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COASTAL EVOLUTION AND EL NIÑO IMPACT IN SANTA AREA, NW PERU, BASED ON ISOTOPIC COMPOSITION OF HOLOCENE MOLLUSKS SHELLS

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Mollusk assemblages from modern and Holocene littoral deposits and from prehistoric shell middens were collected in the coastal areas of Chao and Santa (NW Peru). These assemblages were analysed for their heavy isotope (^{14}C, ^{13}C, ^{18}O) content in order to document paleo-oceanographical changes, notably in relation to paleo-El Niño events. For comparative purposes, modern assemblages were also sampled and analysed.

In the studied area (Fig. 1), the ancient Holocene shoreline lies 4-5 kilometers inland and marks the limit of the maximum Holocene transgression at *ca.* 7000 years BP (Wells, 1988). The coastal plains lie west of 10m high seacliffs. Beach ridge deposits, sand dunes and sea shells cover these coastal progradational plains. A large amount of shells are also present as midden deposits.

The ^{14}C ages obtained on fossil assemblages (Fig. 2) indicate that a sea level maximum was reached at *ca.* 6 500 BP. Between *ca.* 6 500 BP and 4 000 BP a lagoon was present behind a major beach ridge at Santa. After that, in the last 4000 years, a series of beach ridges was formed west of the Santa paleolagoon, while at Chao the bay was progressively infilled (see Fig. 3 for detailed evolution of the coast). It has been hypothesized that the Santa beach ridges were related to major El Niño events (Sandweiss, 1986; Rollins et al., 1986; Wells, 1988). Nevertheless, it was noted that the very strong 82-83 El Niño event did not provoke the formation of any beach ridge in Santa area. It is possible that El Niño related runoff increased the sedimentary supply of the Santa River, but it is not clear that the ridges were effectively built during ENSO events.

Holocene mollusk assemblages in Chao are identical to those found presently in the same area and, therefore, indicate that no significant change occurred in coastal conditions during the Holocene. But at Santa, the fauna observed east of the beach ridge complex is typical of an area located several hundreds of kilometers to the north, in warmer water ("Paita Buffer Zone", Olsson, 1961). To explain this faunal anomaly, Rollins et al. (1981, 1986) and Sandweiss et al. (1983) suggested a reorganization of the Pacific Ocean at that time, i.e. ~5000 BP. On another hand, DeVries and Wells (1990) proposed a local paleogeographical change to explain the presence of the warm-water fauna in Santa. The mollusk assemblages and their isotopic composition confirm the latter interpretation.

