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Methane release in the Early Jurassic period

Arising from: D. B. Kemp, A. L. Coe, A. S. Cohen & L. Schwark *Nature* 437, 396–399 (2005).

Dramatic global warming, triggered by release of methane from clathrates, has been postulated to have occurred during the early Toarcian age in the Early Jurassic period[1]. Kemp *et al.*[2] claim that this methane was released at three points, as recorded by three sharp excursions of $\delta^{13}C_{org}$ of up to 3‰ magnitude. But they discount another explanation for the excursions: namely that some, perhaps all, of the rapid excursions could be a local signature of a euxinic basin caused by recycling of isotopically light carbon from the lower water column. This idea has been proposed previously (see ref. 3, for example) and is supported by the lack evidence for negative $\delta^{13}C$ excursions in coeval belemnite rostra[4]. Kemp *et al.* dismiss this alternative, claiming that each abrupt shift would have required the recycling of about double the amount of organic carbon that is currently present in the modern ocean; however, their measurements are not from an ocean but from a restricted, epicontinental seaway and so would not require whole-ocean mixing to achieve the excursions.

We also question aspects of the timing, magnitude and inferred consequences of the gas-hydrate release events. Kemp *et al.*[2] erect a cyclostratigraphic scheme on which they found their claim that the three carbon isotope spikes all occurred within a 60,000-year period. But they do not explain how a 3‰ recovery could have occurred between their second and third excursions. This interval is only 25% of the residence time of carbon in the oceans (180,000 yr; ref. 5) and is thus too short to represent a relaxation process. Their data show further very rapid declines in $\delta^{13}C_{org}$ values (for example, at 1.6 m and 2.9 m in their section) and these were not given equal status as gas-hydrate-release events. Furthermore, with three, and possibly five, closely spaced release events, there would not have been sufficient time to replenish the clathrate reservoirs between events.

Kemp *et al.*[2] note that one consequence of the release of huge amounts of methane (at least 5,000 gigatonnes of carbon by their calculations) was the development of a severe greenhouse climate and, as a direct (but unexplained) result, the extinction of many marine species. However, this is not supported by the work they cite. The authors suggest that there could have been a sudden rise in seawater temperatures coincident with methane release[6], where "sudden" indicates a period of 0.6 to 0.7 million years (ref. 6). Note also that the temperature rise began in the *Dactylioceras tenuicostatum* subzone[6], whereas the lowest $\delta^{13}C_{org}$ excursion of Kemp *et al.*[2] is not developed until late in the succeeding *Dactylioceras semicelatum* subzone. Furthermore, the younger two release events coincide with a proposed phase of marked cooling, according to stomatal index data[7].

The claim by Kemp *et al.* that the first two methane-release events led to a 67% and 50% loss in species was derived from the work of Harries and Little[8]; however, the resolution of that study is too low to equate the extinction losses to the level of the excursions. The original data set[9] and our later findings[10] show that extinction in these Yorkshire coast sections occurs in Bed 31, where 12 of 14 benthic species go extinct. This crisis was 60,000 years before the first methane-release event, according to the timescale of Kemp *et al.* Other extinctions in the European region were even earlier, with many taxa disappearing at the Pliensbachian–Toarcian stage boundary[11]. There is therefore no evidence to relate the Toarcian mass extinction to the effects of gas-hydrate dissociation events, although they do relate to the development of bottom-water anoxia.

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Kemp et al. *reply*

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Wignall *et al.*[1] suggest that the abrupt negative $\delta^{13}C_{org}$ shifts that we recognize in our data set[2] could be localized features caused by recycling of isotopically light marine carbon. This overlooks two important lines of evidence[2]: that the early Toarcian negative $\delta^{13}C$ excursion is present in several sections around the world[3–5], and that the excursion is recorded in terrestrial plant material[4]. These crucial observations together preclude the possibility that the event was restricted to a localized, marine environment.

Wignall *et al.* cite evidence[6] for a lack of a negative carbon-isotope excursion based on belemnite measurements from Yorkshire: however, this consists of just 24 scattered data points (we used 449 data points[2]) and the sample positions indicate that our abrupt $\delta^{13}C_{org}$ shifts were not sampled. Unambiguous evidence is also presented[6] from a German section for a −2‰ shift in $\delta^{13}C_{belemnite}$. This shift coincides with a negative shift in $\delta^{13}C_{org}$ from the same section and correlates with our data. Our original statement — that the recycling theory places impossible demands upon the marine carbon reservoir — is thus fully supported.

Establishing the cause of the roughly 3‰ recovery between the second and third abrupt negative $\delta^{13}C_{org}$ shifts was beyond the scope of our report[2], but we did not suggest that this recovery was the result of a 'relaxation' process. We also did not claim that hydrate reservoirs replenish themselves over short timescales[1]. It is possible that each pulse of methane release represents dissociation of geographically distinct reservoirs. Wignall *et al.* question why other sharp negative $\delta^{13}C_{org}$ shifts are not ascribed to methane release, but we did in fact mention this possibility in our report[2].

The warming rate of sea water described by Bailey *et al.*[7] is much slower than we suggested because their interpretation is based on a timescale that is incorrect, as shown by mathematically robust cyclostratigraphy[2]. The inception of gradual global warming in the *tenuicostatum* subzone supports the theory that warming began from volcanogenic sources[2,4]. Nevertheless, the major change in temperature occurred in the *semicelatum* subzone[2].

The assumption by Wignall *et al.* that the two younger methane release events coincided with global cooling[8] is incorrect: the correlation between the Bornholm section[8] used to derive the stomatal index results and the Yorkshire section is based on low-resolution $\delta^{13}C$ data[4]. There is a discrepancy between this correlation[8] and that provided by the dinoflagellate zones[9,10] that prevents accurate correlation with our high-resolution data. The decrease in CO_2 and inferred cooling[8] could have occurred between methane pulses as a result of increased weathering and associated CO_2 drawdown, which are known features of the event[11].

The faunal data of Harries and Little[12] reveal two distinct extinction horizons that are coincident with our first two $\delta^{13}C_{org}$ shifts, if their stratigraphy is used. However, even if this work has been superseded since our report[2], it has no bearing on the theory that methane-hydrate dissociation occurred during the early Toarcian, because faunal extinction was not an argument we used to support our theory.

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