Clathrate destabilization as the source of rapid deglacial methane releases

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Introduction

During the last deglaciation, the overall increase in greenhouse gases was punctuated by three rapid jumps. In only ∼150 years, atmospheric carbon dioxide and methane simultaneously increased by 10–15 ppmv and 40–250 ppbv, respectively[1] (Fig. 1). Here, we focus on the potential origin of the rapid methane increases, tying them to marine δ^{13}C excursions (Fig. 2). We argue that clathrate destabilization events in the North Atlantic can explain both the carbon isotopic excursions and the rapid methane increases.

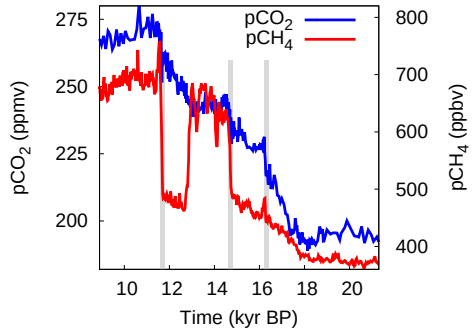

Fig.1 Atmospheric pCO_2 (blue) and pCH_4 (red) across the last deglaciation[1]. The gray-shaded areas indicate the approximate times of the rapid increases in atmospheric pCH_4 and pCO_2.

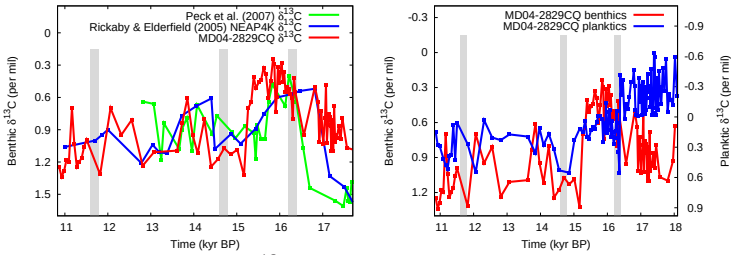

Fig.2 Deglacial marine δ^{13}C from the subpolar North Atlantic exhibits three excursions at the approximate times of the rapid methane releases: (left) benthic foraminifera from cores MD04-2829CQ (red; 58°56.93'N, 9°34.30'W, depth 1743 m; measurements by Rickaby & Hall), NEAP4K (blue; core taken at 61°29'N, 24°10'W, 1627 m)[2], and MD01-2461 (green; core taken at 51°45'N, 12°55'W, 1153 m)[3]; (right) benthic (red) and planktonic (blue) foraminifera δ^{13}C at MD04-2829CQ. Note that δ^{13}C decreases going upward.

Using marine δ^{13}C to identify methane source

Our hypotheses:

Terrestrial release:
→ largest excursions in atmosphere and at surface ocean.
Release at sea from clathrate destabilization:
→ largest excursions at mid-depth close to release sites.
Right panel in Fig. 2 suggests clathrate destabilization most likely!

How would clathrate releases manifest themselves across World Ocean?

Investigate hypothesis through tracer release simulations in three-dimensional ocean model!

Three passive tracer releases at 1100 m depth off Greenland's East coast with 2000 years in between

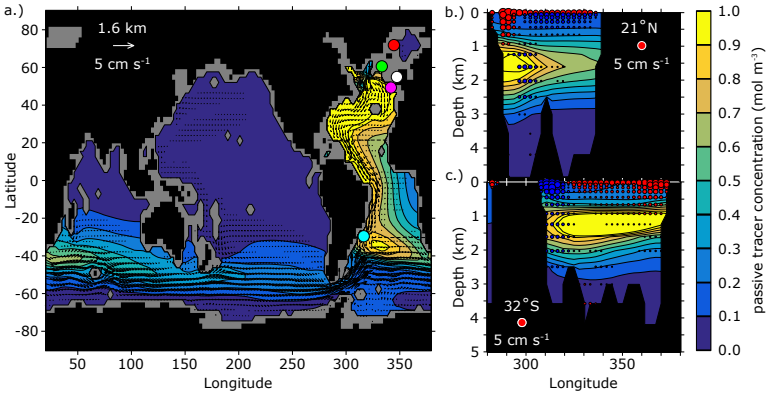

Fig.3 (a) Tracer concentrations (contours) at a horizontal cross-section at 1.6 km depth, 1000 years after the beginning of the first tracer release. Red dot: tracer release locations, green and magenta dots: NEAP4K[2] and MD01-2461[3] cores. The white and light blue dots indicate the locations of the MD04-2829CQ and Brazil Margin cores[4] where pseudo-samples are taken (see Fig. 4). (b, c) Zonal cross-sections at 21°N and 32°S; red dots indicate northward flow, blue dots indicate a flow toward the south, with the sizes of the dots corresponding with the flow speed.

The largest excursions are found at mid-depths throughout the Atlantic (Fig. 4) which is consistent with our observations and with records from the Brazil Margin[4]. The fact that some observational records show three distinct excursions, whereas others show one broad excursion can be explained from differences in sediment accumulation.

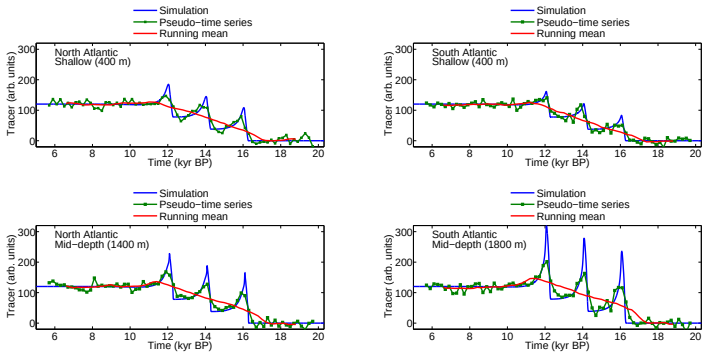

Fig.4 Results from the tracer release model experiment. Left panels: the MD04-2829CQ site, right panels: Brazil Margin. The actual tracer concentration is indicated in blue; in green, pseudo-measurements with a 200-year time between samples which is the approximate time sampling rate of the MD04-2829CQ core. The red lines indicate 2000-year moving averages.

References

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[2] Rickaby & Elderfield, G^3 6: Q05001 (2005)
[3] Peck et al., G^3 8: Q01N10 (2007)
[4] Tessin & Lund, Paleoc. 28: 296–306 (2013)

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