



The Phanerozoic record of deep oceanic circulation and anoxia

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The Phanerozoic record of oxygen-deficient conditions in the water column is reviewed, with attention to postulated "oceanic anoxic events" and associated major changes in biodiversity. Special consideration is given to the relative importance, through the Phanerozoic, of the two main types of deep ocean circulation. Halothermal Circulation (HTC), driven essentially by salinity-induced density differences, involves the formation of Warm Saline Deep Water in the tropics and promotes anoxia. Thermohaline Circulation (THC), driven by temperature-induced density differences, is characterised by Cold Deep Water formed at high latitudes and ventilates the deep ocean. The balance between HTC and THC fluctuated during the Palaeozoic (e.g., Silurian "Primo" and "Secundo" episodes) but HTC may have been overwhelmingly dominant around the Permian-Triassic boundary. Evidence from the deep-ocean record of bioturbated sediments suggests that there has always been a Cold Deep Water component in ocean circulation at least since the mid-Cretaceous and possibly since the Triassic. This suggests that even during episodes of widespread oceanic anoxia (such as the Cenomanian-Turonian Boundary Event), some parts of the ocean were ventilated by deep waters originating in high latitudes and may have been refugia for the survival of benthonic organisms.