

A test for oxygen-sensitive organic matter in modern sediments off the Washington coast

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We have tested the hypothesis that the amounts and types of organic matter preserved in marine sediments represent a dynamic balance between protective sorption to mineral grains and slow oxic degradation during deposition (see Hedges and Keil, 1995; Hartnett *et al.*, 1998). We tested for oxygen-sensitive organic matter by measuring organic carbon/mineral surface area (OC/SA) ratios, and the isotopic, biochemical and pollen compositions, of sediments accumulating along a transect off the Washington State coast (e.g. Prahl *et al.*, 1994; Keil *et al.*, 1994). The time periods over which depositing particles were exposed to O₂ in surface pore waters were estimated at five sites by dividing the depth of O₂ penetration by the average sedimentation rate determined from ¹⁴C profiles.

Results and discussion

A total of >200 sediment samples were analysed from 16 different cores collected at seafloor depths of 100 to 2750 m. The relatively positive $\delta^{13}\text{C}$ values

(-22 to -23‰) and intermediate atomic C/N values (10 to 15) measured at these sites indicate that these sediments contain predominantly marine-derived organic matter. A more consistent offshore decrease in OC/SA was observed than for weight percent organic carbon, indicating that surface-area normalization provided a more useful comparison of organic contents and degradation histories.

The 16 sampling sites represented a range of bottom water O₂ penetration depths, sediment accumulation rates and corresponding O₂ exposure times. Oxygen penetration depths ranged from 0.5–3.5 cm, whereas average sediment accumulation rates decreased seaward from 0.042 to 0.005 cm/yr. The corresponding oxygen exposure times ranged from decades (nearshore) to millennia (~ 175 km offshore). The OC/SA ratios measured in nearshore sediments were in the range (~0.5–1.00 mgOC/m²) typical of upper continental margin deposits, but decreased exponentially offshore as O₂ exposure times increased (Fig. 1). Organic materials accumulating farther offshore also were more degraded, as

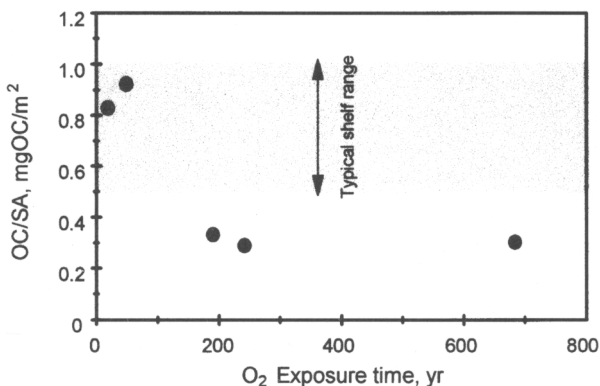


FIG. 1. Organic surface loading of Washington coast sediments.

indicated by high fractions of deoxy sugars and nonprotein amino acids, elevated ratios of vanillic acid to vanillin, and increased percentages of physically-eroded pollen grains. Parallel patterns have been observed in oxidized surface horizons of a deep-sea turbidite, where the only evident reason for these offsets is long-term exposure ($>10^3$ yr) of the upper portion of these initially homogeneous deposits to O_2 diffusing in from overlying bottom water (Cowie *et al.*, 1995).

Conclusion

Organic concentrations per unit mineral surface area, and an array of degradation indicators, demonstrate that extended exposure to molecular oxygen severely limits preservation of organic matter in surface marine sediments accumulating along the Washington margin. Oxidic degradation of organic matter in slowly depositing offshore sediments produces a distinct pattern of compositional offsets

that closely parallel those characterizing oxidized horizons of deep-sea turbidites. If representative of other continental margin regions, the observed losses of oxygen-sensitive sedimentary organic materials are sufficiently extensive to affect the global cycles of carbon and oxygen over geologic time.

References

- Cowie, G.L., Hedges, J.I., Prahl, F.G. and de Lang, G.J. (1995) *Geochim. Cosmochim. Acta*, **59**, 33–46.
- Hartnett, H.E., Keil, R.G., Hedges, J.I. and Devol, A.H. (1998) *Nature*, **391**, 572–4.
- Hedges, J.I. and Keil, R.G. (1995) *Mar. Chem.* **49**, 81–115.
- Keil, R.G., Tsamakis, E., Giddings, J.G., and Hedges, J.I. (1994) *Geochim. Cosmochim. Acta*, **57**, 879–893.
- Prahl, F.G., Ertel, J.R., Goñi, M.A., Sparrow, M.A., and Evesmeyer, B. (1994) *Geochim. Cosmochim. Acta*, **58**, 3035–48.