

RAISED MARSH DEPOSITS NEAR CARTAGENA DE INDIAS, COLOMBIA: EVIDENCE OF EUSTATIC AND CLIMATIC INSTABILITY DURING THE LATE HOLOCENE.

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ABSTRACT

The marsh deposits cropping out near Galerazamba are located at 15 m above sea level and at a distance of 1,250 m from the present day Ciénaga El Totumo. This location suggests frequent changes in the sea level. A radiocarbon age of 4,150±50 yr BP was obtained from mollusc remains at the Ciénaga El Totumo. The age of the marsh corresponds to a dry climate period according to paleoenvironmental data from the northern part of South America. The Ciénaga El Totumo retreated during this dry episode. The fossil biota content found in these raised marsh deposits is poorly diversified and corresponds to the inner part of the marsh.

Keywords: Marsh deposits; Ciénaga El Totumo; Colombia; Late Holocene; Molluscs; C-14.

DEPÓSITOS DE CIÉNAGA LEVANTADOS CERCA DE CARTAGENA DE INDIAS, EVIDENCIAS DE INESTABILIDAD EUSTÁTICA Y CLIMÁTICA DURANTE EL HOLOCENO SUPERIOR

RESUMEN

Los depósitos de ciénaga que afloran junto a Galerazamba están situados a 15 m sobre el actual nivel del mar y a 1,250 m de la actual Ciénaga de El Totumo. Esta posición sugiere la existencia de cambios en el nivel mar. A partir de restos de moluscos se ha obtenido una edad de 4,150±50 años BP. La edad de los depósitos de la ciénaga corresponde a un período de clima seco según los datos paleoambientales de Colombia y de parte del noreste de América del Sur. Durante este período seco la Ciénaga de El Totumo experimentó una retracción. La fauna fósil encontrada en estos depósitos es poco diversificada y corresponde a la parte interna de una ciénaga.

Palabras clave: Depósitos de ciénaga. Ciénaga El Totumo, Colombia, Holoceno superior, C-14, Moluscos.

INTRODUCTION

During the geological survey carried out by the Instituto de Investigaciones Geocientíficas, Minero-Ambiental y Nuclear "INGEOMINAS" in the framework of the "Estudio Geológico de la Región Caribe" project, Barrera (2001) found some outcrops rich in mollusc remains. This survey sought to prepare the geological map of the Galerazamba (Sheet 16) and Barranquilla (Sheet 17) and to assess natural resources and possible environmental hazards.

Given the outcrop conditions, it is not easy to differentiate between the subrecent marsh deposits and those attributed to the Neogene.

South of study area, in the Darien, Holocene marine terraces

show high deformation rates, faulting, and mud volcano intrusions (Page, 1983). Along the Caribbean coast of Colombia the separation of what corresponds to eustatic movements from what can be attributed to tectonic uplift is ambiguous. A wide regional study would help us to yield some insight into this problem.

The littoral zone extending from Cartagena to Galerazamba is a lowland coast with some marshes such as Laguna Honda, Ciénaga Tesca (Gayet & Vernet, 1964) and the Ciénaga El Totumo. This lowland coast is interrupted by cliffs such as Los Morros, Punta Canoas, Punta de Piedras and Punta de la Garita, or Juan Moreno, and the Lighthouse of the Galerazamba area. The studied area is located near the town of Galerazamba and the Ciénaga El Totumo, at the NE of

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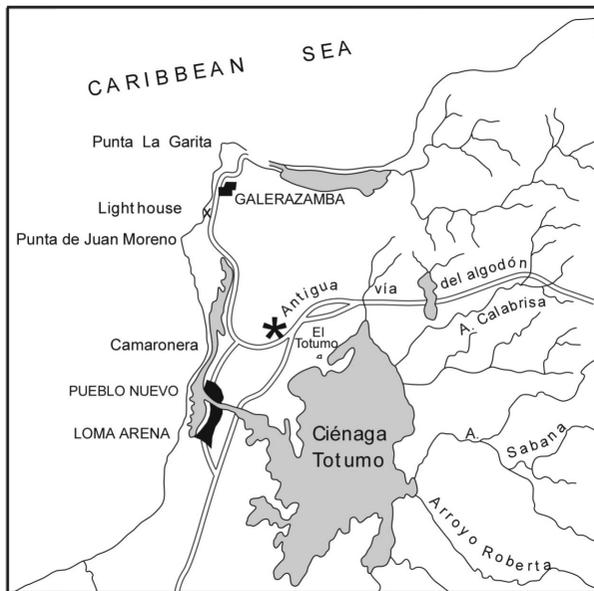


FIGURE 1. Map with the studied area. *Outcrop near Ciénaga El Totumo.

