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# Fuelling the palaeoatmospheric oxygen debate: how much atmospheric oxygen is required for ignition and propagation of smouldering fires?

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Fire is a natural process integral to ecosystems at a wide range of temporal and spatial scales and is a key driver of change in the Earth system. Fire has been a major influence on Earth's systems since the Carboniferous. Whilst, climate is considered the ultimate control on global vegetation, fire is now known to play a key role in determining vegetation structure and composition, such that many of the world's ecosystems can be considered fire-dependant. Products of fire include chars, soots and aromatic hydrocarbon species all of which can be traced in ancient through to modern sediments.

Atmospheric oxygen has played a key role in the development of life on Earth, with the rise of oxygen in the Precambrian being closely linked to biological evolution. Variations in the concentration of atmospheric oxygen throughout the Phanerozoic are predicted from models based on geochemical cycling of carbon and sulphur. Such models predict that low atmospheric oxygen concentrations prevailed in the Mesozoic (251-65ma) and have been hypothesised to be the primary driver of at least two of the 'big five' mass extinction events in the Phanerozoic. Here we assess the levels of atmospheric oxygen required to ignite a fire and infer the likely levels of atmospheric oxygen to support smouldering combustion.

Smouldering fire dynamics and its effects on ecosystems are very different from flaming fires. Smouldering fires propagate slowly, are usually low in temperature and represent a flameless form of combustion. These fires creep through organic layers of forest ground and peat lands and are responsible for a large fraction of the total biomass consumed in wildfires globally and are also a major contributor of carbon dioxide to the atmosphere. Once ignited, they can persist for long periods of time (months, years) spreading over very extensive areas of forest and deep into soil. Smouldering fires are therefore, the oldest continuously burning fires on Earth.

We have combined expertise from both the Earth science and fire engineering disciplines to develop realistic ignition mechanisms and measurements of fire propagation within different levels of atmospheric oxygen. We present data from experimental burns run in the fully controlled and realistic atmospheric environment of the UCD PÉAC facility. The burns are designed to develop our understanding of ignition of fires in the natural world. We have studied ignition and propagation of fire in peat, a natural and highly flammable substance. Peat samples of approximately 100mm by 100mm in cross section and 50mm in depth were exposed to an ignition source ($\sim$100W of electric power) for 30 minutes. Thermocouples were placed throughout the sample to measure temperature changes during the initial 30 minute ignition phase and in order to observe ignition of the peat, intensity of combustion and spread of the smouldering front within the different atmospheric oxygen settings.

We show that ignition and propagation of smouldering in peat does not occur below 16% atmospheric oxygen and that smouldering combustion continues for long periods ($\sim$4 hours in the size sample used) at 18% atmospheric oxygen and above. This suggests that atmospheric levels above 16% atmospheric are required to allow ignition and propagation of smouldering fires and that frequent occurrences of wildfires might only be expected in the geological past when atmospheric levels were above 18% oxygen. Fires play an important role in Earth's biogeochemical cycles; this work suggests that fire feedbacks into the Earth system would likely have been suppressed during periods of low atmospheric oxygen.