Journal of Marine Systems 80 (2010) 184–190

Contents lists available at ScienceDirect

Journal of Marine Systems

journal homepage: www.elsevier.com/locate/jmarsys

The coccolithophore record for the last 11 000 years in the Gulf of California

M.C. Álvarez [a,*], J.A. Flores [a], F.J. Sierro [a], A. Molina-Cruz [b]

[a] Departamento de Geología, Facultad de Ciencias, Universidad de Salamanca, 37008 Salamanca, Spain
[b] Lab. de Ecología de Foraminíferos y Micropaleontología, Inst. de Ciencias del Mar y Limnología (ICMYL), UNAM, 04510 México D.F., Mexico

ARTICLE INFO

Article history:
Received 28 January 2009
Received in revised form 1 June 2009
Accepted 20 September 2009
Available online 25 October 2009

Keywords:
Coccolithophores
Laminated sediments
Nutricline
Thermocline
Younger Dryas
Mid-Holocene
El Niño-Southern Oscillation (ENSO)
Gulf of California

ABSTRACT

We analysed changes in the coccolithophore assemblage over the last 11 000 years in laminated sediments recovered near the mouth of the Gulf of California (NW Mexico). Coccolith preservation in the samples was good: the assemblage was represented by seven taxa. Statistical studies revealed that the group of "small" *Gephyrocapsa* was the dominant taxa and *Florisphaera profunda* and *Emiliania huxleyi* the following species in abundance. We calculated the ratio between inhabitants of the surface and deep photic zones, which allowed us to analyse variations in water column stratification. Oceanographic conditions during the Holocene were relatively constant, and the coccolithophore record was dominated by small placoliths, revealing upwelling conditions and high productivity, which progressively weakened towards the present. Two different events were found around 11 000 B.P. (Younger Dryas) and 6000 B.P. (mid-Holocene). Both intervals were characterised by the dominant presence of *F. profunda* in the assemblage, revealing stratification conditions in the water column and low productivity, the same oceanographic conditions defined during an ENSO (El Niño-Southern Oscillation) event.

1. Introduction and oceanographic setting

The Gulf of California, also called the Sea of Cortés, is located between the Peninsula of Baja California and the Sonora Desert (23°–32° N and 107°–117° W) (Fig. 1). Despite its connection with the Pacific Ocean, the climate in the Gulf has been defined as continental because of the great influence of the surrounding arid areas (Molina-Cruz, 1986).

The Gulf is a narrow and elongated 1600 km-long basin with variable width: 205 km wide in La Paz and 85 km wide at Tiburón Isle. The depth also varies along the Gulf: it is 3000 m deep at the mouth of the Gulf and 15 m deep in the Upper Gulf (Lavín et al., 1997) (Fig. 1). The ocean dynamics are defined by the different seasonal positions of the North-Pacific High and the Sonora Desert Low. During the summer and early autumn, the migration of the Sonora Desert Low Pressure Centre induces south-eastern winds (Fig. 1A). The humid wind produces precipitation mainly on the south-eastern coast, causing the northward movement of surface water (Molina-Cruz, 1986, 1988). Conversely, during the late winter and early spring, the Northeast Pacific High and the Sonora Desert Low Pressure Centre meet in latitude (Fig. 1B), inducing a barometric gradient. This barometric gradient increases the intensity of the geostrophic wind that blows parallel to the longitudinal axis of the Gulf, generating a southward current. The surface water masses located in front of the mouth of the Gulf are California Current Water ($T<22$ °C, $S<34.6$‰), Equatorial Water ($T>25$ °C, $34.6‰<S>34.9‰$) and Gulf of California Water (22 °C$ < T > 25$ °C, $S>34.9$‰) (Álvarez-Sánchez et al., 1978a). The current systems associated with the water masses follow an anticyclonic pattern in the winter with inflow on the Baja California Peninsula side and cyclonic circulation in the summer with the inflow on the continental side (Álvarez-Sánchez et al., 1978b; Lavín et al., 1997; Emilson and Alatorre, 1997). Similarly, it is possible to define upwelling zones that usually take place off the eastern coast of the Peninsula in the summer and off the coast of Guaymas City during the winter (Molina-Cruz, 1986) (Fig. 1).

Sedimentation on the Gulf of California is characterised by the presence of laminated sediments. The concept of laminated sediments has been used to refer to alternations of laminae of different colours (Molina-Cruz et al., 2002). The Bay of La Paz is a well studied region with laminated sediments close to our study area. Here, the laminated sediments are related to a depositional cycle regulated by the pluvial flux (Molina-Cruz et al., 2002); therefore, laminated sediments provide information about the climatic variability in this region at a high resolution (Pérez-Cruz, 2000, 2006).

The main source of interannual variability in the water circulation pattern of the Gulf is the El Niño-Southern Oscillation (ENSO) (Lavín et al., 1997; Ziveri and Thunell, 2000). However, the primary productivity reaction to El Niño events varies along the Gulf: Primary productivity decreases in the southern region where hydrographic conditions are similar to those of the open Pacific (Álvarez-Borrego and Lara-Lara, 1991).

* Corresponding author. Universidad de Salamanca, Facultad de Ciencias, Departamento de Geología, 37008 Salamanca, Spain. Tel.: +34 923294497; fax: +34 923294514.
E-mail address: a2741@usal.es (M.C. Álvarez).

