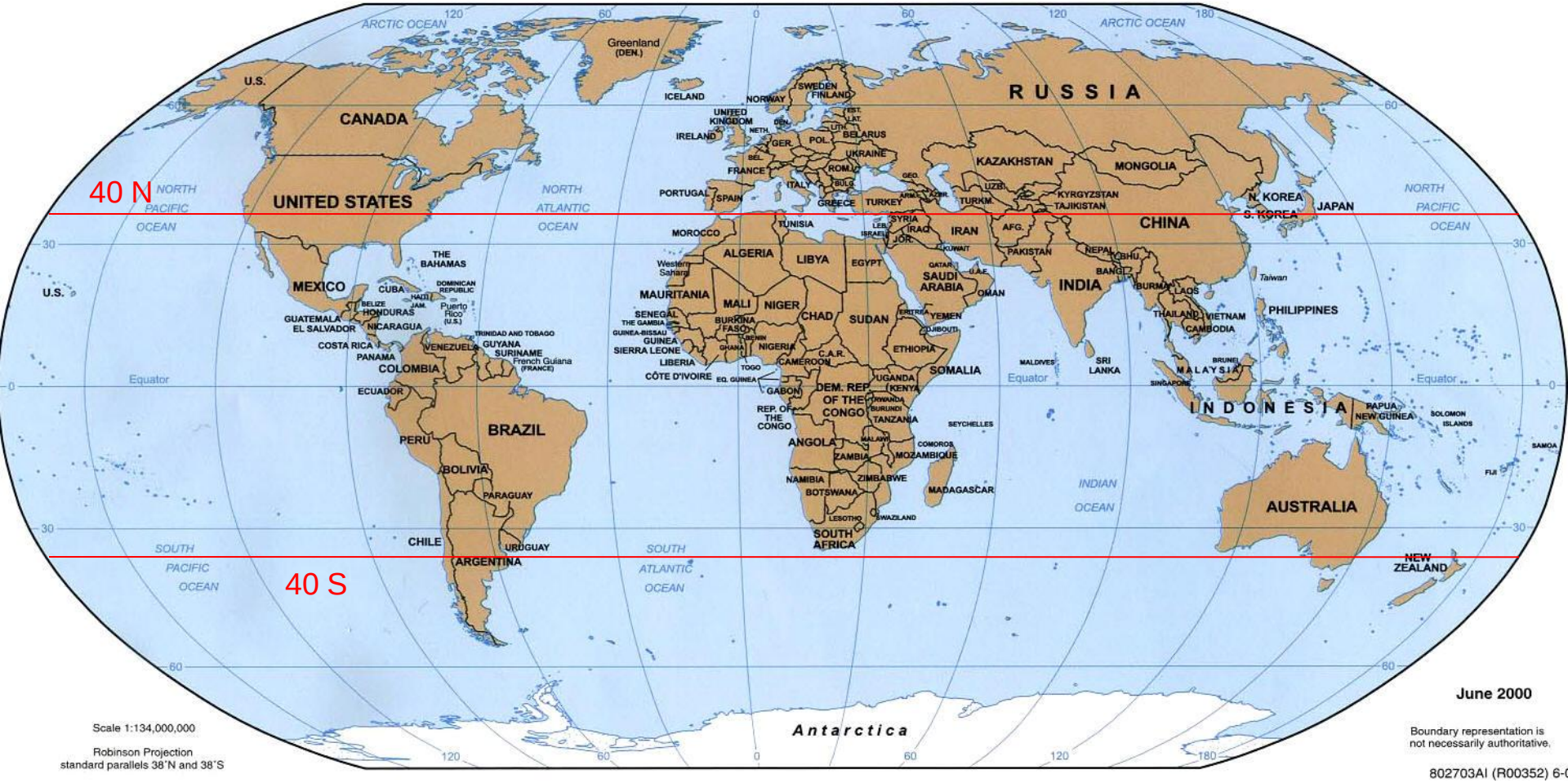
GEOL-201
CARBONATE ROCKS

Carbonates are only one of the types of chemical sedimentary rocks. The others include:

- evaporites
- iron formation
- chert
- phosphates

Carbonates accumulate in warm, clear, shallow marine water

- Within about 40° of the equator
- Rarely in areas where there is a significant input of terrigenous material
- Mostly at depths of less than a few tens of metres, but in some cases in deeper water (up to 4000 m max.)



Scale 1:134,000,000

Robinson Projection
standard parallels 38°N and 38°S

June 2000

Boundary representation is not necessarily authoritative.

