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Some reflections on the natural history of pyrogenic C in boreal forests

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Due to its potential as a long-term C sink, much research has addressed factors controlling the loss and transformation of pyrogenic carbon (PyC) in soil. However, to understand "where does all the PyC go" we need to know how much was initially produced, and more about its natural history. This information is especially lacking for boreal forests, for which there is still no complete determination of PyC stocks or production by wildfire, including that in charred upright and downed stems. PyC could be considered as a distinct litter type, which is produced intermittently, has variable initial properties depending on degree of thermal transformation, and may not enter the soil C pool for decades until charred stems fall and decay. To improve knowledge of charcoal stocks (i.e. visually determined PyC), we used data from a fire history study that determined >2 mm charcoal at 1 cm depth intervals in forest floor and variable mineral soil depths in 51 black spruce and jack pine sites in the Abitibi region of Quebec. Stocks were up to 5640 kg/ha (median 1057) with very high variation within plots, and usually concentrated at or near the mineral soil surface. There was little evidence of time dependence up to 710 y, but lower values in four older plots (790-2355 y, up to 839 kg/ha). Mean sample total C and N were 569 and 4 mg/g (n=32). Carbon-13 NMR spectra showed large differences in younger samples, but increasing aromaticity in older ones, suggesting loss of less recalcitrant C and functional groups. Some reasonably comparable studies also showed up to around 5,000 kg/ha charcoal in the forest floor and upper mineral soil. The high variability up to around 300 y may still reflect variations in original production, despite possible attenuation with time. The few points from older sites were also consistent with average lifetimes of a few hundred years, some fragmentation of larger particles, and movement into surface mineral soil. High spatial variability was also typical. Long-term stabilization of PyC requires either environmental controls (such as permafrost) or association with soil minerals, but much boreal wildfire charcoal appears to remain above or at the mineral soil interface, vulnerable to consumption by subsequent fires. Published studies of mineral soil from Alaska and Siberia using chemical methods (CTOx or BPCA) to determine black carbon (BC) produced rather comparable stocks up to 4000 kg /ha of BC, but 14,000 kg/ha from an intact raised bog where OM was preserved by permafrost. Assembling the full boreal PyC cycle requires overcoming the widespread divide between projects measuring visual charcoal vs. chemically defined BC, which often reflects a research focus on forest floor/fire history vs. mineral soil/biogeochemistry. Methods for BC have been cross-compared, but there has been little such comparison of PyC determined as charcoal vs. BC. To better assess where the PyC went, we need to pool resources to determine how much there was at the start, and its initial position on the "BC Continuum".