0924-7963/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmarsys.2009.10.008

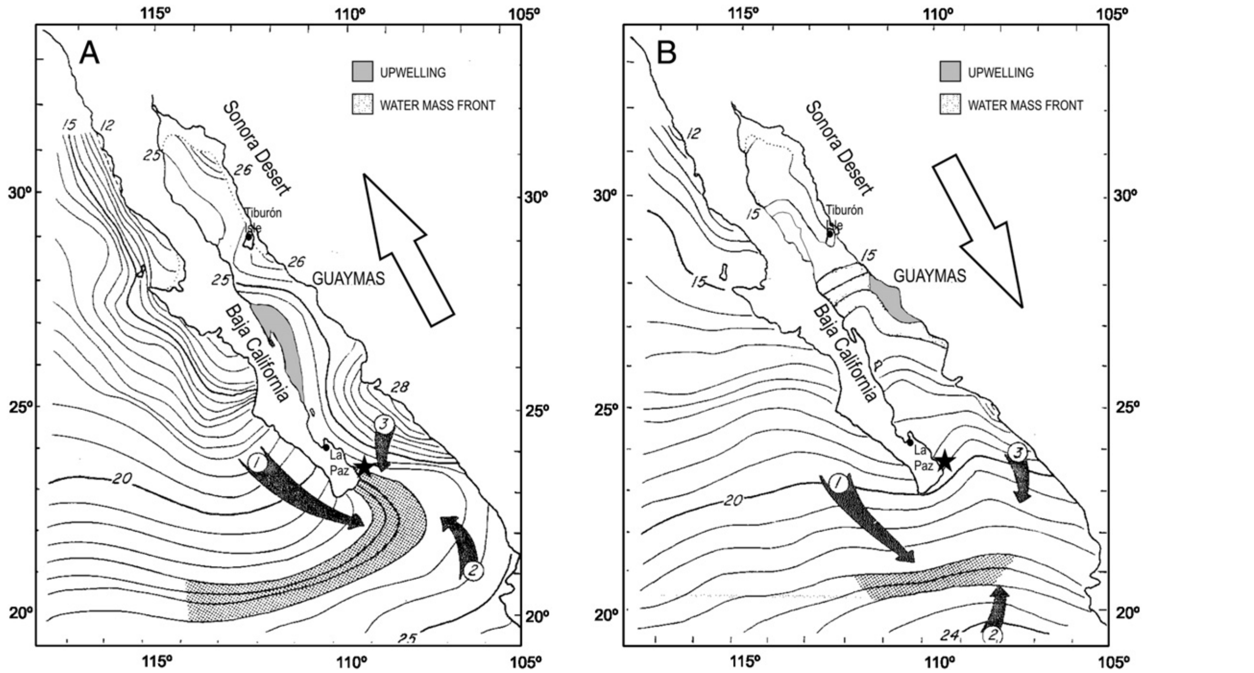

Fig. 1. Location of the gravity core PCM-00.EstC (★) and isotherms distribution. Water masses in the mouth of the Gulf of California: 1, California Current Water. 2, Equatorial Water. 3, Gulf of California Water. Prevailing winds (⇒). A: summer conditions. B: winter conditions. Modified from Molina-Cruz, 1986; 1988.

In general, the Gulf of California is a highly productive basin due to its hydrographic features; however, the southern region (south of 25°N) is characterised by the lowest phytoplankton populations in the entire Gulf (Álvarez-Borrego and Lara-Lara, 1991; Baumgartner et al., 1991; Monreal-Gómez et al., 2001). Specifically, coccolithophore production agrees with the general surface primary productivity according to some of the few coccolithophore studies in the Gulf of California (Hernández-Becerril, 1985, 1987; Ziveri and Thunell, 2000; Cortés et al, 2004).

The present work represents the first paleoceanographic study in the Gulf of California using coccolithophores from gravity core samples as a proxy. The main goal of this study is to monitor the thermocline position and changes in productivity using coccolithophores.

2. Materials and methods

Gravity core PCM-00/EstC is located in the Bay of Los Muertos (Gulf of California, 23°55′550 N–109°44′008 W), at 590 m water depth (Fig. 1), recovered in February 2000, during the PACMEX-00 expedition on board the R/V "*El Puma*" of UNAM (National Autonomous University of Mexico).

This core consists of 205 cm of laminated olive mud. Lamination is present throughout the core and shows a grey colour with variations in tone, thickness and distribution. The absence of macrofossils is noteworthy. An examination of the lamination reveals four intervals (Fig. 2):

Interval 1 (bottom-145 cm) shows wide, poorly defined and few visible laminae (between 0.2 and 0.5 cm of thickness), making identification very difficult and varying from 12 to 15 laminae in this interval. There are no thin laminae.

Interval 2 (145–120 cm) shows abundant thin and few visible laminae (laminae never exceed 1 mm thick).

Interval 3 (120–30 cm) is characterised by wide and thin laminae. The wide laminae are very dark and vary in number from 9 to 11. Between each wide lamina there is a series of thin laminae, similar to interval 2. It is possible to identify each lamina, as wider as thin laminae. In particular, we note a yellow sinusoidal indentation, a very thin white lamina and the widest lamina in the entire core (see Fig. 2 for location).

Interval 4 (30 cm-core top) presents a poorly preserved lamination; the laminae disappear to the wall-core.

