Organic matter preservation in sediments from the North-West African upwelling system

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Coastal upwelling systems are characterized by a high primary productivity, due to wind driven currents that bring to the surface deep, nutrient-rich, water. Intense productivity in these regions is frequently, but not systematically, associated with the formation of organic-rich sediments. The highest rates of organic matter (OM) accumulation in the modern ocean are thus found in some areas beneath upwelling (Calvert, 1987) and high TOC values, up to 16%, were observed for upwelling sediments offshore Peru and Oman (e.g. Eglinton *et al.*, 1994; Lückge *et al.*, 1996). Upwelling regions thus play an important role for OM burial in marine sediments, although they represent less than 1 % of the total surface of ocean. Indeed, the comparison of the assumed location of palaeo-upwellings and of organic-rich deposits indicated that up to half of marine source rocks may originate from upwelling zones (Parrish, 1987). Understanding the mechanism(s) of OM preservation in coastal upwellings and the factors that control OM accumulation in such areas is therefore important. Accordingly, a number of molecular studies were carried out on the OM of sediments underlying upwelling systems. However, they have mostly been concerned, so far, with soluble constituents and they mainly dealt with samples originating from the Peru upwelling.

Studied samples and purposes

The present work was concerned with samples from the North-West African upwelling (Morocco-Mauritania margin), one of the five main upwelling regions in the world. This system underwent large cyclic variations in intensity, reflecting global climate changes, during the last 200,000 years (Sarnthein *et al.*, 1992; Bertrand *et al.*, 1996). It is characterized by low continental riverine inputs since the inland chiefly corresponds to the Sahara. Two samples from the same core, corresponding to the beginning of glacial isotope stage 4 (*c.* 70,000 years; depth bsf 360 cm) and to interglacial isotope substage 5d (ca 90,000 years; depth bsf 480 cm), were examined along with a surface sample. The study was focused on the insoluble and non-hydrolysable fraction of the OM. The main purposes were (i) to examine the abundance and chemical structure of such a refractory organic material (ROM), (ii) to compare the above features for samples deposited under different climatic conditions, (iii) to determine, among the four mechanisms now recognized for sedimentary OM preservation, which one(s) was (were) implicated in the formation of these ROMs and (iv) to draw comparisons between sediments underlying the North-West African and Peru upwelling systems.

To this end, the crude sediments were submitted to extractions and successive drastic chemical treatments for eliminating both the bulk of the mineral compounds and the soluble and hydrolysable organic constituents. The chemical structure of the ROMs thus isolated was examined via a combination of spectroscopic and pyrolytic methods; its morphological features were also examined *via* transmission and scanning electron microscopy.

Results and conclusions

The main observations derived from these combined studies are:

(1) Substantial amounts of ROM (accounting for *c.* 20% of total OM) occur in the two core samples and, although to a lesser extent, in the surface sediment (*c.* 10%).

(2) Similar morphological features and chemical composition were observed for the ROMs isolated from the three samples.

(3) ROMs in the three sediments were formed *via* a degradation-recondensation process: i.e. the classical degradation-recondensation pathway and/or the related, recently recognized, 'sorptive protection' pathway, which implication might be favoured by the presence of clay minerals.

(4) These ROMs are chiefly composed of melanoidin-type macromolecules, originating from the condensation of degradation products mainly derived from proteinaceous material.

(5) ROM formation started in the water column and went on within the sediment.

(6) The two core samples do not exhibit significant differences in ROM relative abundance and composition, although the 360 cm sample shows a substantially higher content in total organic matter (TOC of 1.6 instead of 0.9%). Thus, the higher primary productivity during the colder period was not associated with changes either in the relative contribution of the refractory fraction to total sedimentary OM, or in its mode of formation and chemical structure.

(7) Comparisons with previously described sediments from the Peru upwelling zone (Eglinton *et al.*, 1994) revealed important differences in total OM abundance (TOC of *c.* 10% for the Peru samples against < 2% for the North-West African ones) and in preservation mechanism (natural sulphurization instead of degradation-recondensation). Such contrasted features shall reflect the combined influence of several factors, including upwelling intensity (primary productivity), water depth and, possibly, iron supply.

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