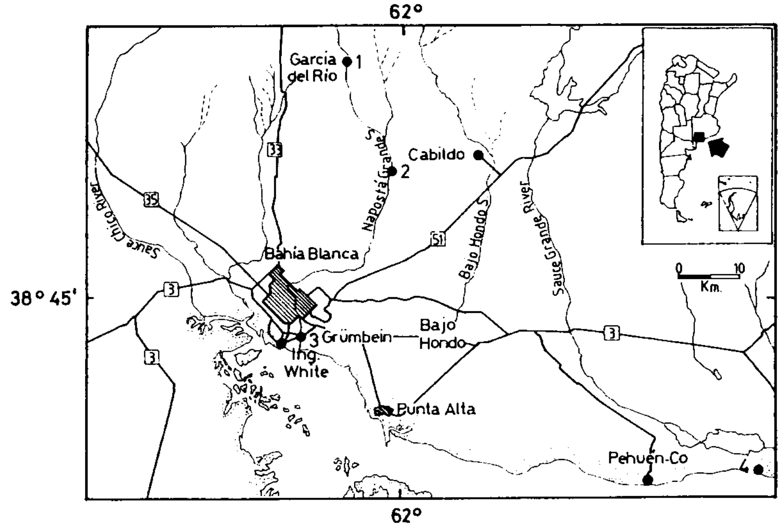


Figure 1. Location map. The four profile studied are represented with numbers 1, 2, 3, 4.

1993, 1995), Prieto (1989, 1993), Borromei & Quattrocchio (1990), Borromei (1992, 1995), Zavala et al. (1992), Gómez et al. (1992) Guerstein et al. (1992), Grill (1993, 1995, 1996), Grill & Guerstein (1995) and Grill & Quattrocchio (1996).

2 MATERIALS AND METHODS

The sediment profiles were subsampled for pollen analysis: 26 samples from Profile 1, 29 samples from Profile 2, 11 samples from Profile 3, and six samples from Profile 4.

The physical-chemical method preparation of Heusser & Stock (1984) was employed to extract the palynomorphs. Microplankton was treated with cold HCl, according to Dale (1976). Five, ten or twenty grams per sample (dry weight) were processed and two tablets of *Lycopodium* spores (11.267) were added to estimate the palynomorph concentration per gram of sediment (Stockmarr 1971). The marine samples, according to Stanley (1966), were stained with T-Safranine, to differentiate primary palynomorphs (homogeneously stained) from those reworked (not homogeneously stained, or unstained).

In order to guarantee that all taxa present are counting, we followed the method of Bianchi & D'Antoni (1986) of 'minimal area'.

In the marine samples, at least 150 palynomorphs were counted (pollen grains + spores + palaeomicroplankton). Percentages of palaeomicroplankton were calculated outside the total sum of palynomorphs.

Fossil pollen assemblages were compared with modern pollen assemblage recorded in the area (Borromei & Quattrocchio 1990) and with surface pollen samples (Prieto 1989, 1993). Likewise, the plant palaeocommunities were compared with present vegetation units studied by Verettoni & Aramayo (1976) for the area of Bahía Blanca, and by Cabrera (1976).

With respect to the marine palaeomicroplankton, the present day ecological characteristics of recent dinocysts (i.e. Wall et al. 1977, Harland 1983) provided the basis to infer palaeoecological conditions.

3 GENERAL FEATURES OF THE AREA

3.1 *Geomorphology and tectonics*

The Napostá Grande creek originates in the Sierras Australes (Napostá Hills) of Buenos Aires province and flows into the Bahía Blanca estuary 108 km to the SE. It is a permanent stream with two areas of different geomorphologic features: a hilly region and the lowland plains (Paoloni et al. 1987). Basement tectonics affect the strike of the creek, from E-W (coincident with a regional fault) to NE-SW (secondary fault of the basement) (Bonorino et al. 1986).

3.2 *Climate*

The Buenos Aires province occupies the central-eastern portion of Argentina, between lat. 33° to 43° S. Consequently, it lies within the temperate zone (Burgos 1968). Because of its position within the country and the South American continent, the oceanicity factor is significant (Burgos 1968), moderating the climate, especially near the coast. The continentality features intensify with distance from the coast (Verettoni & Aramayo 1976).

Both in warm and cold months, the prevailing direction of the winds is NE-SW, because of the activity of the South Atlantic and South Pacific anticyclones. Subantarctic cold air masses from the SW, and warm air masses from the north, caused by the occasional recession of the Pacific anticyclone (Burgos 1968), also affect the climate of the province.

3.3 *Phytogeography and vegetation*

According to Cabrera (1976), the Buenos Aires province belongs to the Neotropical Region, with a small area occupied by the Amazonic Dominion, and the rest by the Chaco Dominion. The latter is represented by the Monte, Espinal and Pampean plant geographic provinces.

The studied area comprises parts of the Austral (in Pampean province) and the Caldén (in Espinal province) districts.

According to the vegetation census made in the area of Bahía Blanca by Verettoni & Aramayo (1976), most of the region is used for grazing and farming and the natural vegetation that occupies the rest, has been modified. These authors recognized the following plant communities: grass steppe in the plains; herbaceous sandy steppe along the coast, on continental dunes and sandy soils (Verettoni 1965); halophytic steppe in the foreland of the coast and saline soils (Verettoni 1961), and shrubby and sub-shrubby forest in those places where the caliche outcrops or is near the surface. This is a modification of the original forest that extended along the coast.

4 STRATIGRAPHY AND AGE

The stratigraphic sections studied along the banks of the Napostá Grande basin comprise fluvial, aeolian and marine sediments. They are generally discontinuous, with a significant development of palaeosols. The stratigraphic units identified in this paper follow those defined by Rabassa (1989).

The Late Pleistocene is represented in the three profiles of the Napostá Grande basin. Although there are no dates for these sediments, their age is inferred on the base of the lithofacies and the fossil vertebrates content.

The Holocene sections have five radiocarbon dates: Profile 1: 2610 ± 60 yr BP (sample 8); profile 2: 1960 ± 100 yr BP (sample 25); profile 3: 5580 ± 130 yr BP (sample 8), 3850 ± 100 yr BP (sample 7) and 3560 ± 100 yr BP (sample 6).

