Ultrahigh-resolution carbon isotope stratigraphy of an abrupt negative shift during the Toarcian Oceanic Anoxic Event

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Take-home message

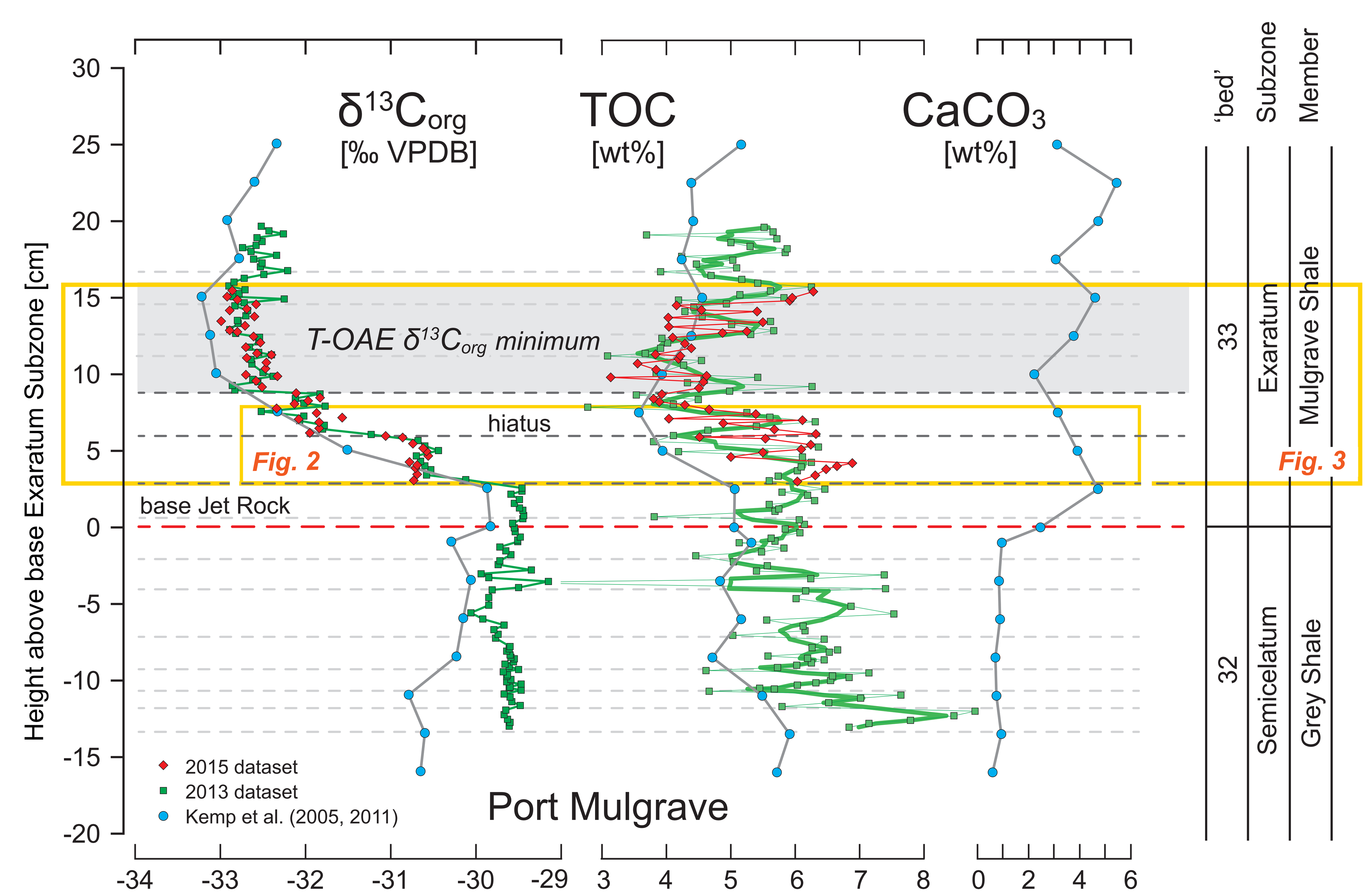
Abrupt shift 'B' in the organic carbon isotope ($\delta^{13}C_{org}$) record of North Yorkshire represents multiple episodes of erosion (by storms) that resulted in nonsequences (diastems) that affect the morphology of the $\delta^{13}C_{org}$ record. On the scale of the Jurassic epeiric sea, some of these erosional surfaces might be useful for correlation.

