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The role of fire in deep time ecosystems

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Fires are very widespread in the world today and fire has also been common in the deep past. Fire is important in structuring contemporary World vegetation maintaining extensive open vegetation where the climate has the potential to support closed forests. The influence of fire on the structure of vegetation and plant traits present in a community vary depending on the fire regime. The fire regime is the characteristic pattern of fire frequency, severity (amount of biomass removed) and spatial extent. Fire regimes depend on the synergy between external physical factors and the properties of vegetation. Changes in the fire regime can be brought about by changes in external conditions such as climate, but also by changes in vegetation such as changes in flammability or productivity that influence the amount of fuel. For example, invasion of grasses into closed wooded habitats has initiated a 'grass fire cycle' in many parts of the world triggering cascading changes in vegetation structure and composition from forest to open grassland or savanna woodland. The spread of flammable invasive species, especially grasses, has even altered fire regimes of fire-dependent flammable communities causing catastrophic ecosystem changes.

We suggest that the spread of angiosperms in the Cretaceous was promoted by the development of novel fire regimes linked to the evolution of novel, highly productive (and flammable) plants. Within the limits of physical constraints on fire occurrence, Cretaceous angiosperms would have initiated a positive feedback analogous to the grass-fire cycle rapidly accumulating fuel that promoted more frequent fires, which maintained open habitats in which rapid growth-traits of angiosperms would be most favoured promoting rapid fuel accumulation etc. Frequent fires would have altered vegetation structure and composition both by increasing mortality rates of fire-damaged trees and reducing recruitment rates of seedlings and saplings where fires recurred before juveniles had reached "fire-proof" sizes. The effect would be to create more open conditions favouring plants with the angiosperm innovations of high photosynthetic rates, rapid maturation and rapid reproduction relative to gymnosperms.

Fire has some analogies to large vertebrate herbivory, particularly in the potential to open forests and create habitat for low-growing sun-loving plants over extensive areas. The role of fire in favouring low-growing 'ruderal', plants of open habitats is similar to that proposed for dinosaurs. A switch from high-browsing dinosaurs in the Jurassic to low-browsing dinosaurs in the Cretaceous has been noted and it has been argued that the switch in browse height would favour fast-growing angiosperms. The dinosaur hypothesis has recently been tested and found wanting, for example in the timing and coincidence of angiosperm abundance and low vs. high-browsing dinosaurs. Our research of the co-occurrence of dinosaur remains and charcoal assemblages in Dinosaur Provincial Park, Alberta, has suggested that it was a dominance of gymnospermous, woody vegetation that was ravaged by fire. In addition, the co-occurrence of dinosaur remains and charcoal is significant in demonstrating that the some dinosaur bone beds may have formed as a result of extensive post-fire erosion/rapid deposition cycles. In this paper we consider the evidence for and against fire as a major factor promoting vegetation change and angiosperm spread in the Cretaceous.