Evolution and revolution in marine (carbonate) carbon cycling

Andy Ridgwell

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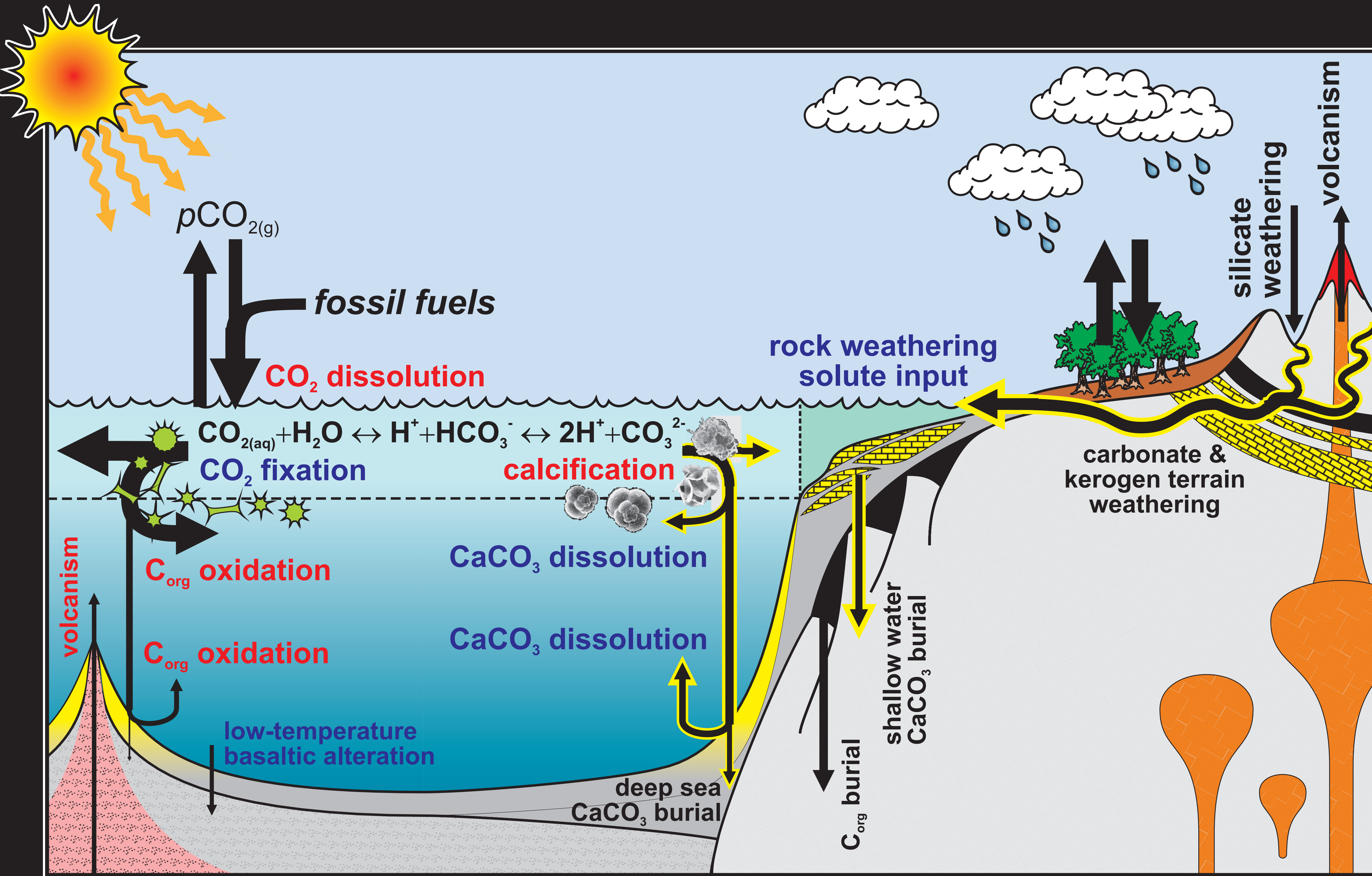
The global carbon cycle: Present-day



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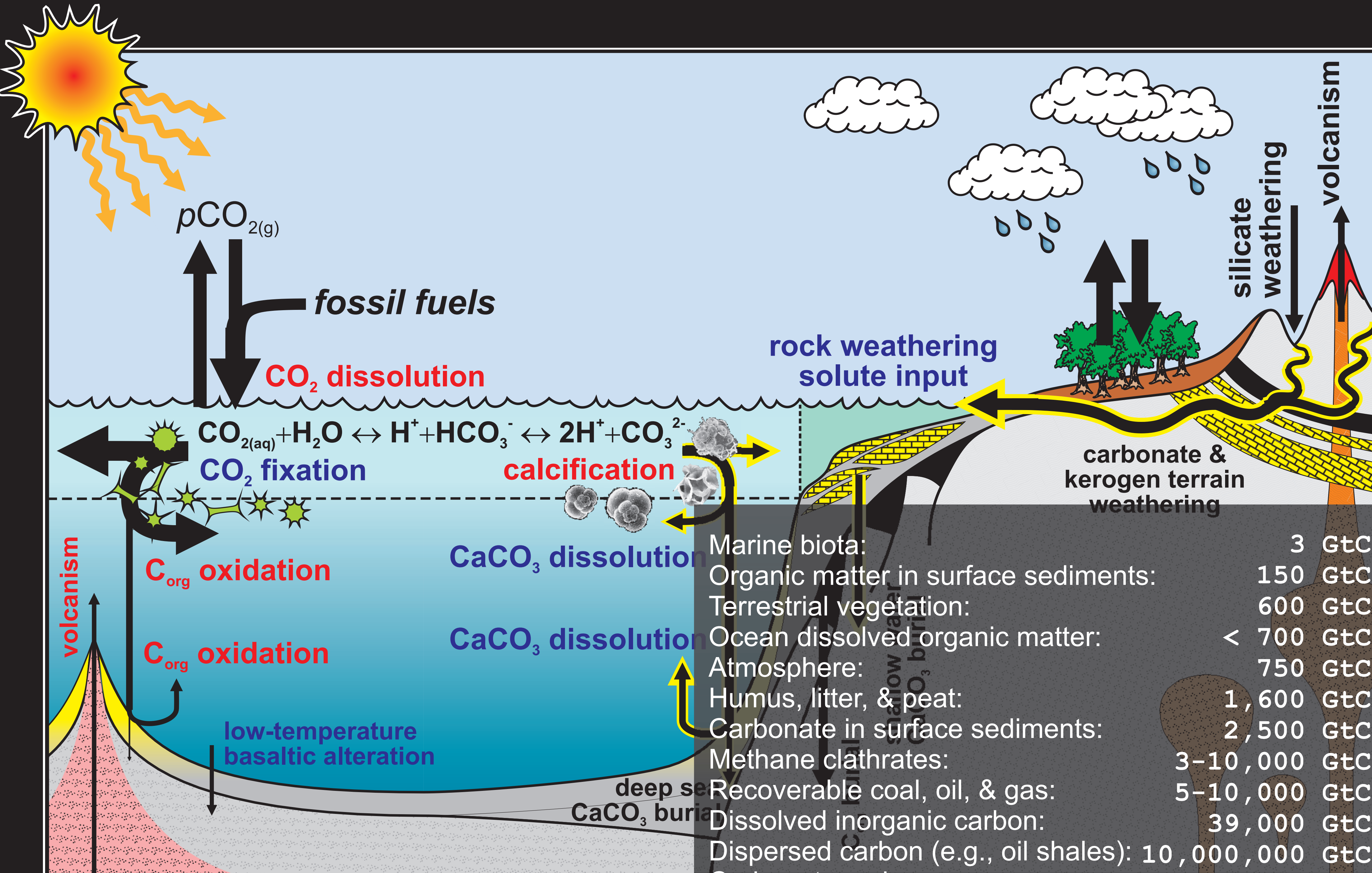

Marine biota:	3 GtC
Organic matter in surface sediments:	150 GtC
Terrestrial vegetation:	600 GtC
Ocean dissolved organic matter:	< 700 GtC
Atmosphere:	750 GtC
Humus, litter, & peat:	1,600 GtC
Carbonate in surface sediments:	2,500 GtC
Methane clathrates:	3-10,000 GtC
Recoverable coal, oil, & gas:	5-10,000 GtC
Dissolved inorganic carbon:	39,000 GtC
Dispersed carbon (e.g., oil shales):	10,000,000 GtC
Carbonate rocks:	40,000,000 GtC

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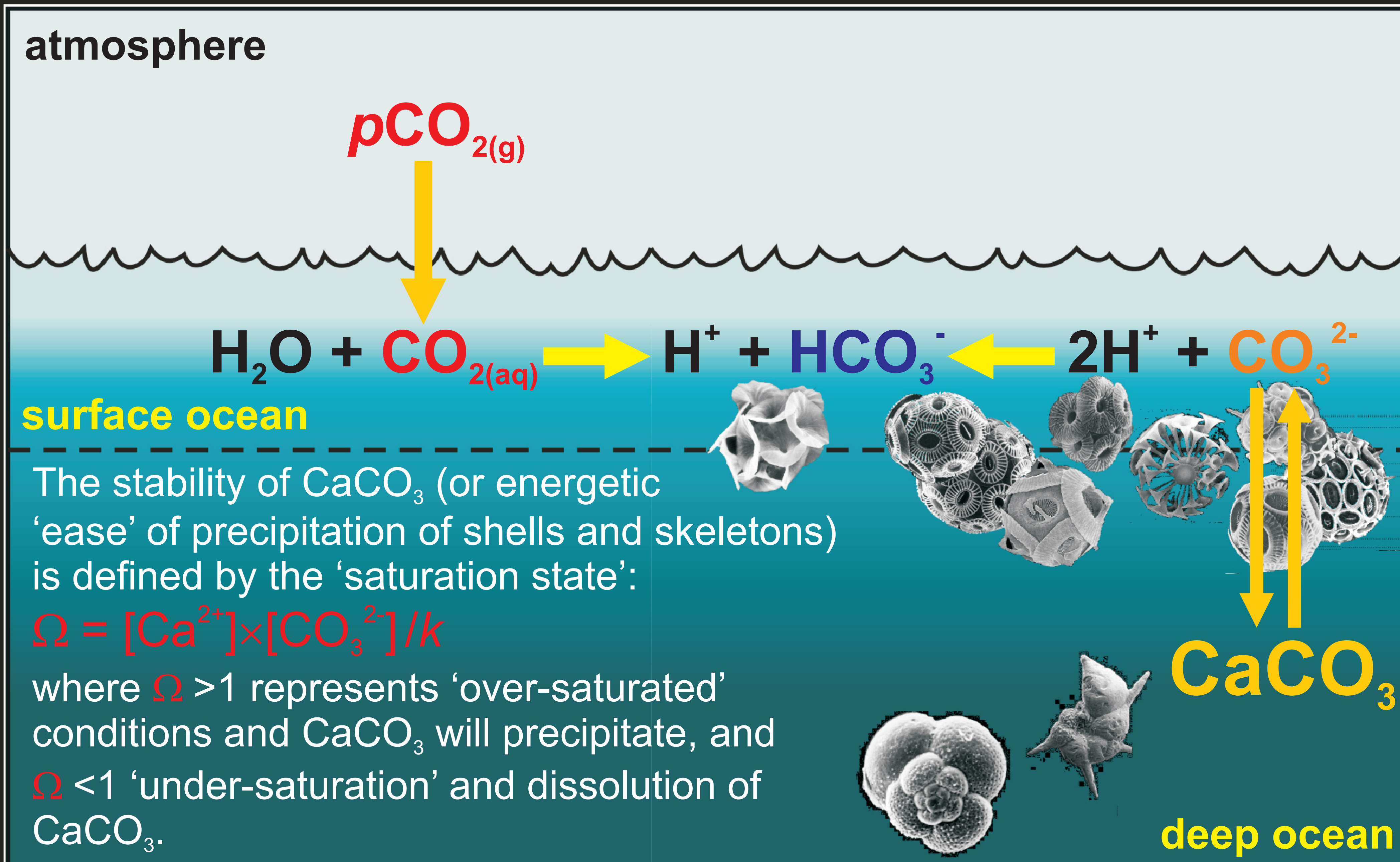
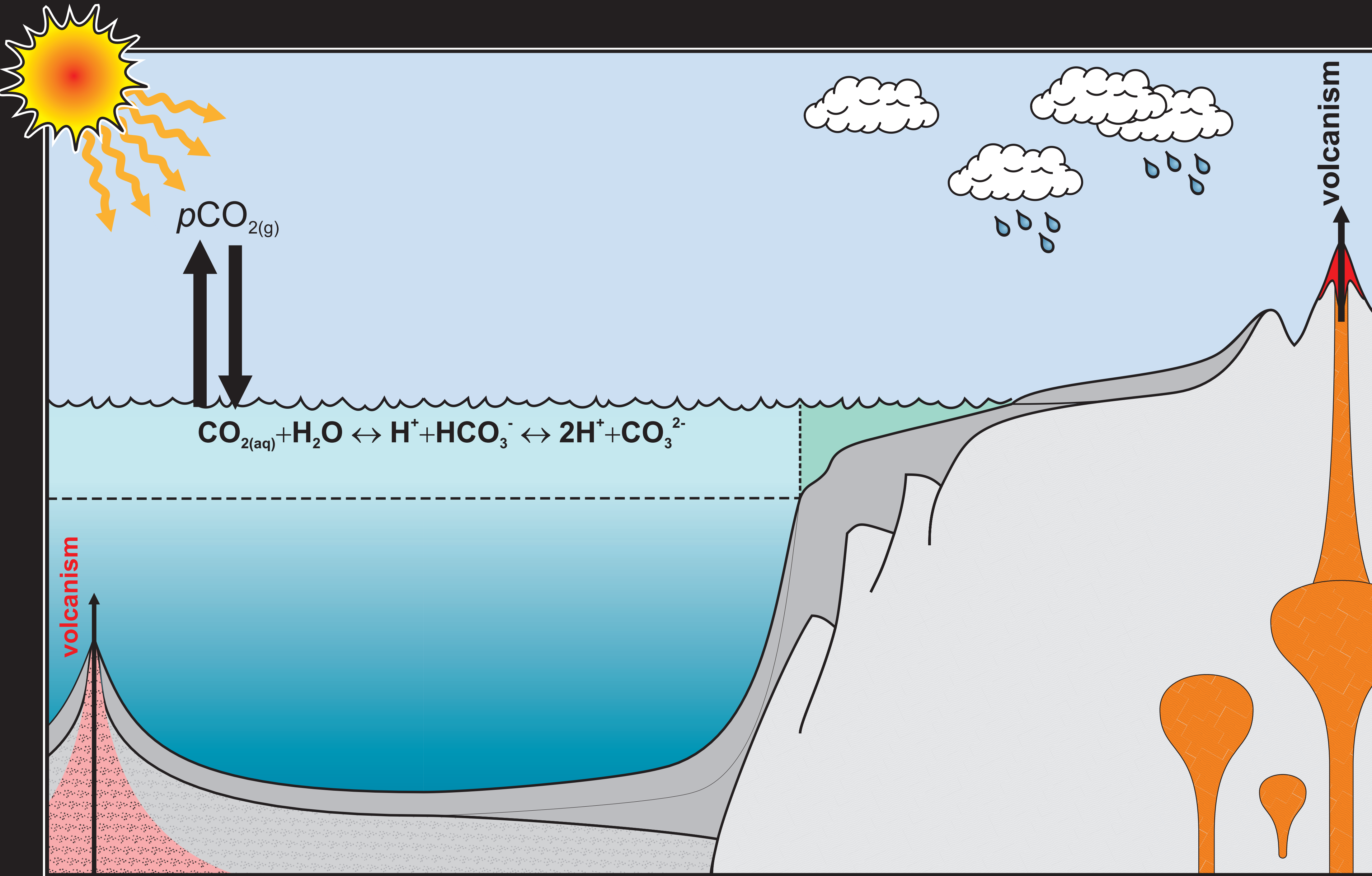