In the layer with 'fossil footprints' at Monte Hermoso I region, sandy-silty deposits are discontinuos, outcropping on the marine abrasion platform. The stratigraphy follows Zavala et al. (1992). There are no dates for the oldest sediment; their age is based on vertebrate fossils. The Holocene sediments have two radiocarbon datings: 7125 ± 75 yr BP (sample 4) and 7030 ± 100 yr BP (sample 3).

The detailed study of the palynologic profiles with stratigraphic comments are given in Grill (1993).

5 PALYNOLOGICAL ZONATION

Pollen diagrams were divided according to the 'pollen zones' of Gordon & Birks (1972, in Birks & Birks 1980), and Interval Zones (Guía Estratigráfica Internacional 1980).

Relative pollen frequencies (%) and concentrations (grains per gram of sediment) of the identified taxa are shown as bar diagrams (Figs 2, 3, 4 and 5).

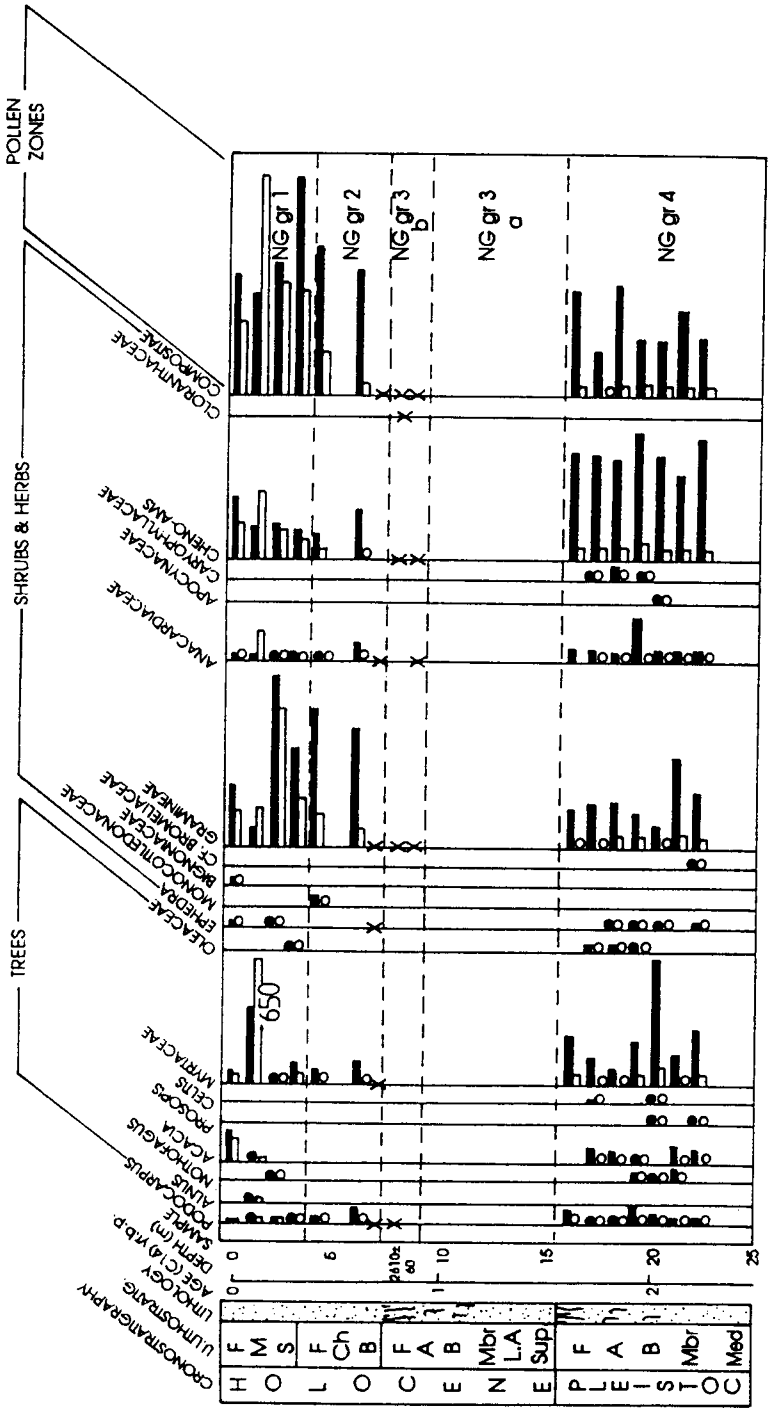
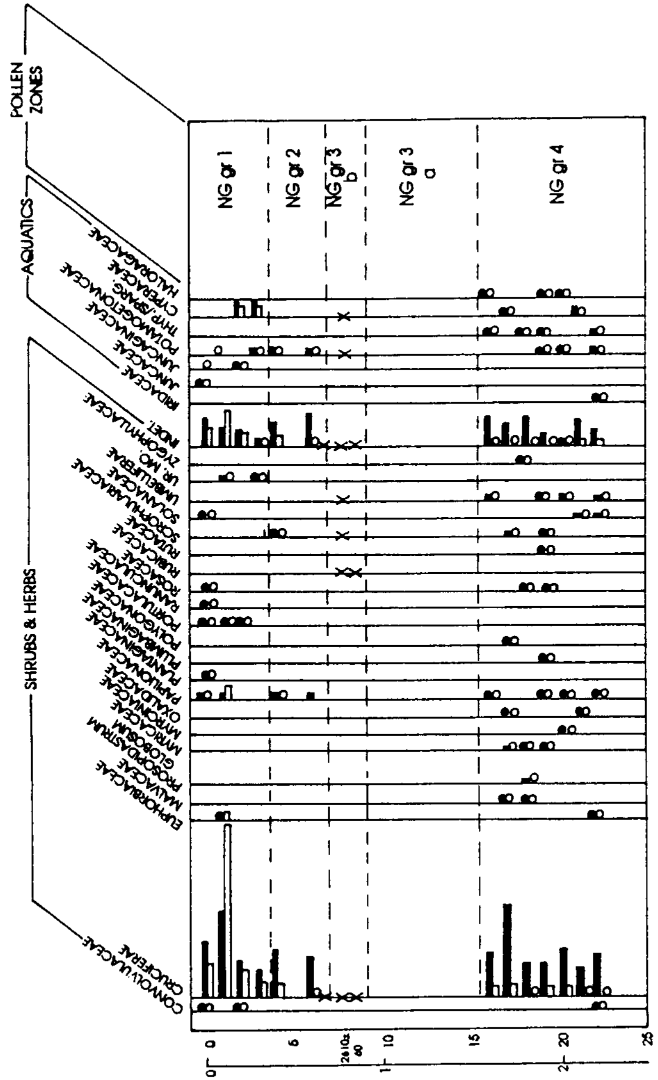


Figure 2. Pollen diagram. Profile 1 (García del Río).



