Journal of Coastal Research	5	1	65-77	Charlottesville, Virginia	Winter 1989

Holocene Levels in the Bahia Blanca Estuary, Argentine Republic

Miguel Angel González

Instituto de Geocronología y Geología Isotópica (INGEIS)
Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)
Pabellón INGEIS, Ciudad Universitaria
1428 Buenos Aires, Republica Argentina

ABSTRACT

GONZÁLEZ, M.A., 1988. Holocene levels in the Bahia Blanca estuary, Argentine Republic. *Journal of Coastal Research*, 5(1), 65-77. Charlottesville (Virginia). ISSN 0749-0208.

Estuarine deposits of the Holocene transgression were studied in the Bahía Blanca estuary (38°50'S and 62°15'W, Argentine Republic). They were called respectively Holocene Clastic-Shelly Beach Ridges and Holocene Pelitic Deposits; the second group was subdivided in Lagoon Deposits and Tidal Flat Deposits. These names indicate geochronological and paleoecologic distinctions.

At least five major episodes of high wave-energy were found, which built the Holocene Clastic-Shelly Beach Ridges, and were named Transgressive Stages (T.S. I to V). Their respective ^{14}C ages, with Probable Geological Age (PGA = the minimum ^{14}C age) are: TS-I: 5990; TS-II: 5470; TS-III: 5100; TS-IV: 4470; TS-V: 3560 BP.

The TS-I represents the maximum Holocene Transgression in the inner estuary. The younger TS (TS-II to TS-V) indicate later high wave-energy episodes, which would appear to be conditioned by culminations of the Progression of the Lunar Perigee Cycle.

The Lagoon Deposits associated with the maximum transgressive episode would indicate semi-arid conditions, comparable to the present climate in the area. The Tidal Flat Deposits were developed at different stages of low wave-energy in the inner estuary, during each regressive episode. In these Tidal Flat Deposits, the $^{18}O/^{16}O$ and $^{13}C/^{12}C$ isotope ratios would indicate the occurrence of the Hypsithermal conditions about 6000BP, which ended about 5300/5200 years Before Present.

ADDITIONAL INDEX WORDS *Argentine Republic; ^{14}C; $^{13}C/^{12}C$; eustasy; Holocene; hypsithermal; $^{18}O/^{16}O$; progression of the lunar perigee; stable isotopes.*

INTRODUCTION

Some evidence of the Holocene transgression and the subsequent regression in the Bahía Blanca estuary (38°50'S and 62°15'W, Figure 1), are presented. This work was performed as part of a larger project named "Geochronology of the Late Pleistocene and Holocene Paleoclimate and Paleoeustasy in the Middle Latitudes of the Argentine Republic". This project is carried out by INGEIS and other research institutions, with the financial support of the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET). The isotope analyses (^{14}C, $^{13}C/^{12}C$ and $^{18}O/^{16}O$) were made in the INGEIS laboratories.

Concerning the terminology that is used in this paper, the traditional stratigraphic names for the Argentine Quaternary deposits, such as *Querandinense, Querandino, Platense* (or *Post-pampeano*), employed by most researchers since the last century to identify the postglacial transgressive and regressive deposits of the coastal areas were applied with many different criteria to designate genetic, lithologic and chronologically different deposits. Thus, following HEDBERG (1980, p. 10), in the present work a chronostratigraphic division is attempted. This terminology also includes a geomorphologic and sedimentological characterization.

Besides the temporal classification of these deposits, this terminology provides a quick paleoecologic distinction and an easy field location, because, at least for the locality in question, the middle Holocene morphological features have not changed up to the present. In this way, the postglacial deposits of the Bahía Blanca estuary were named:

(a) *Holocene Clastic-Shelly Beach Ridges*
(b) *Holocene Pelitic Deposits*.

87032 received 10 August 1987; accepted in revision 9 March 1988.

In both names, the term Holocene has an exact chronological significance. In the first formation, the term "*Clastic-Shelly*" has a sedimentological and environmental implication, and indicates a relatively high depositional energy in the higher part of the normal intertidal zone. The term "*Beach Ridges*" has environmental significance, and clearly indicate deposits exceptional tides and storms reaching above the normal spring-tide ranges.

In the second case, the term "*Pelitic Deposits*" also has a sedimentological sense with environmental connotations, and indicates estuarine deposits formed in episodes of low wave-energy. They were further divided into "*Lagoonal*" and "*Tidal-Flat Deposits*," both of them with precise and clear environmental significance.

DATES

Holocene Clastic-Shelly Beach Ridges

These deposits were widely used for building purposes since the last century, and at present the shelly material is rather scarse.

Location: At the north and northeast margin, in the innermost estuary, near of General D. Cerri village, the oldest and highest deposits form a spit composed of at least six beach ridges up to 10 meters above sea level (GONZÁLEZ *et al.*, 1983a). From General D. Cerri to Ing. White harbor (middle part of the estuary) some younger beach ridges topographically delineate a Late Pleistocene fan delta (GONZÁLEZ,

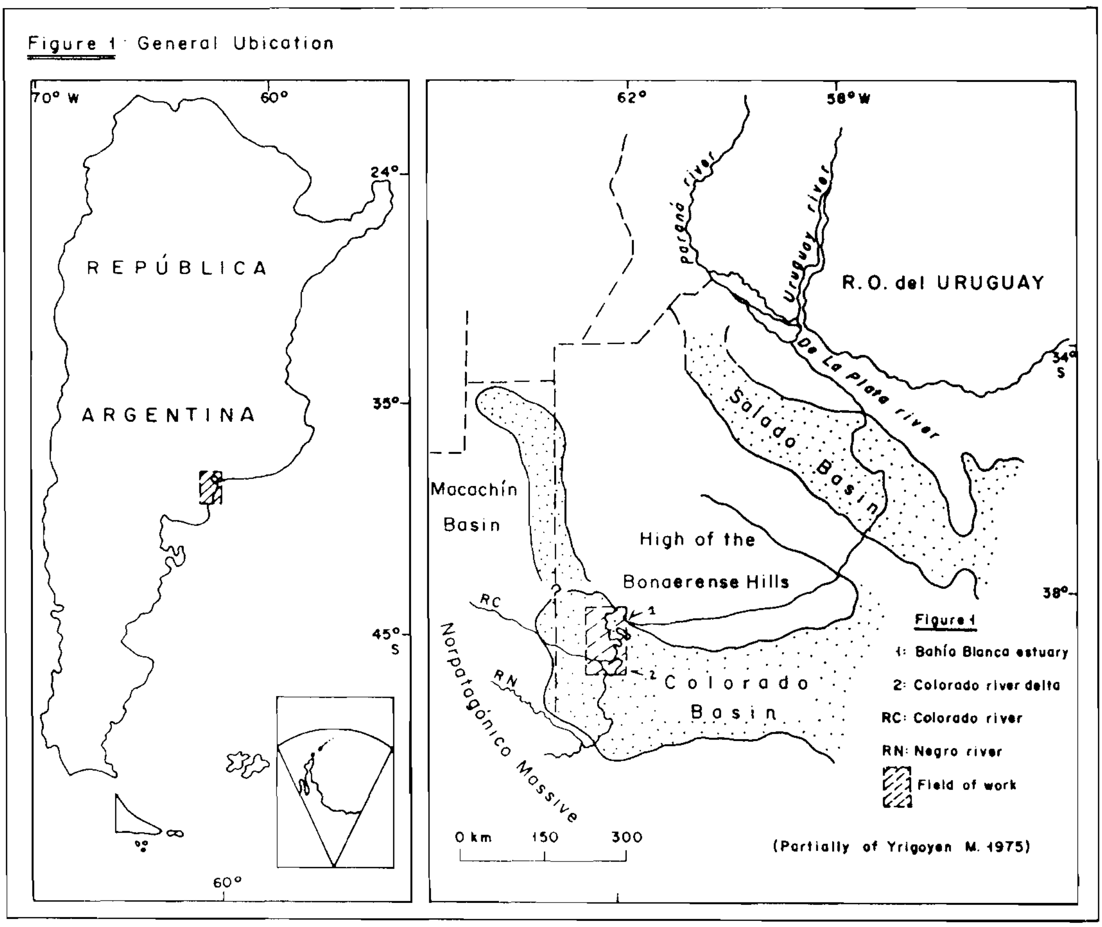

Figure 1. General location.