The global carbon(ate) cycle: In the beginning ...



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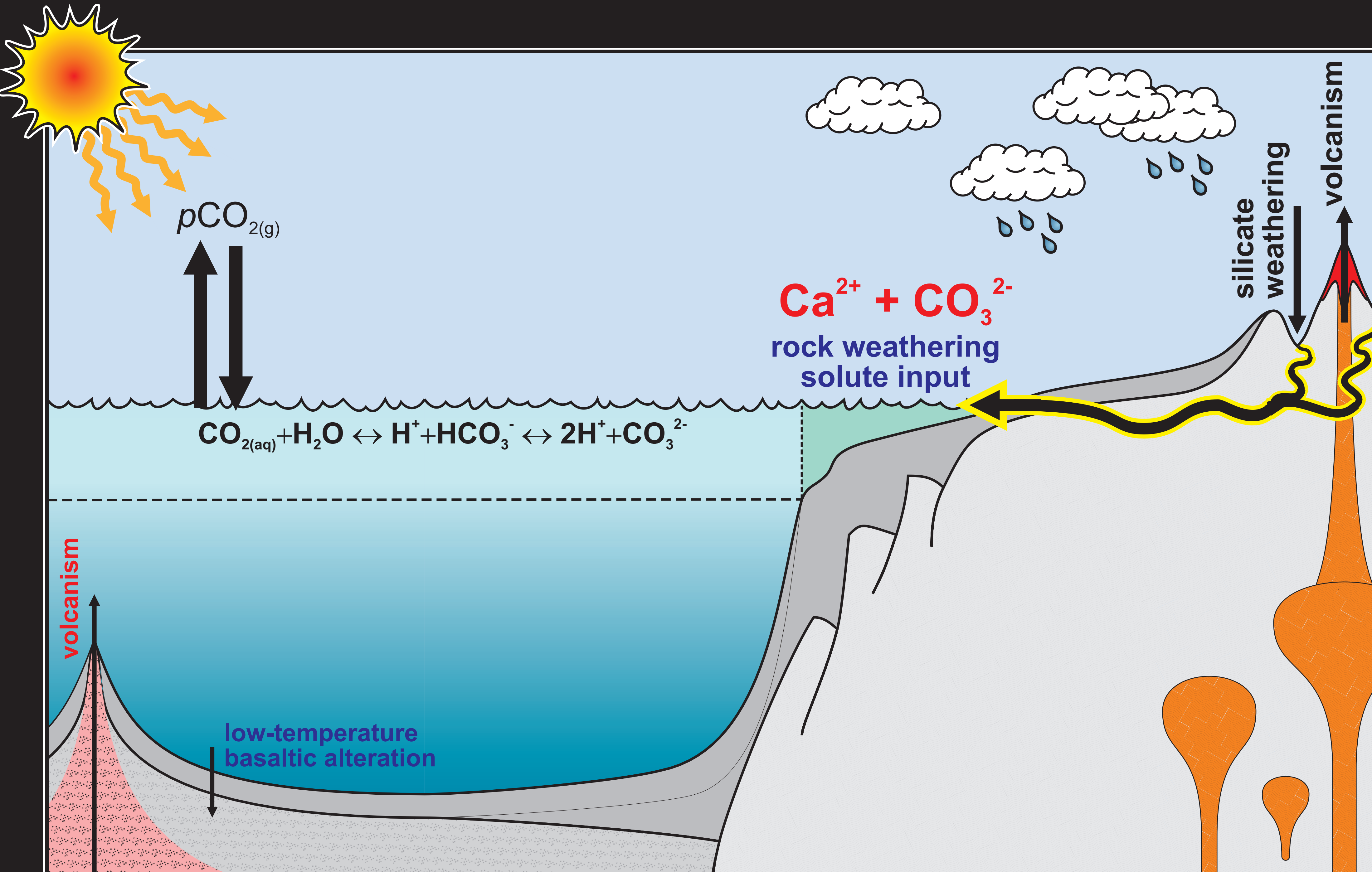
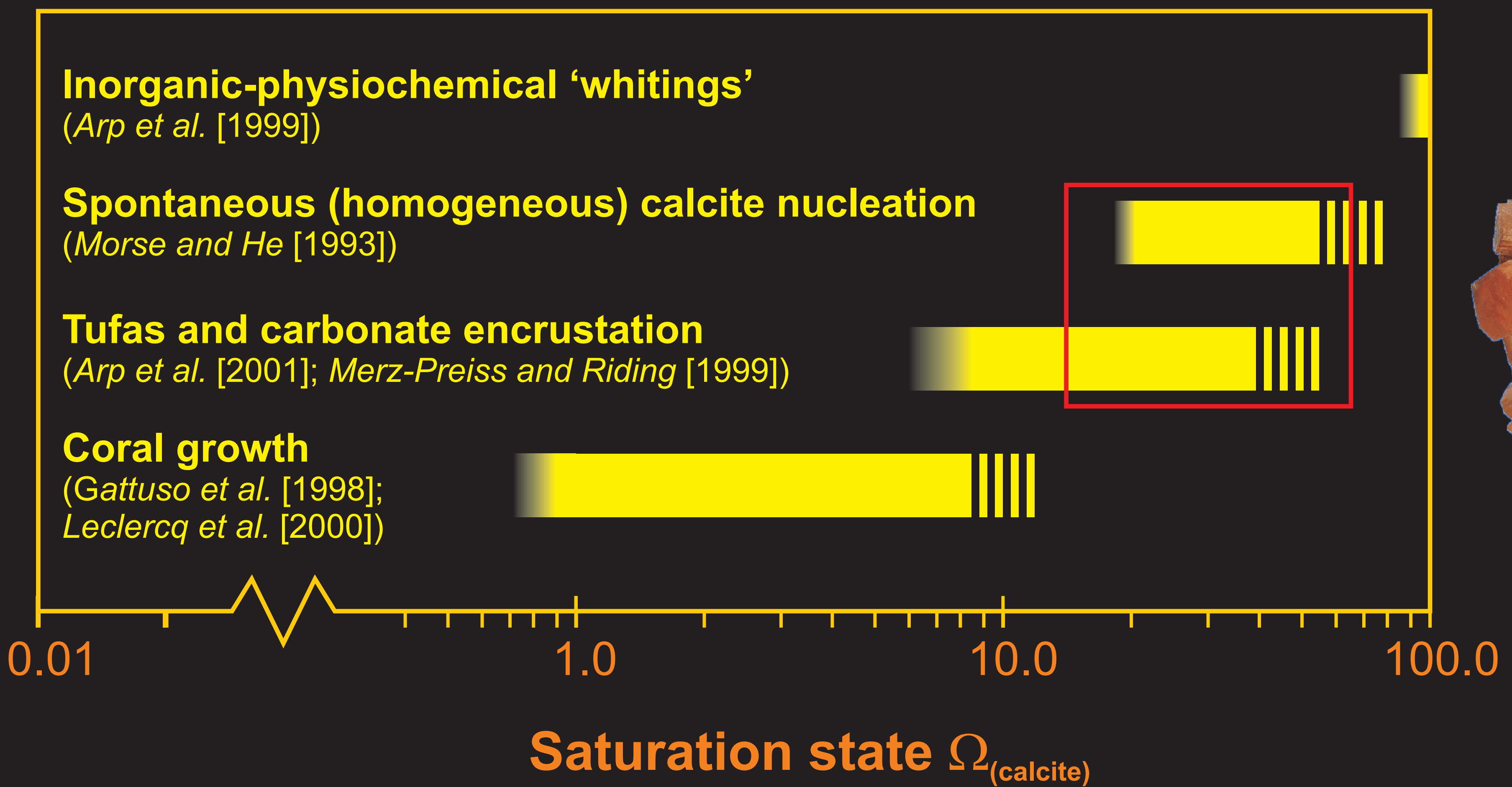


The global carbon(ate) cycle: In the beginning ...

The stability of $CaCO_3$ (or energetic 'ease' of precipitation of shells and skeletons) is defined by the 'saturation state':

