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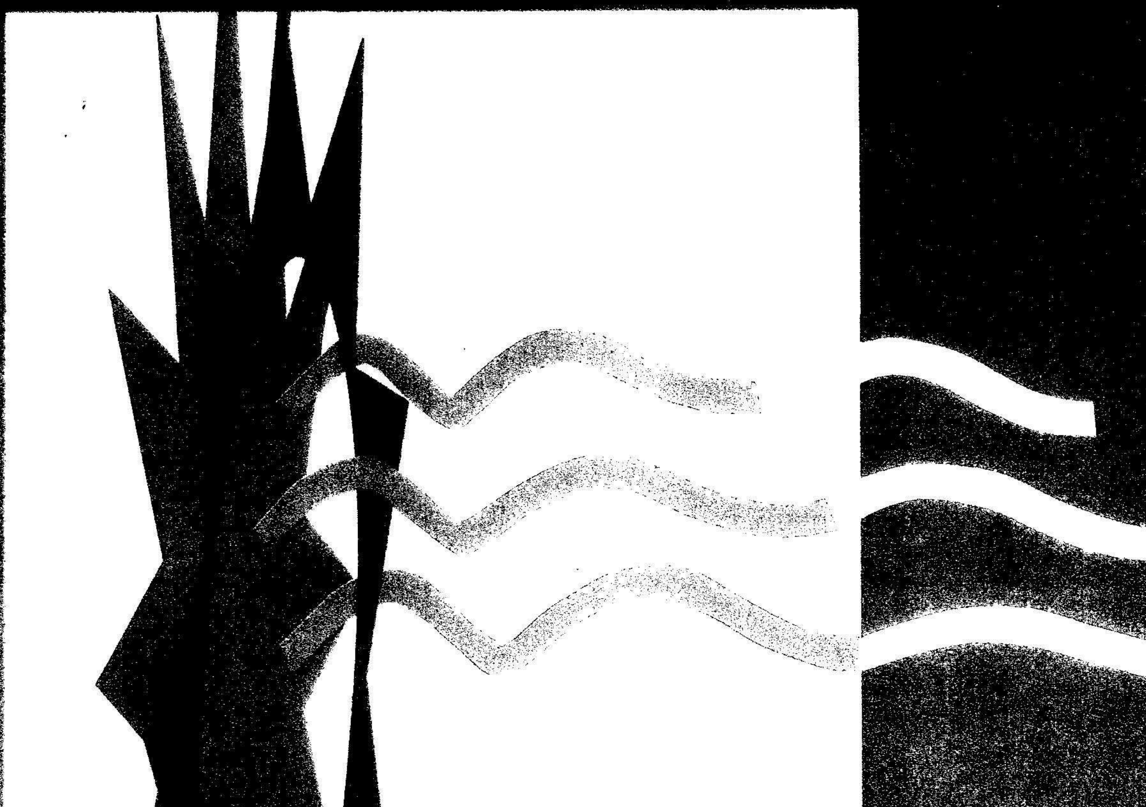

UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA

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THE QUATERNARY DEPOSITS IN LANZAROTE AND FUERTEVENTURA (EASTERN CANARY ISLANDS, SPAIN): AN OVERVIEW

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Abstract

The main Quaternary formations observed in Fuerteventura and Lanzarote (Canary Islands) are aeolian deposits marine terraces and lava flows.

The sand from of all dunes derive from marine deposits containing final Miocene and early Pliocene fauna. The successive regression left the marine bioclastic sand esposed to aeolian erosion. The dunes contain interbedded levels of land snail shells and insect brood cells. Part of the dunes were covered by Pliocene lava flows. A thick calcareous crust developed at their tops. In some areas the sand eroded from those ancient formations built new dunes, anew buried by Upper Pleistocene lava flows. Several layers of little-evolved palaeosols are intercalated into the aeolian sediments. The Mollusca fauna was radiocarbon (c.42 ka; 28-27 ka; 23 Ka; c.15 and 13.8 ka; 9.8-9 ka) and U/Th dated (c.95 ka; c. 138 ka; c.183 ka; c. 235 ka and >350 ka).

Pleistocene fossiliferous marine terraces correspond to isotopic stage 5e and 1. The stage 5e terraces are located at + 5m above msl. Their faunal assemblage (Strombus bubonius) indicates water temperatures much higher than at present and was U/Th and ESR dated at c. 125 ka. Holocene terraces are located at elevations slightly higher than modern beaches and approximately 1 m lower than the Pleistocene terraces. The fauna has been radiocarbon dated c. 4 and 2 ka.

Aeolian formations

The sand from of all dunes in Fuerteventura and Lanzarote islands derive from Messinian marine deposits containing final Miocene and early Pliocene warm water faunas: *Hinnites ercolaniana*, *Chlamys pesfelis*, *Gigantopecten latissimus*, *Ancilla glandiformis*, *Lucina leonina*, *Rothpletzia rudista* and abundant *Strombus coronatus*, *Nerita emiliana* and *Gryphaea virleti* (Meco, 1977, 1981, 1982, 1983), together with large quantities of calcareous algae. Such deposits exist in southern Lanzarote, western and southern Fuerteventura as well as in Gran Canaria. They are younger than the basal flow unit at Ajui in Fuerteventura, (5.8 + 0.5 my; Meco and Stearns, 1981) and older than the lava flow at Janubio in Lanzarote (6.6 + 0.3 my; Coello *et al*, 1993).

