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Links between temperature changes and oceanic-plateau emplacement during the Cenomanian–Turonian Oceanic Anoxic Event (OAE 2)

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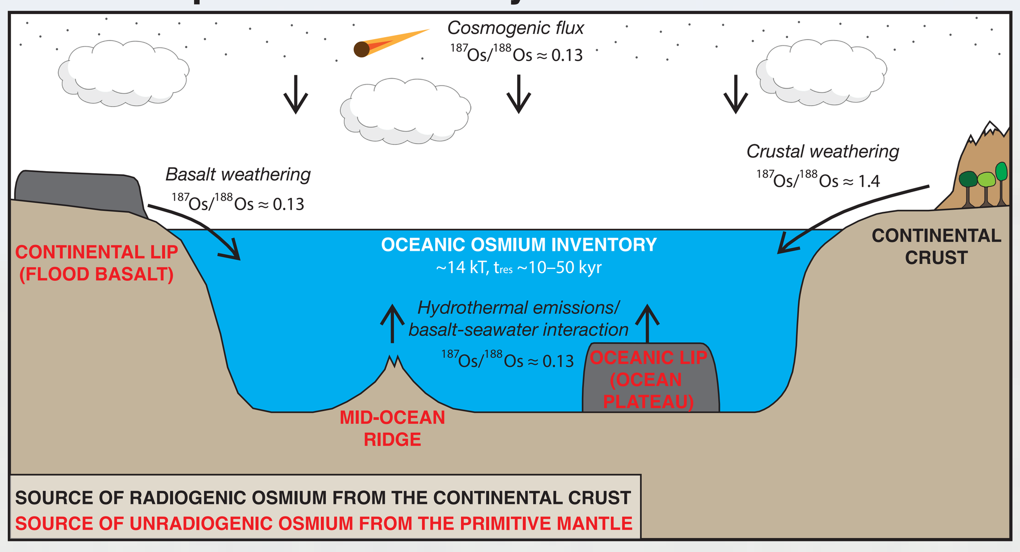
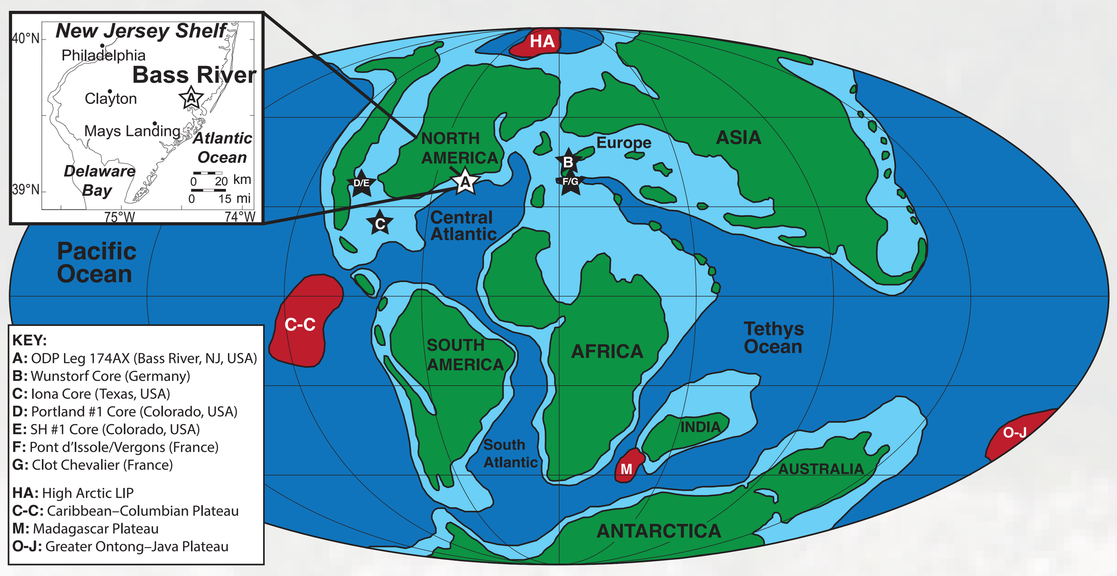
Figure 1: Simplified osmium cycle



Simplified illustration of the main sources of osmium to the ocean (adapted from ref. 6). Mantle volcanism (or seawater-interactions of primitive basalts supply chiefly unradiogenic ^{188}Os, continental weathering chiefly supplies radiogenic ^{187}Os. The proportion of thevarious fluxes controls the seawater $^{187}Os/^{188}Os$ ratio **(e.g. more submarine volcanism will decrease the ratio).**

Figure 2: Cenomanian–Turonian world



Bass River and other examples of studied Cenomanian–Turonian records. Adapted from refs. 2 and 6.