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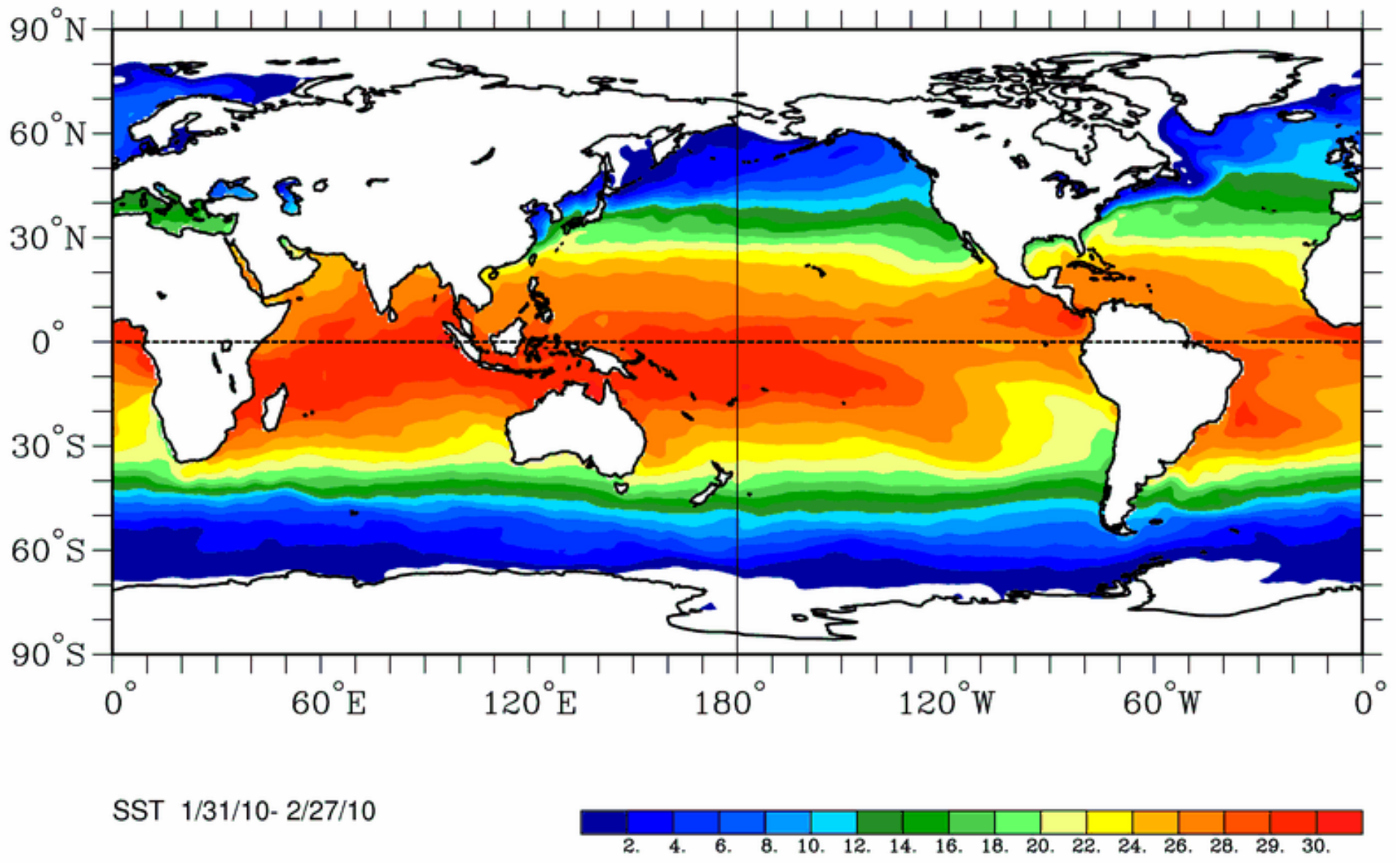
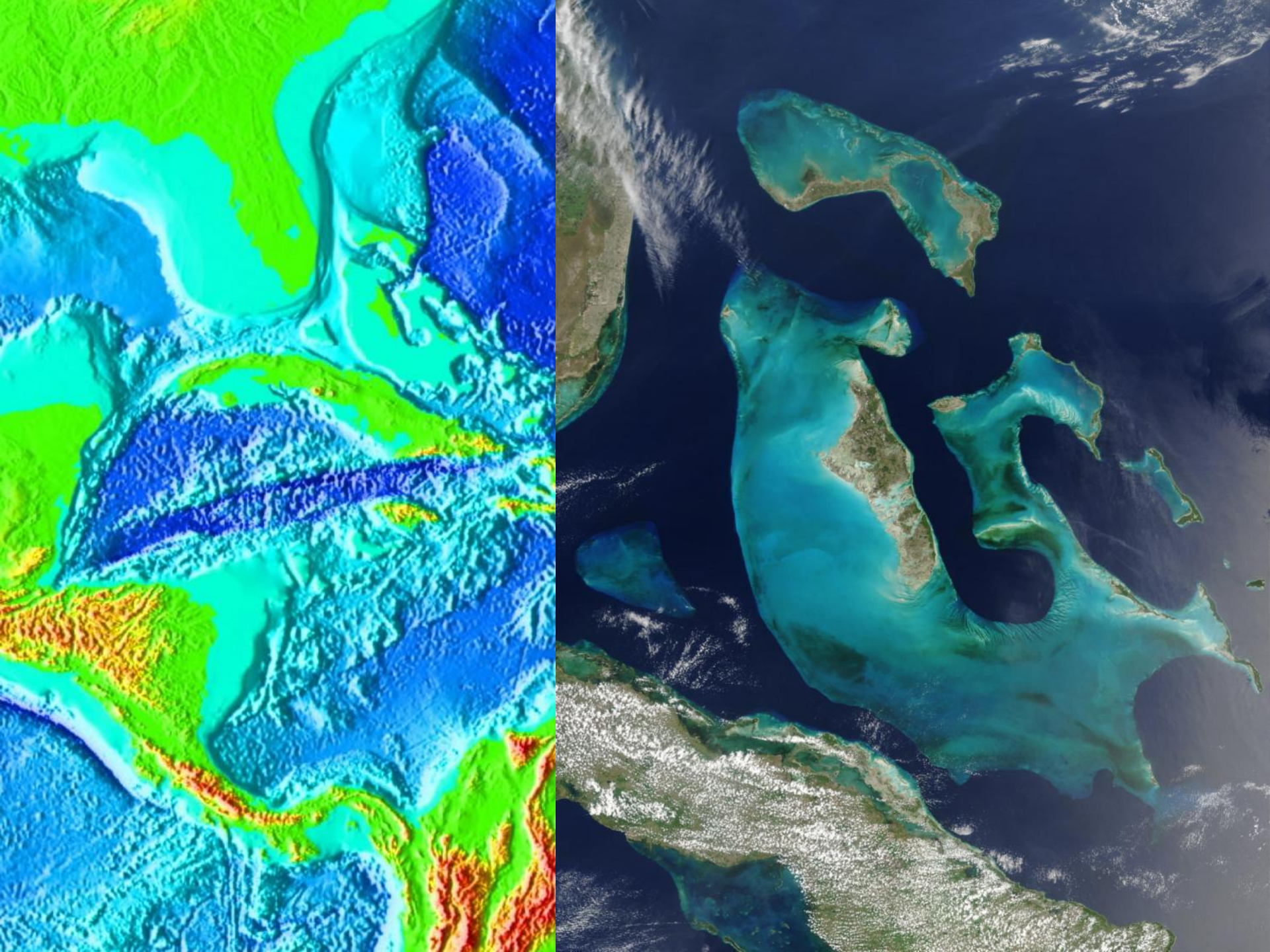
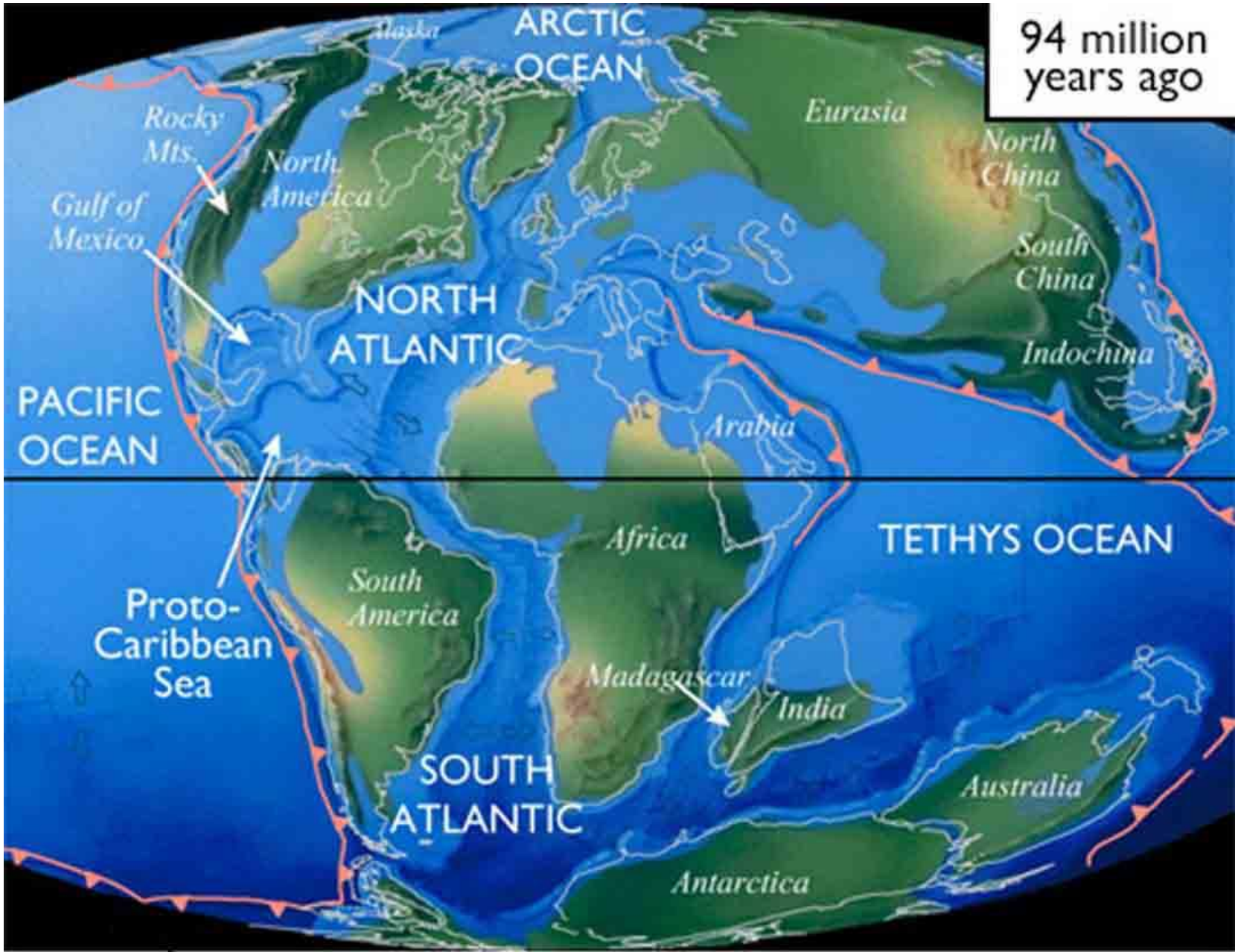
Current average sea-surface temperature is about 20˚+ within 40˚ of the equator

