Holocene changes in deep-water circulation of the Western Mediterranean Basin, links to North Atlantic climate variability

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Abstract: *preliminary results from multicores recovered in the Minorca sediment drift, south of the Western Mediterranean Deep Water formation area, reveal changes in deep-water circulation during the last 2500 yr. Records of grain-size and SST Mg/Ca derived from G. bulloides show oscillations in deep-water current intensities that could be related to cool periods on land, i.e. the Little Ice Age, but also denote some relationship with changes in sea surface salinity likely associated with changes in continental humid conditions.*

Key words: *grain-size, sea surface temperatures, contouritic drift, deep-water circulation, Holocene*

INTRODUCTION

Deep-water formation in the western Mediterranean basin takes place during wintertime due to north-westerly winds cooling of surface waters in the Gulf of Lion (GoL) leading to offshore overturning (Millot, 1999) and/or Dense Shelf Water Cascading (DSWC) (Canals *et al.*, 2006), sinking and spreading by the deep basin as Western Mediterranean Deep Water (WMDW). Equilibrium-depth reached after sinking should be related to the density acquired during the cooling process which depends on the prevalent climate conditions. Accordingly, WMDW flows southward carrying the climate signal from the surface to the deep basin.

South of the area of deep-water formation, the Balearic Promontory acts as a natural topographic barrier that shifts WMDW direction eastward and likely accelerates it bordering the Minorca base of slope leading to formation of a typical peripheral depression and associated sediment drift (Velasco *et al.*, 1996) (Fig. 1). Deep-sea undulations observed in swath-bathymetry and very high seismic reflection data acquired during HERMESIONE cruise onboard the Bio Hesperides during late 2009 demonstrates the importance of intense deep-water currents sweeping this area (Frigola *et al.*, unpublished data) (Fig. 1). Accordingly, the Minorca sediment drift is an invaluable record of past deep-water currents in the Western Mediterranean Basin. In addition, the very high sedimentation rates observed at this site (Frigola *et al.*, 2007) allow carrying out very high resolution studies of past climate conditions.

On previous work *Frigola et al. (2007)* observed millennial-to-centennial scale changes in the grain-size and geochemical composition records of the sediment core MD99-2343 during the Holocene that suggested relative increases of deep-water currents coincident with isotopic enrichments, describing a total of nine ''Minorca abrupt events''. These events occurred at a 1000 yr cyclicity and were tentatively related to North Atlantic climate variability (Grootes and Stuiver, 1997). In order to achieve a very high resolution study of the last 3 millennias, multicores MIN-MC06-1 and MIN-

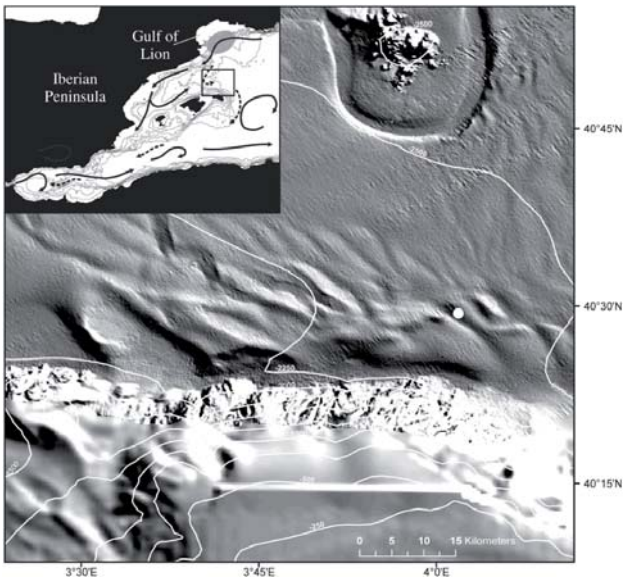

FIGURE 1*. Shaded relief image of the Minorca sediment drift mainly from bathymetric multibeam data (EM120) at 50 m grid-resolution. Note the undulations, lobes and channels created by deep-water currents sweeping the sea-floor. Location of piston core MD99-2343 and multicores MIN-MC06-1 and 2 are showed with a circle. In the upper map, the grey circle show the area of deep-water formation in the GoL. Continuous and dashed black arrows denote surface and deep water circulation in the Western Mediterranean Basin, respectively.*

MC06-2 of 31 cm and 32.5 cm, respectively, were recovered at different coring stations located in the approximate position of piston core MD99-2343 location (Fig. 1).