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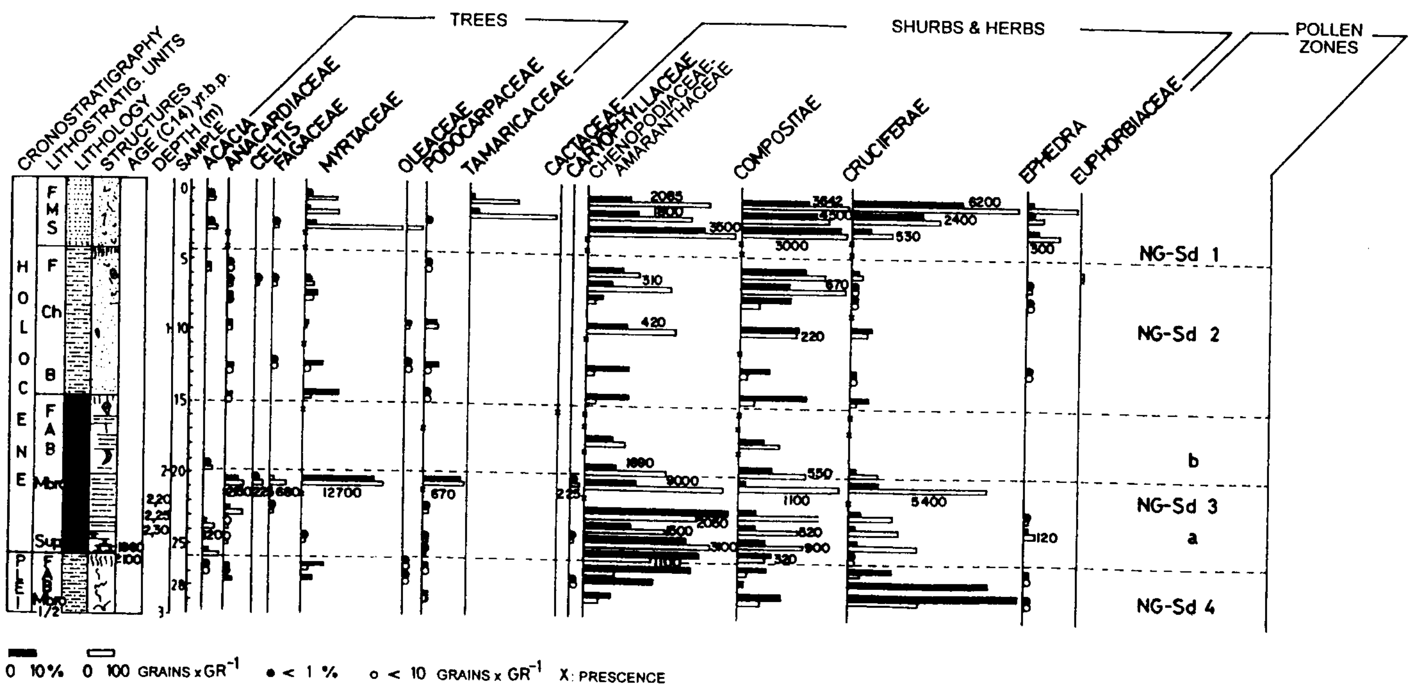
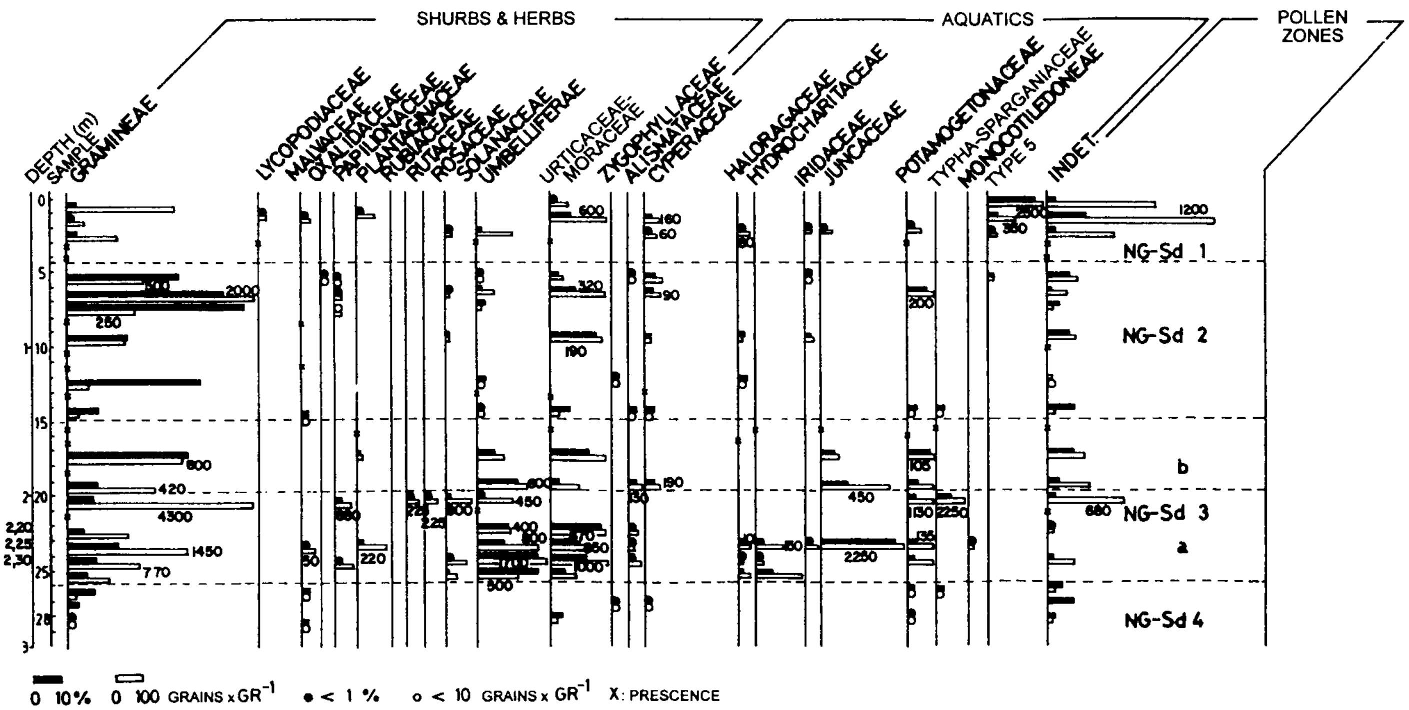


Figure 3. Pollen diagram. Profile 2 (Chacra Santo Domingo).



