

## Upper North Atlantic Deep Water variability during the Holocene

THOMAS M. MARCHITTO AND PETER B. DEMENOCAL

Lamont-Doherty Earth Observatory of Columbia University,  
Palisades, NY 10960 (tmarchit@ldeo.columbia.edu,  
peter@ldeo.columbia.edu)

The earth's climate has been relatively stable over the past 10,000 yr (the Holocene epoch) when compared with glacial times. However, recent work in the North Atlantic has established the presence of significant Holocene cooling events that recur approximately every 1-2 kyr. These events are evident in the southward extent of drift ice and in inferred sea surface temperatures, but as of yet there has been no convincing chemical evidence for associated changes in deep water circulation. Here we examine the Holocene properties of upper North Atlantic Deep Water (NADW) using high-resolution sediment cores from two sites in the North Atlantic.

Ventilation of Labrador Sea Water (LSW), the uppermost component of NADW, is known to be very sensitive to surface ocean forcing today. We present benthic foraminiferal (*Cibicidoides pachyderma*) Mg/Ca and  $\delta^{18}\text{O}$  data from a core on the Laurentian Slope (~1800 m depth) that is well situated to monitor the properties of LSW during the late Holocene. Mg/Ca indicates that during cold periods such as the Little Ice Age, LSW was colder by ~1-3°C. Paired  $\delta^{18}\text{O}$  measurements suggest that cooling was accompanied by freshening, resulting in lower densities during cold periods. This coupling between temperature and salinity is also characteristic of the LSW historical record, but with a much smaller range of variability than we observe on millennial timescales.

Farther downstream, core ODP 658 off northwest Africa (~2300 m depth) is bathed by NADW with a slight admixture of high-nutrient Circumpolar Deep Water. Since Cd and Zn behave like nutrients in seawater, benthic foraminiferal records of these two trace metals may be used to reconstruct the competition between northern and southern source deep waters during the past. Preliminary benthic (*C. wuellerstorfi*) Cd/Ca and Zn/Ca results do not exhibit any obvious relation to the 1-2 kyr Holocene cooling events. Cd/Ca and Zn/Ca do, however, suggest a substantial long-term decrease in nutrients since the mid Holocene. This could indicate an increase in the production of NADW associated with late Holocene (Neoglacial) cooling. Alternatively, it could represent an evolution of "preformed" nutrient concentrations in the North Atlantic.

## Multi-component reactive transport modelling at the Ratones Uranium Mine (Spain)

A. MARCUELLO<sup>1</sup>, P. GÓMEZ<sup>2</sup> M.W. SAALTINK<sup>3</sup>,  
C. AYORA<sup>4</sup>, J. CARRERA<sup>5</sup>

<sup>1,3,5</sup> Departament of geotechnics and Applied GeoScience,  
Technical University of Catalonia (UPC), Barcelona,  
Spain <sup>1</sup>(amaranta.marcuello@upc.es)

<sup>3</sup>(maarten.saaltink@upc.es) <sup>5</sup>(jesus.carrera@upc.es)

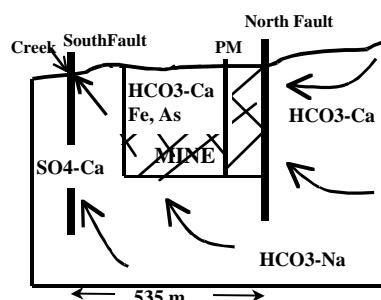
<sup>2</sup> CIEMAT, Avda Complutense 22, E-28040 Madrid, Spain  
2(paloma.gomez@ciemat.es)

<sup>4</sup> Institut Jaume Almera, CSIC, Lluís Solé i Sabaris, s/n, E-  
8028 Barcelona, Spain <sup>4</sup>(cayora@ija.csic.es)

Multi-component reactive transport has been modelled along flow lines around an ancient uranium mine in the west of Spain in a granitic fractured media (figure 1). Because of the reducing conditions and neutral pH, uranium is not a potential contaminant. However, some groundwater samples show extremely high Fe (up to 16 mg/L FeIII) and some As concentrations. Model results allow us to explain a good portion of the experimental data. SO<sub>4</sub><sup>2-</sup>, Fe<sup>2+</sup>/Fe<sup>3+</sup> and As concentrations and pH and pe values are controlled by sulphide and sulfoarsenide oxidation, ankerite dissolution and ferric hydroxide and siderite precipitation. The observed low values of pe can only be explained by assuming sulphide oxidation by Fe<sup>3+</sup> in the deep part of the system. On the other hand, As co-precipitation with goethite does not seem to play a significant role because little mineral precipitates. This, together with the high Fe(III) concentration remains to be explained. Cation exchange with smectites present as fracture filling can explain the evolution from shallow calcium-carbonate water to sodium-carbonate water at depth.

Calculations were performed with RETRASO (Saaltink et al, 1998). This work has been funded by ENRESA.

Figure 1: Vertical section of the Mine showing the groundwater flow and chemical composition.



### References:

- Saaltink M.W., Ayora C. y Carrera J. (1998).- A mathematical formulation for reactive transport that eliminates mineral concentrations. *Water Resources Research.*, 34: 1649-1656.