EARTH SCIENCES WITH PLYMOUTH UNIVERSITY

STRATIGRAPHY AND PALAEOCLIMATE OF SPITSBERGEN, SVALBARD, DURING THE EARLY CRETACEOUS

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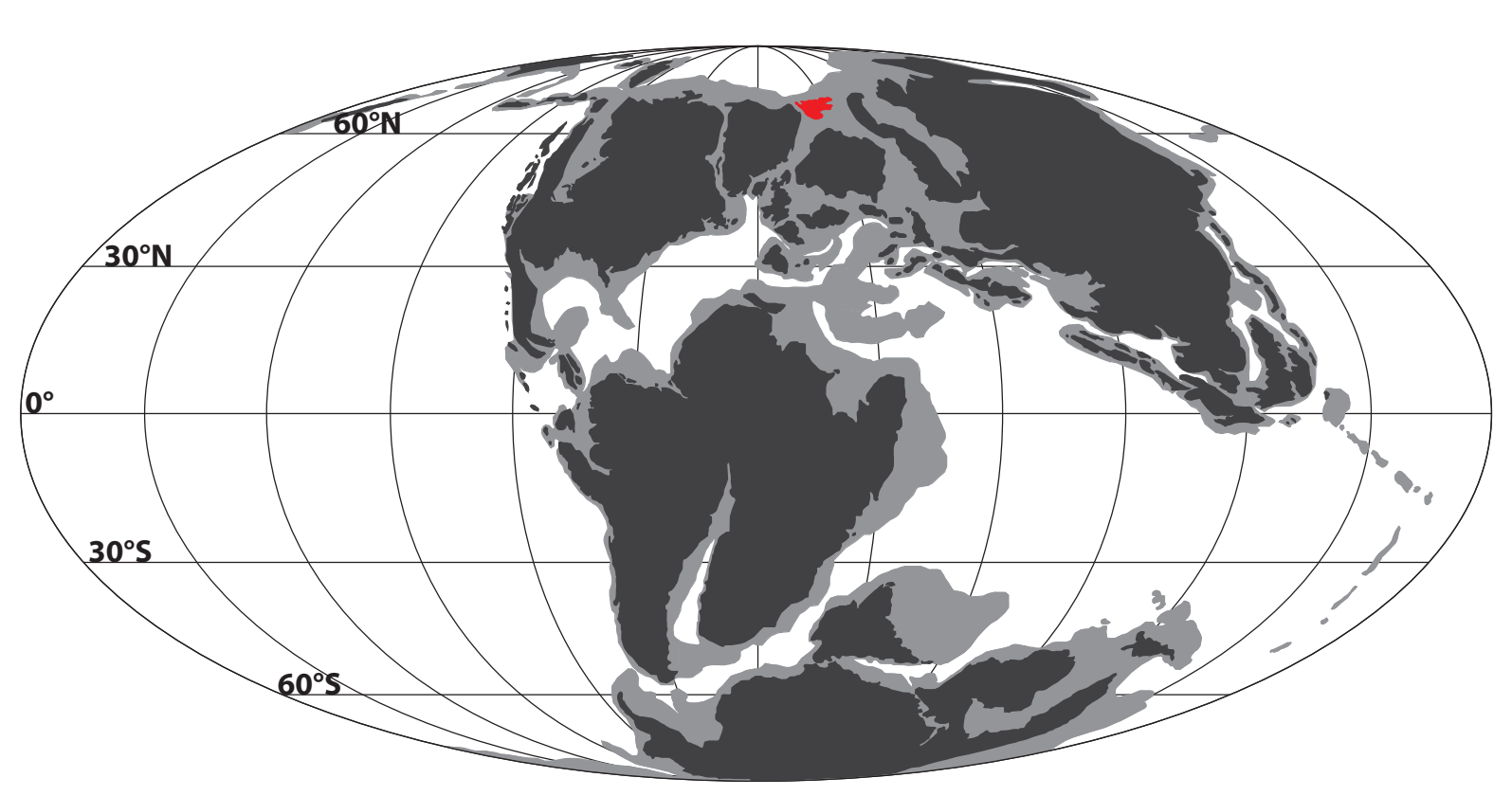
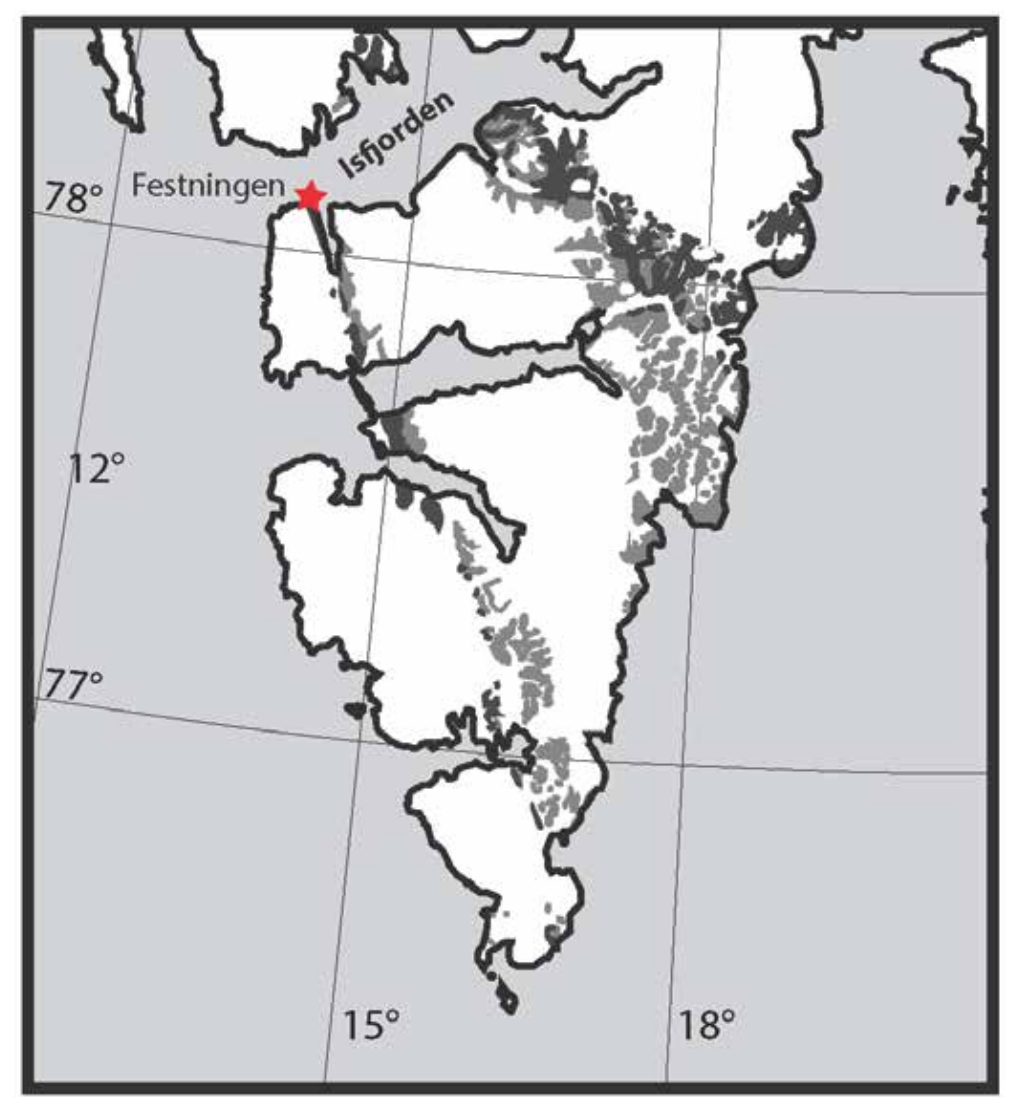
1. INTRODUCTION