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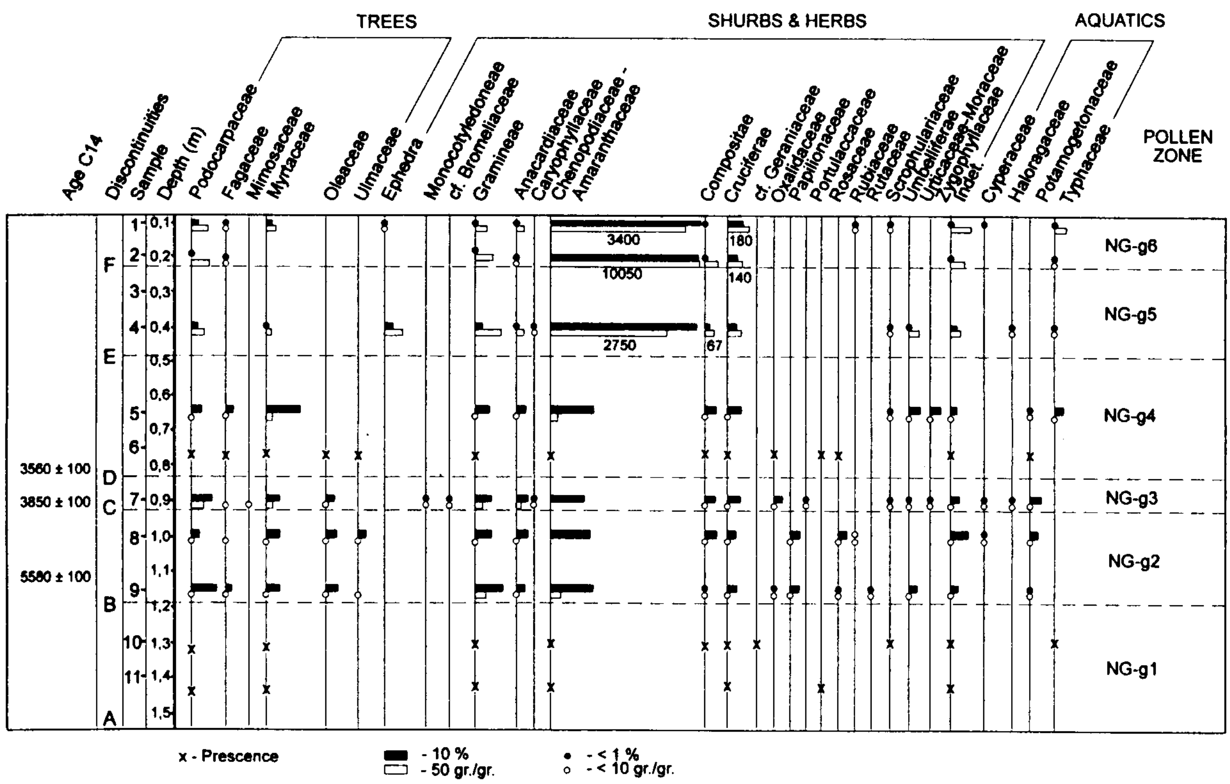

Figure 4. Pollen diagram. Profile 3 (Grumbein).