The post Messinian regression left the marine bioclastic sand exposed to aeolian erosion. It spread over the islands, except for the highest peaks. Part of them were covered at 2.9 my, 2.7 my, 2.4 my and 1.8 my by lava flows, e.g at Barranco de la Cruz, Barranco de Los Molinos, Puerto de Los Molinos and Aljibe de la Cueva (Meco and Stearns, 1981; Coello *et al*, 1992). Those dunes (e g. at Agua Tres Piedras, Meco, 1993 contain interbedded levels of land snail shells, insect brood cells and alluvial deposits. A thick calcareous crust developed on their tops, as well as on the sand scattered over volcanic and plutonic rocks, probably during the early Pleistocene. The sand eroded from those ancient formations (either from the cliffs' faces, or when the calcareous crust was eroded by torrential flows, or from the aeolian erosion of the beach during marine regressive phases), built new dunes which were, in some areas, buried anew by lava flows. Such is the case for those from Montaña Arena and Bayuyo volcanoes wich overlie the Lajares and Cañada Melian dunes in Fuerteventura Pl. I. Several layers of little-evolved palaeosols are intercalated into the aeolian sediments. They are extremely rich in fossil land snails shells (Theba geminata, Hemicycla sarcostoma, Rumina decollata; Fig. 3) and in incredibly numerous insect brood cells (Petit-Maire *et al*, 1986, 1987). Those cells have been determined as Antophoridae and taxonomically associated with Eucera sp; the perforations in the wall of the cells and the existence of unopened cells indicate a preimaginal mortality of c. 47 % due to predation and fungal attacks (Ellis and Ellis-Adams, 1993). Those observations testify to active past biogenic activity and biodiversity within the palaeosols, but also testify to occasional dust flows from the Sahara, since dust is necessary for the brood cells to be constructed by the insects. At several places (Table 1), the Mollusca fauna was radiocarbon and U/Th dated (Petit-Maire *et al.*1986,1987; for detailed stratigraphy and sedimentology cf Damnati et al.,1996, Damnati this volume, Bouab and Lamothe, this volume). Table 1 gives the results of all analyses the validity of which is to be discussed, given the wide uncertainty of radiocarbon ages older than 25 ka and the problems related with Uranium dating of terrestrial Mollusca shells.

Serious problems arise about the validity of some of these ages. The radiocarbon ones around 30 ka are suspicious. However their large number at different sites must probably indicate a real period of humid conditions (also validated by similar observations in the Sahara; Yan and Petit-Maire, 1994, Petit-Maire et al, 1995). Moreover, some of the results are validated by U/Th TIMS and by OSL ages.

Therefore, despite the uncertainty of dating, one recognizes several wetter periods during which pedogenesis and development of biodiversity could take place at this western margin of the Sahara. The three most recent ones, corresponding to the top layers of

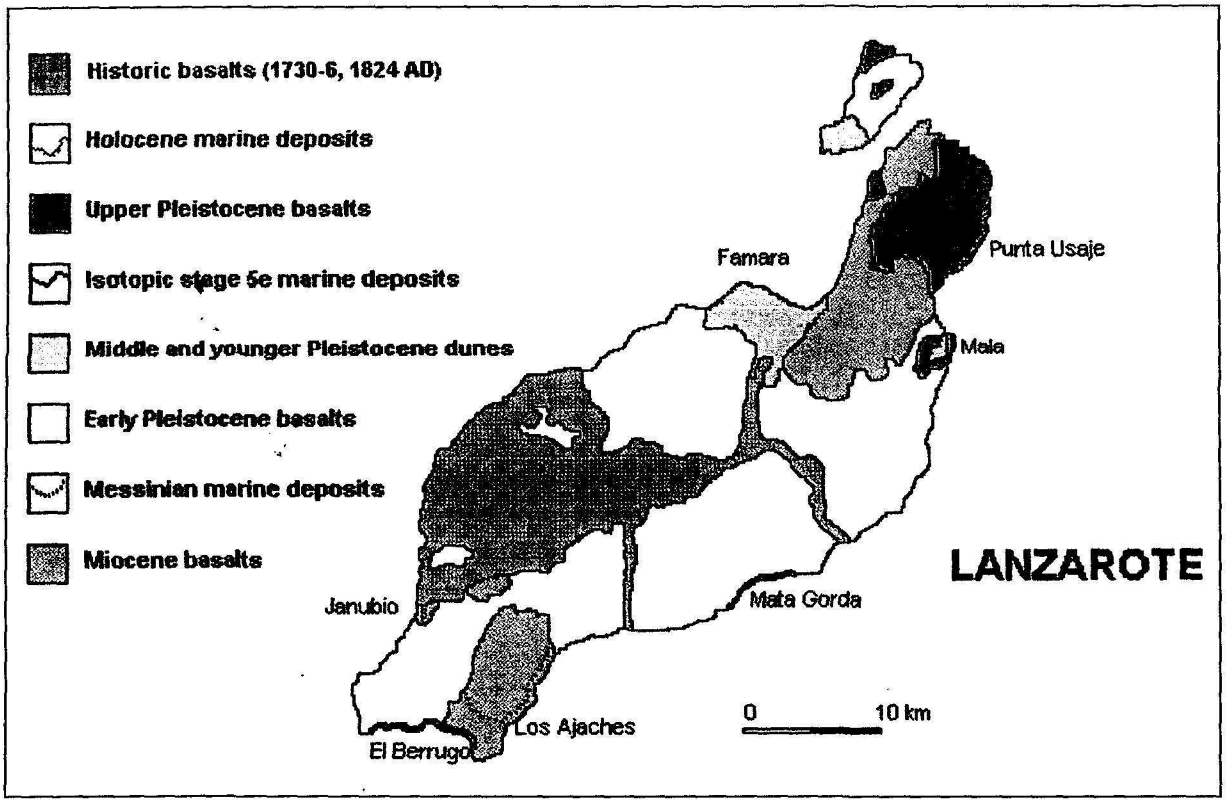

Figura 1. Geological outline of Lanzarote island.