Cartagena and along the road (The old cotton track) from the Galerazamba Lighthouse to the Via del Mar (FIGURE 1).

Some fossil marsh deposits were found during the geological survey carried out in 1997 in the Galerazamba lighthouse area (Atlantic Department), suggesting a possible relationship with the present day Ciénaga El Totumo.

In accordance with the altitude and extension of the fossil marsh outcrop the present day Ciénaga El Totumo could be interpreted as resulting from a marked retreat of the former marsh. In order to corroborate this hypothesis and to evaluate the magnitude of the tectonic activity in the Colombian Caribbean Sea, a radiocarbon date was obtained and a study of the fossil was carried out.

GEOLOGICAL SETTING

From a geological point of view, the northwestern Colombian Coast zone consists of two well established structural provinces: One stable unit, characterized by a sedimentation overlying an undeformed continental crust, and a folded unit, with narrow anticlines and synclines. Both units are separated by the Romeral fault. Two main structural zones are differentiated in the folded unit: the San Jacinto belt and the Sinú belt, both showing the same NE-SW trending (Duque-Caro, 1979). The Sinú belt is the one nearest the sea. The studied zone is located in the Sinú belt (FIGURE 2).

One of the main characteristics of the Sinú belt is the occurrence of processes that control the structures and the uplift of this belt. In the Cartagena-Barranquilla area and in

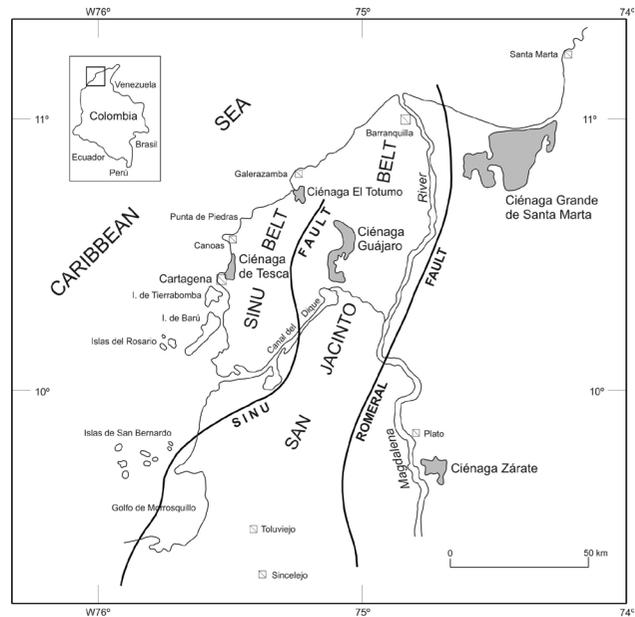


FIGURE 2. Map showing the localities cited in the text and the San Jacinto and Sinú Belts.

the Sinú River, to the south, numerous mud volcanoes both active and extinct are observed (Duque-Caro, 1979). The mud volcanoes are conical in shape with disturbed sedimentary structures or are simple conical hills made up of mud that can reach a height of 20m e.g. the Arboletes, El Totumo, Punta Canoas volcanoes (Duque-Caro, 1984).

Some present day offshore bioherms found in the continental shelf are supported by these diapiric structures (Vernette, 1989b).

Lithostratigraphically, Barrera (2001) determined the Arjona Formation in the studied area. This unit is composed of the sediments forming gentle hills, some of which are conical in shape, cropping out near Galerazamba. However, these outcrops were assigned to the Formation Hibacharo by Bueno (1970). Duque-Caro (personal communication to Barrera) identified the following foraminifera species from the Arjona Formation sediments and yielded a Middle Miocene age for this Formation: *Bulimina corrugata*, *Gyroidina multicostata*, *Gyroidina soldani*, *Cibicides floridanus*, *Siphogenerina multicostata* and *Melonis pompilioides*.

MARINE TERRACES NEAR GALERAZAMBA

Distinct marine terraces and coral platforms located at diverse altitudes are frequent along the Caribbean littoral zone of Colombia, especially between the south of Cartagena and Barranquilla.