1984), and also built up to about the 10 meter level curve.

Description: (a) Lithology: They are composed by clastic sediments and varied amounts of entire or fragmented mollusk shells. The clastic material ranges between middle to coarse sand, with subordinate small to middle-sized pebbles, and isolated layers of coarse gravel. These materials are cross-bedded, with slopes of approximately 5° to 15° seawards, in a typical fore-shore facies.

The gravelly beds are dominated by clasts of *tosca* (local name for the carbonate crusts, caliche, or calcrete) from the eroded Plio-Pleistocene continental loess and loess-like deposits forming the northern and northeastern margin of the estuary (GONZÁLEZ, 1984). There are also subordinate Paleozoic quartzitic clasts, brought by the Sauce Chico and Napostá Grande rivers from the Sierras Australes of the Buenos Aires province. Isolated, scarse porphyric clasts have been brought in by littoral drift from the open coast areas of southern Patagonia.

(b) Biologic Elements: Marine and estuarine mollusk shells are very common in these deposits. The abundance of *Brachydontes rodriguezi* (d'Orbigny) was favored by a well cemented substratum (fan delta tentatively correlated with the Sangamon Interglacial; GONZÁLEZ, 1984), on which those Mytilidae could easily obtain a holdfast. Thus, in the localities where the beach ridges are directly overlying this hard substratum near the Ingeniero White harbor (see Figures 2 and 4), most of these *B. rodriguezi* shells are entire, and often articulated, indicating little transport after death. In contrast, in the inner estuary, here there is not hard substratum, and during the successive episodes of greater littoral drift, the *B. rodriguezi* shells become progressively more fragmented. In the inner estuary (Figures 2 and 3), the smallest fragments of shells are also of *B. rodriguezi*, because of the greater transport distance from their original sessile habitat.

In the coarse clastic levels that were formed during the greatest wave-energy episodes (storms, principally), are found the larger mollusk shells such as *Zidona angulata* Swaison and *Adelomedon* Dall (both are big gastropods) together with some fragments of large colonies of Bryozoa.

Other abundant mollusk species of various habitats are mixed up in the beach ridges, including: *Buccinanops deformis* (King), *B. gradatum* (Deshayes), *B. globulosum* (Kiener), and *B. cochlidium* (Chemnitz); also, *Pitar rostrata* (Koch), *Olivella tehuelchana* (d'Orbigny), *Olivancillaria brasiliana* (Chemnitz), and many others. They were described by IHERING (1907, 1909); FRENGÜELLI (1931); and recently, by FARINATTI (1978). The genus *Buccinanops* d'Orbigny is a Mytilidae predator and its shells are abundant wherever *B. rodriguezi* appear.

(c) Stratigraphic Relations: Near Ingeniero White harbor (Figures 2 and 4), the *Holocene Clastic-Shelly Beach Ridges* are discordant over cemented deposits of the fan delta tentatively correlated with the Sangamon Interglacial (GONZÁLEZ, 1984; GONZÁLEZ *et al.*, 1986). In the inner estuary, near General D. Cerri village (Figures 2 and 3), the beach ridges rest discordantly over older lagoon deposits in a typical transgressive sequence. In the innermost part of the estuary (Salitral de la Vidriera and Estancia Dos Susanas, some kilometers inland to the south west of General D. Cerri), the beach ridges are overlying undifferentiated Cenozoic continental silts (loess and loess-like deposits, with carbonate crusts).

Over these beach ridges, generally there are no younger sediments, and the modern soils are developed on them. Only in Estancia Dos Susanas and the neighbouring areas, the beach ridges are covered by middle Holocene and younger eolian deposits (dunes coming from western semi-arid areas, brought by westerly winds during Holocene arid episodes, such as around 5300/5200 BP., according to GONZÁLEZ and WEILER, 1984).

(d) Genetic Conditions: The *Holocene Clastic-Shelly Beach Ridges* would indicate various major high wave-energy episodes in the inner estuary, which occurred during a regressive episode when these geoforms could be built outside the normal storm and spring-tide ranges. Thus, the beach ridges are still preserved up till today. The ^{14}C ages and the field relations (Figures 3, 4 and 5) let us recognize at least five such episodes of high wave-energy conditions for the building of beach ridges. These episodes were named *Transgressive Stages* (TS) I, II, III, IV and V (GONZÁLEZ *et al.*, 1983b; GONZÁLEZ and WEILER, 1983). The expression

