UNESCO - INTERNATIONAL UNION OF GEOLOGICAL SCIENCES

*EARTH PROCESSES IN GLOBAL CHANGE*

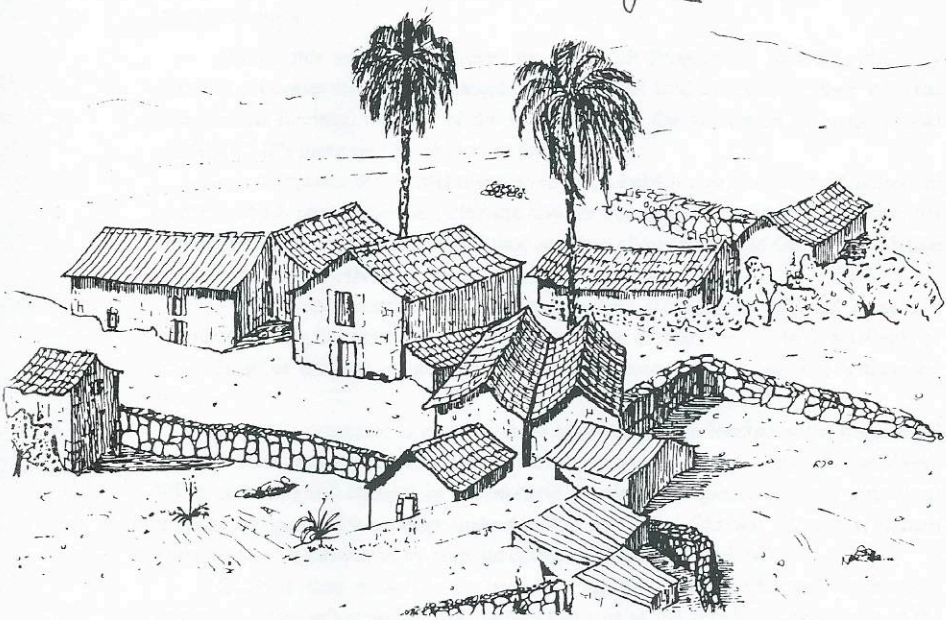
# CLIMATES OF THE PAST

# CLIMATES OF THE PAST

## CLIP meeting 1995

**Lanzarote and Fuerteventura**
**Canary Islands, Spain**

Santiago Santana drawing



Viceconsejería de Cultura y Deportes del Gobierno de Canarias
Cabildo de Fuerteventura - Casa Museo de Betancuria
Cabildo de Lanzarote - Casa de los Volcanes
Universidad de Las Palmas de Gran Canaria

UNESCO - INTERNATIONAL UNION OF GEOLOGICAL SCIENCES

# *- CLIP Program -*

The "Global Change" new multidisciplinary science has emerged from the necessity to anticipate the planet's climatic and environmental future, considering both its natural evolution and wholly original, man-induced changes. Understanding the natural variability of climate is thus a priority goal if one wants to detect future or even current changes.

Within this vast field, covered by the IGBP Programme, including the very complex processes relative to atmosphere, ocean and land interactions, their external and internal forcings, the role of the biosphere, and the generation of mathematical models, CLIP's more specific objectives are :

- to emphasize the pivotal role played in Global Change research by *Geological records* which provide for past climatic and environmental changes realistic data that can be precisely located in space and time and thus allow to validate Global Circulation Models and improve their accuracy for continental areas,

- to facilitate contacts between geoscientists working in different areas and encourage synthetic work and to create a network of members in different fields of Earth Sciences liable to collaborate and widen the scope of their regional or thematic work.

Particular attention is given to those sensitive regions located in the transitional climatic areas, among which the coastal zones where both oceanic changes (sea-level, SSTs, currents) and changes in atmospheric circulation (regional climatic variations) may be compared for a better understanding of Global Change. Moreover, human survival may be threatened by climatic change in deltas and wetlands.

CLIP is thus meant to be useful to all the "Global Change" community, providing a few milestones to help understand part of the appalling complexity of the Planet's mechanisms.

Since its creation at the 29th IGC in Kyoto, CLIP has already held meetings in South Africa (jan. 1993), Barbados (nov. 1993), Indonesia (aug.-sept. 1994) and France (oct. 1994, march 1995). The eastern Canary Islands of Lanzarote and Fuerteventura have been chosen for the 1995 major meeting, since proper CLIP collaborative research have been there developed over the last four years by 9 CLIP

Fuerteventura-Lanzarote islands and the coast of Morocco to the North of Cape Juby (28°N) define a narrow strait (125 km) where the dynamism of the cold Canary Current is maximised. Consequently, the eastern coast of those islands had certainly been very sensitive to the major climatic changes of the Quaternary and one could expect to find there significant geological records of palaeo-SSTs changes, possibly associated with changes in continental aridity. Since 1973, preliminary research has been performed along the Moroccan coast and in Fuerteventura island, both on oceanic records and continental formations of alternate aeolian deposits and palaeosols. CLIP has developed new research, since 1992, both near Tarfaya (Cape Juby) and in the two islands.

We are happy to bring to Fuerteventura and Lanzarote a group of international scientists who will certainly contribute by fruitful discussion and suggestions to the interpretation of the effects of Global Changes upon this key-area over the last two climatic cycles.

Welcome to the Canary Islands !

Nicole Petit-Maire
*Project Leader*

# 4 th CLIP MEETING
## *Canary Islands* - June 1-5, 1995

*Scientific presentations should not be formal but rather a base for discussion, questions, etc. No talk should exceed 15 minutes, in order to leave 15 minutes for immediate discussion. Papers should present **quantified and dated results**, and be related to Global Changes.*

- **May 31** - Arrival in Lanzarote island. The participants have to take a taxi from the airport to Hotel "Los Jameos Playa", Los Pocillos beach, Puerto del Carmen (tel.:34-28-513245). About 7 minutes, 800 pesetas.

- **June 1** - 9.00-9.30: Bus to "La Casa de los Volcanes", in the North of the island (30 km).

10.30-11.30: Official opening by the Vice-Councellor for Cultural Affairs of the Canarian Government, Don Miguel Cabrera, CLIP Officers and Professor J. Meco, organizer. CLIP activities in 1993-95, prospectives. Interest of the Canary islands for Global Change research.

11.30-13.30: Welcome party and lunch.

*13.30: R.A.Bryson: Coastal climate modeling.*

*14.00: E. Bard, S. Cornu, J. Meco, N. Petit-Maire: The Canary current: palaeotemperatures from the Last Interglacial period, based on $^{18}O$ of Strombus bubonius from Fuerteventura island.*

*14.30: B.Damnati: Sedimentological and mineralogical study of "La Mala" quarry, Lanzarote.*

*15.00: N.Bouab and M.Lamothe: Preliminary luminescence dating of Quaternary aeolianites and palaeosols in the Tarfaya(coastàl Morocco) area and Fuerteventura.*

15.30: Coffee break.

*16.00: Z.Guo: The loess / palaeosols formations in China.*

*16.30: M.Bâ: Sedimentary and climatic changes during the recent Quaternary in the Saloum Delta.*

*17.00: M.Fontugne: $^{14}C$ and $^{230}Th/^{234}U$ dating of marine terraces in the Persian Gulf and along the Makran coast (Iran).*

17.30: Return to hotel by bus.

- **June 2** - 9.00: Excursion to Timanfaya National Park (recent volcanic activity).

12.00: Lunch at Timanfaya Restaurant. Return to "Casa de los Volcanes".

*14.00: A.P.Kershaw: Environmental change in Greater Australia from the height of the Last Glacial period.*

*14.30: T.Edgar: Neogene and Quaternary climate and sea level changes in the Gulf of Carpentaria, northern Australia.*

*15.00: M.K.Gagan et al.: Toward near-weekly climatic histories from Late Quaternary corals.*

15.30: Coffee break.

*16.00: Z.Guo: Holocene palaeoenvironments in China.*

*16.30: C.Li: Late Quaternary palaeosols and palaeoclimate in the Yangtze Delta.*

*17.00: U.Radtke: Geochronology of the Pleistocene reefs of Kikai-Jima (Ryukyu islands, Japan).*

17.30: Return to hotel by bus.

- **June 3** - 9.00: Excursion to the aeolian formations, palaeosols and marine terraces in northern Lanzarote (La Mala quarry, National Park Chinijo).

12.30: Lunch in San Jose Castle (Arrecife).

14.00: Return to hotel by bus.

*15.30: F.Audemard: Evidence of Holocene tectonic activity on the Guadalupe thrust, northern Falcon State (Venezuela).*

16.00: Coffee break.

*16.30: A.Craig: Palaeoclimatic change at Salar de Punta Negra, northern Chile.*

*17.00: E.J.Rohling: Mutual influences between the Atlantic Ocean and the Mediterranean Sea during the Quaternary.*

*17.30: O.Conchon: Quaternary climates along the Egyptian Red Sea coast.*

*18.00: B. van Vliet-Lanoe: Permafrost dynamics and ice extension in Europe during the Last Glacial and the Holocene.*

- **June 4** - 9.30: Boat trip to Puerto del Carmen (Lanzarote) - Corralejo (Fuerteventura).

10.00: Arrival Corralejo. Excursion to the aeolian formations, palaeosols, marine terraces and recent volcanoes in northern Fuerteventura.

13.30: Luncheon at El Toston restaurant, El Cotillo.

18.00: Arrival at Hotel "Parador National", Puerto del Rosario (tel.: 28-85-11-50).

- **June 5** - 9.00: Excursion to Matas Blancas marine terrace (stage 5e).

13.00: Lunch at "El Molino" Restaurant, Antigua.

15.30: Reception at Betancuria Museum.

17.00: Return to hotel.

18.00: CLIP general Assembly.

- **June 6** - Departure of participants to Las Palmas from Fuerteventura airport.

# ABSTRACTS

*Strombus bubonius*, a Tropical Mollusc from an isotopic stage 5e marine terrace at Mata Gorda, Lanzarote ( Canary Islands ). Drawn by D. Medina Benítez.

# EVIDENCE OF HOLOCENE TECTONIC ACTIVITY ON THE GUADALUPE THRUST, NORTHERN FALCON STATE (VENEZUELA).

FRANCK AUDEMARD M.[1], JOSÉ A. RODRIGUEZ[1] & JEAN-CLAUDE BOUSQUET[2]

1- FUNVISIS. Apartado postal 76880, Caracas 1070-A, Venezuela. Fax: +(582) 257 99 77.
2- Lab. Géophysique & Tectonique, case 060, Univ. Montpellier II, 34095 Montpellier, France.

The Falcón region during Oligocene and Early Miocene times was mainly a marine basin open to deep sea water on the east. Then, it was rather intensively folded and tectonically inverted by a NW-SE compression in Middle and Late Miocene times, forcing subsequent facies to deposit exclusively on the north flank of the "newborn" Falcon anticlinorium. This inversion had to be active until Early Pleistocene times based on the two following facts: a) the Pliocene La Vela Formation (shallow marine deposits) is cropping out in perfect up-straight position on the north flank of La Vela anticline or dome (Fig. 1) and b) the Plio-Pleistocene Coro Formation (fan conglomerates mainly) is tilted northward up to 65º. However, nowadays is hard to tell if tectonic inversion of this Oligo-Miocene Falcón basin located in northwestern Venezuela is still going on, but the Guadalupe thrust and its western prolongation, tectonic feature responsible for both previously-mentioned tilting, seems to be active, as we intend to demonstrate next.

First of all, let us mention that a set of beach-rock deposits, wave-cut benches and wave notches can be observed at a ≈1 m above msl along the northeastern coast of the State of Falcón, between La Vela and Punta Sauca. We believe that these seaside features might be associated to the maximum highstand of the Holocene transgression reported worldwide at about 4000 to 5000 years ago, thus implying that maximum Holocene sea level should be expected at ≈1 m above msl in the southern Caribbean region. On the other hand, a small patch (< 15 $m^2$) of beach-rock outcrop was found at ≈+2.5 m on the present beach that surrounds the north flank of La Vela anticline (Fig. 1). This deposit is rather thin, less than 10 cm thick, and dips gently to the north (toward the sea). Its northern tip has dropped because wave action has eroded the tender underlying marls of the Miocene Caujarao Formation. $^{14}C$ age determinations carried out on unreworked tests of *Turritella sp.* sampled from it yielded an age of 2700 yr. B.P. Therefore, this beach-rock deposit seems to be uplifted of ≈1.5 m due to the upheaval of La Vela anticline. Since this structure is genetically related to the Guadalupe thrust, this latter seems then to be moving coseismically. Considering a thrust plane dipping at 30º S, the coseismic slip can be roughly estimated at 3 m, capable of generating an Ms ≈7.0 earthquake.

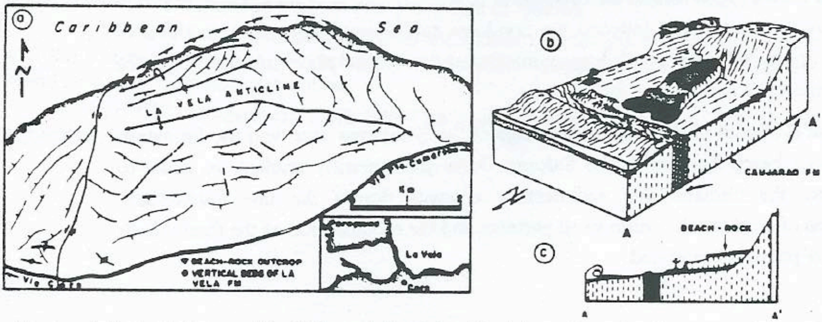



Fig. 1.- a) Geological map of La Vela anticline (simplified from Gonzalez de Juana, 1969), indicating location of marine evidence of Holocene activity. b) Block diagram of uplifted beach-rock outcrop. c) Schematic cross-section of Holocene beach-rock deposit.