$$\Omega = [Ca^{2+}]\times[CO_3^{2-}]/k$$



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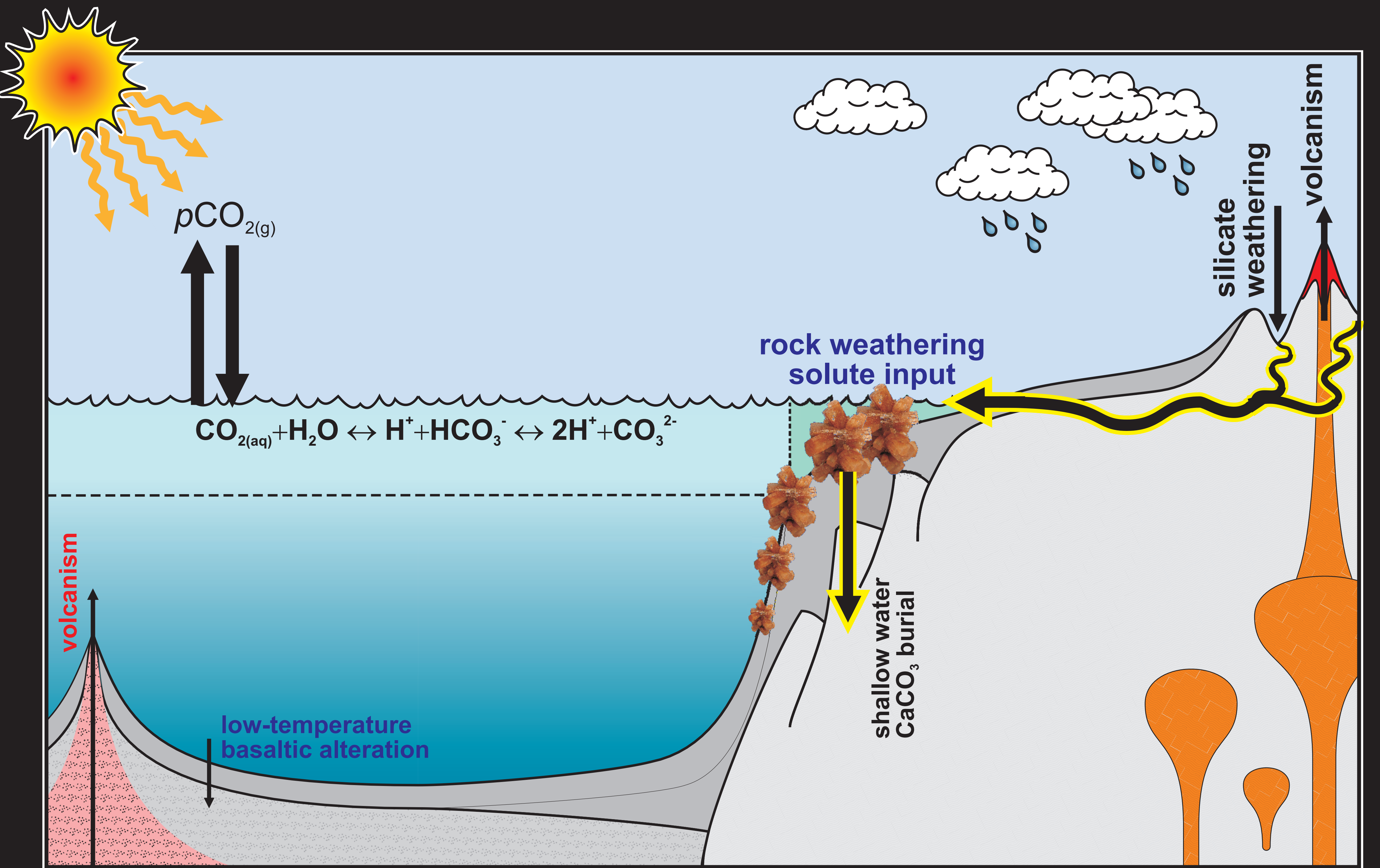
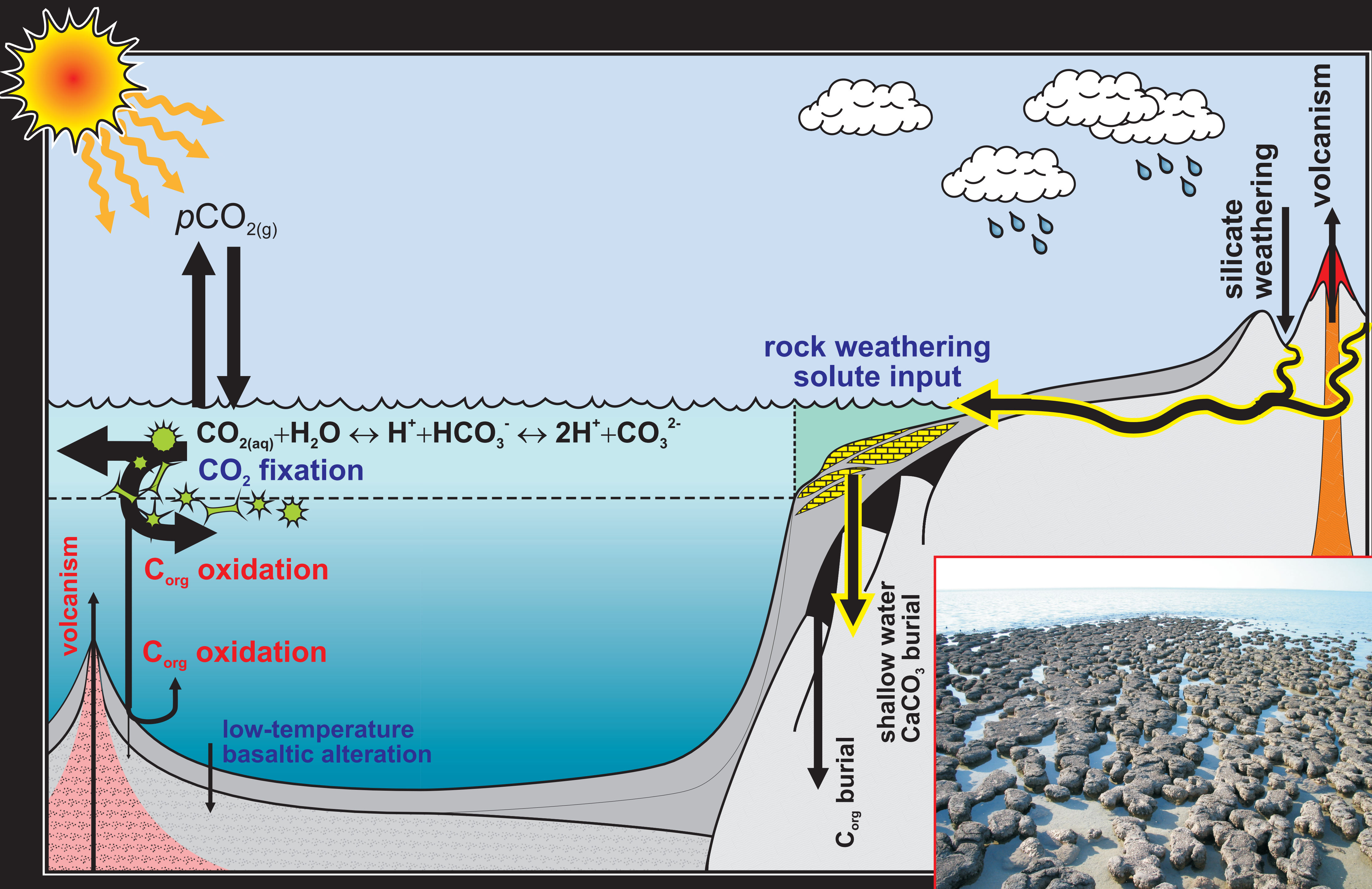


The global carbon(ate) cycle: Early 'evolution'



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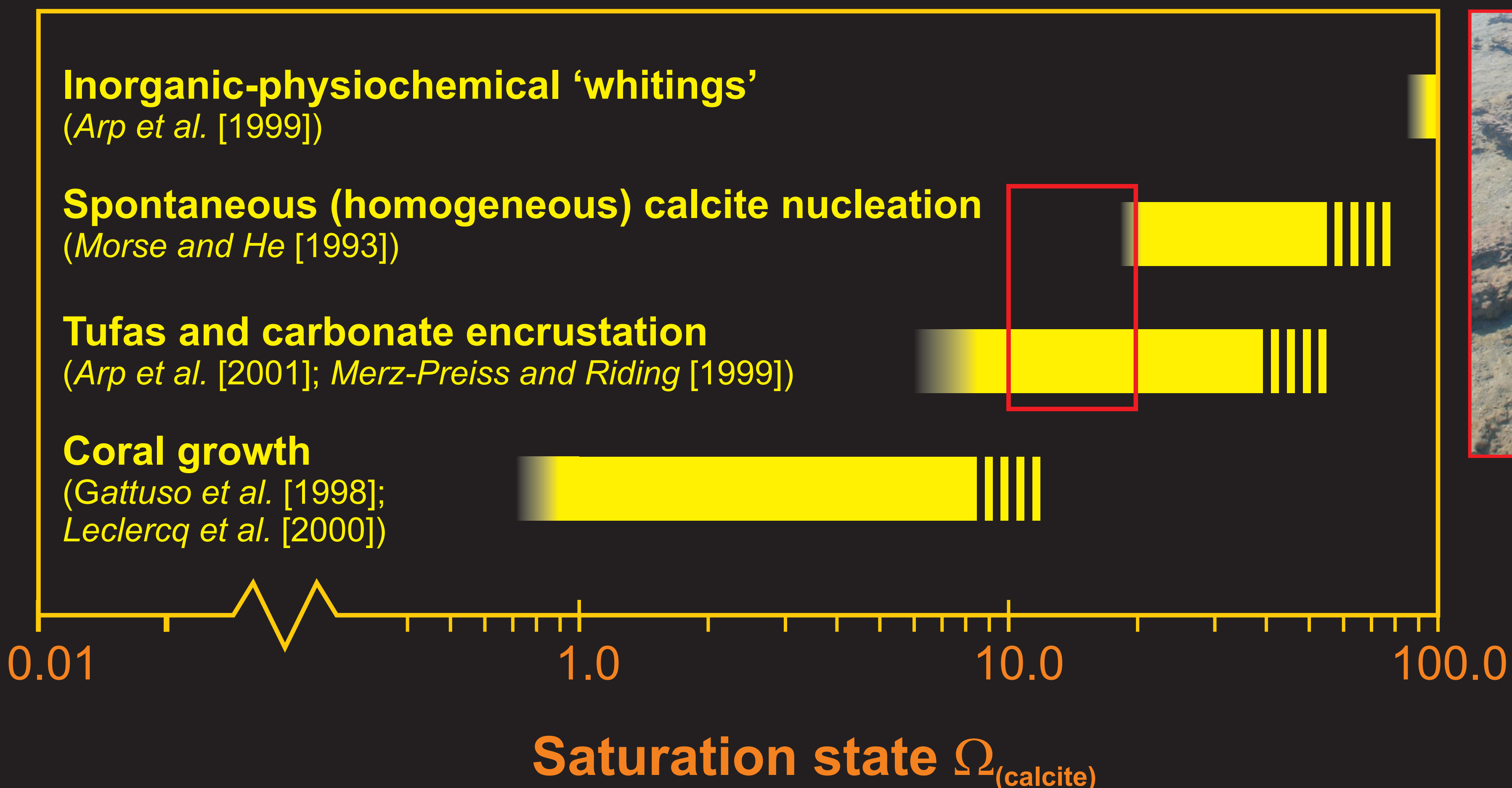
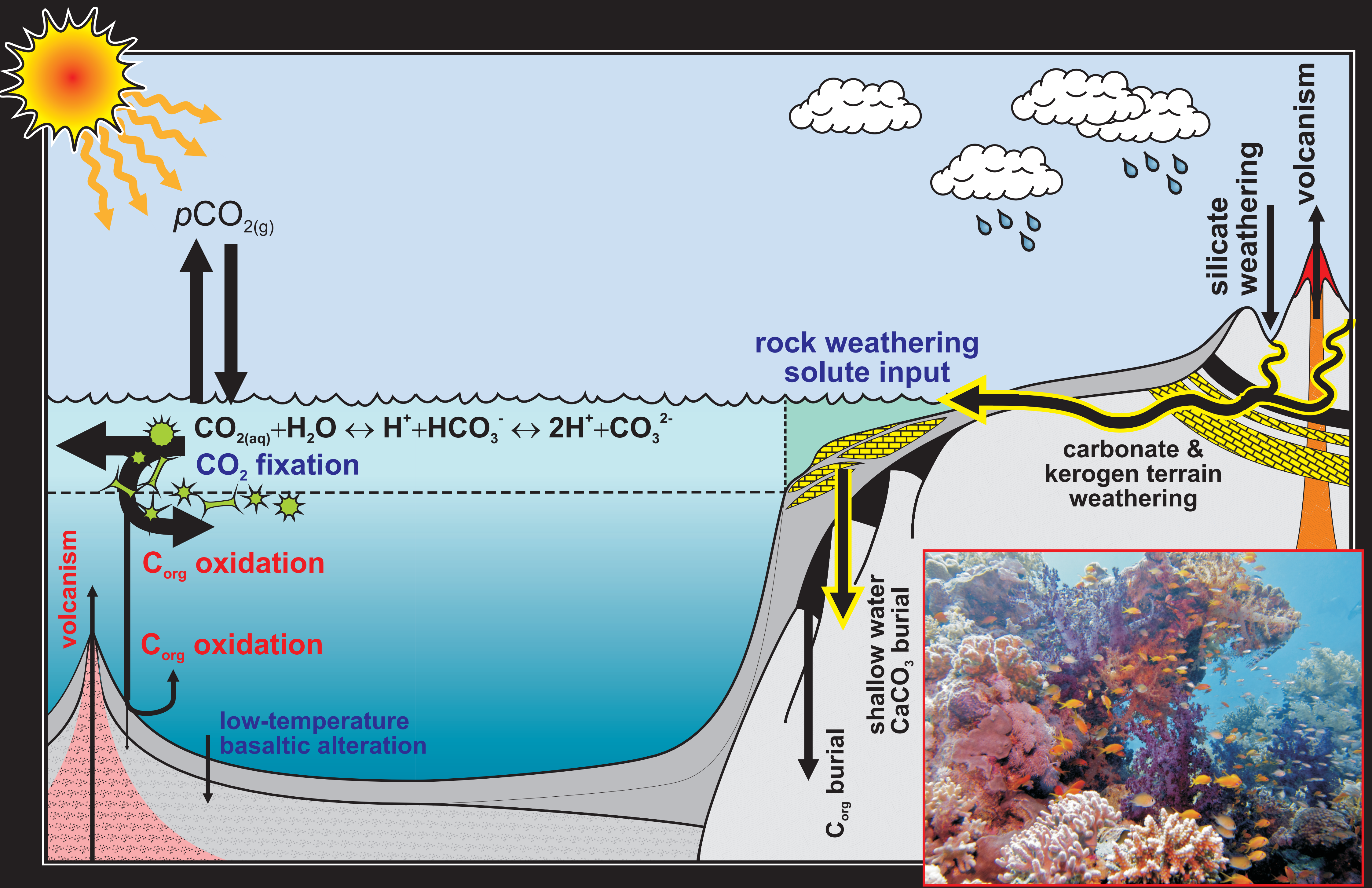