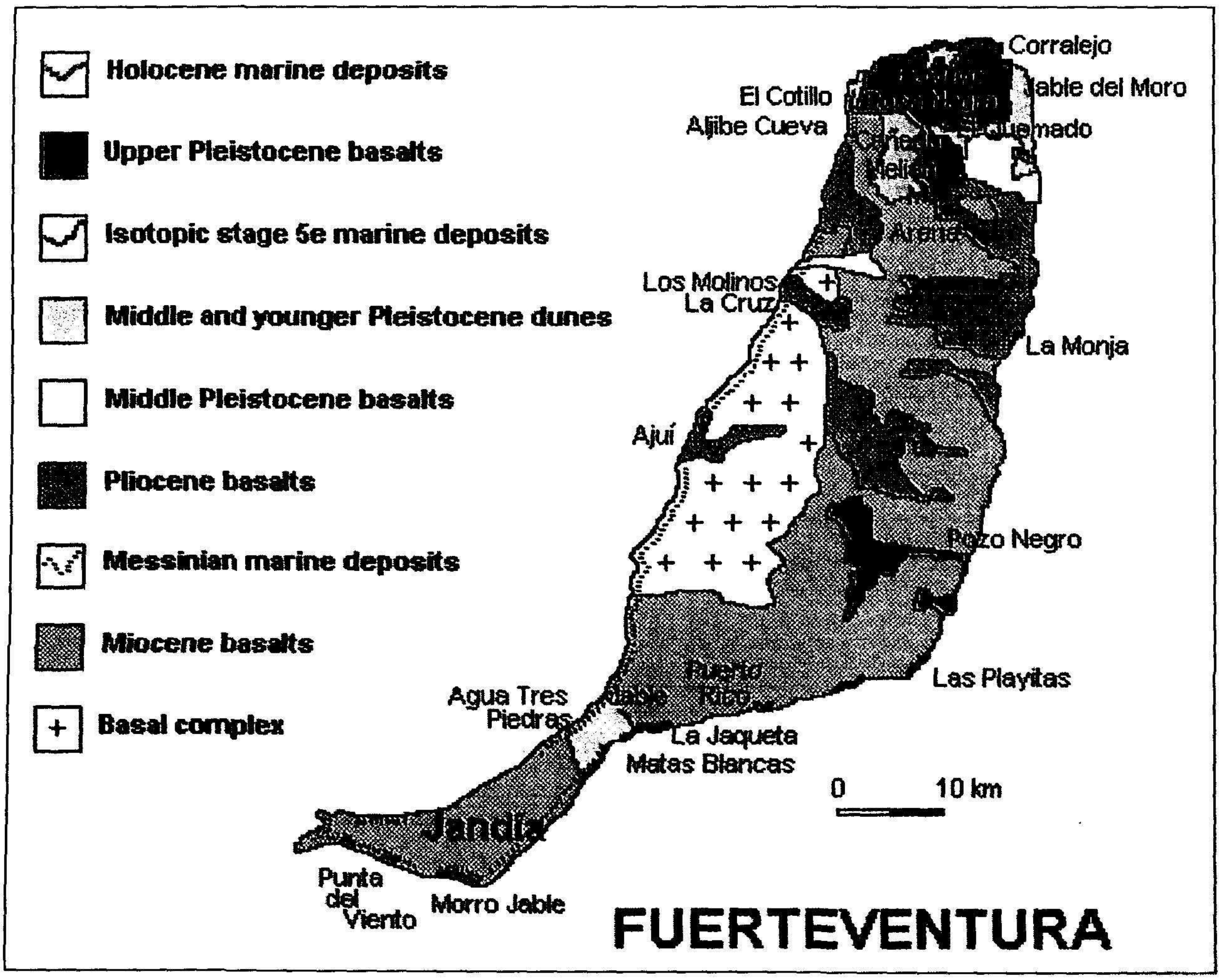

Figure 2. Geological outline of Fuerteventura island.

