Comment on "New insights in the pattern and timing of the Early Jurassic calcareous nannofossil crisis" by M. E. Clémence et al. [*Palaeogeography Palaeoclimatology Palaeoecology 427* (2015) 100–108]

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The recent paper by Clémence et al. (2015) provides extensive data on the evolution of calcareous nannofossils through a well-documented core representing the late Pliensbachian to early Toarcian interval of the Early Jurassic in the south of the Paris Basin. The study focuses on an interval recording a –6 ‰ negative carbon isotope excursion (CIE) in bulk carbonate and the onset of black shale deposition related to the Toarcian Oceanic Anoxic Event (T-OAE). The study by Clémence et al. (2015) takes advantage of a particularly well-documented mineralogical, geochemical and cyclostratigraphic framework at Sancerre comprising an epicontinental record in the NW European realm (Hermoso et al., 2009, 2012; Boulila et al., 2014; Hermoso and Pellenard, 2014). Using calcareous nannofossil counts and morphometrics of *Schizosphaerella punctulata* calcispheres, it is suggested that a "biocalcification crisis" affected the phytoplankton due to global warming and, in turn, that reduced export of carbonate-ballasted particulate organic matter (POM) to the seafloor contributed to the expression of the negative CIE. If correct, this hypothesis would challenge our understanding of the nature of the largest carbon isotope excursion of Mesozoic and Cenozoic eras, and of the mechanisms responsible for the formation of a major hydrocarbon source rocks. However, here we question the arguments presented for assigning reduced calcareous nannofossil abundance in sediment to a temperature control and most importantly the interpretation that reduced pelagic calcification led the oceanic carbon pool towards depleted isotopic values. We emphasis that the negative CIE recorded during the Toarcian OAE was not caused, or significantly enhanced, by diminished efficiency of the biological pump during a period characterised globally by substantial production and accumulation of organic matter.

Clémence et al. (2015) have related to global warming the drop in *Schizosphaerella punctulata* abundance that seems to be observed also elsewhere, as in the Peniche section

(Suan et al., 2008). Before a global picture can be drawn on the relationship between the environmental perturbations and nannofossil abundance, it is of paramount importance to establish robust causal links for the particular section being studied here. It is true that increased sea surface temperature has been suggested by numerous studies at the scale of the Early Toarcian predominantly deriving from geochemical evidence (see review by Jenkyns, 2010). At Sancerre, a warming is compatible with a protracted negative shift in $\delta^{18}O$ of carbonate, but that is recorded three metres higher in the core, coincident with deposition of black shale at 348.25 m (Hermoso et al., 2012). As a matter of fact, there is no direct evidence for an increase in sea surface temperature concomitant with the interval marked by decreased *S. punctulata* abundance from 351 m upwards in the Sancerre core (Fig. 6 of Clémence et al., 2015) raising into question a dominant control on the production by this taxon by temperature. Rather, the level at which *Schizosphaerella* spp. show a drastic decrease in abundance and calcisphere size is coincident with a number of other profound environmental changes such as inferred increase in CO_2^{atm} (and presumably lower pH) and relative sea level fall (Hermoso et al., 2012, 2013).

The size of *S. punctulata* calcispheres is the most striking observation used by Clémence et al. (2015) to argue for reduced pelagic carbonate production prior to the CIE, as size reduction cannot be ascribed to enhanced calcite dilution by detrital minerals (quartz and clays). The observation of decreased calcisphere size is not only registered in the Paris Basin, but was previously reported from the Peniche section in the Lusitanian Basin (Suan et al., 2008). In modern phytoplankton, increased specific growth rate sets the generation time of the extant phytoplanktonic population with consequences on cell size (Tang, 1995). Ecological models predict that if cells divide often, their cellular volume will tend to get smaller (Van Rijssel and Giekes, 2002; Atkinson et al., 2003). As such, there is a conundrum between micropalaeontological interpretation and ecological prediction under the assumption that unfavourable conditions reduced biocalcification of *S. punctulata*. In the context of Early Toarcian environmental settings, it could be hypothesised that enhanced nutrient supply accompanying the major carbon cycle disturbance (Cohen et al., 2004; Hermoso et al., 2012) promoted nitrogen-rich cells, circumstances under which phytoplankton with relatively low growth rate and small cell size flourish (Marañón, 2015). We note that this hypothesis may be supported by the recognition of a "fertility event" by Clémence et al. (2015) from 351 m up to the onset of black shale deposition. In any case, there is not a straightforward explanation that can account for this palaeoecological feature. Thus, we would like to stress that it remains rather undemonstrated from a biogeochemical perspective that a postulated global warming at Sancerre was detrimental for *S. punctulata* growth (including its abundance and size). Considerable debate around the ecology of this taxon (Cobianchi and Picotti, 2001; Erba, 2004; Mattioli and Pittet, 2004; Tremolada et al., 2005; Bour et al., 2007) additionally makes it very difficult to relate patterns in nannofossil abundance and size with environmental forcing.

The importance of biominerals produced by the calcareous phytoplankton (coccoliths and calcispheres) as a means of enhanced flux of POM to the seafloor is well argued (e.g., Deuser et al., 1981; Lam et al., 2011; Raven and Crawfurd, 2012). The sensitivity of the "physical" carbonate pump is all the more important in the Early Jurassic, as this time period lacked the diatoms and planktonic foraminifera of the present day. Diminished efficiency of this component of the biological pump, if recognised at a global scale, may have therefore reduced the ballasting of ^{12}C-rich POM to the seafloor, as suggested by Clémence et al. (2015). However, in this paper, it is suggested that reduced calcification had an effect on the global isotopic carbon cycle through reduced ballasting of POM to the seafloor, hence decreasing carbon isotope values of the surface of the ocean. However, compelling global-scale sedimentological and geochemical evidence indicates substantially high primary productivity during the CIE and the T-OAE, with widespread accumulation of organic matter on the seafloor (e.g., Jenkyns, 1988; Jenkyns, 2010), and the age model adopted by Clémence et al. for the Sancerre core does not indicate any significant local condensation, arguing against slow sedimentation as a cause of organic enrichment.

In such proximal settings as the Paris Basin with very high quartz and clay content in sediments, the ballast of organic matter through a relatively thin water column probably also remained important, regardless change in calcite content (Kennedy et al., 2002). During the CIE, there was significant increase in the riverine run-off and discharge of detrital sediment to the basin (Cohen et al., 2004; Hermoso and Pellenard, 2014), potentially aiding export of POM to the seafloor.

In conclusion, it cannot be established from the presented data that the nannofossil trends observed at Sancerre – specifically decrease in abundance and size of *S. punctulata* – correspond to a "biocalcification crisis" due to increased temperature. A causal link between diminished pelagic carbonate production and carbon isotope composition of sediments appears unlikely considering continuously high primary productivity and organic carbon export to the seafloor during the Oceanic Anoxic Event, and the time lag of more than ~ 120 kyr (cf. Fig. 6) that separates the onset of the supposed *S. punctulata* 'crisis' and the negative CIE.

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