Background

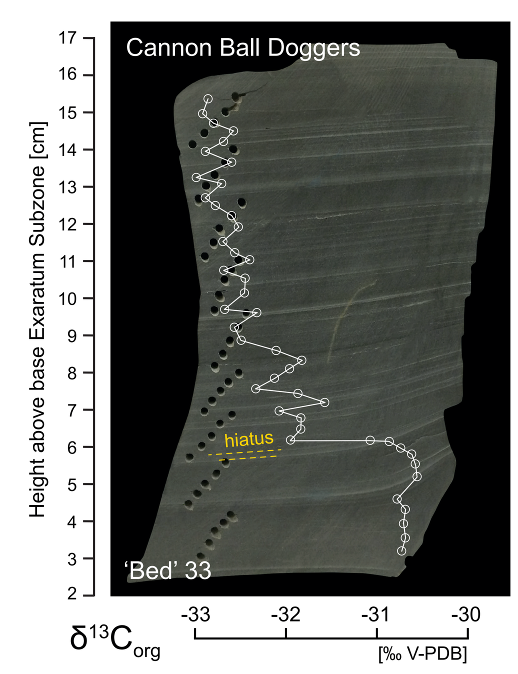
The $\delta^{13}C_{org}$ record of the Lower Toarcian of North Yorkshire contains three abrupt shifts attributed by Kemp et al. (2005) to pulses of methane release. A very similar abruptly stepped morphology of the $\delta^{13}C$ record is present in the Sancerre core, Paris Basin, and in the Mochras core, Cardigan Bay Basin, which suggests that the process responsible for the abrupt shifts is at least regional. Trabucho-Alexandre (2015) and Trabucho-Alexandre et al. (2022) argued that the abrupt shifts in the $\delta^{13}C$ record are an artefact of erosive processes and do not represent geologically abrupt input of carbon from an extremely ^{13}C-depleted carbon source.

Results

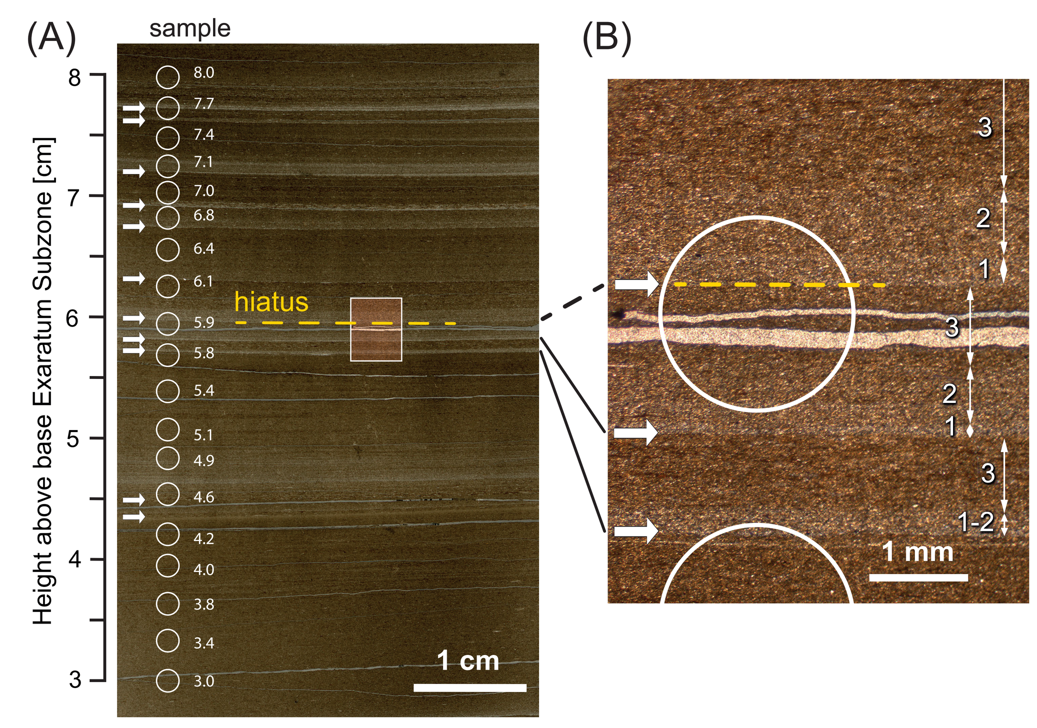
We show that abrupt shift 'B' (*sensu* Kemp et al. 2005) occurs in a thin-bedded mudstone facies and that the abrupt shift of 3.3 ‰ takes place in three steps: the first step between 2.5 and 3.35 cm, the second step between 5.6 and 6.35 cm, and the third step between 8.65 and 8.9 cm. The second step is responsible for most of the shift and coincides with the lower bedding plane of a thin bed. The nondepositional (and erosional) bedding plane is overlain by a laminaset of coarser silt, which makes the bedding plane stand out. We speculate that the other (smaller) steps are associated with cryptic bedding planes.