# SEDIMENTARY AND CLIMATIC CHANGES DURING THE RECENT QUATERNARY IN THE SALOUM DELTA

Mariline BA

Département de Géologie, Université C.A. Diop, Dakar, Sénégal.

The senegalese coast was influenced by several transgressions during the recent Quaternary. The most important one, which moreover determined the present-day landscape, is the Nouackchottian (7.000 - 4.000 yrs BP). However, in the Delta of the Senegal river, the subrecent period is characterized by fluvial sedimentation and the environmental changes are apparently linked to changes in climatic conditions occurring after 5.000 yrs BP. In the Saloum Delta (southern coast), sea-level did not change significantly during the last 6.000 years. Morphological and sedimentological changes observed in the late Holocene sequences were apparently induced by a constraining climatic background.

During the maximum of the Nouakchottian transgression (5.500 yrs BP), new embayments formed. Towards 4.000 yrs BP, the longshore drift induced the formation of beach barriers in the Saloum Delta. These beach barriers, deposited on an extensive thick green mud (dated 6.130 to 3.500 yrs BP), deviated the Saloum river southwards.

Climatic changes modified the barriers development:

- phases of aridity corresponded to aeolian transport of silt and sand. These sediments were trapped behind the barriers,
- exceptional swells induced the breakage of the sand spits. The mouth was deplaced northwards, the beach barrier integrated the deltaic plain and the longshore drift constructed a new barrier forward.

The evolution of the present breakage of the Sangomar sand and the formation of the fossil beach barriers in the Saloum Delta are currently studied, in order to reconstitute the climatic and sedimentary changes during the late Quaternary. Alternation of north swell / south swell patterns and the modification of the fossil beach barriers are possibly correlated.

# THE CANARY CURRENT: PALAEOTEMPERATURE FROM THE LAST INTERGLACIAL PERIOD, BASED ON $\delta^{18}O$ OF *STROMBUS BUBONIUS* FROM FUERTEVENTURA ISLAND (28°N, CANARY ARCHIPELAGO)

***E. Bard, **J. Pätzold, ***J. Meco, ****N. Petit-Maire**

*Géosciences de l'Environnement, Case 431, Faculté de St Jérôme, Université Aix-Marseille III, 13397 Marseille Cedex 13. France
**Fachbereich Geowissenchaften, Universität Bremen, D-2800 Bremen 33, Germany
***Depto de Biologia, Universidad de Las Palmas de Gran Canaria, Tafira. 35017 Las Palmas. Spain.
****Laboratoire de Géologie du Quaternaire, CNRS, Case 907. Luminy.13288 Marseille Cedex 9. France.

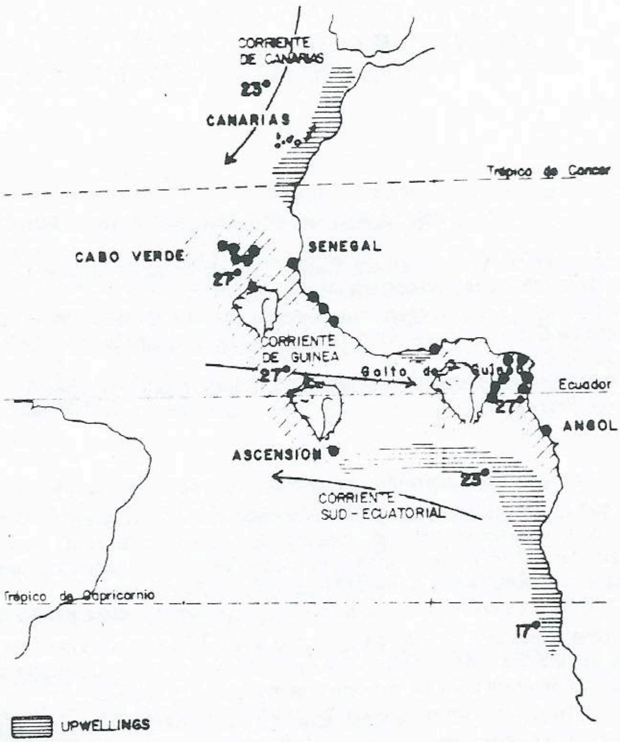
In order to quantify the paleo SST corresponding to the marine terrace with *Strombus bubonius*, dated stage 5 in Fuerteventura island, the d $^{18}O$ in this Mollusk' s shells was measured both in modern *S. bubonius* and in fossil samples from Fuerteventura. The modern shells were collected at different locations in the Gulf of Guinea where this species is presently geographically restricted.

1) The sampling scheme followed the growth spiral of the Mollusc, in order to obtain time series of 3 - 4 yrs : as expected, the d $^{18}O$ generally exhibits a cyclic pattern related to the SST seasonality. The isotopic seasonality in Fuerteventura *S.b.* is not significantly different from the modern one in the Gulf of Guinea.

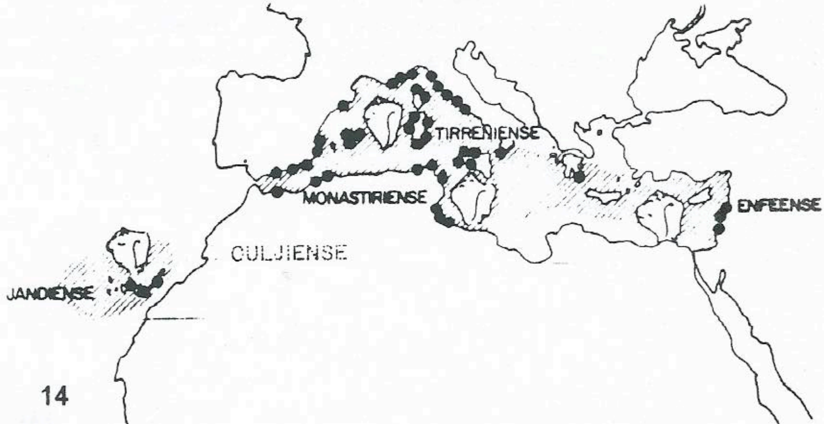
2) The d $^{18}O$ SSTs reconstructed for the modern shells are in rough agreement with the values recorded in climatological maps, which suggests that *S.b.* shells are useful for paleo SSTs reconstructions.

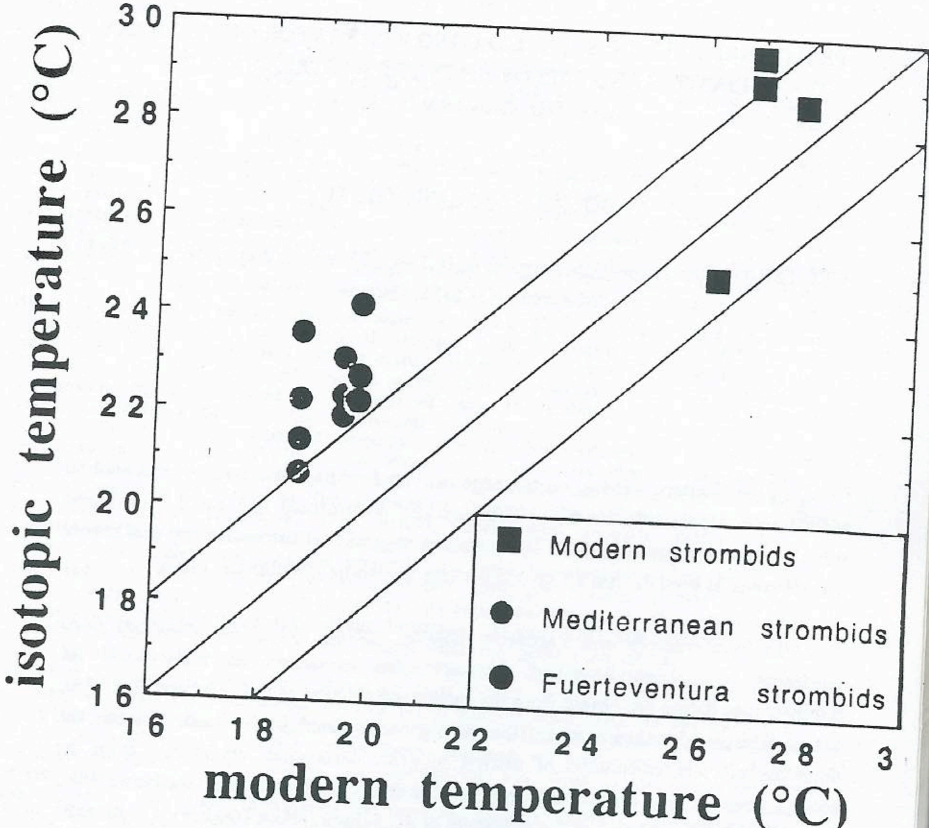
The d $^{18}O$ in three fossil shells from Fuerteventura show a palaeo SST 2° to 4°C higher than nowadays.

Present-day geographical distribution of *Strombus bubonius*




Geographical distribution of *Strombus bubonius* during the Last Interglacial.




isotopic temperature (°C)
modern temperature (°C)
30
28
26
24
22
20
18
16
16
18
20
22
24
26
28
3
Modern strombids
Mediterranean strombids
Fuerteventura strombids

# PRELIMINARY LUMINESCENCE DATING RESULTS FOR QUATERNARY EOLIANITES AND PALEOSOLS IN THE WESTERN SAHARA AND THE CANARY ISLANDS

BOUAB N. and LAMOTHE M.

GEOTERAP, Département des Sciences de la Terre, Université du Québec. CP 8888_A.
Montréal, H3C 3P8, Canada.

In the Western Sahara, on the edge of Tah Sebkha, the alternation of aeolian sediments and paleosols are being lithologically documented and dated by infrared stimulated luminescence (IRSL). These studies suggest that successive dry and humid periods cover at least the last 80 ka and perhaps the whole last climatic cycle.

In Fuerteventura and Lanzarote Islands, similar but more developed dune sequences have been described. However, the minerals commonly used for luminescence dating are absent from the sand-sized fraction of the sediment. For IRSL dating, feldspar of grain size up to 100 μm is generally used. In the Canary Islands, the dune deposits are constituted of detrital biogenic carbonates, originating from the coastal environment, and by minerals eroded from fresh and / or weathered local volcanic rocks. On account of the proximity of the Sahara (about 100 km), a systematic search for exotic minerals that could be carried by winds and current action, was initiated and showed the presence of 45 to 90 μm feldspars. Preliminary IRSL results on the bottom part of the Fuerteventura sequence (Rosa Negra) show that the Quaternary climatic fluctuations recorded here could cover a time range similar to the Tah sequence, *i.e.* the oceanic isotopic stages 3 to 5.

4th CLIP meeting, Canary Islands, June 1-7, 1995

## Data concerning Quaternary climates along the Egyptian Red Sea coast.

*CONCHON, Odette, and **BALTZER, Frédéric
*Département des Sciences de la Terre, Université Paris-Sud, F91405 ORSAY
**URA 723 CNRS, UPS, F91405 ORSAY

The Quaternary sedimentary sequence and geomorphology characterizing the piedmont of the East Egyptian coastal range indicate significant climatic changes. The climate of this region is *presently hyper-arid* (mean annual rainfall, 4 mm, over 25 years).

The Quaternary sediments comprise alluvial fans, alluvial terraces and reef complexes, unconformably overlying Pliocene and Miocene formations . They have been affected by several tectonic phases (Baltzer et *al.*, 1992). An interpretation of climatic changes, based on the properties of continental detrital sediments and on palaeofaunas in coastal formations, is proposed.

The quantitative **chronostratigraphical scale** necessary to date the various climatic episodes is based on the isotopic dating of reefal complexes. The reef (1R) flanking the present shoreline and culminating 6 to 8m above present mean sea level (PSL) was dated by uranium series as 124.2 $^{+4.9}_{-6.2}$ to 115.7 $^{+6.5}_{-2.2}$ ky, thus corresponding to the Last Interglacial, isotopic stage 5e (Reyss et *al.*, 1993). North and South of the studied area, littoral marine sediments 1m above PSL, were dated as Holocene, 7.700 to 5.600 y BP (Plaziat et *al.*, 1994). On the other hand, the relative chronostratigraphy is based on a series of reefs (built during high stands of sea level) intercalated between the continental sediments.

Six or seven periods of continental accumulation (Freytet et *al.*, 1993) are organized in four terraces F'/F. The oldest (4F') terrace is characterized by large rounded boulders, transported by stream flow; it could not be correlated with a marine formation. A phase of fluvial incision followed this sedimentation, and the subsequent detrital sediments (3F') include debris flow deposits overlain by a complex of four successive reefs (2R), located 1 to 2 km inland from the modern coast; these ancient reefs cannot presently be dated by uranium series, being too calcitized. At Wadi Nahari, fluvial sediments (3F) are braided channel deposits whose upper parts were cemented by phreatic calcite, and this continental sedimentation ended with a travertinous limestone. A reef (ER) also locally overlies the (3F) sediments at Nahari, 0.8km inland from the present shoreline.

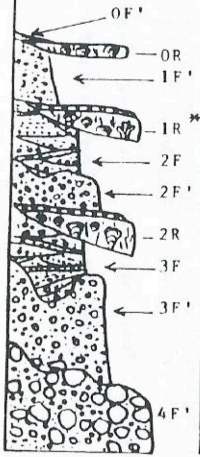
The old (2R) reefs are overlain by debris flows and (or) sheet flood deposits (2F'), on which the reef (1R) was built along the coast .

Modern wadis (0F) are incised in fans (1F'), and the reefs (1R) are cut by a cliff along the modern shoreline, against which the modern fringing reef (OR) is built.

Relatively humid **climatic conditions** occurred at least occasionally during the *Last Interglacial*, as indicated by Charophytes and fresh water Gastropods in several sites along the Egyptian Red Sea coast (Plaziat et *al.*, 1994). An arid episode subsequent to the Last Interglacial is deduced from a laminar calcrete horizon coating the emerged reefs (1R) (Freytet et *al.*, 1994).