RESULTS AND DISCUSSION

Grain-size analyses were performed on the total and the de-carbonated fraction by using a Coulter Laser Size particle analyzer at 0.5 cm resolution. In addition, oxygen isotopes and Sea Surface Temperature derived from Mg/Ca analysis on *Globigerina bulloides* were also performed at 0.5 cm resolution. Multicores were dated by ^{14}C dates on monospecific foraminiferal samples resulting in a mean sedimentation rates of 12 and 20 cm kyr^{-1}, respectively, which are in the order of the 24 cm kyr^{-1} observed at the top of core MD99-2343. Hence, MIN-MC06-1 covers the last 2500 yr while MIN-MC06-2 covers the last 1600 yr, reaching a time resolution of 40 and 20-40 yr, respectively.

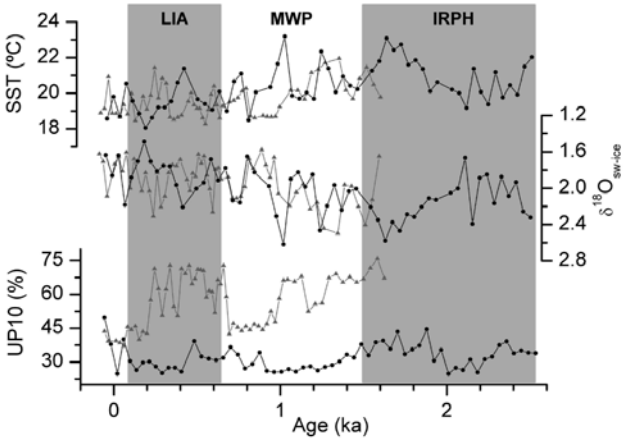

***FIGURE 2**. SST (ºC) Mg/Ca derived from G. bulloides, $d^{18}O_{sw\text{-}ice}$, and UP10 fraction (grain-size fraction above 10 microns) from MIN-MC06-1 (black curve) and MIN-MC06-2 (grey curve).*

Grain-size results from multicore MIN-MC06-1 and 2 show two main increases in the UP10 fraction. While the youngest one can be related to the Little Ice Age (LIA) cold period, the other event occurs during the late phase of the «Iberian Roman Holocene Period» (IRHP) (Fig. 2) and likely denotes changes in the salinity of the surface waters due to drier conditions on land (Martin-Puertas *et al.*, 2009) instead of a cooling period. This interpretation is supported by a significant increase in $d^{18}O_{sw\text{-}ice}$ derived from $d^{18}O$ and SST (Herrera, in prep.) (Fig. 2). In addition, SST Mg/Ca derived on *G. bulloides* from these multicores show a variability that, although is not always in phase, could be related to changes in solar intensity at mid-latitudes. The non total synchrony observed between these multicores is likely related to uncertainties in the chronologies and could also respond to complex sedimentation processes affecting location of both multicores due to deep-water circulation through the channels shaping the Minorca sediment drift (Fig. 1). Finally, more devoted investigation is still needed to better describe the effects of WMDW on the deep basin.

CONCLUSIONS

Preliminary results from two multicores recovered in the Minorca sediment drift reveal grain-size and SST-Mg/Ca derived variability that can be related to recent climatic periods. Coldest SST are related to the Little Ice Age. Changes in humidity that increased surface salinity appear to be related to stronger deep water currents particularly during the IRHP. More detailed study is still needed but these results show the high potential of this sediment environment as record of recent past climate conditions.

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REFERENCES

Canals, M., Puig, P., de Madron, X.D., Heussner, S., Palanques, A., and Fabres, J., 2006, Flushing submarine canyons: Nature, v. 444, p. 354-357.

Frigola, J., Moreno, A., Cacho, I., Canals, M., Sierro, F.J., Flores, J.A., Grimalt, J.O., Hodell, D.A., and Curtis, J.H., 2007, Holocene climate variability in the western Mediterranean region from a deepwater sediment record: Paleoceanography, v. 22, PA2209, doi:10.1029/2006PA001307.

Grootes, G.A., and Stuiver, M., 1997, Oxygen 18/16 variability in Greenland snow and ice with 10^{-3}-to 10^{5}-year time resolution: Journal of Geophysical Research, v. 102, p. 26,455-26,470.

Herrera, G. in prep, Variability of Deep and Intermediate Mediterranean water properties during the last two climatic cycles. PhD Thesis. Universitat de Barcelona.

Millot, C., 1999, Circulation in the Western Mediterranean Sea: Journal of Marine Systems, v. 20, p. 423-442.

Martín-Puertas, C., B. L. Valero-Garcés, A. Brauer, M. P. Mata, A. Delgado-Huertas, and P. Dulski (2009), The Iberian-Roman Humid Period (2600-1600 cal yr BP) in the Zoñar Lake varve record (Andalucía, southern Spain): Quaternary Research, 71, 108-120.

Velasco, J.P.B., Baraza, J., and Canals, M., 1996, La depresión periférica y el lomo contourítico de Menorca: evidencias de la actividad de corrientes de fondo al N del Talud Balear: Geogaceta, v. 20, p. 359-362.