Royo y Gómez (1950) reported the presence of two marine terraces in the Isla de Tierrabomba: the upper and the

lower. The upper terrace, at 20-26m high above sea level, corresponds to a reef limestone formed by Lithothamnium. This formation was subsequently interpreted as an abrasion terrace, the surface gravels of which contain abundant boring traces (Porta & Solé de Porta, 1960; Burel & Vernet, 1981). This terrace has an age of 125,000 years and could be related to the Marine-Isotope-Stage 5c (Page, 1983). The lower terrace, at 3m high above sea level, contains a large number of molluscs. A detailed study of the fauna was carried out by Porta & Solé de Porta (1960), which was enlarged by Porta, et al. (1963). Richards & Broecker (1963) published radiocarbon dates of $2,850 \pm 150$ yr B.P. Additional datings of coastal deposits along the Caribbean coasts of Colombia situated between 0.5 and 2.5 m, were reported by Page (1983) and Vernet (1989a). These datings vary between $1,450 \pm 130$ yr and $5,100$ yr BP.

MARSH DEPOSITS

Grey colored muddy sediments overlie an irregular surface of the Arjona Formation, Middle Miocene in age, in the proximity of Galerazamba. This would indicate the existence of an erosive phase. At the moment, it is not easy to determine the magnitude of this erosion since to the north as well as to the south of this zone Pliocene deposits exist. Perhaps some parts of the Arjona Formation were emerged. These deposits crop at 2 km. from the sea shore and 1.25km. from the Ciénaga El Totumo (FIGURE 1). Their maximum altitude is about 15m above sea level. The thickness of the marsh deposit is variable and reaches up to 1m.

These deposits with accumulations of seashells resemble the subfossil marsh deposits observed towards the north. Burel & Vernet (1981) also indicated similar deposits in the internal part of the Ciénaga Honda, located at + 3m a.s.l. and with an age of $2,700 \pm 90$ yr BP.

Pollen analyses of the sediments of Galerazamba were negative. The fauna resembles that found in marshes such as the Ciénaga Grande of Santa Marta today (Cosel, 1986), but much less diversified. Remains of peat or plants were not found although a vegetation of mangrove swamps is evidenced by the prints of fixation of *C. rhizophorae*.

In the study of the current Ciénaga of Tesca (Gayet & Vernet, 1984) indicate the existence of a coastal spit that temporarily blocks the communication of the marsh with the sea. During the dry season the river contribution is scarce and the communication with the sea is blocked. During the wet season the coastal spit breaks up and the communication with the sea is restored. The presence of *Haplousina tuberosa* in the deposits of Galerazamba provides evidence of the existence of temporary communications with the sea.

FAUNA COMPOSITION

The study of the fauna content was based on a random method using different sample volumes and a total sample weight

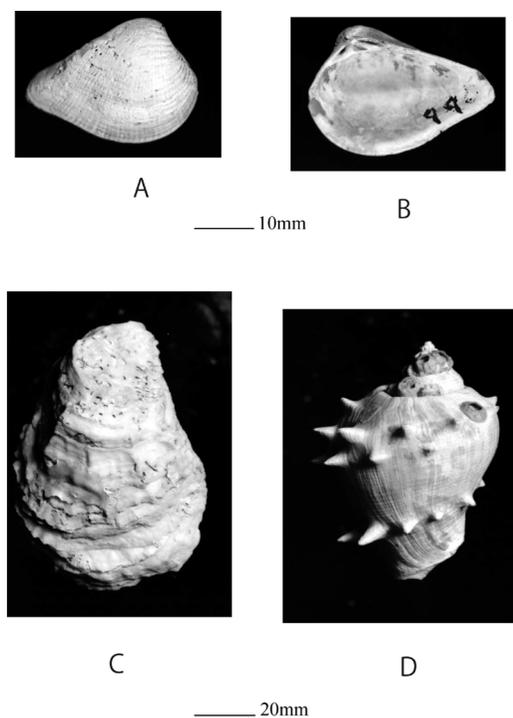


FIGURE 3. Right valve of *Anomalocardia brasiliana*. 5A external view. 5B Internal view. 5C *Crassostrea rhizophorae*. External view of the left valve. 5D *Melongena melongena* with the specimens of *Balanus* sp. on the spire.

of 4 kg. The fossil content is mainly formed by molluscs. The sediment is barren in ostracods and foraminifers. The mollusc assemblage is poorly diversified. A total of 8 species were recovered:

Briozoa
Haplousina tuberosa Canu & Bassler
 Mollusca
Anadara ovalis (Bruguière)
Crassostrea rhizophorae (Guilding)
Anomalocardia brasiliana (Lamarck)
Protothaca pectorina (Lamarck)
Neritina virginea (Linné)
Melongena melongena (Linné)
 Crustacea
Balanus sp.