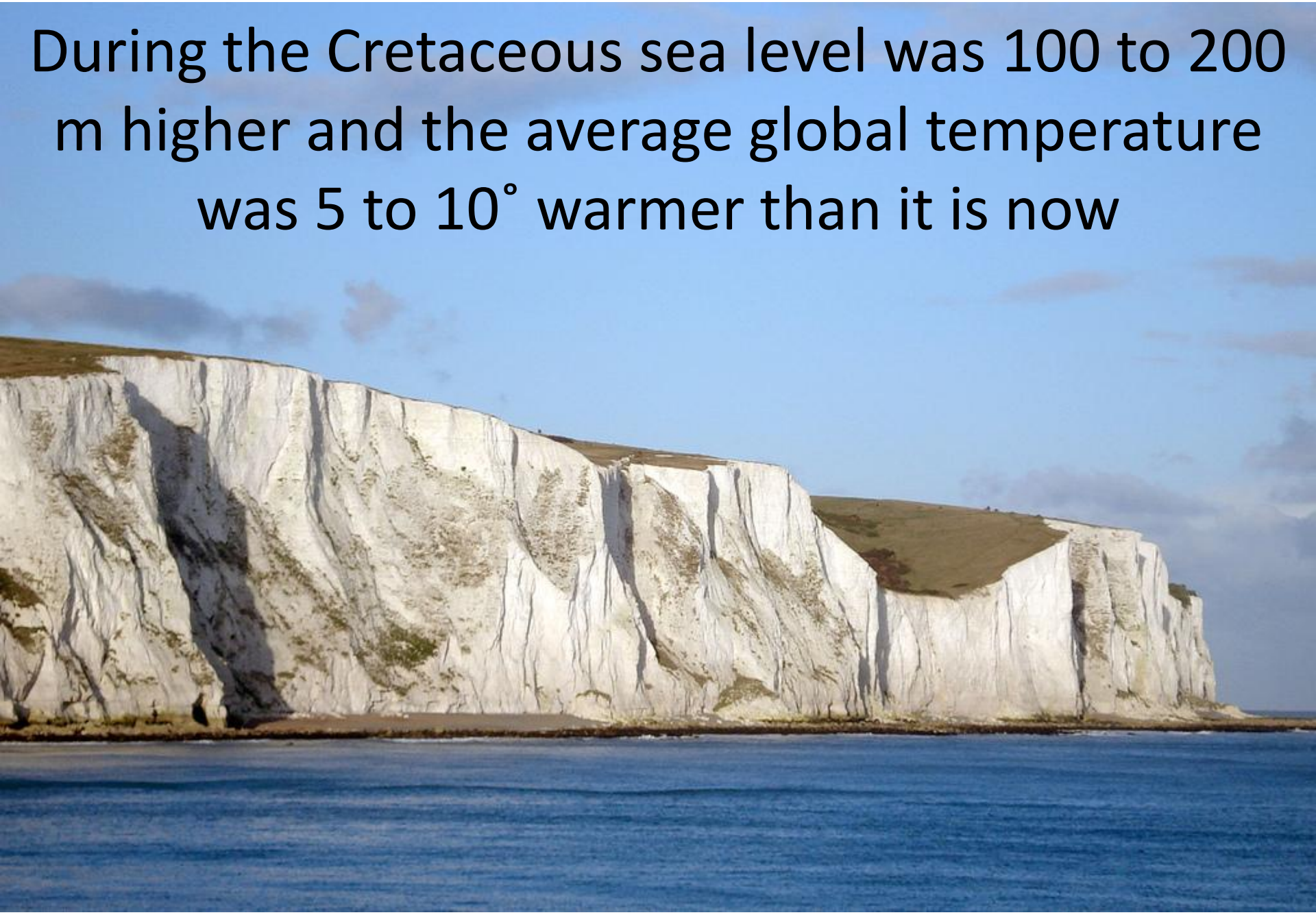




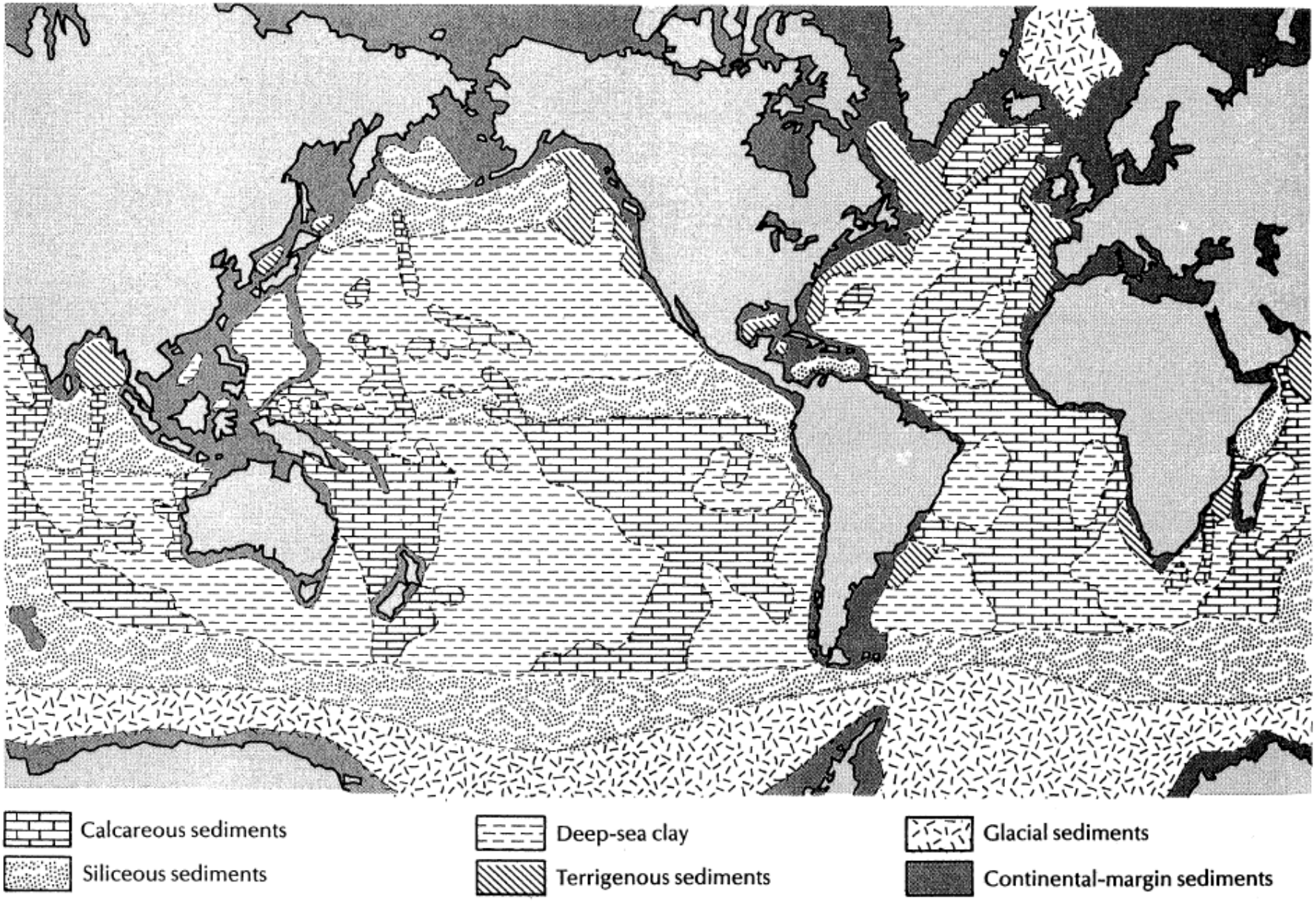
Cretaceous


94 million years ago
ARCTIC OCEAN
Alaska
Rocky Mts.
North America
Gulf of Mexico
Eurasia
North China
South China
Indochina
NORTH ATLANTIC
PACIFIC OCEAN
Arabia
Africa