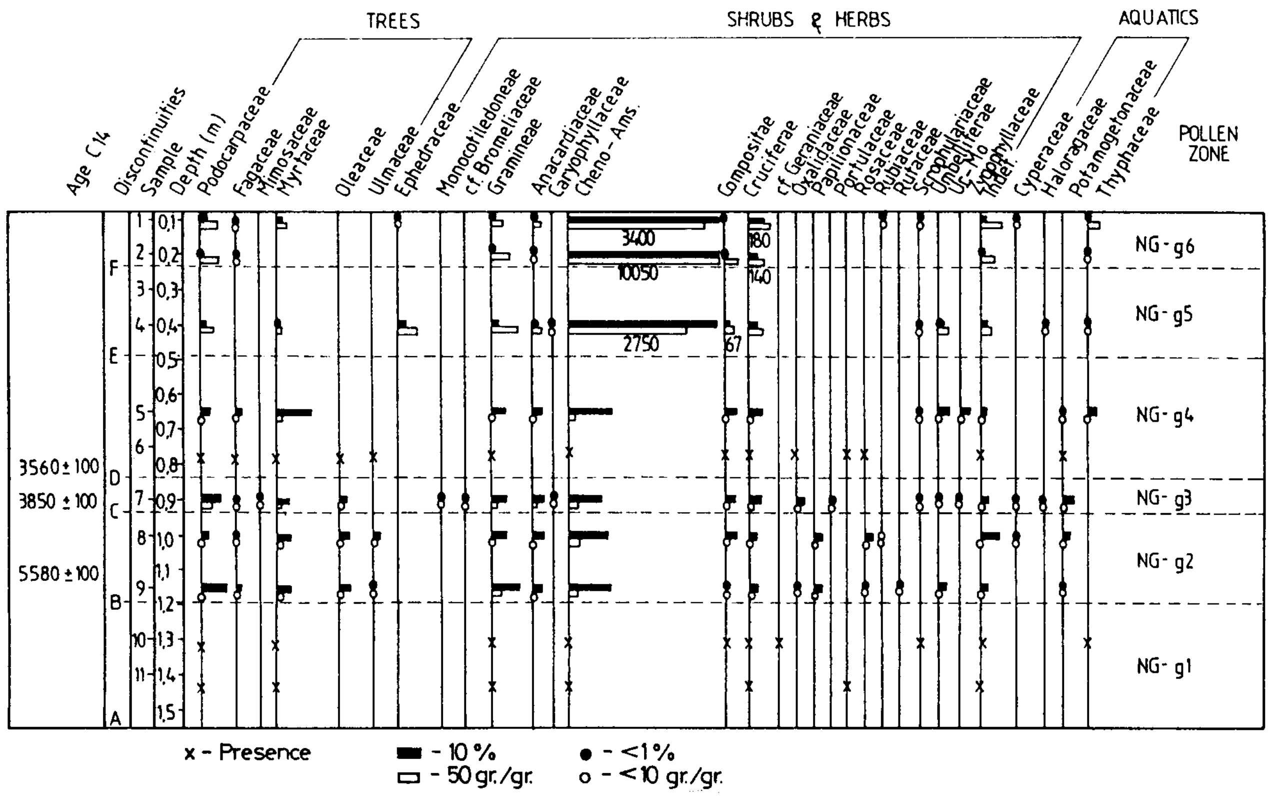

Figure 4. Continued.

Fifteen pollen zones and 4 subzones were identified in the four profiles. See detailed analysis in Grill (1993).

6 PALAEOENVIRONMENTAL AND PALAEOCLIMATIC EVALUATION. DISCUSSION AND CONCLUSIONS

Comparison between vegetation changes and associated lithofacies changes reveals palaeoenvironmental and palaeoclimatic changes for the Late Pleistocene and Holocene in this area (see Tables 1, 2, 3 and 4).

Chronostratigraphic correlation among the four profiles studied led to the elaboration of a chronostratigraphic (Fig. 6) and palynostratigraphic chart (Fig. 7) for the studied area.

This information is related to other pollen studies from the Buenos Aires province, including Borromei (1995) in the Sauce Grande river and Prieto (1989, 1993) in the Sauce Chico and Tapalqué creek.

Other data supplied by fossil vertebrates studied by Deschamps (Quattrocchio et al. 1988 and C. Deschamps, pers. comm.) and Deschamps & Tonni (1992) and ostracods studied by D. Martínez (in Quattrocchio et al. 1988 and Zavala et al. 1992) in the same profiles, are also discussed.

Table 1. Palaeoclimates, palaeoenvironments and vegetation communities registered in García del Río (Profile 1).

Epoch	Pollen zones		Vegetation communities	Palaeo-environments	Palaeo-climates
Holocene	NG-Gr1	Compositae, Gramineae and exotic pollen	Psammophytic Herbaceous steppe	Aeolian	Semiarid
	NG-Gr2	Compositae Gramineae	Psammophytic Herbaceous steppe	Aeolian with fluvial plains	Arid-semiarid
	NG-Gr3b	Gramineae Compositae	Gramineous steppe	Fluvial plains	Warm humid
	NG-Gr3a	Barren	?	?	
Late Pleisto-cene	NG-Gr4	Chenopodiaceae Amaranthaceae, Compositae	Psammophytic Herbaceous steppe with shrubby wood elements	Aeolian with ephemeral streams	Arid-semiarid
		Barren	?	Aeolian	Extremely arid

Table 2. Palaeoclimates, palaeoenvironments and vegetation communities registered in Chacra Santo Domingo (Profile 2).

Epoch	Pollen Zones		Vegetation communities	Palaeo-environments	Palaeo-climates
Late holocene	Ng-sd1	Chenopodiaceae-Amaranthaceae, Compositae, Cruciferae	Psammophytic Herbaceous steppe	Aeolian	Semiarid
	Ng-Sd2	Gramineae Compositae	Gramineous steppe	Aeolian with fluvial plains	Humid
	Ng-Sd3b	Gramineae Chenopodiaceae-Amaranthaceae	Gramineous steppe	Fluvial plains	Humid
	Ng-Sd3a	Chenopodiaceae-Amaranthaceae	Gramineous steppe with Hidrophytic communities	Lacustrine	Warm humid
Late pleisto-cene	Ng-sd4	Cruciferae	Psammophytic Herbaceous steppe with shrubby wood elements	Aeolian with ephemeral streams	Arid - semiarid

Table 3. Palaeoclimates, palaeoenvironments and vegetation communities registered in Grumbein (Profile 3).

Epoch	Pollen zones		Vegetation communities	Palaeo-environments	Palaeo-climates
Holocene	NG-g1	Chenopodiaceae Amaranthaceae	Halophytic steppe	Fluvial	Arid-Semiarid
	NG-g2	Chenopodiaceae Amaranthaceae	Halophytic steppe	Fluvial	Arid-Semiarid
	NG-g3	Chenopodiaceae-Amaranthaceae, Myrtaceae	Herbaceous Halophytic steppe/ Gramineous	Fluvial plains marine	Humid
	NG-g4	Chenopodiaceae-Amaranthaceae, Podocarpaceae	Herbaceous Halophytic steppe/ Gramineous	Marine	Humid
	NG-g5	Chenopodiaceae-Amaranthaceae, Gramineae	Herbaceous Halophytic steppe/ Gramineous	Marine	Humid
	NG-g6	Chenopodiaceae-Amaranthaceae, Gramineae, Compositae (presence)	?	Marine	Humid

