The evolution of the Atlantic-Mediterranean Gateways during the Neogene and Quaternary

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The Mediterranean is a semi-confined basin with a mean depth of around 1500 m separated from the Atlantic by a narrow sill, the Straits of Gibraltar, which is only 10 km wide and 300 m deep. Its reduced dimensions impose a low heat exchange by marine advection with the open Ocean and, therefore, local climatic conditions (strong evaporation in relation to precipitation) become very important.

The main factors governing the Atlantic-Mediterranean water exchange are: a) Atlantic water properties, b) local Mediterranean climate (the evaporation-precipitation balance E-P) and c) the geometry of the thresholds (BETHOUX, 1984). However, these parameters did not remain constant through time and therefore the Atlantic Mediterranean water exchange was very variable throughout the Neogene and Quaternary with the subsequent influence over the Mediterranean and global ocean history. After the closure of the Mediterranean-Indian Ocean connection, the only communication of the Mediterranean with the Global Ocean was through the Betic-Rifian corridors throughout the Miocene, and the Alboran-Gibraltar strait during the Pliocene and Quaternary. These regions did have a very important interest for paleoceanographic studies.

The climatic and oceanographic evolution throughout the Miocene was characterized by repetitive episodes of expansion and retreat of the antarctic ice sheets, causing global sea level changes. For a particular interval of time and a specific geometry of the North Betic Corridor, the global sea level rises and falls will determine different sections of the upper and lower Atlantic-Mediterranean flows and therefore different patterns of water exchange between them. The depth and width of the sills is also related to the tectonic and sedimentary evolution of the gateway (uplift, subsidence, olistostrome sliding, overthrusting, sedimentary filling, etc.). On the other hand, the global climate evolution and particularly the local climatic response, led the Mediterranean to modify the patterns of exchange with the open Ocean.

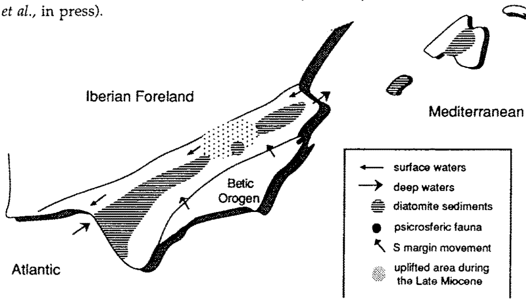
From the Paleoceanographic point of view, the Mediterranean evolved during the Miocene from being a region of the Open Ocean to becoming a marginal sea with important implications for its hydrography and its biotic communities.

During the Lower Miocene, both foredeeps were large and deep enough to allow the deep Atlantic waters to enter into the Mediterranean. Psychrospheric microfaunas of that age were found by BENSON (1976) in different places of the Betic Foredeep. During the Middle and Late Miocene the foredeeps became pregressively narrower and shallower and the deep communication restricted, leading the Mediterranean to become a marginal sea. Specially at the Langhian-Serravallian boundary an important reduction in the section of the Betic corridor occurred, causing the restriction of deep communication and conditioning the evolution of the deep Mediterranean ecosystems from that time to the present day related to an increase in the residence time of Mediterranean waters (VERGNAUD GRAZZINI, 1983).

During the Middle to Upper Miocene, diatomite sediments accumulated mainly in the southern margin of the Betic passage from the Atlantic coast to the Balearic Islands. The micropaleontologic and sedimentary features of these siliceous sediments, along with their preferred location in the southern part of the basin, strongly suggest that they were related to the coastal upwelling of deep Atlantic waters during a period of estuarine circulation between the Atlantic and the Mediterranean (SIERRO *et al.*, 1989, 1990). Deep microfaunas and diatomite sediments are found at least to the Middle Tortonian (approx. 8 to 7 Ma), supporting the hypothesis of a deep communication until that time through this gateway.