The global carbon(ate) cycle: Control of ocean saturation



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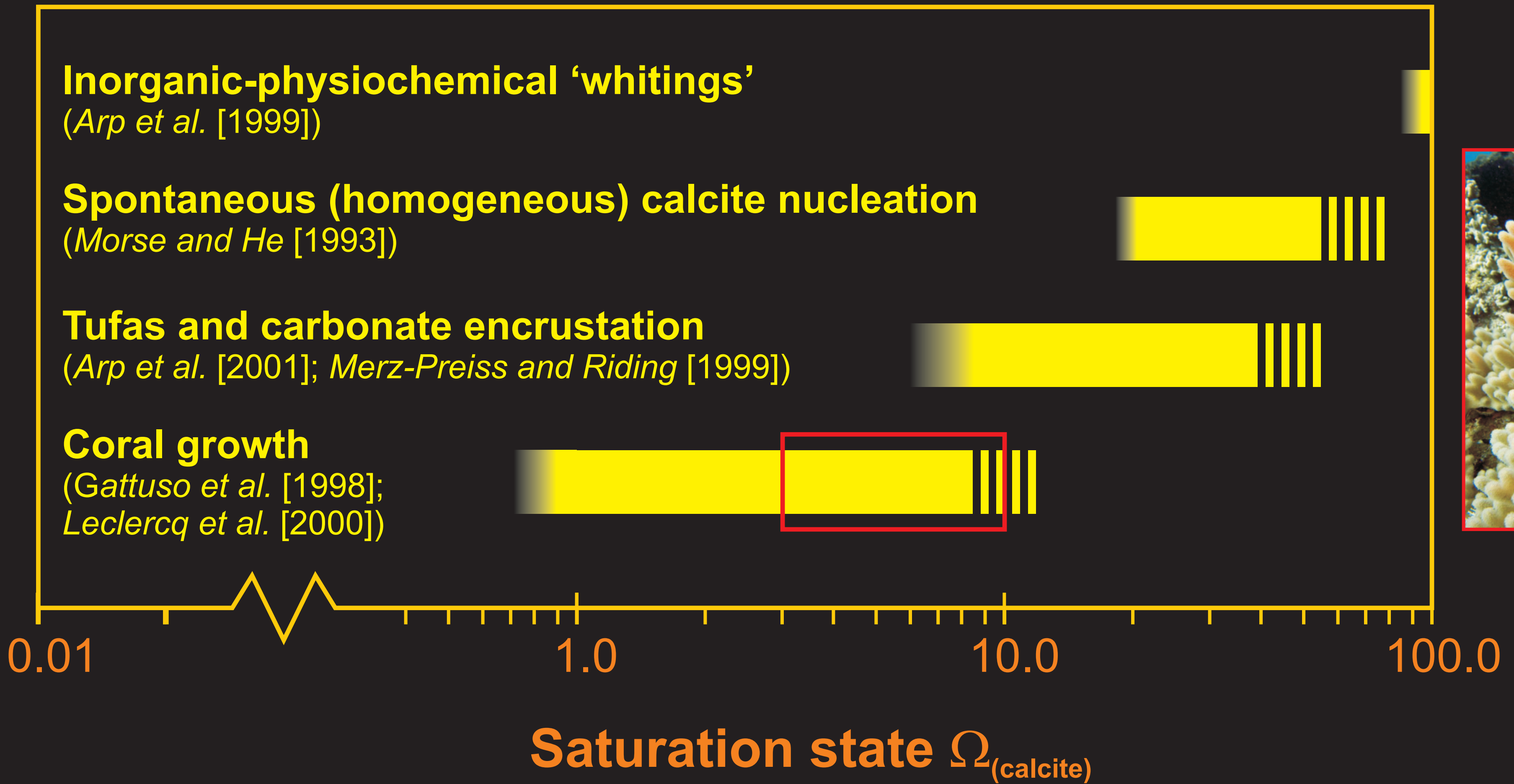

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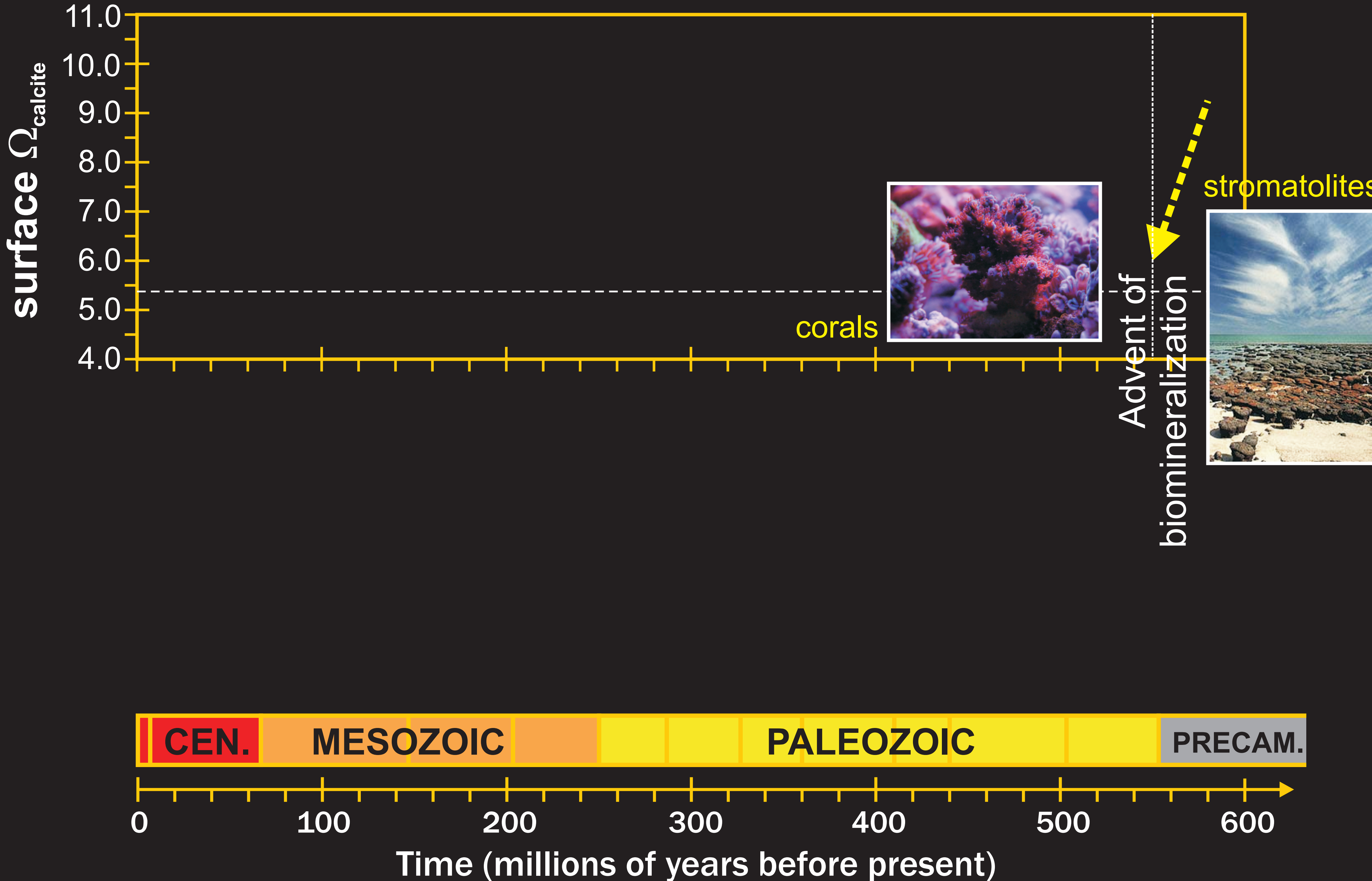

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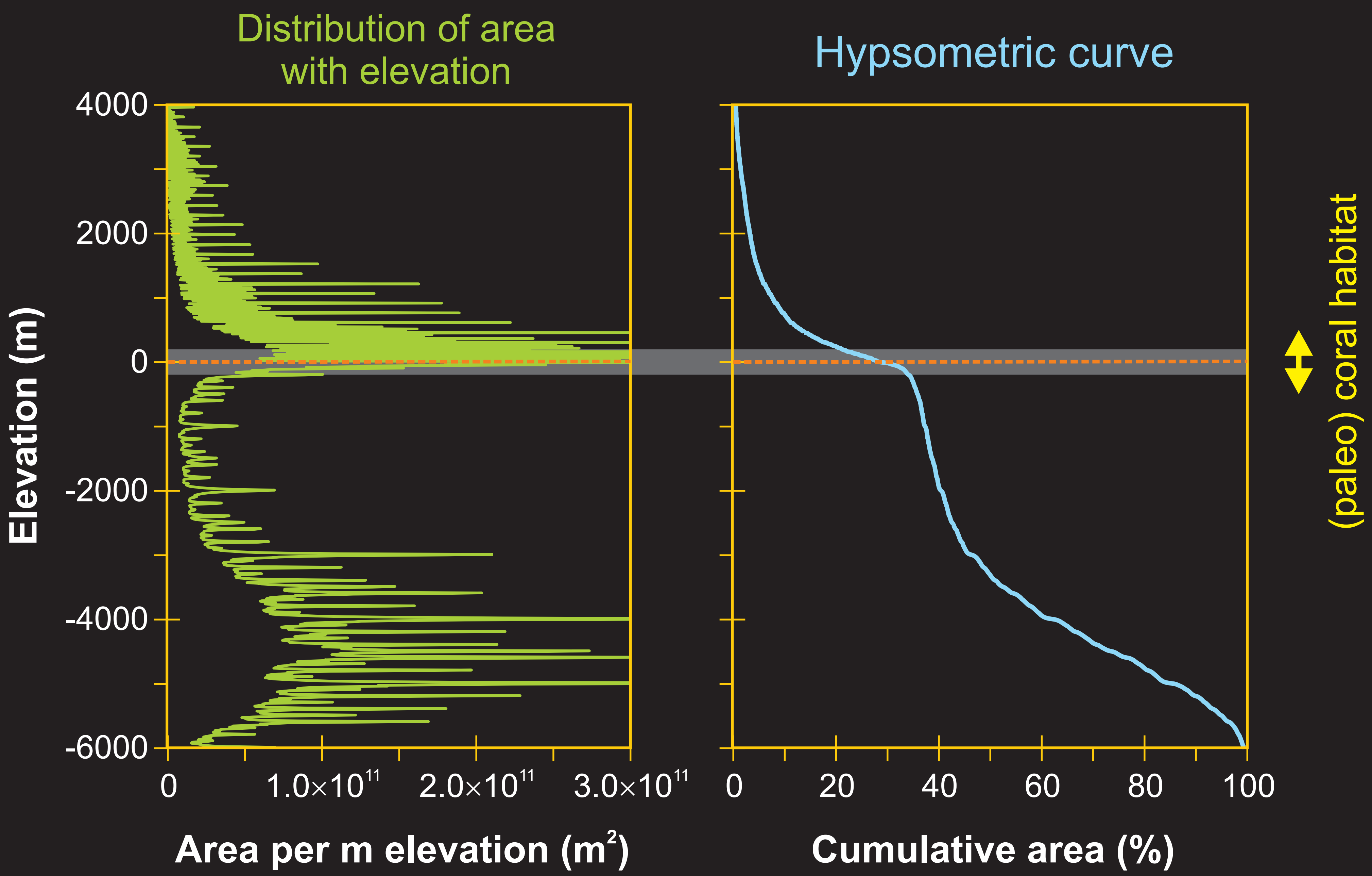

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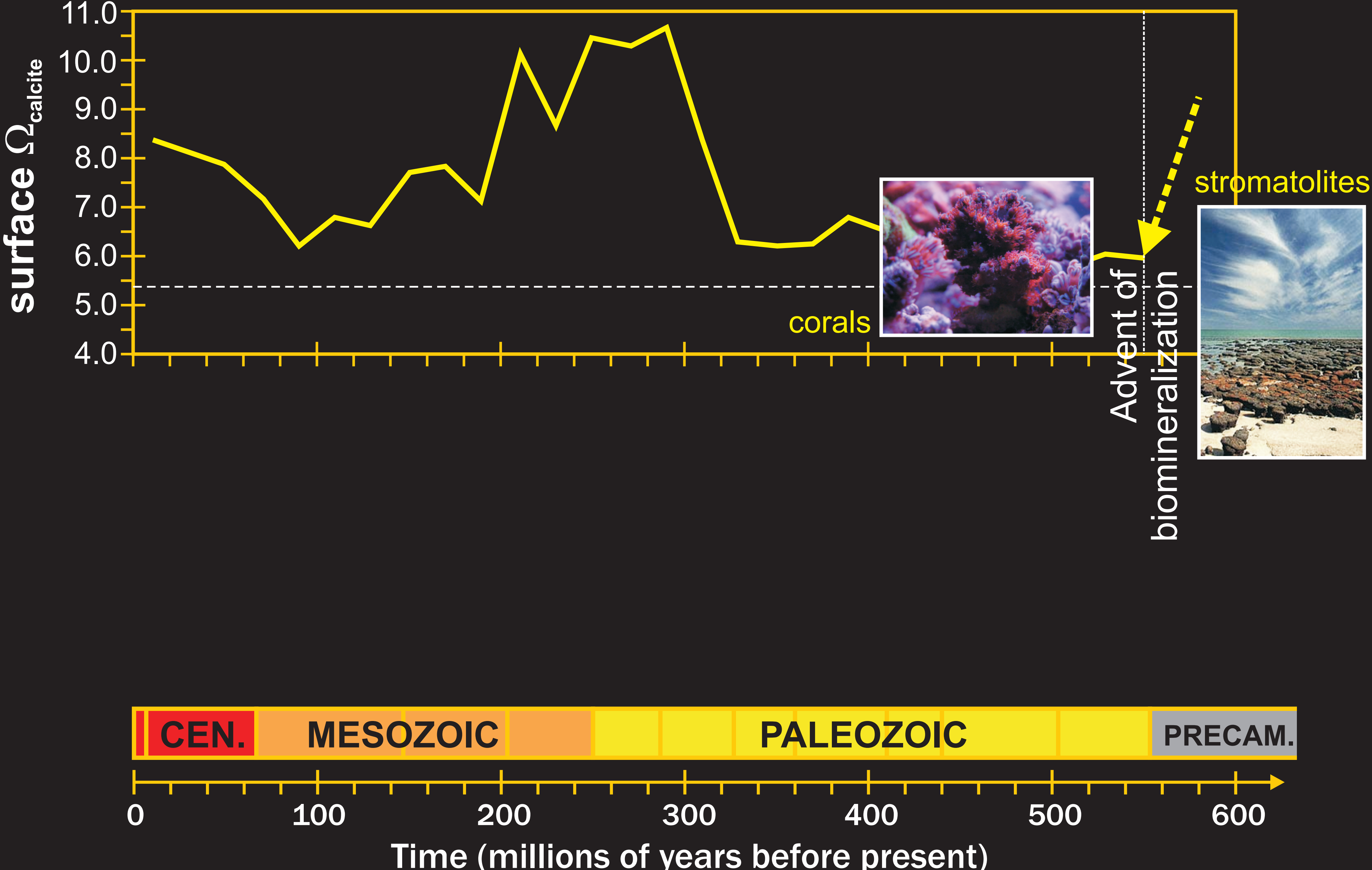

