

Biogeosciences Discuss., referee comment RC2 https://doi.org/10.5194/bg-2021-4-RC2, 2021 © Author(s) 2021. This work is distributed under the Creative Commons Attribution 4.0 License.

## Comment on bg-2021-4

Anonymous Referee #2

Referee comment on "Ideas and perspectives: Emerging contours of a dynamic exogenous kerogen cycle" by Thomas M. Blattmann, Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-4-RC2, 2021

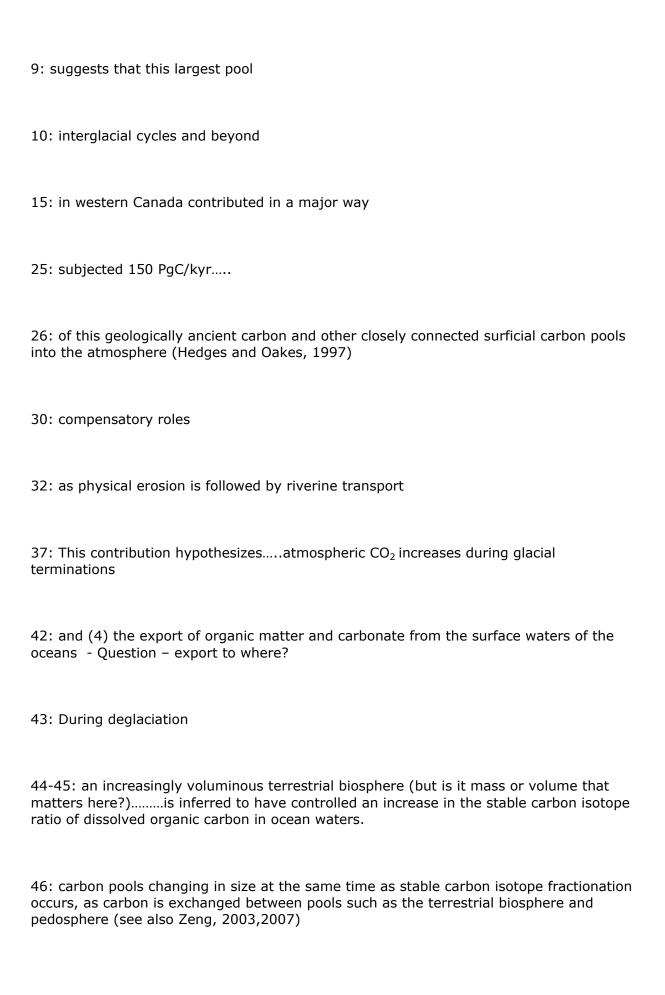
Review for Biogeosciences of "Ideas and Perspectives:Emerging contours of a dynamic exogenous kerogen cycle" by Thomas M Blattmann

## Overview:

I found this a novel, interesting, and generally well-written paper that argues that weathering of kerogen-containing lithologies exposed at the surface after continental deglaciation may prove to be a significant source of carbon dioxide to the atmosphere, and one which is of particular significance in terms of climate forcing. Whilst the argument is supported more by calculations and logical arguments than it is by direct measurements and observations, I still found it fairly compelling - to the point that I am convinced that the idea is worth pursuing via in situ measurements and carefully designed and executed experiments. It is certainly worth publishing if only to give exposure to the idea and to stimulate discussion and field monitoring of natural carbon emissions from kerogen sources as well as to provoke detailed modelling of likely CO<sub>2</sub> fluxes from kerogen sources on geologically and climatically relevant timescales (and detailed mapping (in time and space) of likely source regions for kerogen-derived greenhouse gas emissions). Some articulation of likely important source regions for such emissions would be a valuable contribution to the paper and the broader scientific discussion that it is likely to stimulate. It is certainly a paper that gave me a kick and made me challenge my prior assumptions and thinking about climate/greenhouse gas emission linkages.

On that basis I think it is worthy of publication, although, at the detailed level, I think the text needs a thorough edit. Below I have provided a set of suggestions that I hope might help with this.