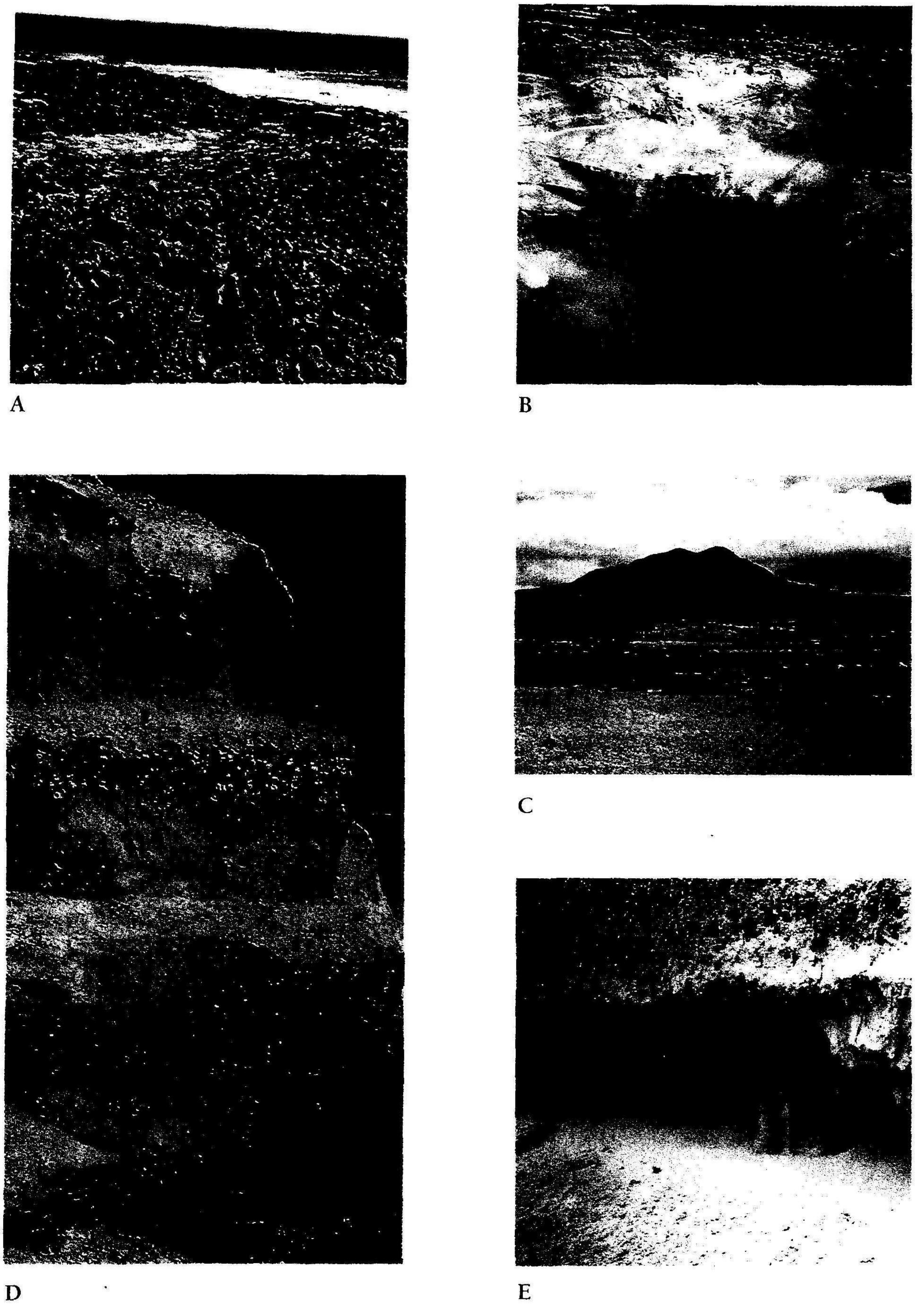

Plate I. Basaltic lava flows overlying the Middle Pleistocene dunes at (A, B) Mala in Lanzarote and at (C) Nothern Fuerteventura (Montaña Arena volcano). Layers of Hymenoptera nests and land snails (D), and fossil roots (E) in paleodunes at Cañada Melián section.

Fuerteventura formations, fit what is known of the Sahara climatic evolution: one to three wet episodes during stage 3 (c. 42 ka; 28-27 ka; 23 ka), two short wetter episodes corresponding to global warming steps (c. 15 and 13.8 ka) and the Early Holocene (beginning at 9.8 ka). Some U/Th and OSL ages point to stage 5. Older ones indicate possible wet phases which could be of any former interglacial.

Not a single age corresponds to stages 2 an 4, which pleads for the validity of the results. Besides, the above episodes fit the climatic evolution in the Sahara (Petit-Maire *et al.*, 1995) . However, the ages sometimes (in particular in Mala section) do not fit stratigraphy: considering that land snails are foraging species, they possibly may be found fossilized in layers older than the very animal. Still, these ages indicate wet periods during which they could live.

At present, mobile dunes exist (Fig. 1) at Famara (Lanzarote), (Fig. 2) Corralejo and Jandia (Fuerteventura). Their sand also derives from the older dunes, remobilised by the winds from the north, as in past scenarios. Weather conditions can still occasionally bring Saharan dust across to the islands.

Marine deposits

Fossiliferous marine terraces have long been observed along the coasts of the eastern Canary Islands. They correspond to the Mio-Pliocene and to isotopic stages 5e and 1.

Mio-Pliocene terraces

Sequences of emergent strandlines features («raised beaches») in the eastern Canary Islands have been attributed to a series of Pleistocene levels (Crofts, 1967; Lecointre, Tinkler and Richards, 1967; Klug, 1968; Muller and Tietz, 1975; Klaus, 1983) following Mediterranean and Moroccan models. K-Ar ages, more complete paleontological data (Meco, 1975, 1977,1981,1982,1983; Meco and Stearns, 1981) and ESR dating (Radtke, 1985), however concurred to assign them to Mio-Pliocene (Messinian) deposits on emergent coastal platforms.

We shall not discuss them in this paper.

Stage 5e terraces

At Mata Gorda, El Berrugo, Las Playitas, Matas Blancas (Photo 6 A, B), Puerto Rico, Punta del Viento and Morro Jable beaches (Fig. 1 and 2) terraces located at +5 m above msl have been observed since 1975 (Meco, 1975,1977). They are very fossiliferous. The fauna includes *Strombus bubonius, Conus testudinarius* (= *Conus ermineus*), Harpa rosea (= *Harpa doris*), *Murex saxatilis* and the coral *Siderastrea radians* Proliferating large *Patella* (group *Patella ferruginea*), *Thais haemastoma* and 15 other species (Meco *et al.*, 1987) are also present. This faunal assemblage indicates water temperatures much higher than at present. *Harpa rosea* never found in the Mediterranean, presently lives only in the Cape Verde Islands and the Gulf of Guinea (Gabon, Bioko Island, Pagalu Island). *Strombus bubonius* is typically a warm water species, now found from Senegal and Cape Verde Islands down to Congo, *i.e.* along coasts limited to the north by the Canary Current and to the south by the Benguela Current (Meco, 1972). The water temperatures of both currents are lower than 23 °C in the summer time, therefore, it cannot live in the present day cold current regime of Cape Juby (Fig. 4 and 5A). Those

