

# Sedimentation, reworking and preservation of organic matter in surficial sediments of the N-W african upwelling system

E. Lallier-Vergès

UMR 6531-FR09 CNRS, Université d'Orléans, Géosciences  
45067 Orléans, France

P. Martinez  
P. Bertrand

UMR 5805 CNRS, Université Bordeaux I, 33405 Talence, France

C. Rabouille

CFR-CNRS, Avenue de la Terrasse, 91198 Gif/Yvette, France

D. Kéravis

UMR 6531-FR09 CNRS, Université d'Orléans, Géosciences  
45067 Orléans, France

Previous studies performed on ancient marine sediments enriched in organic carbon have demonstrated the main role of microbial diagenesis in the acquisition of petrographic and geochemical characters of organic matter (OM). Among the main microbial processes involved in OM degradation/preservation, a major role has been devoted to the sulphate reduction which, associated to a large organic delivery from the photic zone, may explain the high hydrocarbon potential of some organic sediments. This process has been recognized in ancient source-rocks from the Kimmeridge Clay Formation from U.K. (i.e. Boussafir *et al.* 1995) as in modern upwelling sediments from Oman and Peru Margins (i.e. Eglinton *et al.* 1994). The early microbial sulphate reduction is thought to enhance the preservation of lipid-rich OM by the natural sulphuration pathway of labile lipidic molecules. The aim of this study is to recognize in a modern upwelling environment assumed to be submitted to a high organic production, the role of such processes on the present preservation of OM. For this, a combined petrographic and geochemical study of total OM has been performed on surface sediments recovered by a multi-tube corer, at different water-depths along a W-E transect, below the upwelling zone of Mauritania (SEDORQUA cruise, Bertrand *et al.* 1996).

## Porewaters

The downcore porewater analyses display the main successive degradation processes observed in marine environments. The surficial sediments are well-oxygenated (Jorissen *et al.*, in press) as revealed by the O<sub>2</sub> concentrations (160 to 220 µmol/l). Below 1 to 2 cm beneath the water-sediment interface, they

support denitrification conditions as observed on O<sub>2</sub> and NO<sub>3</sub> profiles. Sulphate reduction is presently efficient below 5 cm which is the depth where NO<sub>3</sub> concentrations are close to 0. Deeper the water-column of the sample location is, deeper in the sediment the redox limit appears.

## Palynofacies studies

Several typical organic components previously identified in recent marine sediments have been found. Amorphous organic matter is the dominant constituent while recognizable organic structures are only in minor quantities (marine microfossils and blade-shaped higher-plant debris). Whatever the depth in the core is, the sedimentary OM deposited at shallow depths is composed of a dominant 'optically' amorphous orange OM as in Oman and Peru Margins (Lückge *et al.* 1996). Its proportion in surface sediments diminishes with increasing water-depths while proportions of a texturally degraded brown OM increase.

## Geochemical analysis

<sup>210</sup>Pb measurements indicate higher activities in surface sediments at 1200m (52 dpm/g) than at 3010m (36 dpm/g) due to the higher organic sedimentation rates at shallower depths. The <sup>210</sup>Pb vertical profiles show that bioturbation exists from the water-sediment interface in 7S core but only in a sub-surface layer (5–15 cm) in 11S core. For these bioturbated zones, the calculated bioturbation rates are quite similar (0.54 cm<sup>2</sup>/y at 3010 m and 0.41 cm<sup>2</sup>/y at 1200 m). In surface sediments, TOC contents obtained by Rock Eval pyrolysis vary between c. 5.2% and 1.2% with increasing water-depths. HI

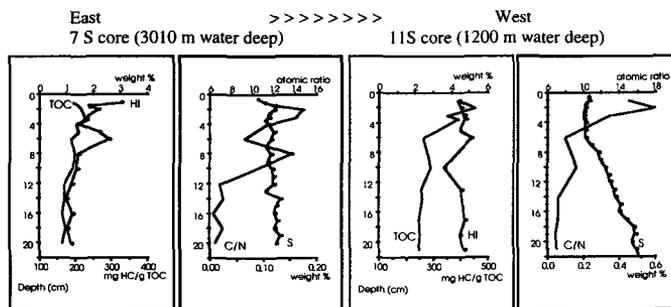


FIG. 1. Tracing subsurface water flowpaths by means of dissolved Ba/Sr, Ca/Sr and  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios.

values, typical of type II organic matter, vary between *c.* 400 and 300 mg HC/g TOC as the TOC contents do. Atomic C/N values, typical for OM deriving from marine algae, decrease from 18 to 11 with increasing water-depths. Similarly, the total S contents range from 0.22% to 0.08% and the total sulphide contents from 0.2% to 0.01%. This general evolution in surface sediments shows the enhancing effect of organic degradation with increasing water-depth. This is due first to a larger distance from the productive upwelling cell and also to a longer transit time linked to both greater water column and more pronounced advection.

Only the two sites with contrasted water-depths are herein presented (fig. 1). The shallower core, recovering the higher organic fluxes, presents the higher TOC values which decrease down the very first centimetres until the present sulphate reduction boundary. The deeper core does not present the uppermost diminution of TOC but only slight variations until stable values around 1%. The C/N profiles exhibit typical degradation profiles with enrichment in nitrogen probably by adsorption onto clay minerals, with stable values under the bioturbated zone. HI values diminish in 7S core but stay around 400 mg HC/g TOC in 11S. Despite the low sulphur values, the S content, sulphide contents and associated trace elements as Mo continuously increases from the water-sediment interface to the base of the cores. This increase is present whatever the TOC profile is. Geochemical analyses of OM reveal that the S/Fe ratio is close to the pyrite one, excepted in the buried sediments (> 10 cm) where it is slightly higher, showing small amounts of organic sulphur (0.5–0.8 sediment weight %).

## Discussion

With increasing depth in the cores, the OM decay is

observed through a rapid TOC decrease in the first 5–6 cm of the shallower cores. A comparison with other techniques for organic carbon analysis reveals that hydrolyzable and volatile OM is still abundant in these surface sediments (*c.* 50% of OM). Below this surface layer, the sediments of shallower site (11S), despite the microbial degradation, reveal stable organic carbon content which is two times higher than at the deep-water site. The effects of the microbial sulphate reduction are visible downcores as seen by the continuous increase of sedimentary sulphide contents. These peculiar S profiles without TOC variation associated suggest a continuous sulphur fixation with time due to a prolonged degradation of metabolizable OM and sulphate supplied downwards by porewaters. This may also be the reflect of upwards  $\text{HS}^-$  diffusion in porewaters. In conclusion, at shallower water-depths compared to deeper ones, below the 5 upper cm, anoxic sediments contain a resistant OM with a good hydrocarbon potential and in the mean time an increased sulphide content (pyrite and a few organic sulphur). Assuming the encountered organic sulphur content, the early sulphuration is here likely not much involved in organic preservation as proposed for Holocene sediments from the same location (Zeghouah, unpubl. thesis, Paris). This is thought to be due to the present medium organic fluxes which permit the degradation of metabolizable compounds during transportation by oxic and suboxic processes and do not allow abundant labile lipids to enter the anoxic domain, in order to be largely sulphurized. This effect is probably amplified by advection, which increases the residence time of particles in water column and oxic water-sediment interface through successive deposition and reworking (Biscaye and Anderson, 1994). However it is expectable that natural sulphuration may be amplified during periods of larger organic delivery: glacial times for example.