The bivalves are more abundant (71.4%) than the gastropods (28.6%). The most abundant species are *Anomalocardia brasiliana*, *Crassostrea rhizophorae* and *Melongena melongena*, (FIGURE 3) all of them exhibiting different growing stages.

TAXONOMIC REMARKS

Anomalocardia brasiliana is the most abundant species. It has an equivalve form. In the samples collected the number of right and left valves is practically the same. Length,

height and convexity of 200 specimens were measured. All the parameters have a normal distribution (FIGURE 4) and TABLE 1).

Diagram plots of Length/Height, Length/Convexity and Height/Convexity are shown in (FIGURE 5). The correlation coefficient values are high, only the Height/Convexity shows a low value (TABLE 1).

Crassostrea virginica is a polymorph taxon extending from the North American coastline to Yucatan (Mexico). Southward of this locality it is replaced by *Crassostrea rhizophorae* reaching Brazil (Stenzel, 1979). However, its taxonomic status is not yet well defined. Galtsoff (1964), Abbot (1964), Newball & Karriker (1983) and Harry (1985) consider the *C. rhizophorae* to be a synonym of *C. virginica*, whereas other authors think that it is an ecomorph. Buroker et al. (1979) and Malchus (1995) point out that *C. virginica* should be a superspecies including *C. rhizophorae*. In Colombia most authors refer to this controversy but continue to regard *C. rhizophorae* as a different species (Cosel, 1986; Diaz & Puyana, 1994). We subscribe to the last opinion.

Specimens collected near the Ciénaga El Totumo show considerable dimorphism. Some specimens have a smooth left valve. Radial ribs in numbers of 3 or 4 can be observed on some specimens.

According to Stenzel (1971; Reprinted 1979) the specimens developing radial ribs live in habitats exposed to sunlight while the smooth specimens are typical of shady areas. Both morphotypes exist among the specimens from the Ciénaga Grande de Santa Marta featured by Cosel (1986).

The diameter measured on 22 specimens from the Ciénaga El Totumo ranges from 55 to 90.3 mm. These values are in agreement with those of the present day populations.

TAPHONOMY

The fauna assemblage is well-preserved. No diagenetic traces are observed. Most specimens of *Anomalocardia brasiliensis* and *Crassostrea rhizophorae* have the valves closed. In the disarticulated specimens both right and left valves are present in equal numbers. Same times, *C. rhizophorae* is very abundant and forms patches, with many of the specimens in life position. It is usual to observe prints of fixation on the mangrove roots.

PALEOECOLOGY

Most elements of the fauna show their optimum development on lime-silt substrates of shallow waters. The bivalve assemblage corresponds to infaunal and filter-feeding species. Only *Crassostrea rhizophorae* is epifaunal. The fauna of Ciénaga El Totumo are similar to those described by Cosel (1986) from the Ciénaga Grande de Santa Marta, although far less diversified. All the species tolerate a wide range of salinity and can tolerate salinity values of 1‰ as pointed out by Cosel (1986).

The presence of specimens of *Balanus* sp. and *Aplousina tuberosa* an, encrustant bryozoan, on the *Melongena melongena*, denote marine influence, at least temporarily. The fauna and the characteristics of the outcrop are related to the Ciénaga El Totumo.