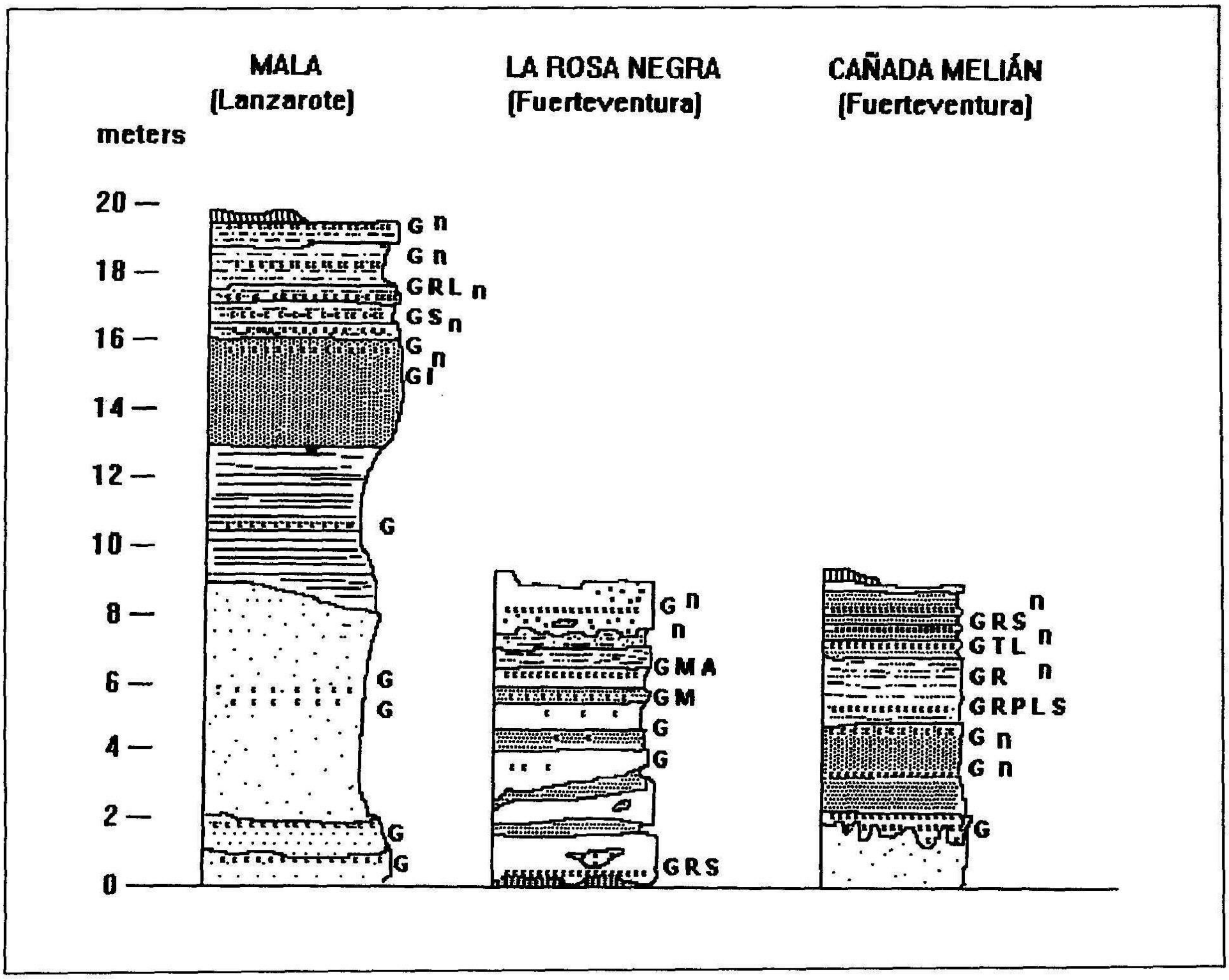

Figure 3. Mollusca fauna from the sections in Quaternary aeolian formations, Eastern Canary Islands. Layers of land snails are interbedded into the sand dunes. (Geochronology and lithostratigraphy studied by Bouab and Lamothe, this volume, and Damnati, this volume). The number of species (biodiversity) increases with humidity. A: *Theba pisana cf arietina* (Rossmässler 1846) G: *Theba geminata* (Mousson 1857); I: *Theba impugnata* (Mousson 1857); L: *Pomatias laevigatum* (Webb & Berthelot 1833); M: *Monilearia lancerottensis* (Webb & Berthelot 1833); n: Hymenoptera nests; P: *Parmacella auriculata* Mousson 1872; R: *Rumina decollata* (linné 1758); S: *Hemicycla sarcostoma* (Webb & Berthelot 1833); T: *Trochoidea despreauxii* (d'Orbigny 1839).

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Webb, P.B. & Berthelot, S.: (1833) Synopsis molluscarum terrestium et fluviatilium quas in itineribus per insulas Canarias observarunt, *Ann. Sci. nat.* 28:307-326.

deposits were attributed (Meco, 1975,1977; Meco et al, 1987) to the last interglacial under the name of Jandian, from the Jandía Peninsula in Fuerteventura. They were U/Th and ESR dated from 103 ka to 178 ka (Table 2).

Such terraces *with Strombus bubonius* are also known during stage 5 along the Mediterranean coast (Meco, 1977). In the southern coast of Spain they are dated 180 ka, 150 ka, 128 ka, 110 ka, 95 ka, 85 ka, 80 ka and 30 ka (Zazo et al.,1981; Hillaire-Marcel *et al.*, 1986). This wide range of ages is likely to be rather attributable to the method's uncertainties or to the reworking of older shells into the last interglacial deposits, as observed today when *Strombus bubonius* removed from the Pleistocene beach is found at Matas Blancas in the current beach sediments.

The colonisation of the eastern Canary Islands during stage 5 implies SSTs much higher than nowadays and a disappearance of the upwelling along the Senegalian and Saharan coasts, allowing larvae migration during the summer. The analysis of isotopic SSTs from Matas Blancas *Strombus bubonius* is in progress by Bard *et al.* (Cornu et al.,1993). However, a problem arises, considering the absence of *Strombus bubonius* in the 5e (Ouljian) terraces of the Atlantic coast of northern Africa (Ortlieb 1975; Meco, 1977), which could be explained by the fact that the main path of inflowing Atlantic tropical warm water into the Mediterranean (Alboran Sea) is around two large anticyclonic gyres, easily observable on satellite imagery (Fig. 4 and 5B).

Holocene terraces

Beach rocks are preserved at scattered localities in Fuerteventura and Lanzarote (Fig. 1 and 2), at elevations slightly higher than modern beaches and approximately 1 m lower than the Pleistocene terraces. After the ancient name of Fuerteventura (Erbania), they have been named Erbanian (Meco *et al.*, 1987).

Those deposits contain boulders from the Jandian sandstone and conglomerates. The Erbanian sea carved a notch in the cliffs-walls of «Los Jameos del Agua» cave, in Lanzarote, at approximately 2 m above present msl. It also carved a coastal erosion platform in the Jandian conglomerates, as seen at Las Playitas in Fuerteventura. The last marine pulsation (Erbanian ll) left a berm and beach-rocks, for example at La Jaqueta, Puerto Rico and La Monja. The fauna in this berm is analogous to the one living along the modern littoral zone. It is characterized by the abundance of *Cerithium vulgatum*, reaching up to 70% in the collected samples, and by the decrease of Patella (11%) and *Thais hameastoma* (2%) in relationship to the Jandian fauna, which typically contains more *Patella* (almost 56%) and *Thais haemastoma* (17%) than the Erbanian .