TETHYS OCEAN
South America
Proto-Caribbean Sea
Madagascar
India
SOUTH ATLANTIC
Australia
Antarctica

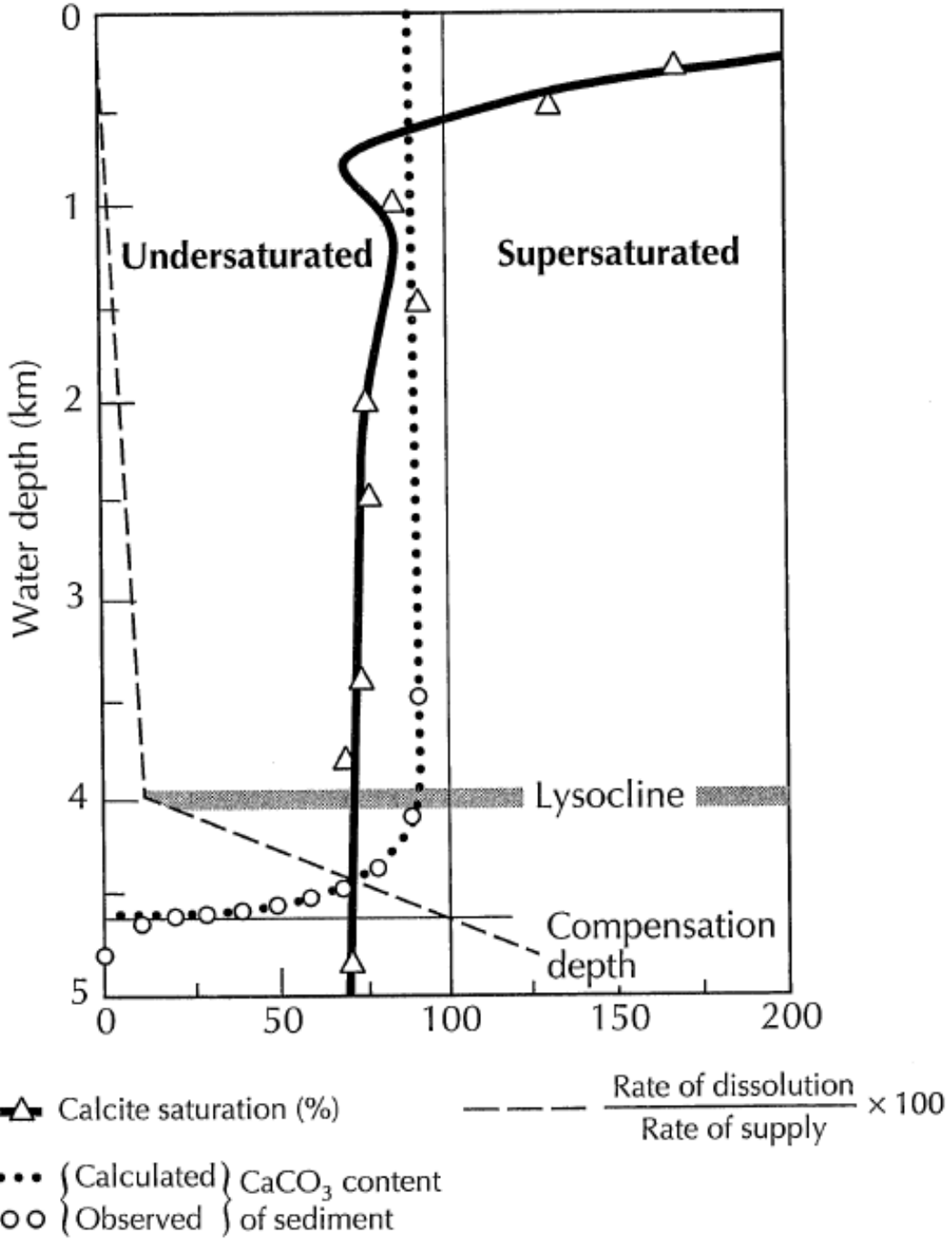
During the Cretaceous sea level was 100 to 200 m higher and the average global temperature was 5 to 10˚ warmer than it is now