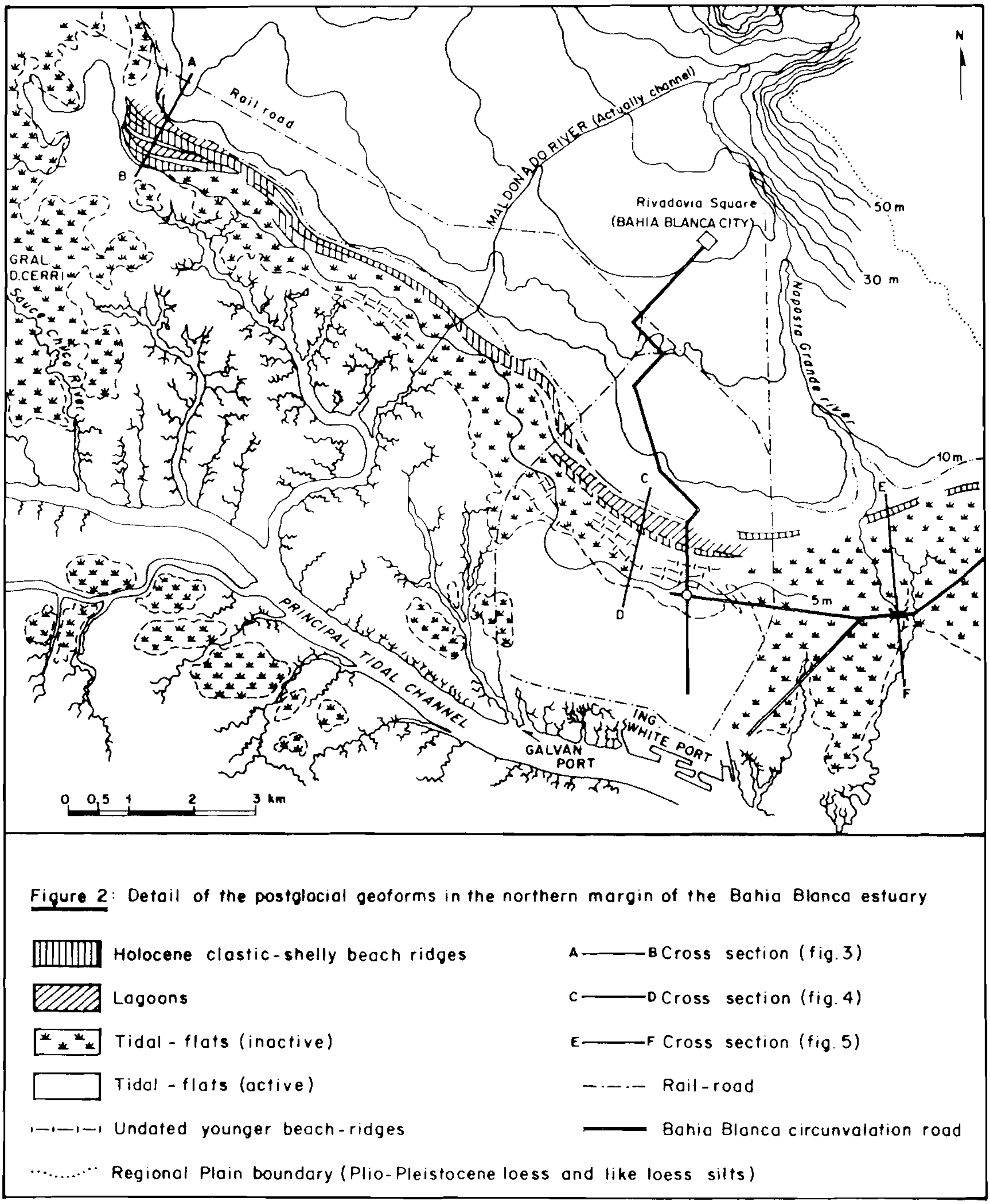

Figure 2. Detail of the Holocene geoforms in the northern margin of the Bahía Blanca estuary.

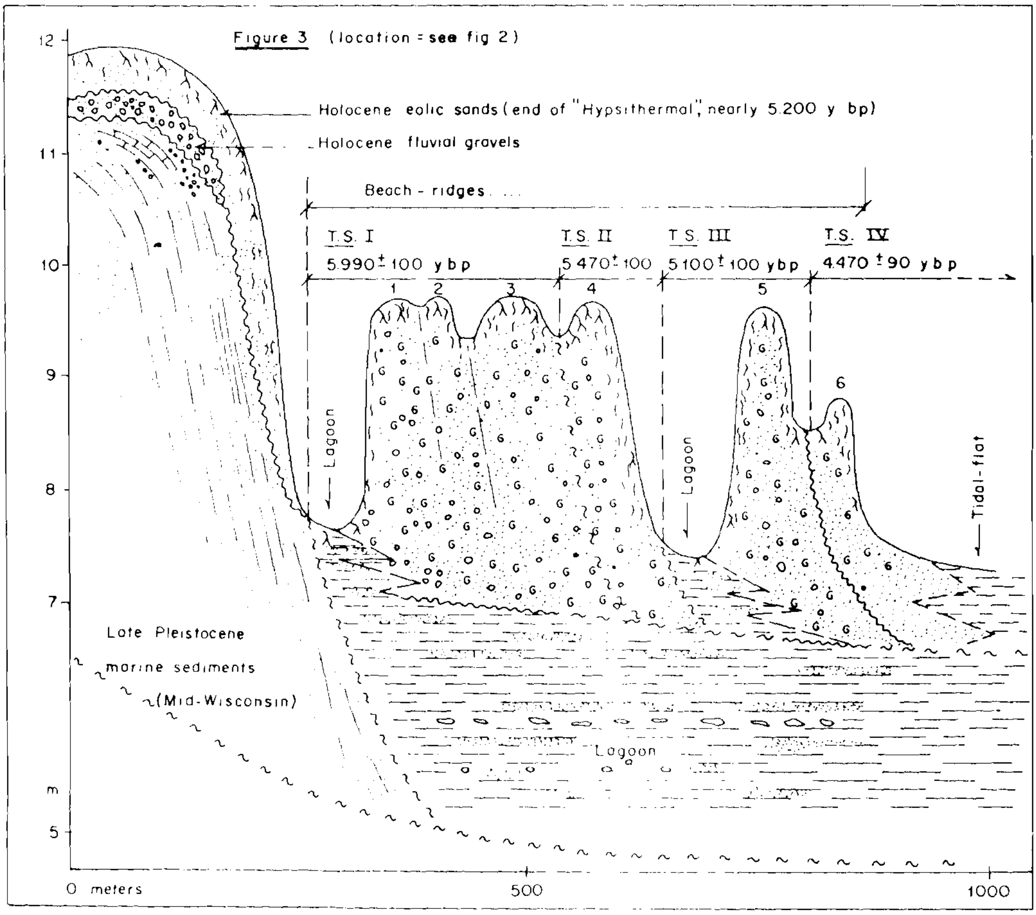

Figure 3. Cross-section over Holocene beach-ridges, inner estuary (A-B in Figure 2).

"Transgressive Stage" is used on account of their basal relations; each beach ridge appears in a discordant relationship over previous deposits such as lagoon facies; but it does not necessarily mean that these Transgressive Stages indicate transgressions of thermoeus-atic, tectonoeustatic or other origin.

GONZÁLEZ and WEILER (1983) postulate hat these beach ridges and those present in the ieighbouring Colorado river delta, seem to be a esponse to two main factors: first, most impor-ant are the solar activity peaks identified by ISCOE (1978), which conditioned the major Iolocene transgressions (thermoeustatic ansgressions), represented by TS-I (*probable eological age ca.* 5990 ± 115 BP). The second-factor seems to be the Progression of the Lunar Perigee Cycle, causing unusual tide episodes during the maximum Moon-Earth proximity, along with the regressive episode. They are represented by the other TS, younger than TS-I. Concerning this factor, following a suggestion by Dr. R. W. Fairbridge, GONZÁLEZ and WEILER (1983) found a possible rhythmicity close to 500 years for the beach ridges built from 7000 BP to 400 BP, in Bahía Blanca estuary and the Colorado river delta (see Figure 6).

(e) Geochronology: The ^{14}C age dating was performed in the INGEIS laboratory, according to the methodology described by ALBERO *et al.* (1980). Analytical data and all the ^{14}C ages for