Palaeogeographic reconstruction of the Early Cretaceous globe (Blakey, 2011). Spitsbergen shown in red. ▲

Dramatic changes in global climate occurred during the Early Cretaceous, a period traditionally believed to be invariantly "greenhouse". Here, we examine evidence from palaeo-high latitude Svalbard, and show that large global changes in the carbon cycle are preserved in the terrestrial carbon isotopic record from Early Cretaceous sediments. These carbon isotope excursions are linked to global climatic events, and we examine other climate/temperature proxies from the Early Cretaceous succession at the Festningen locality. Furthermore, we improve age constraints on the succession using carbon isotope stratigraphy.

Outline of Spitsbergen, with Festningen denoted by a star. The Mesozoic Adventdalen Group is marked on, the dark grey representing the Janusfjellet Formation (Upper Jurassic - Lower Cretaceous) and the light grey representing the overlying Helvetiafjellet and Carolinefjellet formations (Lower Cretaceous) (after Dallmann et al., 2002). ▶



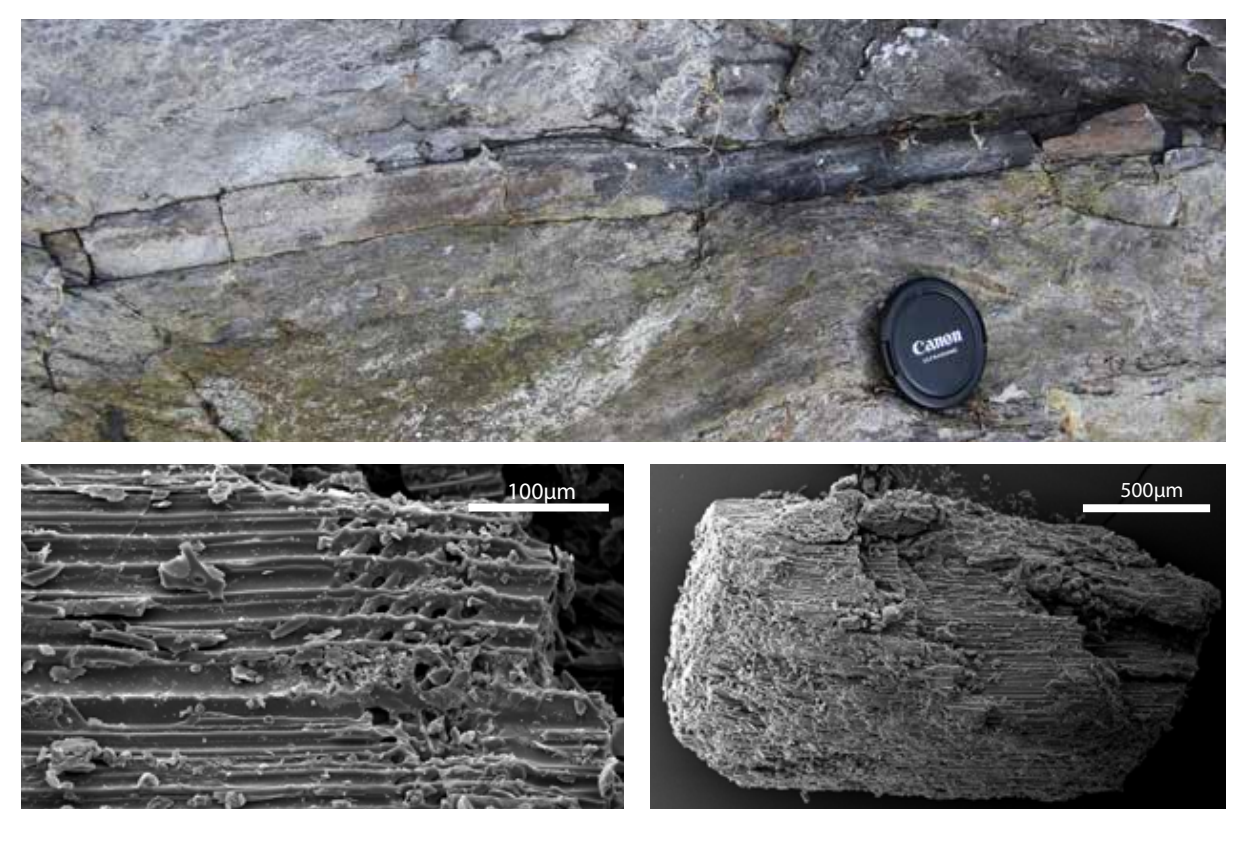
2. METHODS

Fieldwork was carried out in August 2014 and July 2015 at the the Festningen locality, Spitsbergen, Svalbard (78°09.98'N, 13°94.32'E). Macro-plant material was sampled wherever it occurred in the 780 m succession. Bulk rock samples were collected at a resolution of 1 sample every 0.5 m for the entire 780 m succession. Conventional sedimentary logging was carried out at scale of 1 m = 2cm. Woody material was characterised by light microscopy and SEM surface studies using a Jeol JSM 6610LV SEM at Plymouth University. A representative number of bulk rock samples were analysed for TOC at Plymouth University using a Skalar Primacs SLC Analyzer. 500 bulk rock samples were selected for $\delta^{13}C$ analysis, and 139 samples of woody material selected for $\delta^{13}C$ analysis. Samples were ground to a fine powder using an agate mortar and pestle. Powdered samples were decarbonated by placing the sample in a 50 ml polypropylene centrifuge tube and treating with 10 % HCl for 1 hour until all the carbonate had reacted. Samples were then rinsed with deionized water, centrifuged and rinsed again until neutrality was reached (following the method of Gröcke et al., 1999).