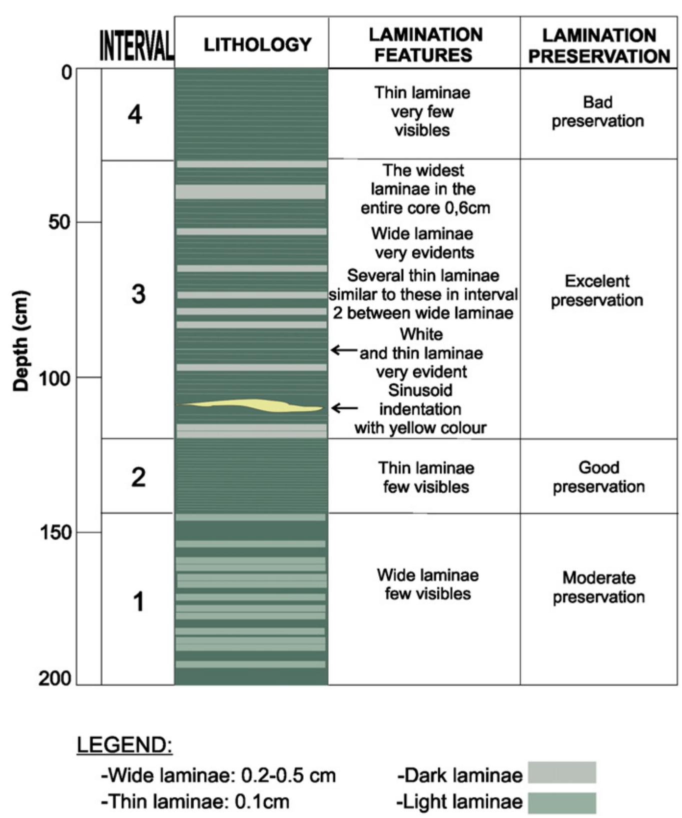

Fig. 2. Sedimentological description of PCM-00/Est. C. Gravity core (02-03-2000).

Table. 1
Age model. Rate 13C/12C = d13C pdb (% O) = reference delta (according with reference standar, (Craig, 1957).

Core	Depth (cm)	Lab. code	14C Age (year B.P)	14C Age corrected (year B.P)	Ratio 13C/12C (‰)	Calibrated age	Calibrated age B.P
PCM-00/Est.C	16–17	Beta-158481	1530+/−50	1870+/−50	−4.1	430 (550) 650 A.D	1520 (1400) 1300
PCM-00/Est.C	115–116	Beta-157642	6180+/−40	6570+/−40	−1.2	5250 (5140) 5030 B.P	7200 (7090) 6980
PCM-00/Est.C	202–203	Beta-157643	9930+/−50	10,280+/−50	−3.6	9420 (9210) 9130 B.P	11,370 (11,160) 11,080

Calibrated age = calendar years (calibration 2 sigma, probability 95%).
Calibrated age = core top compared to year 1950 A.D.
Calibrated age B.P = core top compared to year 0 B.P.

2.1. Age model and sedimentation rate

Three radiocarbon age points were acquired on shells of forams (*Pulleniatina obliquiloculata*, *Globorotalia limbata*, *Orbulina universa* and *Globigerina* sp) in the Beta Analytic Inc. Laboratories in Miami, Florida (USA).

These data were translated into calendar ages using the Calib Radiocarbon Calibration program version 4.3 (Stuiver et al., 2000 based on Stuiver and Reimer, 1993) and shown in Table 1. These data allow us to estimate a sedimentation rate of around 0.16 mm/year. We assume that sediments corresponding to the first 569 years are missing: according to this, 679 years BP (≈1271 BC) is the calculated date for the first 2 cm.

2.2. Sample preparation

A 2 cm systematic sample was analysed representing a ~125 year interval.

Samples were prepared using 0.5 g of sediment dissolved in 10 ml of buffered solution. Smear slides were then prepared.

Observations were made using a light polarising microscope (1250×), counting around 400 coccoliths (Fatela and Taborda, 2003).

3. Results

3.1. Coccolithophore assemblage

The coccolithophore assemblage is mainly represented by seven taxa, with the group of "small" *Gephyrocapsa* (Flores et al., 1999) being the dominant taxa (more than 55% in abundance). *Florisphaera profunda* (18%), *Emiliania huxleyi* (11%) and *Helicosphaera carteri* (6%) are the following species by abundance, with *Gephyrocapsa oceanica* and *Calcidiscus leptoporus* following at around 3%. *Umbilicosphaera sibogae* is the less abundant species, slightly exceeding 1%.

E. huxleyi shows a great variability in abundance along the core (Fig. 3). Their maxima appear at 8500 and 5000 years B.P. and the minima appear at 11 000, 6000 and 2000 years B.P. *G. oceanica,* "small" *Gephyrocapsa* and *H. carteri* show very low variability; the trend is also not well defined in each case. Nevertheless, the record of abundance of "small" *Gephyrocapsa* seems to exhibit a slight negative trend, more significant because it is the dominant taxa in the assemblage.

The record of abundance of *C. leptoporus* follows an opposite trend to that of *U. sibogae*, although both show a general upward increasing trend.

The abundance of *F. profunda* is low all along the core, with only two picks at the base of the core (11,252 BC to 10,500 BC) and at around 6000 years B.P.