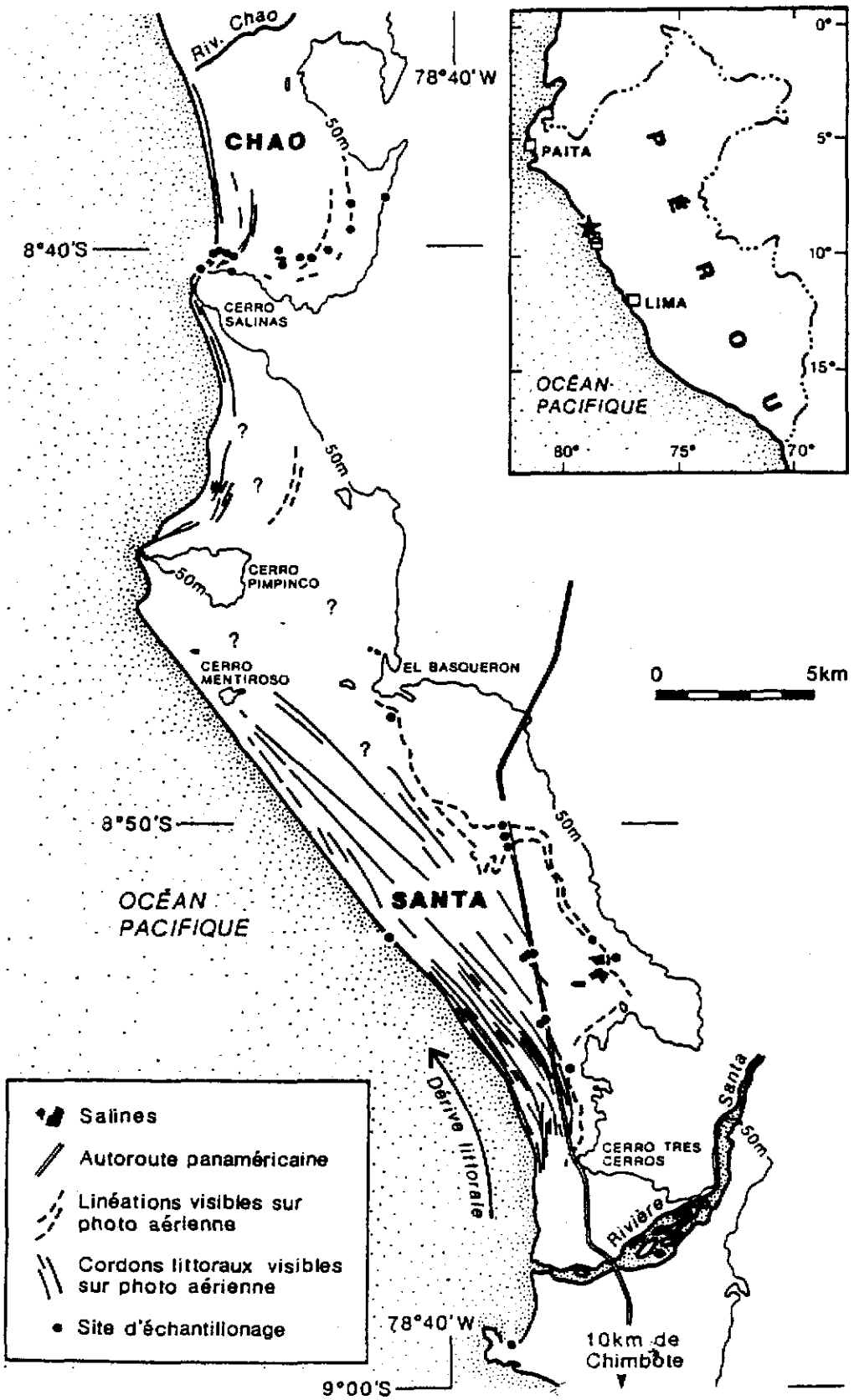


Figure 1. Studied area that comprises both bays of Santa and Chao (From Perrier et al., 1992).

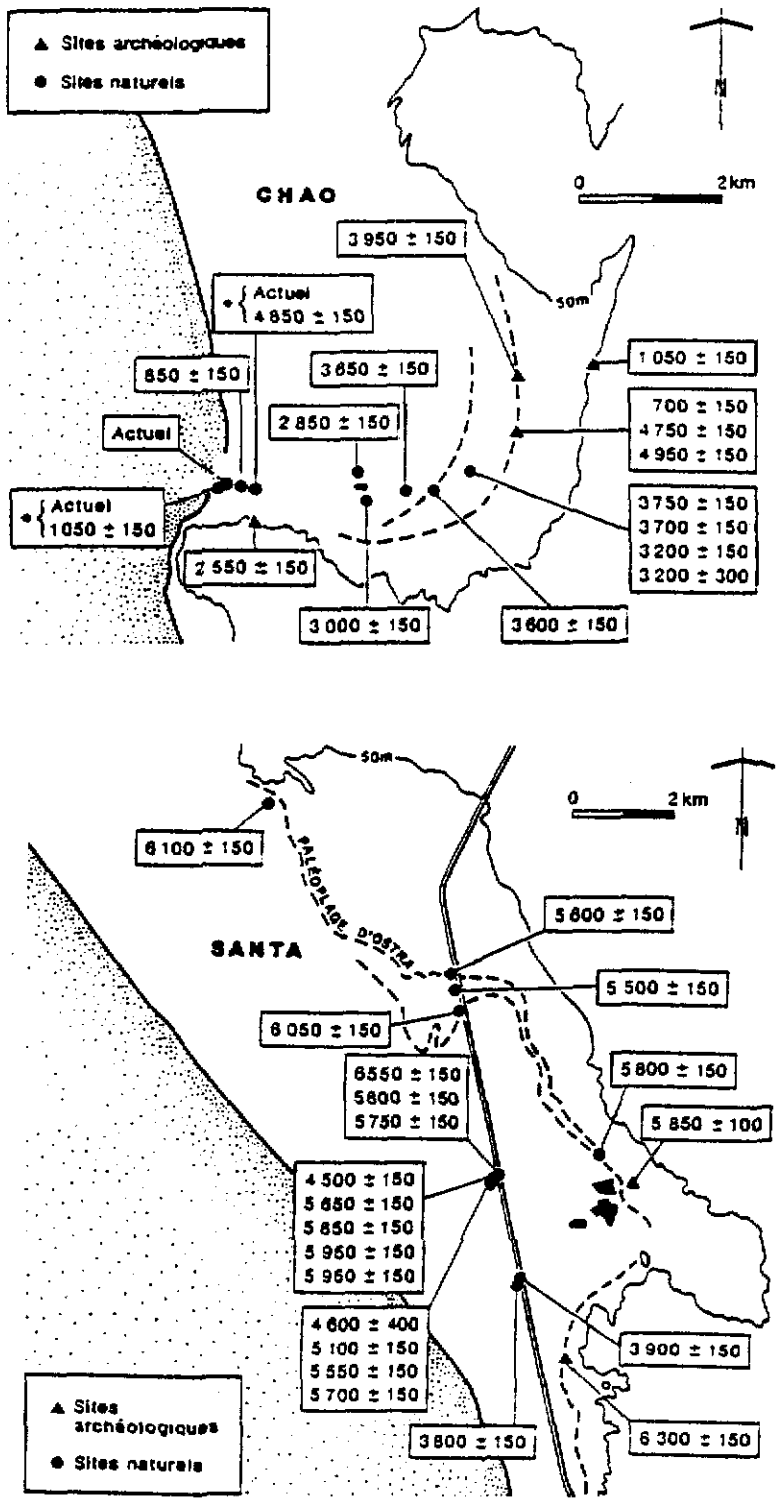
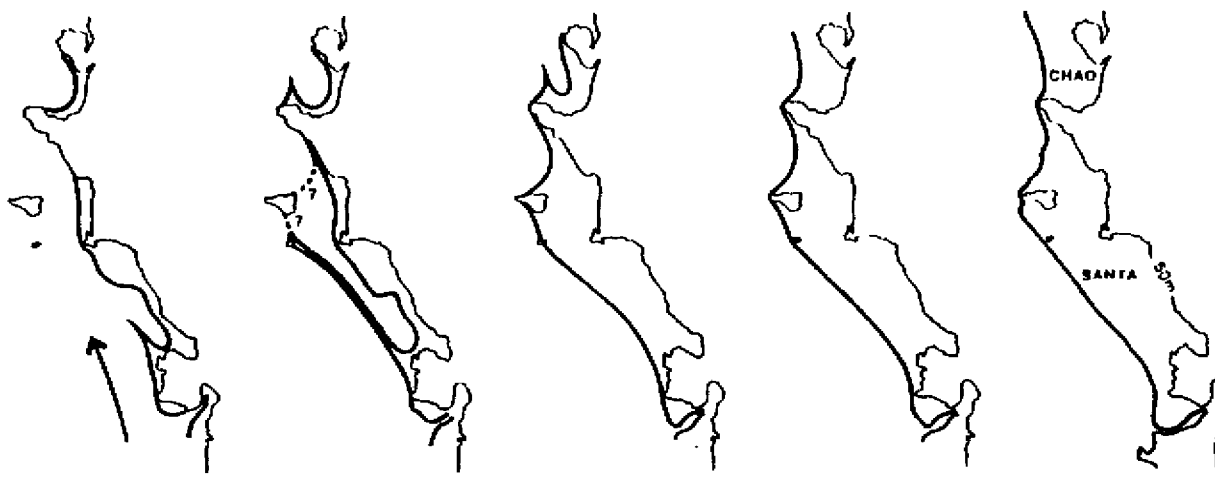