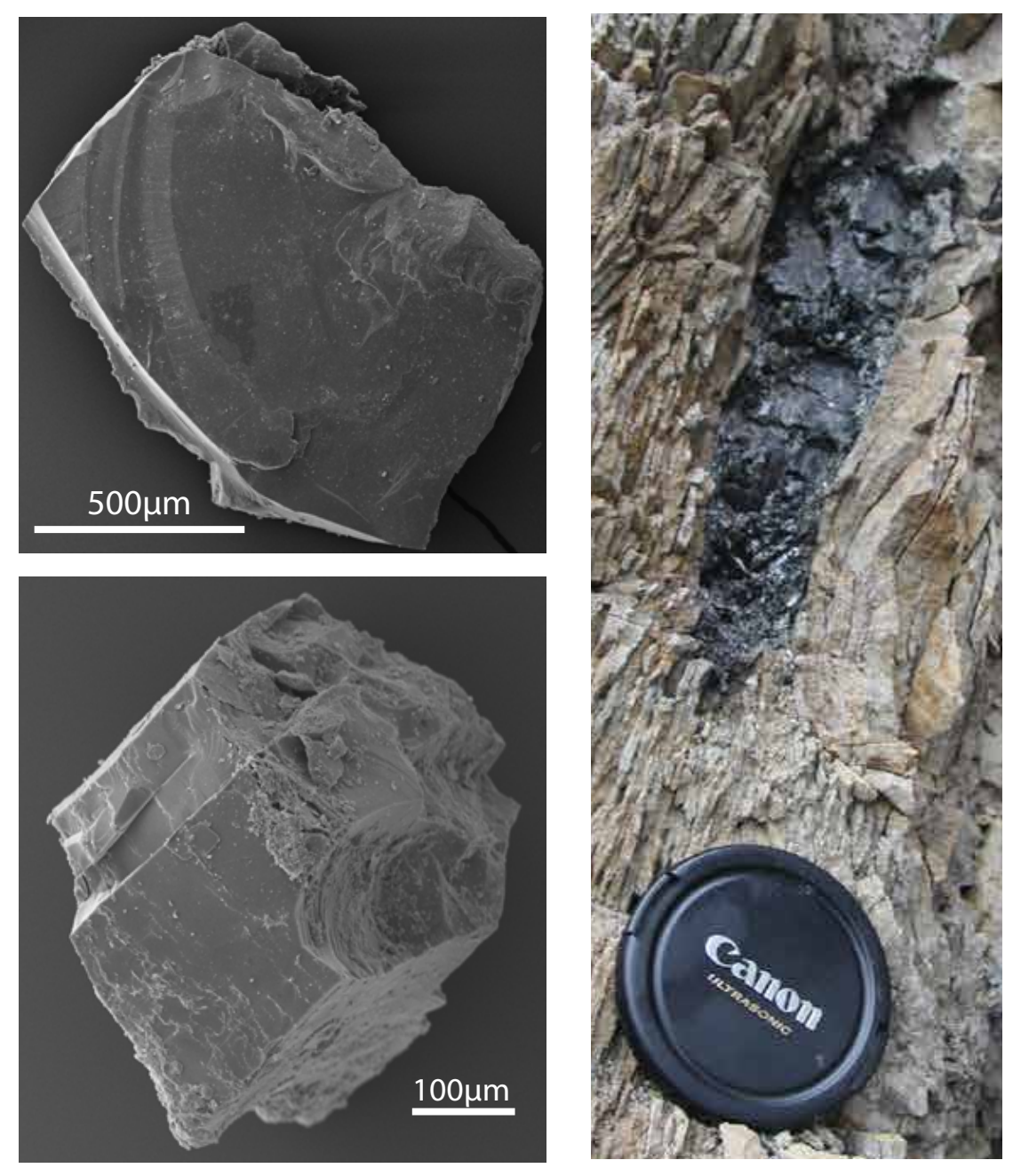
3. CHARACTERISATION OF ORGANIC MATERIAL

Woody material: discrete fragments of coal, charcoal and wood

Charcoal

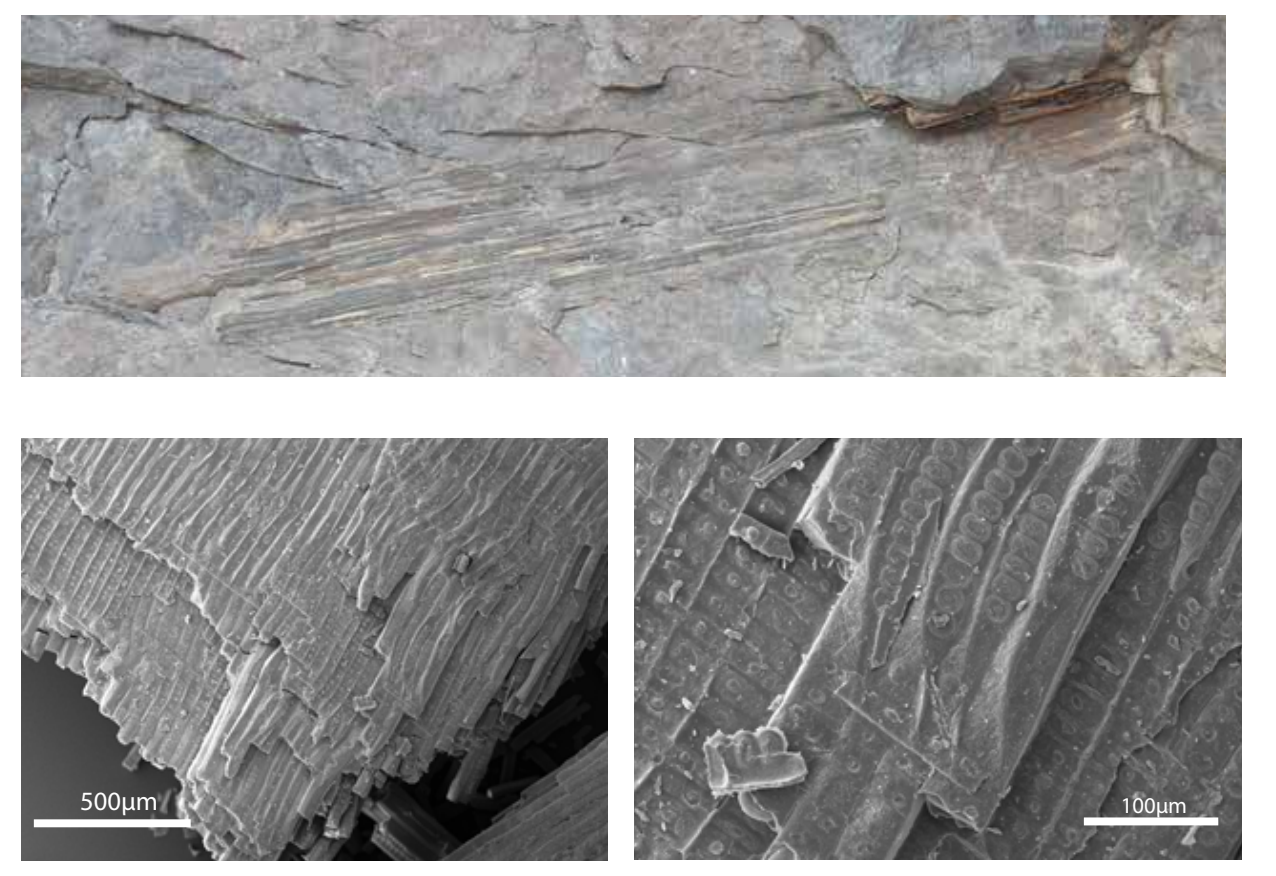


Coal

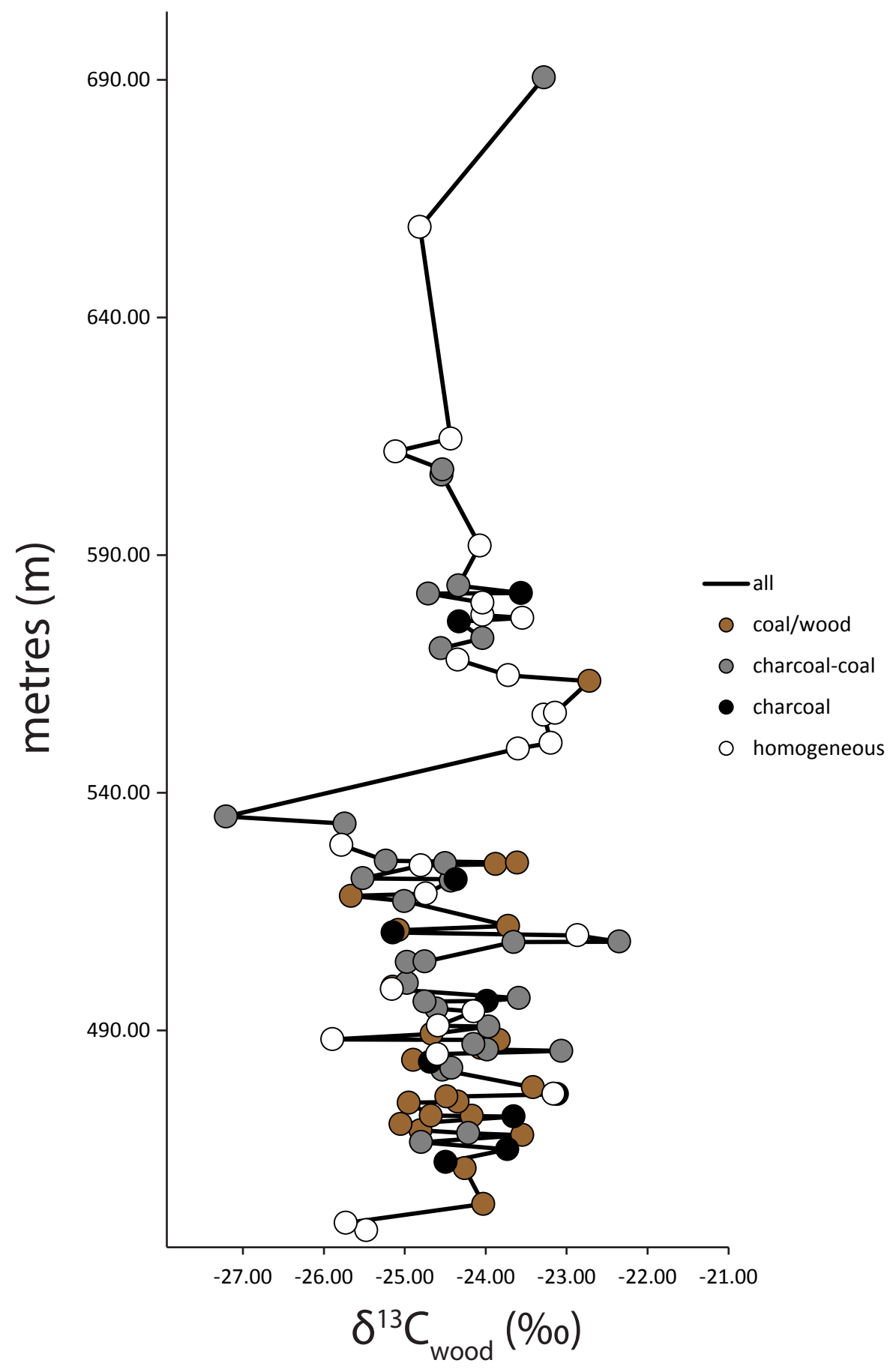