In the Red Sea region, we assume that the Last Glacial maximum (20 - 18 ky BP) was arid, as in neighbouring modern deserts (Pachur et *al.*, 1987, Petit-Maire et *al.*, 1991).

Although quantitative data are rare for modern river and fan deposits in arid areas (Laronne and Reid, 1993), certain properties of the Quaternary continental sediments (abundance of large boulders, types of stratification, phreatic cementation, travertine) suggest that strong sporadic water discharges and somewhat permanent river flow prevailed in this area (Freytet et *al.*, 1994; Conchon et *al.*, 1994). These runoff regimes imply semi-arid episodes, and sometimes tropical semi-arid conditions, which thus took place during the *transitional phases* between the maximum glacial and interglacial stages (fig.1). A tentative comparison could be envisaged with the modern sedimentation of the Mehran river, in the semi-arid region of South-East Zagros, Iran, where the mean annual rainfall reaches 200 to 300 mm.




| Virtual section | Lithostratigraphy and (or) transport processes | Main erosion phases | Tentative climatic conditions<br>Mean annual rainfall (mm)<br>80 150 250 400 500<br>HA A MA SA TSA | Chronostratigraphy |
|---|---|---|---|---|
| 0F', 0R | braided ephemeral streams (0F-F')<br>reefs and beaches (0R) | | HA to A | Holocene |
| | | | A | Last Glacial (st.2) |
| 1F', 1R *, 2F | sheet floods (1F')<br>reefs and beaches (1R)<br>braided rivers (2F) | Incision | A to MA<br>A to SA<br>SA (occasionally)<br>SA to TSA | Last Interglacial* (5e |
| | | | A | Glacial |
| 2F', 2R, 3F | debris flows, sheet floods (2F')<br>reef and beach complex (2R)<br>braided rivers (3F) | Incision | A to MA<br>MA to SA<br>SA to TSA | Interglacial |
| | | | | Glacial |
| 3F' | debris flows (3F') | Incision | A to MA<br>MA to SA | |
| | ? | | | Interglacial |
| | | | | Glacial |
| 4F' | metric-boulders, gravel unit (4F') | Incision | A to MA<br>SA to TSA | |

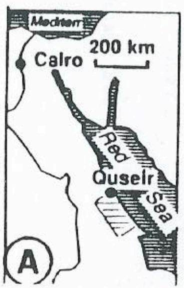



Fig.1.- Stratigraphic virtual section representing the succession of Quaternary deposits between Quseir and Wadi Gemal, the correlative climatic conditions, and a tentative chronostratigraphical scale. * Isotopic stage 5e was based on 9 coral samples dated in 5 places from the region studied.

On the schematic section, the oldest fan deposits (4F') are figured below the younger ones, although they are topographically higher --- deposits (3F') succeed to (4F') after a deep incision; deposits (2F') succeed in the same way to (3F') after incision, and (1F') after incision of (2F'). The oldest reefs (2R) are also situated higher than the youngers (1R and 0R), being elevated by tectonism.
HA=hyperarid, A=arid, MA=moderately arid, SA=semi-arid, TSA=tropical semi-arid conditions.
A) Area studied. Q = Quseir.

# PALEOCLIMATIC CHANGE AT SALAR DE PUNTA NEGRA, NORTHERN CHILE

A. CRAIG

Department of Geography, Florida Atlantic University, Boca Raton, Florida, USA.

Previous reports on the Salar de Punta Negra in northern Chile, by archaeologist Lynch (1984,1986), hypothesized the existence of various high lake level geomorphic features, correlated with regional Quaternary climatic change, and overflow into adjacent salares. His 1990 report concludes these features have been obliterated by other mass wasting processes. My 1992 study of Salar de Punta Negra indicates the present lake level has never been exceeded, and no stranded terraces nor beaches exist. Early Holocene human occupation of shoreline spring sites is evident, and paleokarst features are present in adjacent Jurassic limestone of the La Profeta formation. Other Chilean salares may be better candidates for correlation of Late Pleistocene climatic changes already documented by ice cap studies.

# PALAEOCLIMATES IN LANZAROTE ISLAND, CANARY ARCHIPELAGO: SEDIMENTOLOGICAL AND MINERALOGICAL STUDY OF "LA MALA" QUARRY.

B. Damnati*, S. Bieda*, N. Petit-Maire** and G. Shimmield***

* LGQ du CNRS. CEREGE. B.P. 80. 13545. AIX-EN-PROVENCE. France.
** URA 164. CNRS Luminy. Case 907. 13288 Marseille Cedex 9. France.
*** Geology and Geophysics Department, Grant Institute. Edinburgh. EH93jw. UK

Lanzarote, a volcanic island, is only about 100 km from the moroccan coast of the Sahara. Its climate is arid to semi-arid. The mean annual precipitation is 105 mm. The important aeolian formations in this island are interbedded with palaeosols. A quarry cutting into those formations ("La Mala"), in the north of the island, has been sampled and some sedimentological and mineralogical parameters (granulometry, carbonates, clay minerals) were studied. The preliminary results show that:

- in the lowest unit, between +0 and +2 m, the sediment is rich in the > 125 µm fraction. However, the silt fraction (<63 µm) is important (about 30 % of the total sediment). The carbonates are abundant in the coarser fraction (>125 µm). This unit is enriched in illite and kaolinite in its lowest part, and in smectite in its upper part.
- the middle unit, between +2 and +16 m, composed of sands (*c.* 100 %). The carbonates are abundant (*c.* 90 %). The illite + kaolinite / smectite ratio is very high.
- the upper unit, between +16 and +22 m is intercalated between evolved soils and poorly evolved soils. The evolved soils are marked by more silt, less carbonate and more smectite. The poorly evolved soils are characterised by more sand, more carbonate and more illite + kaolinite.

Those three lithostratigraphical units are related with three climatic periods. The lowest one corresponds to a transitional period of climatic instability, with mixed aeolian sediments (from the Sahara and local sources) and clays. The middle unit is a typical fossil dune, a witness for a very arid climate. The upper unit is a new transitional period, the humid conditions being more accentuated than during the lowest unit phase.

U/Th dating of the Helicidae shells in the paleosols is uncertain. The lowest and middle units are off the U/Th dating limit ($\geq$ 350 ka). The upper unit is dated at 95 $\pm$ 4 ka and 138.3 $\pm$ 6 ka. OSL dating is current (cf. Bouab and Lamothe, same vol.).

# NEOGENE AND QUATERNARY CLIMATE AND SEA LEVEL CHANGES IN THE GULF OF CARPENTARIA, NORTHERN AUSTRALIA

T. EDGAR. B. CECIL. M. GRIM and R. MATTICK

U.S. Geological Survey, 917 National Survey, Reston. Va. 22092. USA.

The Gulf of Carpentaria is a shallow cratonic sea that lies between northern Australia and New Guinea, and it contains sediments that record both sea-level and climatic history. The maximum water depth in the gulf is about 70 m. and the bottom gradient can be less than 1 : 16.000 in some areas. making the floor of the gulf very sensitive to sea-level change. Small changes in sea-level affect the stratigraphy over a wide area. A high-resolution seismic survey conducted by the U.S. Geological Survey and the Australian National University recorded reflections from the upper 100 to 150 m of the sedimentary section. At least 10 reflections in this section are interpreted as exposure surfaces with coeval buried channels, some of which cut as deep as 80 m into pre-existing strata. Because the extremely flat and shallow sea floor makes it improbable that submarine channels could be cut into underlying sediments. these channels are interpreted as riverine or estuarine.

During glacial stages, sea-level dropped more than 70 m. and the gulf of Carpentaria became dry. Rivers flowed from the southern part of the gulf of Carpentaria north to northwest across the area now covered by the Arafura Sea and into the Indian Ocean. Large incised channels, as wide as 2 km. indicate that rainfall may have been higher than in modern times in the catchment basin of the gulf region.

In 1966, 10 holes will be continuousely cored to a total depth of 100-150 m below the floor of the gulf. at locations selected on the basis of the geophysical data already acquired.

# $^{14}C$ AND $^{230}Th$ / $^{234}U$ DATING OF MARINE TERRACES IN THE PERSIAN GULF AND ALONG THE MAKRAN COAST (IRAN)

M. Fontugne[1], J.L. Reyss[1], C. Hatté[1], I. Bentaleb[1], P.A. Pirazzoli[2], A. Haghipour[3]

[1] Centre des Faibles Radioactivités, Laboratoire Mixte CNRS-CEA, Avenue de la Terrasse, F 91198 Gif-sur-Yvette Cedex. FRANCE.

[2] Laboratoire de Géographie Physique, CNRS-URA 141, 1, place A. Briand, 92190 Meudon Bellevue, FRANCE.

[3] Qeshm Free Area, PO Box 15875, 1548 Teheran. IRAN.

The Iranian coast along the Persian Gulf and the Oman Sea is characterized by an important tectonic activity, allowing uplift of shorelines and coral terraces. Tectonic trends can be deduced from the Holocene and upper Pleistocene raised terraces, along a 2.000 km long sector from Busheir to Gwater, at the Pakistanese border. Sequences of up to 20 superimposed shorelines have been identified. The $^{14}C$ and $^{230}Th$ / $^{234}U$ dating of these terraces allow to calculate the uplift rates, that are notablely lower than those estimated previously by Vita-Finzi (1982), and to estimate the relative variations of sea level during the last two climatic cycles.

# TOWARD NEAR-WEEKLY CLIMATIC HISTORIES FROM LATE QUATERNARY CORALS

M.K. Gagan[1], S. Anker[2], D. Hopley[3], A.R. Chivas[1] and P.J. Isdale[4]

[1] Research School of Earth Sciences, Australian National University, Canberra, ACT 0200

[2] Marine Resources Division, Australian Geological Survey, Canberra, ACT 2601

[3] Sir George Fisher Centre, James Cook University, Townsville, Qld. 4811

[4] Australian Institute of Marine Science, Townsville, Qld. 4811.

Knowing the exact timing of climatic events, in addition to their magnitude, will be crucial when coral-based palaeoenvironmental data are ultimately used to refine predictive climatic models. Unfortunately, traditional density band and geochemical chronometers cannot provide the time-control required to fully utilise the high-resolution proxy climate records being extracted from corals. We will briefly present near-weekly skeletal carbon isotope ( $^{13}$C) measurements from massive *Porites* corals which reveal sharp $^{13}$C-enrichments closely corresponding to the annual synchronised spawning event in the Great Barrier Reef and eastern Indian Ocean. The $^{13}$C-response to spawning should provide an accurate, "built-in" chronometer since the annual spawn-times are separed by exactly 12 or 13 lunar months and can be forecasted to within $\pm$ 3 days. Thus, for near-weekly proxy data extracted from living corals, where the lunar phase can be hindcasted exactly, it should be possible to produce continuous time-series with aggregate errors of no more than $\pm$ 10 days. Synchronised spawning is common for long-lived massive corals and, to date, has been documented in the Great Barrier Reef, eastern Indian Ocean, Caribbean, Red Sea, and elsewhere, so it should provide a widely applicable chronometer.

Application of the spawning chronometer should not be limited to modern corals, however, because present-day coral morphologies and zonation patterns have prevailed for hundreds of thousands of years and it is probable that spawning biorhythms have also remained intact. For late Quaternary corals, the mean spawn-time could yield "floating" chronologies with internal age precisions of better than $\pm$ 2 weeks for the majority of years. Such chronologies should make it possible to examine the sensitivity of the tropical ocean-atmosphere to large-scale forcings, as manifested through subtle shifts in the intra-seasonal timing of climatic events.

Work is under way to document possible changes in the timing and magnitude of the Indo-Australian monsoon, and the El Niño, during the mid-Holocene warm period. Continuous cores have been extracted from well-preserved coral micro-atolls (6 m diameter) from the Orpheus Islands and the Great Barrier Reef; they have been radiocarbon dated to 5.5 ka. This is an interesting time-period because several palaeoclimate records suggest that the period around 6 ka, in general, was a time of marked climatic instability, particularly in tropical northern Africa. Preliminary examination of coral UV fluorescence patterns (indicating monsoonal runoff) in the 150-year-long Orpheus core suggests that monsoonal rainfall in northeast Australia was generally greater and less variable than at present. The obvious lack of periodic droughts begs the question of whether or not the El Nino, as we know it today, was in full operation at 5.5 ka. One way possibly answering this question is to examine the sea-surface temperature patterns (using skeletal Sr/Ca and $\delta^{18}O$) leading up to the weak droughts, marked by subdued UV Fluorescence. If the El Niño is primarily responsible for northeast Australian droughts, as it is today, we should see the warm-to-cool SST phase which is well documented for the west Pacific arm of the present-day El Niño.

# SKETCH MAP OF HOLOCENE PALEOENVIRONMENTS IN CHINA

Zhengtang GUO
Institute of Geology, Chinese Academy of Sciences, Beijing, 100029, China.

*(CLIMEX PROJECT)*

Variability of climates over the last 10.000 yrs may be crucial for understanding the non orbital climatic forcing and evaluating the consequences of possible future greenhouse warming. Mapping the Holocene $^{14}C$-dated climatic indicators, considering both the spacial and temporal variations cannot only provide accurate boundary conditions for climatic models, but is also a valuable method for identifying and timing the short-duration climatic events. We present here a sketch map of Holocene palaeoenvironments in China, based on 400 reliable radiocarbon dates of climatic indicators collected from the related literature of the last 10 years, with particular emphases on the arid areas which are more sensitive to climatic changes.