4. Discussion

Coccolithophores in PCM-00/EstC are typically related to the subtropical assemblage (Flores and Sierro, 2007; Saavedra-Pellitero, 2006; Saavedra-Pellitero et al., 2007, in press), showing slight variation along the core. However, relevant changes in the ratio between coccolithophores living in surface waters and those blooming in the deep photic zone were observed.

As, inhabitants of the surface photic zone in our assemblage, we included the small placoliths (*E. huxleyi*+"small" *Gephyrocapsa*) (Okada and Honjo, 1973; Okada, 1983; Young, 1994), which have been considered as two taxa with ubiquitous distributions in the ocean (McIntyre and Bé, 1967; Okada and McIntyre, 1979) and, associated with periods of high primary productivity or upwelling (Okada and Wells, 1997). In contrast, the main species of the deep photic zone is *F. profunda* (Okada and Honjo, 1973; Okada, 1983; Young, 1994; Wells and Okada, 1997). The abundance of this species has been linked to variability in the nutricline/thermocline depth (Molfino and McIntyre, 1990a; Beaufort et al., 1997), although it can increase during relatively warm intervals (Tanaka and Tada, 2000). The *N* ratio (Flores et al., 2000) determines the proportion between both taxa and is a good index to monitor changes in the positions of the nutricline and thermocline with associated changes in productivity (Beaufort et al., 2001; Turk et al., 2001) (Fig. 4).

4.1. The Holocene record

During the Holocene, the general coccolithophore record did not vary in PCM-00EstC. It is not possible to identify significant variations in the assemblage abundance or in the *N* ratio proportion.

For the coccolithophore abundance (Fig. 3), it was possible to recognise an almost constant trend in each taxon all along the core. Only in the case of "small" *Gephyrocapsa*, *C. leptoporus* and *U. sibogae* was it possible to identify a slightly changed path. Specifically, for "small" *Gephyrocapsa* we note a slight decreasing trend to the top of the core, although they continue to be the dominant taxa in the coccolithophore assemblage. This decrease may be linked to a gradual trend of weakening upwelling or more stratified waters in the mouth of the Gulf of California. Since the upwelling on the occidental side of the Gulf of California are related to south-eastern prevailing winds (Molina-Cruz, 1986, 1988), it is possible to deduce a consequent weakening in the intensity of these winds. Moreover, the increasing trends shown by *C. leptoporus* and *U. sibogae* linked to oligotrophic conditions and tropical and subtropical waters (Okada and Honjo, 1973; Okada and McIntyre, 1977; Fincham and Winter, 1989; Giraudeau and Rogers, 1994; Ziveri et al., 1995; Giraudeau, 1992) are in agreement with a progressively more temperate surface waters and increased stratification.

With respect to the *N* ratio data (Fig. 4), the trend follows a progressive reduction from 0.9 to 0.8 showing a slight reduction in the productivity, a deeper nutricline/thermocline and more stratified waters. Nevertheless, the absolute values indicate a general high productivity.

Ziveri and Thunell (2000) studied coccolithophores in sediment traps collected in the central part of the Gulf of California (Guaymas Basin). They found an alternation in the abundance of *G. oceanica,* the dominant species in the assemblage, and *E. huxleyi* and *F. profunda.* The alternation was related to non-ENSO and ENSO events, respectively. In our case, no such alternation is evident the PCM-00/EstC coccolithophore assemblage; conversely, *G. oceanica* has an insignificant presence in the assemblage and the reactions of *E. huxleyi* and *F. profunda* are opposite in the entire core determining every species alternate conditions. The upwelling events can therefore be correlated to global events in which the climate was colder and an increase in the