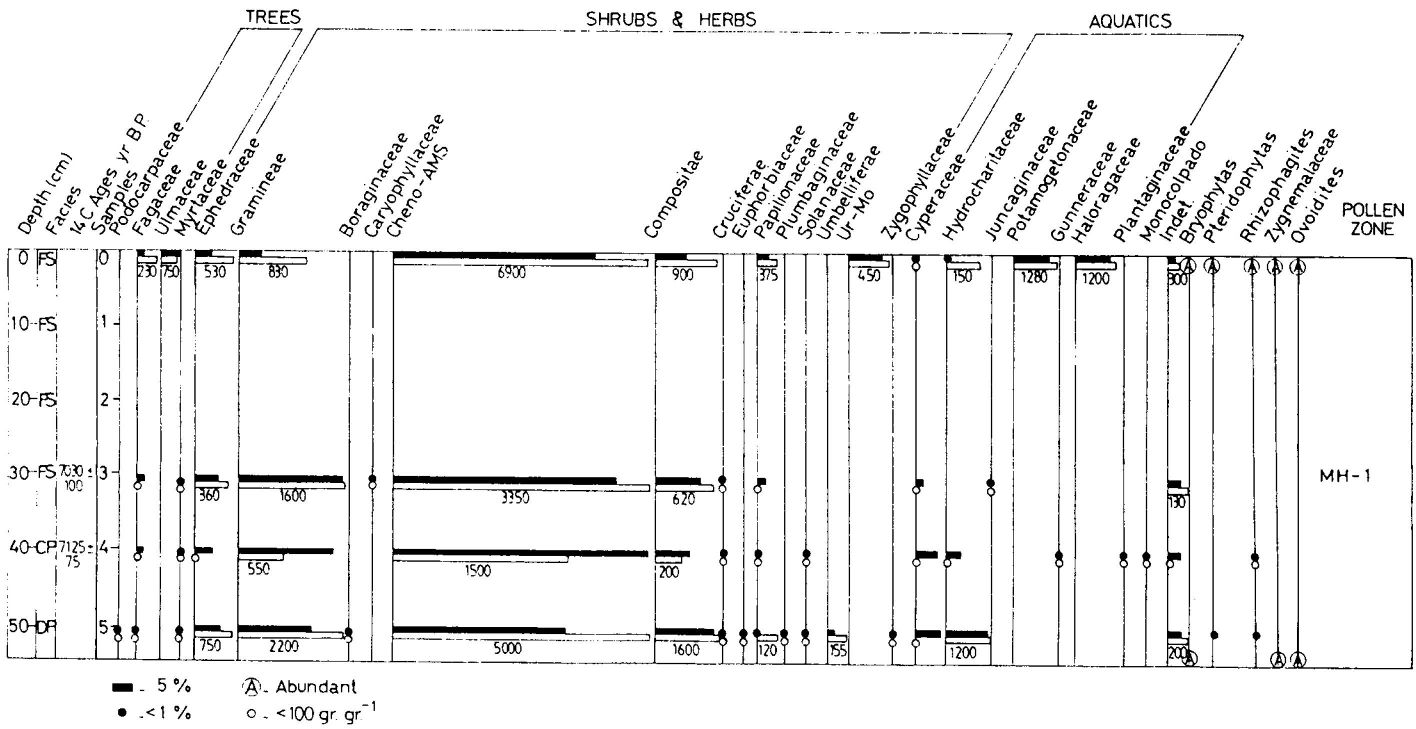

Figure 5. Pollen diagram. Profile 4 (Monte Hermoso I).

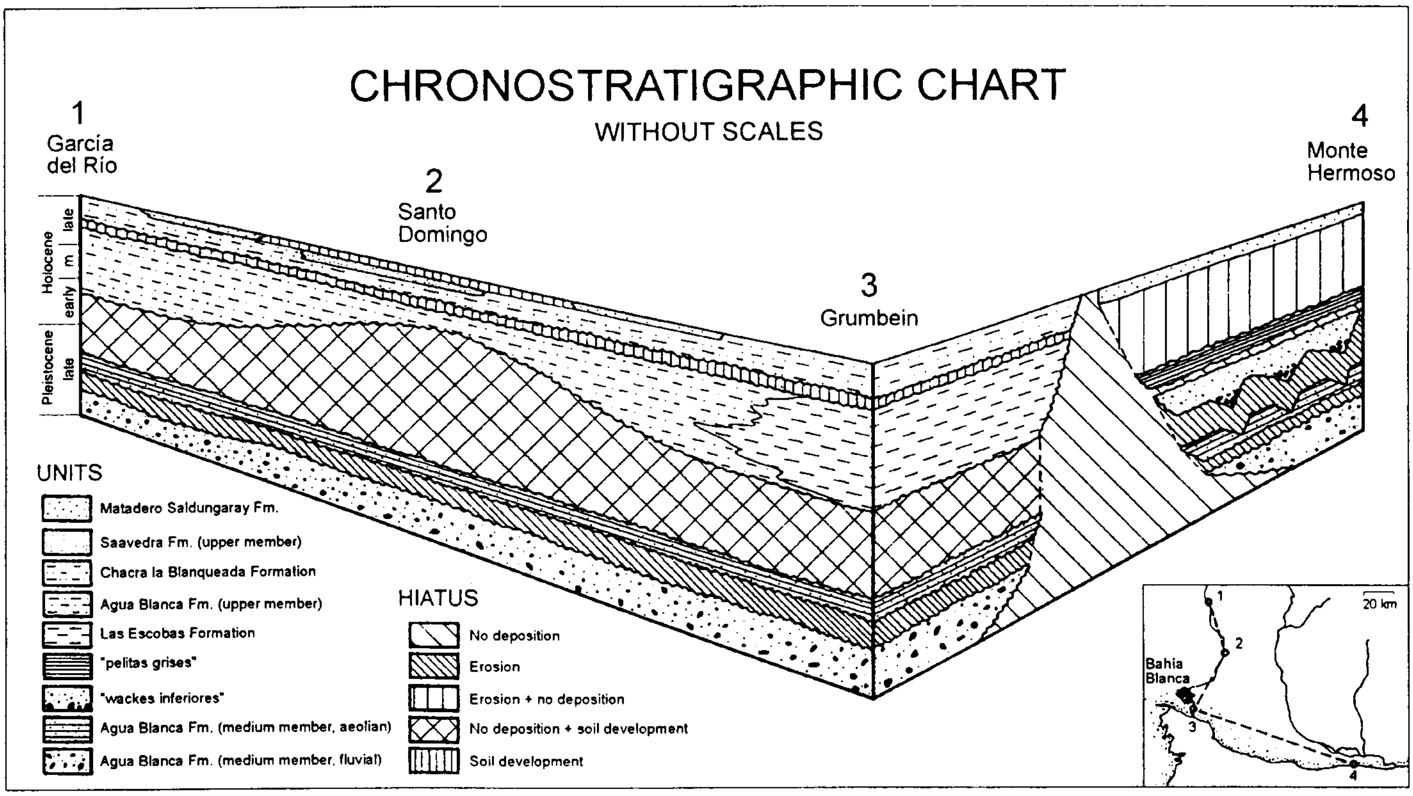

Figure 6. Chronostratigraphic chart of studied area.