Figure 2. Geochronological data from the Santa and Chao areas (from Perrier et al., 1992): uncorrected ^{14}C ages on fossil shells.



Isotopic data on mollusk assemblages provide a more precise insight regarding these paleogeographical conditions. Modern shells in the studied area have a mean ^{18}O content of +0.9°/oo corresponding to a temperature of CaCO3 precipitation near 16.5-18.5°C. This range of temperature is effectively observed along the coast of Peru near Chimbote during normal years. When an El Niño event occurs, the ^{18}O content of the shell carbonate decreases in response to the temperature rise of sea water. A decrease of 1.4°/oo/PDB has been recorded on a shell of *Trachycardium procerum*, analysed for seriated measurements in order to document a recent El Niño event (see Perrier et al., same volume). Relatively low ^{13}C values on modern shells correspond to the endobenthic conditions of most of the analyzed species (*Chione broggi, Trachycardium procerum, Tagelus dombeii*). Holocene shells (Fig. 4) of most of the species show low $\partial^{13}C$ relative to the endobenthic conditions. The increase in ^{13}C content on shells of *Ostrea palmula* from Santa is related to the epibenthic condition of the species. The $\partial^{13}C$ tend to be closer to atmospheric equilibrium. The ^{18}O content of their carbonate shells also increased between 6 000 and 5 000 BP. This increase seems to be related to the formation of the paleo-lagoon, active from 6 500 to 4 000 BP. Similarily, the $\partial^{18}O$ isotopic composition of shells of *Tagelus dombeii* dated at 4 500 BP, tends to be much higher than the modern values, also suggesting an increase in ^{18}O content in response to the final evaporation stage of the lagoon. The presence of warm-water species in the Santa lagoon may be a consequence of warm water invasion related to paleo-El Niño events during which larvae may have been brought from lower latitudes. At Chao (Fig. 5), we observe a sudden increase in ^{18}O values between *ca.* 4000 and 3700 BP in *Mulinia edulis* and *Mesodesma donacium*, two cold-water species from open environments. This may also correspond to water enrichment by evaporation in partially closed environment behind a sandbar.

Isotopic analysis on sea shells from the Santa area completed previous studies based principally on fossil assemblages and sedimentologic data (Wells, 1988; DeVries and Wells, 1990). The geochemical analysis suggest an increase of salinity/evaporation between 6500 and 4000 BP in the Santa lagoon. Chao data indicate that, since 4000 BP, no significant changes in the water temperature was recorded.