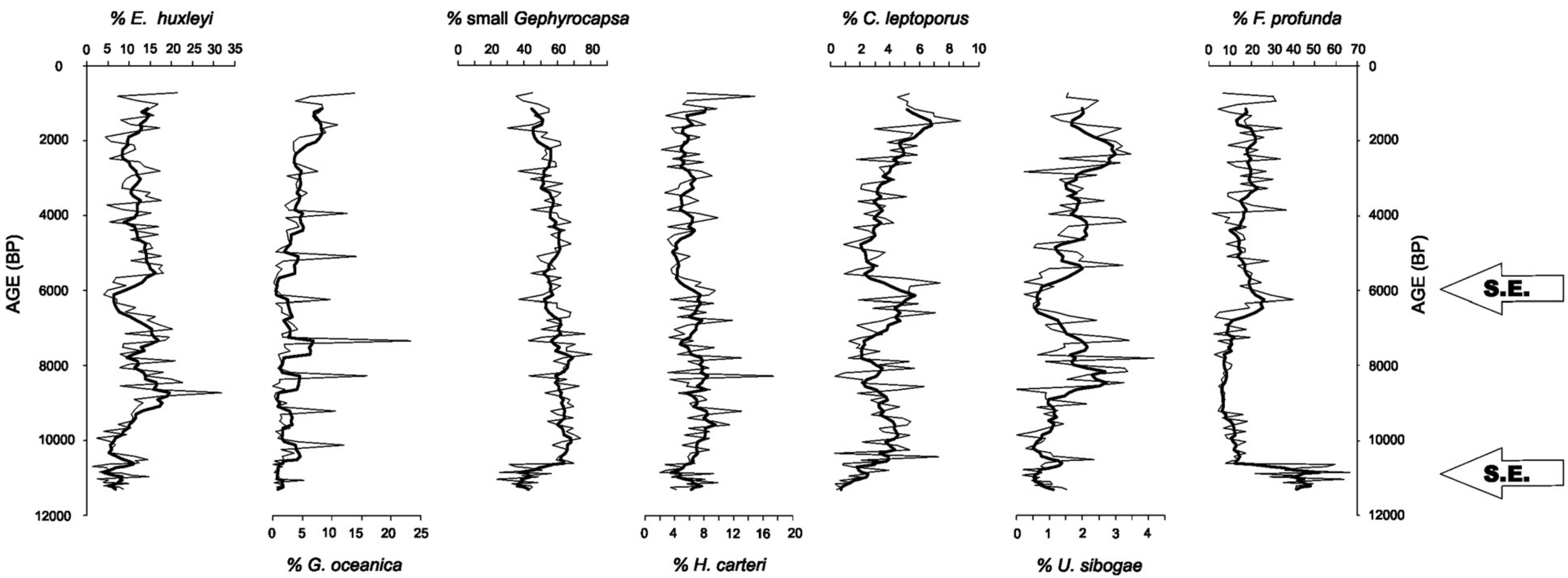

Fig. 3. Coccolithophore relative abundances. Five points smooth data (solid line) was applied in order to better show the trend of the abundance. S.E. (Stratified Event).

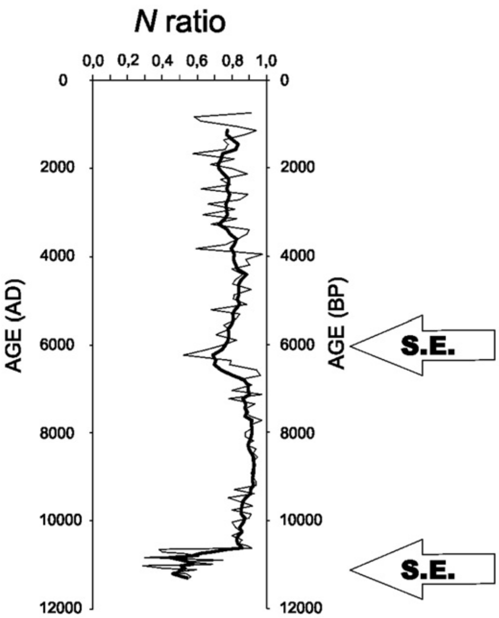

Fig. 4. *N* ratio, productivity index (Flores et al., 2000). The *N* ratio range is limited to between zero and one, so values close to zero imply a relatively deep nutricline/ thermocline position and values close to one are interpreted as a relatively shallow nutricline/thermocline position. S.E. (Stratified Event).

intensity of the Trade Winds created strong upwelling (Pérez-Cruz, 2000). It is possible to consider the mouth of the Gulf of California under upwelling conditions during the Holocene but upwelling could be losing intensity or length in the event from bottom to top part.

4.2. ENSO-like events

The general trend in Holocene shows two exceptions, analysed as follows.

According to the data shown in Figs. 3 and 4, at the base of the core, around 11 000 years B.P., *F. profunda* was dominant while *E. huxleyi* and "small" *Gephyrocapsa* show low percentages (Fig. 3). Consequently, the *N* ratio falls to close to 0.4, the lowest values observed in the entire core. These low values in the *N* ratio are interpreted in terms of stratification of the water column. The high abundance of *F. profunda* reveals a strong stratification with a deep nutricline/ thermocline and low productivity in surface waters (Molfino and McIntyre, 1990b; Flores et al., 2000; Beaufort et al. 2001). These oceanographic conditions are similar to those prevailing during an ENSO (El Niño-Southern Oscillation) event in the tropical Pacific (Beaufort et al., 2001; Lamy et al., 2001), suggesting that the influence of the ENSO oscillations reaches the Gulf of California.

According to our age model, this interval (around 11 000 years B.P.) with abundant *F. profunda* is probably correlated to the YD (Younger Dryas), a global cold period (Kennett, 1990; Molfino and McIntyre, 1990b). However, the coccolithophore assemblage is typically subtropical, and none of the species found in this interval can be related to a cold event. Oceanographic conditions with strong water stratification near the mouth of the Gulf of California can be explained by taking into account the role of the prevailing winds. Upwelling on the occidental side of the Gulf of California is generated by the inflow of south-eastern winds (Molina-Cruz, 1986, 1988), so its weakening during the YD due to the global southward motion of the climatic bands is expected (Broccoli et al., 2006; Garcin et al., 2007). In this sense, the south-eastern winds could move southward, losing their influence in the Gulf of California and favouring stratification in the surface waters of the occidental coast during the YD.