The fauna has been radiocarbon dated at four different sites in Fuerteventura (Table 3). Those radiocarbon ages indicate two periods of ocean stillstands, one around 4 ka and another after 2 ka. At La Monja and La Jaqueta, an alluvial deposit is interbedded between those two pulsations (Erbanian I and ll). It is possibly related with a similar deposit recorded inland, dated 3.3±0.1 ka (Rognon and Coudé-Gaussen, 1987).

Material	Site	14C age BP	U/Th corrected age	OSL age	Author(s)
Land snails	Famara	0.3±0.05 ka			Hillaire-Marcel et al,1995
Land snails	Jandía	7.93±0.7ka			Gif- 9070
Land snails	Corralejo	8.84 ±0.7ka			Gif- 9063
Land snails	Jandía	9.8±0.14 ka			Petit-Maire et al., 1986
Land snails	Jandía	13.85±0.2 ka			Rognon et al., 1989
Land snails	Corralejo	15±0.2ka			Petit-Maire et al.,l986
Land snails	Corralejo	23.22±0.35 ka			Gif - 9057
Land snails	P.Negro	23.6± 0.55 ka			Petit-Maire et al.,l986
Land snails	Famara	26.76±0.23 ka			Hillaire-Marcel et al.,1995
Land snails	Famara		27.4 ± 2.1 ka		Hillaire-Marcel et al.,1995
Land snails	Rosa N.	28.46 ± 0.63ka			LGQ - 142
Egg-shell	Jandía	28.95 ± 0.53 ka			Gif-9054
Land snails	Jandía	29.66± 0.7ka			Gif-8847
Land snails	Famara		30.2±0.9 ka		Hillaire-Marcet et al 1995
Land snails	Famara		30.6±0.9 ka		Hillaire-Marcet et al 1995
Land snails	Famara		31.2±0.6 ka		Hillaire-Marcet et al 1995
Land snails	Famara		31.6±0.9 ka		Hillaire-Marcet et al 1995
Marine shell*	Jandía	31.7±1.1 ka			Gif-9059
Land snails	Jandía	31.8±0.15 ka			Gif-9059
Egg-shell	Jandía	32.1±1.1 ka			Walker et al. 1990
Land snails	Famara		32.3±2.2 ka		Hillaire-Marcel et al.,1995
Land snails	Rosa N.	32.5±1.2 ka			LGQ-143
Land snails	Rosa N.	>33.8 ka			LGQ-141
Land snails	Rosa N.	>33.8 ka			LGQ-140
Land snails	Famara	33.91± 0.38 ka			Hillaire-Marcel et al., 1995
Land snails	Famara	34.2±0.37 ka			Hillaire-Marcel et al., 1995
Land snails	Famara	37.42±0.4g ka			Hillaire-Marcel et al., 1995
Land snails	Famara	38.73±0.5 ka			Hilaire-Marcel et al., 1995
Land snails	Famara	38.27±0.72 ka			Hilaire-Marcel et al., 1995
Marine shell*	Jandía	≥40 ka			Gif - A-93246
Land snails	Famara	40.76±0.6 ka			Hillaire Marcel et al., 1995
Land snails	Famara		from 41 to 27 ka		Hilaire-Marcel et al., 1995
Land snails	Famara		42.2±1 ka		Hilaire-Marcel et al., 1995
Land snails	Famara		43.15±07 ka		Hilaire-Marcel et al., 1995
Land snails	Famara		53.8±2.8 ka		Hilaire-Marcel et al., 1995
Land snails	Mala		94.9±07 ka		Shimmield
Land snails	Mala		138.3±5.02 ka		Shimmield
Land snail	Mala		138.3±7.4 ka		Shimmield
	Rosa N.			181±27 ka	Bouab & Lamothe, this vol.
Land snail	C. Melián		182.4±6.6 ka		Shimmield
	Rosa N.			183±27 ka	Bouab & Lamothe, this vol.
Land snails	C.Melián		224.4±4.9 ka		Shimmield
Land snails	C.Melián		229.0±7.5 ka		Shimmield
Land snails	Mala		235±4.65 ka		Shimmield
Land snails	C.Melián		241±4.9 ka		Shimmield
	Rosa N.			318±45 ka	Bouab & Lamothe, this vol.
Land snails	Mala		>350 ka		Shimmield
Land snails	Mala		>350 ka		Shimmield
Land snails	C.Melián		>350 ka		Shimmield

*Brought by fossil shearwater or by prehistoric man

Table 1. Radicarbon, U/Th TIMS and OSL ages of the Pleistocene/Holocene dunes.

Photo 6. *Strombus bubonius* in a stage 5e beach-rock at Matas Blancas, leewards of Jandía Peninsula, Fuerteventura.

Material	Site	U/Th age	ESR age	Author(s)
S. bubonius	Morro Jable	103 (116-91) ka		Radtke, 1985
S. bubonius	Matas Blancas	103.8±2 ka		Zazo et al. 1993
S. bubonius	Puntas del Viento		104.8 ka	Radtke, 1985
S. bubonius	Matas Blancas	106±7 ka		Meco et. al.,
S. bubonius	Puerto Rico		108 ka	Radtke, 1985
S. bubonius	Matas Blancas	112±7 ka		Meco et.al.,1992
S. bubonius	Matas Blancas		128.7 ka	Radtke, 1985
S. bubonius	Puerto Rico		135 ka	Radtke, 1985
S. bubonius	Matas Blancas	136 (154-122) ka		Radtke, 1985
S. bubonius	Matas Blancas		137.6 ka	Radtke, 1985
S. bubonius	Puerto Rico		147.2 ka	Radtke, 1985
S. bubonius	Matas Blancas	178±43.8 ka		Zazo et.al., 1993

Table 2. U/Th and ESR ages of stage 5e marine terraces.

