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Oxic Sediments

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Definition

Pore waters within oxic sediments contain measureable amounts of dissolved oxygen. In general, pore water oxygen concentrations decline with depth due to organic matter degradation. The depth of oxygen penetration varies depending on the sedimentation rate, mixing processes, the flux and type of organic carbon, and the oxygen content of bottom waters.

Overview

Sediments at the seafloor are porous and poorly consolidated and thus readily allow diffusion of bottom waters and the dissolved gases that they contain into the sediment. With depth, sediments undergo compaction and eventually lose contact with overlying seawater. While sediment pore waters at or close to the sediment-water interface in the global ocean commonly contain dissolved oxygen, the concentration of oxygen declines with depth due to organic matter degradation.

Deposited organic matter is degraded at the seafloor and during burial in the sediments, with less than 1% surviving to become part of the rock record (Emerson and Hedges 1988). Aerobic respiration is the first pathway used by microbes for organic matter degradation, as it is associated with the largest free energy yield. As such, aerobic respiration is responsible for the majority of organic carbon remineralization in the oceans and sediments (Bender and Heggie 1984). At low dissolved oxygen concentrations (<10 μM), the rate of aerobic respiration begins to decline, and anaerobic respiration processes may proceed with alternate electron acceptors (▶ "Suboxic Sediments", this volume). Aerobic respiration tends to be most prolific at the sediment-water interface, but oxygen may be present in pore waters for centimeters or even meters below the sediment-water interface.

The depth of oxygen penetration in sediments is highly variable and is controlled by the chemical, physical, and biological setting. One major control is the concentration of oxygen in overlying bottom waters. The concentration of dissolved oxygen in surface waters is set by atmospheric oxygen levels, as well as the solubility of O_2 gas in water, which is itself controlled by salinity and temperature. At depth in the water column, oxygen is consumed by respiration, but the rate of

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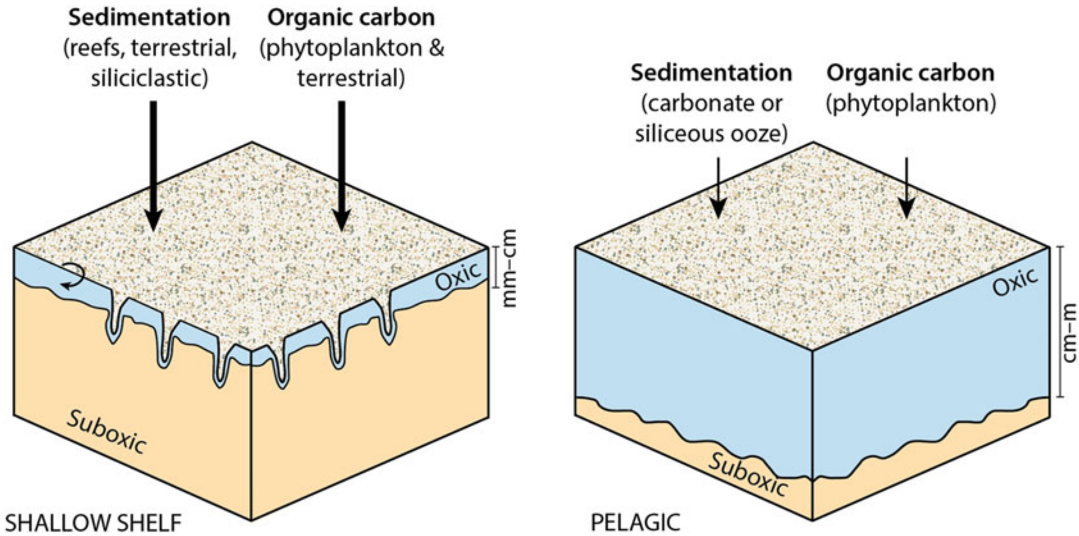

Oxic Sediments, Fig. 1 The depth of the oxic zone in sediments is partly controlled by the sedimentation rate, the flux of organic matter, and mixing processes. In general, the oxic zone extends deeper into the sediments in pelagic settings where sedimentation rates and organic carbon fluxes are lower

decline depends on the local carbon cycle and mixing rates. Oxygen levels in oceanic bottom waters vary from up to 300 µM below polar surface waters to <5 µM below oxygen minimum zones in intense upwelling regions. Higher oxygen levels at the sediment-water interface increase the average depth to which oxygen can persist in the sediments.

Sedimentation rate exerts another important control on the depth of oxygen penetration, by influencing the amount of time organic matter remains exposed at or near the sediment-water interface (Fig. 1). Under the high sedimentation rates common in coastal and shallow shelf environments (~1 mm year^{-1}), organic matter rapidly loses contact with overlying bottom waters. Therefore, a relatively large fraction of organic matter is often buried in such sediments, and oxygen in pore waters is rapidly consumed (Fig. 1). In contrast, under the low sedimentation rates common in deeper water settings (<0.01 mm year^{-1}), organic matter remains exposed to oxic bottom waters for longer (thousands of years), and so there is less organic carbon leftover to drive anaerobic heterotrophic communities in the sediments.

Mixing in shallow water environments can disturb any stratification, bringing anoxic sediments from a few centimeters depth back into contact with oxic bottom waters. Mixing may occur mechanically, for example, during storm events or, biologically, through bioturbation (Kristensen 2000). More intense mixing results in re-oxidation of reduced species and allows deeper oxygen penetration (Fig. 1). The properties of the sediments can influence the degree of contact between bottom waters and pore waters. For example, fine-grained sediments, such as mud, have a lower porosity and so limit diffusion of oxygen from bottom waters into pore waters. This facilitates a steeper oxygen gradient than coarse-grained sediments, such as sand.

The flux and type of organic matter is also an important variable. Large fluxes of organic matter, as are common in coastal environments, can result in more rapid consumption of the available oxygen in shallow sediments. Furthermore, organic matter varies considerably in terms of its reactivity, with phytoplankton-derived carbon easier to digest than terrestrial organic matter which contains more refractory plant lignin. All of these parameters contribute to the exposure time of marine sediments to oxic conditions.

Cross-References

► Suboxic Sediments

References and Further Reading

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