Introduction:

The Cenomanian–Turonian Oceanic Anoxic Event (OAE 2) was one of the most severe global crises of the Mesozoic Era. As well as the development of widespread marine anoxia and organic-carbon burial (typically recorded by the preservation of organic-rich shales and a positive carbon isotope excursion – CIE), a number of other environmental perturbations took place, including siginificant climing warming.[1]

This enhanced organic-matter burial, potentially aided by carbon sequestration via increased silicate weathering, resulted in an abrupt pulse of global cooling within the overarching warming during the early part of OAE 2, dubbed the Plenus Cold Event (PCE).[1–4] However, the exact timing of this cooling was likely geographically diachronous.[5]

The ultimate driver of OAE 2 is largely thought to have been intense volcanic activity related to the formation of one or more Large Igneous Provinces (LIPs): represented as on the order of 1 Mkm of igneous material emplaced on to/in to the Earth's crust geologically rapidly (<1 Myr). For OAE 2, several oceanic LIPs (oceanic plateaus) have been implicated.[see 6–8]

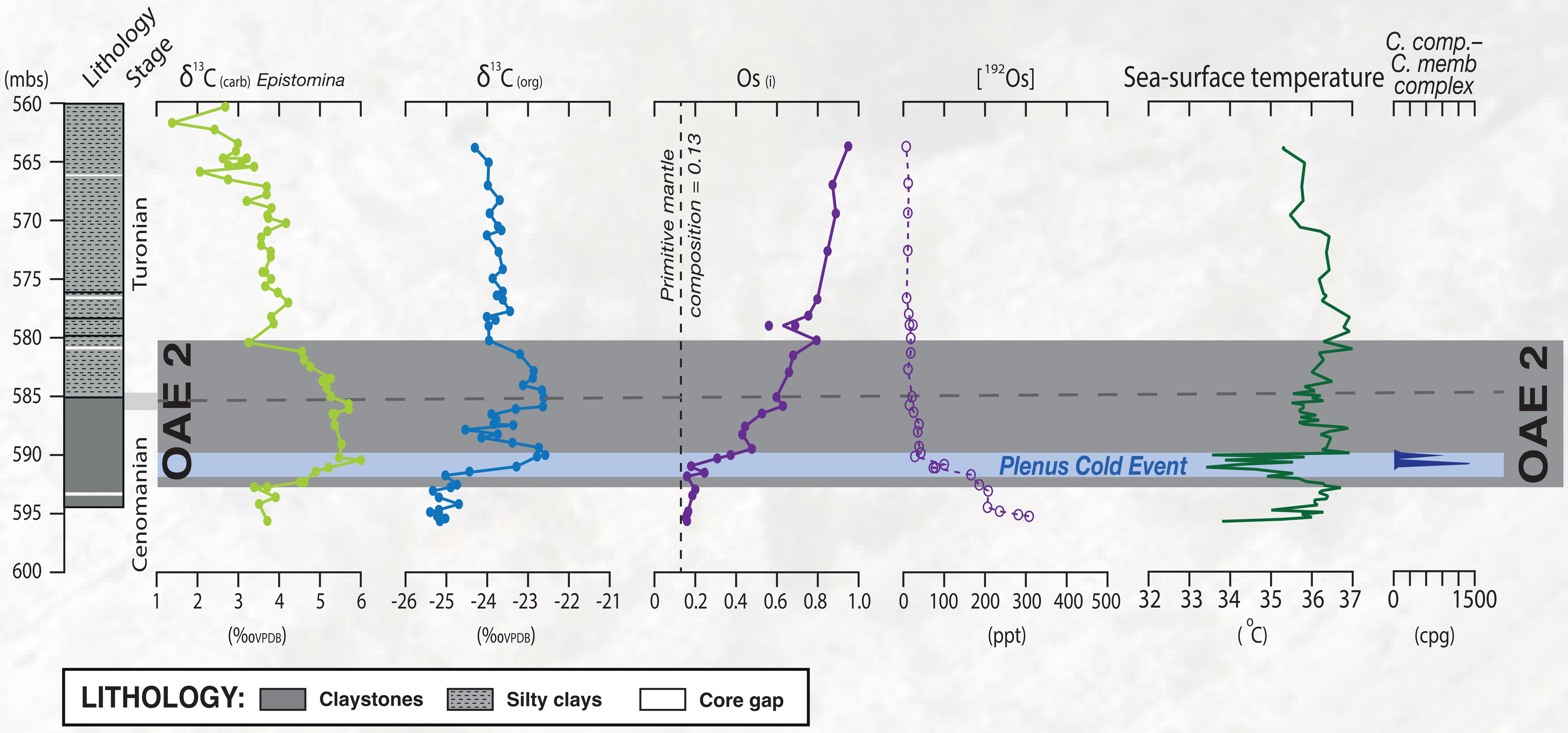
A limited number of radioisotopic dates support a temporal link between oceanic-plateau activity and OAE 2; however, the stronger evidence comes from a shift in the osmium- (Os-) isotope composition of seawater ($Os_{(i)}$) to near mantle-like values (Figure 1) recorded in multiple records of the OAE from several ocean basins.[7–10] This plateau emplacement is thought to have begun ~60 kyr prior to OAE 2.[10]

