The Global Weathering Thermostat: Fact, fiction, and computer models

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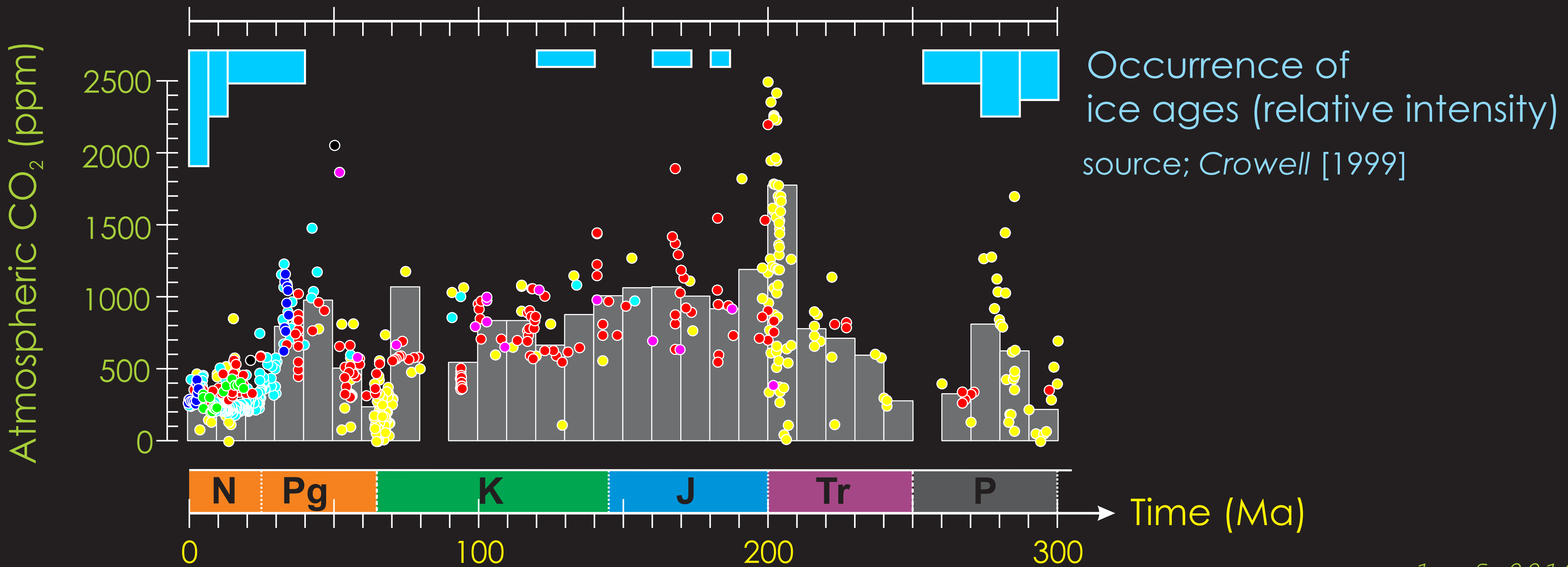
Introduction

From: *Hönisch et al.* [2012]



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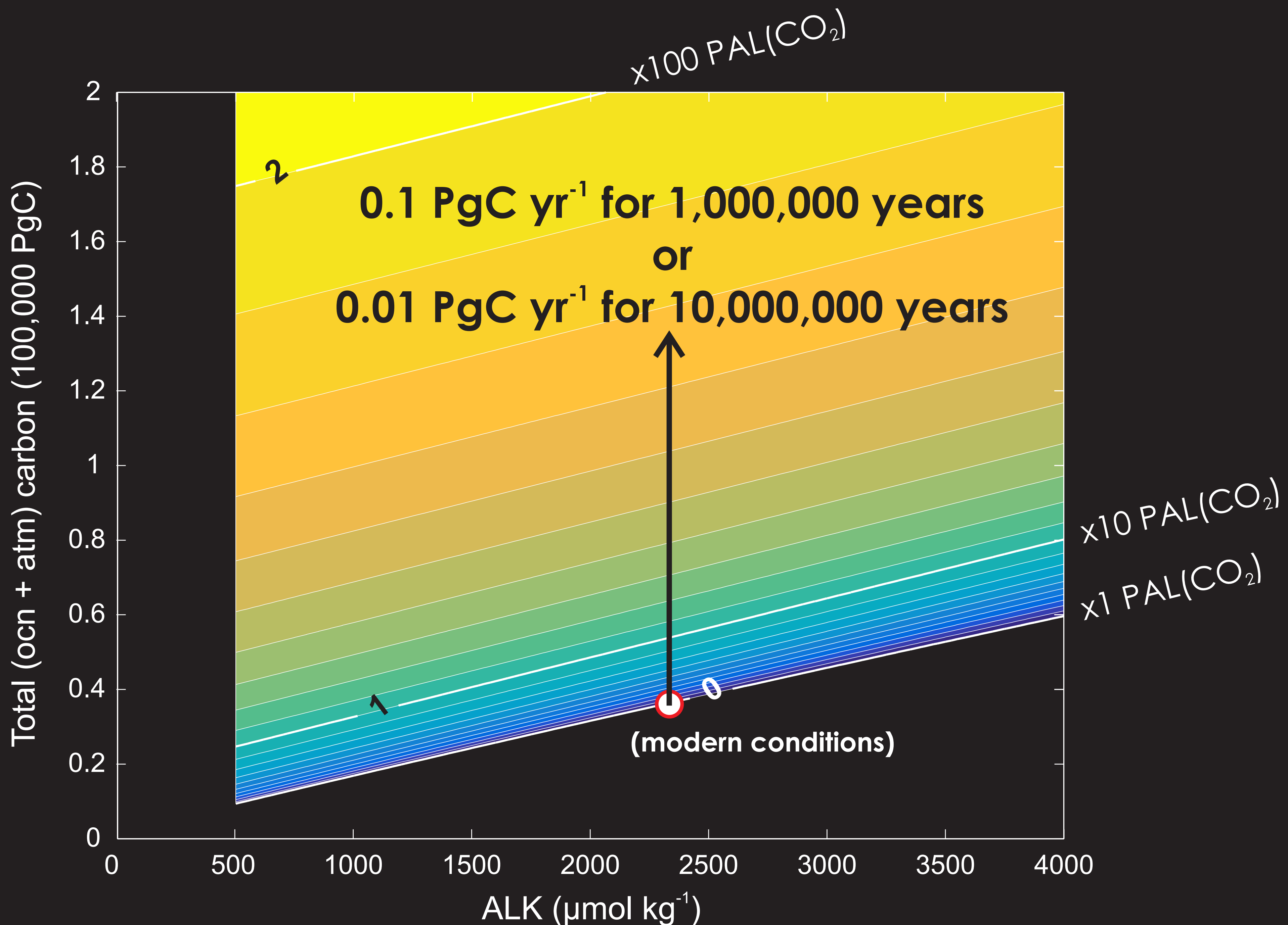


Introduction

Terrestrial weathering can be (approximately equally) divided into carbonate ($CaCO_3$) and calcium-silicate ('$CaSiO_3$') weathering:

(1) $2CO_{2(aq)} + H_2O + CaSiO_3 \rightarrow Ca^{2+} + 2HCO_3^- + SiO_2$

(2) $CO_{2(aq)} + H_2O + CaCO_3 \rightarrow Ca^{2+} + 2HCO_3^-$

Ultimately, the (alkalinity: Ca^{2+}) weathering products must be removed through carbonate precipitation and burial in marine sediments:

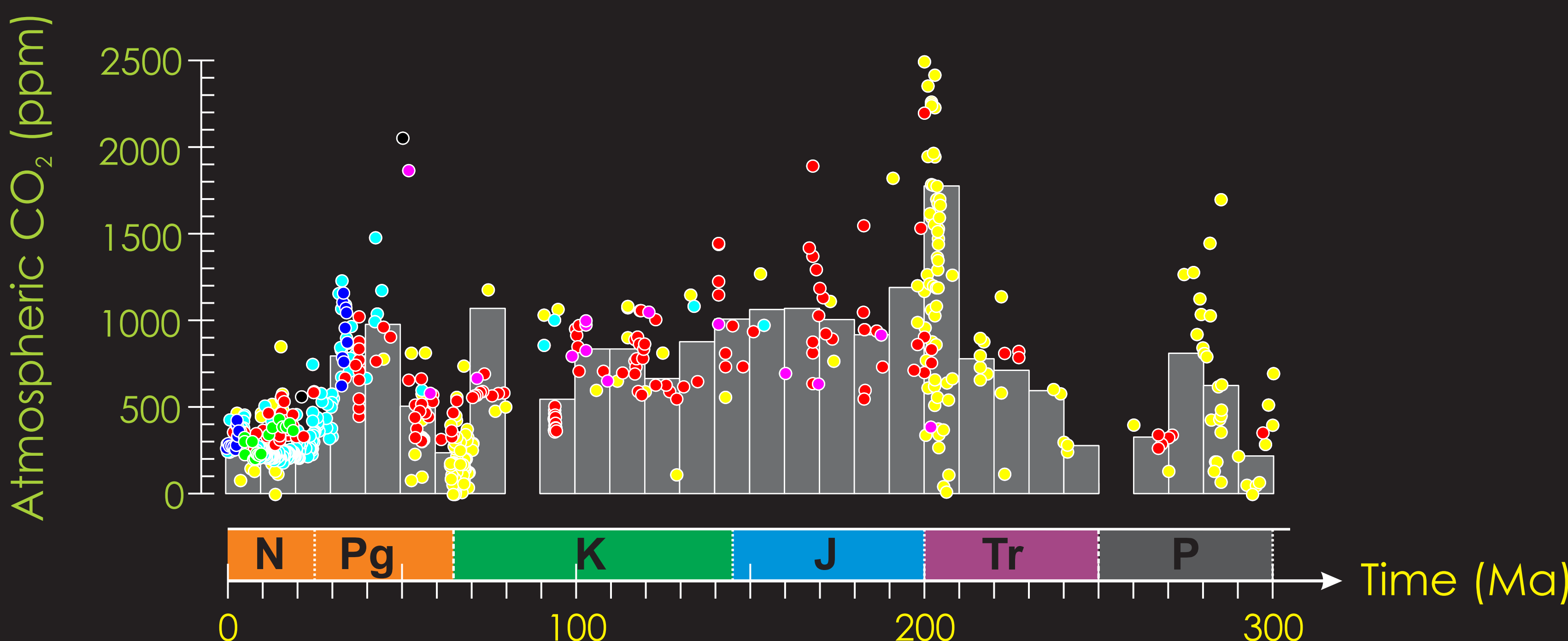
(3) $Ca^{2+} + 2HCO_3^- \rightarrow CO_{2(aq)} + H_2O + CaCO_3$

It can be seen that in (2) + (3), that the CO_2 removed (from the atmosphere) during weathering, is returned upon carbonate precipitation (and burial). In (1) + (3) (silicate weathering) CO_2 is permanently removed to the geological reservoir. This CO_2 must be balanced by mantle (/volcanic) out-gassing on the very long term.

Furthermore, the rate of silicate weathering should scale with climate.

Hence a ca. 100 kyr time-scale **silicate weathering feedback** is formed:

higher pCO_2 → higher temperatures (& rainfall) → higher weathering rates → lower pCO_2



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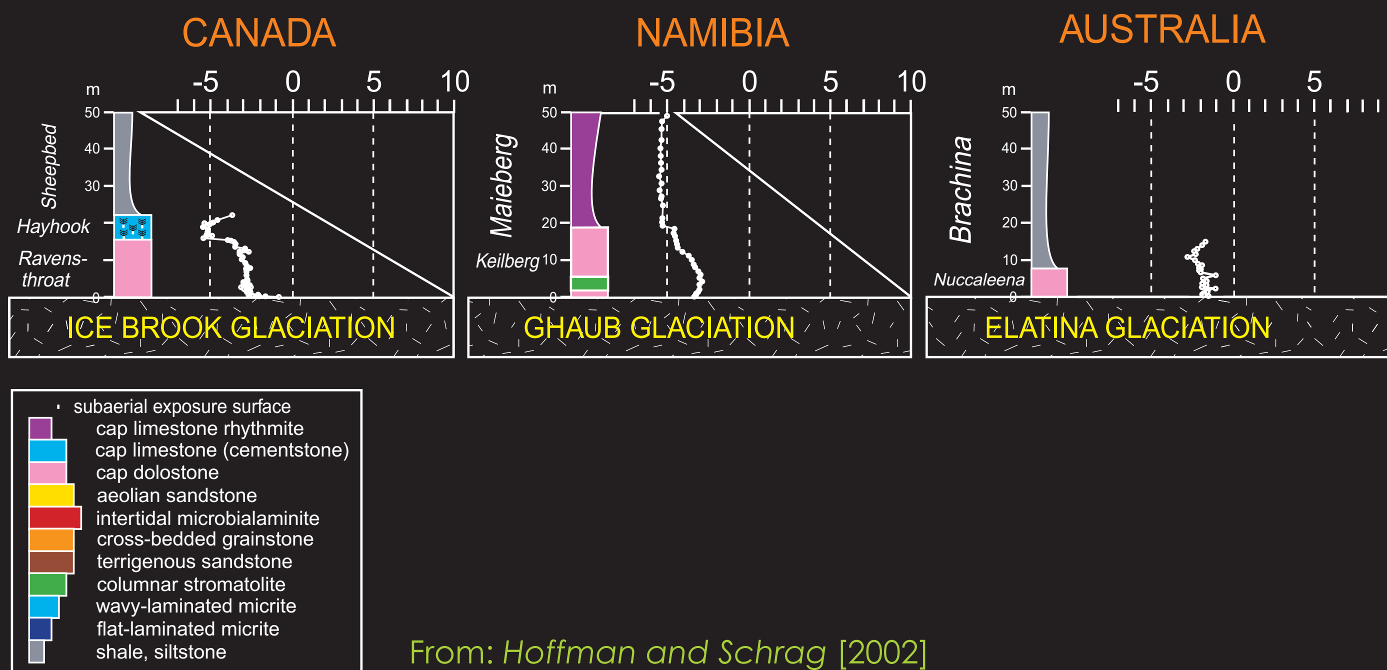