Deep Ocean Sediments

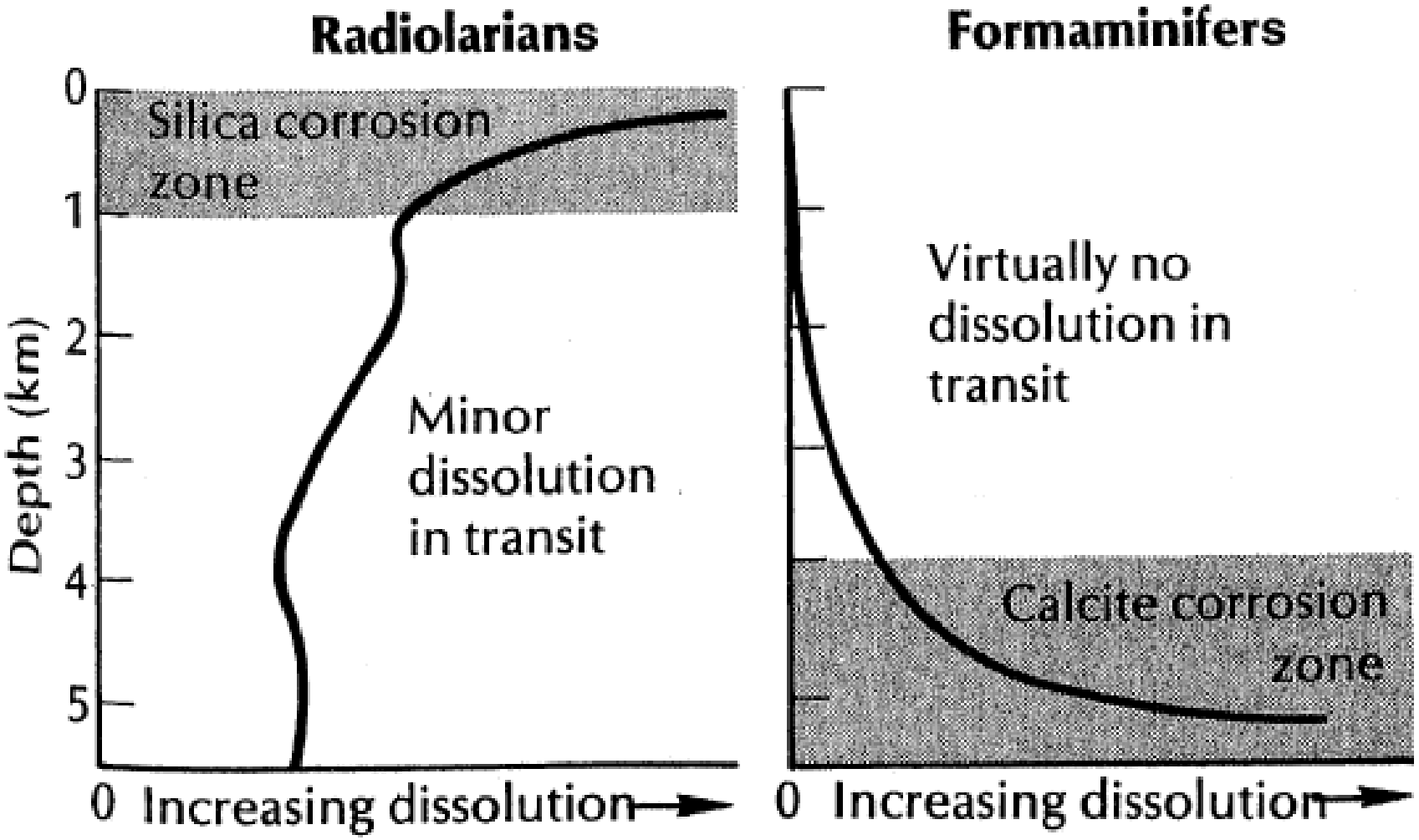


Prothero and Schwab, 2004

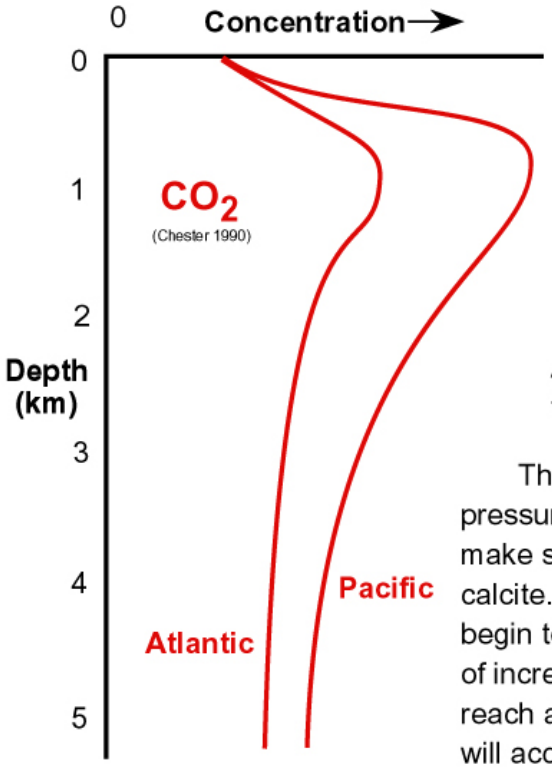


Prothero and Schwab, 2004

Silica vs Carbonate



Variation in concentration of solutes in the oceans IIIa: carbon dioxide and the carbonate compensation depth (CCD)



In the deeper reaches of the ocean, $CaCO_3$ is more prone to dissolve for three reasons:

a) lower temperature (K_{sp} for both calcite and aragonite increases with decreasing T) [1]

b) greater pressure (K_{sp} for both calcite and aragonite increases with increasing P) [2]

c) acidity resulting from the presence of CO_2, as suggested by these reactions:

$$\underset{\text{Carbon dioxide}}{CO_2} + H_2O \rightarrow \underset{\text{Carbonic acid}}{H_2CO_3}$$

$$\underset{\text{Carbonic acid}}{H_2CO_3} + \underset{\text{Calcite}}{CaCO_3} \rightarrow Ca^{2+} + \underset{\text{Bicarbonate}}{2HCO_3^-}$$

As discussed in Part III of this series, concentrations of CO_2 in abyssal waters are greater than those in surface waters because oxidation of sinking organic particles produces CO_2.

