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Biogeosciences Discussions

Interactive comment on "Black (pyrogenic) carbon in boreal forests: a synthesis of current knowledge and uncertainties" *by* C. M. Preston and M. W. I. Schmidt

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We look forward to submitting a revised version, taking the reviewers' comments into consideration. Please also look at our responses to the individual reviewers' comments.

The response to our boreal-centric PyC review clearly indicates that we failed to explain sufficiently our approach and goals. We do appreciate the reviewers' comments on errors, omissions and ambiguous passages, and as detailed below, we will revise the MS accordingly. However, most of these are minor points, and we wish here to respond to the big issues. The main issues are that the information in the MS is not confined to boreal regions (indeed, the title should have said "regions" rather than "forests"), that

certain sections are superfluous and/or misplaced, and that improper comparisons are made. The concept for this review was developed during many discussions and interactions with scientists working in boreal regions, especially modellers and ecologists. They are interested in black carbon (or charcoal, or whatever general term one wants to use) because it is expected to be highly resistant to decay, and therefore should potentially contribute to long-lasting C pools. They want information for incorporating BC into carbon budget models for boreal forests and peatlands. They need to know how much BC is produced in forest fires, and how long it might last, especially in soil. They also want to know how much ends up in the atmosphere. At the same time, we found great interest in the possible influence of charcoal on boreal soil function, and several studies have explored this using natural chars collected from forest fire sites, laboratory-generated chars and commercially-available black carbon. Many people would like to know how to analyse for black carbon, but have little or no chemistry background, and find the literature totally inaccessible, and most of the methods quite beyond their laboratory capabilities or budgets. However, they would like to have some factors to relate various measures of chemically-defined BC to visually-defined charcoal. We wanted to make the background material quite comprehensive (without too much detail), so that readers of a variety of backgrounds could learn the BC basics. Therefore, the concept evolved that the review should cover the general definitions, characteristics and analytical techniques for the various forms of black carbon (BC) or more generally pyrogenic C (PyC), and summarize the information available on production, stocks, and losses, and the effects on soil organic matter (SOM) and soil function. This had to include non-boreal information to supplement the very limited information from boreal regions. Relying only on the very few boreal-based papers would result in misleading estimates of boreal production of PyC. Similarly, while the effects of fire on SOM characteristics have been studied mostly in more southern soils, boreal scientists should be made aware of the general concepts, in addition to the specific studies of the effects of charcoal on boreal forest soil function (these are mainly effects on microbial or plant function, not on SOM chemistry). We also gathered information about decom-

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position of other recalcitrant geochemical substrates, in so far as they might provide insight or research approaches for estimating turnover time of PyC in boreal regions. These are examples of using surrogate or circumstantial evidence to get some idea of what might be expected in our target region. Sections 7 and 8 are clearly focussed on boreal regions, but supported also by insights and information from a broader perspective.

Early in the preparation of this MS, it became apparent that there were very serious limitations to the availability of boreal data, and in fact, rather few studies of BC or charcoal production and storage in any forests. Of the published studies, hardly any were based on wildfires, which is a major disturbance in boreal forests, consuming some third of the C fixed in primary production. Also, while BC specialists have been focused on using chemical techniques to determine the fractions resistant to various measures of oxidation, or BC based on production of benzenecarboxylic acids (BPCAs), or on spectroscopic techniques, most fire scientists and ecologists continue to measure what is visually assessed as charcoal. There is also a vast paleobotanical literature on charcoal in peat and sediment cores. In these studies, charcoal abundance is tracked, but it is is hardly ever quantified on a mass/area basis. These different groups are worlds apart, and rarely interact in collaborative research; therefore a major goal of our MS was to bring together the diverse interests in, and approaches to, PyC/BC/charcoal research. We wanted a review with the basic information in one place, not something highly specialized and minimal where readers need to look up another specialized reference at every step. We wanted extreme interdisciplinarity, which was why Biogeosciences was our journal of choice. We cannot emphasize enough how huge the gap is between those using sophisticated chemical approaches (even the simpler thermochemical methods fall into this category) to analyse BC in soils and sediments, and those in forest or peat ecology, fire science, most soil science, and indeed, carbon budget modelers. We would not expect everyone to want to read it through (and thank the reviewers for doing so), but to be able to access easily the information on specific topics.

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Reviewers find it inappropriate to compare results obtained by very different methods (mainly BC vs visually-determined charcoal), or to think about lifetimes of recalcitrant geochemicals in comparison with BC/PyC/charocal. In the first case, this is the reality of much data currently available for boreal forests, and are likely to remain more readily available in the future, and one very large research gap is the need for some factors relating various measures of BC to charcoal. The recent results of BC ring trial (Hammes et al., 2006b) may provide some first steps. We hope that our synthesis will encourage very distant scientific tribes to seek each other out and develop collaborative projects. It also seems entirely reasonable to look at some other recalcitrant geochemicals. Except for the very small fraction of photosynthate that is preserved through geological time by lack of oxygen (less than 0.5% of C fixed), everything is decomposed eventually, by chemical or microbial processes; “the only long-term shelter from mineralization in within anoxic marine sediments which accumulate one mole of organic carbon for every 500-1000 fixed by photosynthetic organisms” (Hedges and Oades, 1997). Looking at the turnover time of substrates like ocean sediments, black shale and coal gives some surrogate estimates of how long the most recalcitrant BC might last. In fact, the turnover times are in the same general range as the one useful study we found for charcoal in a forest soil profile in British Columbia (Gavin, 2003). This comparison is a starting-point that may encourage more research on the mechanisms and timescales of PyC loss or preservation. A very recent study (Wengel et al., 2006) compared the degradation of charcoal and organic matter in black shales by a fungus

The reviewers criticize a lack of focus, then recommend even further dilution of effort by splitting the paper into two or covering the whole world. Neither is feasable or within our expertise. The extrapolation to the whole world would actually be a lot more difficult than suggested and would negate our primary aim.

We will submit a revision with special concern that the title, abstract and introduction more clearly define our aproach and objectives. Some sections deemed will be reduced or eliminated, and the rationale for inclusion of non-boreal material will be more

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clearly justified. We will work to compress, eliminate or rearrange sections to improve the flow, but like many things in science, the topics may not always fit into the most tidy sequence. A few new references will be added, mainly the following, but these should be balanced by removal of some others. All of the minor points will be addressed, as detailed below. We hope that the revision will be acceptable and useful to the interdisciplinary target audience of Biogeosciences.

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Interactive comment on Biogeosciences Discuss., 3, 211, 2006.