Exploring New Methodologies for Studying Paleofire

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Introduction

- The Carboniferous has a rich plant fossil record that captures numerous well-preserved *in situ* assemblages
- Carboniferous charcoal records indicate prevalent wildfire associated with higher than present atmospheric Oxygen levels
- Our understanding of the behavior and paleoecological impacts of wildfire under hyperoxic conditions is limited
- Methods for modeling extant wildfires and their impacts can be applied to paleo-landscapes
- My aim is to combine experimental hyperoxic combustion work using extant plants as paleofuel analogs with wildfire models applied to reconstructed paleo-landscapes, in order to better characterize the role of fire in Carboniferous ecosystems

Types of Wildfire

Crown Fuels: canopies of taller trees, emergents.

Ladder Fuels: intermediate height trees and shrubs, lower branches on tall trees, vines. *Critical to surface fire to crown fire transition.*

Surface Fuels: duff, litter, surface logs, shrubs, grasses. *Most consumed layer during wildfire; critical to suppression and restoration efforts.*

Ground Fuels: deep duff, roots, buried logs. *Sometimes smolders instead of undergoing flaming combustion.*

Passive Crown Fire: Surface fire that occasionally moves into the crown.

Active Crown Fire: Sustained crown fire that moves with the surface fire below.

Independent Crown Fire: Sustained crown fire that continues even in the absence of surface fire.

Describing Wildfire

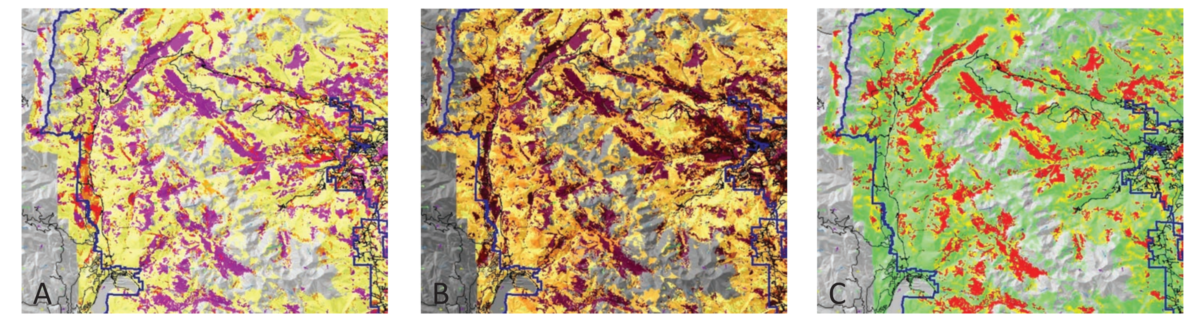
Topography	Weather	Ladder & Crown Fuels
Slope	Wind	Crown base height
Peaks & valleys	Relative humidity	Canopy cover & distribution
		Canopy density & fuel load

Fire Behavior	Ground & Surface Fuels	First Order Impacts
Rate of spread	Dead vs alive	Burn area and patchiness
Fireline intensity	Size class	Burn intensity
Torching & crowning	Surface area to volume	Total biomass consumed
Fuel consumption	Fuel bed continuity	Mortality
Smoldering vs flaming		

Modeling Wildfire

Pseudoempirical Models

Use a combination of simplified physical descriptions of fire behavior and empirical measurements. Most commonly used programs are based on the Frandsen-Rothermel equations, which model fire spread as a series of ignitions.