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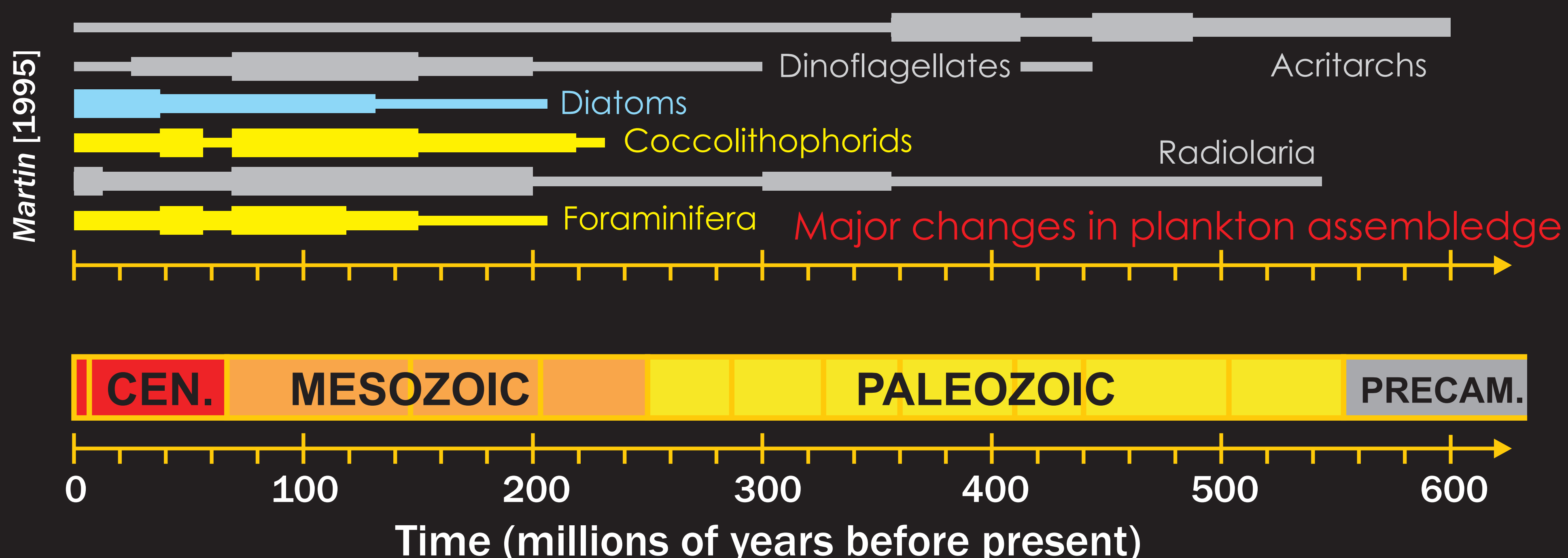

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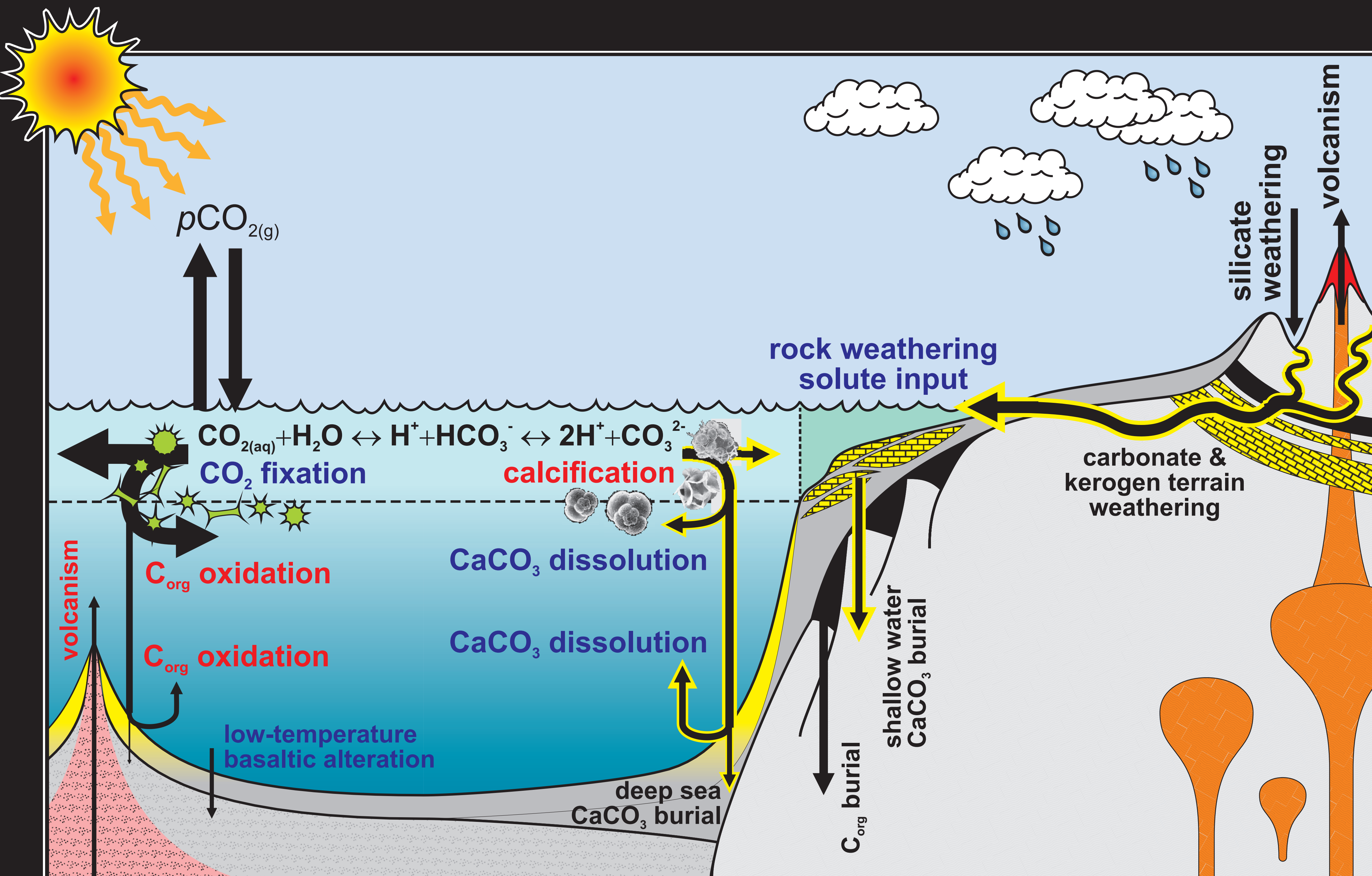

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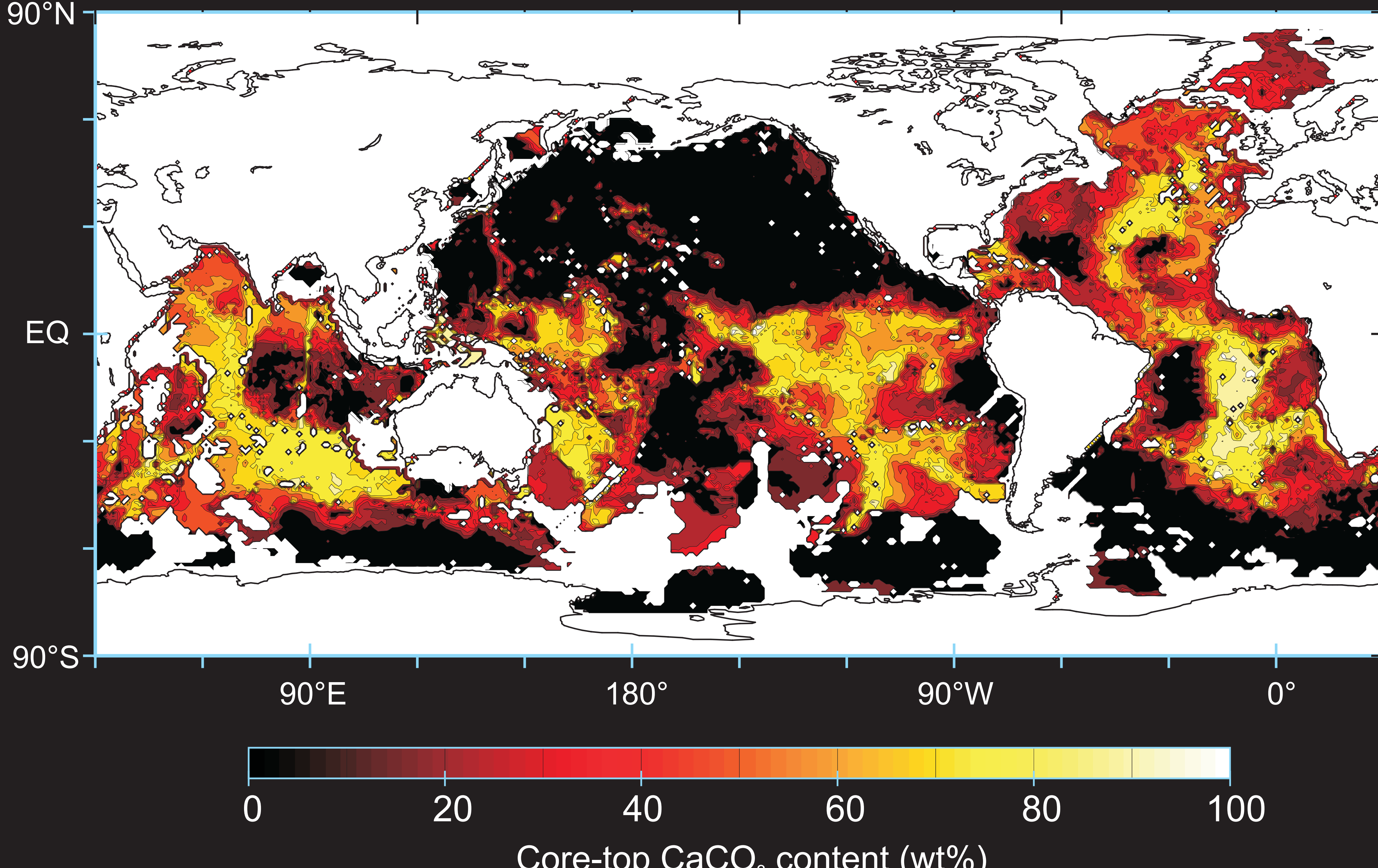
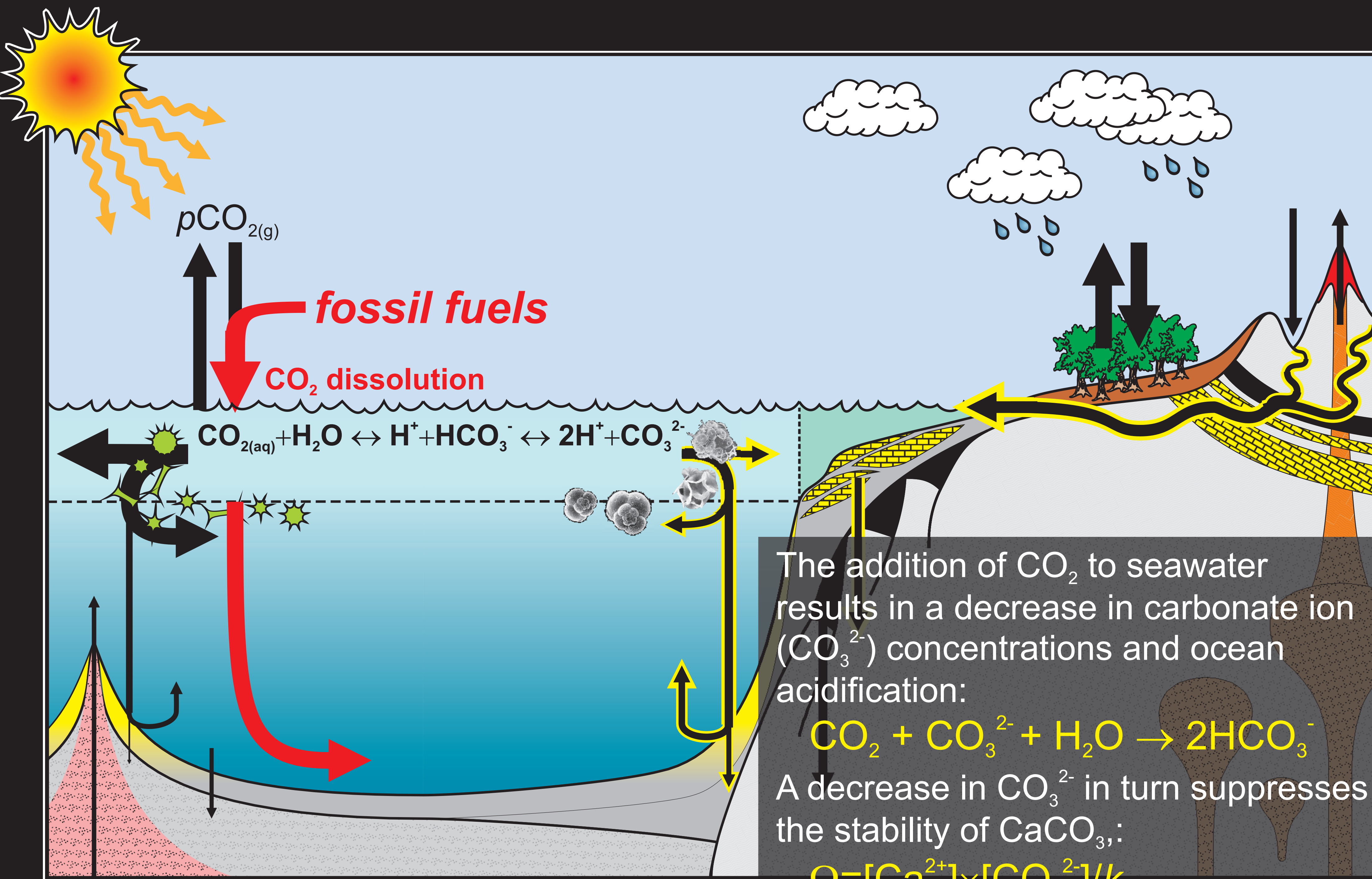