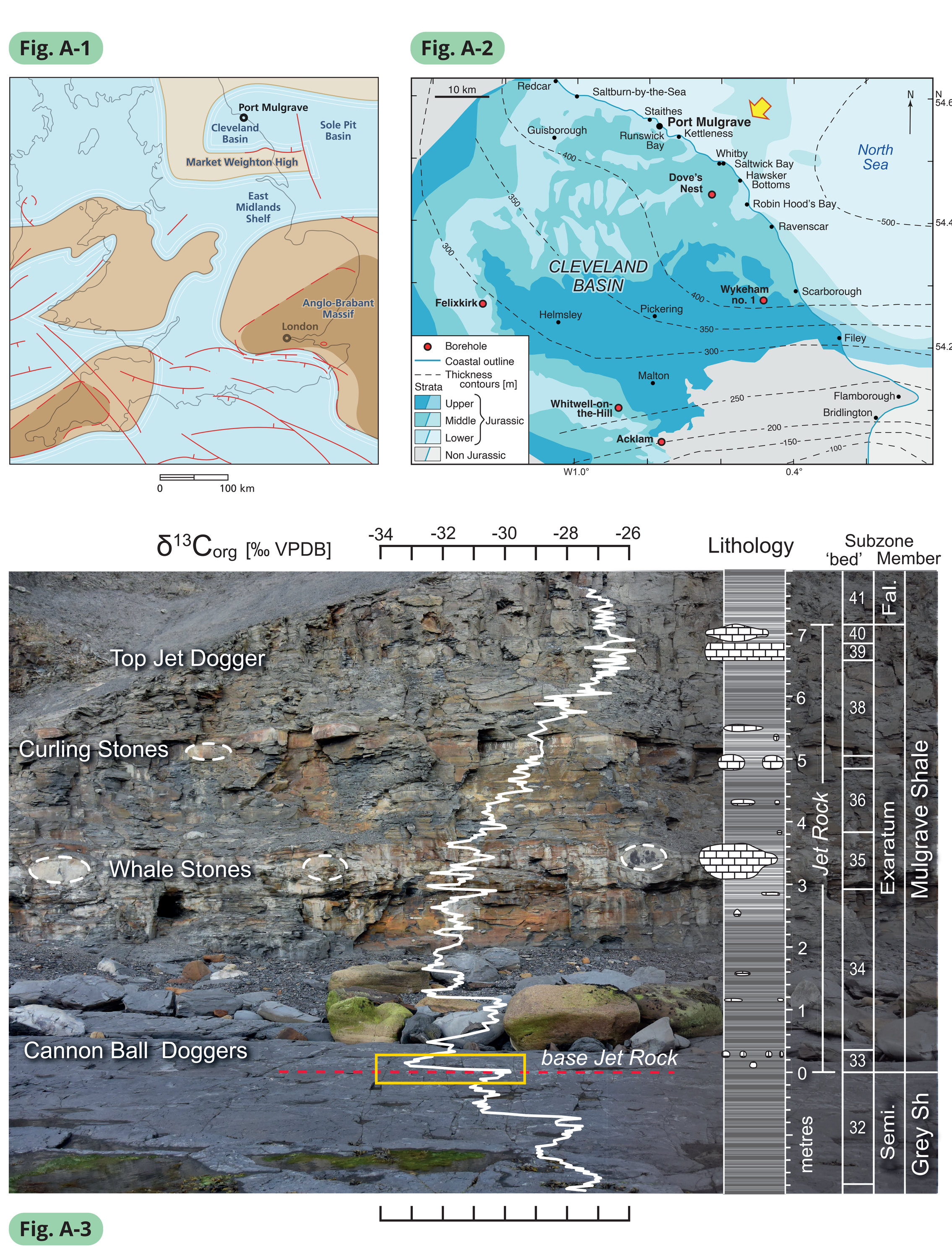
▲ **Figure 1** | Ultrahigh-resolution organic carbon isotope ratio ($\delta^{13}C_{org}$) and total organic carbon (TOC) curves across the Semicelatum–Exaratum subzonal boundary. For reference, we present the data of Kemp et al. (2005, 2011) from this interval, which also include carbonate content. TOC values of Kemp et al. (2011) are whole rock; our data are insoluble residue values. The 2013 dataset comprises 123 subsamples of three halved blocks that stack to form a stratigraphic interval that is ~33 cm thick. The distance between successive subsamples in this dataset is on average 2.7 mm. The 2015 dataset comprises 45 subsamples from a single halved block that is ~13 cm thick (Fig. 2). The distance between successive subsamples in this dataset is on average 2.8 mm. Base of Exaratum Subzone follows Kemp et al. (2005, 2011).