Line by Line Review (i.e. suggested changes to the text that I think would improve it's readability and clarity):



47: In addition, during times of most rapid $CO_2$ increase during transitions from glacial to interglacial periods, negative stable carbon isotope shifts in atmospheric $CO_2$ occurred (Fig.3; Smith et al., 1999; Schmitt et al., 2012).
49: This is a strong indicator that respired organic carbon was acting as a direct source to the atmosphere (Bauska et al., 2016).
51: that was depleted in or devoid of radiocarbonthereby limiting the potential contributions from a modern biospheric organic carbon source. BUT does it actually limit the contributions, or just their detectability?
53-54: deep ocean was the predominant source for carbon transferred to the atmosphere during glacial terminations
55-56: please explain what you mean by "requires a complex overlay of processes to reconcile"
58-59: suggest that the release, via kerogen oxidation, of $CO_2$ to the atmosphere during deglaciation contradicts or complements the commonly held notions of a strictly increasing terrestrial organic carbon pool and major changes in $CO_2$ exchange between the ocean and the atmosphere.
58-60: needs some supporting references
62: accumulated fromsupports the idea thatwas more extensive
63: cold interludes in Earth history during which glacial erosion and ice rafting dominated (BUT – what did they dominate?)
64: reburial in high latitude glaciated regions
66: kerogen cycle by keeping
69: frost shattering, together with the retreat of glaciers, exposesthereby accelerating

oxidation and the release of kerogen-derived CO<sub>2</sub>......declines into an interglacial period. 73. Analogously, glaciers have also been invoked as agents for accelerating chemical weathering of carbonate and silicate minerals by increasing sediment yield and creating a reactive substrate with high surface area. Carbonate weathering can be a source of CO<sub>2</sub> to the atmosphere when sulphuric acid is the solvent involved. (I assume this is a by product of sulphide mineral (pyrite) oxidation? Please clarify this) 77. direct conversion to CO<sub>2</sub> leads to considerable.... 78-79: This is a process by which CO<sub>2</sub> can be injected directly into the atmosphere and impact glacial-interglacial cycles (Figure 2) 90: faster than those of the average Earth surface 95: also proposes the oxidation of overridden soil organic carbon during and after glaciation and calculates a 600 PgC release.... 115: fluxes an order of magnitude greater than the global average 120-127: Are the kerogen oxidation and oceanic release mechanisms for CO<sub>2</sub> increase mutually exclusive? You make it sound as though they are, but I'm not clear why that would be the case. 115: oxidation fluxes an order of magnitude greater than the global average can be sustained for millennia after deglaciation. 134: extending across much... 137: within the Province of Alberta 139: Cretaceous soils and the oil sands......the latter enhanced by aerial exposure across palaeosurfaces

140: over tens of thousands

145: Laboratory incubations designed to simulate CO<sub>2</sub> respiration from bituminous materials reveal fluxes that are markedly higher than those associated with oxidation of rock disseminated forms of kerogen (Table 1)

147-148: at rates 1-2 orders of magnitude higher than those reported for rock disseminated kerogen, and 3 orders of magnitude greater than the average for Earth's surface.

152: when temperatures of subaerially exposed outcrops of oil sands reach 60°C

153: experiments on bitumen

155-156: that investigated the oxidative decay of hydrocarbon fractions also suggest similarly high fluxes when scaled to natural systems, even though these studies were conducted over periods of only a few weeks