During the high sea level periods of the Upper Tortonian the hemipelagic sediments of the Guadalquivir basin were affected by bottom currents. These sediments were compared to recent sediments of the Gulf of Cadiz winnowed by the Mediterranean outflowing Waters (MOW) (SIERRO & FLORES, 1989; FLORES, SIERRO & BARAZA, 1991).

Immediately prior to the Tortonian Messinian boundary a large volume of olistostromes coming from the South partially filled the basin, causing a fast change in the geometry of the basin The coincidence of this event during a period of low *sea level* probably determined a restriction or closure of the Northbetic strait near the Tortonian-Messinian boundary. At the same time some anomalies were described in the calcareous plankton assemblages of the Mediterranean in relation to those of the Atlantic (FLORES, SIERRO and GLACON, in press; SIERRO *et al.*, in press).



On the other hand, BENSON *et al.* (1991) recognized an Atlantic Mediterranean water reversal near the Tortonian-Messinian boundary based on the occurrence of psychrospheric faunas in the South Rifian Gateway. During the Messinian the South Rifian Basin evolved almost parallely to the Guadalquivir Basin, but probably, the last episodes of water exchange immediately before the Salinity Crisis occurred through the South Rifian Corridor.

After the Messinian salinity crisis the Atlantic-Mediterranean water exchange probably took place through the Gibraltar-Alboran Corridor. The tectonic and sedimentary evolution of this area have conditioned the exchange dynamics since the Pliocene. The sea level rise approximately isochronous with the Micene-Pliocene boundary which reestablishes the communication is recorded in the Guadalquivir Basin by a condensed section related to a downlap surface.

REFERENCES

BENSON R.H., 1976.- Miocene Deep Sea Ostracodes of the Iberian portal and the Balearic Basin. *Mar. Micropaleont.*, 1:249-262.
BENSON R.H., EL-BIED RAKIC K. & BONADUCE G., 1991.- An important water mass "reversal" in the Rifian Corridor (Morocco) at the Tortonian-Messinian boundary. *Paleoceanography*, 6(1):164-192.
BETHOUX J.P., 1984.- Paléo-hydrologie de la Méditerranée au cours des derniers 20 000 ans. *Oceanol. Acta*, 7,1:43-48.
FLORES J.A, SIERRO F.J. & BARAZA J., 1991.- Preliminary data on the Holocene Calcareous Nannoflora assemblage in the Gulf of Cadiz (Spain). *INA newsletter*, 13/2, 49.
FLORES J.A., SIERRO F.J. & GLAÇON G., (Submited to Micropaleontology) Calcareous plankton analysis in the pre-evaporitc sediments of the ODP site 654 (Tyrrhenian Sea, Western Mediterranean).
SIERRO F.J. & FLORES J.A., 1989.- Winnowed sediments in the Guadalquivir basin. Evidence of an Atlantic/Mediterranean water flow exchange before the Mediterranean salinity crisis? Abstract. Third International Conference on Paleoceanography, Cambridge, 1989.
SIERRO F.J., FLORES J.A., BARCENA M.A., CIVIS J. & GONZALEZ-DELGADO J.A., 1990.- Afloramientos de aguas profundas atlanticas en el Estrecho Norbético: Implicaciones en la dinamica Atlantico-Mediterraneo durante el Mioceno. *Resumenes V Jornadas de Paleontologia*. Valencia, 1990,147-148.
SIERRO F.J., FLORES J.A., CIVIS J., GONZALEZ DELGADO J.A. & FRANCES G., in press.- Late Miocene Globorotaliid event stratigraphy and biogeography in the Atlantic and Mediterranean. *Mar. Miocropaleontol.*
VERGNAUD GRAZZINI C., 1983.- Reconstruction of Mediterranean Late Cenozoic hydrography by means of carbon isotope analyses. *In*: Reconstruction of marine paleoenvinonments. *Utrecht Micropaleont. Bull.*, 30: 35-69.

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