▲ **Figure 2** | Subsampled (2015 dataset) halved block with $\delta^{13}C_{org}$ results. Vertical placement of $\delta^{13}C_{org}$ data points (white circles) was corrected for variable deformation across the sample to reflect their true positions (drill holes) in the thin bedded stratigraphy.



▲ **Figure 3** | **(A)** Scan of the thin section containing the second step (between 5.6 and 6.35 cm) of abrupt shift 'B'. White circles show the position of drill holes. White arrows show the position of bedding planes that stand out due to the presence of a basal silt laminaset. **(B)** The abrupt shift takes place in a thin bedded mudstone facies. The thin beds often exhibit a tripartite internal stratigraphy interpreted by Macquaker et al. (2010) as the product of wave-enhanced sediment gravity flows.



◀ **Figure A** | **1** | Paleogeographic map of England and Wales during the Early Jurassic. The principal structures affecting sedimentation in the Early Jurassic are shown. The Cleveland Basin was a more subsident area of the epeiric sea of northwest Europe. Water depth at the time of deposition is estimated to have been a few tens of metres. Redrawn after Jenkyns et al. (2001) and Wright (2022).

2 | Map of eastern North Yorkshire showing the geographic distribution of Jurassic sediments in the Cleveland Basin, isopachs for the Lias Group, and the location of Port Mulgrave (arrowed) and other relevant localities and boreholes. Redrawn after Rawson and Wright (1995) and Kent (1980).

3 | Field photograph of the lower cliff face immediately west of the old harbour of Port Mulgrave annotated with the $\delta^{13}C_{org}$ data of Kemp et al. (2005) and the stratigraphic framework of Howarth (1962). The four distinctive concretionary horizons in the Jet Rock are shown. The yellow rectangle at the base of the Jet Rock shows the studied interval, which corresponds to abrupt shift 'B' of Kemp et al. (2005).

Other records

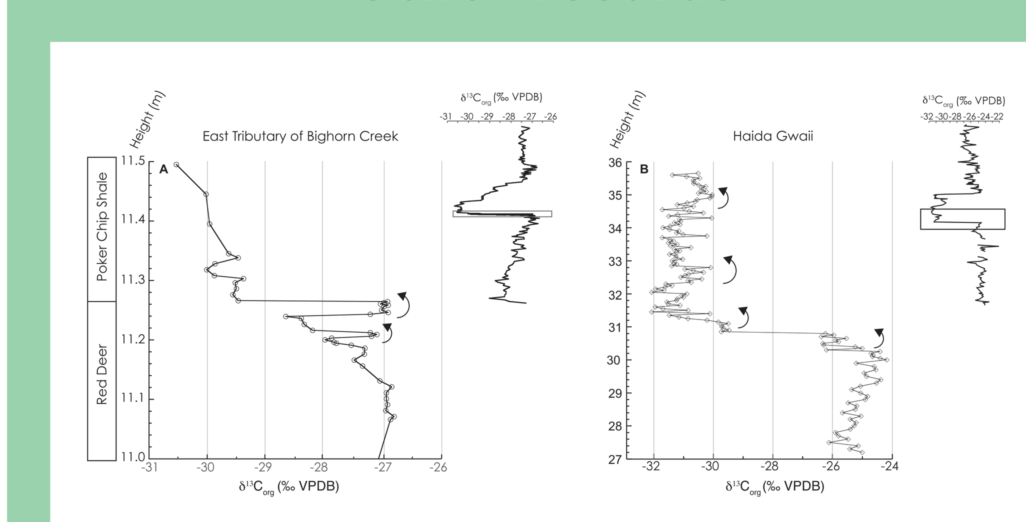


Figure | High-resolution $\delta^{13}C$ records of the Toarcian Oceanic Anoxic Event in western North America (Them et al. 2017). **A** East Tributary of Bighorn Creek and **B** Haida Gwaii. Boxes are placed around the complete $\delta^{13}C_{org}$ records to show the stratigraphic context of the high-resolution records.

In Haida Gwaii, British Columbia, Canada, the negative excursion is bound by two abrupt shifts but no stepwise excursion can be observed. In the East Tributary of Bighorn Creek, Alberta, Canada, abrupt shifts in the $\delta^{13}C$ record are associated with bedding planes of sandstone beds and surfaces where carbonate content changes. In both western North American examples, there are also abrupt shifts in the other direction, that is, towards less ^{13}C-depleted values.

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