(Analysis performed on a Jeol JSM 6610LV SEM at Plymouth University.)

Wood

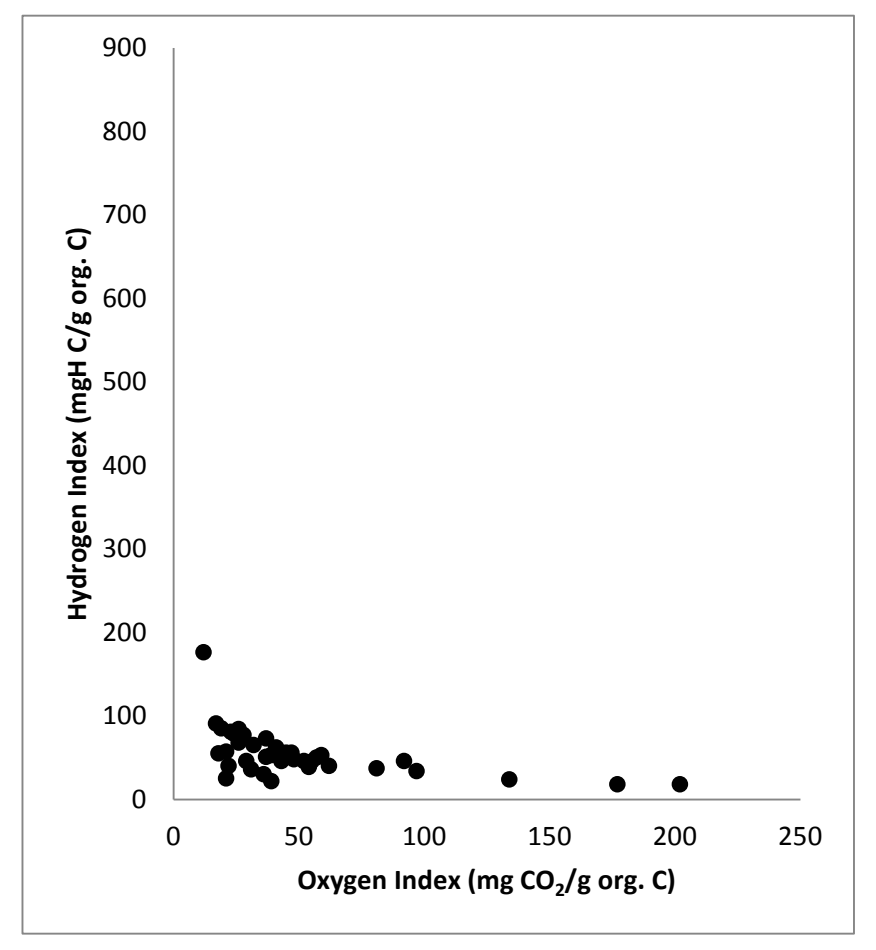


The isotope data show an overlapping range of values and no appreciable difference between each preservation state. Hence the range of preservation observed is unlikely to have an impact on the overall long-term trends of the $\delta^{13}C_{wood}$ curve. This has been previously shown by Gröcke et al. (2002) and Hesselbo et al. (2000).