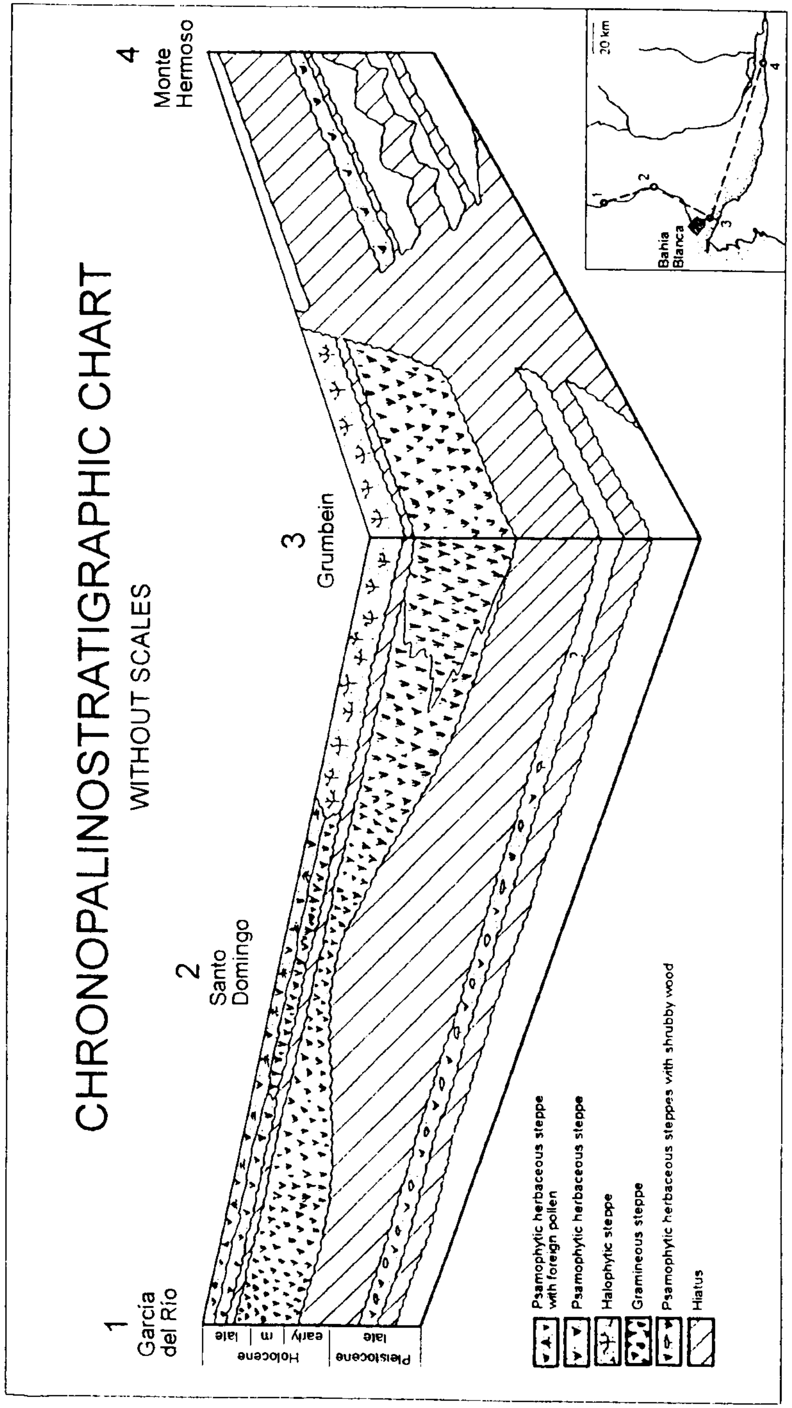

Figure 7. Palynostratigraphic chart of studied area.

Table 4. Palaeoclimates, palaeoenvironments and vegetation communities registered in Palaeoicnological Sites of Monte Hermoso I (Profile 4).

Epoch	Pollen zones		Vegetation communities	Palaeo-environments	Palaeo-climates
Holocene	MH-1	Chenopodiaceae-Amaranthaceae, Gramineae	Herbaceous Psamophytic steppe associated to Lacustrine body	Interdune	Humid (locality)

6.1 *Late Pleistocene*

The pollen assemblages recorded in sediments of Late Pleistocene age (the NG-gr4 and NG-sd4 Zones) are characteristic of vegetation communities of halophytic and herbaceous psammophytic steppes, with representatives of the shrubby forest. They suggest arid to semiarid palaeoclimatic conditions, similar to those today characteristic for the western Pampa, where precipitation ranges between 400 and 600 mm per year (Prieto 1989). Within these communities, Cruciferae dominate the assemblages in Profile 2. The development of these herbaceous taxa may imply an environmental disturbance, caused by aridity and strong aeolian activity, that may have caused also a decrease of grasslands (León & Anderson 1973).

Cool climatic conditions favor the development of quick growing plants such as the Cruciferae among others (Grime 1979). It can be inferred that during the Late Pleistocene the climate was cool-arid to extremely arid in the studied area.

The supposed extreme aridity could also be the cause of barren samples recorded in the bottom of Profile 1, upper middle basin of Napostá Grande creek.

The associated lithofacies suggest an aeolian environment with ephemeral water, reflecting extremely arid to semiarid conditions for the Late Pleistocene.

Another factor for the aridity may be related with a lower than present sea level, dated at 12.000 ± 100 yr BP ^{14}C by Aramayo & Bianco (1996) for a site approximately 75 km east from Napostá Grande and by Bayón & Zavala (1997) for Farola Monte Hermoso (Buenos Aires province).

The ostracods *Darwinula* sp. and *Larseypridopsis aculeata* (D. Martínez, pers. comm.), found in the Sandy Middle Member of the Agua Blanca Formation (Profiles 1 and 2 of Napostá Grande creek), suggest shallow and standing water bodies, fresh to slightly saline. The low species diversity and low frequency may imply alternating periods of temporary water and dryness (D. Martínez, pers. comm.).

The vertebrates found in the same profiles (*Lama guanicoe*, *Chaetophractus villosus* and *Lagostomus maximus*) suggest arid to semiarid open areas of grasslands and steppes (C. Deschamps, pers.comm.).