Radiocarbon dates of coastal deposits indicate that a large-scale Holocene marine transgression in China began at about 7.200 $^{14}C$-yrs BP and has been maintained until about 2.500 $^{14}C$-yrs BP, with possible fluctuations. During this period, the coastline moved about 80 km westward in the Bohai Sea region and about 200 km at the lower reaches of the Yangtze River, compared with the present-day position.

Radiocarbon dates of palaeosols, lacustrine deposits and plant remains, selected from the modern desertic regions in northern China, reveal that the Holocene climates have experienced striking humid-dry fluctuations at timescales of several hundred years, as also reflected by the variations in vegetation, lake salinity and mountain glaciers. Since the studied region is located within the Asian monsoon zone, these short-duration climatic events evidence significant oscillations of the Asian summer monsoon during the Holocene. At least 5 drier stages and 4 humid stages can be recognized, which are not directly attributable to either orbital forcing or ice-sheet changes. During the humid stages, most of the aeolian dunes in the eastern part of China were fixed, which returned to moving states during the dry stages. The dunes areas in western China were reduced during the humid stages, but the dunes were never totally fixed, probably due to the higher continentality and strong evapotranspiration. Archeological radiocarbon dates indicate that human occupation in the desertic regions was strongly dependent on the palaeoclimates, with a time lag of several hundred years relative to the changes in soil and hydrological conditions.

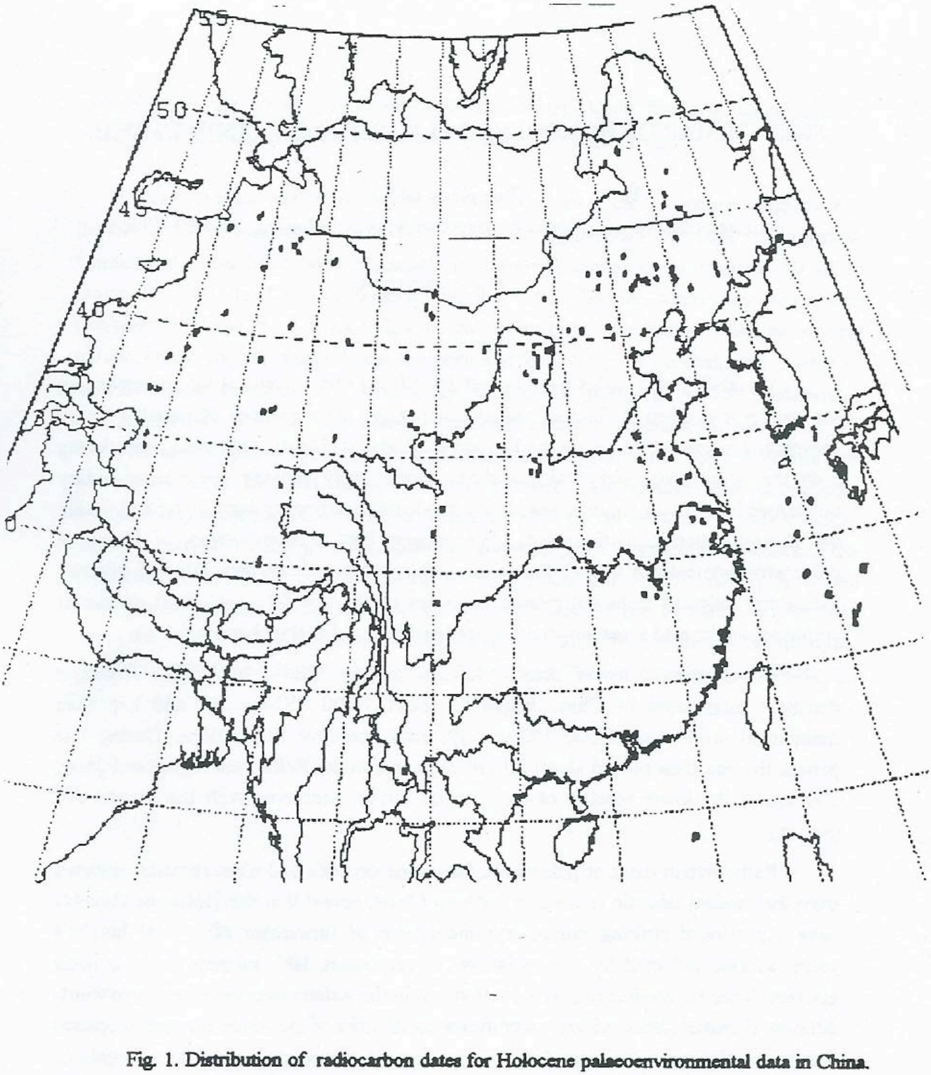



Fig. 1. Distribution of radiocarbon dates for Holocene palaeoenvironmental data in China.

# HOLOCENE TECTONIC AND CLIMATIC RECORDS FROM *PORITES SP.* ALONG THE COAST OF MENTAWAI ISLAND (INDONESIA)

W.S. HANTORO, A. MUTHOLIB, N. NGANRO, S. SHOFIYAH and L. HANDAYANI

LIPI, Jl Citisu 21/154 D, Bandung 40135, Indonesia.

*Porites sp.* provides a good continuous record of the Quaternary oceanic changes along the eastern margins of the Indian Ocean.

*Porites sp.* micro atolls are numerous in the sheltered coast of Mentawai Island, West of Sumatra. Their rapid growth (1-2 cm/yr) allows to produce massive micro atolls, 4 to 6 $m^3$ big. Living and dead *Porites sp.* micro atolls usually show an outside and/or an inside-stepping morphology that reveals an interruption in vertical growth, during their life. This unique stepping had been produced by vertical changes of coral position relative to sea level, due to vertical land movement and possible climatic deterioration. The movement is contemporaneous of strong seismic shocks related to the subduction under Sumatra, which takes place at the plate boundary. The $^{14}C$ and U/Th dates of the emerged micro atolls show that the vertical movement is continuously active since the Holocene.

# POTENTIAL EFFECTS OF CLIMATE CHANGE ON AUSTRALIAN AND SOUTHEAST ASIA

Peter KERSHAW
Geography and Environmental Science Department, Monash University, Clayton, Victoria, Australia.

Some indication of the effects of cooling, warming and changes in precipitation on this region can be gauged from interpretation of palaeoenvironmental records, particularly for the height of the last glacial period centred on 17.000 years BP, in climate terms. During the last glacial period, temperatures were at least 6°C lower than today at higher latitudes and altitudes but probably only about 2°C lower in the lowland tropics. There was only local ice development on high peaks and on the Central Plateau of Tasmania. These lower temperatures were accompanied by lower absolute rainfall, probably at least 50 % lower than present, and resulted in much of the region becoming effectively drier than today. In some areas, however, particularly inland southern Australia, moisture levels were the same or even higher than present. These conditions, together with higher wind speeds resulted in an almost total elimination of trees in southern Australia and replacement of some rainforests by open woodland in tropical higher rainfall areas. At the height of the Holocene amelioration, precipitation was substantially higher, and seasonality less than present, resulting in an expansion of wetter forests communities around the continental margins. Effects on the arid centre of the Australian continent were minimal and little response is noted in vegetation or lake levels. Temperatures, where measurable, were slightly lower than present, particularly in summer. This can be explained by solar radiation input being lower than today in the southern hemisphere and increased cloud cover.

# ENVIRONMENTAL CHANGE IN GREATER AUSTRALIA FROM THE HEIGHT OF THE LAST GLACIAL PERIOD

A. Peter KERSHAW

Centre for Palynology and Palaeoecology, Department of Geography and Environmental Science, Monash University, Clayton, Victoria 3168, Australia.

At a very general level, the whole of the region may have experienced similar climatic trends in environmental change through the last 18,000 years. The cold Last Glacial Period experienced lower rainfall than today but its effectiveness, particularly at higher latitudes, was still significant. Seasonality during this period was high and, together with stronger winds, appears to have excluded extensive tree survival over much of southern Australia.

Temperature rise preceded a rise in precipitation during the 'late glacial' resulting in widespread aridity centred on 12,000 BP. The most rapid changes occurred between 12,000 BP and 9000 BP although there is little evidence for a Younger Dryas reversal in climatic amelioration. During this time forest and particularly woodland expanded in southern Australia.

Highest temperatures may have been achieved in the very early Holocene before a peak in effective precipitation in all areas at some time between about 8000 BP and 4000 BP. This precipitation peak was accompanied by major expansions of rainforest and wet sclerophyll forests in wetter areas and a further spread of open forest. Both precipitation and temperature declined after this time with some subsequent minor fluctuations, but a major feature of the late Holocene was the development of climatic variability, perhaps related to the onset or intensification of ENSO.

General directions, if not magnitudes, of change are largely predictable from a consideration of the effects of ice cap melting and associated sea level rise and orbital changes in solar radiation as well as atmospheric circulation changes resulting from these global forces. However, data limitations related to a sparse and geographically biased distribution of sites, generally coarse temporal resolution of records, and lack of record quantification in vegetation and climatic terms, prohibit detailed analysis of regional variation except in southeastern Australia.

# LATE QUATERNARY PALEOSOLS AND PALEOCLIMATE IN THE YANGTZE DELTA

Congxian LI and Qingqiang CHEN
Department of Marine Geology and Geophysics, Tongji University,
Shanghai 200092, China.

The late Quaternary stratigraphy in the Yangtze Delta consists of alternate marine and terrestrial strata. The first terrestrial stratum, dated 15.000-25.000 yrs BP, with a burial depth of 3-28 m, shows a sharp boundary with overlying marine and freshwater marsh deposits, and gradually turns into underlying marine facies (fig. 1,2). In the terrestrial stratum, plant roots and debris, cracks filled with clays are found, and distinct paleosol features (such as microcracks filled with pyrite, siderite, rhodochrosite, iron oxide concretions, ferrugineous nodules) have been revealed by micro-morphological study. The chemical analysis of the clay fraction ($<2\mu m$) shows that the ratio of $SiO_2$ / $Al_2O_3$ is 2.8-3.7, and the ratio of $SiO_2$ / $R_2O_3$ is 2.0-2.9. The dominant clay mineral is illite, accompanied with smectite and kaolinite. These suggest that the terrestrial stratum had experienced subaerial exposure and been subjected to pedogenesis. The multiple clay rich layers, the relatively steady distribution of active chemical elements, such as Ca, Mg, Na, suggest possible identification with aquisols (meadow soils) developed from fluvial and lacustrine deposits.

According to phytolith analysis, the herbaceous vegetation predominated during the paleosol formation (fig. 3). There are elongated , pointed, pipe shaped, spine shaped, cubic or spheric phytoliths from *Gramineae* and *Chenopodiaceae*. These are from relatively colder and drier environments of northern China, which cover a larger percent in the plant assemblage of the paleosols. Thus, the paleoclimate of the last glacial in the Yangtze Delta was colder and drier than at present. It was similar to the present one in the temperate zone of northern China, while a subtropical climate now exists in the Yangtze Delta. The paleosols also contain some layers with a large percent of phytoliths from subtropical *Gramineae*, which infers that a warm and humid climate corresponded to the formation of those paleosols.

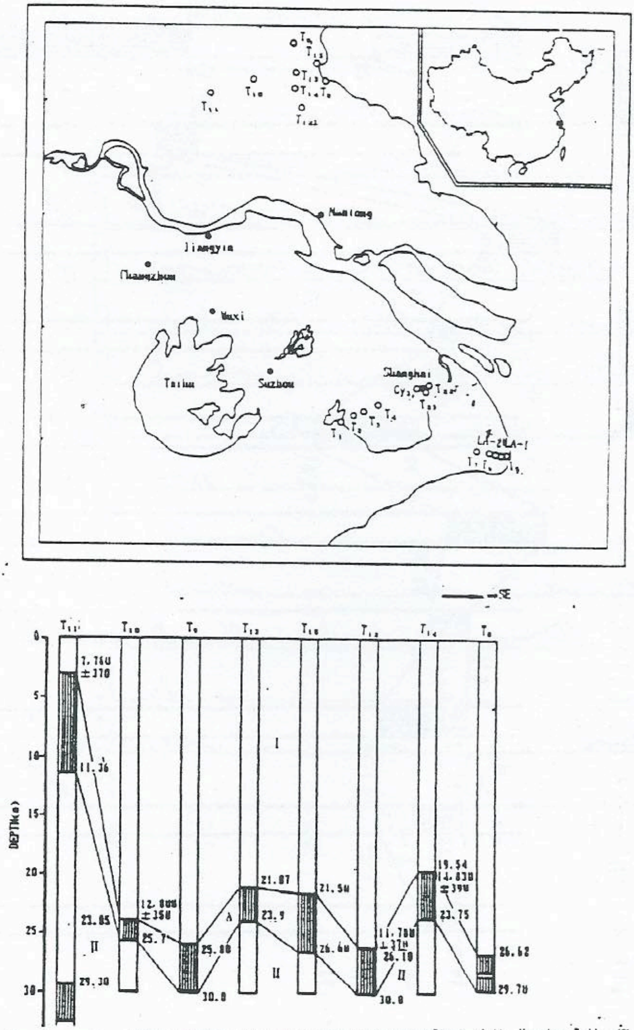



Fig. 1 Location of Drilling Cores (1) and Section in Northern Flank of the Yangtze Delta (2)
A. First Paleosol Horizon B. Second Paleosol Horizon
I First Marine Stratum(including fresh water marsh deposits in the West)
II Second Marine Stratum