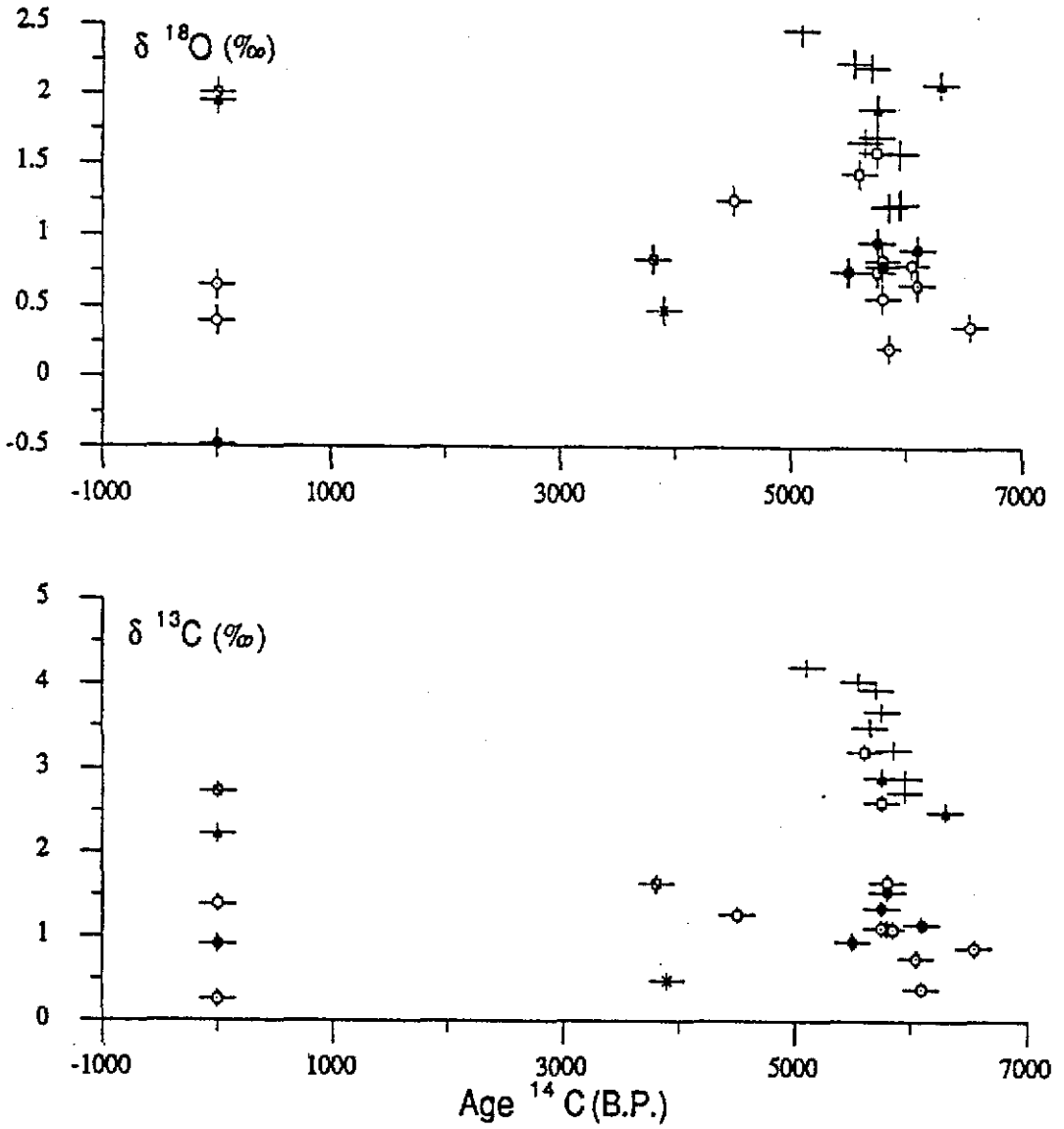


Figure 4. Isotopic composition of carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) in modern and fossils shells from Santa. The values of the calcitic shells *Balanus sp.*, *Argopecten circularis* and *Ostrea palmula* are expressed in aragonite (+1.7 ‰ in $\delta^{13}C$ et +0.8 ‰ in $\delta^{18}O$).

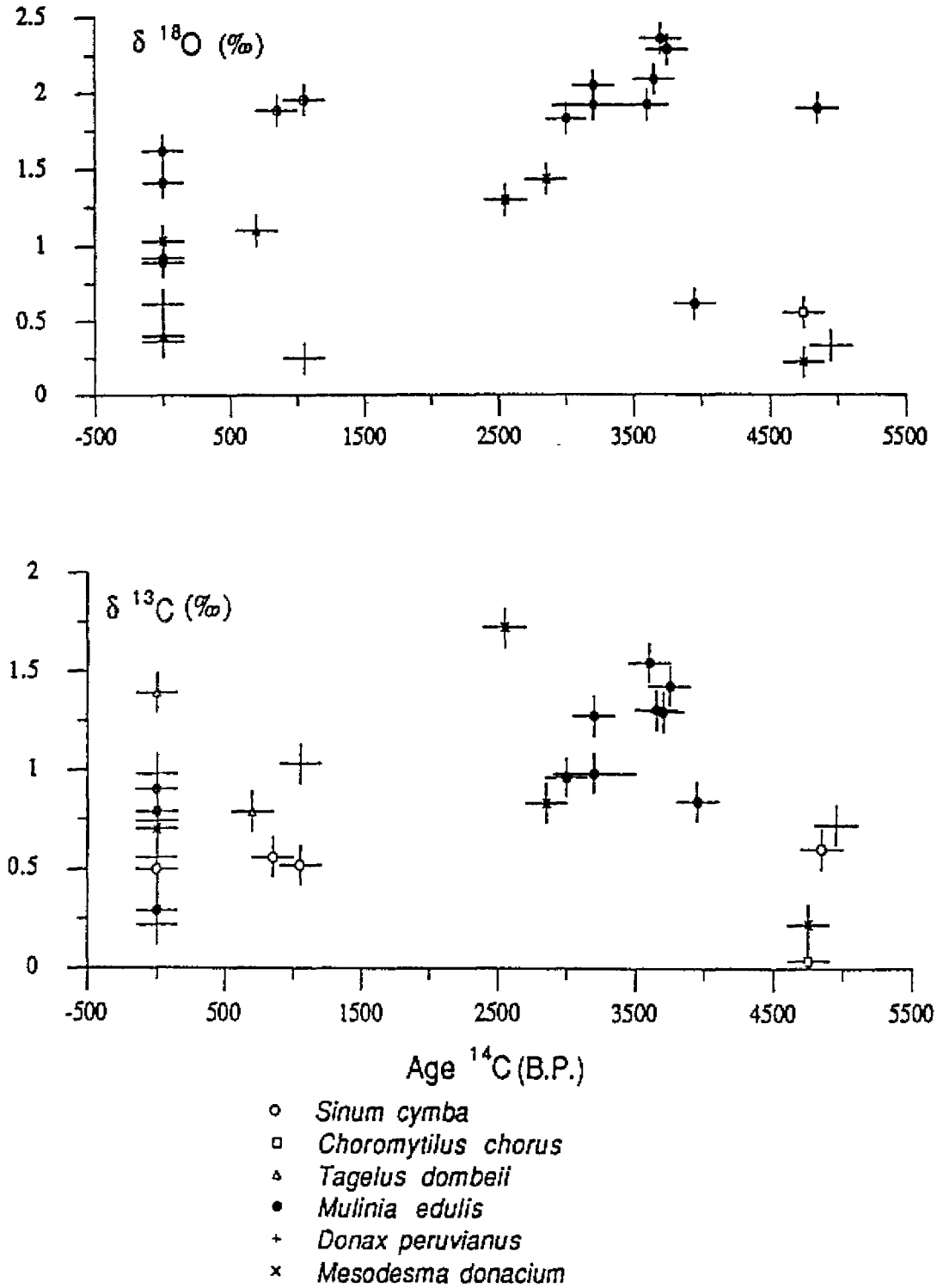


Figure 5. Isotopic composition of carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) in modern and fossils shells from Chao.