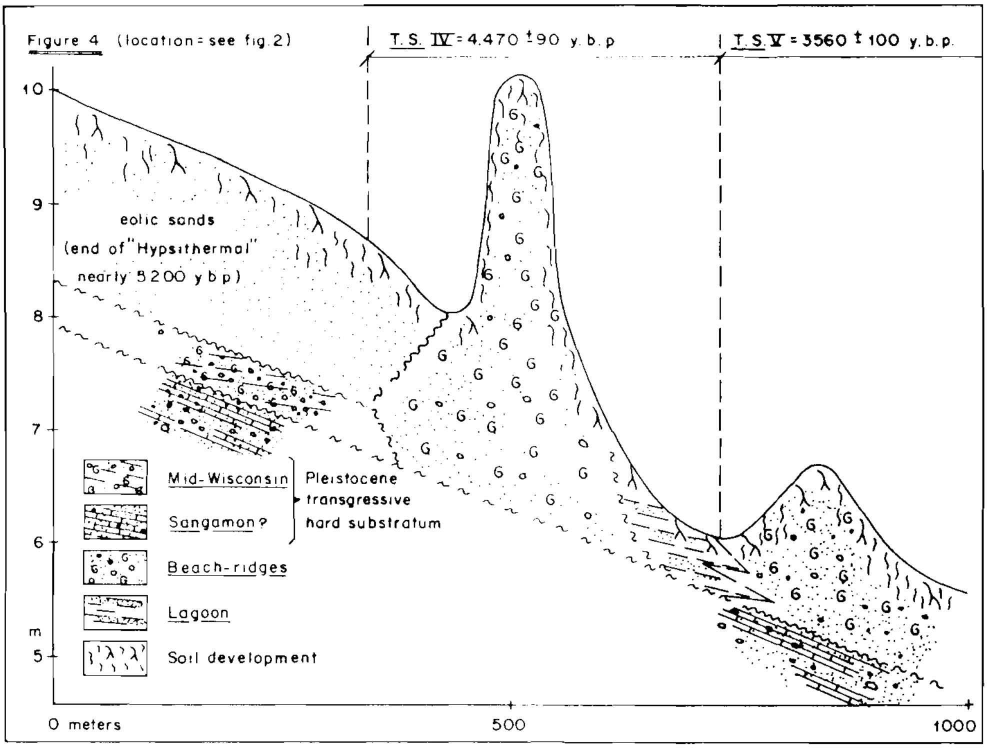

Figure 4. Cross-section over Holocene beach-ridges, middle estuary (C-D in Figure 2).

each of the five Transgressive Stage deposits, are presented in Tables 1 and 2.

As GONZÁLEZ *et al.* (1982, 1983a) pointed out, it is very difficult to obtain a representative ^{14}C age for the building time of a high wave-energy deposit such as these beach ridges. The mixture of clastic and biogenic material of very different habitat such as, for example, *Pitar rostrata* (koch), *Brachydontes rodriguezi* (d'Orbigny) and *Tagelus* Gray, and probably different true ages, are deposited altogether. Thus, GONZÁLEZ *et al.* (1983a) defined the probable geological age (PGA) criterium, as the minimum ^{14}C age obtained for a high wave-energy deposit. This PGA is the closest age to the building episode of each deposit.

Therefore, the ^{14}C ages presented in this work for each Transgressive Stage, are considered as PGA. Thus, the PGA for TS-I is 5990 ± 115 BP which corresponds to the maximum postglacial transgressive episode, represented by the inland beach ridge.

Younger TS have the following PGA:

TS-II:	5470 ± 100BP
TS-III:	5100 ± 100 BP
TS-IV:	4470 ± 90 BP
TS-V:	3560 ± 100 BP

These younger TS deposits would correspond to high wave-energy episodes and could be related to the culmination of the Progression of the Lunar Perigee Cycle, as indicated in the previous section (Genetic Conditions).

Holocene Pelitic Deposits

All the clay, mud-clay and sandy-clay deposits are as much transgresive (Lagoons) as they are regressive (Tidal Flats). They were deposited in the estuary since the maximum development of the Holocene Transgression. On the one hand, lagoonal sediments developed inland of the respective beach ridge belt formed during each Transgressive Stage. On the other hand,

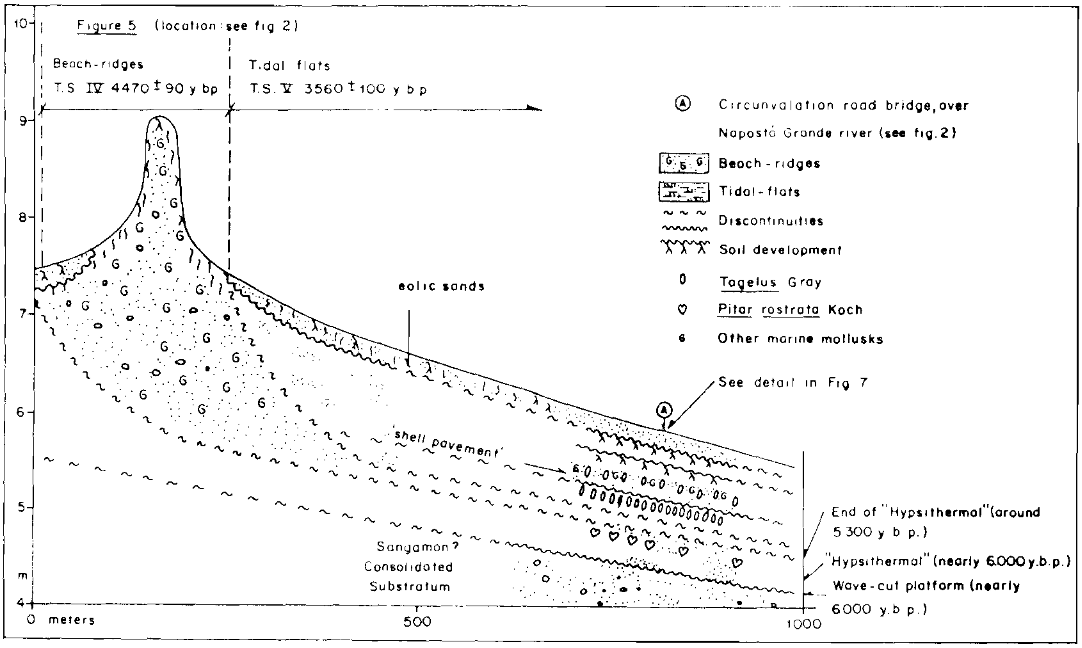

Figure 5. Cross-section over Holocene beach-ridges and tidal flats, middle estuary (E-F in Figure 2).

there are tidal flat deposits that are younger than each minor TS, and, particularly, younger than TS-V (PGA: 3560 ± 100 BP).

Lagoonal Deposits: (1) Location: These deposits are well developed in the inner estuary, near General D. Cerri village (Figures 1 and 2), from near 10 meters above sea level to minor height, with more than 2.5 meters thick (Figure 3).

(2) Description: (a) Lithology: The Lagoonal Deposits are essentially dark-brownish clays (wet samples) to rosy brownish clays (dry samples). They have high plasticity and are interbedded with fine eolian sands, in this layers without bioturbation. There are frequently little biogenic cylindrical bore-holes (worms?) lined by thin organic clay films, which are possible evidence of poor edaphic development such as found at present. Near the local creek outlets, are found gravel lenses with tosca (caliche or calcrete) pebbles.

(b) Biological Contents: The Lagoonal Deposits contain fragments of the estuarine genus *Tagelus* Gray, and a few shells of *Littoridina australis* (d'Orbigny), but calcareous microfossils such as ostracods and foraminifers have not yet been found (Dr. E. Musacchio, *personal comm.*).

(c) Stratigraphic Relations: Figures 3, 4 and 5 show some stratigraphic cross sections of different sites along the north and northeast margin of the estuary (their geographic location is shown in Figure 2).

The Oldest Lagoonal Deposits were found discordantly over Late Pleistocene transgressive sediments of the Sangamon Interglacial, and Mid-Wisconsin Interstadial transgressive deposits (GONZÁLEZ, 1984; GONZÁLEZ *et al.*, 1986). Generally, they are covered with an erosional discordance by the Holocene Clastic-Shelly Beach Ridges of all the above-mentioned Transgressive Stages (see Figures 3, 4 and 5). Inland of the TS-I and TS-III (see Figure 3), and also TS-V (see Figure 4) beach ridges, the modern soil is developed over these lagoonal sediments.