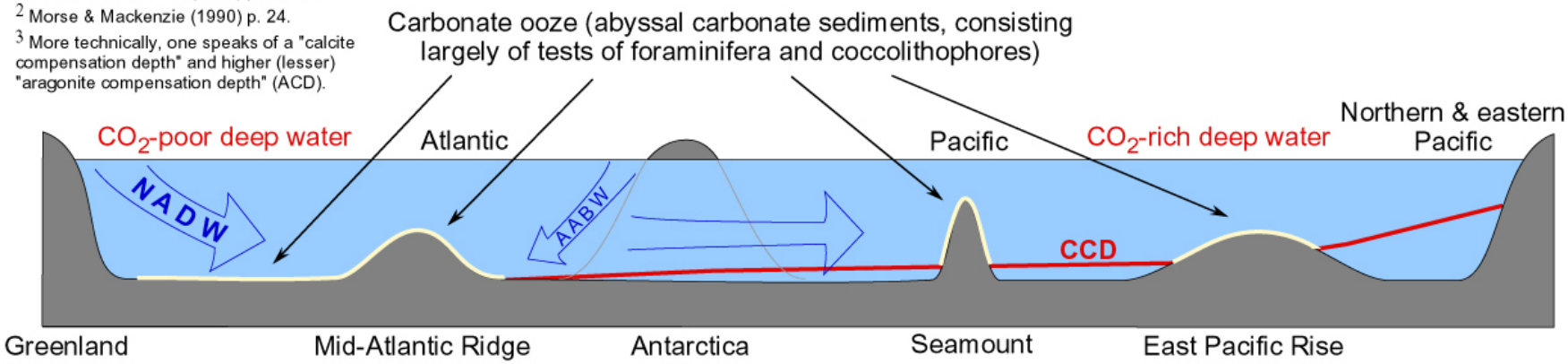
Thus at depth in the ocean, temperature, pressure and acidity commonly combine to make seawater undersaturated with respect to calcite. Calcite particles sinking past this depth begin to dissolve in a lysocline (the depth zone of increasing dissolution rate) and eventually reach a depth at which no carbonate sediment will accumulate on the seafloor. This depth is the carbonate compensation depth (CCD),[3] which is thus named because it is the depth at which the rate of dissolution of $CaCO_3$ equals ("compensates for") the rate of $CaCO_3$ sedimentation. Thus seafloor deeper than the CCD will be devoid of carbonate sediments. The CCD is higher (less deep) in the Pacific because deep water in the Pacific has more CO_2 and so is more acidic.

Notes:

[1] Morse & Mackenzie (1990) p. 23 etc.

[2] Morse & Mackenzie (1990) p. 24.

[3] More technically, one speaks of a "calcite compensation depth" and higher (lesser) "aragonite compensation depth" (ACD).



Seamounts: "the snow-capped peaks of the abyssal Pacific"

Aragonite vs Calcite

Aragonite ($CaCO_3$)

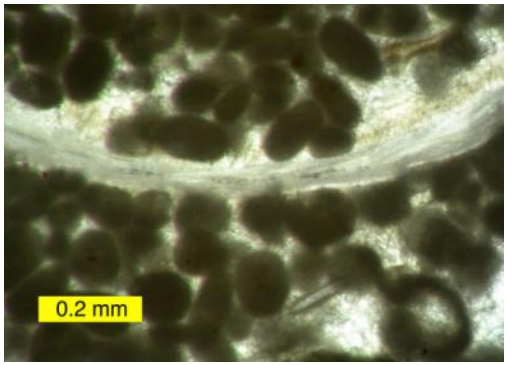
Calcite ($CaCO_3$)

Dolomite ($(Ca,Mg)CO_3$)

Classification of Carbonate Rocks Folk vs Dunham

Components of carbonate rock

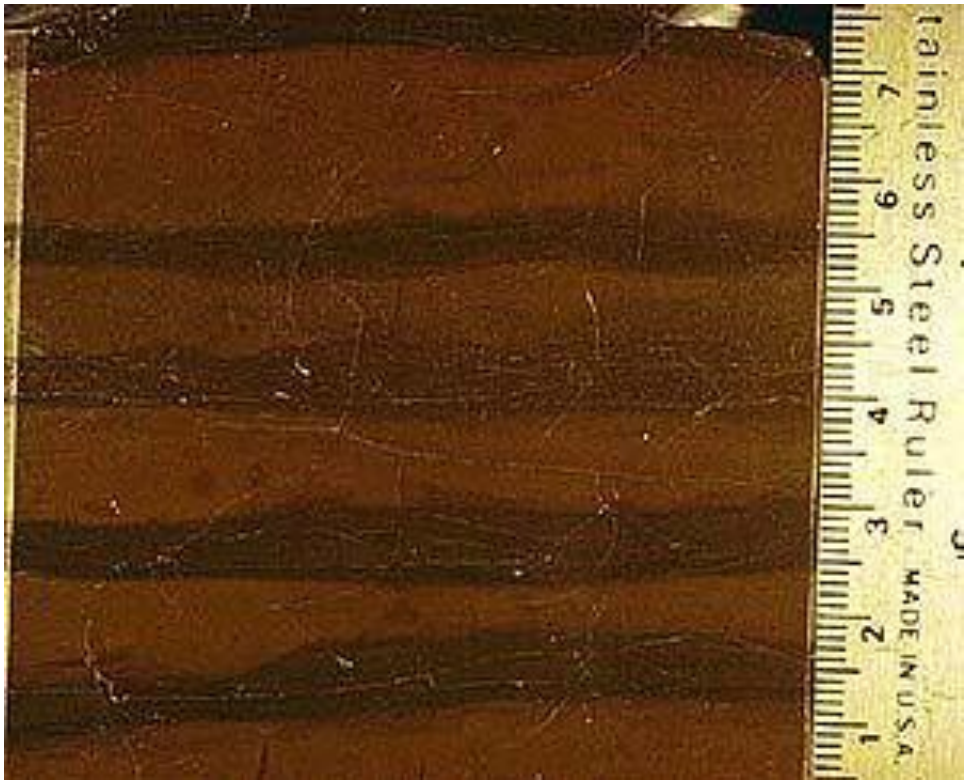
- Carbonate mud (micrite)
- Spar (calcite crystals)
- Skeletal (shell) fragments
- Oolites
- Pellets