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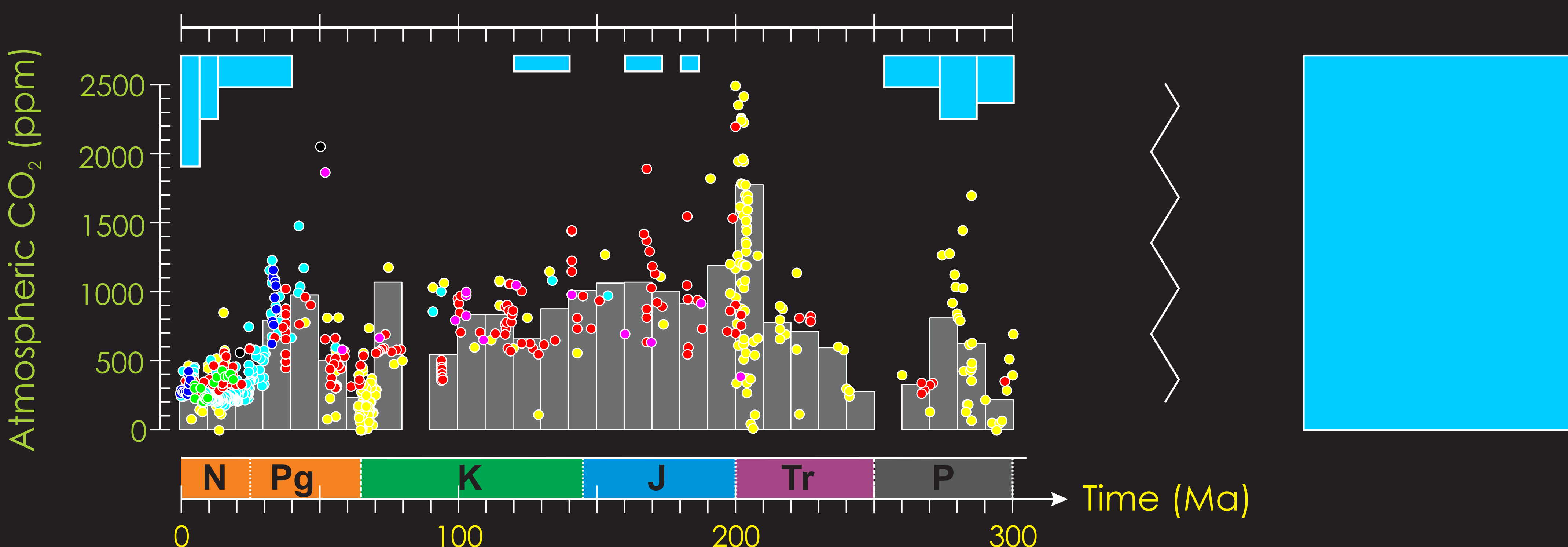

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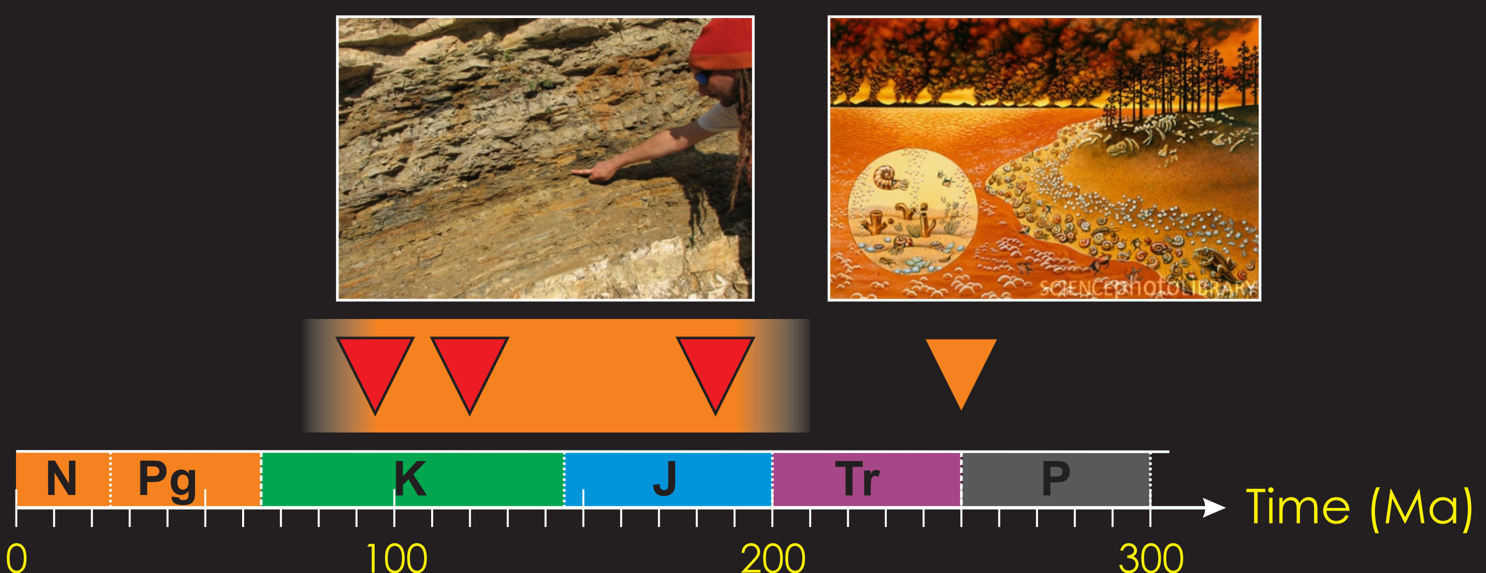

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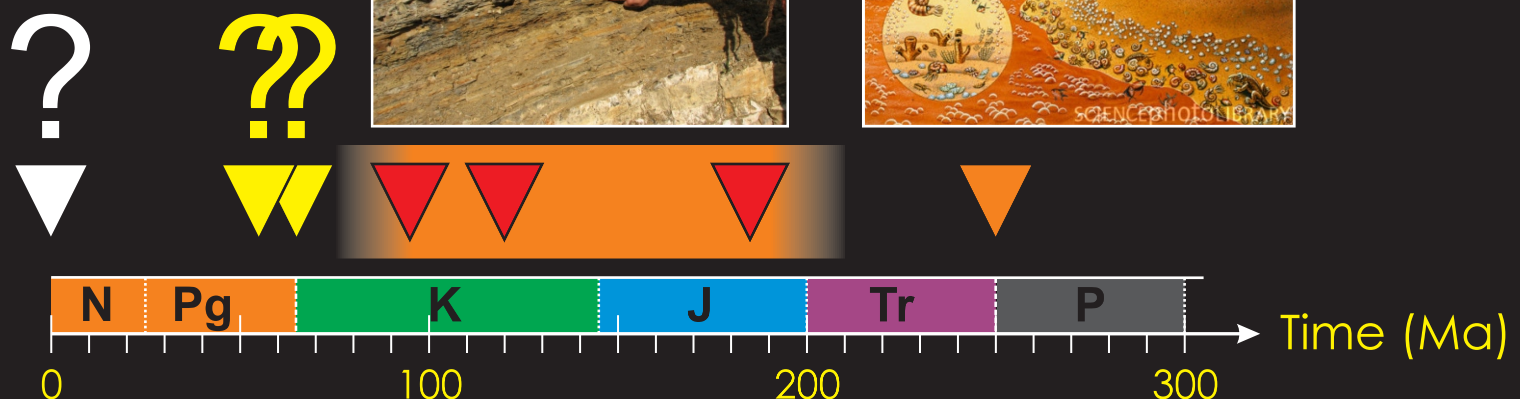
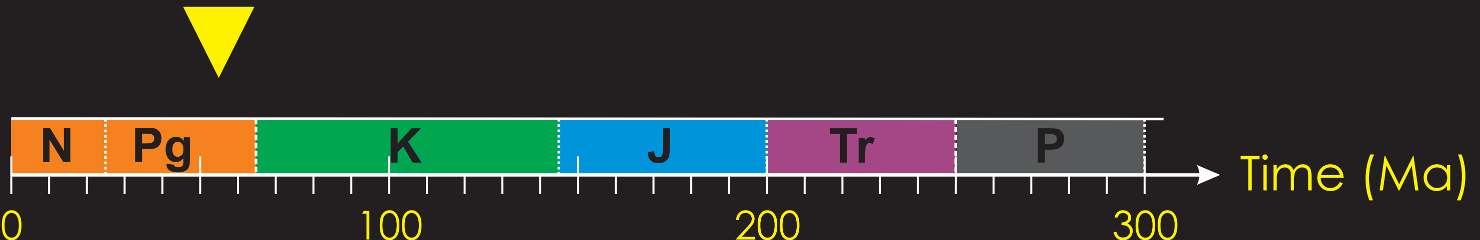


Background – the Paleocene-Eocene Thermal Maximum



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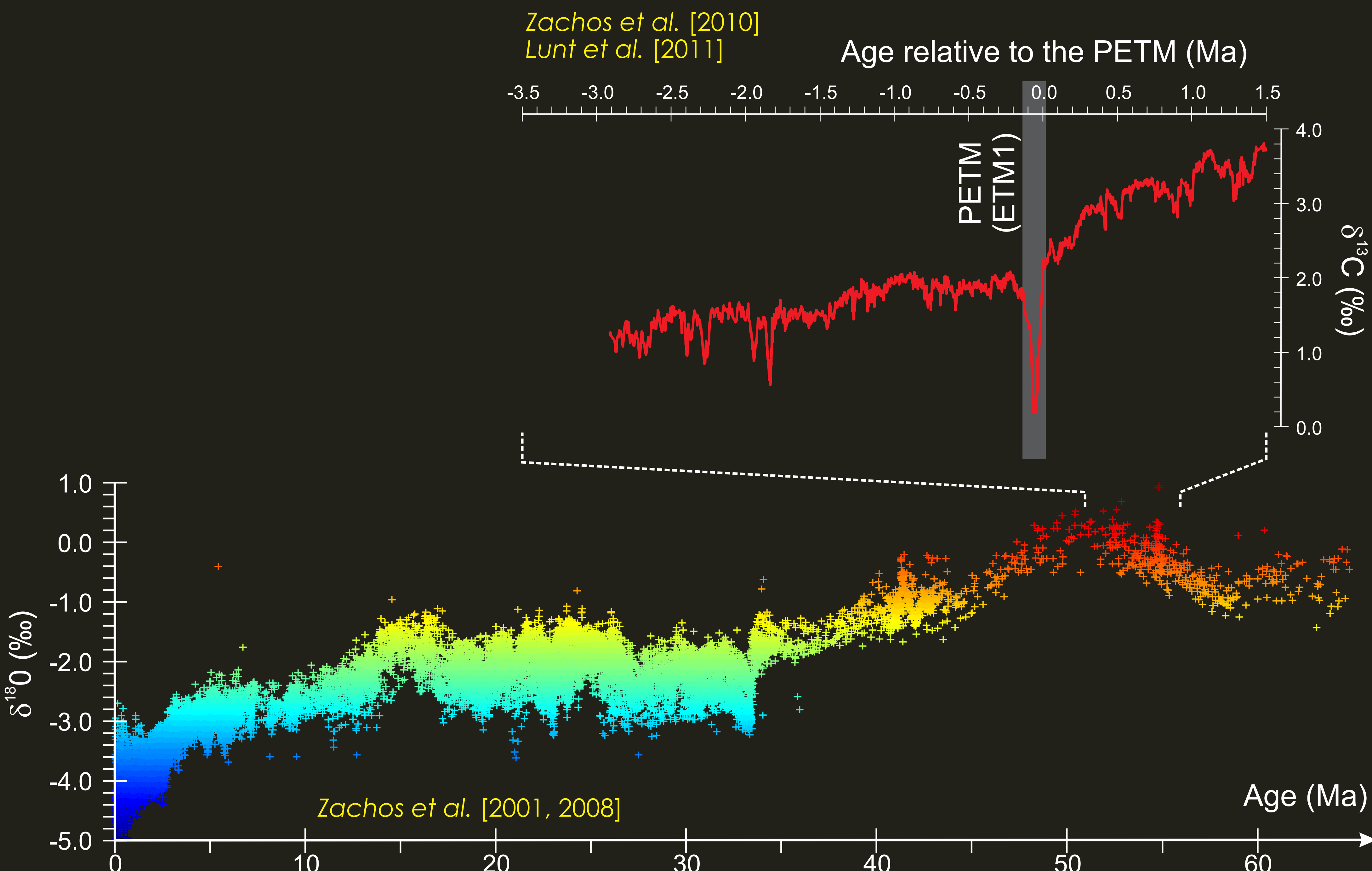
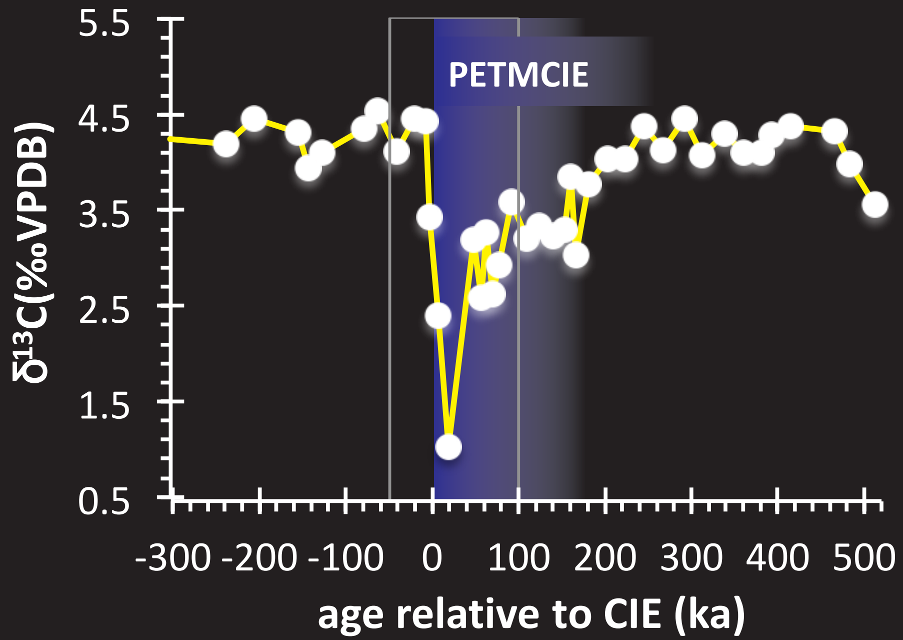
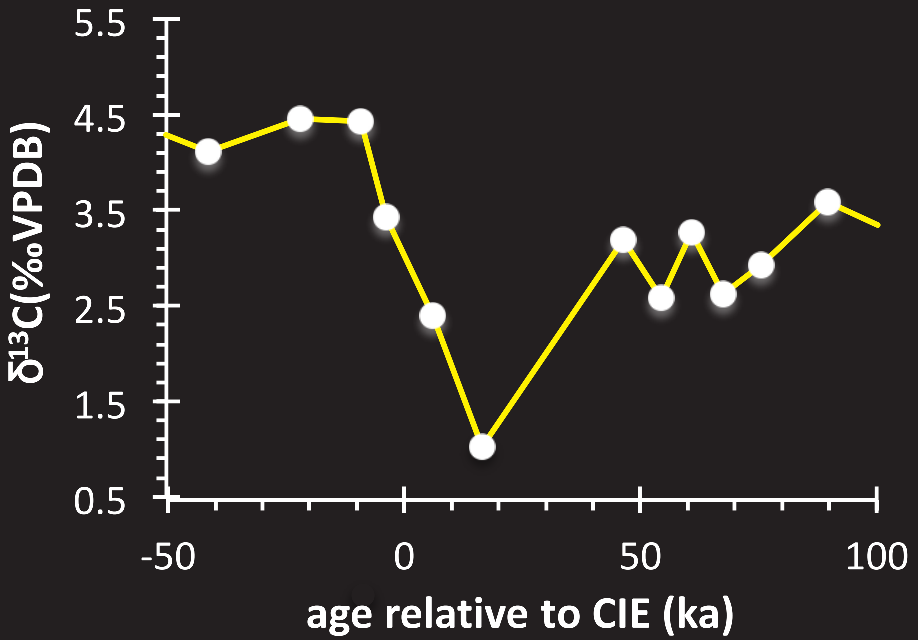