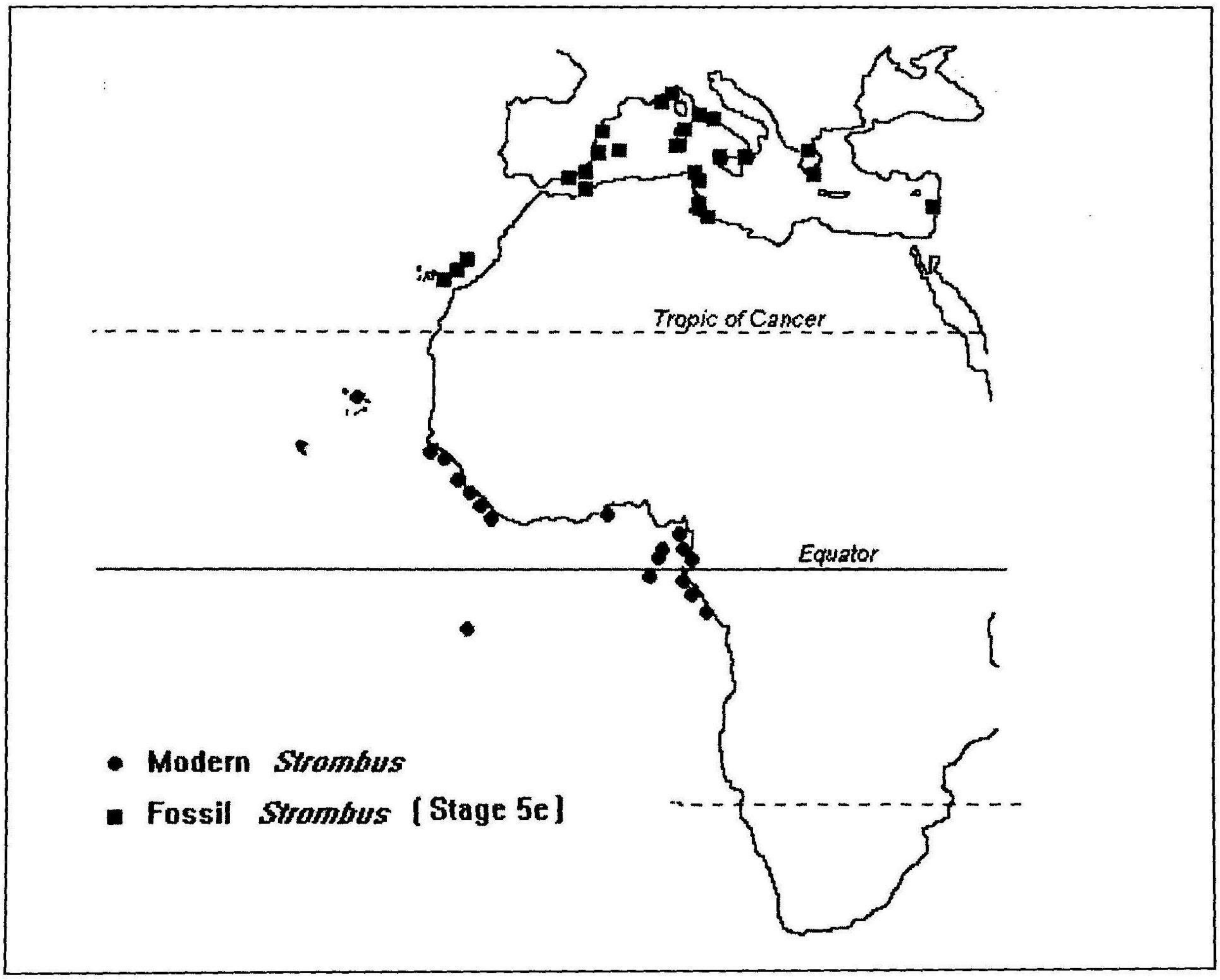

Figure 4. Geographical distribution of *Strombus bubonius* at present and during the last interglacial period.