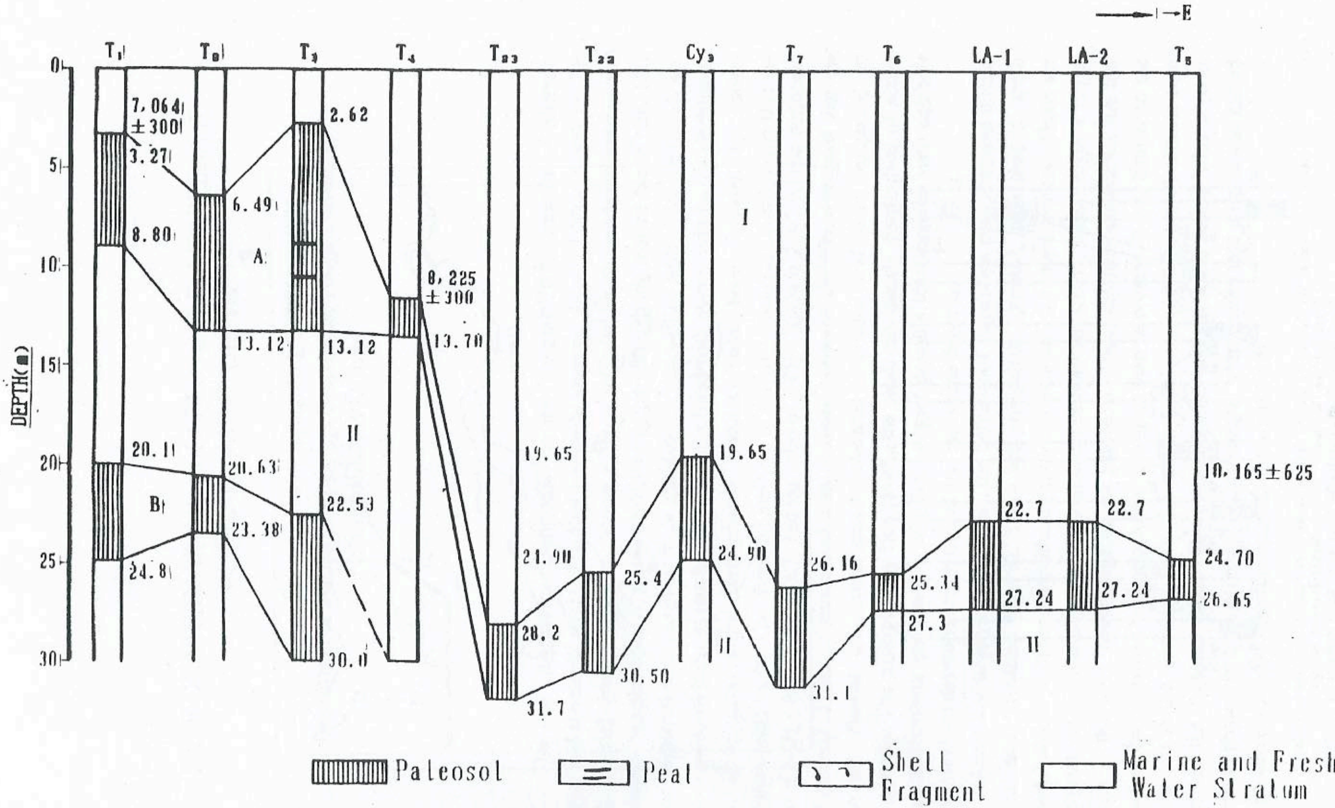



Fig. 2 Section in Southern Flank of Yangtze Delta

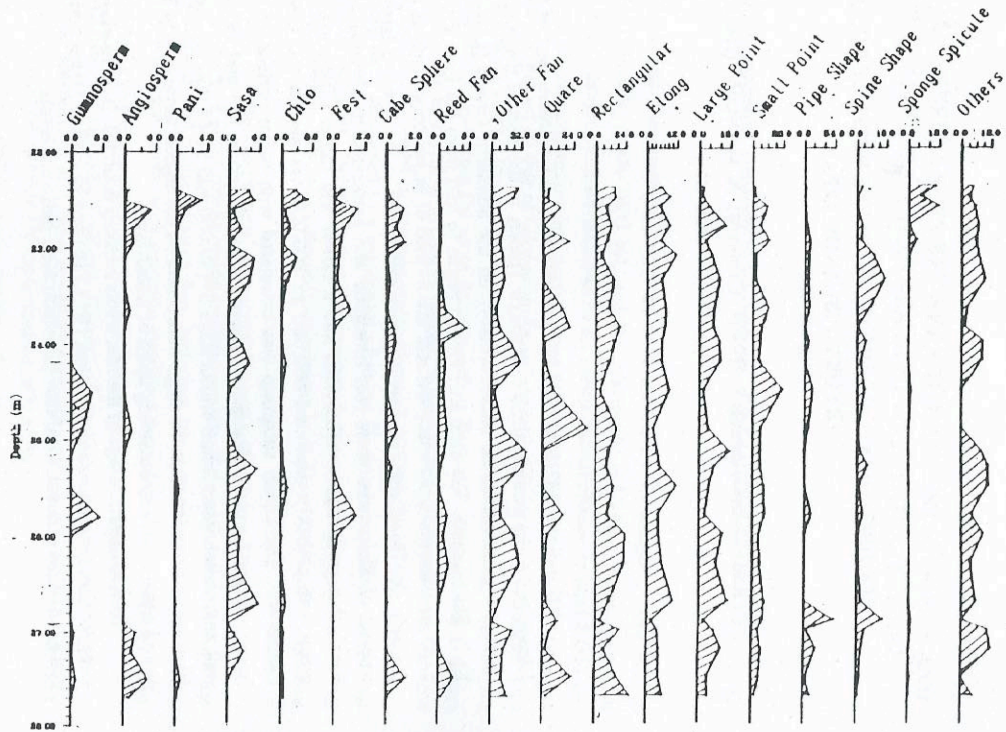



Fig. 3 Phytolith Spectorum of LA-1 Core in Yangtze Delta

# GEOCHRONOLOGY OF THE PLEISTOCENE REEFS OF KIKAI-JIMA (RYUKYU ISLANDS, JAPAN)

U. RADTKE (Cologne), R. GRÜN (Canberra), A. MANGINI (Heidelberg), A. OMURA (Kanazawa)

Kikai-Jima (28°19'N, 129°59'E) is located in the northern part of the Ryukyu Islands and is the nearest island to Ryukyu Trench, to the East of the island chain. Its Quaternary limestones lie unconformably on the Shimariji Group (Late Miocene to Early Pleistocene). The Shimariji Group began to fold from the Late Pliocene to the Early Pleistocene. Quaternary terraces are formed of raised coral reefs as a veneer on the bedrock. This Ryukyu group is widely distributed in the Ryukyu Islands Arc and consists of Pleistocene coral reef limestone and associated terrigenous deposits. On Kikai, this group can be subdivided into a Lower and Upper subgroups. The Lower group was probably deposited 600.000 to 800.000 yrs ago in the Lower Middle Pleistocene. The Upper subgroup was correlated with warm periods of the oxygen isotope stages 7 and 5e with the substages 5a and 5c (up to 185 and 195 m a.s.l.) as well as with two interstadials within stage 3 (40.000 and 50-65.000 yrs, up to 30 and 50 m a.s.l.). Samples of the 5e stage were found on the highest terrace up to 224 m a.s.l.,. which indicates a strong uplift of Kikai-Jima.

Nevertheless, the age of the reef tracts remains doubtful. Both re-examination of some localities and new dating results (Th / U(16) and 35 ESR (35)) support the doubts that Kikai-Jima is not an ideal tool for establishing paleo sea-levels.

# MUTUAL INFLUENCES BETWEEN THE ATLANTIC OCEAN AND THE MEDITERRANEAN SEA DURING THE QUATERNARY

E.J. Rohling

Dept. of Oceanography, University of Southampton, Highfield, Hampshire SO17 1BJ, U. K.

Planktonic foraminiferal fauna in both the newly investigated core KS310 (35°55N, 1°34,5W; depth 1900 m), and the previously published records from the Alboran Sea (western Mediterranean) show an abrupt faunal change around 8.000 BP. Dominance of *Neogloboquadrina pachyderma* (dextrally coiled) with *Globigeriana bulloides*, is replaced by that of *Globorotalia inflata* with *Globigerina bulloides*. This change probably marks the onset of more or less modern conditions, with distinct geostrophic fronts separating the jet of Atlantic inflow from the ambient Mediterranean waters. According to a hydraulic control model for the Strait of Gilbratar with variable sea level, the inflow volume of Atlantic water around 8.000 BP (sea level at about -30 m) may have amounted to a maximum of about 86 % of its present value. Our reconstruction suggests, therefore, that the modern front-dominated conditions in the Alboran Sea prevail only when the inflow volume is at least 86 % of the present volume.

Planned palaeo- and physical oceanographic research now concentrates on:

- evaluation of those results, using realistic models of the circulation through the Strait of Gilbratar and in the Alboran Sea, including the dynamics of the subsurface (outflow) layers, since recent work suggests that these may play as important a role in the dynamics of gyres and fronts in the Alboran Sea as surface water inflow;
- detailed reconstruction of the history of exchange through the Strait of Gilbratar, and specifically of subsurface Mediterranean outflow (the related salt flux into the Atlantic may be relevant for the formation of NADW).

The combined results will portray the mutual influence between the Mediterranean Sea and the Atlantic Ocean, *i.e.* how signals from the one basin are being transmitted and / or fed back to the other, and at which time-scales.

# PERMAFROST DYNAMICS AND ICE EXTENSION IN EUROPE DURING THE LAST GLACIAL AND THE HOLOCENE

B. VAN VLIET-LANOE

Geosciences CNRS. Université de Rennes I. P-35042 Rennes Cedex. FRANCE.

Most studies concerning Wetchselian permafrost are related to ice wedge cast, sand wedges and cryoturbations. Little attention has been paid to other processes like fragipan or "Lameliefelckenzonen". The work of N. Romanovski has shown that many wedge-like forms are related, for rheological reasons, to the southern areas of permafrost, such as peat or sands wedges.

Recent data from Siberia and the Mackensie Delta have shown the importance of degradation forms of wedges to understand abrupt climate change, *e.g* at the onset of the Holocene.

Other data collected by the author in Svalbard, northern Québec and Nunavik, have shown the relationship between short warming events, regressive slow degradation, and aeolian sedimentation during the general cooling trend prevailing since the Subboreal. This situation is very similar to these occuring during the Welchselian Pleniglacial and especially the middle of isotopic stage 2. A re-analysis of wedge cast from France, Belgium, Netherlands and Poland demonstrate clearly that:

1- the ice wedges are juvenile forms,

2- the permafrost adjacent to the wedges was relatively ice poor,

3- cryoturbation was syngenetic with the ice wedge activity and during the degradation phase (deformation by differential frost heave),

4- the degradation was slow in most cases, without running water during the summer,

5- a cyclic answer wedge growth -> wedge decay -> loess deposition, occurred several times in western Europe during the Last Glacial,

6- the eldest forms are of the Elserian age and did not reach later on a more southern extension.

7- many wedges-like structures, especially in the Mediterranean area (including southern France) are not of periglacial origin but are related to neotectonics.

Permafrost installation in western Europe is, like soil erosion, related to low insolation ratio in spring and summer, low precipitation (< 200 mm/yr) and a prostrated tundra vegetation, even close to the ice caps such as in Poland. This system does not explain the cyclicity (*cf supra:* 5).

Plotting the period of activity of the successive polygonal soils and comparing it to the dates of the Heinrich layers on the North Atlantic floor, a good correlation is observed. The cyclicity in ice wedges activity could be explained as in the present North Atlantic zone as follows:

| | |
|---|---|
| thick ice cap, drought, catabatic wind. | permafrost extension and ice wedge growth, progressive prostration of vegetation. |
| abrup short warming < 100 yrs, related with the ice cap thinning (Heinrich events).<br>restored cyclonic circulation. | regressive degradation.<br>increasing summer length and vegetation development, limited by drought.<br>important river activity: loess deposition in the late summer. |
| increasing thickness of the ice cap, catabatic wind activity. | reaggradation of the ice wedge polygons with decrease of loess sedimentation. |

This situation is particularly clear for the Pomeranian Stadial. The cooling of the Younger Dryas is more complex. Holocene permafrost regression from the Late Glacial is mostly related with high summer insolation until 6.000 BP. At that time, permafrost has totally disappeared, except for the Svalbard and mountain areas. The present-day situation is related with an extension since the Subboreal, and especially since the Little Ice Age. The cooling observed since 1947 allows a present-day completitive extension.

In conclusion, if permafrost extension seems well correlated with summer insolation, ice wedge activity is an accidental event related with the coolest events of the Glaciation. The concept of active, low active and inactive ice wedges suggered by Mackay has also to be applied to fossil permafrost.

# PALAEOCRYOLOGICAL MAPS OF EURASIA FOR 18.000 AND 7.000 YEARS BP

N.N. ROMANOVSKI, K.A. KONDRALYEVA, G.E. ROZENBAUM, M.O. LEIBMAN and O.N. LISITSYNA

Moscow State University, Moscow, Russia.

The compilation of Palaeocryological maps (PCMs) covering the territory of the former USSR, showing recent permafrost extent, has some particularities resulting from both the wide extent of recent permafrost, and the large amount of different information available concerning both recent and palaeocryolithosone (RCLZ and PCLZ).

1- PCMs of different scales and degree of information covering the former USSR territory, as well as geocryological maps including palaeocryological information (or based on such information) exist. These maps are the geocryological map of the USSR, the cryolithological map of the USSR (Popov, 1975) and several dozen special and regional maps.

2- Geocryological maps contain information on the extent, temperature, thickness, ice content, cryogenic composition, periglacial processes and phenomena, both recent and palaeo, that are very useful for palaeomap compilation. This is to emphasize the difference between the Russian and the European compilation methods. In Europe, PCMs can be compiled only based on the fossil periglacial phenomena and in Russia fossils are only one of the indicators for periglacial environment.

3- The extent of permafrost linked with climate, relief, and lithology are established in Russia that are helpful in reconstruction of the southern limit of isolated and continuous permafrost in the regions of different continentality and geological composition in the East-European and the West-Siberian plains, Middle-Siberian highlands and East-Siberian mountains.