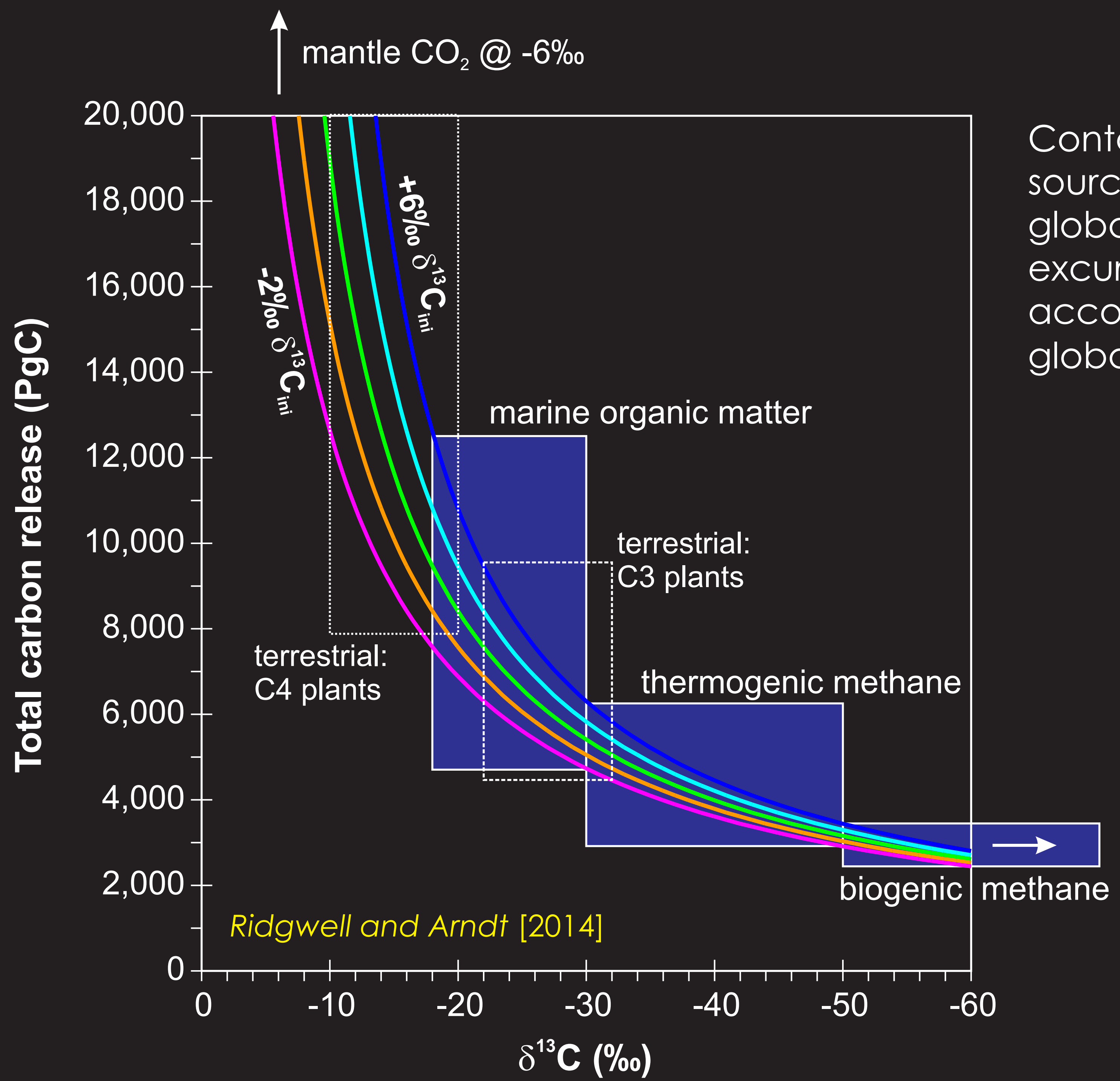
Background – 'Traditional' ($\delta^{13}C$) carbon interpretation





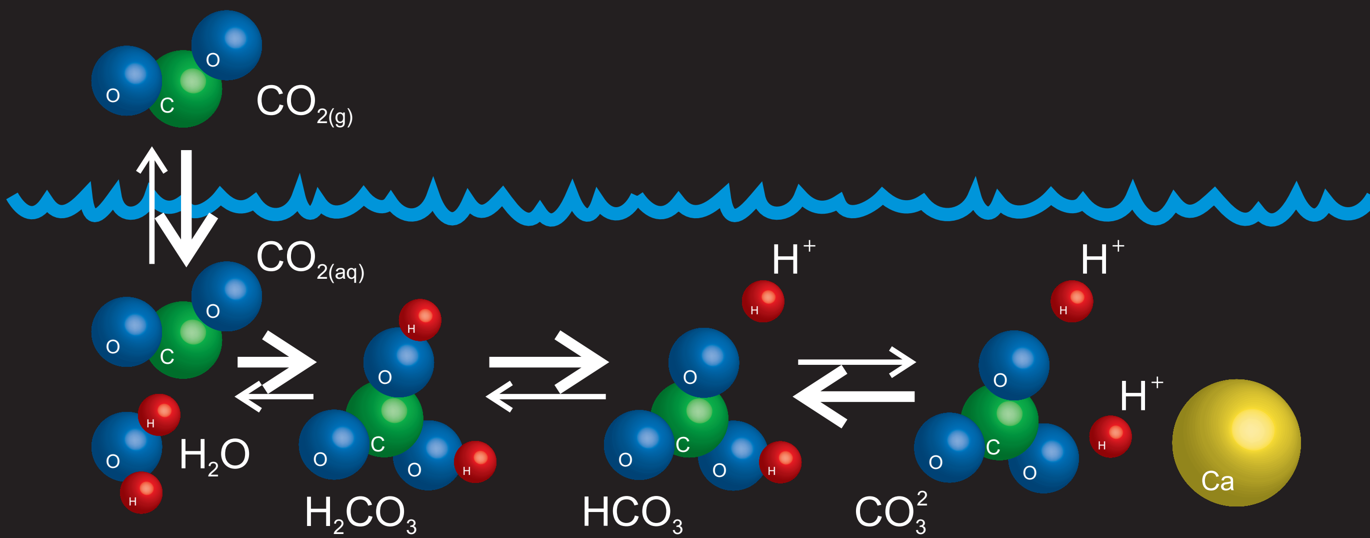
Site 401 (North East Atlantic)

Background – ‘Traditional’ ($\delta^{13}C$) carbon interpretation



Contours of carbon release vs. source isotopic signature for a global -4‰ carbon isotopic excursion. Contours differ according to the initial mean global $\delta^{13}C$.

Background – 'non-traditional' carbon interpretation



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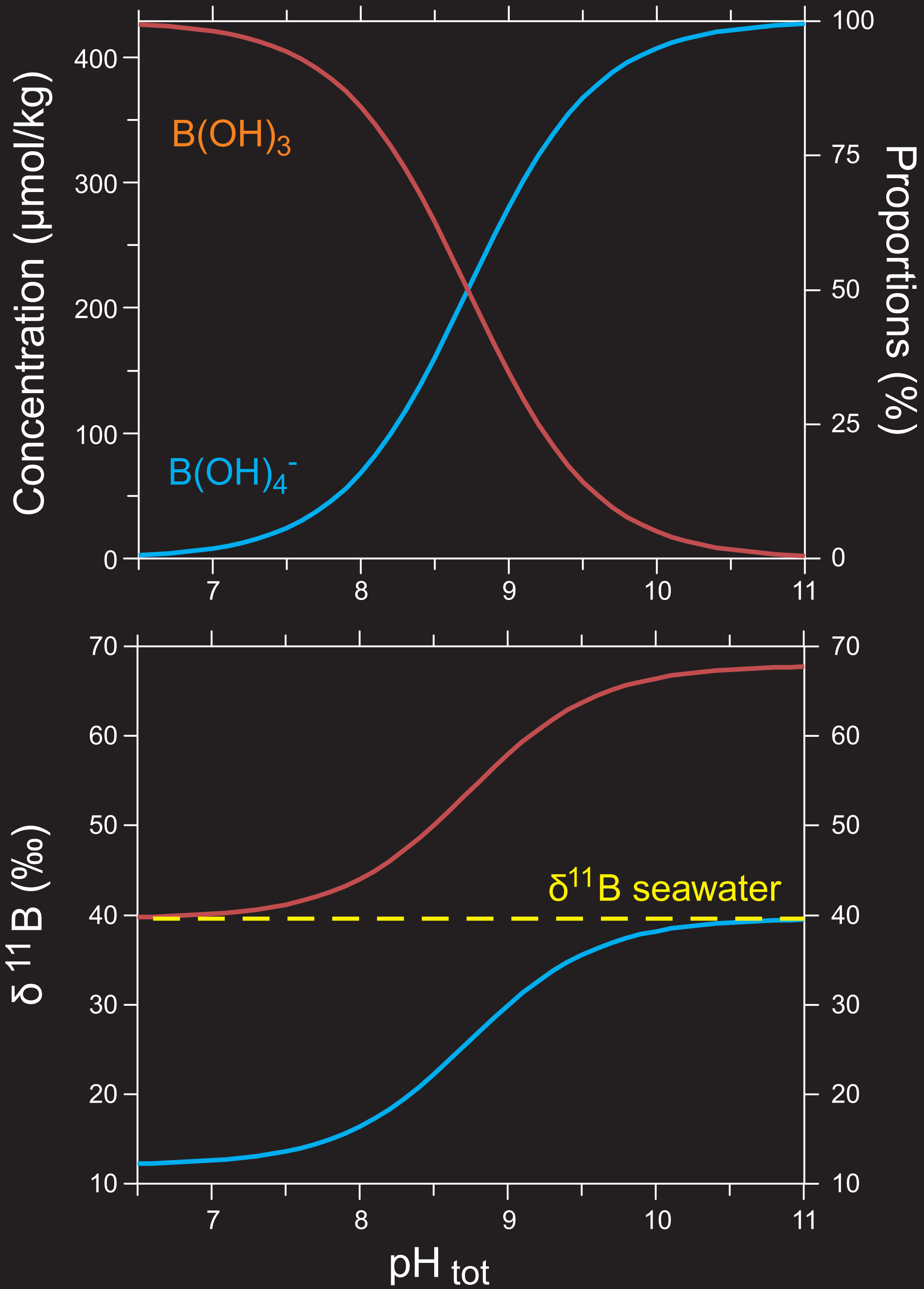

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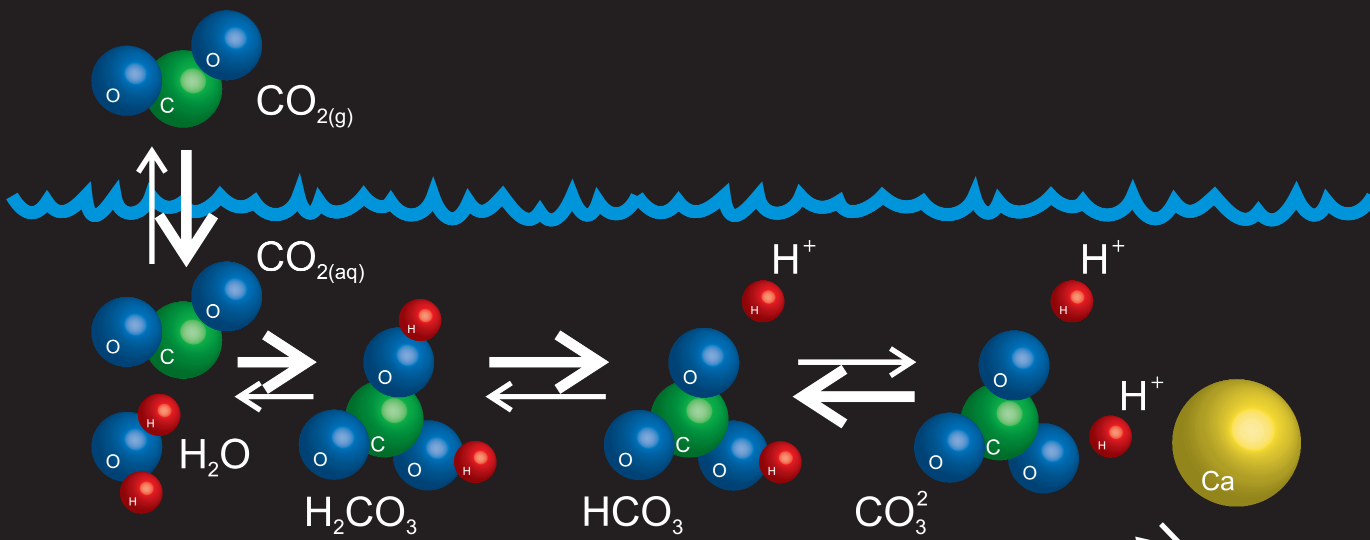

