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Exploring Early Angiosperm Fire Feedbacks using Coupled Experiments and Modelling Approaches to Estimate Cretaceous Palaeofire Behaviour

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Using the fossil record we are typically limited to exploring linkages between palaeoecological changes and palaeofire activity by assessing the abundance of charcoals preserved in sediments. However, it is the behaviour of fires that primarily governs their ecological effects. Therefore, the ability to estimate variations in aspects of palaeofire behaviour such as palaeofire intensity and rate of spread would be of key benefit toward understanding the coupled evolutionary history of ecosystems and fire.

The Cretaceous Period saw major diversification in land plants. Previously, conifers (gymnosperms) and ferns (pteridophytes) dominated Earth's ecosystems until flowering plants (angiosperms) appear in the fossil record of the Early Cretaceous (∼135Ma). We have created surface fire behaviour estimates for a variety of angiosperm invasion scenarios and explored the influence of Cretaceous superambient atmospheric oxygen levels on the fire behaviour occurring in these new Cretaceous ecosystems. These estimates are then used to explore the hypothesis that the early spread of the angiosperms was promoted by the novel fire regimes that they created.

In order to achieve this we tested the flammability of Mesozoic analogue fuel types in controlled laboratory experiments using an iCone calorimeter, which measured the ignitability as well as the effective heat of combustion of the fuels. We then used the BehavePlus fire behaviour modelling system to scale up our laboratory results to the ecosystem scale.

Our results suggest that fire-angiosperm feedbacks may have occurred in two phases: The first phase being a result of weedy angiosperms providing an additional easily ignitable fuel that enhanced both the seasonality and frequency of surface fires. In the second phase, the addition of shrubby understory fuels likely expanded the number of ecosystems experiencing more intense surface fires, resulting in enhanced mortality and suppressed post-fire recruitment of gymnosperms trees. Both of these were assisted by rising levels of atmospheric oxygen that increased ignitability, surface fire spread rates and fire intensity. Therefore, the expansion and ecological success of the angiosperms appears to have been tied to the coupled influences of the prevailing superambient oxygen levels in the atmosphere and to fuel driven changes in palaeofire behaviour.