From: *Archer* [1996] (*GBC*)

Deep-sea sedimentary buffering



The addition of CO_2 to seawater results in a decrease in carbonate ion (CO_3^{2-}) concentrations and ocean acidification:

$$CO_2 + CO_3^{2-} + H_2O \rightarrow 2HCO_3^-$$

A decrease in CO_3^{2-} in turn suppresses the stability of $CaCO_3$,:

$$\Omega = [Ca^{2+}] \times [CO_3^{2-}] / k$$

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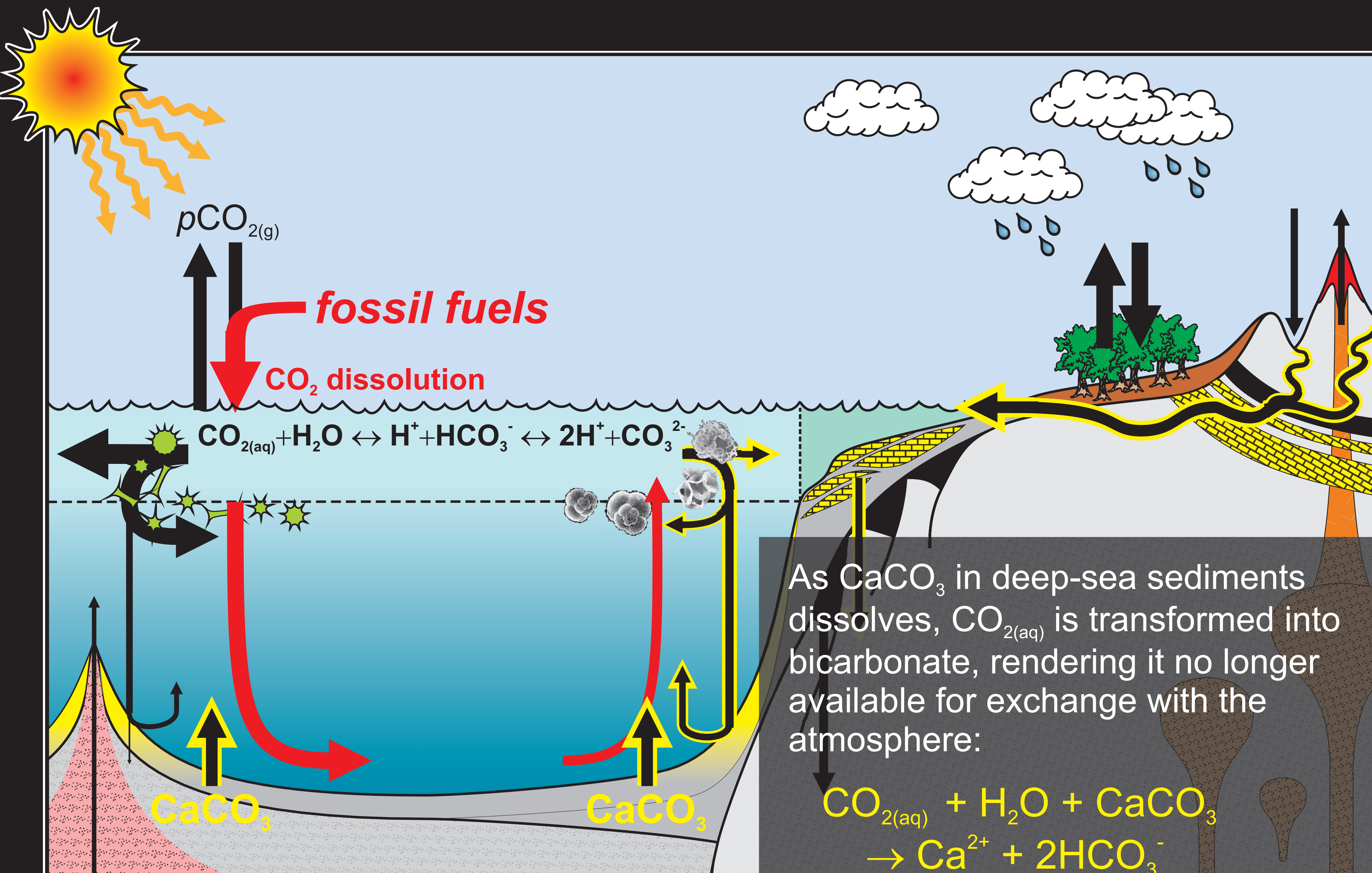

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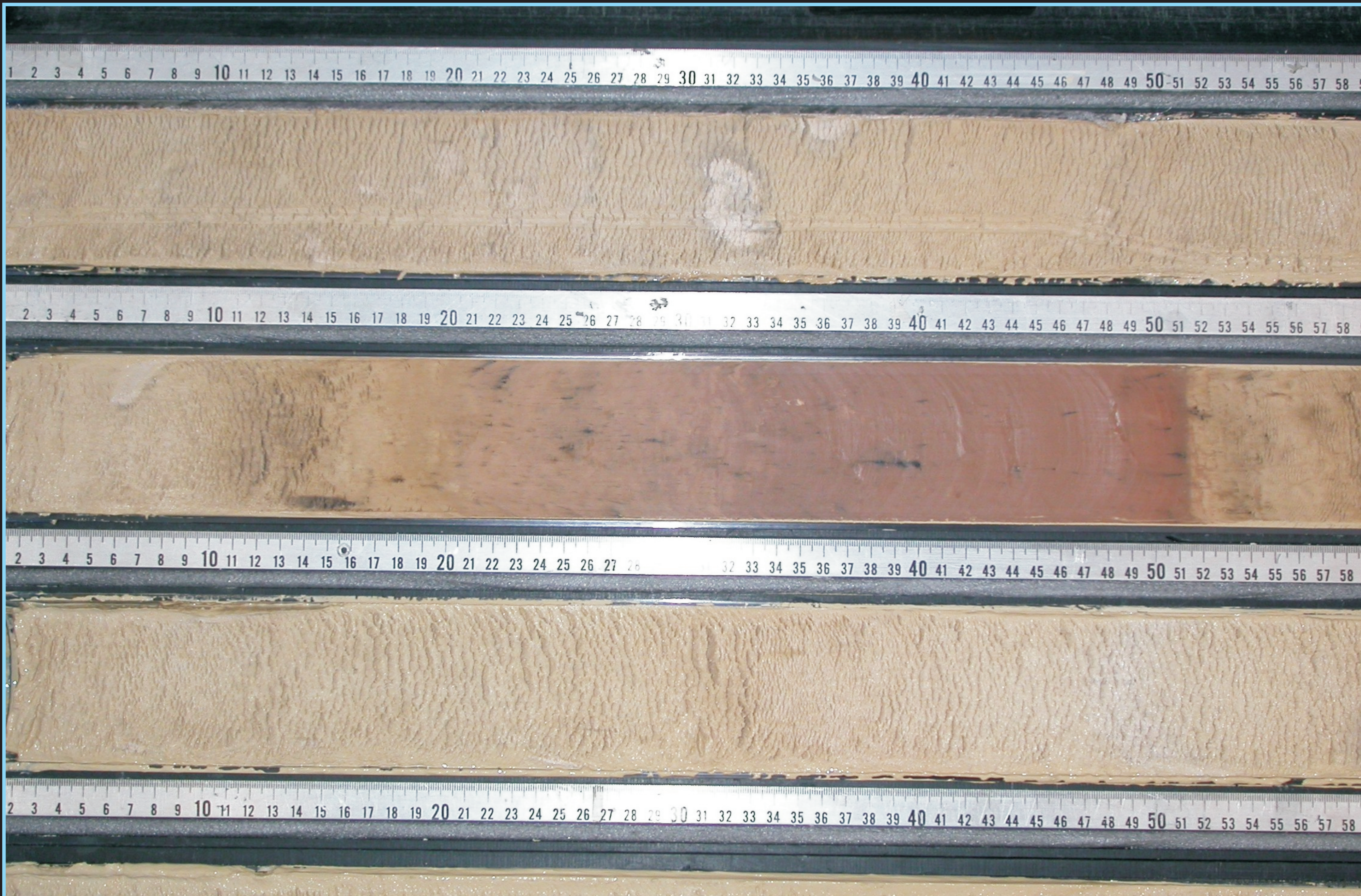

Sediments spanning the Palaeocene-Eocene boundary recovered from ODP Leg 208 (Walvis Ridge)
Picture courtesy of Dani Schmidt (University of Bristol)

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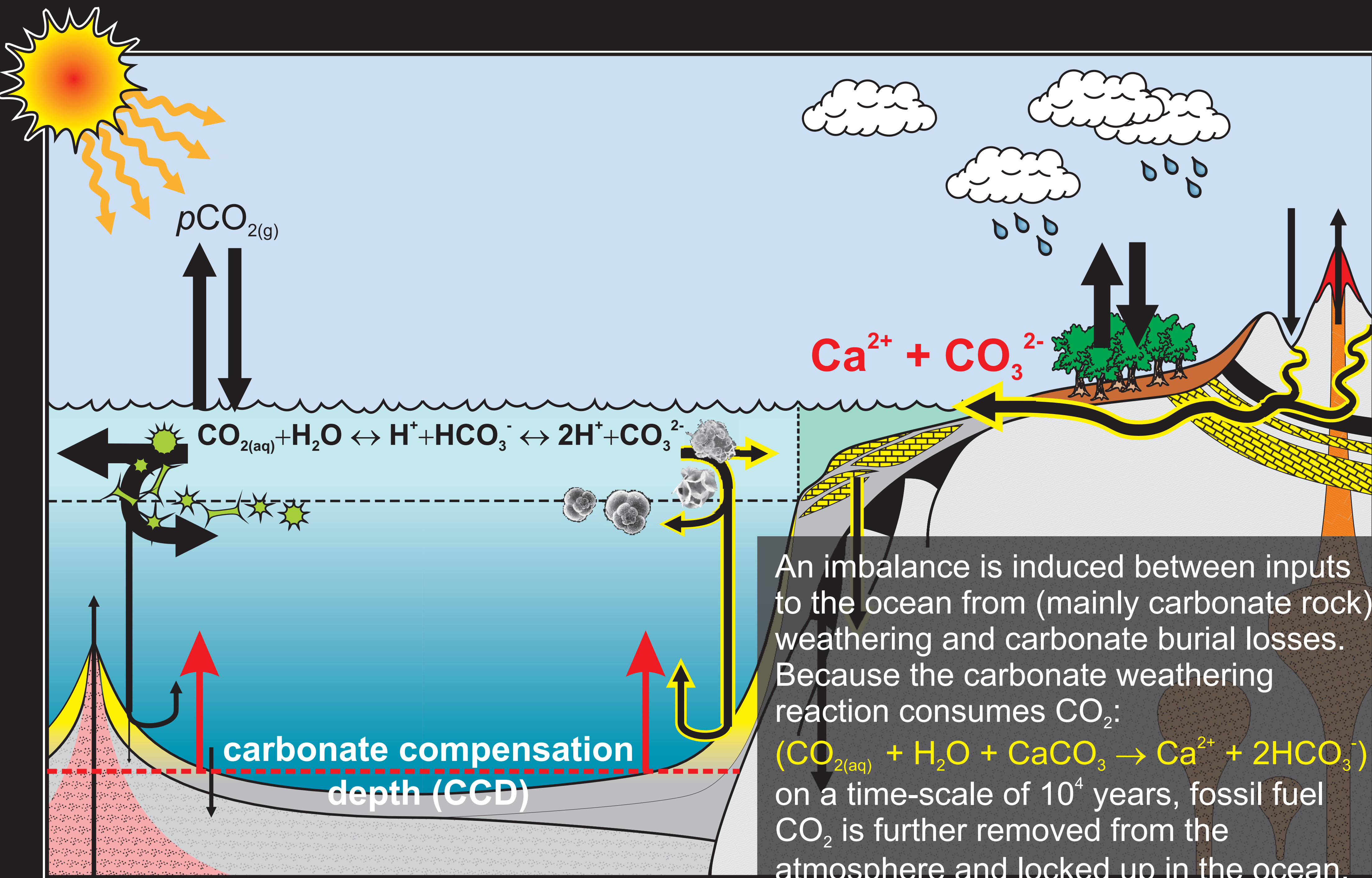

An imbalance is induced between inputs to the ocean from (mainly carbonate rock) weathering and carbonate burial losses. Because the carbonate weathering reaction consumes CO_2:

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

on a time-scale of 10^4 years, fossil fuel CO_2 is further removed from the atmosphere and locked up in the ocean.