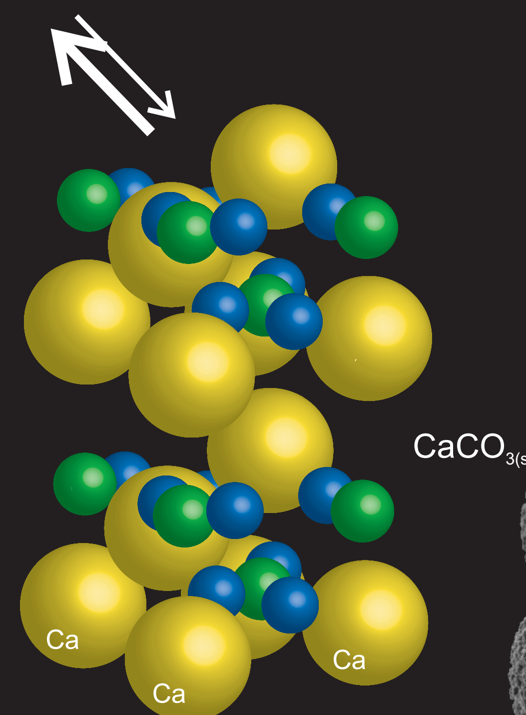

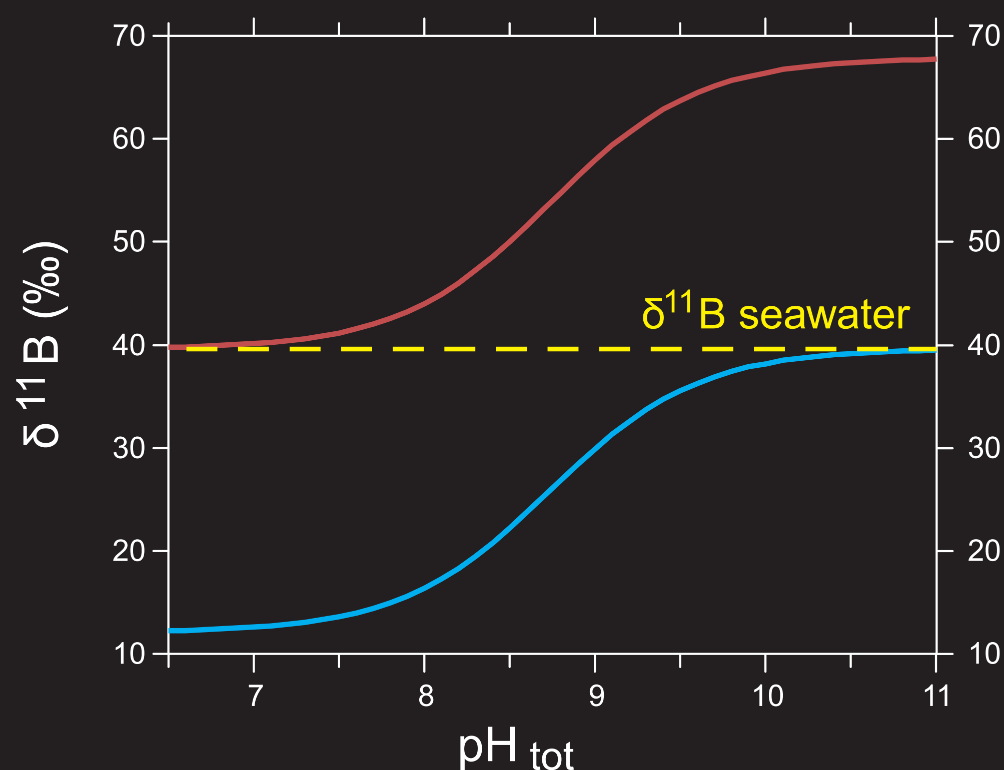

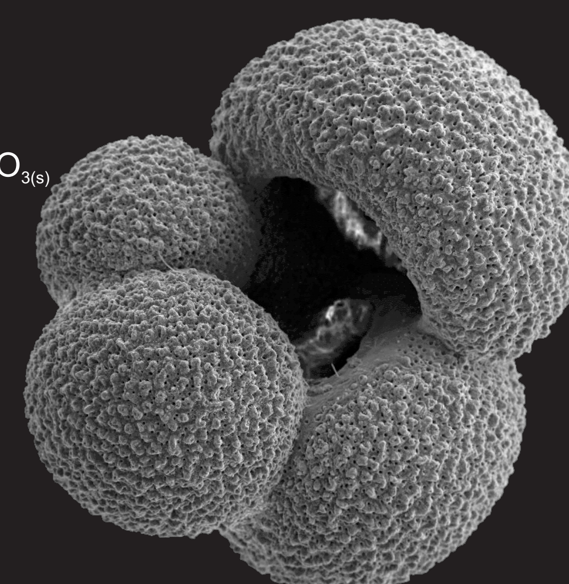

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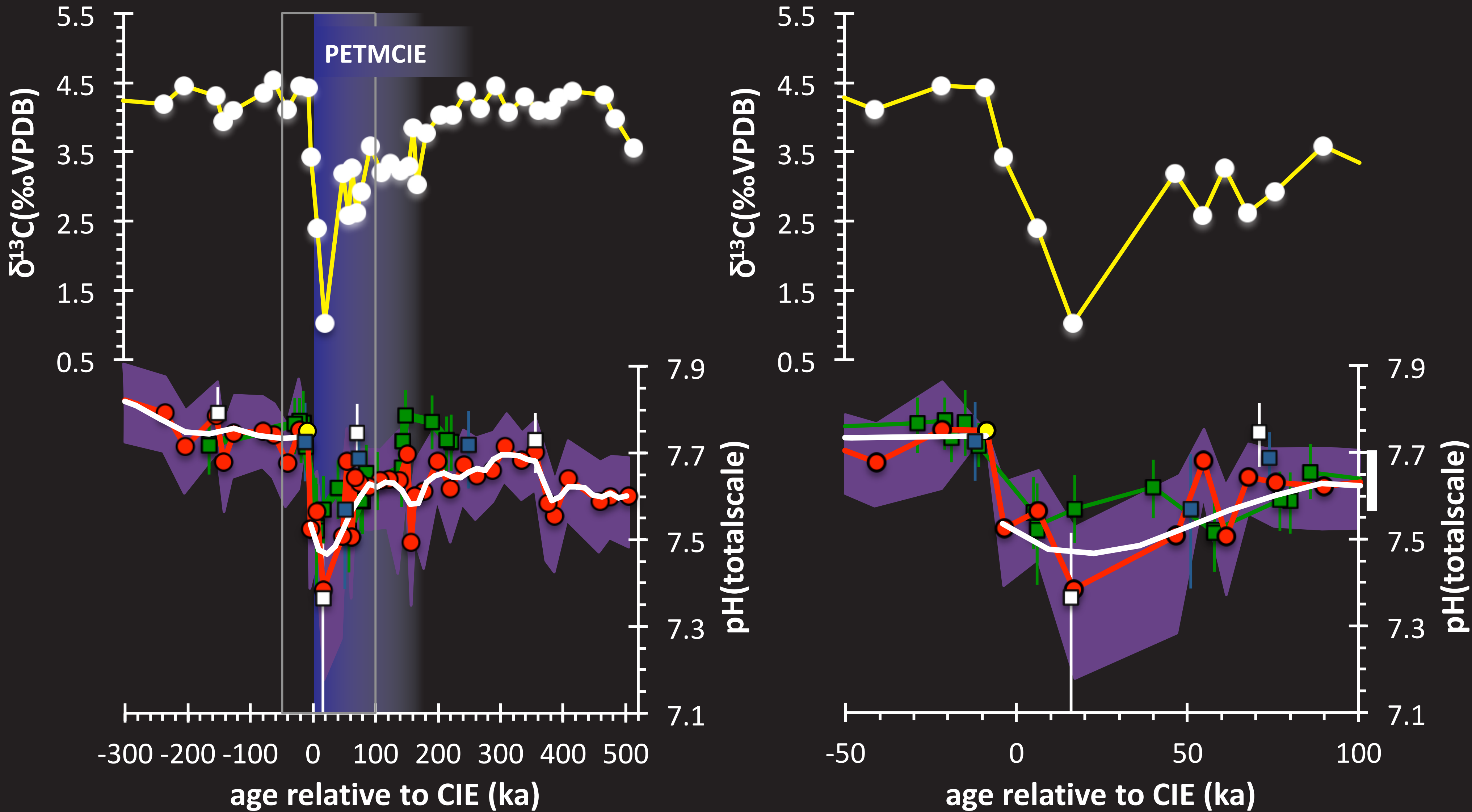
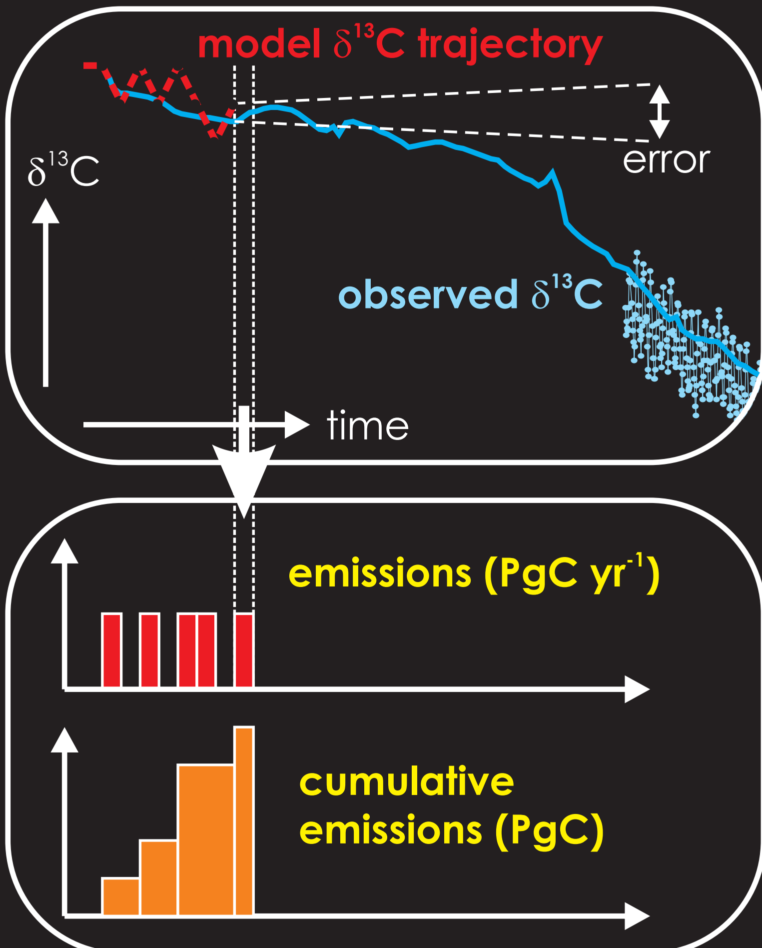


Site 401 (NE Atlantic)		[this study]
Site 865 (Eq. Pacific)	Site 1263 (ES Atlantic) Site 1209 (N Pacific)	[*Penman et al.*, 2014]