CHRONOLOGY

The geomorphology of the deposit, especially their altitude above sea level, as well as the fauna composition suggest a possible Pleistocene age. Thus, the uranium-series disequilibrium method was used because it provides accurate data from the marine oxygen isotopic stages 3 to 7 (Ivanovich & Harmon, 1992). The absence of coral remains (usually

TABLE 1. N=number of specimens. OR=observed range, X= arithmetic mean, s=standard deviation, CV=coefficient of variation, and R=correlation coefficient.

| | N | OR | X | S | CV | R |
|------------------|----------|-----------|----------|----------|-----------|----------|
| Length | 200 | 8.5-29.8 | 17.8 | 4.52 | 0.25 | |
| Height | 200 | 6.5-22.3 | 13.8 | 3.37 | 0.24 | |
| Convexity | 200 | 2.1-9.0 | 5.5 | 1.46 | 0.26 | |
| Length/Height | | | | | | 0.97 |
| Length/Convexity | | | | | | 0.95 |
| Height/Convexity | | | | | | 0.42 |

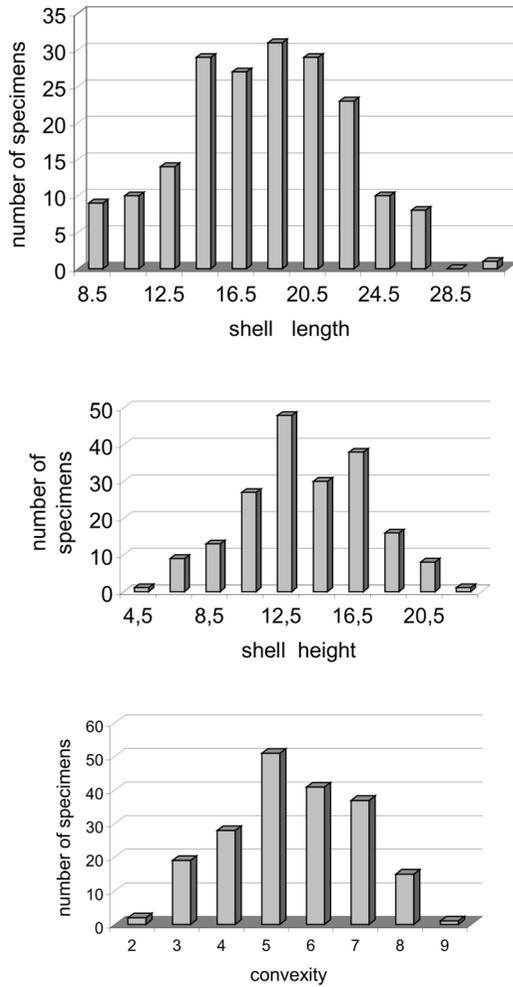


FIGURE 4. Histograms of Length, Height and Convexity in *Anomalocardia brasiliana*. Data measured on right valves.

scarce in fossil beach deposits) constrains this method as a rude age approximation. Despite these limitations, a dextral shell of *Crassostrea rhizophorae* weighing 20.14 g was analyzed. TABLE 2 shows the radioisotopic measurements obtained by alpha spectrometry following the procedure described by Bischoff & Fitzpatrick (1991). This shows that molluscs are unsuitable samples for uranium-series dating methods -as was pointed out by Kaufmann et al. (1971)- given that they absorb diagenetic thorium with the result that it is impossible to differentiate between the amount of ^{230}Th derived from its radioisotopic father ^{234}U and the amount absorbed from other sources. Given that the enrichment in ^{230}Th provides older dates, the “true” age of this marsh deposit would be younger than the 50 kyr obtained by U/Th dating method.

Taking into account that the beach terrace could be dated by the radiocarbon method, 100 g of samples of *Melongena*

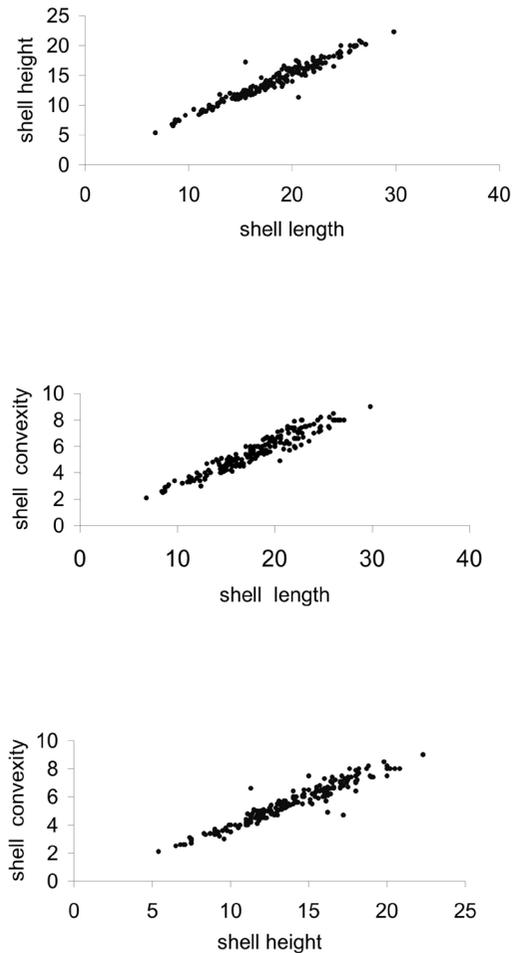


FIGURE 5. Diagram plots of Length/Height, Length/Convexity, and Height/Convexity. Data measured on right valves.