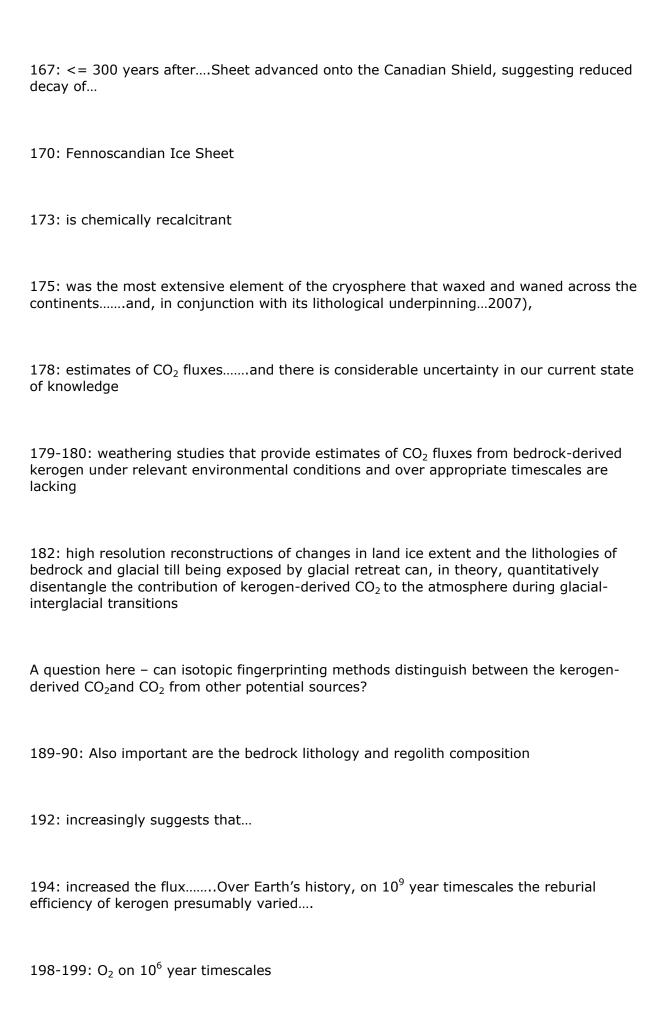
158: fluxes reported by Chang and Berner (1998,1999)...an underestimate

160: CO<sub>2</sub> can be released under anaerobic conditions

162-163: what is meant by a super-carbon source terrain? Maybe useful to identify some specific examples

163: during glacial-interglacial transitions. This statement makes me wonder whether you have given any thought to what happens in interglacial-glacial transitions. Are you just assuming that overriding by ice shuts off exchanges between substrate and atmosphere – but would that necessarily preclude gas transfer through permeable substrates along the hydraulic potential gradient from thick ice in the interior to thin ice at the margins where gas could escape to the atmosphere?

164-5: Sheet had retreated.....and was exposing



200: to understand changes in atmospheric chemistry through geologic time
201: the changing efficiency of the reburial of kerogen needs to be evaluated
204: geospatial variability in what ?
205: for quantifying, and establishing the importance of the reburial of kerogen in recent times, it's utility diminishes quickly for strata that pre-date the Last Glacial Maximum owing to it's radioactive decay.
210: isotopic shifts at the beginning of interglacials that are attributable to kerogen oxidation
211: consistent with the hypothesis presented here
216: the hypothesis presented proposes
218: the rate of decrease of $^{14}$ C CO $_2$ subsidedmirrored by changes, during deglaciation, in the lithologies of the Canadian Shield that were exposed at the surface, which contain relatively minor amounts of reactive kerogen.
220The coincidence in time of global trends in atmospheric chemistry with spatiotemporal patterns in the distribution of freshly deglaciated terrainsuggests that a burst (or bursts) of respired ${\rm CO_2}$ contributed to the characteristic deglacial increase in atmospheric ${\rm CO_2}$ .
224: soil and vegetation taking hold on the deglaciated landscape
228: patterns of glacial retreat that expose glacially ground, kerogen-rich or even bituminous parent material.
230: have been proposed to explain CO <sub>2</sub> increases

232: retreat, and the oxidation of finely ground kerogen, provide
234: such as the oxidation of subglacial paleosols and permafrost-bound organic carbonand by volcanic emissions triggered by deglacial unloading of the lithosphere
243-4: accelerated oxidation of ancient terrestrial organic carbon at glacial terminations
246-7: the hypothesis presented
250: timescales, entirely
252: exposed fresh weathering profiles
255-6: and increased supplies of ground kerogen
268: provide a strong incentive
269: kerogen cycle in glacial-interglacial climate patterns
270-271: may provide an outlook for geological processes that is relevant today
271: (Steffen et al. 2018) is missing from the reference list
Figure 1 caption: showing the fixation of atmospheric $CO_2$ by both terrestrial and marine primary productivityconstitutes the total organic carbon burial into the endogenous kerogen pool.