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Pre-Quaternary fires, the carbon cycle and effects on the Earth system.

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Wildfires not only produce soot and microscopic charcoal (often characterized as black carbon) but also macroscopic charcoal typically generated from surface vegetation and litter at a wide range of temperatures. Techniques commonly used to quantify black carbon and soot are poorly suited to analysis of low-temperature and larger charcoal. Most of the coarser charcoal fraction rarely accumulates in soils but is transported by water and accumulates in a range of depositional environments. Charred macro-scopic and meso-scopic charcoals are inert and, once buried, have a relatively greater preservation potential than uncharred plants. Charred fossils can preserve exquisite anatomical details, affording important insights into the vegetation burnt. The geological record of charcoal provides evidence of wildfires from the late Silurian onwards, with rare gaps, such as during the Middle Devonian, probably as a result of extremely low oxygen levels. It was not until the Devonian-Carboniferous boundary, when oxygen levels rose steeply, that wildfires first became prolific. Extensive deposits of charcoal occur in the Mid-Mississippian and coals of the Late Palaeozoic contain abundant charcoal. Many Permian coals contain up to 70% charcoal and it has been proposed from modeling that oxygen levels may have reached levels in excess of 30% at this time. The consequences of this were dramatic. In India alone more than 100,000 million tonnes of charcoal was deposited during the Permian. Many Early Cretaceous and Paleocene coals contain abundant charcoal. Extensive wildfires in the Pre-Quaternary had a major impact upon sedimentary systems through post-fire erosion and as a consequence affected the cycling of carbon. The in-

creased burial of burnt and unburnt organic matter following post-fire erosion events would have caused a long-term reduction in atmospheric carbon dioxide but would also have driven up oxygen levels. This rise in atmospheric oxygen level would have facilitated the burning of wetter vegetation and resulted in more frequent fires, thereby creating an increase in carbon burial and leading to a positive feedback loop. Fire currently has a major effect on the stability, structure and health of many ecosystems and would have had similar influence in the past especially at greatly elevated levels of atmospheric oxygen. While some fires that lead to the burial of charcoal may ultimately contribute to a reduction in the long-term atmospheric carbon dioxide composition, the burning of fossil peats/coals, even by natural fires, will have the reverse effect. It has been claimed that global peat fires at the Paleocene-Eocene boundary may have played a part in the negative isotope excursion at the Paleocene-Eocene Thermal Maximum (PETM: data determined using carbon isotopic compositions and modeling). While charcoal studies indicate evidence of burning of the living and recently senesced biomass we can find no evidence of extensive peat-burning at this time and conclude that this was not a factor in the PETM. The fossil record of charcoal illustrates the profound impact that wildfire must have had upon the Earth System in the past and indicates that the impact of increasing fire frequency and intensity during the current period of rapid Global change should not be underestimated when considering the whole Earth System.