Dunham classification of carbonate rocks

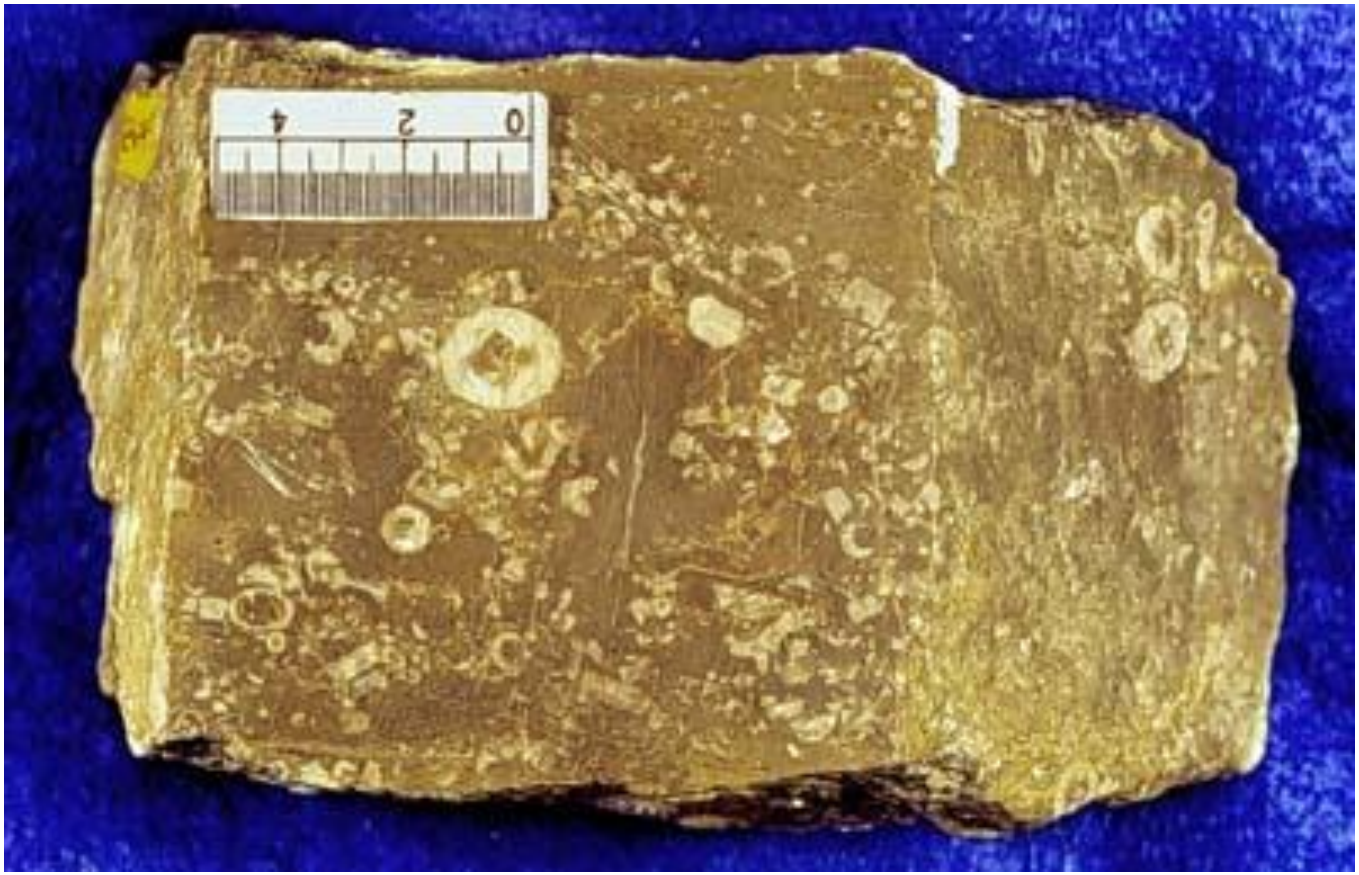
Mudstone

Finely laminated carbonate sediments with no visible clasts.
(Devonian Swan Hills Formation, Alberta)