Modelling methodology

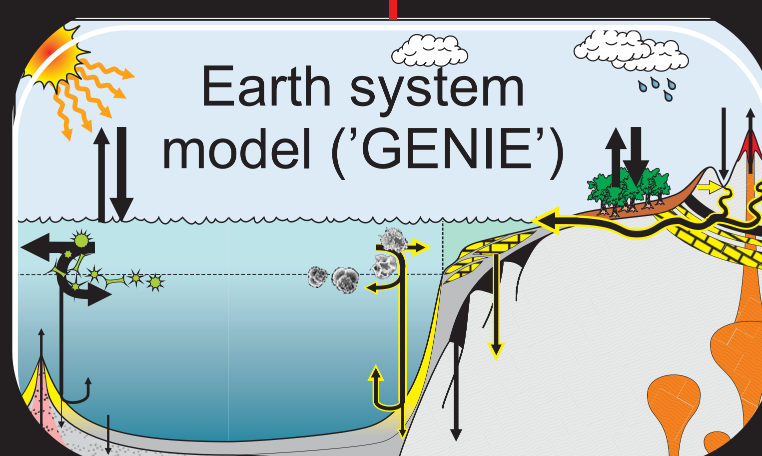


1. Calculate model-data 'error':
too high ⇒ emit carbon
'OK' ⇒ do nothing

2. If CO_2 emissions required:
Add CO_2 to atmosphere
(here: assume $\delta^{13}C_{emisisons}$)

3. Calculate new atmospheric CO_2 $\delta^{13}C$ value in model
<REPEAT>

Earth system model <u>including</u> explicit silicate weathering feedback



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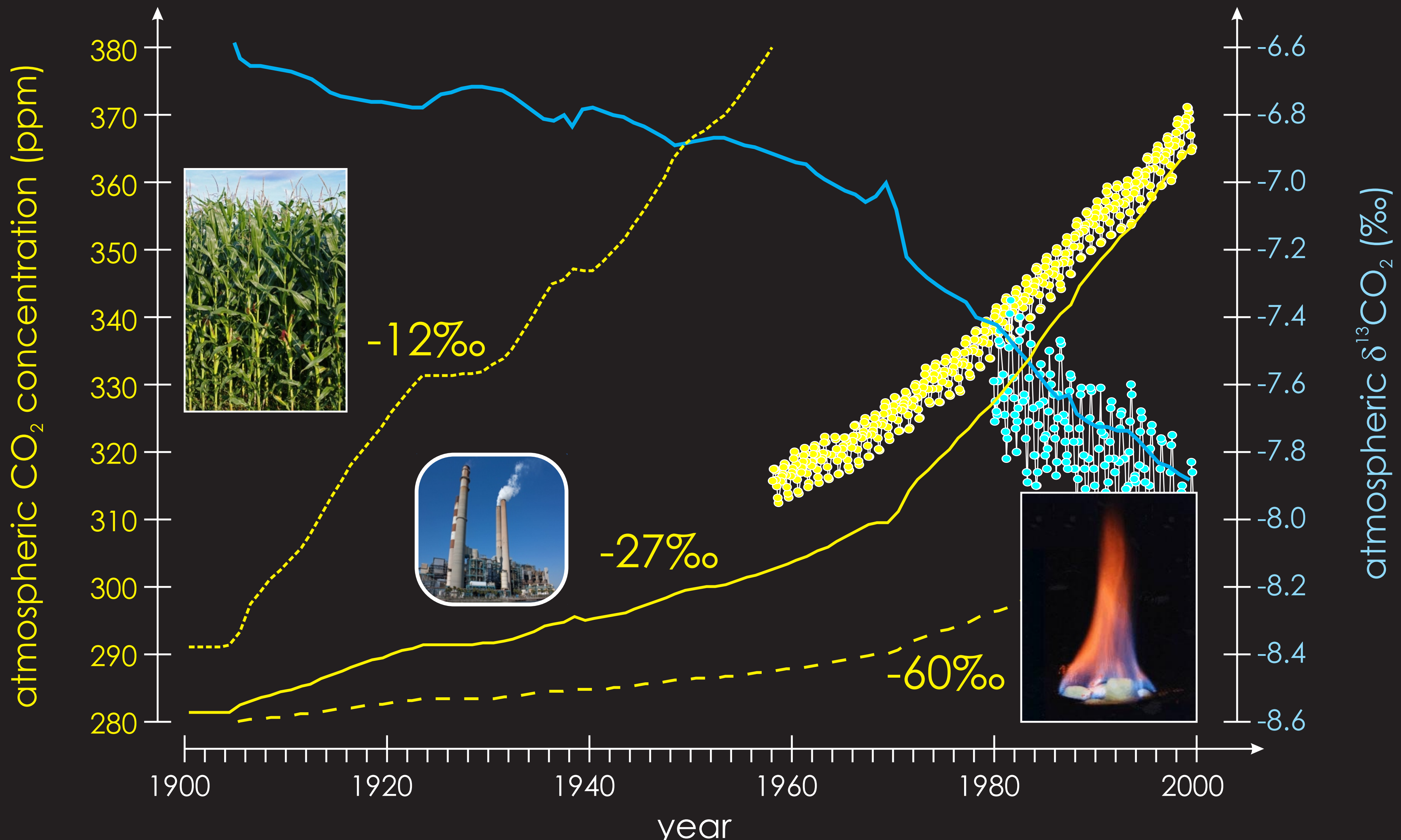
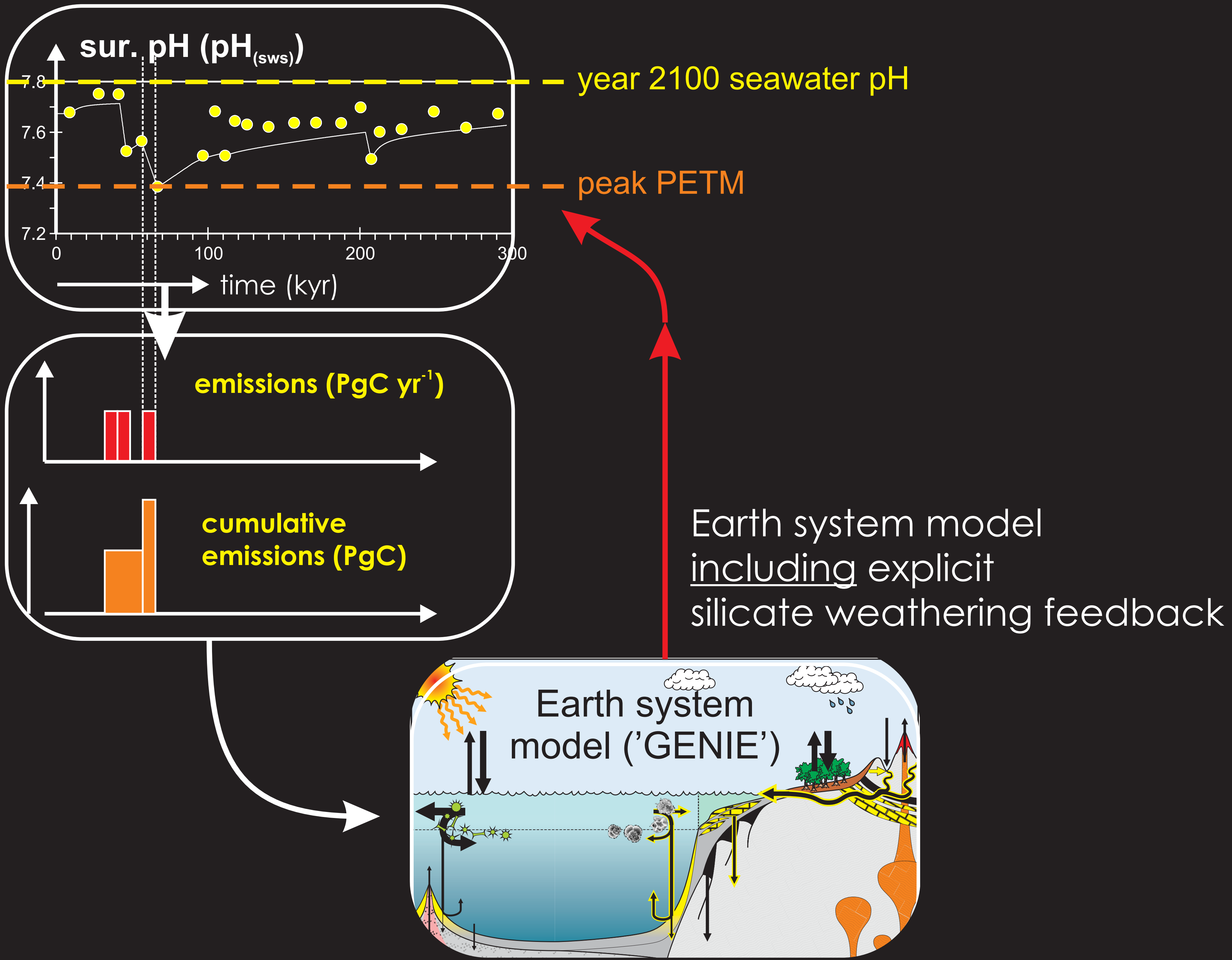


Assimilating surface ocean pH change (only)



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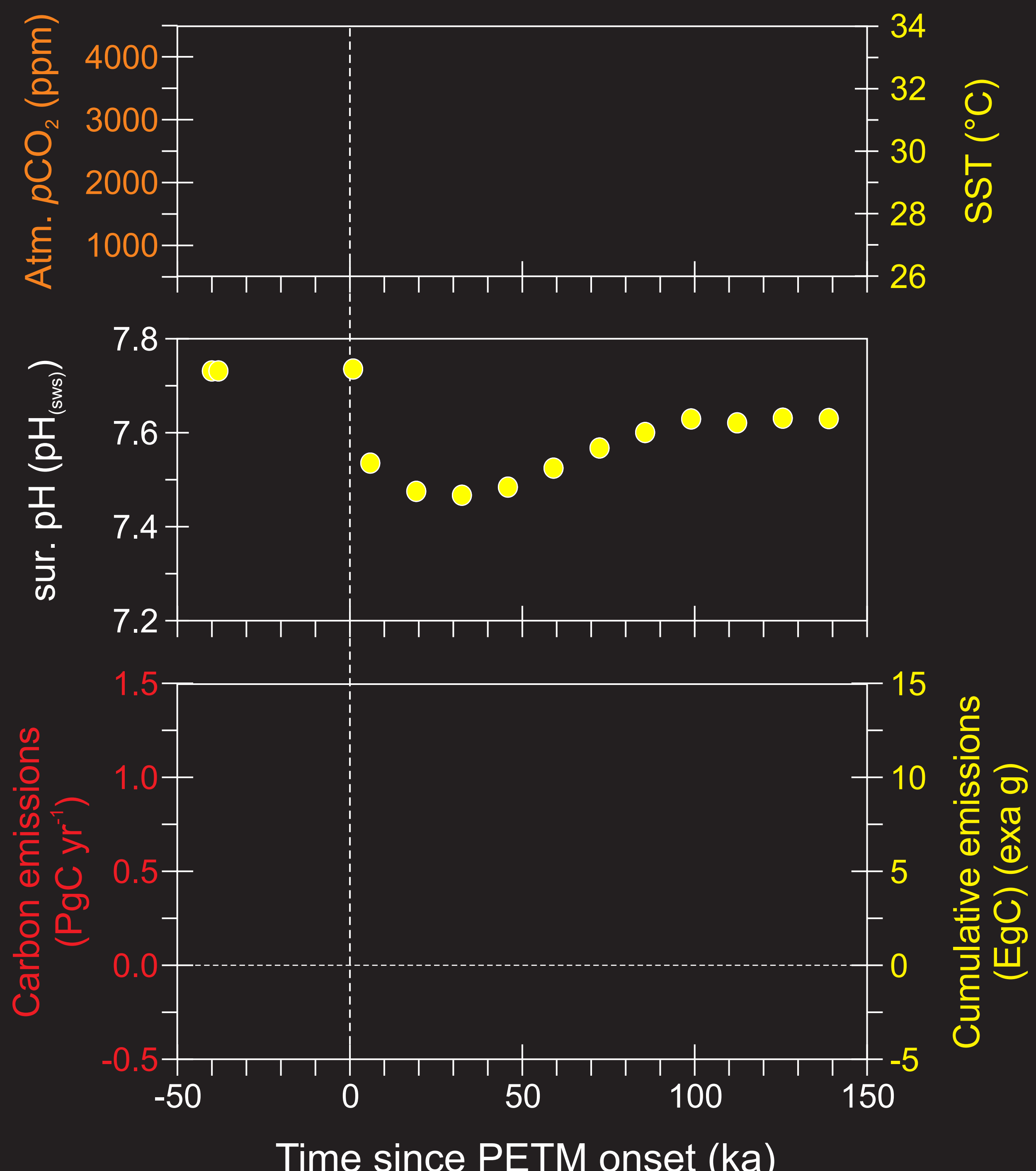

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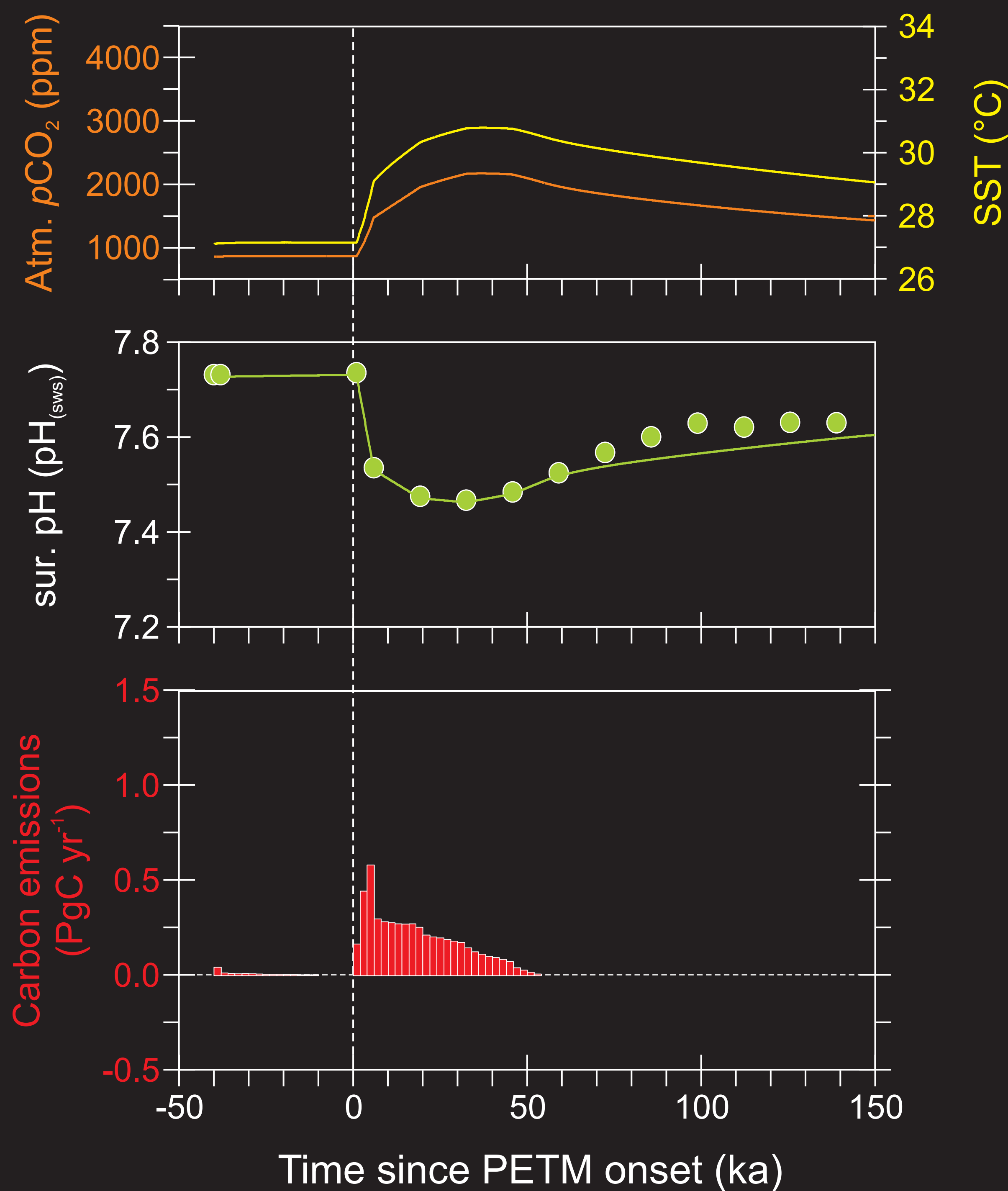

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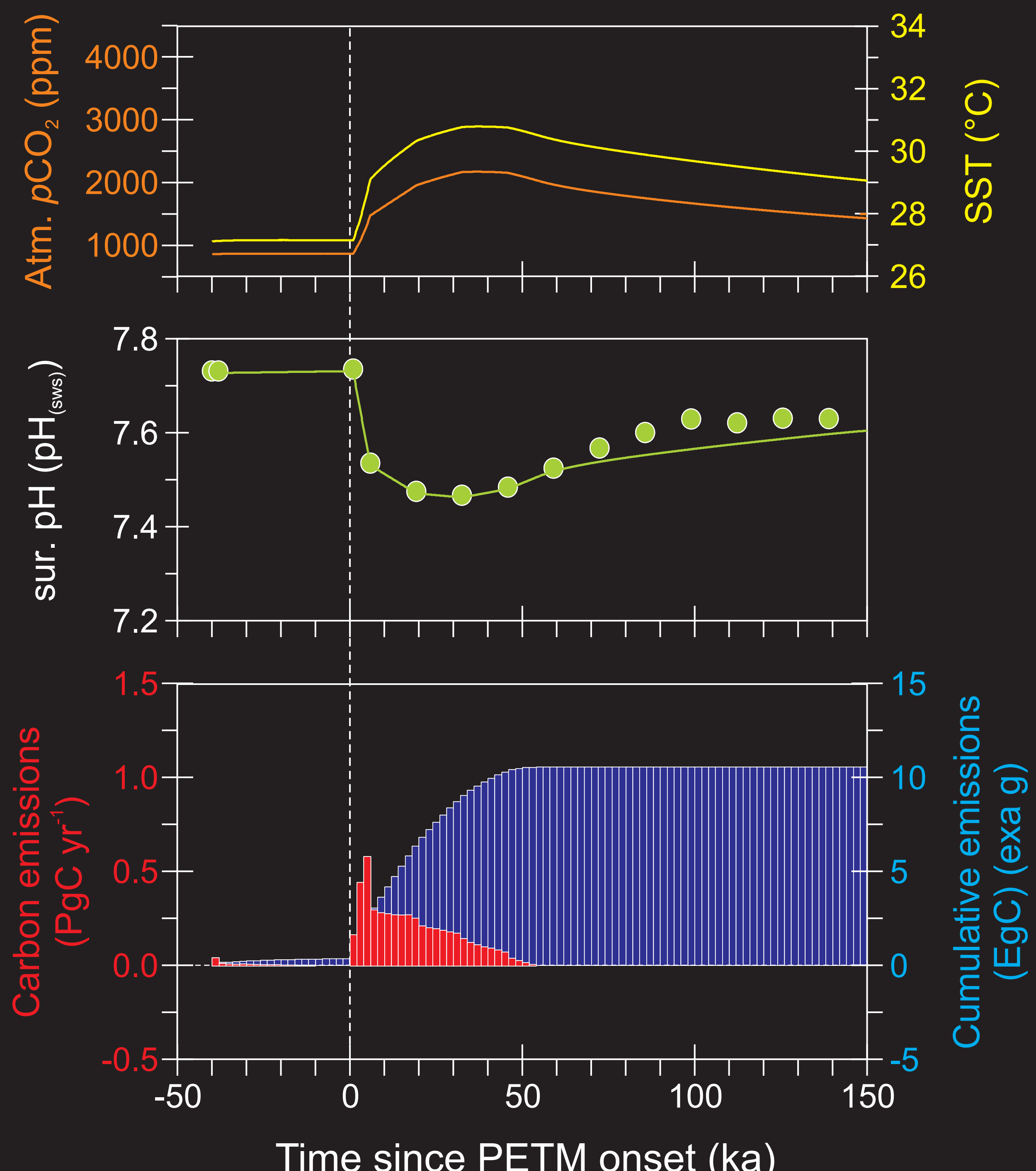