4- RCLZ thickness and extent contain important information on PCLZ spreading and formation rates for both epochs. To illustrate, the southern relic permafrost limit of the North-Eastern Europe and West Siberia can confidently be considered as a southern limit of continuous PCLZ at 18.000 yr BP. The same can be applied to the abrupt permafrost thickness change from 100-180 to $\geq 300$ m in Middle Siberia. Permafrost of $\geq 300$ m thickness cannot form more quickly than over several tens of thousands years thus is Late Cainozoic. Wherever 100-150 m of permafrost can form for the period of several thousands years and thus can be Late Holocene.

5- Ice content and cryogenic composition of permafrost essentially depend upon the type of freezing. The most valuable ice content and massive ice occurrence are characteristic of marine and lake deposits. Holocene thawing of these types of permafrost destroyed their high ice content that resulted in the formation of the "inverted" (thermokarer) relief. That is why the southern continuous permafrost limit for the Holocene Optimum within the aggraded plains coincides with the southern limit of massive ice spreading, high ice content and "inverted" relief.

The "ice complex" is the evidence of cold periglacial conditions: low ground temperature, continuous spreading and subaerial regime of permafrost formation, absence of glaciation and arctic sea transgression and so on. Thus, the fragments of "ice complex" in depression of mountaneous regions of West Siberia area mark the southern limit of continuous permafrost 10.000 yr BP.

6- In Northern Eurasia beside the limit of continuous and discontinuous permafrost, the permafrost limits within the bared Arctic shelf, subglacial permafrost limits in Siberia according to the spreading of primordially frozen basal material with fossil glacial ice (18.000 yr BP) and relic permafrost within the accumulative plains (7.000 yr BP) are to be shown on the PCM as indicators of former periglacial environment.

**Audemard F.** FUNVISIS. Apartado 1892. Caracas 1011. VENEZUELA. Fax (58-2) 2579977

**Bâ M.** Département de Géologie, Faculté Sciences et Techniques, Université Cheikh Anta Diop. BP 150063. Dakar Fann. SÉNÉGAL. Fax (221) 273413

**Bouab N.** Départment des Sciences de la Terre. BP. 8888-Succ. A. Montréal. H 3C 3P8, CANADA, Fax (1) 5149877865

**Conchon O.** Laboratoire de Pétrologie Sédimentaire. Université Paris-Sud. Bât. 504, 91405 Orsay, FRANCE, Fax (33) 164465938

**Craig A.** Department of Geography, Florida Atlantic University, Boca Raton, Florida 33431, USA. Fax (1) 4073672744

**Damnati B.** CEREGE. BP 80. 13762 Les Milles Cedex. FRANCE. Fax (33) 42971595

**Edgar N.T.** U.S. Geological Survey, 917 National Center, Reston , Virginia 22092. USA, Fax (1) 7036486684

**Fontugne M.** C.F.R., Domaine du CNRS, Avenue de la Terrase. 91198 Gif-sur-Yvette Cedex. FRANCE. Fax (33) 169823568

**Gagan M.** Research School of Earth Sciences, The Australian University, Camberra, A.C.T. 0200, AUSTRALIA, Fax (61) 62490738

**Guo Z.** c/o N. Petit-Maire

**Hantoro S.W.** LIPI, JL. Cisitu 21/154D. Bandung 40135. INDONESIA, Fax (62) 222504593

**Kershaw P.** Geography and Environmental Science Department, Monash University, Clyton Victoria 3168. AUSTRALIA, Fax (61) 39052948

**Meco J.** Departamento de Biología (Paleontología) . Universidad de Las Palmas de Gran Canaria, 35017 Las Palmas. ESPAÑA. Fax (34) 28452922

**Petit-Maire N.** URA 164. CNRS. Case 907. 13288 Marseille Cedex 09. FRANCE. Fax (33) 91413856

**Radtke U.** Geographisches Institut. Universität zu Köln, Albertus-Magnus Platz D-50923 Köln, DEUTSCHLAND. Fax (49) 2214705124

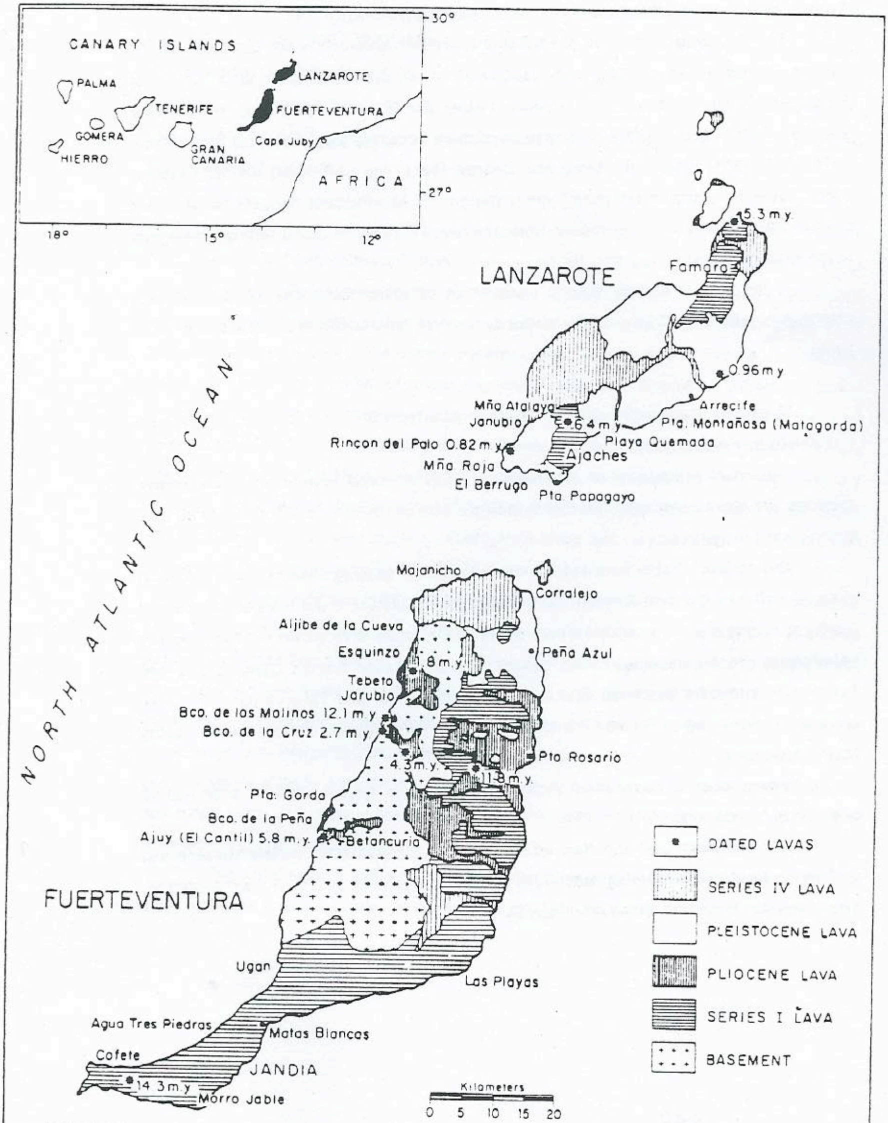
**Rohling E.J.** Department of Geology , Utrecht University, Budapestlaan 4. P.O.Box 80021, 3508 TA Utrecht. NETHERLANDS. Fax (31) 30535030

**Romanovskii N.N.** Geocryology Dept., Geology Faculty, Moscow State University 119899 Moscow. RUSSIA. Fax (095) 2544933 or 9328889

**Van Vliet-Lanoe B.** Laboratoire de Pétrologie Sédimentaire, Campus de Beaulieu, 35042 Rennes Cedex, FRANCE, Fax (33) 99286100

# THE EASTERN CANARY ISLANDS

## GEOLOGY ( Meco and Stearns, 1981 , adapted from Fuster *et al.*,1968 )



The Canary Islands have had a long and complex volcanic history, the general outlines of wich are rather well known (Hausen, 1958, 1959; Fuster *et al.*, 1968; Rothe, 1974; Schmincke, 1976). Abdel-Monem *et al.* (1971-1972) provided a chronological framework of K-Ar dates, locally amplified by Rona and Nalwalk (1970) and McDougall and Schmincke (Lietz and Schmincke, 1975, McDougall and Schmincke, 1977).

The chronological position of emergent strand line features ("raised beaches") on the eastern islands (Fuerteventura and Lanzarote) have been attributed to a series of Pleistocene "levels" (Crofts, 1967; Lecointre, Tinkler, and Richards, 1967; Klug, 1968; Müller and Tiez, 1975; Klaus, 1983 ). K-Ar ages and more complete paleontological data (Meco, 1975, 1977, 1981, 1982, 1983; Meco and Stearns, 1981) and ESR dating method (Radtke, 1985), however, concur in assigning them to two groups: Mio-Pliocene deposits on emergent coastal platforms and, late Pleistocene-Holocene beach deposits in littoral settings analogous to the modern beaches.

In the eastern Canary Islands, sequences of eolian formations interbedded with paleosols cover the last 30 Ka, as evidenced by several radiocarbon date (Petit-Maire *et al.* 1986).

Three pricipal stages in the volcanic development of the Canary islands were established by Hartung ( 1857) :

"Basement complexes" on several islands may comprise several intrusive/extrusive episodes, are characteristically intruded by multiple dike complexes, and are separated by a strong unconformity from:

"Old basalts" ("table land basalts" of Hausen), the capping flows of major subaerial volcanic edifices. Hausen believed them to be time-equivalent in the several islands and posibly remnants of a once-contiuous lava plateau. K-Ar ages have shown this hypothesis to be incorrect. In a general way, "old basalts" erptions ceased first on Gran canaria and Fuerteventura (middle Miocene); later on Gomera, lanzarote, and Tenerife (late Miocene); and last on Hierro and La Palma ( Pleistocene) . The major volcanic edifices are not strictly contemporaneous.

"Young basalts" have been erupted on, all islands except Gomera after mature disection of "old basalts".

Salic volcanism built important edifices on Gran Canaria in the middle Miocene and on Tenerife ( including the young cone, Teide, the highest peak in Spain) in the Pleistocene. It has been less important on the other islands.

Mio-Pliocene emergent littoral deposits and sallow-water marine deposits are associated with coastal platforms developed during dissection of the "old basalts". Platforms and associated marine deposits are commonly covered. were adequate drainage led from adjacent uplands. by alluvial fans. Most of the latter appear to have stabilized soon after emergence of the platforms which they overlie and. later. to have been dissected. Like the major volcanic edifices which they modify. coastal platforms were not developed simultaneously on all islands..

## LATE PLEISTOCENE LITTORAL DEPOSITS

**(from Meco, J., Petit-Maire, N., and Reyss, J.-L., 1992)**

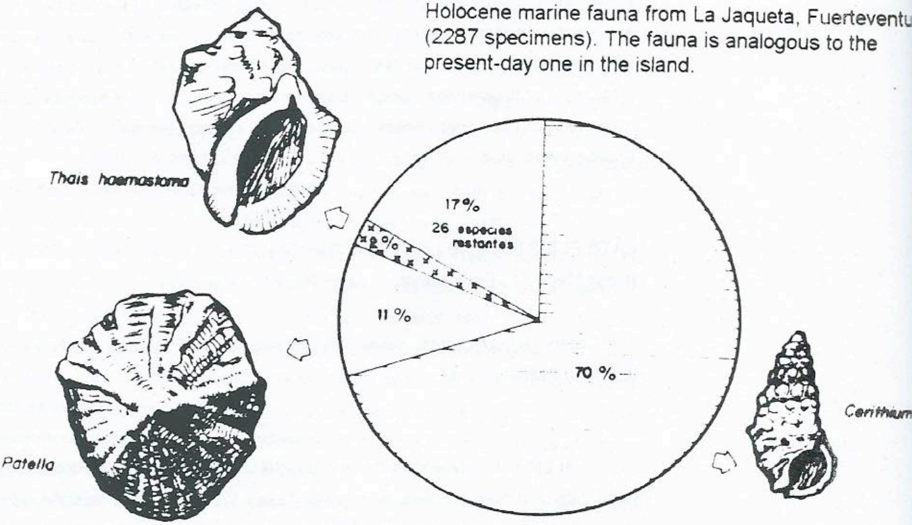
The Canary Islands Current during isotopic stage 5. as implied by the fauna of a marine terrace at Fuerteventura

At 28° N. Fuerteventura Canary Island is located 103 Km. off the Moroccan coast at Cape Juby and fully exposed to the cold Canary Current. A very fossiliferous beach-rock level is exposed at several places along its coast, at altitudes varying between -2 and +3 m relative to the upper limit of the current intertidal zone. The fauna includes several species. many of which are typical of warm equatorial waters: *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 are also associated. These deposits were. in preliminary research. described as "last interglacial" (Meco. 1975). and Jandian ( Meco *et al.*. 1987) and attributed to the oceanic stage 5 (Meco. Petit-Maire and Reyss. 1992). in similarity with the levels in the Mediterranean and Atlantic Saharan coasts.

