



Letter to the Editor

Soil charcoal stability over the Holocene – Comment to the paper published by de Lafontaine and Asselin, Quaternary Research, v. 76, 2011, pp. 196–200

The purpose of this letter is to give arguments against a Holocene stability of soil charcoal that appears in [de Lafontaine and Asselin \(2011\)](#). However, de Lafontaine and Asselin are acknowledged for their impressive soil charcoal data-set, which contributes to advancing our understanding of the role of fire in boreal forests (see, for example, [de Lafontaine and Payette, 2012](#)).

Black pyrogenic carbon, of which charcoal is a main form, has attracted much research interest in recent years ([Preston and Schmidt, 2006](#); [Ascough et al., 2011](#)) and there is data on both the amount of charcoal that is produced when boreal forests burn ([Clark et al., 1998](#); [Ohlson and Tryterud, 2000](#)) and the size of the charcoal pool in boreal forest soils ([Zackrisson et al., 1996](#); [Ohlson et al., 2009](#)). In addition, there is a large body of data on historical boreal forest fires and their return intervals (e.g., [Bradshaw et al., 1997](#); [Niklasson and Granström, 2000](#); [de Lafontaine and Payette, 2011](#)). Importantly, when data on Holocene fire-return intervals are combined with data on charcoal production and the size of the soil charcoal pool, it becomes obvious that the size of the contemporary soil charcoal pool is too small, given that charcoal should remain stable over the Holocene. For example, the size of the soil charcoal pool in the boreal forest averages 150 g m^{-2} across Scandinavia ([Ohlson et al., 2009](#)); but with a production of 20 to $70 \text{ g charcoal m}^{-2}$ in a single fire event ([Clark et al., 1998](#); [Ohlson and Tryterud, 2000](#)), this implies far too few fire events over the Holocene, if the soil charcoal was stable.

So, why then is soil charcoal not stable over the Holocene? First, charcoal is a heterogeneous material and forms a continuum of compositional types dependent upon production variables, especially temperature ([Ascough et al., 2011](#)). Charcoal produced at low temperature typically holds lignocellulosic fragments ([Ascough et al., 2008](#)), and such charcoal degrades faster in the soil than high-temperature charcoal, which shows features of completely ordered graphite ([Ascough et al., 2011](#)). Every forest fire provides unique combinations of fuels and temperatures that will produce a range of different charcoal forms, of which some will degrade relatively quickly, and other slowly. Recalcitrant forms of charcoal will consequently be gradually overrepresented in the soil charcoal pool over time.

Second, soil charcoal is an attractive habitat for microorganisms ([Zackrisson et al., 1996](#); [Hockaday et al., 2007](#)), and as the soil charcoal microbial community is characterized by high biological activity ([Pietikäinen et al., 2000](#)), this contributes to charcoal alteration and degradation. Here it is likely that low-temperature charcoal will undergo biologically driven mineralization faster than high-temperature charcoal ([Baldock and Smernik, 2002](#)).

Third, abiotic processes such as gelifluction and cryoturbation degrade soil charcoal ([Preston and Schmidt, 2006](#)). It is also likely that a fire event may consume a proportion of the charcoal produced by previous fires ([Kane et al., 2010](#)), although the influence of fire on the size of the soil charcoal pool remains poorly understood. It is, however, clear that soil charcoal cannot be generally stable over millennia.

References

- Ascough, P.L., Ascough, P., Bird, M.I., Wormald, P., Snape, C.E., Apperley, D., 2008. Influence of pyrolysis variables and starting material on charcoal stable isotopic and molecular characteristics. *Geochimica et Cosmochimica Acta* 72, 6090–6102.
- Ascough, P.L., Bird, M.I., Francis, S.M., Thornton, B., Midwood, A.J., Scott, A.C., et al., 2011. Variability in oxidative degradation of charcoal: influence of production conditions and environmental exposure. *Geochimica et Cosmochimica Acta* 75, 2361–2378.
- Baldock, J.A., Smernik, R.J., 2002. Chemical composition and bioavailability of thermally altered *Pinus resinosa* (red pine) wood. *Organic Geochemistry* 33, 1093–1109.
- Bradshaw, R.H.W., Tolonen, K., Tolonen, M., 1997. Holocene records of fire from the boreal temperate zones of Europe. In: Clark, J.S., Chachier, H., Goldammer, J.G., Stocks, B. (Eds.), *Sediment Records of Biomass Burning and Global Change*. Springer, Berlin, pp. 347–365.
- Clark, J.S., Lynch, J., Stocks, B.J., Goldammer, J.G., 1998. Relationships between charcoal particles in air and sediments in west-central Siberia. *The Holocene* 8, 19–29.
- de Lafontaine, G., Asselin, H., 2011. Soil charcoal stability over the Holocene across boreal northeastern North America. *Quaternary Research* 76, 196–200.
- de Lafontaine, G., Payette, S., 2011. Shifting zonal patterns of the southern boreal forest in eastern Canada associated with changing fire regime during the Holocene. *Quaternary Science Reviews* 30, 867–875.
- de Lafontaine, G., Payette, S., 2012. Long-term fire and forest history of subalpine balsam fir (*Abies balsamea*) and white spruce (*Picea glauca*) stands in eastern Canada inferred from soil charcoal analysis. *The Holocene* 22, 191–201.
- Hockaday, W.C., Grannas, A.M., Kim, S., Hatcher, P.G., 2007. The transformation and mobility of charcoal in a fire-impacted watershed. *Geochimica et Cosmochimica Acta* 71, 3432–3445.
- Kane, E.S., Hockaday, W.C., Turetsky, M.R., Masiello, C.A., Valentine, D.W., Finney, B.P., et al., 2010. Topographic controls on black carbon accumulation in Alaskan black spruce forest soils: implications for organic matter dynamics. *Biogeochemistry* 100, 39–56.
- Niklasson, M., Granström, A., 2000. Number and sizes of fires: long-term spatially explicit fire history in a Swedish boreal landscape. *Ecology* 81, 1484–1499.
- Ohlson, M., Tryterud, E., 2000. Interpretation of the charcoal record in forest soils: forest fires and their production and deposition of macroscopic charcoal. *The Holocene* 10, 519–525.
- Ohlson, M., Dahlberg, B., Økland, T., Brown, K.J., Halvorsen, R., 2009. The charcoal carbon pool in boreal forest soils. *Nature Geoscience* 2, 692–695.
- Pietikäinen, J., Kiikkilä, O., Fritze, H., 2000. Charcoal as a habitat for microbes and its effect on the microbial community of the underlying humus. *Oikos* 89, 231–242.
- Preston, C.M., Schmidt, M.W.I., 2006. Black (pyrogenic) carbon: a synthesis of current knowledge and uncertainties with special consideration of boreal regions. *Biogeosciences* 3, 397–420.
- Zackrisson, O., Nilsson, M.-C., Wardle, D.A., 1996. Key ecological function of charcoal from wildfire in the boreal forest. *Oikos* 77, 10–19.

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