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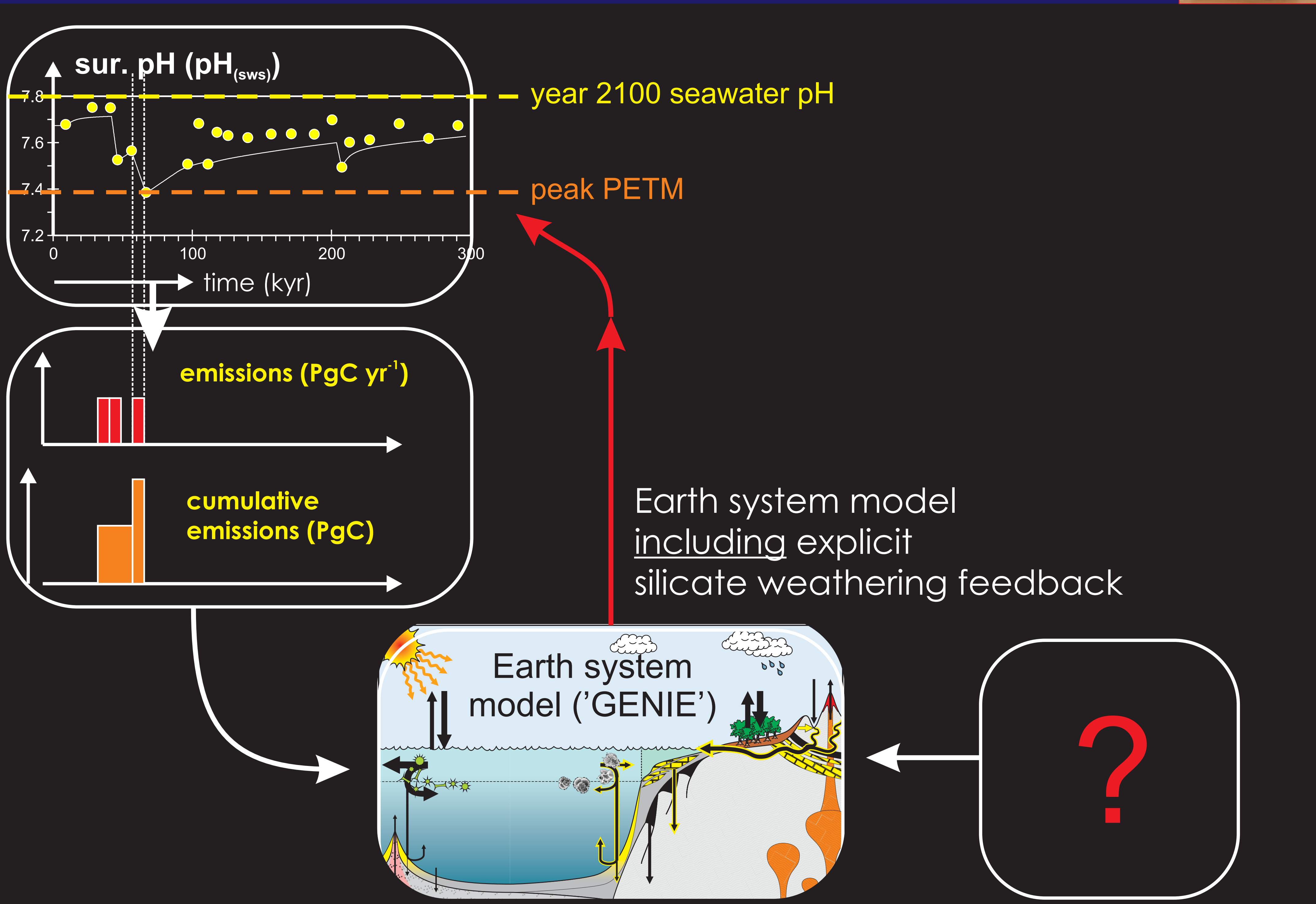
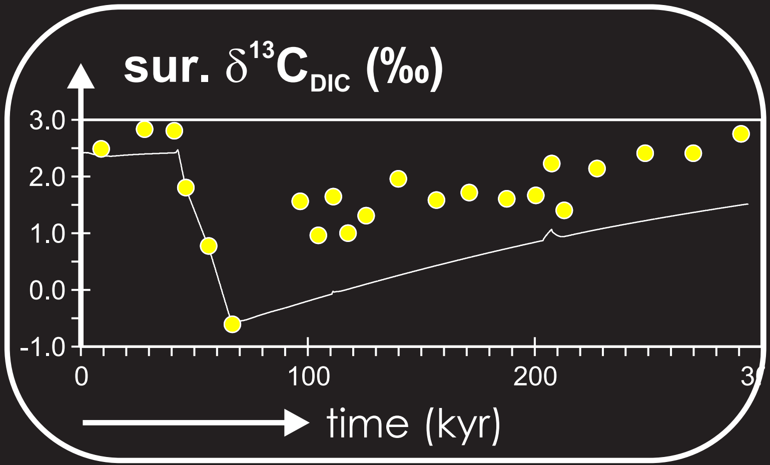


Assimilating surface ocean pH and $\delta^{13}C$



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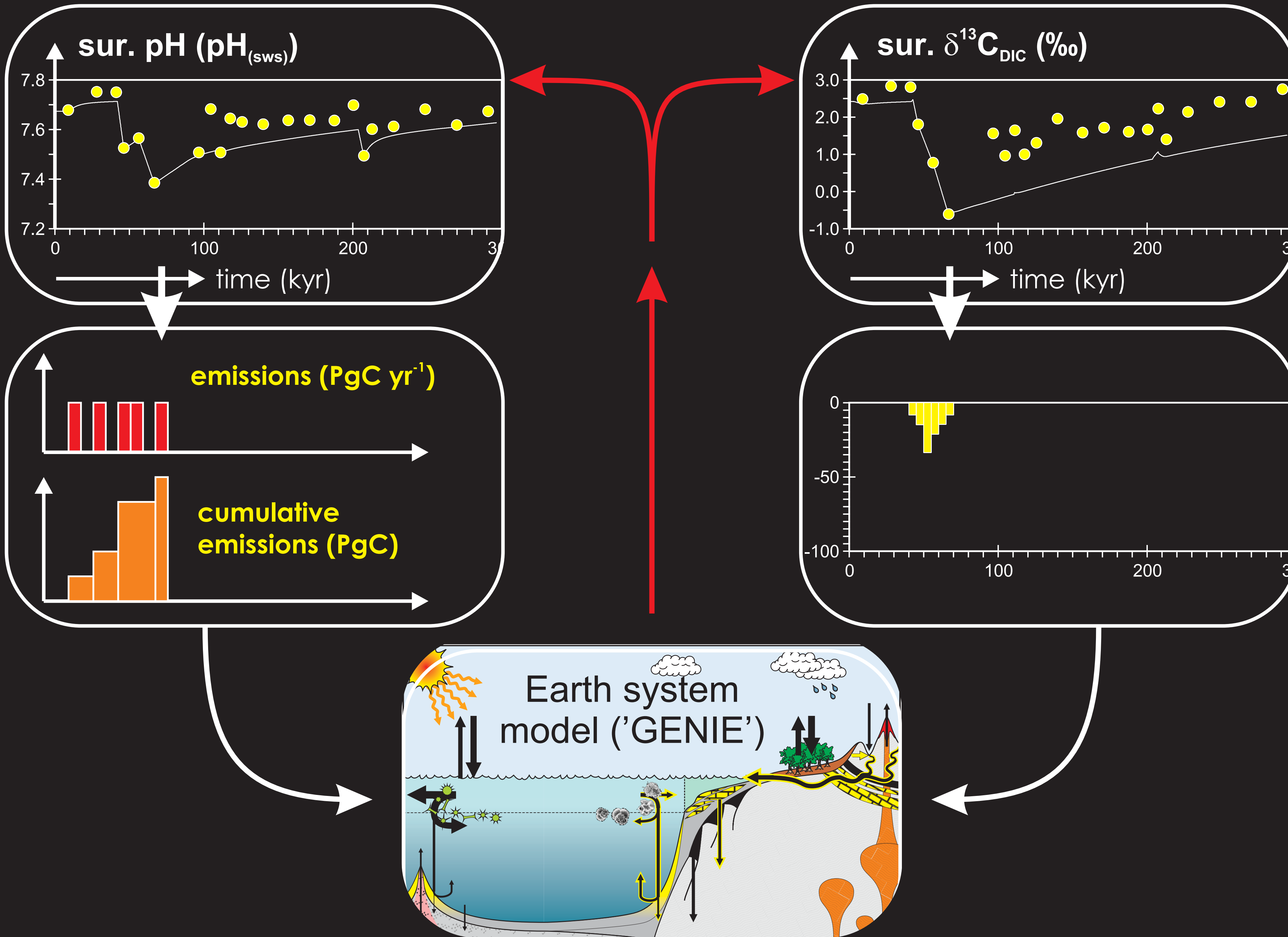

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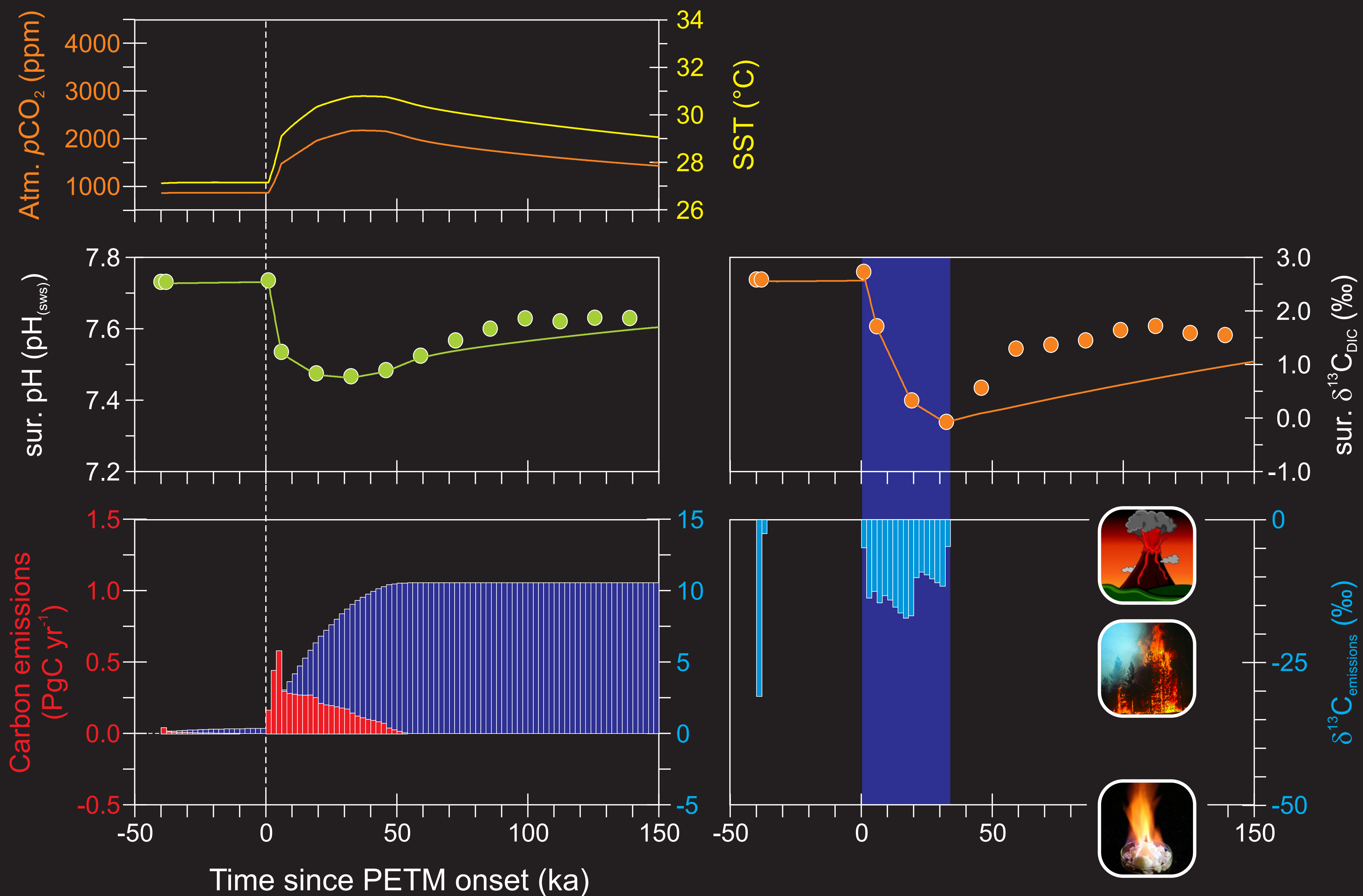