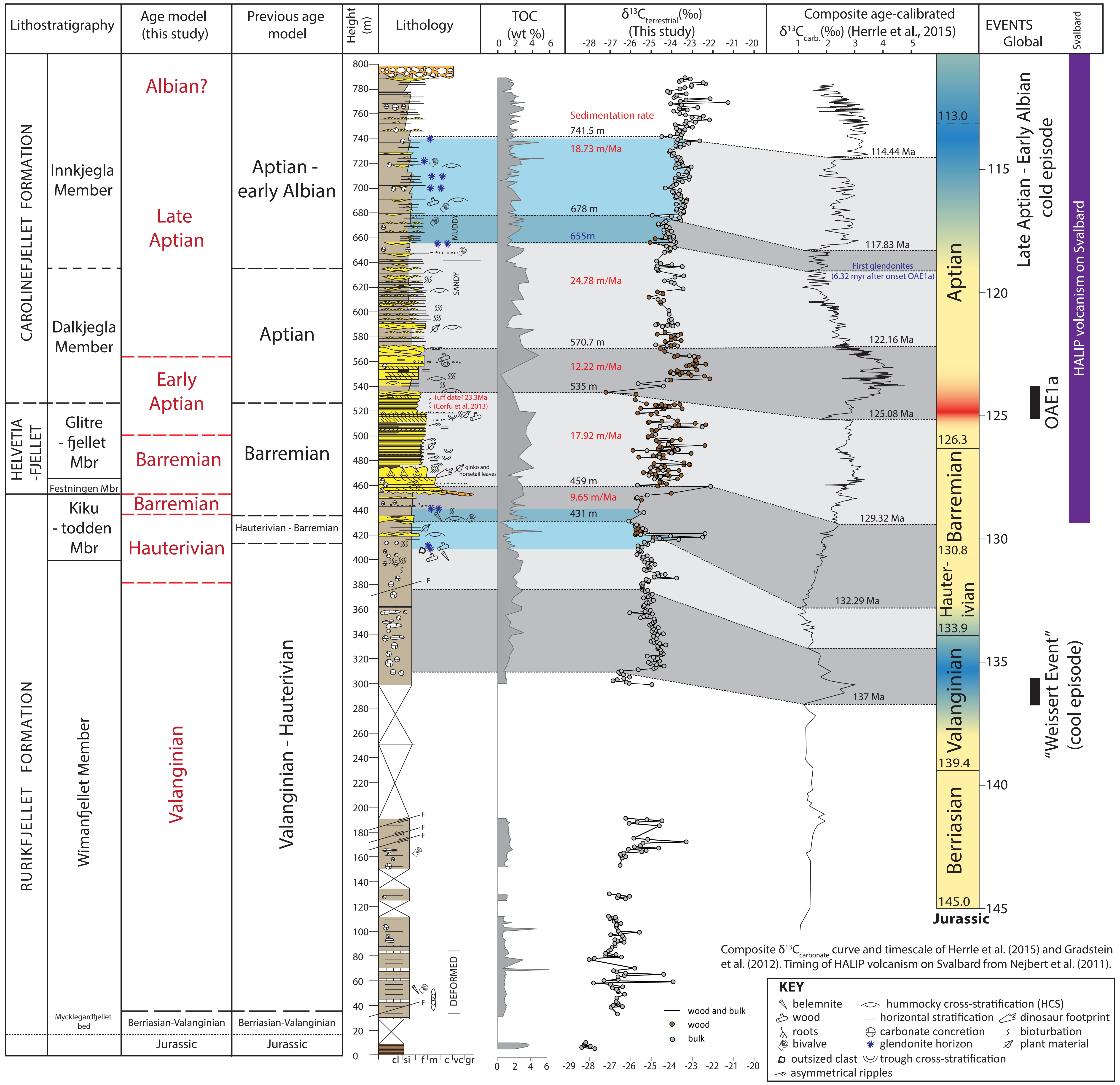
$\delta^{13}C$ of woody material showing the different preservational states of the wood samples. ▼

Bulk organic matter: derived from high plant material (type III kerogen)



Rock Eval hydrogen and oxygen indices displayed on a Van Krevelen diagram. The pilot samples all clearly fall within type III kerogen. Analysis courtesy of L. Percival, University of Oxford. ◀

4. THE FESTNINGEN SECTION: RECORDS OF GLOBAL CARBON CYCLE AND CLIMATE CHANGE



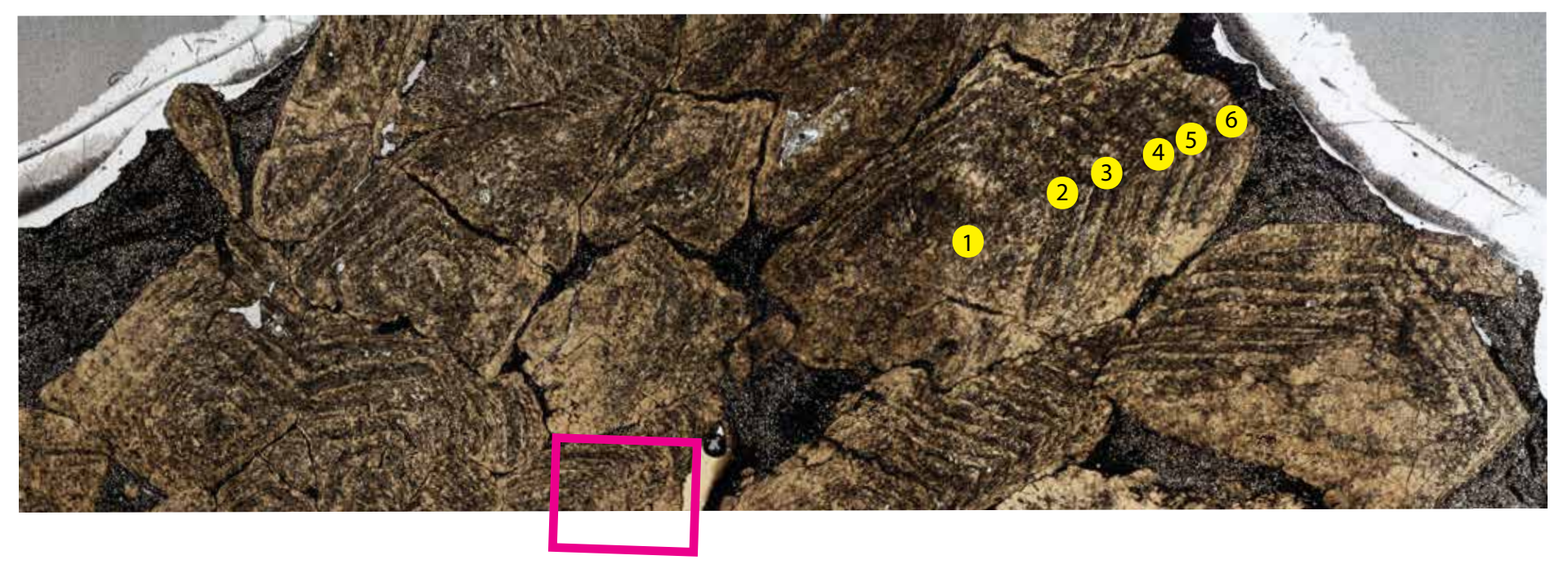
Composite $\delta^{13}C_{carbonate}$ curve and timescale of Herrle et al. (2015) and Gradstein et al. (2012). Timing of HALIP volcanism on Svalbard from Nejbert et al. (2011).