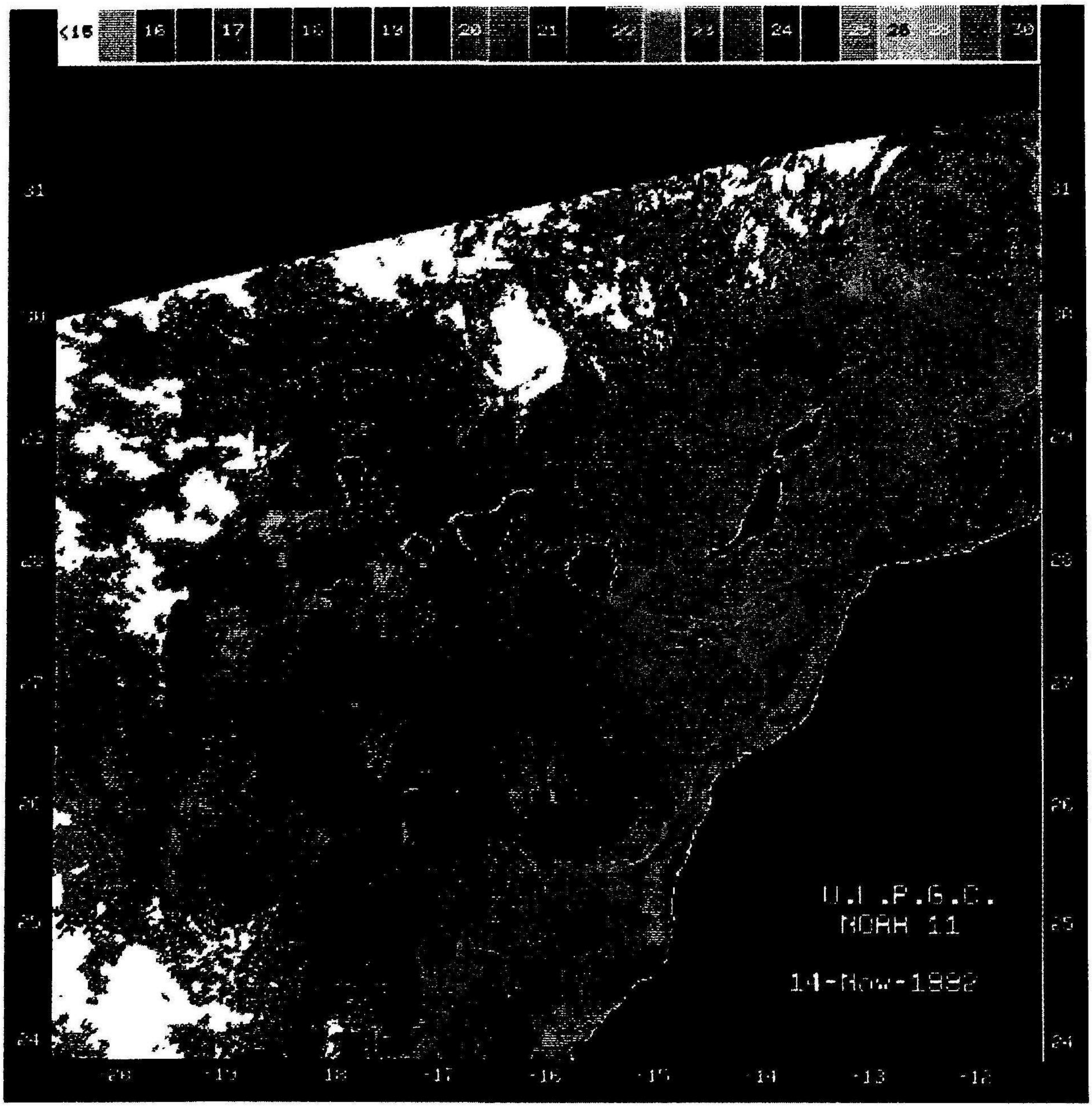

Figure 5A. Sea surface temperatures derived from NOAA/AVHRR satellite imagery show the North -African coast upwelling (A) and the main path of inflowing Atlantic warm water into the Mediterranean Sea (B). It could explain the differences observed between the Ouljian fauna, when compared with the Jandian and Tyrrhenian faunas.

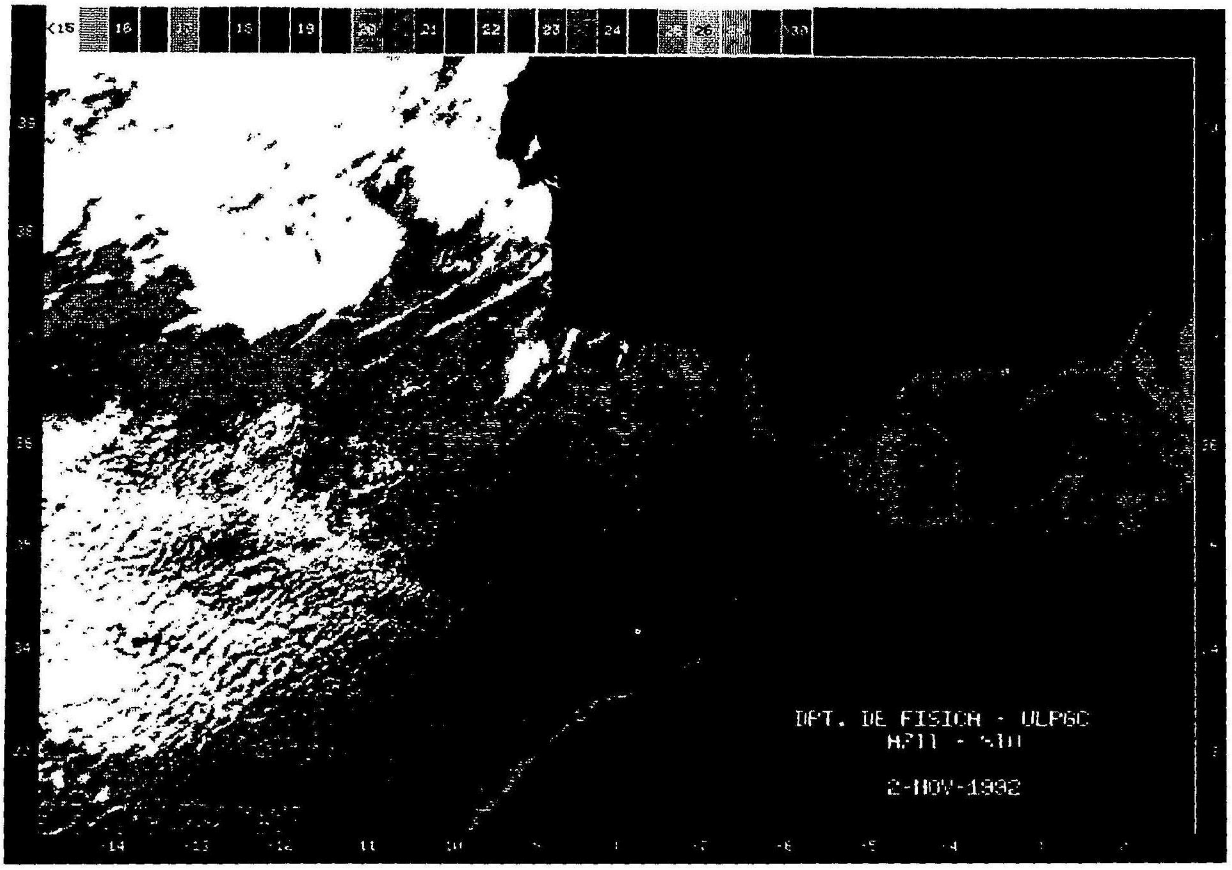

Figure 5B.

Site	^{14}C BP age	Authors
La Monja	1020 + 40	(Gif-9061)
Puerto Rico	1140 + 70	(Ki-2336) Radtke, 1985
La Jaqueta	1249 + 149	(LGQ-83) Meco, 1988
La Jaqueta	1363 + 151	(LGQ-82) Meco, 1988
La Jaqueta	1400 + 70	(Gif-7039) Meco et al.,1987
Puerto Rico	1940 + 70	(Ki-2336) Radtke, 1985
Corralejo	3640 + 100	(Gif-5346) Meco et al.,1987
La Monja	3960 + 70	(Gif-9060)
La Monja	4350 + 50	(Gif-9058)

Table 3. Radiocarbon dating of Holocene marine terraces

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