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ISOTOPIC RECORD OF RECENT AND PALEO-EL NIÑO EVENTS ON MOLLUSK SHELLS FROM NW PERU.

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During the 1982-83 El Niño event, one of the strongest of the last few centuries, the incursion of warm water along the northern and central coast of Peru increased the sea surface temperature by as much as 9°C near Chimbote. This strong temperature rise had a non-negligible effect on dynamics of the coastline and on the marine and nearshore fauna. Though, the short duration of the El Niño oceanographic anomaly (a few months only) makes it difficult to be registered in the geological record. Seriated measurements of stable isotope composition of mollusk shells may be very useful for the reconstruction of past oceanographic conditions along the Peruvian coast in relation to paleo-El Niño events.

This study is based on isotopic data (^{14}C, ^{13}C, ^{18}O) from seriated measurements of mollusk shells collected at Samanco (modern material) and at Santa (Holocene sites). Only valves of *Trachycardium procerum* with growth-ring disturbances were chosen for this study. This species has been mentioned as able to record paleoecologic stresses of El Niño type in the shell carbonate (Rollins et al., 1986, 1987). The main morphological signal recognized on shells that experienced and survived the last major El Niño event (1982-1983) is a change in the slope of the shell. Other discernable growth anomalies observed on *Trachycardium procerum* shells may also be related to El Niño stress conditions. One of the objectives of this work was thus to determine the geochimical significance of those growth anomalies in this species and to verify to what extent they may be used to reconstruct El Niño like conditions.

As shown in Fig. 1, the isotopic signature of El Niño events in modern mollusk shells of *Trachycardium procerum* presenting growth-ring disturbances is found in (1) a strong depletion in ^{18}O (1.2 and 2 °/oo) closely associated to a temperature increase in the nearshore area, and (2) a shift in ^{13}C, with a sharp and short increase at the beginning of the warming event followed by a depletion in heavy isotope when colder conditions resume. It is assumed that the analysed shells experienced the 1982-1983 El Niño oceanographic anomaly. The ^{13}C fluctuations are thought to indicate changes in the oxidation rate of organic carbon at the sediment/water interface (i.e. the shell's habitat) responding to carbon fluxes and therefore to productivity.

The isotopic trends of four fossil mollusks of the same species are not easily compared with the modern ones. The Santa area, in Mid-Holocene time, corresponded to a restricted environment (DeVries and Wells, 1990; Perrier et al., 1992; Perrier et al., this volume). Combined isotopic and paleoecologic data in the Santa area (Fig. 2) confirm this reconstruction. The increase in ^{18}O values in *Ostrea palmula* are interpretated to be a con-