A similar event with abundant *F. profunda* was observed in the middle of the core (around 6000 years B.P.) (Figs. 3 and 4), although the increase in *F. profunda* is of lower magnitude and the *N* ratio only falls to values of 0.6–0.7. This change in the coccolithophore assemblage indicates water column stratification on the occidental coast of the Gulf of California in the mid-Holocene with low surface productivity, and, by analogy with the YD, a higher influence of the El Niño events in this area. However, vertical stratification was probably much lower than that seen for the YD. Prevailing ENSO conditions in the Gulf of California during the mid-Holocene were reported by Pérez-Cruz (2000), who recognized the dominance of Equatorial Water around the 5700–6000 B.P. by the abundance of the radiolarian species *Tetrapyle octacantha*, in the Bay of La Paz, a region close to our study area. She related this event to the Hipsithermal Period or Holocene Climate Optimum. According to Molina-Cruz (1988), Equatorial Water enters the Gulf during times of weakened California

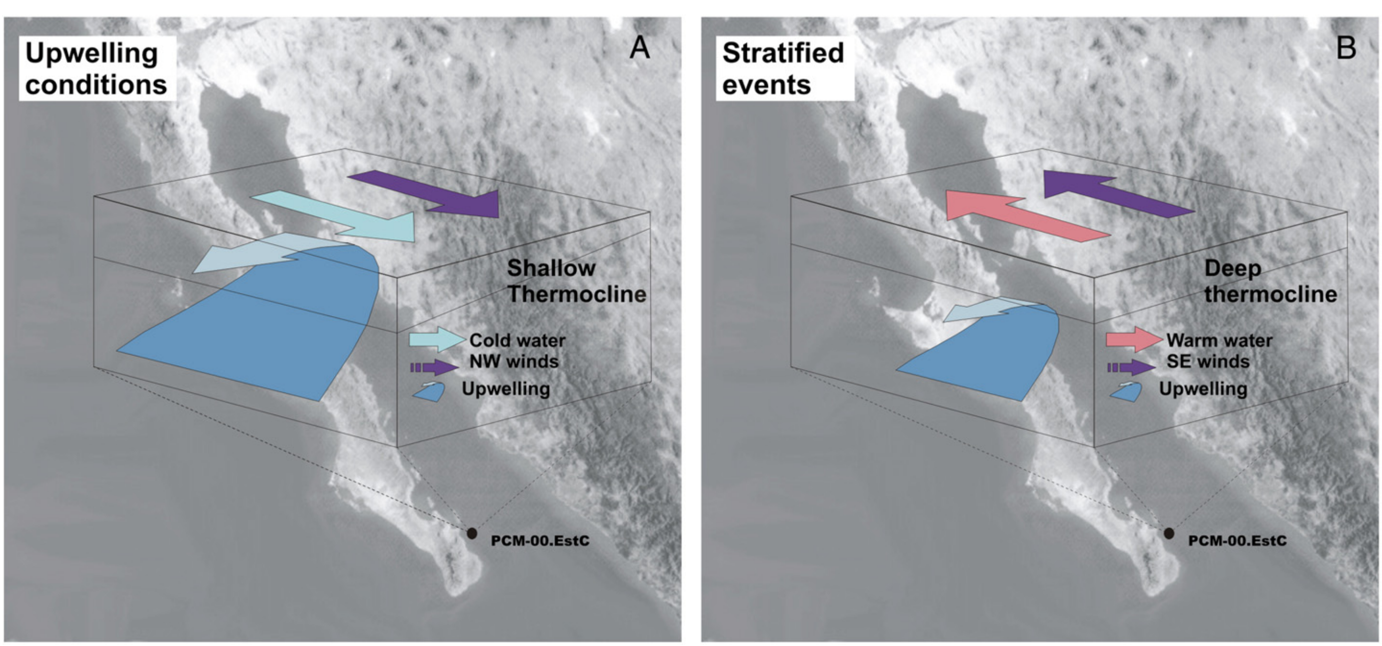

Fig. 5. Surface water model for the mouth of the Gulf of California during the last 11 000 years. A. Upwelling conditions. B. Stratified events.

Current and prevailing south-eastern winds. At present, the most important penetration of Equatorial Water into the Gulf of California occurs during the ENSO events (Lavín et al., 1997; Pérez-Cruz, 2000). We conclude that during this period, the Gulf of California was under the influence of an ENSO event.

5. Conclusions

The relation defined between inhabitants of the surface and deep photic zones and the PCM-00/EstC coccolithophore assemblage allows us to establish the ocean conditions in the mouth of the Gulf of California related to surface water stratification.

Upwelling conditions and high productivity are found to have been the prevailing surface ocean features on the occidental coast at the mouth of the Gulf of California during the Holocene, as shown by the small placoliths controlling the assemblage and the high *N* ratio values. Nevertheless, a weakening along the core is also present, showing up as a slight decrease in the "small" *Gephyrocapsa* trend (Fig. 5A).

The great abundance of *F. profunda* and the very low *N* ratios allow us to recognise a very stratified surface water mass with a deep nutricline/thermocline and a low productivity in the cool YD, ocean conditions that are similar to those described during an ENSO (El Niño-Southern Oscillation) event (Fig. 5B).

Another stratified time with a deep nutricline/thermocline and low productivity was present around 6000 B.P. At that time, the ocean conditions, similar to those in an ENSO event, were again present, but with respect to the previous YD there was a weaker presence of the oscillating processes (Fig. 5B).

Acknowledgments

We thank the Instituto de Ciencias del Mar y Limnología of UNAM (Universidad Nacional Autónoma de México) for providing samples. The "El Puma" crew and PACMEX-00 Oceanography Expedition are also acknowledged. We also wish to thank the suggestions and critical comments on this study of all anonymous reviewers, who helped improve the original manuscript. This study was supported by the Research Interchange Grant: Universidad de Salamanca and Universidad Nacional Autónoma de México.

