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Fire in the Earth System: A deep time perspective

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Although the earliest evidence of fire, determined from the presence of fossil charcoal, is late Silurian, it is not until the end of the Devonian that there is evidence of a widespread rise of fire events. This increase appears after the rise of forests in the mid-late Devonian and has been linked to a rise in atmospheric oxygen concentration. From that time onward there is extensive evidence of fire as a major Earth System process. With the occurrence of widespread fires comes the development of several important feedback mechanisms. In the short term, fires may be considered "reverse photosynthesis", as they release CO2 into the atmosphere. However, the production of charcoal, that remains inert on burial, acts as a long-term carbon sink. This charcoal (carbon) burial leads to a reduction of atmospheric CO2 but an increase in O2. Experiments have shown that widespread fires require between 13-15% atmospheric O2 to burn and spread. In addition, increasing atmospheric O2 concentration promotes hotter fires and the combustion of higher moisture content plant matter. More intense fires burning a greater range of vegetation provides further feedback: frequent and intense fires typically lead to extensive post-fire erosion, which in turn causes the rapid burial of more plant material, which again in turn leads to further carbon drawdown. In general, fires occur during drier periods, when potential fuel builds up, but during periods of elevated O2 concentration, such as in the Permian and mid-late Cretaceous, may occur more frequently than at the present day.

Ferns, conifers and angiosperms radiated and diversified during periods of high fire activity and there may be a linkage. Both ferns and weedy angiosperms favour disturbed habitats, while early conifers appear to be adapted to drier environments and many of the earliest are preserved as charcoalified remains. Of particular significance is the interlinkage between increased fire activity and evolution of the angiosperms. Early angiosperms were predominantly herbaceous and appear to have favoured disturbed habitats. As has been noted fires were frequent during this interval and represents a major ecological disturbance factor. A large proportion of our understanding of early angiosperm evolution comes from charcoalified flowers. This is also the case with C4 grasslands where fire appears to be a major contributor to their success. However, we observe a decrease in fire activity from the mid-Eocene onwards, especially in wetland habitats and we note especially the evolution of a more modern tropical rainforest structure that does not promote fire.