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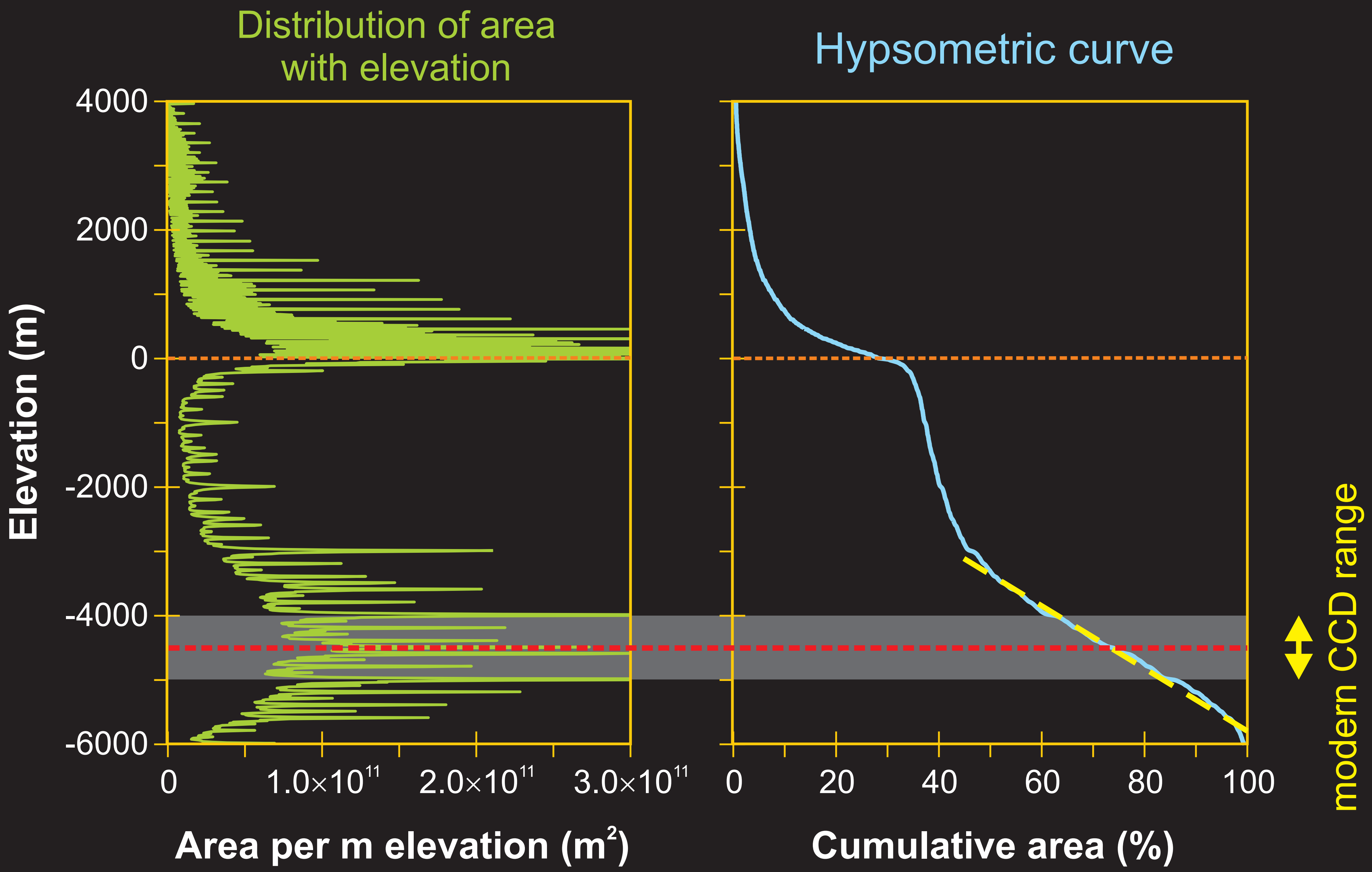

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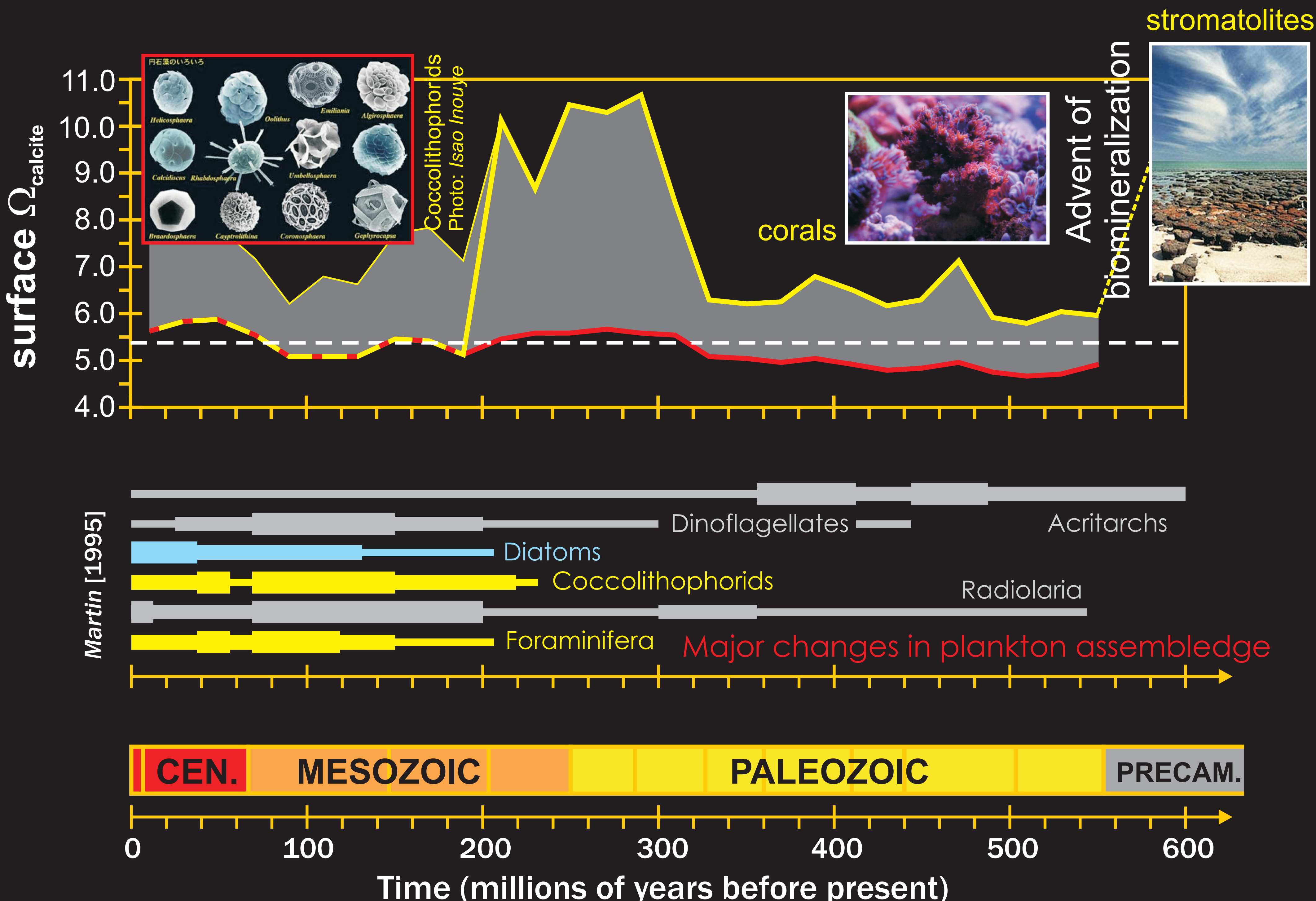

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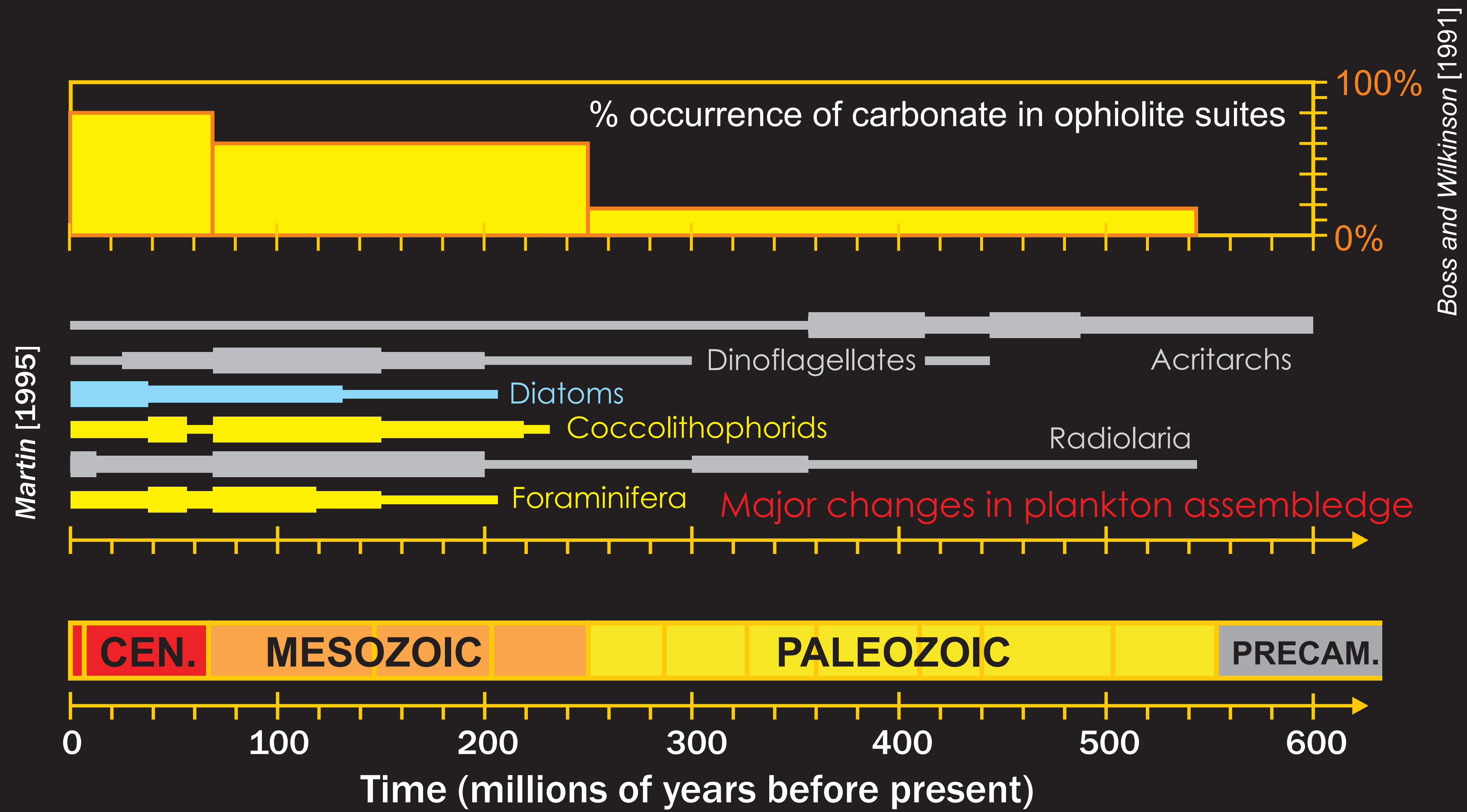

The importance of worms (metazoans)