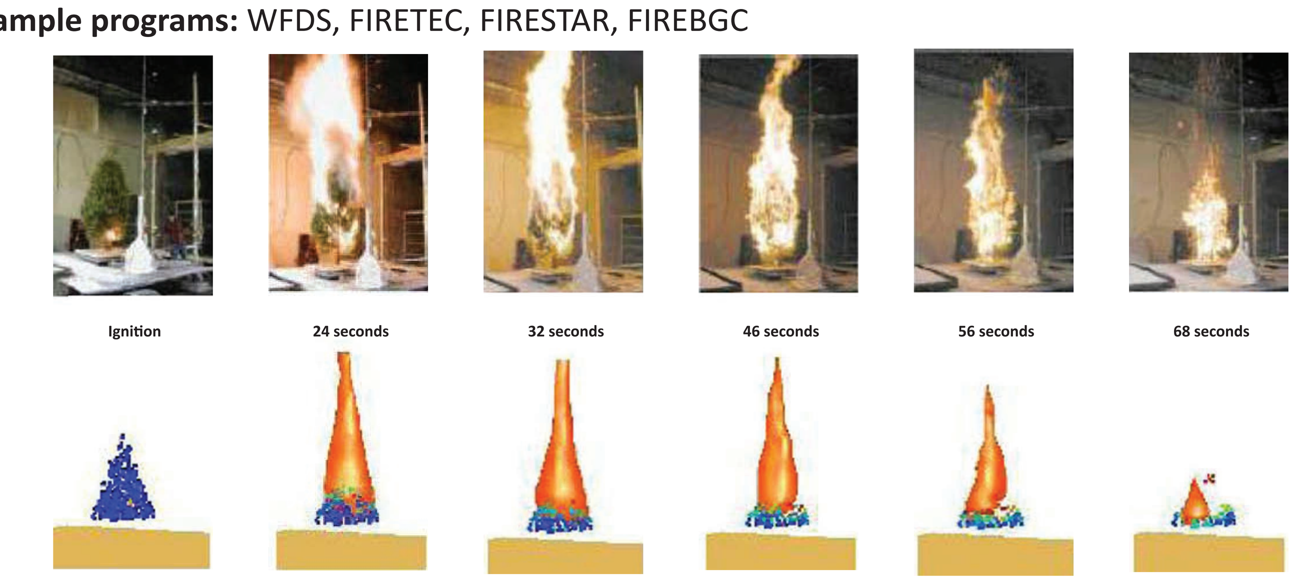
FLAMMAP simulation of (A) flame length, (B) rate of spread, and (C) crown fire activity. Warmer colors indicate higher values. Adapted from USGS (2008).

Benefits: Computationally fast, widely implemented, effective within well-defined scope.
Drawbacks: Inherently limited outside of original experimental scope; require empirical input; limited ability for modeling crown fire; unable to model smoldering combustion or spotting behavior.
Example programs: BEHAVE, FLAMMAP, NEXUS, FARSITE

Physics-based Models

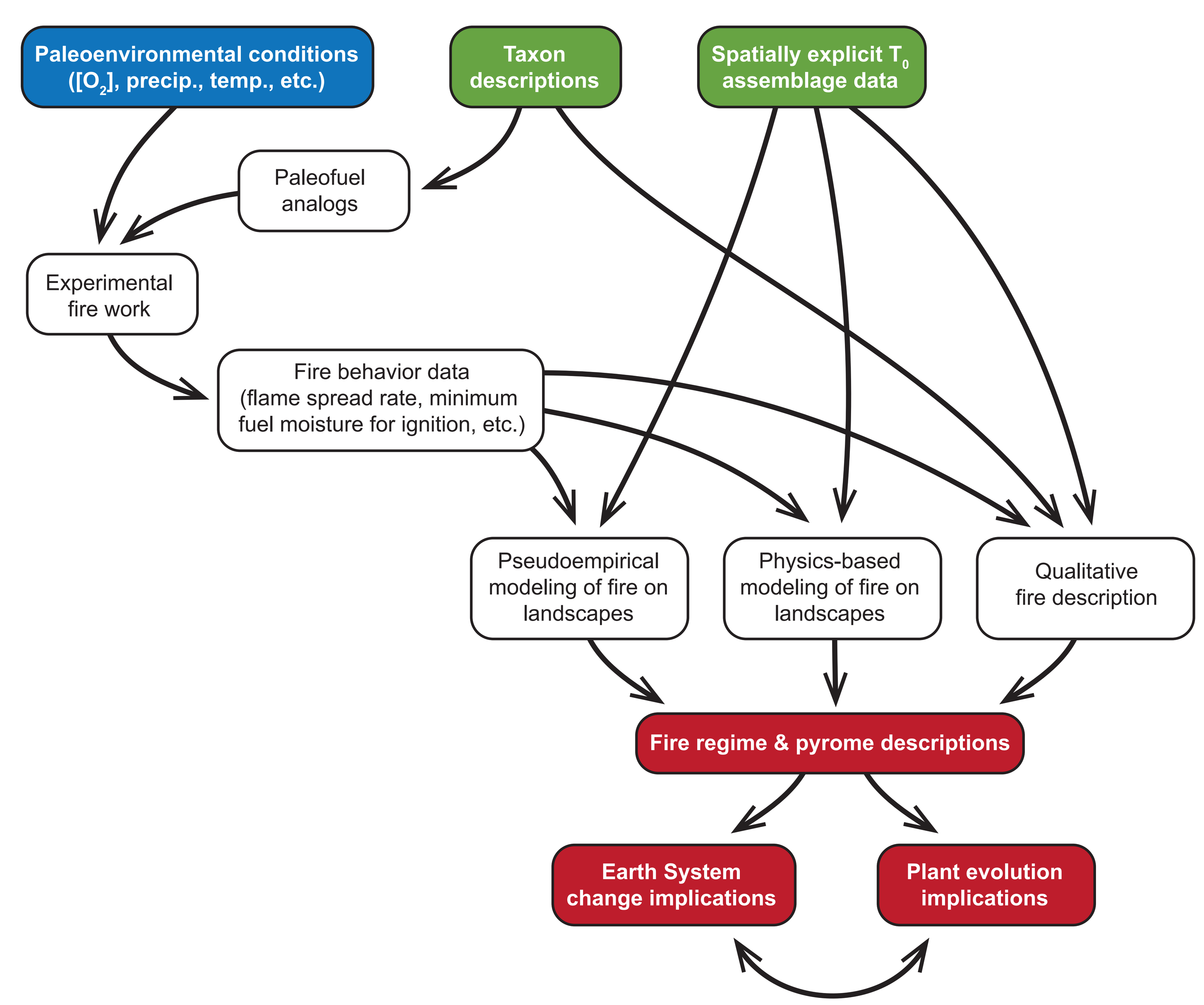
Use first principles of physics and thermodynamics along with explicit models of the chemistry of combustion to describe fire behavior. These models still require empirical work for validation.

