Biogeosciences Discussions

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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_2 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):

9: suggests that this largest pool

10: interglacial cycles and beyond

15: in western Canada contributed in a major way

25: subjected 150 PgC/kyr…..

26: of this geologically ancient carbon and other closely connected surficial carbon pools into the atmosphere (Hedges and Oakes, 1997)

30: compensatory roles

32: as physical erosion is followed by riverine transport

37: This contribution hypothesizes…..atmospheric CO_2 increases during glacial terminations

42: and (4) the export of organic matter and carbonate from the surface waters of the oceans - Question – export to where?

43: During deglaciation

44-45: an increasingly voluminous terrestrial biosphere (but is it mass or volume that matters here?)……is inferred to have controlled an increase in the stable carbon isotope ratio of dissolved organic carbon in ocean waters.

46: carbon pools changing in size at the same time as stable carbon isotope fractionation occurs, as carbon is exchanged between pools such as the terrestrial biosphere and pedosphere (see also Zeng, 2003,2007)

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 radiocarbon……thereby 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 from….supports the idea that…..was 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, exposes……thereby accelerating

oxidation and the release of kerogen-derived CO_2…….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_2 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_2 leads to considerable….

78-79: This is a process by which CO_2 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_2 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_2 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_2 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

167: <= 300 years after….Sheet advanced onto the Canadian Shield, suggesting reduced decay of…

170: Fennoscandian Ice Sheet

173: is chemically recalcitrant

175: was the most extensive element of the cryosphere that waxed and waned across the continents…….and, in conjunction with its lithological underpinning…2007),

178: estimates of CO_2 fluxes…….and there is considerable uncertainty in our current state of knowledge

179-180: weathering studies that provide estimates of CO_2 fluxes from bedrock-derived kerogen under relevant environmental conditions and over appropriate timescales are lacking

182: high resolution reconstructions of changes in land ice extent and the lithologies of bedrock and glacial till being exposed by glacial retreat can, in theory, quantitatively disentangle the contribution of kerogen-derived CO_2 to the atmosphere during glacial-interglacial transitions

A question here – can isotopic fingerprinting methods distinguish between the kerogen-derived $CO_2$and CO_2 from other potential sources?

189-90: Also important are the bedrock lithology and regolith composition

192: increasingly suggests that…

194: increased the flux……..Over Earth's history, on 10^9 year timescales the reburial efficiency of kerogen presumably varied….

198-199: O_2 on 10^6 year timescales

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 subsided……..mirrored 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.

220-…The coincidence in time of global trends in atmospheric chemistry with spatiotemporal patterns in the distribution of freshly deglaciated terrain……suggests that a burst (or bursts) of respired CO_2 contributed to the characteristic deglacial increase in atmospheric 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_2 increases

232: retreat, and the oxidation of finely ground kerogen, provide……

234: such as the oxidation of subglacial paleosols and permafrost-bound organic carbon….and 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 productivity……..constitutes the total organic carbon burial into the endogenous kerogen pool.