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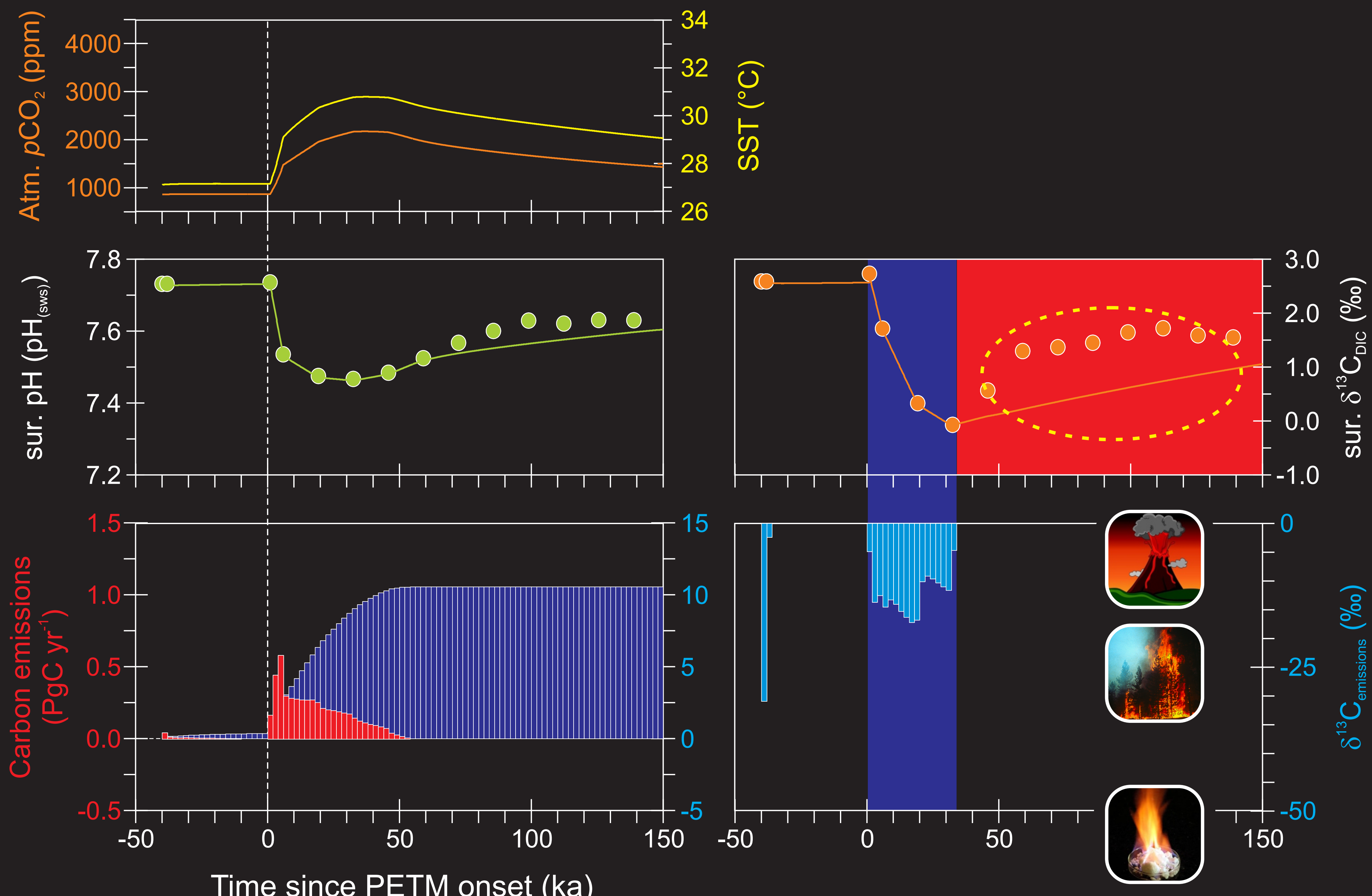

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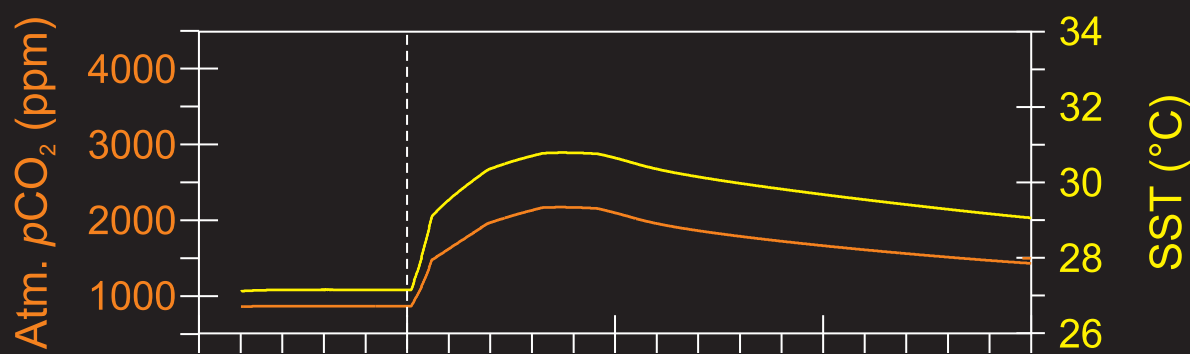

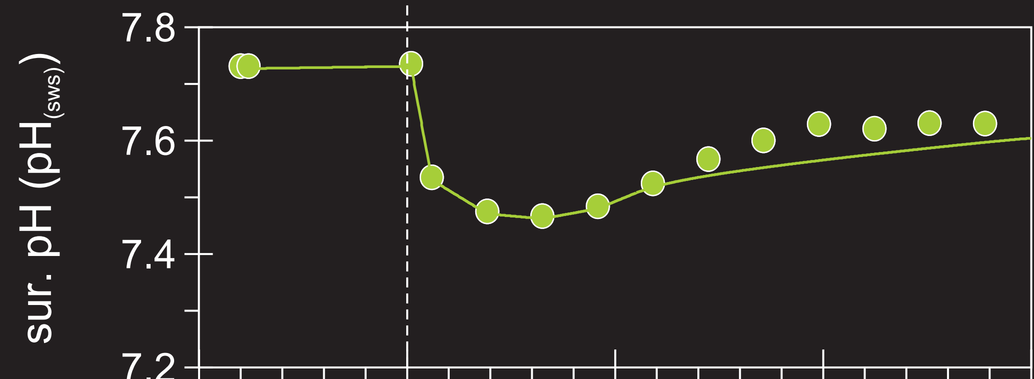

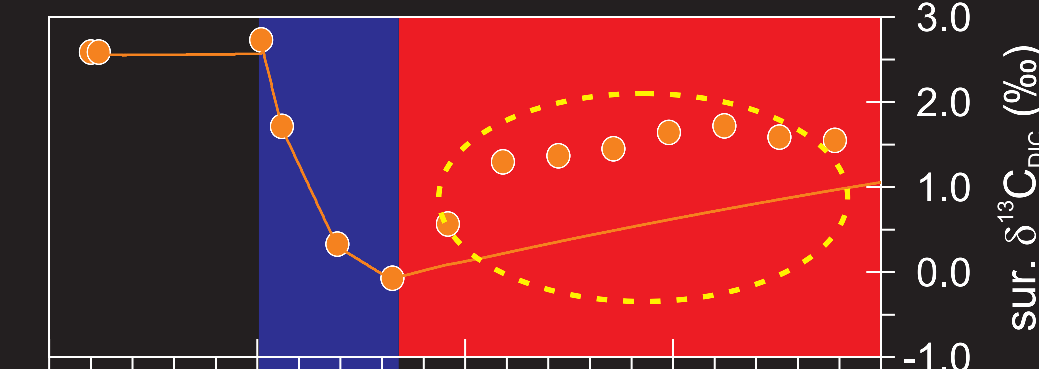

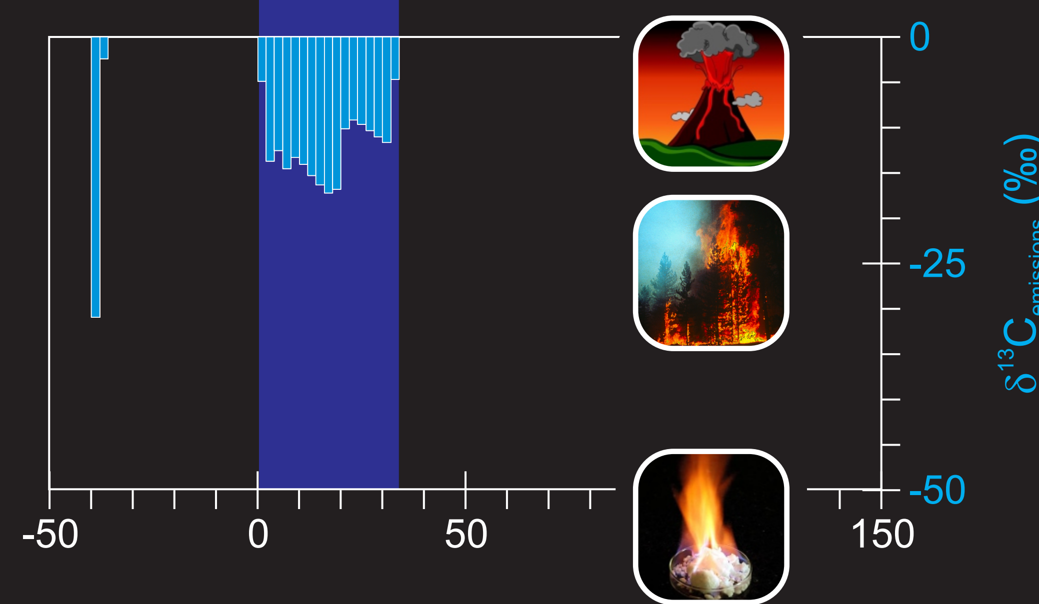

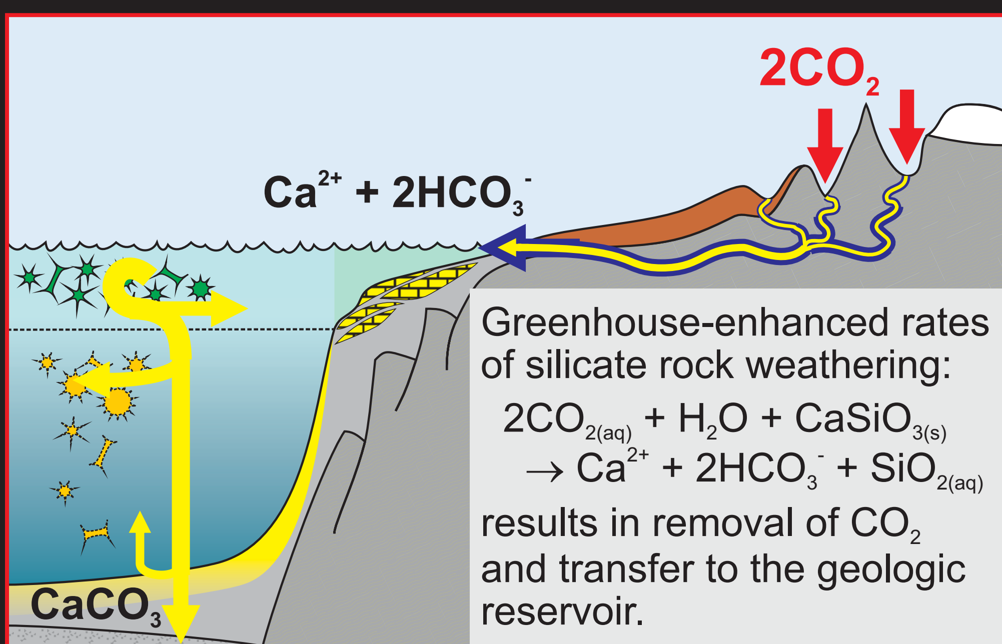

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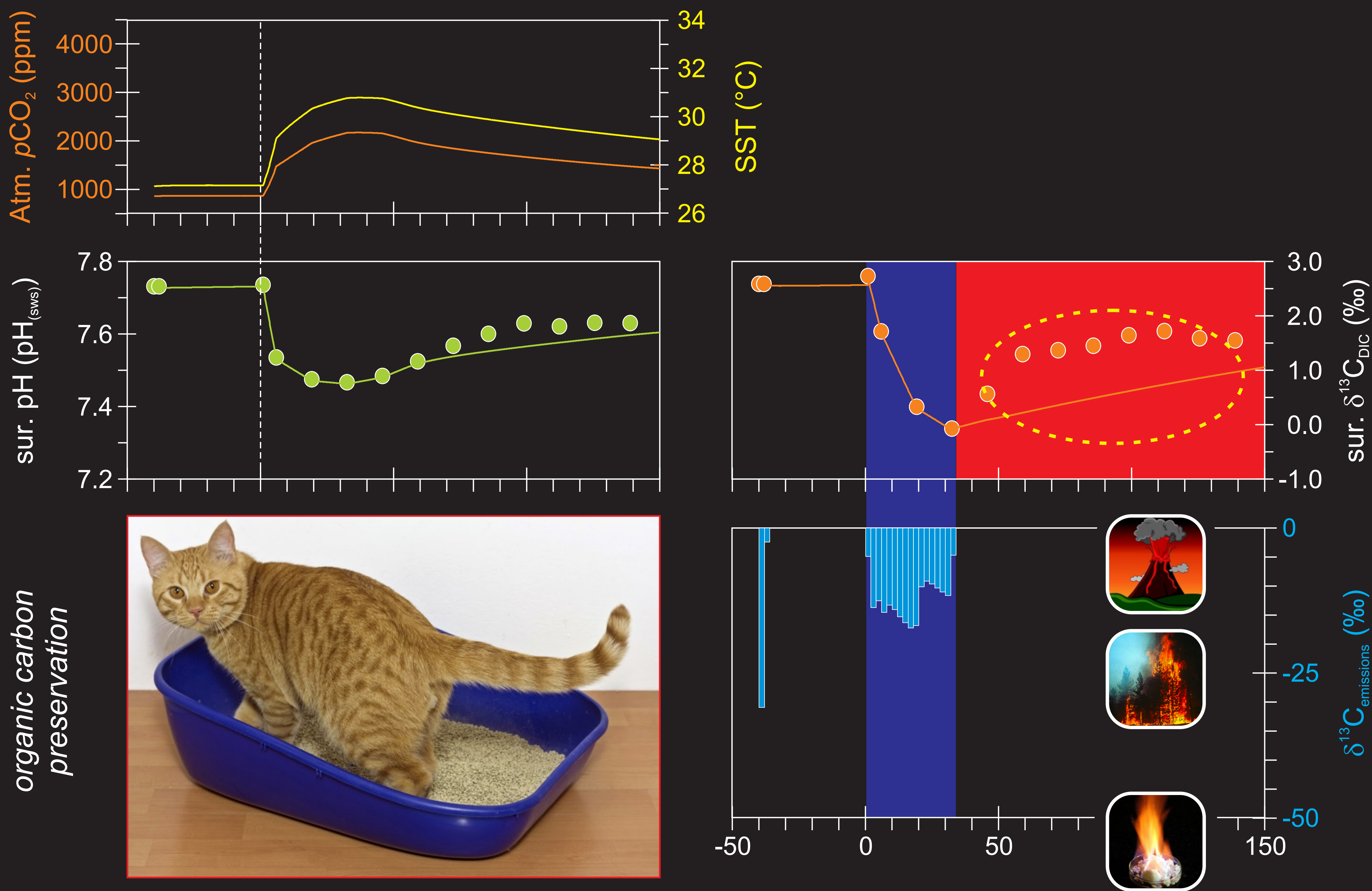