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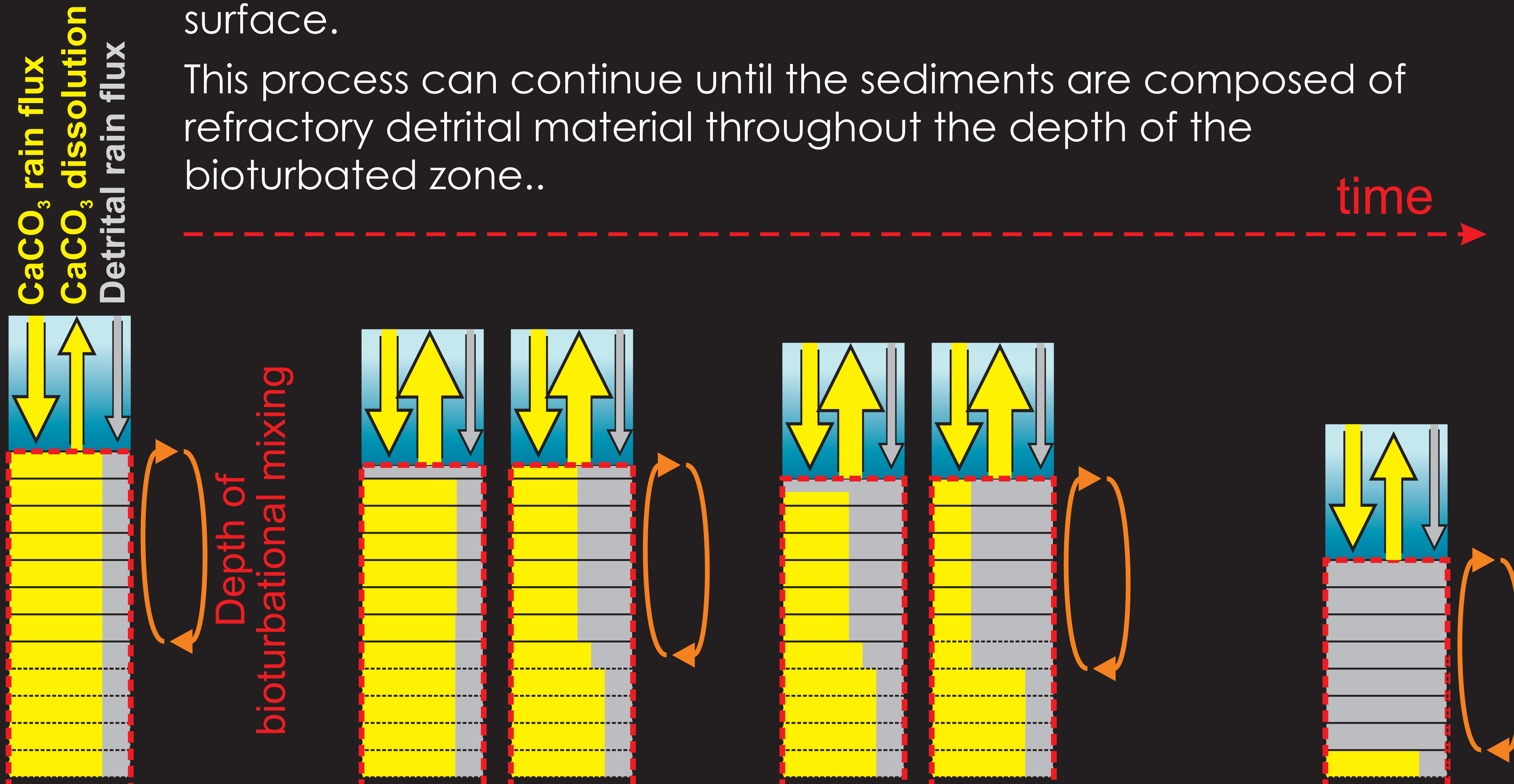
As $CaCO_3$ is dissolved form the surface sediments, previously-deposited carbonate is mixed upwards and brought to the surface.

This process can continue until the sediments are composed of refractory detrital material throughout the depth of the bioturbated zone..



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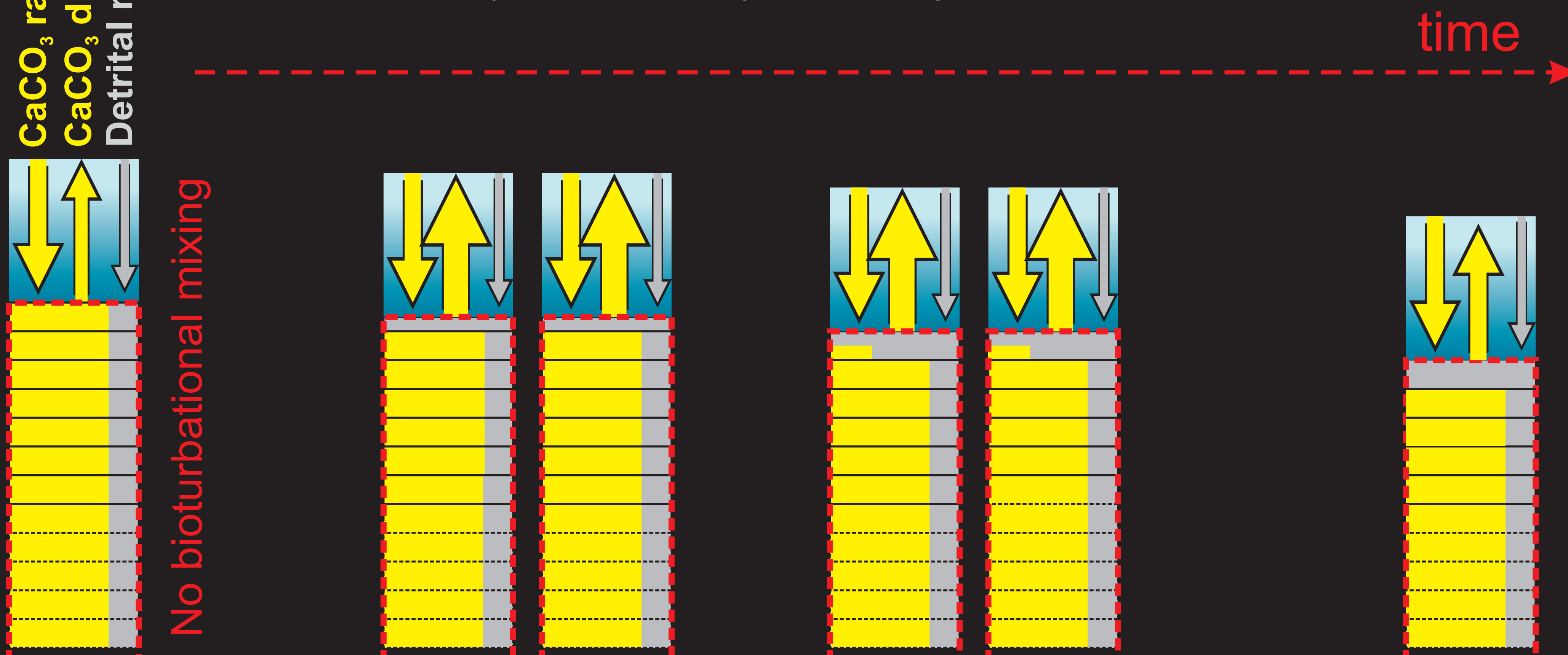
With no bioturbation, dissolution of $CaCO_3$ still continues until the surface sediments are composed purely of refractory detrital material, but now the depth of the clay layer is set by the diffusive limit for $CaCO_3$ dissolution (ca. 1 cm).



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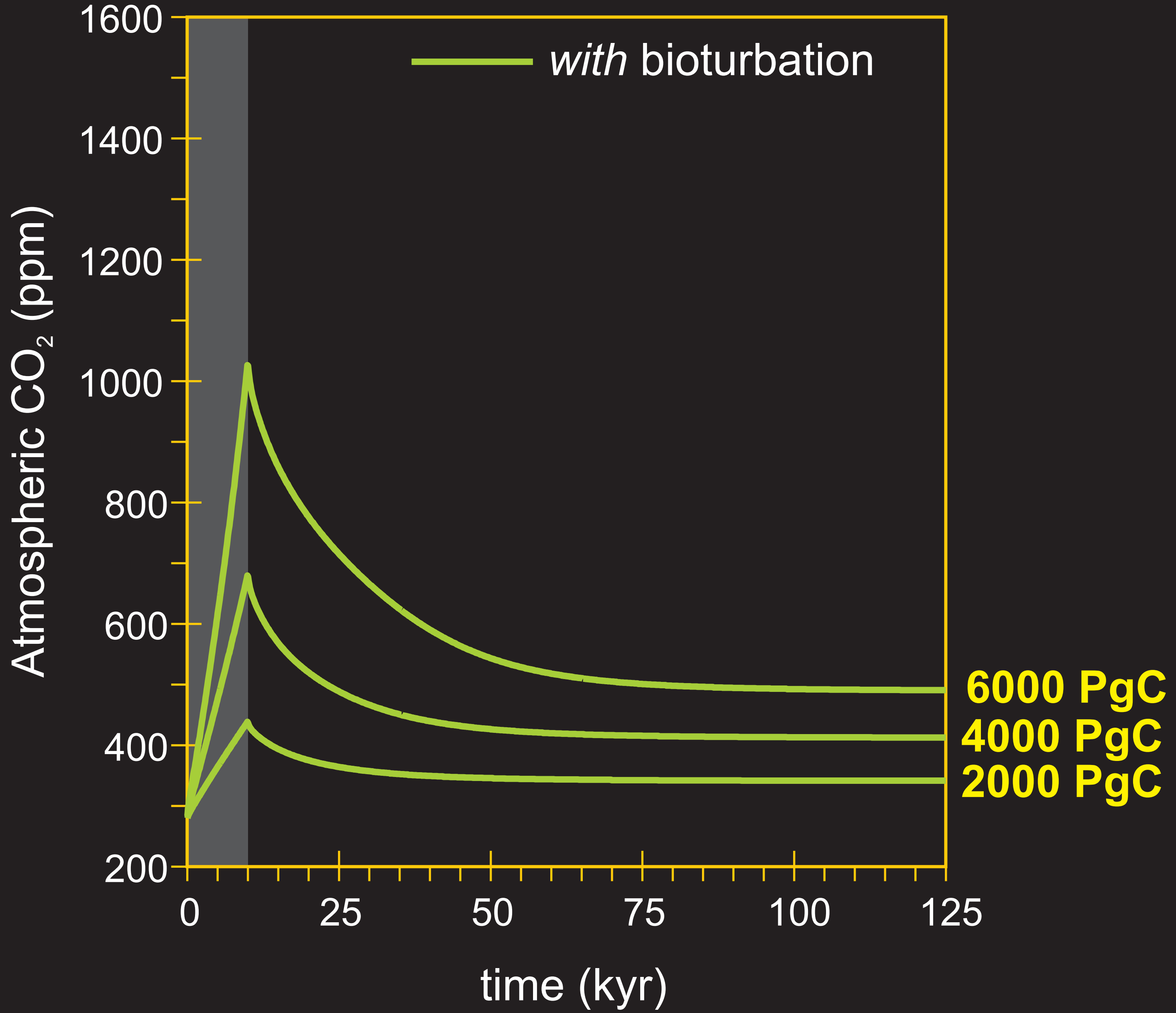

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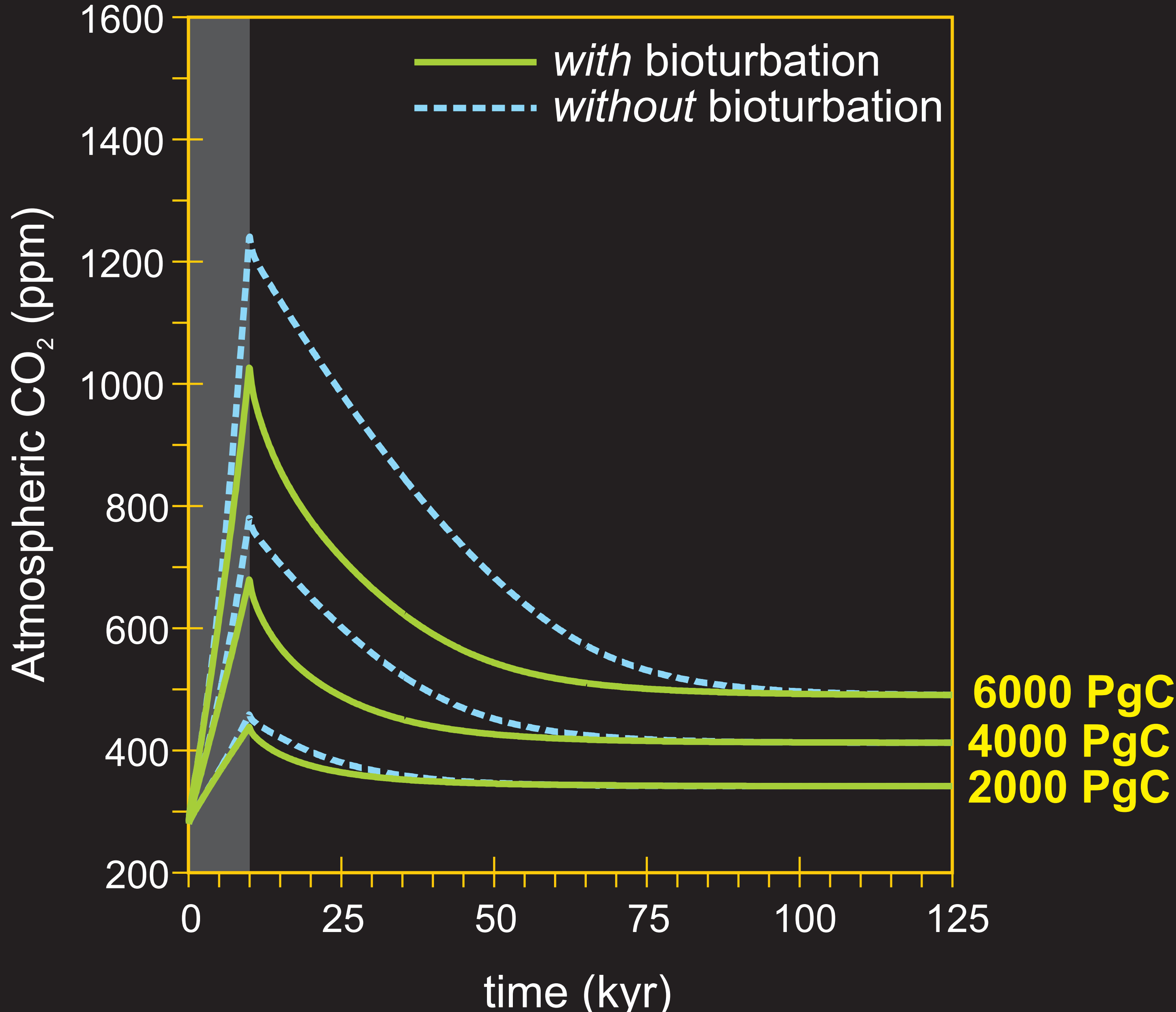

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