melongena were analyzed in the Laboratori de Datació per Radicarboni of the Barcelona University (UBRC-600). TABLE 2 shows the analytical values and the Holocene age of this deposit ($4,150 \pm 50$ yr BP). The reported $\delta^{13}\text{C}$ value of *Melongena consors* is lower than the $\delta^{13}\text{C}$ found in carbonates generated in a marine environment (Stuiver & Polach, 1977) and suggests a continental water influence in the environment where *Melongena melongena* thrived.

CLIMATIC CONDITIONS AND COMPARISON WITH OTHER AREAS

In the lower Magdalena Valley, near Mompós (Department of Sucre), the palynological data of Van der Hammen (1986) determine different dry climatic phases in the Holocene. One of these is located in 4,000 yr BP. This author also provides data on the lower basins of the Cauca and San Jorge Rivers.

TABLE 2. Uranium series radiometric data from *Crassostrea rhizophorae*. Method U/Th

| Sample | Lab-reference | ²³⁸ Th ppm | ²³² Th ppm | ²³⁴ U/ ²³⁸ U | ²³⁰ Th/ ²³⁴ U | ²³⁰ Th/ ²³² Th | Age |
|--------|---------------|-----------------------|-----------------------|------------------------------------|-------------------------------------|--------------------------------------|------------------|
| Gz-7 | JA5798 | 0.21 | 0.2 | 1.24+/- 0.02 | 0.38+/- 0.01 | 1.54 | 51185+/- 1800 |

Radiocarbon data from *Crassostrea rhizophorae*. Method ¹⁴δC

| Sample | Lab-reference | Material | weight g | δ ¹³ C ‰ | Age y BP |
|---------------------|---------------|----------|----------|---------------------|-----------|
| <i>M. melongena</i> | UBAR-650 | Shell | 105.2 | -6.348 | 4150+/-50 |

Other areas in Colombia, although further from the studied area, have provided us with data indicating dry periods. So in the Caquetá (Colombian Amazonia) Van der Hammen et al. (1992) pointed out the existence of a dry period between 3,800 and 4,000 yr BP.

In the Llanos Orientales Behling & Hooghiemstra (1998) recorded a retraction of the Laguna Angel (Department of Meta) dated between 5,260 and 3,000 yr BP.

Moreover, in the Sabana de Bogotá, the archaeological shelter located at an altitude of 2,570 m recorded a relatively dry phase dated about 5,000 yr BP. This phase corresponds to a decline in human activity.

In Venezuela, in the Lake Santa Teresa, Rull (1992) noted out a forest retreat and a retraction of the lake level between 5,000 and 3,900 yr BP. The climatic conditions have a large incidence in the North of South America.

It is evident that there is consensus on all these dates.

The height of the outcrop above the present day sea level was mainly caused by a tectonic uplift given the significance of the muddy diapirism in the region.

At the lighthouse cliff and Punta de Juan Moreno, south of Galerazamba, coral remains overlies the Arjona Formation (Hibacharo Formation in Bueno (1970) affected by tectonics. The coral remains are found at + 20 m a.s.l. A radiocarbon analysis provided an age of 2,237±95 yr BP.

CONCLUSIONS

The marsh deposits cropping out near Galerazamba overlies parts of the Arjona Formation dated as Miocene. The fauna is dominated by: *Anomalocardia brasiliensis*, *Crassostrea rhizophorae* and *Melongena melongena*. This assemblage resembles the assemblage currently living in the marsh but less diversified, suggesting more restricted environmental conditions. A dry climatic period reduced the river contribution to the Ciénaga El Totumo, causing a retraction in

its extension. A C-14 age of 4,150±50 yr BP was obtained. *Balanus* sp. and *Aplousina tuberosa* an encrusting bryozoan indicate a temporal connection with the open sea.

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