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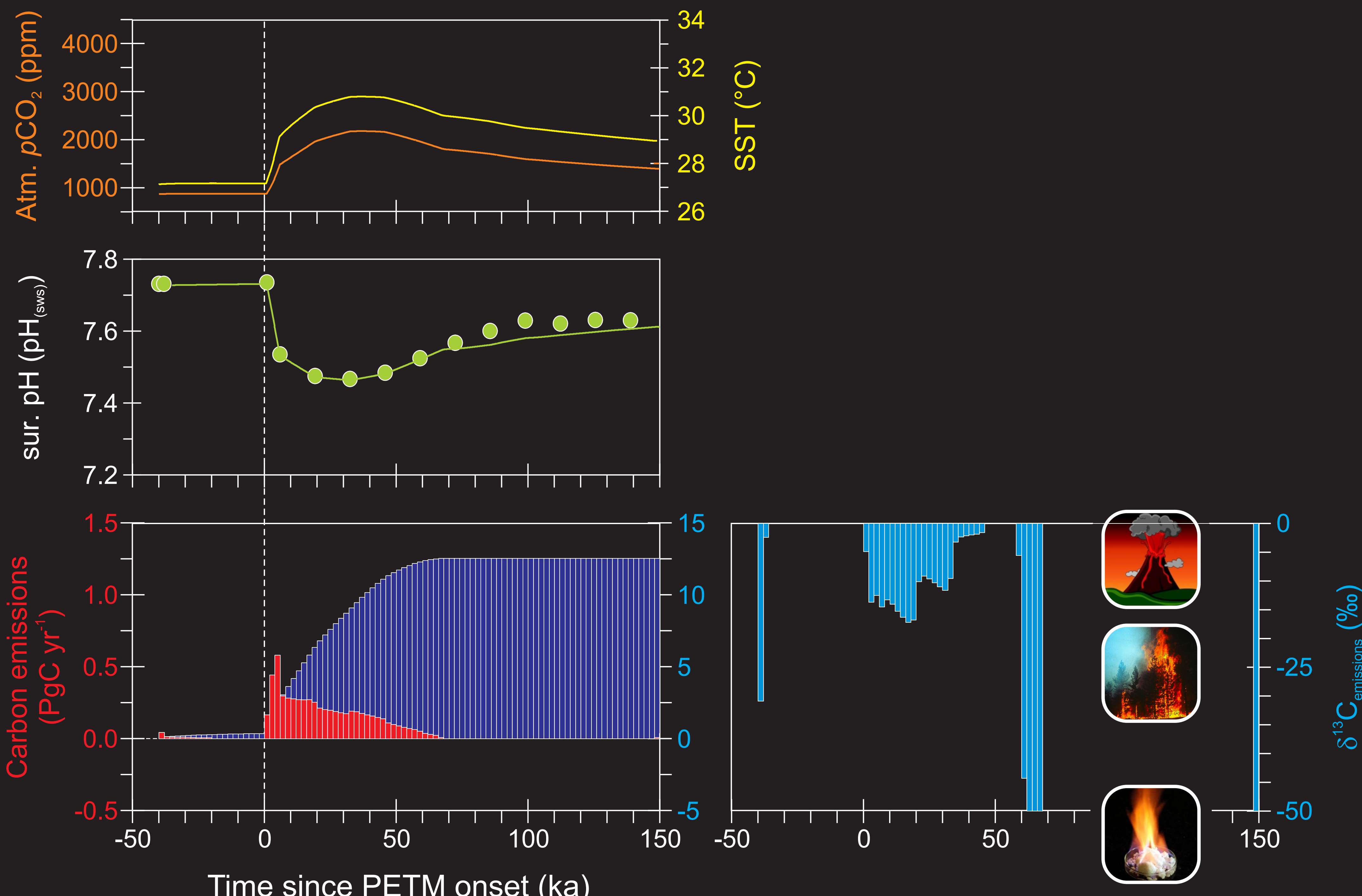

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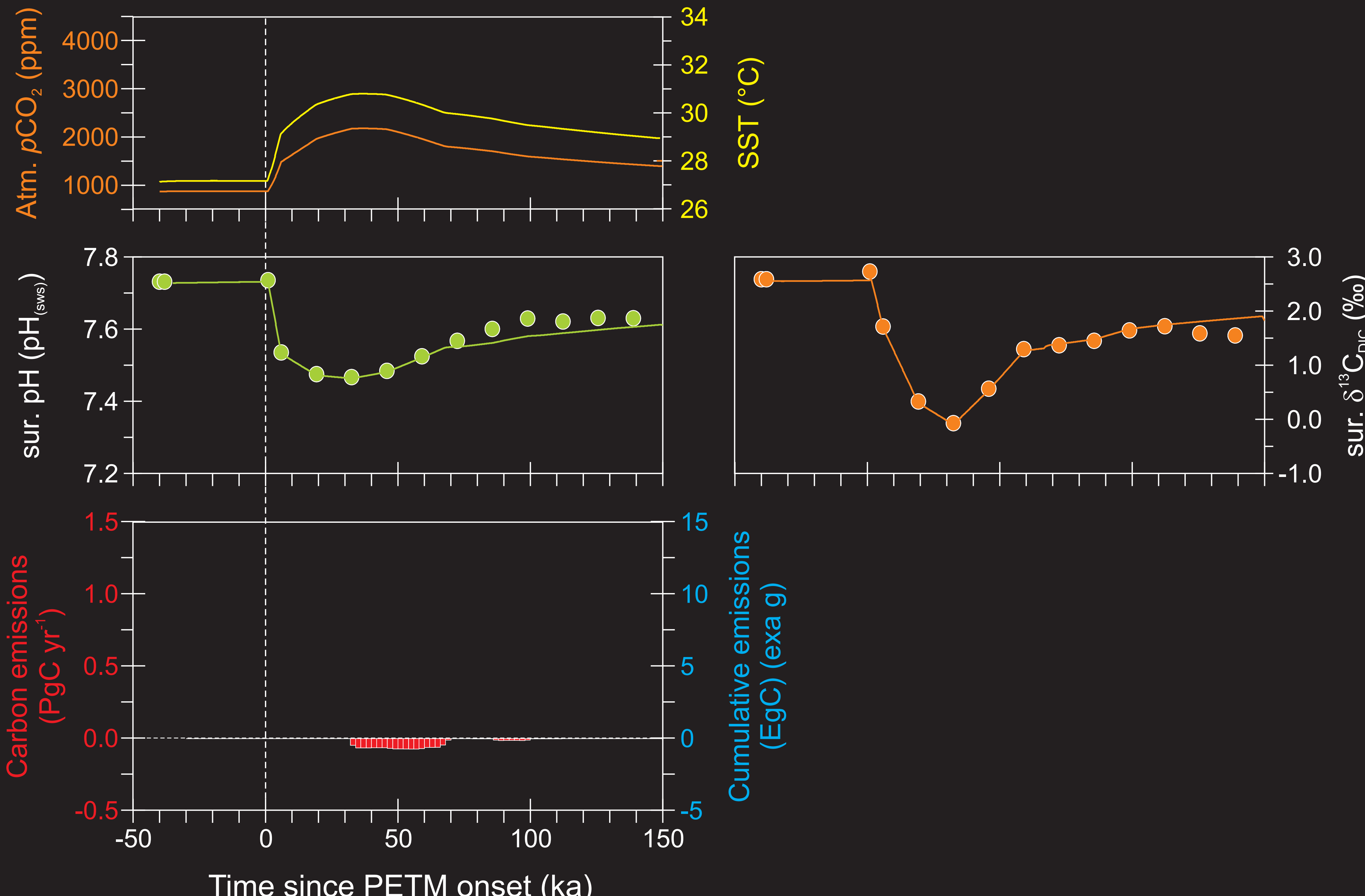

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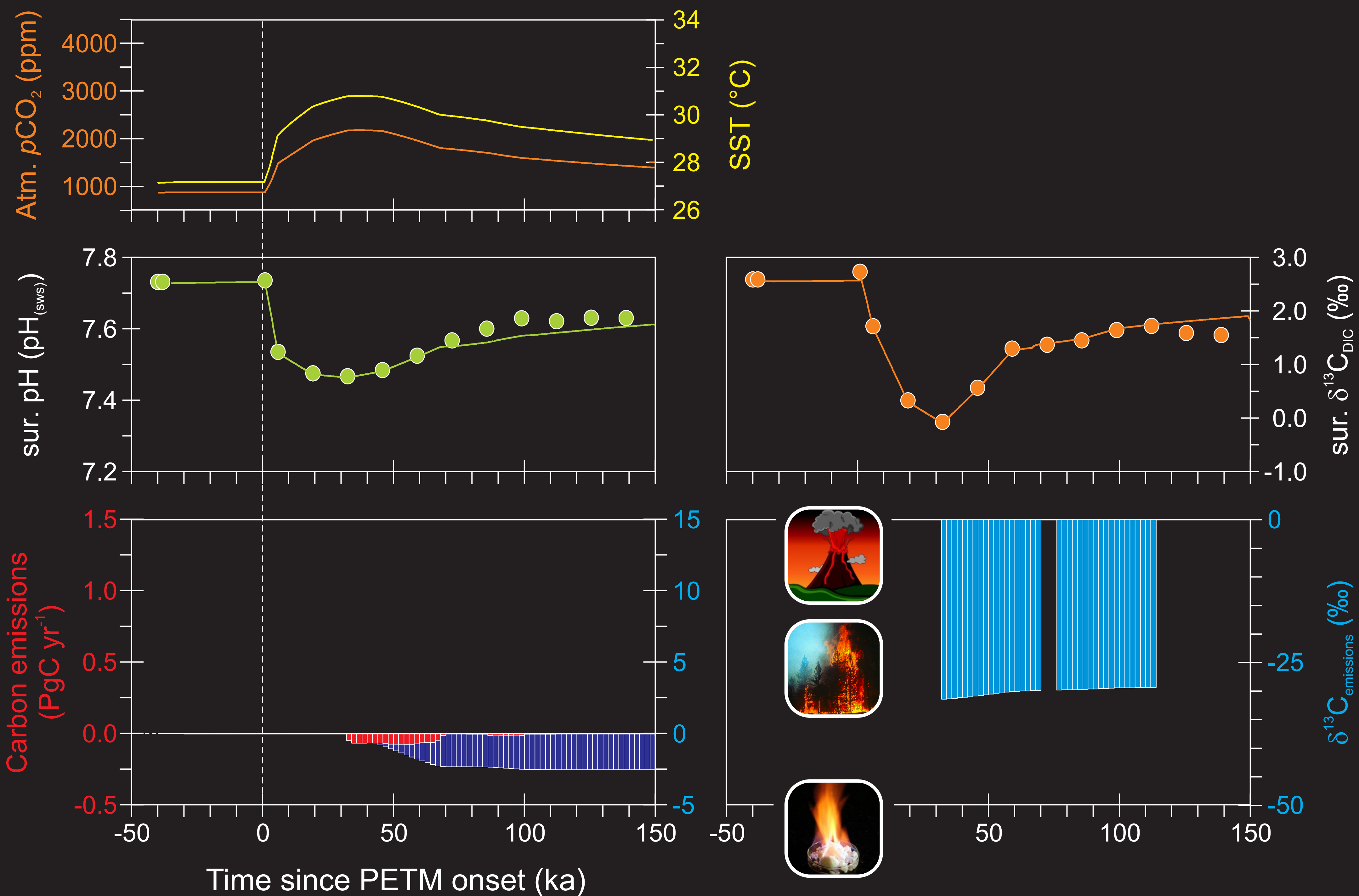
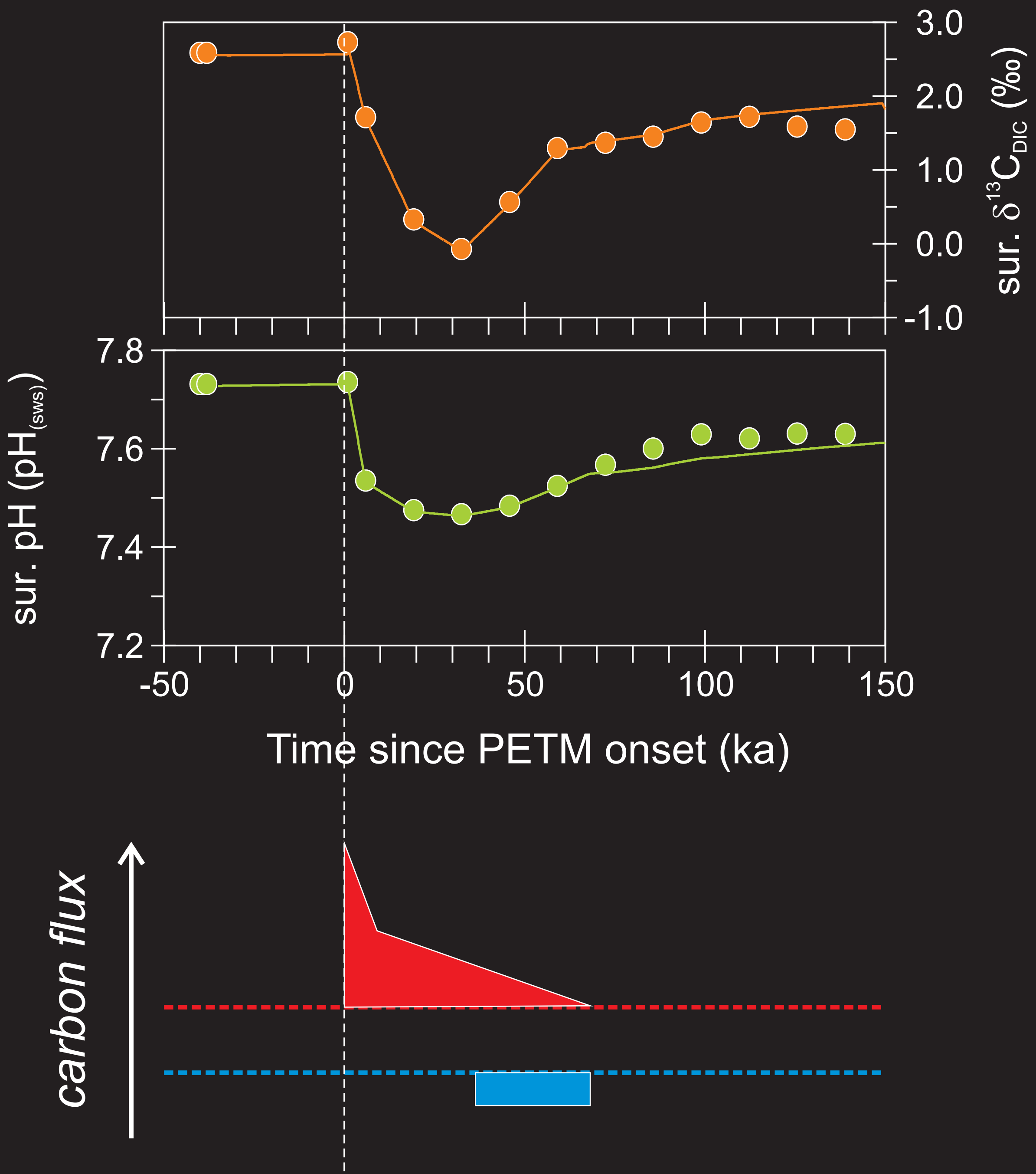


Conclusions – silicate weathering vs. C_{org} burial



PETM warming and ocean acidification was likely primarily driven by mantle carbon input (~10,000 PgC) at rates no more than ca. 5% of modern fossil fuel emissions.

Silicate weathering was responsible primarily responsible for the removal of excess carbon and climatic cooling.

Enhanced marine organic carbon burial (~2000 PgC) played a key role in the recovery from the event.

Carbon release continued throughout the event.

Thanks to:

Sarah Greene [Bristol], *Sandy Kirtland Turner* [UC Riverside], *Phil Pogge Von Strandmann* [UCL]

Marcus Gutjahr [GEOMAR], *Philip Sexton* [The Open University], *Gavin Foster* [NOC]