(d) Genetic conditions: The name indicates their lagoonal origin. They were developed simultaneously with the building of the beach ridges of each Transgressive Stage. At least, for each lagoon associated with the TS-I, II and III

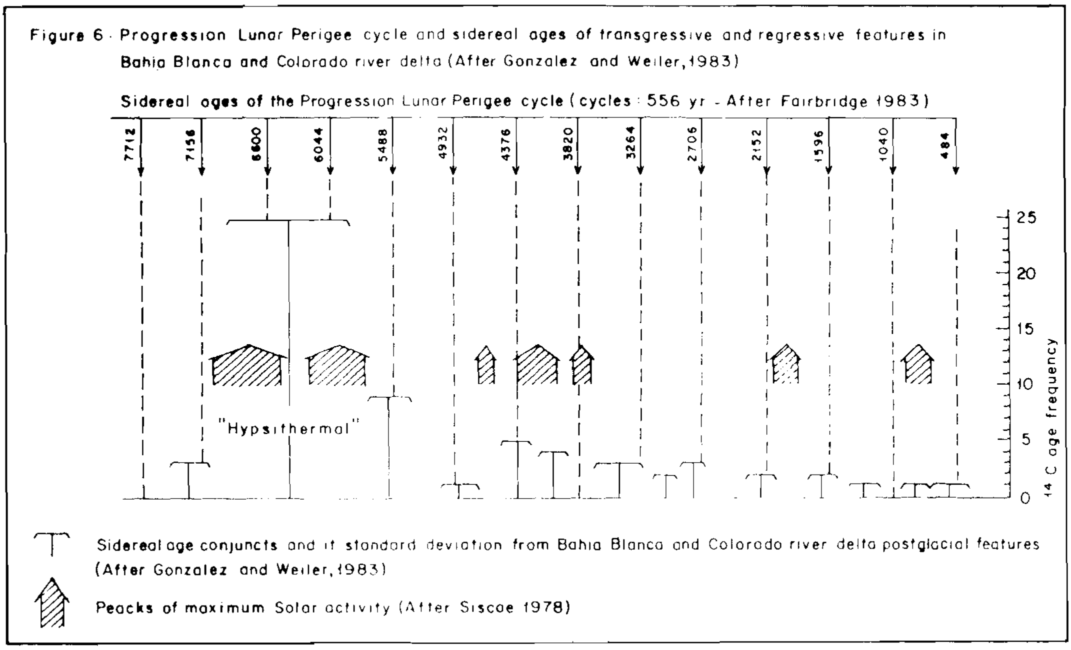

Figure 6. Progression Lunar Perigee cycle and sidereal ages of transgressive and regressive features in Bahía Blanca estuary and Colorado river delta. (After González and Weiler, 1983).

(PGA: 5990 ± 115 BP; 5470 ± 100 BP and 5100 ± 100 BP, respectively) the lack of calcareous microfossils and bioturbation, the scarcity of mollusk shells, and the presence of interbedded eolian sands, probably indicate short recurrent episodes of water cover with brief periods of dessication. Despite the lack of dessication cracks or similar structures, and also the lack of evaporitic deposits, these lagoonal deposits seem to be similar to the deposits described by BRINKMANN (1964; pp. 113-114) for arid and semiarid conditions. The lack of distinctive soil development levels and organic matter such as peat also indicates an arid or semi-arid climate, not very different from the present climate (mean annual precipitation of around 550 mm).

Tidal Flat Deposits: (1) Location: The Tidal Flat Deposits are well developed between the beach ridges of the TS-IV (PGA: 4470 ± 90 BP) and the tidal channels of the present estuary, and appear from the inner part (Gral. D. Cerri, Figures 2 and 3), as far as their external part.

(2) Description: (a) Lithology: Clays of high plasticity predominate. In the oldest (and highest) tidal flats, the color ranges from gray-darkish at depth, to gray-greenish in upper levels, and to rosy-brownish in shallowest levels. The younger ones, but including also some high and thus inactive tidal flats, have gray-darkish sediments, with abundant organic matter. In these deposits, some discontinuity surfaces were found. Over each of them, there is a size-diminishing (fining-up) sedimentary sequence. From a profile of 1.56 meters of tidal flat deposits about 6 meters above sea level (Figure 2; bridge of the Bahía Blanca Circunvalation Way, over the Napostá Grande River), at least five discontinuity surfaces (see Figures 5 and 7) were found. The fining-up sequences over each of them generally begin with scattered fine gravel, pebbles, sands, entire or fragmented mollusk shells and, also "shell pavements". In the two younger discontinuity surfaces there is some paleosoil evidence (GONZÁLEZ *et al.*, 1983c).

(b) Biological Elements: The persistence and continuity of brackish to marine waters seaward from the beach ridges in the estuary, favoured the biological development. They have

Table N°1. *Analytical dates of the ^{14}C ages presented in this paper.*

Sample N°	Activity $^{14}C\%$	$\delta^{13}C$ Sample	Activity Standard NBS cpm %	Activity back ground cpm	$\delta^{13}C$ Standard	Age Years Before Present
AC-0311	32.67 ± 0.26	0.8 ± 0.3	57.06 ± 0.27	10.56 ± 0.09	− 19.0 ± 0.2	5990 ± 115
AC-0312	31.46 ± 0.26	1.02 ± 0.3	57.53 ± 0.23	10.91 ± 0.10	− 19.0 ± 0.2	6600 ± 120
AC-0313	32.57 ± 0.30	2.30 ± 0.1	57.37 ± 0.22	10.57 ± 0.08	− 19.0 ± 0.2	6100 ± 120
AC-0314	32.18 ± 0.25	2.60 ± 0.2	57.53 ± 0.23	10.91 ± 0.10	− 19.0 ± 0.2	6350 ± 110
AC-0315	35.18 ± 0.27	2.10 ± 0.1	57.53 ± 0.23	10.91 ± 0.10	− 10.0 ± 0.2	5280 ± 105
AC-0316	35.68 ± 0.27	1.40 ± 0.2	57.53 ± 0.23	10.91 ± 0.10	− 19.0 ± 0.2	5100 ± 100
AC-0316bis	34.26 ± 0.38	3.10 ± 0.1	56.85 ± 0.12	10.38 ± 0.09	− 19.0 ± 0.2	5400 ± 140
AC-0317	34.61 ± 0.27	1.60 ± 0.1	57.53 ± 0.23	10.91 ± 0.10	− 19.0 ± 0.2	5460 ± 105
AC-0337	38.40 ± 0.30	3.00 ± 0.4	57.18 ± 0.23	10.80 ± 0.10	− 19.0 ± 0.2	4220 ± 100
AC-0338	33.69 ± 0.34	1.90 ± 0.3	56.85 ± 0.12	10.38 ± 0.09	− 19.0 ± 0.2	5580 ± 130
AC-0348	39.02 ± 0.28	1.70 ± 0.3	56.85 ± 0.12	10.38 ± 0.09	− 19.0 ± 0.2	3920 ± 90
AC-0349	37.14 ± 0.27	1.00 ± 0.1	57.32 ± 0.17	9.96 ± 0.07	− 18.4 ± 0.2	4470 ± 90
AC-0350	36.92 ± 0.33	3.00 ± 0.3	57.32 ± 0.17	9.96 ± 0.07	− 18.4 ± 0.2	4520 ± 110
AC-0380	33.67 ± 0.26	1.80 ± 0.2	56.58 ± 0.24	9.57 ± 0.10	− 20.0 ± 0.2	5420 ± 110
AC-0381	33.34 ± 0.26	3.00 ± 0.1	57.32 ± 0.17	9.96 ± 0.07	− 18.4 ± 0.2	5720 ± 100
AC-0382	32.21 ± 0.26	1.20 ± 0.4	56.93 ± 0.21	9.77 ± 0.09	− 17.6 ± 0.2	6000 ± 110
AC-0383	33.35 ± 0.27	1.30 ± 0.2	58.94 ± 0.10	10.85 ± 0.09	− 19.0 ± 0.2	6130 ± 110
AC-0384	35.33 ± 0.27	2.60 ± 0.2	58.94 ± 0.10	10.85 ± 0.09	− 19.0 ± 0.2	5470 ± 110
AC-0386	40.06 ± 0.33	1.10 ± 0.2	56.93 ± 0.21	9.77 ± 0.09	− 17.6 ± 0.2	3570 ± 100
AC-0387	39.01 ± 0.28	1.90 ± 0.1	57.32 ± 0.17	9.96 ± 0.07	− 18.4 ± 0.2	3950 ± 90
AC-0388	36.00 ± 0.27	2.00 ± 0.3	57.93 ± 0.24	10.07 ± 0.10	− 18.6 ± 0.2	4950 ± 100
AC-0389	36.94 ± 0.27	1.70 ± 0.2	57.93 ± 0.24	10.07 ± 0.10	− 18.6 ± 0.2	4660 ± 100
AC-0390	32.55 ± 0.34	1.53 ± 0.2	58.94 ± 0.10	10.85 ± 0.09	− 19.0 ± 0.2	6420 ± 135
AC-0391	33.78 ± 0.26	3.14 ± 0.2	58.94 ± 0.10	10.85 ± 0.09	− 19.0 ± 0.2	6000 ± 105
AC-0511	38.92 ± 0.36	2.60 ± 0.2	56.58 ± 0.24	9.57 ± 0.10	− 20.0 ± 0.2	3850 ± 120
AC-0512	39.96 ± 0.28	2.40 ± 0.2	56.58 ± 0.24	9.57 ± 0.10	− 20.0 ± 0.2	3560 ± 100
AC-0559	33.68 ± 0.27	3.30 ± 0.2	56.58 ± 0.24	9.57 ± 0.10	− 20.0 ± 0.2	5440 ± 110