Benefits: Can be used for surface and crown fire, and potentially smoldering combustion and spotting behavior; not as limited by scope of available empirical data.
Drawbacks: Validation is still a critical challenge; computationally slow; accurate description of all the physical processes involved and their contributions at various spatiotemporal scales is ongoing.
Example programs: WFDS, FIRETEC, FIRESTAR, FIREBGC



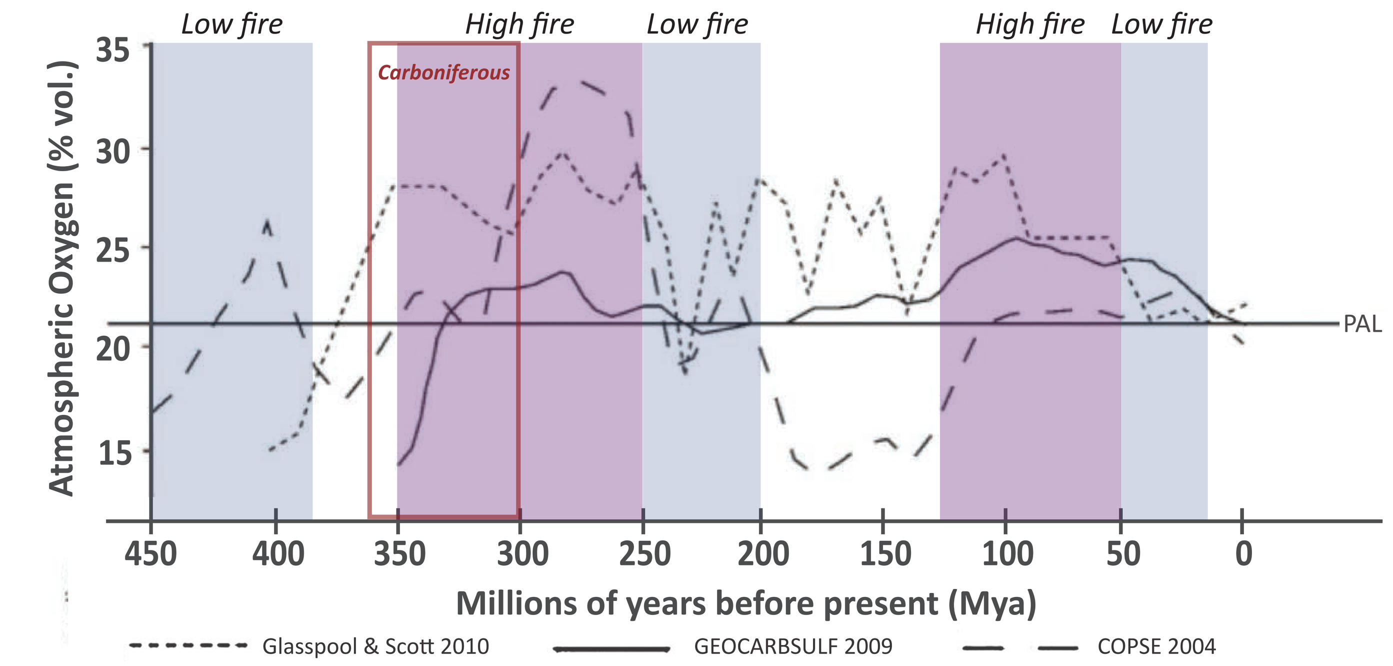
Combustion of a 2.4m Douglas fir (*Pseudotsuga menziesii*). Wildland-Urban Fire Dynamics Simulator (WFDS) simulation results visualized in Smokeview (NIST fire visualization tool) and experimental results. Taken from Mell et al. (2009), Figure 10.