However, direct comparisons between Os-isotope records of volcanism and temperature change proxy trends have seldom been undertaken for OAE 2.

This study presents new Os-isotope trends from a record of OAE 2 from the Bass River Core (ODP Leg 174 AX; NJ, USA), which was deposited on the New Jersey Shelf area of the Proto North Atlantic (Figure 2). Previous studies have clearly defined the OAE 2 level by a positive CIE,[2,11] and highlighted the elevated sea-surface temperatures typical of OAE 2, as well as the Plenus Cold Event cooling.[2]

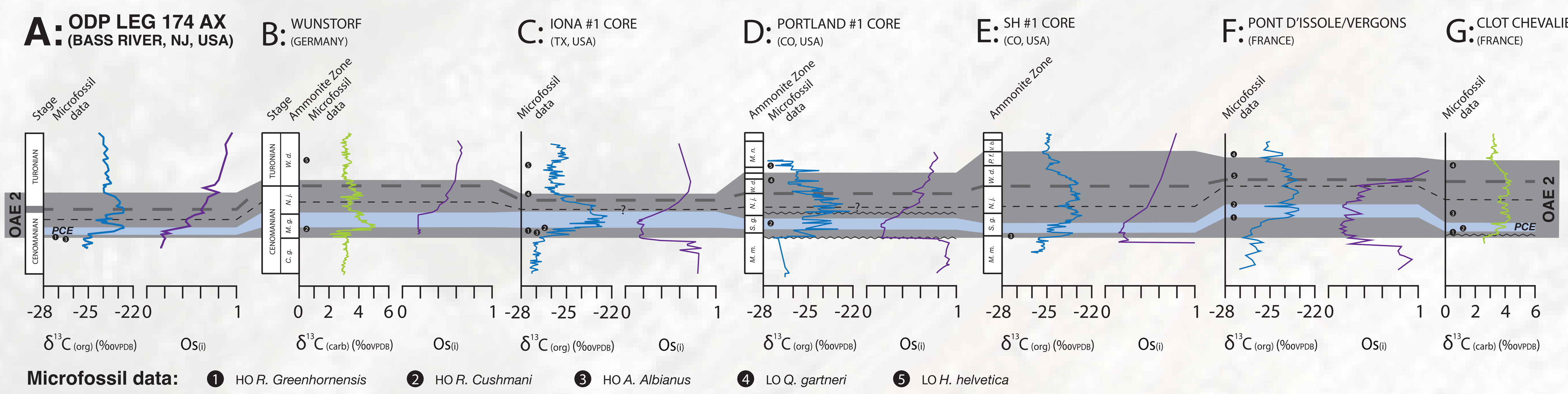
Using globally documented OAE 2 Os-isotope trends, we employ Os-isotope stratigraphy to refine the age constraints and placement of the Cenomanian–Turonian boundary (CTB) in the Bass River record. Additionally, the osmium records of volcanic activity are compared to the palaeotemperature trends from the same site.