References

Álvarez-Borrego, S., Lara-Lara, J.R., 1991. The physical environment and primary productivity of the Gulf of California. In: Dauphin, J., Simoneit, B. (Eds.), The Gulf and Peninsular Province of the Californias: American Association of Petroleum Geology Memoir, vol. 47, pp. 555–567.
Álvarez-Sánchez, L.G., Stevenson, M.R., Wyatt, B., 1978a. Circulación y masas de agua en la región de la boca del golfo de California en la primavera de 1970. Ciencias Marinas 5 (1), 57–69.
Álvarez-Sánchez, L.G., Wyatt, B., Stevenson, M.R., 1978b. Corrientes en la región de la boca del Golfo de California en la primavera de 1970. Ciencias Marinas 5 (1), 105–118.
Baumgartner, T.R., Ferreira-Bartrina, V., Moreno-Hentz, P., 1991. Varve formation in the central Gulf of California: a reconsideration of the origin of the dark laminae from the 20th century varve record. In: Dauphin, J., Simoneit, B. (Eds.), The Gulf of California and Peninsular Province of the Californias. Memoir, vol. 47. American Association of Petroleum Geologist, pp. 617–635.
Beaufort, L., Lancelot, Y., Camberlin, P., Cayre, O., Vincent, E., Bassinot, F., Labeyrie, L., 1997. Insolation Cycles as a major control of Equatorial Indian Ocean primary production. Science 278, 1451–1454.
Beaufort, L., de Garidel-Thoron, T., Mix, A.C., Pisias, N.G., 2001. ENSO-like forcing on oceanic primary production during the Late Pleistocene. Science 293, 2440–2444.
Broccoli, A.J., Dahl, K.A., Stouffer, R.J., 2006. Response of the ITCZ to Northern Hemisphere cooling. Geophysical Research Letters 33, L01702. doi:10.1029/2005GL024546.
Cortés, M.Y., Bollmann, J., Cervantes-Duarte, R., Silverberg, N., 2004. Living coccolithophores at the marginal Basin Alfonso at Bay of La Paz, Gulf of California. 10 INA Conference, Lisbon. Journal of Nannoplankton Research 26 (2), 22.
Craig, H., 1957. Isotopic standards for carbon and oxygen and correction factors for mass spectrometric análisis of carbon dioxide. Geochimica et Cosmochimica Acta 12, 133–149.
Emilson, I., Alatorre, M.A., 1997. Evidencias de un remolino ciclónico de mesoescala en la parte sur del Golfo de California. In: Lavín, M.F. (Ed.), Contribuciones a la oceanografía física en México. Monografía, vol. 3. Unión Geofísica Mexicana, pp. 173–182.
Fatela, F., Taborda, R., 2003. Confidence limits of species proportions in microfossil assemblages. Marine Micropaleontology 45, 169–174.
Fincham, M.J., Winter, A., 1989. Paleoceanographic interpretations of coccoliths and oxigen-isotopes from the sediment surface of the Southwest Indian Ocean. Marine Micropaleontology 13, 325–351.
Flores, J.A., Sierro, F.J., 2007. Paleoceanography, Biological proxies/Coccolithophores. In: Elias, S.A. (Ed.), Encyclopedia of Quaternary Science. Amsterdam, Elsevier, pp. 1634–1646.
Flores, J.A., Gersonde, R., Sierro, F.J., 1999. Pleistocene fluctuations in the Agulhas Current Retroflection based on calcareous plankton record. Marine Micropaleontology 37, 1–22.
Flores, J.A., Bárcena, M.A., Sierro, F.J., 2000. Ocean-surface and wind dynamics in the Atlantic Ocean off Northwest Africa during the last 140000 years. Palaeogeography, Palaeoclimatology, Palaeoecology 161, 459–478.
Garcin, Y., Vincens, A., Williamson, D., Buchet, G., Guiot, J.I., 2007. Abrupt resumption of the African Monsoon at the Younger Dryas–Holocene climatic transition. Quaternary Science Reviews 26, 690–704.
Giraudeau, J., 1992. Distribution of recent nannofossil beneath the Benguela system: southwest African continental margin. Marine Geology 108, 219–237.
Giraudeau, J., Rogers, J., 1994. Phytoplankton biomass and sea-surface temperature estimates from sea-bed distribution of nannofossils and planktonic foraminifera in the Benguela upwelling system. Micropaleontology 40 (3), 275–285.
Hernández-Becerril, D.U., 1985. Estructura del fitoplancton en el Golfo de California. Ciencias Marinas 11, 23–38.
Hernández-Becerril, D.U., 1987. Vertical distribution of Phytoplankton in the Central and Northern part of the Gulf of California Mexico June 1982. Marine Ecology 8, 237–252.
Kennett, J.P., 1990. The Younger Dryas cooling event: an introduction. Paleoceanography 5 (6), 891–895.
Lamy, F., Hebbeln, D., Röhl, U., Wefer, G., 2001. Holocene rainfall variability in southern Chile: a marine record of latitudinal shifts of the Southern Westerlies. Earth and Planetary Science Letters 185, 369–382.
Lavín, M.F., Beier, E., Badan, A., 1997. Estructura hidrográfica y circulación del golfo de California: escalas estacional e interanual. In: Lavín, M.F. (Ed.), Contribuciones a la oceanografía física en México. Monografía, vol. 3. Unión Geofísica Mexicana, pp. 141–171.