Proposed Research



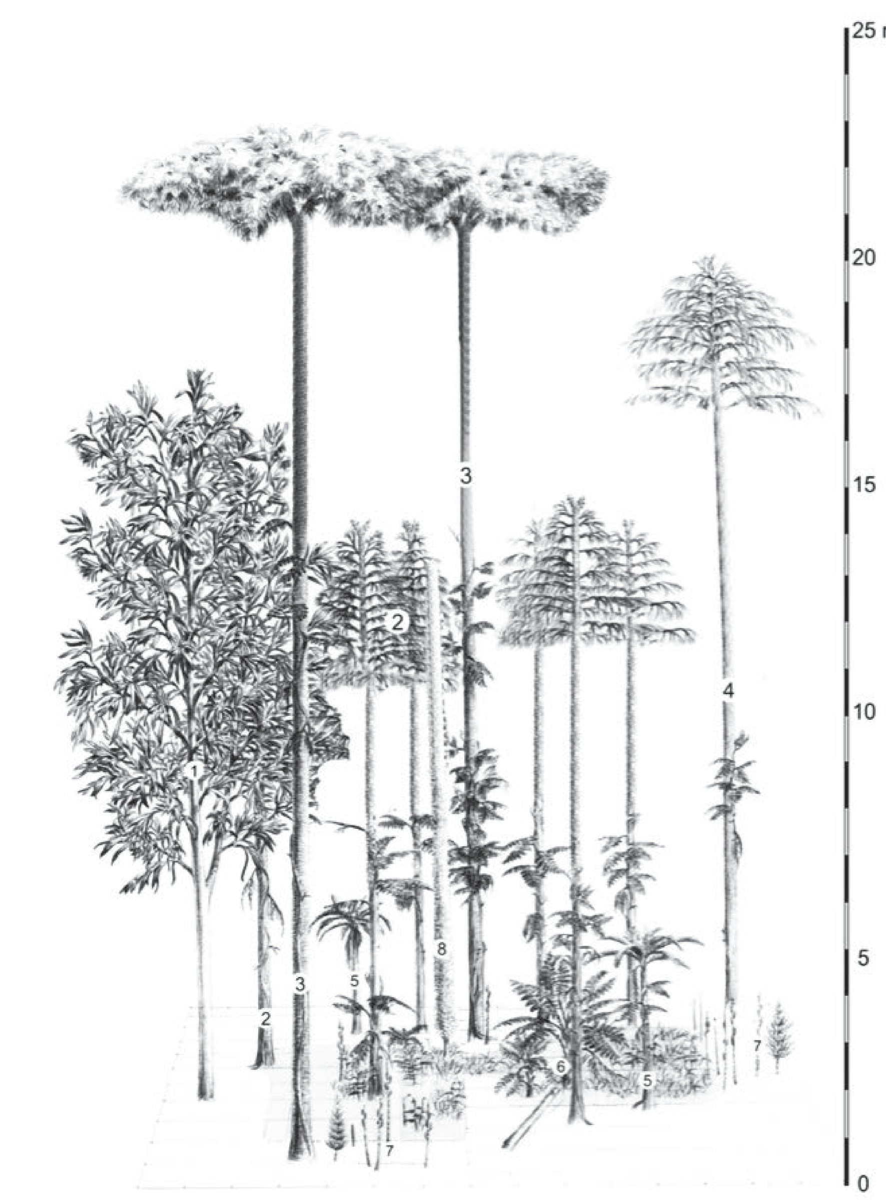
Fire in the Carboniferous

Atmospheric Oxygen Levels Through Time



Reconstructions of paleoatmospheric Oxygen levels from Glasspool & Scott's (2010) Oxygen proxy method, Berner's (2009) GEOCARBSULF model, and Bergman et al.'s (2004) COPSE model. Time periods estimated to have high fire activity are indicated in purple; those with low fire activity are highlighted in light blue. PAL refers to present atmospheric Oxygen levels. Adapted from Belcher et al. (2012), Figure 12.1.

Reconstruction of a Carboniferous Peat Swamp



Reconstruction of a Bolsovian (Middle Pennsylvanian) peat-forming forest from the Lower Radnice Coal. Taken from Opluštil et al. (2009), Figure 23. This spatially explicit *in situ* assemblage highlights the rich plant fossil record from this time period, which can be used to generate accurate taxon and landscape reconstructions. Key: 1. *Cordaites borassifolius*; 2. *"Lepidodendron" simile*; 3. *Lepidophloios* cf. *acerosus*; 4. *Lepidodendron lycopodioides*, 5. *Psaronius* with *Pecopteris aspidioides* foliage; 6. *Medullosa* with *Laveineopteris loshii* foliage; 7. *Stylocalamites* with *Palaeostachya gracilima* cones; 8. *Lepidodendron longifolium*.

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