Similar conditions were recorded in the Sauce Grande river valley in the Sandy Middle Member, Upper submember, SG-4 Zone (Borromei 1995). Prieto (1989) in Tapalqué creek inferred, in sediments older than 10,000 yr BP similar conditions to those at present in western Buenos Aires province. The end of the EQ1 Zone is correlated with the NG-sd4 Zone, in the Sandy Middle Member of the Agua Blanca Formation in Napostá Grande creek (Profile 2). In both zones pollen associations are dominated by Cruciferae. Over the EQ1, SG-4 and NG-sd4 Zones there is a regional discontinuity.

The Late Pleistocene/Holocene contact is characterized by development of palaeosoils that can be correlated with Puesto Callejón Viejo Palaeosoil (Fidalgo et al. 1973, Fidalgo 1992). In some sectors this contact is transitional and in others there is a discontinuity. Because the palaeosoils are truncated, the pedogenetic event in the pollen record is inferred by presence of *Glomus* sp. and some fungal spores typical from palaeosoils. According to Dimbleby (1957), pollen grains percolate down to 30 cm from the soil. This may explain their absence in the pollen records within the development of the palaeosoils.

6.2 *Holocene*

The early Holocene pollen record of the MH-1 Zone in Profile 4 from Monte Hermoso I is dated at 7125 ± 75 and 7030 ± 100 ^{14}C yr BP and reflects the development of a vegetation community characteristic of coastal dunes (psammophytic herbaceous) and of interdune ponds with a slight marine influence. Sea level was still lower than present. This community suggests locally humid conditions.

The ostracods *Sarscypridopsis aculeata, Lymnocythere* sp. 1 and 2 and *Cyprinotus salinus* found in Profile 4, suggest the development of a standing water body probably poly-mesohalyne with abundant nutrients and good oxygenation (D. Martínez in Zavala et al. 1992).

Temperature and humidity reachs its maximum during the mid Holocene, recorded at the mouth of Napostá Grande creek in the NG-g6 Zone (Profile 3). Between 6000 and 5580 ± 100 ^{14}C yr BP, the high species diversity and abundance of marine dinocysts and acritarchs indicate the maximal marine transgression in this sector of the basin. These assemblages and the poor pollen preservation (NG-g5) reflect neritic/estuarine conditions enclosures during the deposition of the sediments (Grill & Quattrocchio 1996). This event may be correlated with the SG-3 Zone of Sauce Grande river (Borromei 1995).

Between 5600 and 3000 yr BP, (Profile 3; NG-g4 Zone) a higher diversity of the sporomorphs associated with representatives of the gramineous steppe approximately suggests more temperate conditions in this sector. This zone maybe correlated with the SCH-4 and 5 Zones of Sauce Chico creek (Prieto 1989).

This relative rise of sea level lead to flooding of the river-beds producing deposition of grey pelitic facies.

The warmer climatic conditions, associated with sea level rise, are partially inferred in the pollen records of the Napostá Grande basin, because the sediments of this age have been eroded or are palynologically barren. The destruction of the pollen grains may have been due to an intense activity of microorganisms under wet climate (Havinga 1970, Birks & Birks 1980, Dimbleby 1985, among others).

However, the expansion of the gramineous steppe during this interval is recorded in Buenos Aires province in the Sauce Grande river middle valley (the SG-3 Zone, with a top age of 5010 ± 120 ^{14}C yr BP, Borromei 1995). In the Sauce Chico creek, facies and hydrophytic associations recorded by Prieto (1989; SCH-3 and 2 Zones; SCH-2; 6170 ± 170 ^{14}C yr BP) may suggest the presence of humid grassland prairie and ponds within the valley. This Zone is equivalent to the EQ-2 (humid prairie and lacustrine) and EQ-3 (gramineous steppe) zones recorded in Tapalqué creek (Empalme Querandíes) by Prieto (1989).

Approximately at 3000 yr BP, the marine influence ended in the lower basin of the Napostá Grande creek (NG-g3 Zone, Profile 3).

After 2610 ± 100 ^{14}C yr BP (NG-gr2 Zone, Profile 1), psammophytic herbaceous steppe developed with representatives of the shrubby forest, suggesting arid to semiarid conditions. This Zone is equivalent to the SG-2 Zone recorded in the Sauce Grande river middle valley with a bottom age of 2830 ± 90 ^{14}C yr BP (Borromei 1995).

An interval of higher humidity is inferred at approximately 2000 yr BP (1960 ± 100 ^{14}C yr BP, NG-sd3 Zone, Profile 2), in the middle basin of the Napostá Grande creek (chacra Santo Domingo), based on the development of hydrophytic communities characteristic of lacustrine environments, associated with gramineous steppe. Likewise, a relative rise of temperature may be inferred by the southward expansion of the Brazilian fauna, i.e. *Holochilus brasiliensis* and *Cavia aperea* (Quattrocchio et al. 1988; Deschamps & Tonni 1992). In this profile, the Late Holocene lies discontinuedly over the Late Pleistocene. Neotectonic activities are inferred for this area (Quattrocchio et al. 1988).

The sympatry of Brazilian faunistic representatives with Patagonian elements (*Lestodelphys halli* and *Lama guanicoe*) may suggest vegetated water bodies that would locally modify the arid and semiarid regional conditions, providing pathways for Brazilian elements (Deschamps & Tonni 1992).

The increase in moisture can be recognized throughout the basin by development of palaeosoils, that can be correlated with the Puesto Berrondo Palaeosoil (Fidalgo et al. 1973, Fidalgo 1992).

Ostracods suggest shallow, isolated water bodies of low energy and salinity, and with rather dense aquatic vegetation. One of the species, *Clamidoteca incisa,* has its southern occurrence at this site. Brackish to fresh water conditions are inferred through the abundance of *Cyprideis salebrosa* (Bertels & Martínez 1990).

The persistence of gramineous steppe in the middle sector of the basin (NG-sd2 Zone) suggests the continuity of locally humid conditions, which are associated with fluvial overflows.

Influence of grazing and farming under semiarid conditions is registered in the upper middle and middle basin of Napostá Grande creek (Profiles 1, NG-gr1 Zone and 2, NG-sd1 Zone).

After 3000 yr BP, vegetation communities characteristic of halophytic steppe were established in the lower basin of Napostá Grande creek (Profile 3, NG-g2 and 1 Zone). These communities are similar to those of the present coastal environments.

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