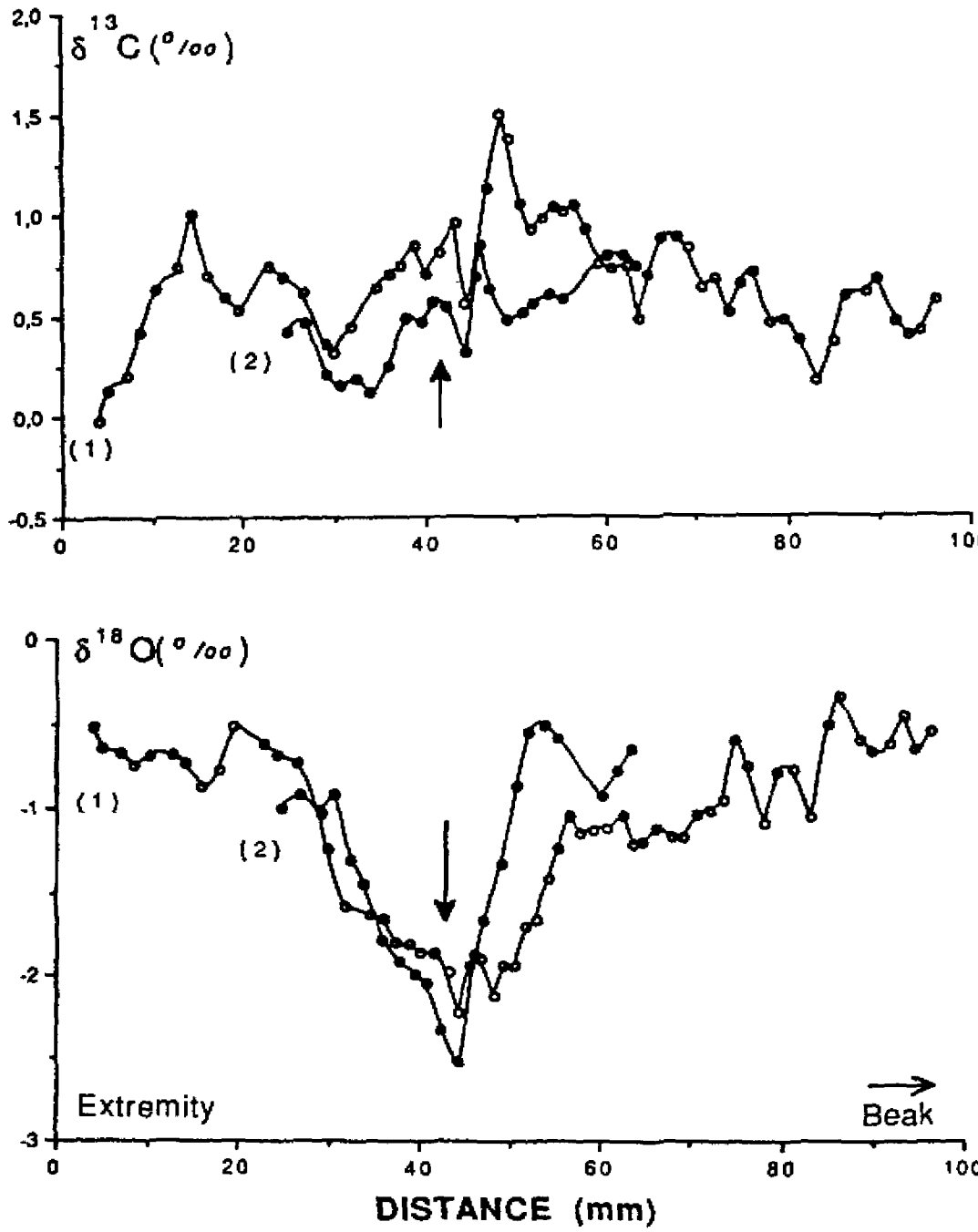

Figure 1 Isotopic profiles ($\delta^{13}C$ and $\delta^{18}O$) on two modern specimens of *Trachycardium procerum* The arrow indicates the growth disturbance as observed on the surface shell

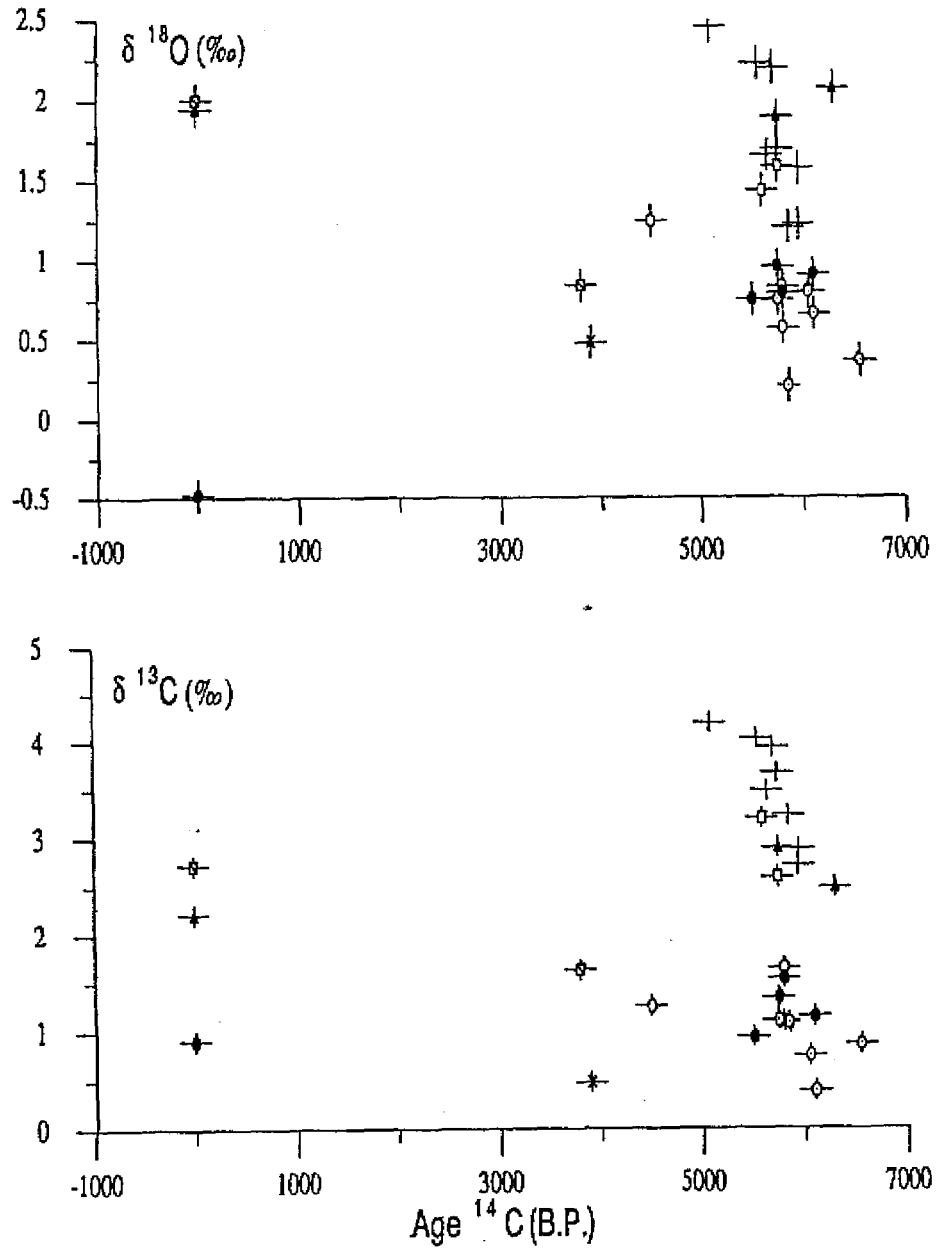

Figure 2. Isotopic composition of carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) in modern and fossils shells from Santa. *Balanus sp.*, *Argopecten circularis* and *Ostrea palmula* are expressed in aragonite (+1.7 ‰ in $\delta^{13}C$ et +0.8 ‰ in $\delta^{18}O$).