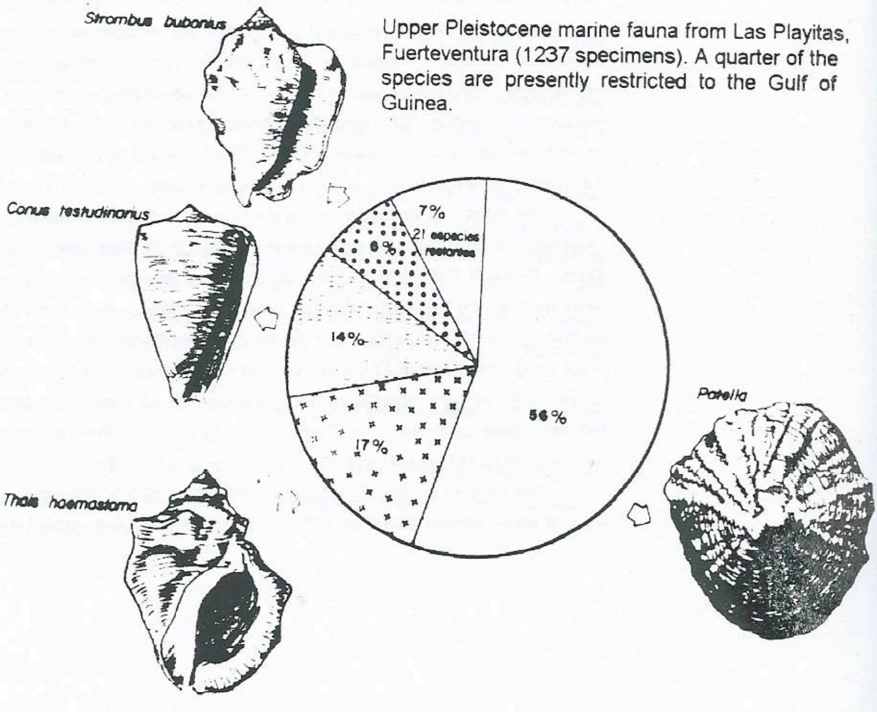
The fauna indicates water temperatures much higher than at present. *Harpa rosea.* never found in the Mediterranean, presently lives only in the Cabo Verde and Gulf of Guinea (Gabon. Fernando Poo = Bioko, Annobom = Pagalu ): *Strombus bubonius* is tipically a warm water species. now found from Senegal to Angola, *i.e.* along coasts limited to the North by the Canary Current and to the South by the Benguela Current. the water temperatures of which being both inferior to 23°C in the summer time. It could thus not live in the present cold current regime of Cape Juby. During the Tyrrhenian, it is well known in the Mediterranean but has never been described in the Ouljian along the coast of Morocco ( Meco, 1977). It is surprising to find at Fuerteventura.

Two samples of *Strombus bubonius* collected at +0.5 m above the present high tide level, at Matas Blancas beach are U/Th dated at 106±7 Ka and 112 ±7 Ka (Meco, Petit-

Holocene marine fauna from La Jaqueta, Fuerteventur (2287 specimens). The fauna is analogous to the present-day one in the island.




Upper Pleistocene marine fauna from Las Playitas, Fuerteventura (1237 specimens). A quarter of the species are presently restricted to the Gulf of Guinea.



Maire, and Reyss. 1992) which correspond to stage 5, close 5e of oceanic chronology as determined in the Caribbean (Bard, hamelin, and Fairbanks, 1990 ).

Important modifications in sea-surface temperatures along the coast of the eastermost canary Islands, during the Upper Pleistocene, are thus brought to evidence and infer wide changes in the Canary Current relative to its present location, temperature and dynamism.

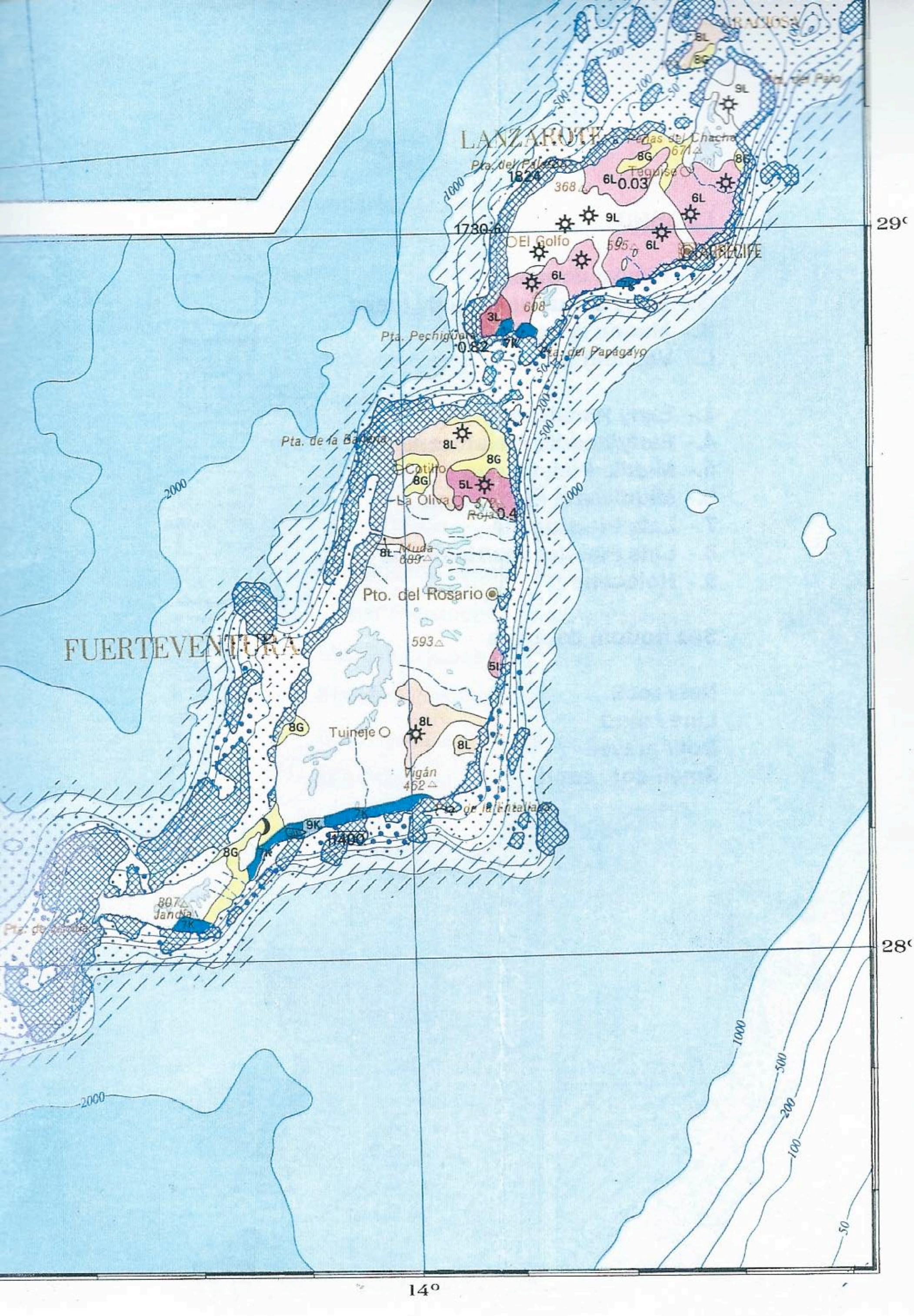
## HOLOCENE MARINE DEPOSITS

Holocene beach-roks are present at Barranco de La Monja in the middle of the eastern coast of Fuerteventura. These deposits have been 14C dated close 4.000 B.P.. They are also present at Corralejo in the North of the island, and generally they are preserved at scattered localities on Fuerteventura reaching elevations only somewhat higher than modern beach deposits in the same localities and approximately one meter lower than upper Pleistocene marine deposits or Jandian.

Holocene marine deposits have been named Erbanian (Meco *et al.*, 1987 ). The Erbanian takes its name from Erbania, the former name of Fuerteventura. The Erbanian conglomerates contain boulder from Jandian sandstone and conglomerates. The Erbanian sea carved a notch in the cliffs and a coastal erosion platform on the Jandian conglomerates.

A last marine pulsation (Erbanian II ) lefts a berm and beach-roks dated close 1.400 B.P. at La jaqueta and Puerto Rico in the Southern coast of the island and at La Monja. The fauna contained in this berm is analogous to the existent one in the littoral of Fuerteventura, is characterized by the abundance of *Cerithium vulgatum*, reaching the rate of 70% in the collected samples, and by the decrease of *Patella* (11%) and *Thais haemastoma* (2%) in relationship to the Jandian fauna which contains more *Patella* (almost 56 %) and *Thais haemastoma* (17 %), than Erbanian.

**Meco, J.-** Quaternary Map of the Canary islands,
and **Rey Salgado, J., Díaz del Río, V., and Medialdea, T.-**
Sea botton deposits *in Quaternary Map of Spain, Esc. 1/1000.000*
Geological Survey of Spain, Madrid, 1989.


LANZAROTE
Pta. del Palo
Peñas del Chache
671
Teguise
Pta. del Pallo
1824
368
6L 0.03
9L
8G
8L
6L
1730.6
El Golfo
595
ARRECIFE
3L
608
Pta. Pechiguera
0.82
7K
Pta. del Papagayo
Pta. de la Ballena
Cotillo
8G
8L
5L
La Oliva
Roja 0.4
Muda
689
Pto. del Rosario
593
FUERTEVENTURA
5L
Tuineje
Vigán
462
Pta. de la Entallada
9K
1400
807
Jandía
Pta. de Jandía
1000
500
200
100
50
2000
29°
28°
14°

## LEGEND

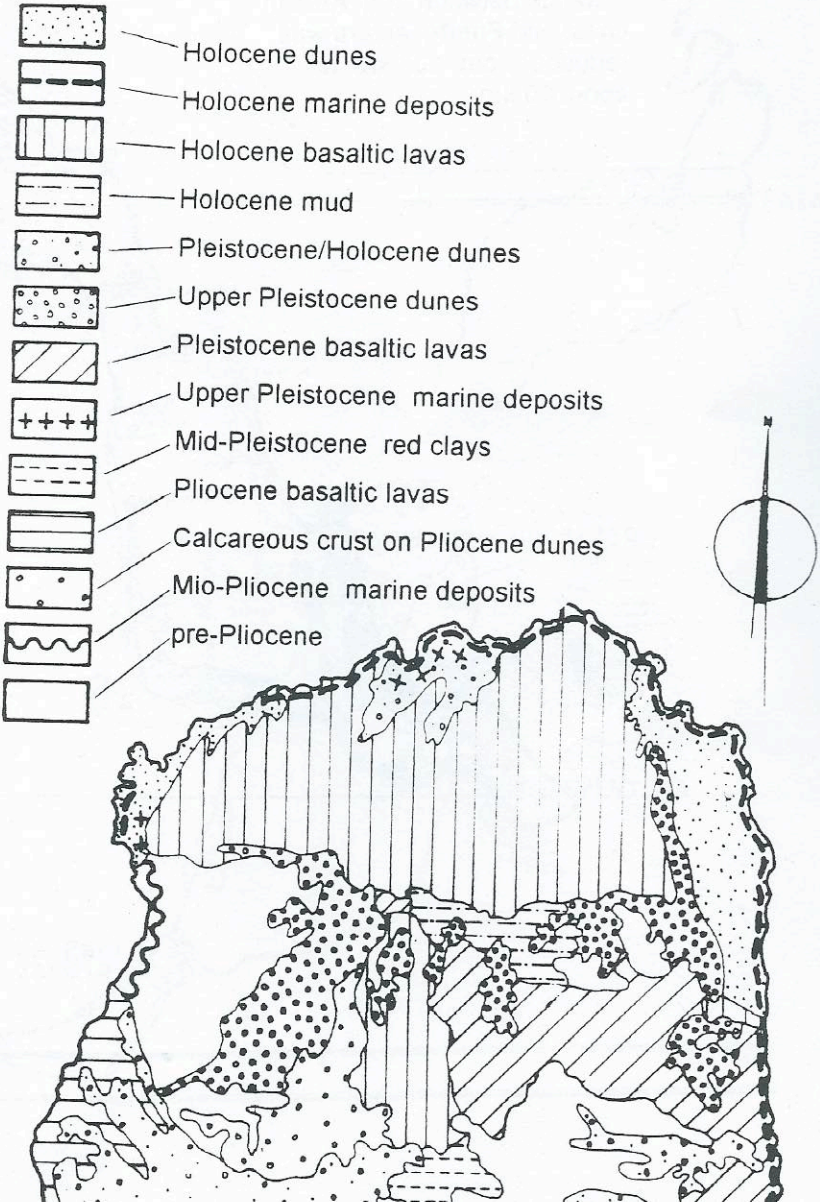
D .- Fluvial deposits
G.- Eolic sands and sandy loess
K.- Marine deposits
L.- Volcanic rocks

3.- Early Pleistocene
4.- Early/middle Pleistocene
5.- Middle Pleistocene
6.- Middle/late Pleistocene
7.- Late Pleistocene
8.- Late Pleistocene/Holocene
9.- Holocene

