Ecosystem response to Cretaceous OAEs - the continental perspective

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Cretaceous oceanic anoxic events (OAEs) were marked by persistent marine anoxia–euxinia and globally significant burial of sedimentary organic matter (‘black shales’), associated with major perturbations of the global carbon cycle and likely linked to LIP volcanism. The most pronounced and widespread events are the Early Aptian OAE1a (~121 Ma) and Cenomanian-Turonian OAE2 (~94.5 Ma), both of which were associated with hyperthermal conditions, i.e. significant sea-surface temperature (SST) warming in the range of several degrees. Warm ocean surface and bottom waters in combination with attenuated meridional temperature gradients resulted in reduction of an already sluggish oceanic circulation and were an important driver of organic-carbon accumulation in the world oceans during OAEs.

Despite significant progress in our understanding of the causes and consequences of Cretaceous OAEs in the marine realm, information on the response of continental ecosystems is scarce. Due to the absence of OAE-equivalent continental sequences, the response of terrestrial vegetation can only be studied from palynological assemblages retrieved from marine strata. At present, available spore-pollen OAE records are exclusively derived from northern hemisphere mid-latitude sites located in the western Tethys region.

For the Early Aptian OAE1a, continuous and taxonomically differentiated palynological data-sets are restricted to core and outcrop material from the Belluno (Italy) and Maestrat basins (Spain). Existing records show similar stratigraphic trends in spore-pollen assemblages with a marked increase in thermophile and drought-adapted conifer pollen (*Classopollis* spp.) at the very onset of the OAE1a, followed by a stepwise decline during the main phase of organic carbon accumulation. Above the organic-rich interval, the assemblage is characterized by dominance of bisaccate (Belluno Basin) or araucaria-type (Maestrat Basin) conifer pollen interpreted to reflect subsequent cooling in the aftermath of OAE1a.

Spore-pollen data covering the Cenomanian-Turonian OAE2 interval is reported from the Southern Provencal Basin (France) and Iberian Trough (Spain). In contrast to the gymnosperm-dominated vegetation of the Early Aptian, early Late Cretaceous mid-latitude vegetation already contains significant amounts of angiosperms (dominantly Normapolles-type forms). In the Southern Provencal Basin, combined evidence from TEX_{86} analyses and spore-pollen assemblages documents the dynamics of mid-latitude vegetation to the hyperthermal conditions associated with OAE2. A transient phase of climatic instability and cooling during the exceptionally warm OAE2 episode is marked by the proliferation of open, savanna-type vegetation rich in angiosperms at the expanse of conifer-dominated forest ecosystems.
Despite the exceptionally warm temperature estimates characterizing both mid-Cretaceous OAEs, the continental hinterland (i.e. the palaeo-European archipelago) supported a rich and diverse vegetation, adapted to persist under elevated temperatures. Life-limiting conditions for plant growth due to heat stress associated with OAEs might have persisted in continental interior regions of the subtropics or close to the equator. The changes in terrestrial vegetation observed across the mid-Cretaceous OAEs indicate that volcanogenic global warming severely impacted continental ecosystems resulting in significant compositional and ecological changes and highlight the importance of deep-time data in assessing long-term vegetation response to global climate warming.

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