important calcareous microfossil assemblages (foraminifera and ostracods).

Marino (in: GONZÁLEZ *et al.*, 1983c), employed these microfossil assemblages to make a paleosalinity diagram for the Holocene transgressive/regressive episode in the Bahía Blanca estuary. They have abundant mollusk shells and in two beds bearing *Tagelus* Gray (Figure 7), they are articulated and in life position (see GONZÁLEZ *et al.*, 1983c). Also, there are some articulated shells of *Pitar rostrata* (Koch), and shells of *Buccinanops deformis* (King), *B. cochlidium* (Chemnitz), *B. globulosum* (Kiener), *Crepidula acculeata* (Gmelin), *Brachydontes rodriguezi* (d'Orbigny), and *Labiosa canaliculata* (Say).

(c) Stratigraphic Relations: In the vicinity of Ingeniero White and Galván harbors (see Figures 2, 5 and 7), these Tidal Flat Deposits cover a wave-cut platform eroded about 6000 BP, over Sangamon deposits (GONZÁLEZ, 1984; GONZÁLEZ *et al.*, 1986). In the inner estuary, near the Sauce Chico river, the Tidal Flat Deposits are discordant over fine and medium grained beds, composed of Paleozoic quartzite pebbles brought by this river from Sierras Australes of the Buenos Aires Province. Also, in other parts of the inner estuary, these Tidal Flat Deposits are overlying the Holocene Lagoonal Deposits described above, that were exposed as a substratum during each high wave-energy episode.

Over the Tidal Flat Deposits, there are thin layers of eolian sandy silts, or a poorly developed soil, with halophytic communities, such as *Salicornia, Atriplex, Scirpus, Heliotropium, Sesevium, Limonium* and *Cressa* genus (VERETTONI, 1961; PÉREZ, 1979).

(d) Genetic Conditions: The name used characterizes these deposits genetically. In the lower part of the 1.56 meters profile described above, GONZÁLEZ *et al.* (1983b), using isotopic methods on the carbonate mollusk shells of *Littoridina australis* (d'Orbigny), found a maximum fresh water contribution to the estuarine waters (minimum $^{13}C/^{12}C$ isotope ratios); these waters could be allocthonous, brought from the Sierras Australes by the Sauce Chico and Napostá Grande Rivers. In the same mollusk shells of this lower part the minimum $^{18}O/^{16}O$ isotope ratios (Figure 7) seem to indicate the

Table N°2. *Geoforms and Probable Geological Ages of each Transgressive Stage.*

Sample N°	Age (BP)		Sample location in each profile, and corresponding geoform	Transgressive Stages and Probable Geological Ages (BP)
AC-0314	6350 ± 110	upper		
AC-0312	6600 ± 120	middle	beach ridge 1-fig. 3-	*TS-I = 5990 ± 115*
AC-0313	6100 ± 120	middle	-Inland-	
AC-0311	5990 ± 115	lower		
—	—	—	beach ridge 2-fig. 3-	
AC-0390	6420 ± 135	middle	beach ridge 3-fig. 3-	
AC-0391	6000 ± 105	middle		
AC-0383	6130 ± 110	middle		
AC-0384	5470 ± 110	middle	beach ridge 4-fig. 3-	*TS-II = 5470 ± 100*
AC-0381	5720 ± 100	lower		
AC-0382	6000 ± 110	lower		
AC-0338	5580 ± 130	lower-	tidal flat -fig. 5-	
AC-0317	5460 ± 105	upper		
AC-0316bis	5400 ± 140	lower		
AC-0315	5280 ± 105	lower		
AC-0380	5420 ± 110	lower	beach ridge 5-fig. 3-	*TS-III = 5100 ± 100*
AC-0559	5440 ± 110	lower		
AC-0316	5100 ± 100	lower		
AC-0388	4950 ± 100	middle		
AC-0389	4660 ± 100	middle	beach ridge 1-fig. 4-	
AC-0349	4470 ± 90	middle		*TS-IV = 4470 ± 90*
AC-0350	4520 ± 110	middle	beach ridge 2-fig. 4-	
AC-0386	3570 ± 100	lower		
AC-0387	3950 ± 90	lower	beach ridge -fig. 5-	
AC-0337	4220 ± 100	middle		*TS-V = 3560 ± 100*
AC-0348	3920 ± 90	middle	tidal flat -fig. 5-	
AC-0511	3850 ± 120	middle		
AC-0512	3560 ± 100	middle		

maximum Holocene temperature episode in the marine water. The authors correlated these isotopic episodes with the Hypsithermal. In the same profile, in a younger layer, but older than the one with *Tagelus* shells in life position (3850 ± 100 BP, see Figure 7), a maximum $^{18}O/^{16}O$ and also a maximum $^{13}C/^{12}C$ isotope ratios was interpreted as the end of the Hypsithermal climatic conditions (see Figure 7; see GONZÁLEZ *et al.*, 1983c).

In the surrounding land areas, abundant eolian sands form a continuous blanket, deposited around 5300/5200 BP. These eolian sands seem to indicate an increase in the arid climatic conditions, also coinciding with the end of the Hypsithermal (GONZÁLEZ and WEILER, 1984; GONZÁLEZ, 1984).

The Tidal Flat Deposits younger than the bed with *Tagelus* shells (3560 ± 100 BP, see Figure 7), and reaching the present-day tidal channels, were formed during the youthful development of the estuary, with some yet undated episodes of relatively high wave-energy, as indicated by the intercalated discontinuities.