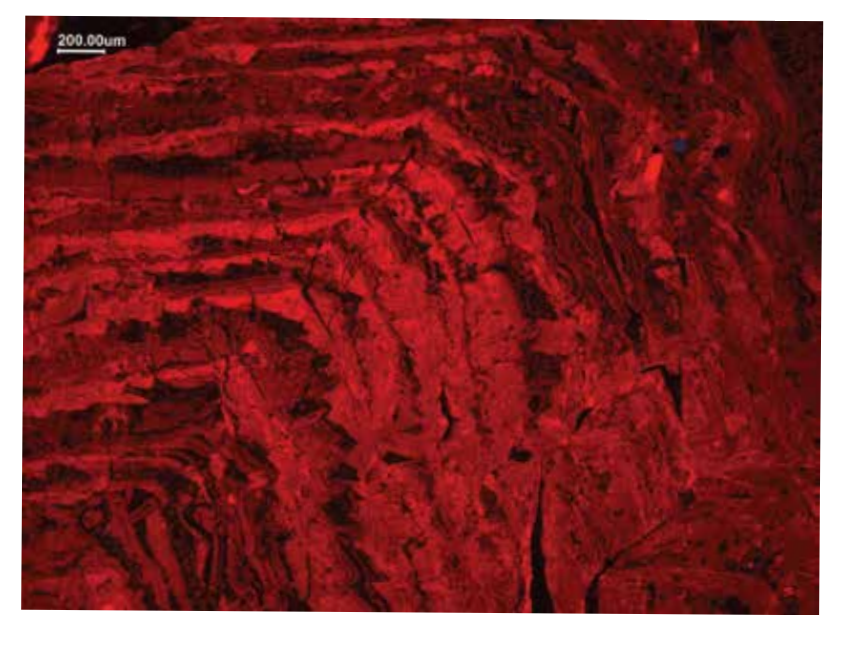
KEY

belemnite	hummocky cross-stratification (HCS)	
wood	horizontal stratification	dinosaur footprint
roots	carbonate concretion	bioturbation
bivalve	✳ glendonite horizon	plant material
outsized clast	trough cross-stratification	
asymmetrical ripples		

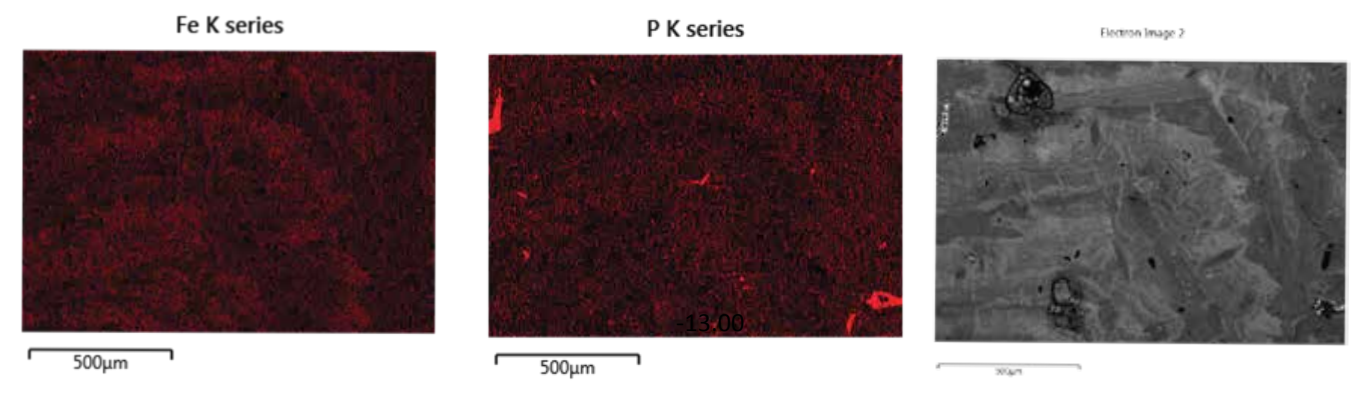
5. GLENDONITES: organic-rich zoned calcite nodules; pseudomorphs after ikaite ($CaCO_3.6H_2O$). Ikaite can only grow at temperatures between 0-8°C under high alkalinity, high phosphate conditions.