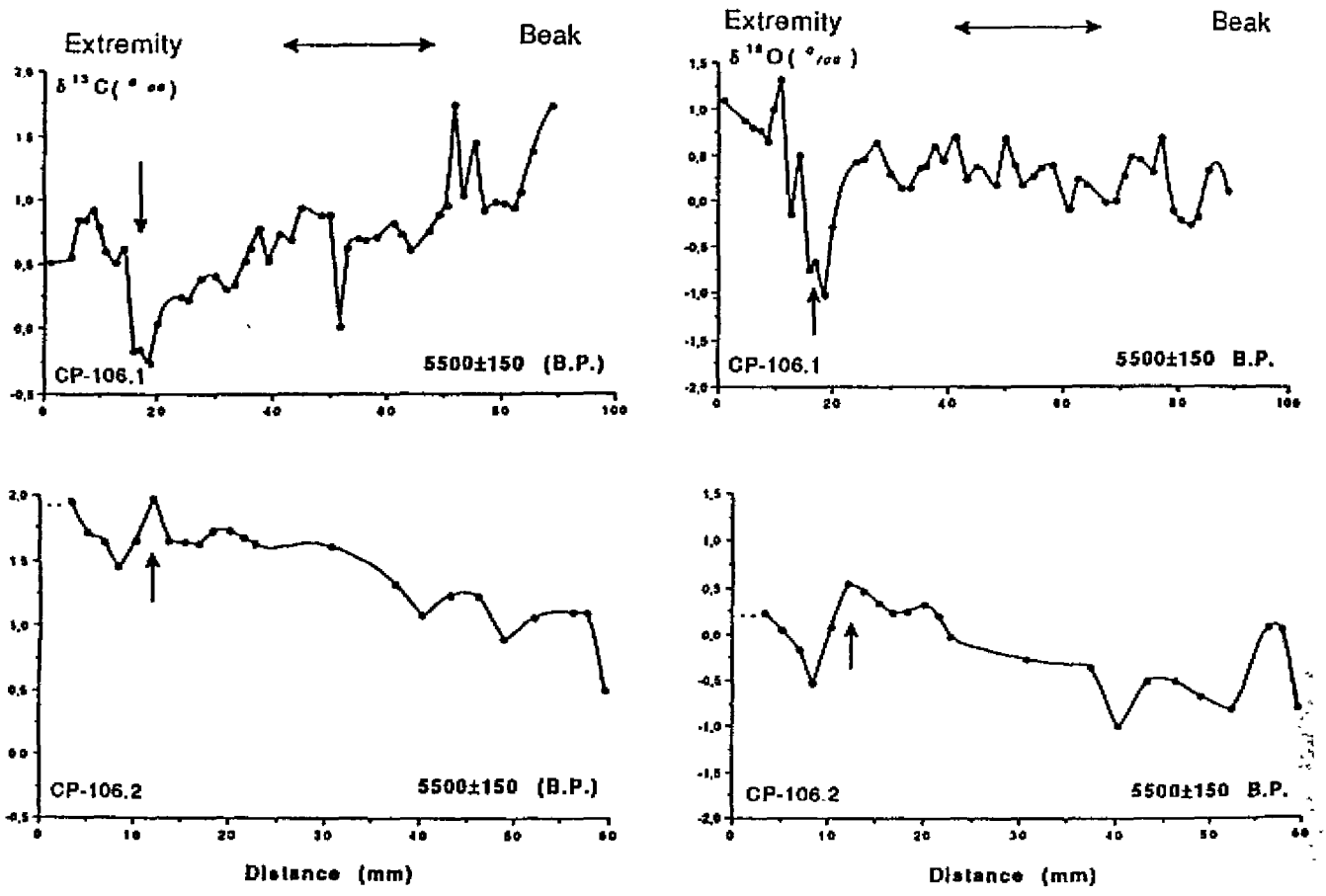

Figure 3. Isotopic profiles ($\delta^{13}C$ and $\delta^{18}O$) on two fossil specimens of *Trachycardium procerum* dated 5500 =/-150 BP from Santa area. The arrow indicates the growth disturbance as observed on the surface shell.