McIntyre, A., Bé, A.W.H., 1967. Modern coccolithophores of the Atlantic. I. Placoliths and Cyrtopliths. Deep-Sea Research 14, 561–597.
Molfino, B., McIntyre, A., 1990a. Precessional forcing of nutricline dynamics in the Equatorial Atlantic. Science 249, 766–769.
Molfino, B., McIntyre, A., 1990b. Nutricline variation in the Equatorial Atlantic coincident with the Younger Dryas. Paleoceanography 5 (6), 997–1008.
Molina-Cruz, A., 1986. Evolución oceanográfica de la boca del Golfo de California. Anales del Instituto de Ciencias del Mar y Limnología 13 (2), 95–120.
Molina-Cruz, A., 1988. Late quaternary oceanography of the mouth of the Gulf of California: the polycystine connection. Paleoceanography 3 (4), 447–459.
Molina-Cruz, A., Pérez-Cruz, L., Monreal-Gómez, M.A., 2002. Laminated sediments in the Bay of La Paz, Gulf of California: a depositional cycle regulated by pluvial flux. Sedimentology 49, 1401–1410.
Monreal-Gómez, M.A., Molina-Cruz, A., Salas-de-León, D.A., 2001. Water masses and cyclonic circulation in Bay of La Paz, Gulf of California, during June 1998. Journal of Marine Systems 30, 305–315.
Okada, H., 1983. Modern nannofossils asseblages in sediments of coastal and marginal seas along the western Pacific Ocean. Utrecht Micropaleontological Bulletin 30, 171–187.
Okada, H., Honjo, S., 1973. The distribution of oceanic coccolithophorids in the Pacific. Deep-Sea Research 20, 355–374.
Okada, H., McIntyre, A., 1977. Modern coccolithophores of the Pacific and North Atlantic Oceans. Micropaleontology 23, 1–55.
Okada, H., McIntyre, A., 1979. Seasonal distribution of modern coccolithophores in the western North Atlantic Ocean. Marine Biology 54, 319–328.
Okada, H., Wells, P., 1997. Late Quaternary nannofossil indicators of climate change in two deep-sea cores associated with the Leeuwin Current off Western Australia. Palaeogeography, Palaeoclimatology, Palaeoecology 131, 413–432.
Pérez-Cruz, L., 2000. Estudio paleoceanográfico y sedimentológico holocénico de la bahía de La Paz, Golfo de California. PhD. Thesis, Universidad Nacional Autónoma de México, 168p.
Pérez-Cruz, L., 2006. Climate and ocean variability during the middle and late Holocene recorded in laminated sediments from Alfonso Basin, Gulf of California, Mexico. Quaternary Research 65 (3), 401–410.
Saavedra-Pellitero, M., 2006. Distribución biogeográfica de las asociaciones de cocolitóforos en el Pacífico ecuatorial y suroriental. M.Sc.Thesis, Universidad de Salamanca, 173 pp.
Saavedra-Pellitero, M., Flores, J.A., Sierro, F.J., 2007. Nuevas aportaciones a la biogeografía de cocolitóforos en el Pacífico ecuatorial y suroriental. Geogaceta 42, 91–94.
Saavedra-Pellitero, M., Flores, J.A., Karl-Heinz, B., Sierro, F.J., in press. Coccolith distribution patterns in surface sediments of Equatorial and Southeastern Pacific Ocean. Geobios. doi:10.1016/j.geobios.2009.09.004.
Stuiver, M., Reimer, P.J., 1993. Extended 14C data base and revised Calib 3.0 14C age calibration program. Radiocarbon 35, 215–230.
Stuiver, M., Reimer, P.J., Reimer, R.W., 2000. CALIB 4.3. [WWW program and documentation] Seattle: University of Washington and Belfast: Queen's University of Belfast. URL: http://radiocarbon.pa.qub.ac.uk/calib/calib.html.
Tanaka, Y., Tada, R., 2000. Calcareous nannofossil assemblages of the last 27 K.y. in Hole 1017E, Santa Lucia slope, off Point Conception. In: Lyle, M., Koizumi, I., Richter, C., Moore Jr., T.C. (Eds.), Proceedings of the Ocean Drilling Program, Scientific Results, vol. 167, pp. 303–308.
Turk, D., McPhaden, M.J., Busalacchi, A.J., Lewis, M.R., 2001. Remotely sensed biological production in the equatorial Pacific. Science 293, 471–474.

Wells, P., Okada, H., 1997. Response of nannoplankton to major changes in sea-surface temperature and movements of hydrological fronts over Site DSDP 594 (south Chatham Rise, southeastern New Zealand), during the last 130 Kyr. Marine Micropaleontology 32, 341–363.
Young, J.R., 1994. Functions of coccoliths. In: Winter, A., Siesser, W.G. (Eds.), Coccolithophores. Cambridge University Press, Cambridge, pp. 63–82.
Ziveri, P., Thunell, R.C., 2000. Coccolithophore export production in Guaymas Basin, Gulf of California: response to climate forcing. Deep-Sea Research II 47, 2073–2100.
Ziveri, P., Thunell, R.C., Rio, R., 1995. Export production of coccolithophores in an upwelling region: Results from San Pedro Basin, Southern California Borderlands. Marine Micropaleontology 24, 335–358.