▼ Thin section of glendonite from 441 m. Pink box outlines section further analysed under CL and SEM. Yellow circles indicate how transects are taken accross zoned crystals.



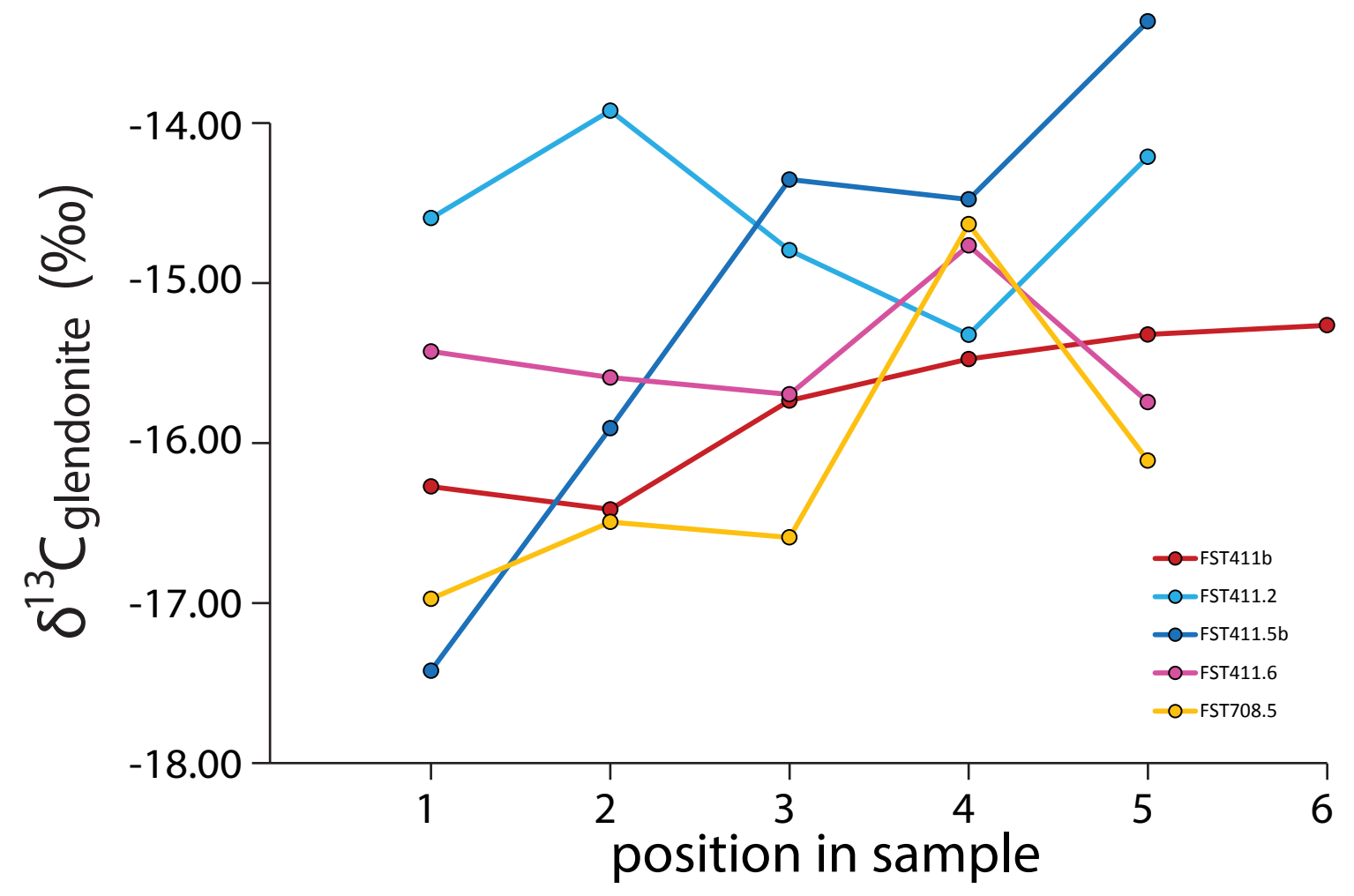


Cathodo-luminescence image: dark areas are iron-rich. ▲



SEM element mapping: P and Fe in different zones. ◀

Anti-correlation of phosphorus and iron in glendonites is consistent with a high phosphate requirement for ikaite growth. Carbon isotope values are consistent with carbon derivation from an organic matter source, with some mixing of carbon from a carbonate source.



◀ Carbon isotopic values for transects accross zoned glendonite crystals (e.g. see photograph of thin section, above), from position one (centre) to 5 or 6 (outer edge).

6. CONCLUSIONS

The Valanginian "Weissert" Event and Early Aptian carbon isotope excursion (CIE) are recorded in the terrestrial carbon isotope record at Festningen. Glendonites, thought be indicators of cold water, are found just above the positive excursion which characterises the Weissert Event, and 120 m above the Early Aptian CIE.

Our carbon isotope curve allows us to constrain the Valanginian - Hauterivian, Barremian - Aptian and Early Aptian - Late Aptian boundaries more precisely. However, the only known U-Pb date from a tuff in the Helvetiafjellet Formation (Corfu et al., 2013) is inconsistent with the Gradstein et al. (2012) timescale for the Early Aptian OAE CIE.

The Valanginian "Weissert" Event is thought to be associated with a global cooling episode; the Early Aptian CIE with an ocean anoxic event (OAE1a) and extreme global warmth; and the Late Aptian - Early Albian with a global cooling event. Glendonites appear in the succession at the end of the "Weissert event" and at the beginning of the Late Aptian cooling episode. This suggests that Spitsbergen experienced cooling slightly out of phase with the "whole Earth", consistent with observations today that the high latitudes are experiencing more rapid climate change than the equatorial regions.

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