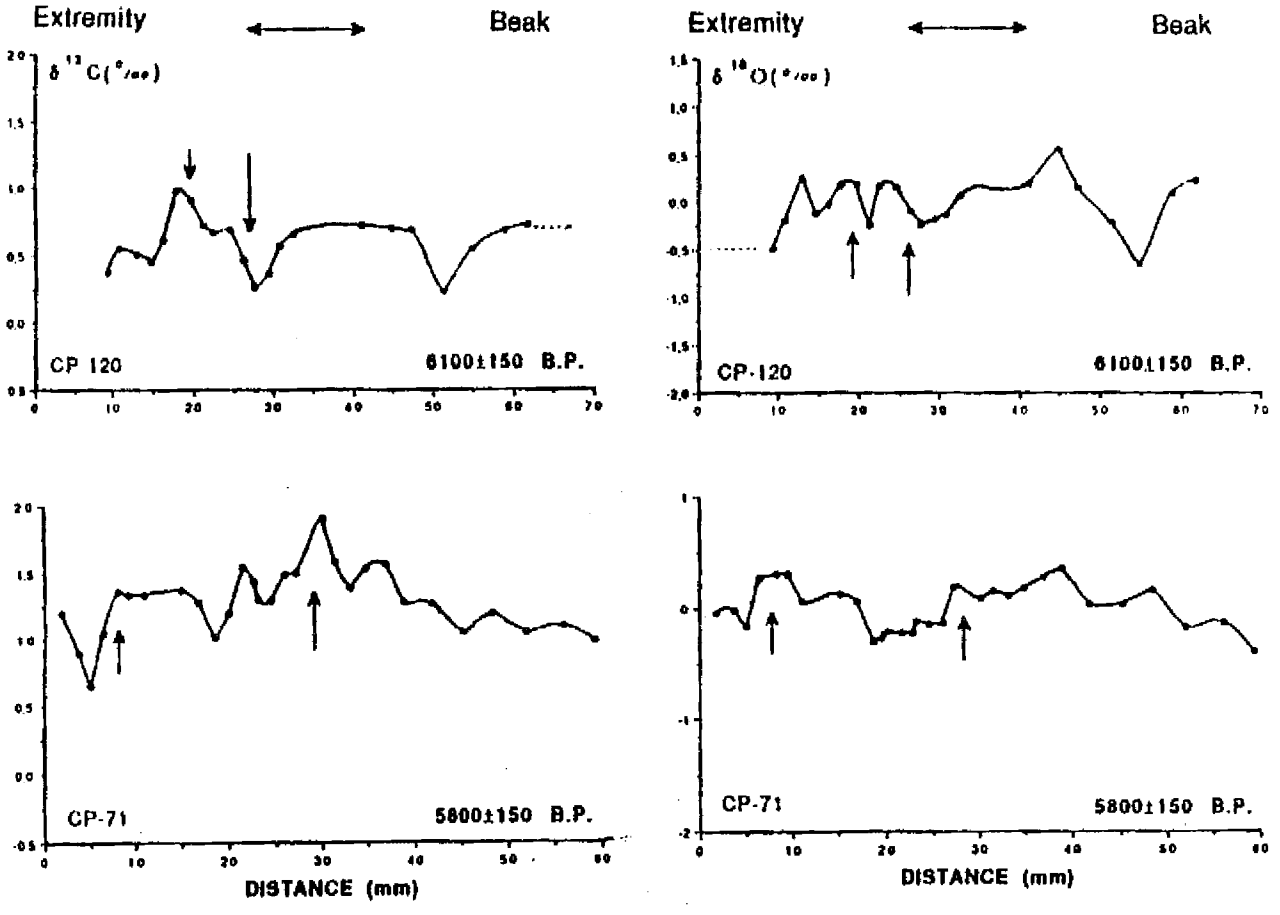

Figure 4. Isotopic profiles ($\partial^{13}C$ and $\partial^{18}O$) on two fossil specimens of *Trachycardium procerum* dated respectively 6100 =/ -150 BP and 5800 +/- 150 BP from Santa area. The arrow indicates the growth disturbance as observed on the surface shell.

sequence of water enrichment in response to evaporation into the lagoon. The conditions in the Santa lagoon cannot, therefore, be exactly correlated to those of the open shoreline registered by the modern specimens. Moreover, only a few specimens were found at Santa and, among them, four showed a superficial growth disturbance. The nature of the disturbance, however was not clear (natural or catastrophic). In fossil mollusks of the Santa area (Fig. 3 and 4), the ^{18}O content associated with the growth anomaly tend to decrease but the values are much smaller in amplitude except for one (CP-106.1) with a decrease of 1.6 °/oo. Most of the ^{13}C profiles on the fossil samples have a small increase associated with the growth disturbance similar to those observed on modern valves. Although the ^{13}C and ^{18}O profiles are not identical, the variations may be specifically related to geographical conditions.

We conclude that it becomes possible to recognize isotopically El Niño event in the carbonate shell of some mollusks. Records of this type of event may extend throughout the Holocene and the Pleistocene (marine terrace shell material). Even if this approach is time consuming and expensive, it should provide strong and convincing evidence of the ecological stress that is induced by the strong and very strong El Niño events of the past.

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CARACTERISTICAS DE LA ATMOSFERA FRENTE AL PERU DURANTE 1990

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El estudio de la influencia de los parámetros meteorológicos sobre los oceanográficos de diferente escala espacio-temporal ha cobrado en los últimos años gran interés, debido a lo cual actualmente se realiza un monitoreo contínuo tanto de la atmósfera como de las condiciones oceanográficas de superficie, con el objeto de contar con los elementos necesarios para predecir o realizar seguimientos de la evolución de fenómenos de macroescala como El Niño. Muchos son los trabajos que reportan la relación entre la atmósfera y el océano en la ocurrencia de fenómenos de macroescala (Wyrtki, 1982, Rasmussen and Wallace, 1983 y Philander, 1983). En base a ellos se ha podido establecer los principios que rigen la dinámica tanto de la atmósfera como del océano en el Pacífico ecuatorial.

En este reporte se presenta una sinópsis gráfica de las condiciones meteorológicas y oceanográficas observadas en el año 1990 en base a datos tomados en el Perú durante los cruceros de investigación oceanográfica que ejecutó el BIC F. NANSEN. Además se comparan los resultados con los reportados por el CAC/NOAA y CLIMANALISE/BRASIL con el fin de relacionarlos dentro de un marco global y se discute los aspectos climáticos típicos a la fase inicial de un evento El Niño que estaría gestándose en los meses de enero a marzo y cómo éstos desaparecen en el mes de junio, cuando la atmósfera del Pacífico Tropical adquiere un comportamiento cuasi normal.

Del análisis de las condiciones meteorológicas observadas en superficie, se puede decir que las condiciones atmosféricas en enero de 1990 fueron similares a las del inicio de un evento El Niño con un ligero calentamiento en el Pacífico Ecuatorial el cual fue evolucionando hasta el mes de marzo en donde se apreció, especialmente frente al Perú, un retorno hacia las condiciones normales, observándose además en los meses de mayo a julio, una intensificación del campo de presión atmosférica en superficie y un incremento de los vientos alisios del S.E. en el Pacífico Ecuatorial.