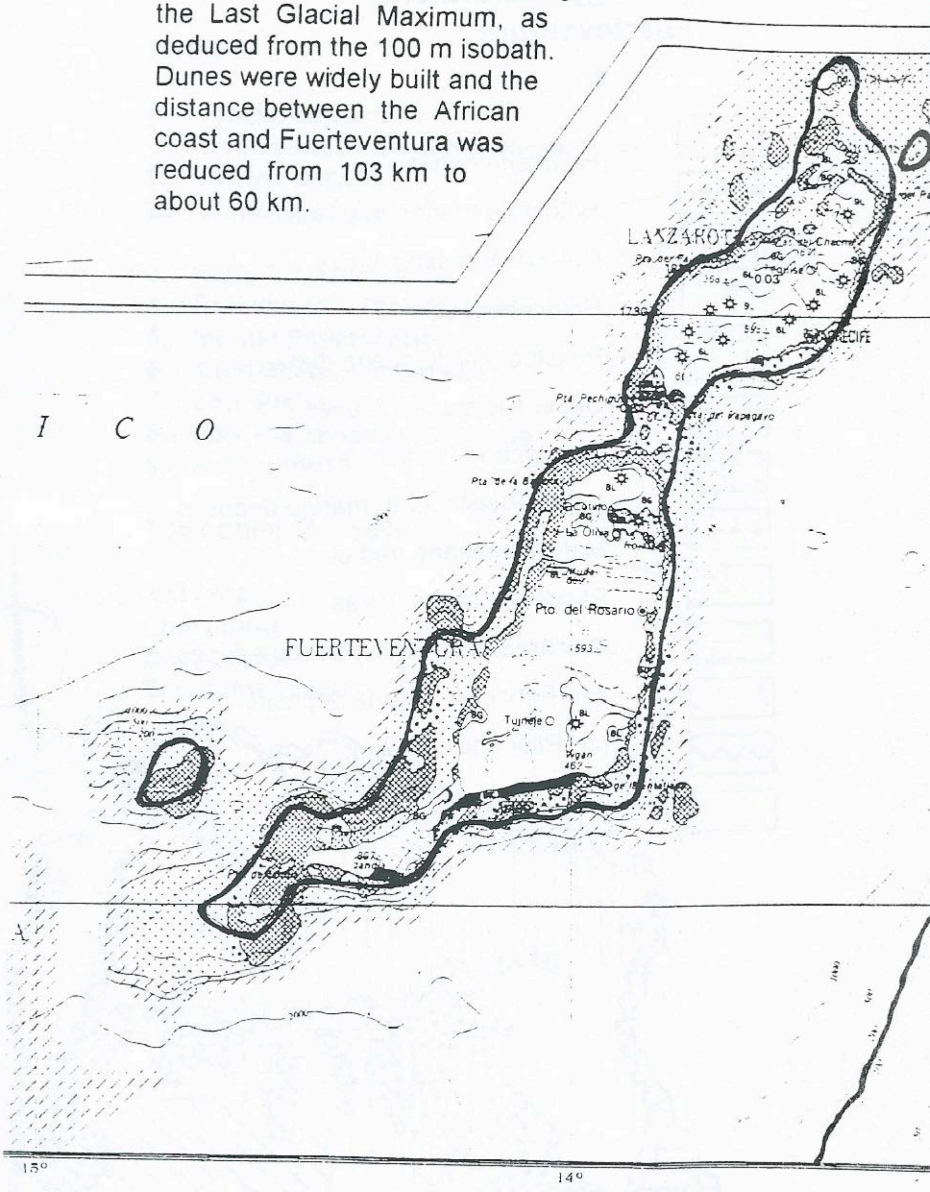
Sea bottom deposits

Net / rock
Line / mud
Dot / gravel
Small dot / sand

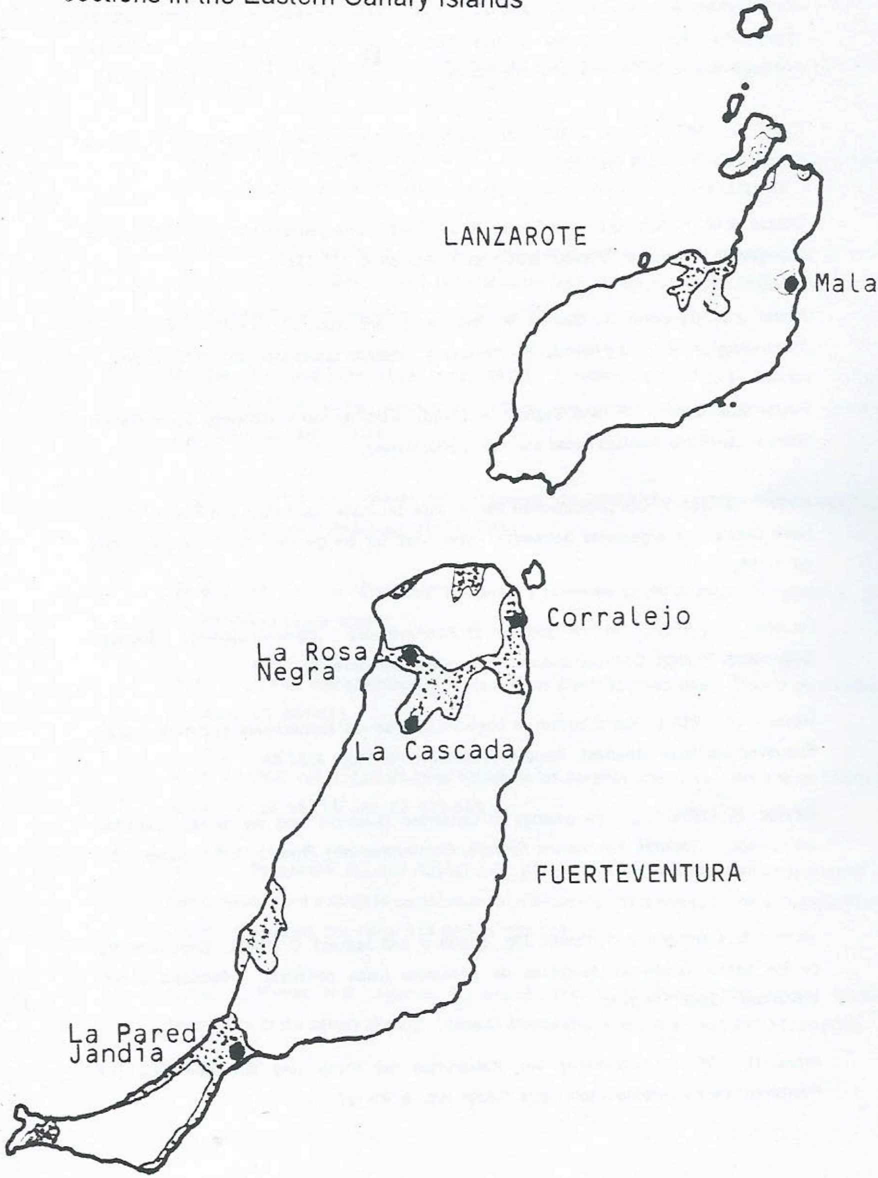
# Outline of the Plio-Quaternary geology in northern Fuerteventura



The eastern Canary Islands during the Last Glacial Maximum, as deduced from the 100 m isobath. Dunes were widely built and the distance between the African coast and Fuerteventura was reduced from 103 km to about 60 km.



Aeolian formations and location of the studied sections in the Eastern Canary Islands



### References


Abdel-Monem, A., Watkins, N.D., and Gast, P.W. (1971). Potassium-argon ages, volcanic stratigraphy, and geomagnetic polarity history on the Canary Islands: Lanzarote, Fuerteventura, Gran Canaria, and La Gomera. *American Journal of Science* **271**, 490-521.

Crofts, R. (1967). Raised beaches and chronology in north west Fuerteventura , Canary Islands *Quaternaria* **9**, 247-260

Driscoll, E.M., Hendry, G.L., and Tinkler, K. J. (1965). The geology and geomorphology of Los Ajaches, Lanzarote. *Geological Journal (Liverpool)* **4**, 321-334

Fuster, J.M., Cendrero, A., Gastesi, P., Ibarrola, E., and Ruiz, J.L. (1968) . *Geology and Volcanology of the Canary Islands. Fuerteventura* . Instituto Lucas Mallada CSIC, Madrid.

Fuster, J.M., Santin, S.F., and Sagredo, A. (1968). *Geology and Volcanology of the Canary Islands. Lanzarote.* Instituto Lucas Mallada CSIC, Madrid.

Hartung, G. (1857). Die geologischen Verhältnisse der Inseln Lanzarote und Fuerteventura. Neue Denkschrift allgemeine Schweitzer Gesellshaft fur die gesam. *Naturwissenschaften* **15**, 1-168.

Hausen, H. (1958) . On the geology of Fuerteventura (Canary Islands). *Societas Scientiarum Fennica, Commentationes Physico-Mathematicae* **22**, 1-211.

Hausen, H. (1958 ). Contribución al conocimiento de las formaciones sedimentarias de Fuerteventura (Islas Canarias). *Anuario de Estudios Atlánticos* **4**, 37-84.

Hausen, H. (1959). On the geology of Lanzarote, Graciosa, and the Isletas (Canarian archipelago). *Societas Scientiarum Fennica, Commentationes Physico-Mathematicae* **23**, 1-117.

Ibarrola, E., Cantagrel, J.M., Fuster, J.M., Coello, J. and Jamond, C. (1988). Geocronología de las series volcánicas neógenas de Lanzarote (Islas canarias). *Simposio sobre: Volcanismo. SGE*, 345-348.

Klaus, D. (1983). Verzahnung von Kalkkrusten mit Fluss- und Strandterrassen auf Fuerteventura/ Kanarische Inseln. *Ess. Geogr. Arb.* **6**, 93-127.

Klug, H. (1968). Morphologische Studien auf den Kanarischen Inseln. Beitrage zur Küstenentwicklung und Talbildung auf einem vulkanischen Archipel. *Schr. Geogr. Inst. Univ. Kiel* **24** (3).

Krejci-Graf, K. (1961). Vertikal-Bewegungen der Makaronesen. *Geologische Rundschau* **51**, 73-122.

Lecointre, G., Tinkler, K.J., and Richards, G. (1967). The marine Quaternary of the Canary Islands. *Academy of Natural Science of Philadelphia Proceedings* **119**, 325-344.

Lietz, J., and Schmincke, H.-U. (1975). Miocene-Pliocene sea-level changes and volcanic phases on Gran Canaria (Canary Islands) in the light of new K-Ar ages. *Palaeogeography, Palaeoclimatology, Palaeoecology* **18**, 213-239.

McDougall, I., and Schmincke, H.-U. (1978). Geochronology of Gran Canaria, Canary Islands: Age of shield building volcanism and other magmatic phases. *Bulletin Volcanologique* **40-1**, 57-77.

Meco, J. (1975). Los niveles con "Strombus" de Jandía (Fuerteventura, Islas canarias) *Anuario de Estudios Atlánticos* **21**, 643-660.

Meco, J. (1977). *Los "Strombus" neógenos y cuaternarios del Atlántico euroafricano.* Ed. cabildo Gran canaria, Madrid.

Meco, J. (1981). Neogastrópodos fósiles de las Canarias orientales. *Anuario de Estudios Atánticos* **27**, 601-615.

Meco, J. (1982, 1983) . Los Bivalvos fósiles de las canarias orientales . *Anuario de Estudios Atlánticos* **28**, 65-125, and **29**, 579-595.

Meco, J., Petit-Maire, N., and Reyss, J.-L. (1992). Le Courant des Canaries pendant le stade isotopique 5 d'après la composition faunistique d'un haut niveau marin a Fuerteventura (28°N). *C.R. Acad. Sci. Paris* **314** Série II, 203-208.

Meco, J., Pomel, R.S., Aguirre, E., and Stearns, C.-E. (1987) The Recent Marine Quaternary of the canary islands. *Trabajos Neógeno-Cuaternarios del CSIC* **10**, 283-305.

Meco. J. and Stearns, C.E. (1981) Emergent littoral deposits in the Eastern Canary Islands. *Quaternary Research* **15**. 199-208.

Müller. G.. and Tietz. G. (1975). Transformation of carbonate sands into limestone and dolostone: Fuerteventura. canary islands. Spain. *Proceedings, IXth International Congress of Sedimentology, Nice.* , 143-148.

Petit-Maire. N., Delibrias. G.. Meco. J.. Pomel. S.. and Rosso. J.C. (1986) Paléoclimatologie des Canaries orientales (Fuerteventura) . *C.R. Acad. Sci. Paris* **303**. 1241-1246.

Radtke. U. (1985). Untersuchungen zur zeitlichen Stellung mariner Terrassen und Kalkrusten auf Fuerteventura ( kanarische Inseln. Spanien) . *Kieler geographische Schriften* **62**. 73-95.

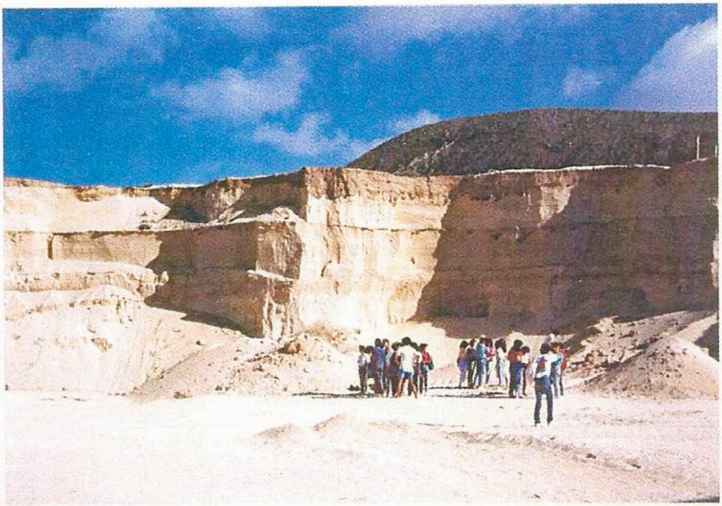
Rona, P. A., and Nalwalk. A.J. (1970). Post-early Pliocene unconformity on Fuerteventura, Canary Islands. *Geological Society of America Bulletin* **81**. 2117-2122.

Rothe. P. (1974). Canary Islands . Origin and evolution. *Naturwissenschaften* **61**.526-533.

Schmincke. H.-U. (1976). The geology of the Canary Islands. *In* Kunkel. G. Ed., *Biogeography and Ecology in the canary Islands* **30**. 67-184. Monographiae Biologicae. The Hague.

Tinkler. K.J. (1966). Volcanic chronology of Lanzarote (canary Islands). *Nature* **209**.1122-1123.

Walker. C.A.. Wragg. G.M. and Harrison. C.J.O. (1990) A new shearwater from the Pleistocene of the Canary Islands and its bearing on the evolution of certain *Puffinus* shearwaters. *Historical Biology*. **3**. 203-224.



CLIP meeting 1995

Lanzarote and Fuerteventura

CANARIAS, ESPAÑA