Figure 3: Volcanism and temperature proxy data from Bass River (ODP Leg 174 AX)



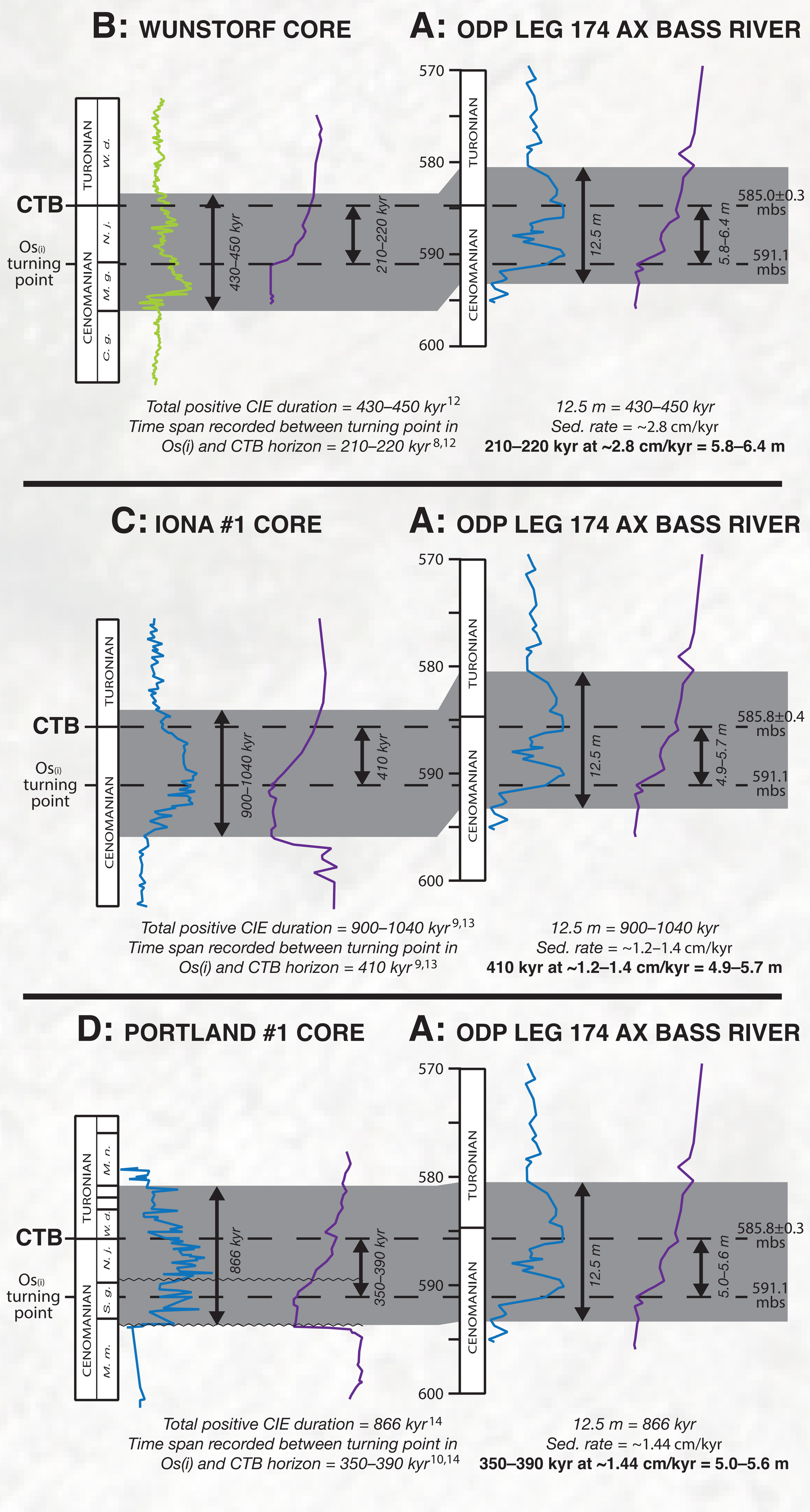
Foraminiferal carbon-isotope data from ref. 11 , organic carbon-isotope data from ref. 2 and this study, sea-surface temperature, and boreal-fauna abundance data from ref. 2.