DISCUSSION

From the above evidence, it seems that in the Bahía Blanca estuary, the Holocene transgression was not marked a single cycle of high sea level and subsequent continuous drop to the present sea level. On the contrary, several factors were active in the estuarine facies and here the sedimentary record shows many complications that permit different interpretations.

In earlier publications many episodes of high wave-energy were recognized which built the Holocene Clastic-Shelly Beach Ridges, reaching above the normal spring-tidal levels (Transgressive Stages, TS I-V).

There is an abundant bibliography concerning to relative Holocene sea level oscillations (FAIRBRIDGE, 1976; FAIRBRIDGE and HILLARE MARCEL, 1977; van de PLASCHE, 1982;

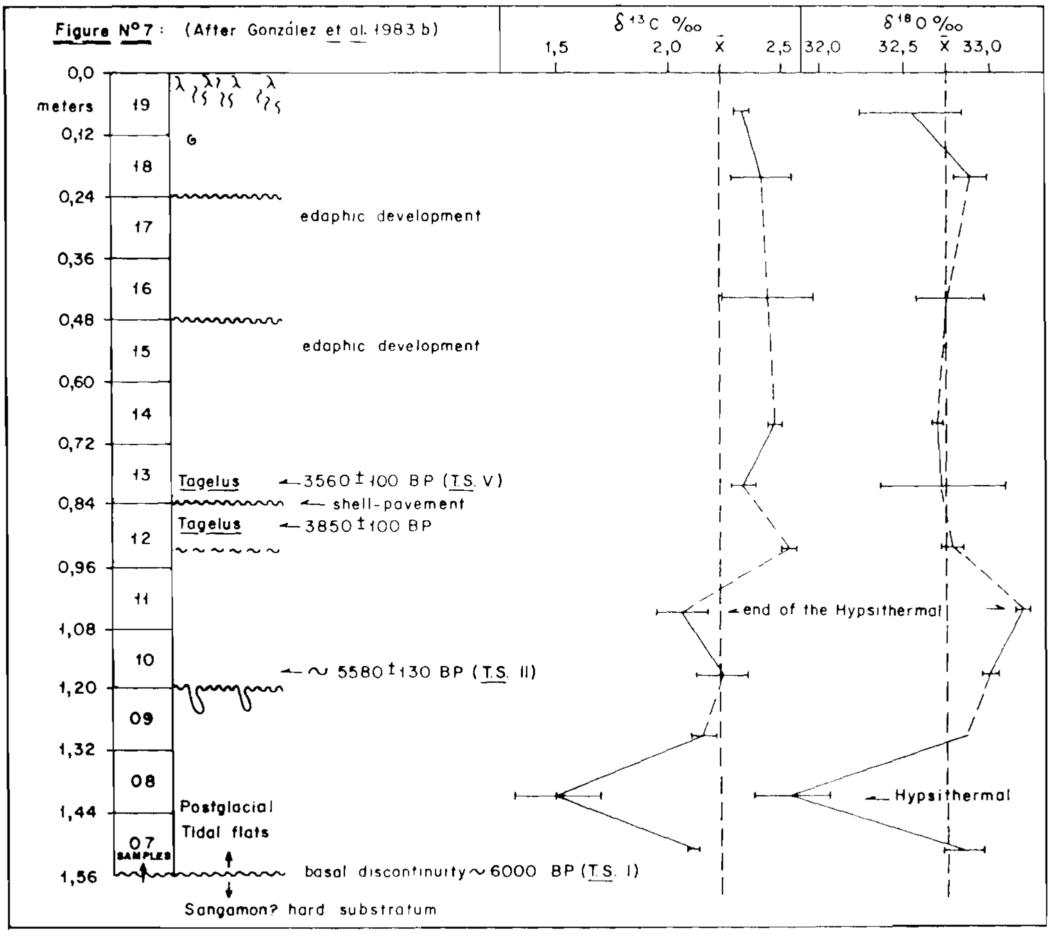

Figure 7. Stable isotope ratios in the Holocene tidal-flats (see *A* in Figure 5). The sharp decrease in $\delta^{18}O$ and $\delta^{13}C$ values was interpreted as Hypsithermal signal. The consecutive isotope points across each observed discordance in the deposits, were connected by a dotted-line.

MÖRNER, 1976; COLQUHOUN *et al.*, 1981). All indicated evidences of a probable rhythm of 400-500 years in the sea level oscillations. Specifically it was pointed out the particular importance of the relative high sea levels that occurred around 4700-4300 BP. and 3800-3500 BP. (COLQUHOUN *et al.*, 1981; COLQUHOUN, *written comm.*).

Likewise in South Carolina (U.S.A.), MOSLOW and COLQUHOUN (1981) found a still-stand or slowly dropping sea level that occurred about 4000-3500 BP. The development of tidal flats in the Bahía Blanca estuary and neighbouring areas (Colorado River delta; WEILER, 1983; GONZÁLEZ and WEILER, 1983) around 3850 ± 100 BP. and the lack of high wave-energy deposits (beach ridges) at these times, would indicate an episode of reduced wave-energy that would correspond with the still-stand or slowly dropping sea level at this time.

Finally, and also in coincidence with other observations of COLQUHOUN *et al.* (1981), the Holocene high wave-energy deposits in the Bahía Blanca estuary, have shown a probable rhythmicity close to 500 years, and the respective ages (PGA) of these deposits have some coincidence with the successive culminations of the Progression of the Lunar Perigee Cycle, as was indicated by GONZÁLEZ and WEILER (1983).

CONCLUSIONS

The following conclusions may be expressed:

(1) The maximum Holocene transgression in the Bahía Blanca estuary occurred at an age younger than 5990 ± 115 BP. This episode is represented by the beach ridges of the Transgressive Stage I, with a probable geological age (PGA) of 5990 ± 115 BP.

(2) This maximum transgressive episode coincided with a local climatic amelioration, correlated with the Hypsithermal episode. At this time, the Bahía Blanca estuary received the maximum fresh water input, as is indicated by the minimum $^{13}C/^{12}C$ isotope ratios in the carbonate of mollusk shells. These fresh waters were probably was brought down from the Sierras Australes of the Buenos Aires Province by the Sauce Chico and the Napostá Grande Rivers. Also, at this same time the estuarine waters reached their maximum Holocene temperature, as is indicated by the minimum $^{18}O/^{16}O$ isotope ratios in the same shell carbonates.

(3) In spite of the fact that the Hypsithermal is isotopically well defined with the estuarine sediments being influenced by marine waters, this climatic warming seems to have only been accompanied by some precipitation in the neighhouring inland area, but not more than the present. This interpretation may be inferred from the arid or semi-arid environmental characteristics of the lagoonal deposits associated with the maximum transgressive episode. Likewise, the only good Hypsithermal (6000 BP; BUSCHIAZZO and PEINEMANN, 1983) soil development in the surrounding land areas occurred in the lower fluvial terraces under the influence of river waters.