Figure 4: OAE 2 site-to-site stratigraphic correlation



Carbon-isotope data from refs. 2–4,12–14,18 and this study. Osmium-isotope data are from refs. 8–10 and this study.

Figure 5: The Bass River CTB age model



Carbon-isotope data from refs. 2,12–14 and this study. Osmium-isotope data from refs. 7,9 and this study. Age models for the Wunstorf Core, Iona #1 Core, and Portland #1 Core from refs. 12,13, and 14, respectively.

Results and Discussion:

A relative enrichment in 'common' ^{192}Os, very low unradiogenic $Os_{(i)}$ ratios in the basal OAE 2 strata, and recovery to more radiogenic values in the upper part of the OAE level are all consistent with other Cenomanian–Turonian ($Os_{(i)}$) records (Figure 3) This suggests that global ocean (rather than local) Os trends are recorded, with the low $Os_{(i)}$ interpreted as marking intense oceanic-plateau activity, as for previous studies.[7–10]

There is no record of the initial shift to unradiogenic $Os_{(i)}$ values below OAE 2 strata, which marks the onset of oceanic-plateau activity; this might be preserved in sediments deposited below the bottom of the Bass River core.

There is a negative CIE within the overarching positive excursion at Bass River, reminiscent of the negative CIE which is typically associated with the PCE at other OAE 2 sites. However, correlating the Bass River C- and Os-isotope records with other sites indicates that the Bass River negative CIE is too high with respect to the $Os_{(i)}$ curve for that excursion, and may mark a subsequent CIE sometimes seen just below the CTB (Figure 4).

Age models of the duration of the whole OAE 2 CIE and the time interval recorded between the CTB and turning point in $Os_{(i)}$ towards radiogenic values from the Wunstorf, Iona #1, and Portland #1 cores (refs., 12,13,14; Figure 5) suggest that the CTB at Bass River should be placed at 585.5±0.7 mbs. This estimate assumes a constant sedimentation rate at Bass River; if the basal OAE strata were actually condensed (as reported for other records), the CTB level may in fact be slighly higher, more consistent with carbon-isotope correlations (as proposed by ref. 2).

Comparing the palaeotemperature and $Os_{(i)}$ data from Bass River highlights that oceanic-plateau activity was ongoing during the sea-surface temperature fall at that location, but was waning by the time that the PCE ended and relatively low for 100s kyr through the second half of OAE 2 when global temperatures were high. This is the opposite of what might be expected, and suggests a complex relationship between oceanic-plateau activity and climate change during OAE 2.

Methods:

Re-Os analyses were performed by NTIMS techniques on a ThermoScientific Triton N-TIMS at Durham University, following carius-tube digestion with $Cr^{VI}O_3$-H_2SO_4 followed by Os purification by solvent extraction and microdistillation after ref. 15, and Re purification by single-bead anion chromatography after treatment by NaOH and acetone.[16] Procedural blanks were 19.4±2.0 pg for Re, 0.07±0.01 pg for Os, with a $^{187}Os/^{188}Os$ ratio of 0.16+0.05 (n=4). Mean standard $^{187}Os/^{188}Os$ (50 pg DROsS) and $^{187}Re/^{185}Re$ (125 pg ReSTD) values were 0.160749±0.000159 (1 σ) and 0.59820±0.00082 (1 σ), respectively, consistent with running averages for the lab.[17]

New organic carbon-isotope data for the Bass River core were generated on decarbonated powders by analysis on a Thermo Delta-V couped to an EA Isolink CN mass spectrometer at Utrecht University.

Acknowledgements and references:

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