(4) During the development of the Holocene transgressive-regressive cycle, there were at least five episodes with exceptional high wave-energy, which built beach ridges in the inner parts of the estuary. These five episodes are named Transgressive Stages (TS) I to V, and the respective ^{14}C ages of them, with probable geological age (PGA) character, are:

TS-I:	5990 ± 115 BP (maximum Holocene Transgression)
TS-II:	5470 ± 100 BP (after Holocene Transgression)
TS-III:	5100 ± 100 BP (after Holocene Transgression)
TS-IV:	4470 ± 90 BP (after Holocene Transgression)
TS-V:	3560 ± 100 BP (after Holocene Transgression)

(5) The deposits that in this locality represent high wave-energy episodes, at least according to the present researches, seem to indicate a rhythmicity of around 500 years. This rhythmicity would support the idea of the Progression of the Lunar Perigee Cycle (close to 556 years) in explaining the origin of the local high wave-energy deposits, as was suggested by R. W. Fairbridge (*written comm.*).

(6) There is evidence of a relative still-stand of sea level (or somewhat slowly dropping sea level) nearly 3850 ± 100 Before Present.

ACKNOWLEDGEMENTS

The author is grateful to Dr. Enrique Linares, director of the INGEIS, for his cooperation; to Lic. Nilda Weiler, for her constructive criticism about all the aspects of this work; to Dr. R.W. Fairbridge for the ideas concerning the importance of the Progression of the Lunar Perigee Cycle in the littoral deposits; to Dr. D. Colquhoun, for his written comments concerning his researches in South Carolina; to Lic. Miguel Albero, for his critical comments and to Lic. Beatriz Coco for the English manuscript observations. He is specially grateful to the INGEIS staff, particularly to the Stable Isotopes and Radiocarbon Laboratories.

LITERATURE CITED

ALBERO, M.C.; ANGIOLINI, F.E.; BALBUENA, J.L.; CODIGNOTTO, J.O.; LINARES, E., and WEILER, N.E., 1980. Primeras edades carbono-14 de afloramientos de conchillas de la República Argentina. *Asoc. Geol. Arg., Rev.* 35(3), 363-374.

BUSCHIAZZO, D.E. and PEINEMANN, N., 1983. Suelos sódicos de las Sierras Australes. *Asoc. Geol. Arg., Rev.*, 38(1), 101-106.

BRINKMANN, R. 1964. *Compendio de Geología General.* Barcelona: Labor S.A., 347p.

COLQUHOUN D.J.; BROOKS, M.J., MICHIE, J.; ABBOT, W.B.; STAPOR, F.W.; NEWMAN, W., and PARDI, R.R., 1981. Location of Archaeological Sites with respect to Sea Level in the Southeastern United States. *Striae*, 14, 144-150.

FAIRBRIDGE, R.W., 1976. Shellfish-eating preceramic indians in coastal Brazil. *Science*, 191, 353-359.

FAIRBRIDGE, R.W. and HILLAIRE-MARCEL, C., 1977. An 8000 yr. paleoclimatic record of the 'Double-Halle' 45 yr. Solar Cycle. *Nature*, 268, 413-416.

FARINATTI, R., 1978. Microfauna de moluscos querandinenses (Holoceno), Ingeniero White, provincia de Buenos Aires. *Asoc. Geol. Arg., Rev.*, 33(3), 211-232.

FRENGÜELLI, J., 1931. Observaciones geológicas en la región costanera Sur de la provincia de Buenos Aires. *Anales de la Fac. de Cs. de la Educación* (Paraná), 2, 1-145.

GONZÁLEZ, M.A., 1984. Depósitos marinos del Pleistoceno superior en Bahía Blanca (Buenos Aires, Argentina). 9°Congr. Geol. Arg., Actas 3, 538-555.

GONZÁLEZ, M.A.; ALBERO, M.C., and ANGIOLINI, F.E., 1982. Ingresiones marinas del Pleistoceno y Holoceno en Bahía Blanca (Provincia de Buenos Aires, República Argentina). Sus edades carbono-14 y su correlación con eventos similares reconocidos en otros puntos de la costa en la provincia de Buenos Aires. *4° Semana de la Oceanografía*, CNIAPSO-IADO (Bahía Blanca), Resúmenes, 21.

GONZÁLEZ, M.A.; WEILER, N.E.; ALBERO, M.C., and ANGIOLINI, F.E., 1983a. Interpretación de edades carbono-14 invertidas y mezcladas en la espiga de playa de General D. Cerri (Bahía Blanca, provincia de Buenos Aires). *Ameghiniana*, 20(3-4), 227-237.

GONZÁLEZ, M.A.; PANARELLO, H.O.; MARINO, H., and VALENCIO, S.A., 1983. Niveles marinos del Holoceno en el estuario de Bahía Blanca (Argentina). Isótopos estables y microfósiles calcáreos como indicadores paleobamientales. *In: Oscilaciones del nivel del mar durante el Ultimo Hemiciclo Deglacial en Argentina.* (Mar del Plata), IGCP, Project N°61, Symp, *Actas*, 48-68.

GONZÁLEZ,M.A. and WEILER, N.E., 1983. Ciclicidad de niveles marinos holocénicos en Bahía Blanca y en el delta del río Colorado (provincia de Buenos Aires), en base a edades carbono-14. *In: Oscilaciones del nivel del mar durante el Ultimo Hemiciclo Deglacial en Argentina* (Mar del Plata), IGCP Proect N°61, *Actas*, 69-90.

GONZÁLEZ, M.A. and WEILER, N.E., 1984. Cambios climáticos del Holoceno medio en latitudes medias de la República Argentina. *Segunda Reunión del Grupo Periglacial Argentino* (Mendoza), *Actas*, 87-105.

GONZÁLEZ, M.A.; WEILER, N.E., and GUIDA, N.G., 1986. Late Pleistocene transgressive deposits from 33° S.L. to 40° S.L., Argentine Republic. *Journal of Coastal Research*, Special Issue N°1, pp. 39-48.

HEDBERG, H.D., 1980. *Guía Estratigráfica Internacional.* (H.D. Hedberg, Ed.) Barcelona, Reverté S.A., p. 205.

IHERING, H. von, 1907. Les mollusques fossiles du Tertiarie et du Crétacé Superieur de l'Argentine. *Museo Nacional de Buenos Aires, Anales*, 3, 1-611.

IHERING H. von, 1909. Mollusques du Pampéen de mar del Plata et Chapadmalán, etc. *Museo Nacional de Buenos Aires, Anales*, 17.

MÖRNER, N.A., 1976. Eustasy and Geoid Changes. *Journal of Geology*, 84(2), 123-151.

MOSLOW, T.F. and COLQUHOUN, D.J., 1981. Influence of sea level change on barrier island evolution. In: *Variations du niveau marin et leurs consequences en morphologie littorale dans les pays mediterraneens et extra-europeens. Symposium*, 7(4), 327-487.

PEREZ, A., 1979. La vegetación de los suelos salinos. *Univ. Nac. del Sur*, (Bahía Blanca), Dpto. Cs. Naturales, *Monografías*, 1-24. Unpublished.

PLASSCHE, O. van de, 1982. Sea-level change and water level movements in the Netherlands during the Holocene. *Academisch Proefschrift, Vrije.* Universiteit Amsterdam, 1-148.

SISCOE, G.L., 1978. Solar-Terrestrial influences on weather and climate. *Nature*, 276, 348-352.

VERETTONI, H.N., 1961. Las asociaciones halófilas del partido de Bahía Blanca. Univ. Nac. Del Sur, (Bahía Blanca), Ph. Doctoral Thesis, 1-105. Unpublished.

WEILER, N.E., 1983. Rasgos morfológicos evolutivos del sector costanero comprendido entre Bahía Verde e Isla Gaviota, provincia de Buenos Aires. *Asoc. Geol. Arg., Rev.*, 38(3-4), 392-404.