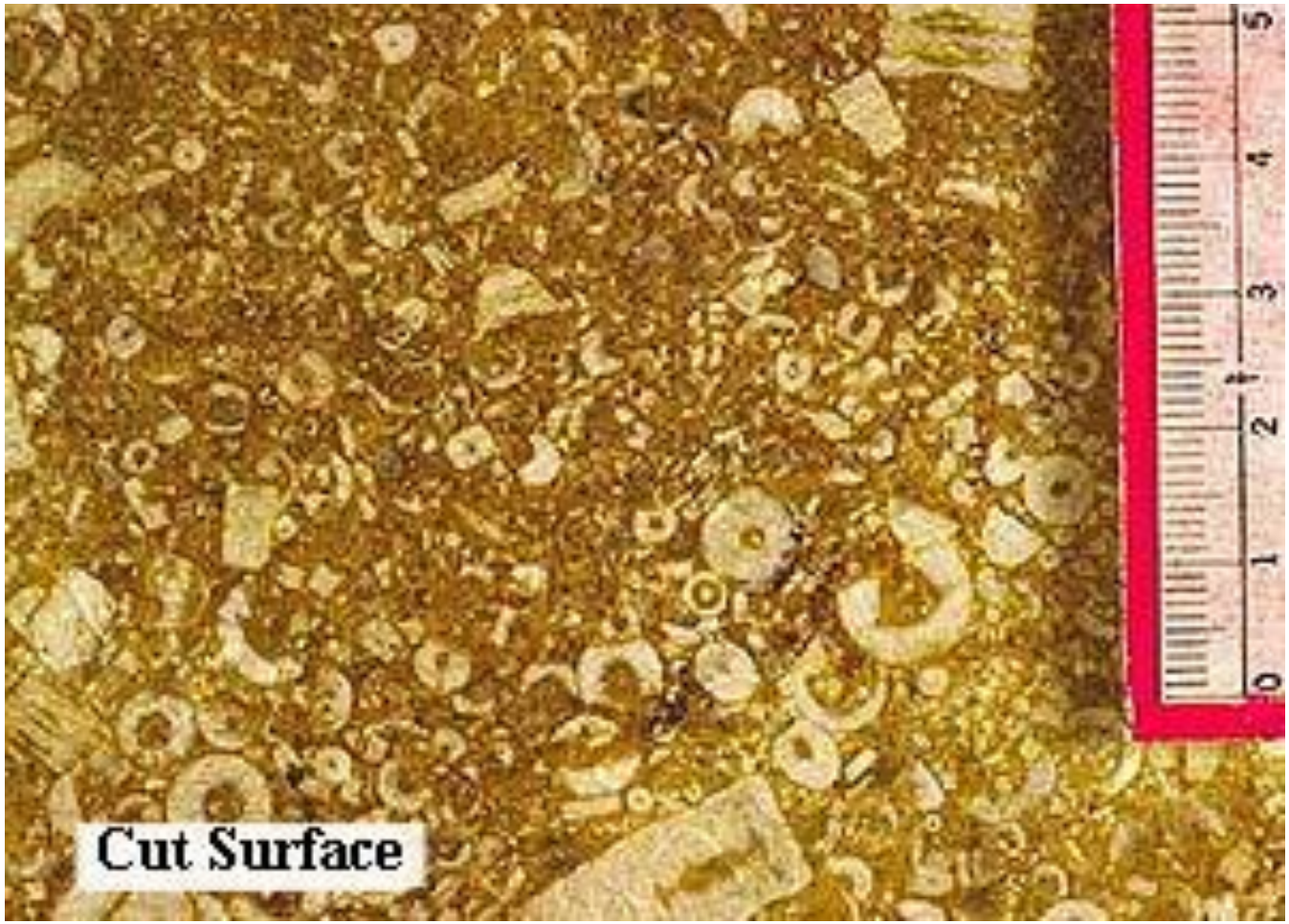
Wackestone

Most of the grains are not touching. They are supported by the micritic matrix.



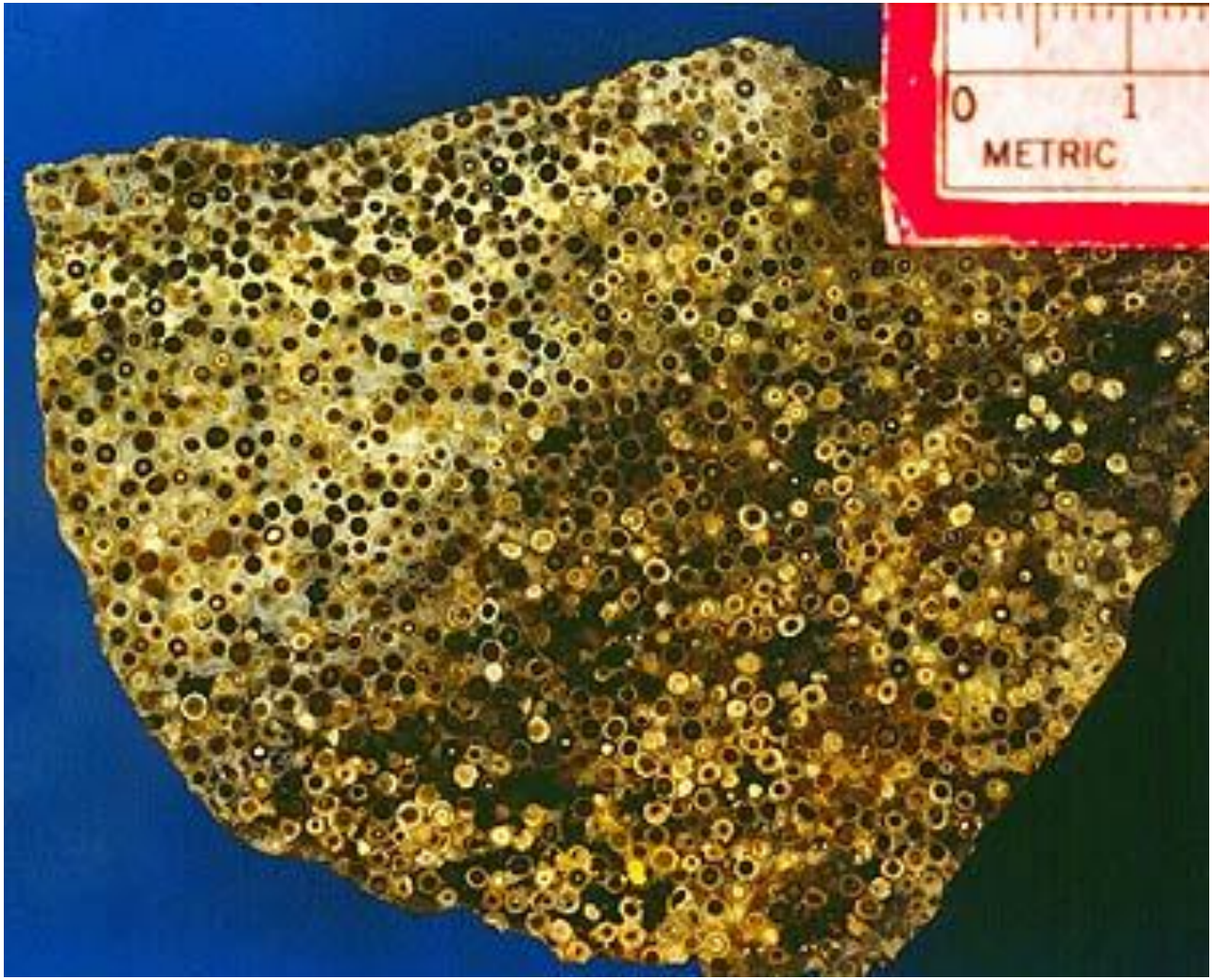
Packstone

The skeletal fragments (crinoids in this case) are touching; it is clast-supported, but it has a micritic matrix.



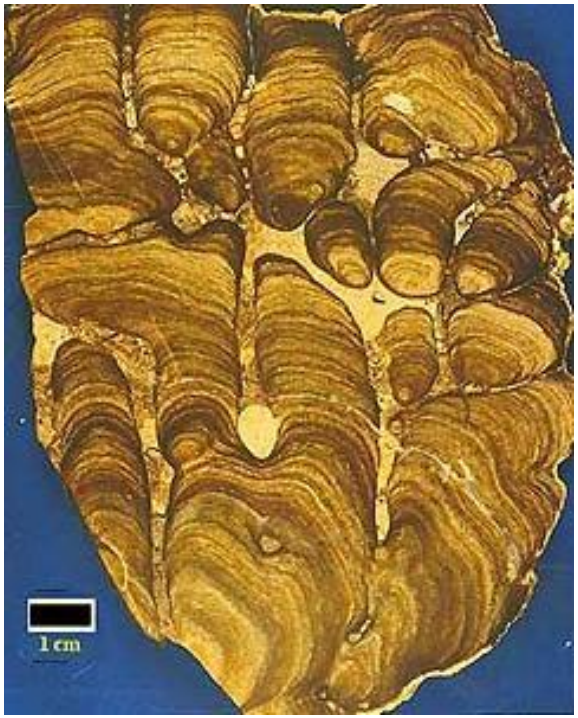
Grainstone

A grain-supported oolite rock that did not originally have a muddy matrix. The space between the oolites is filled with sparry calcite.



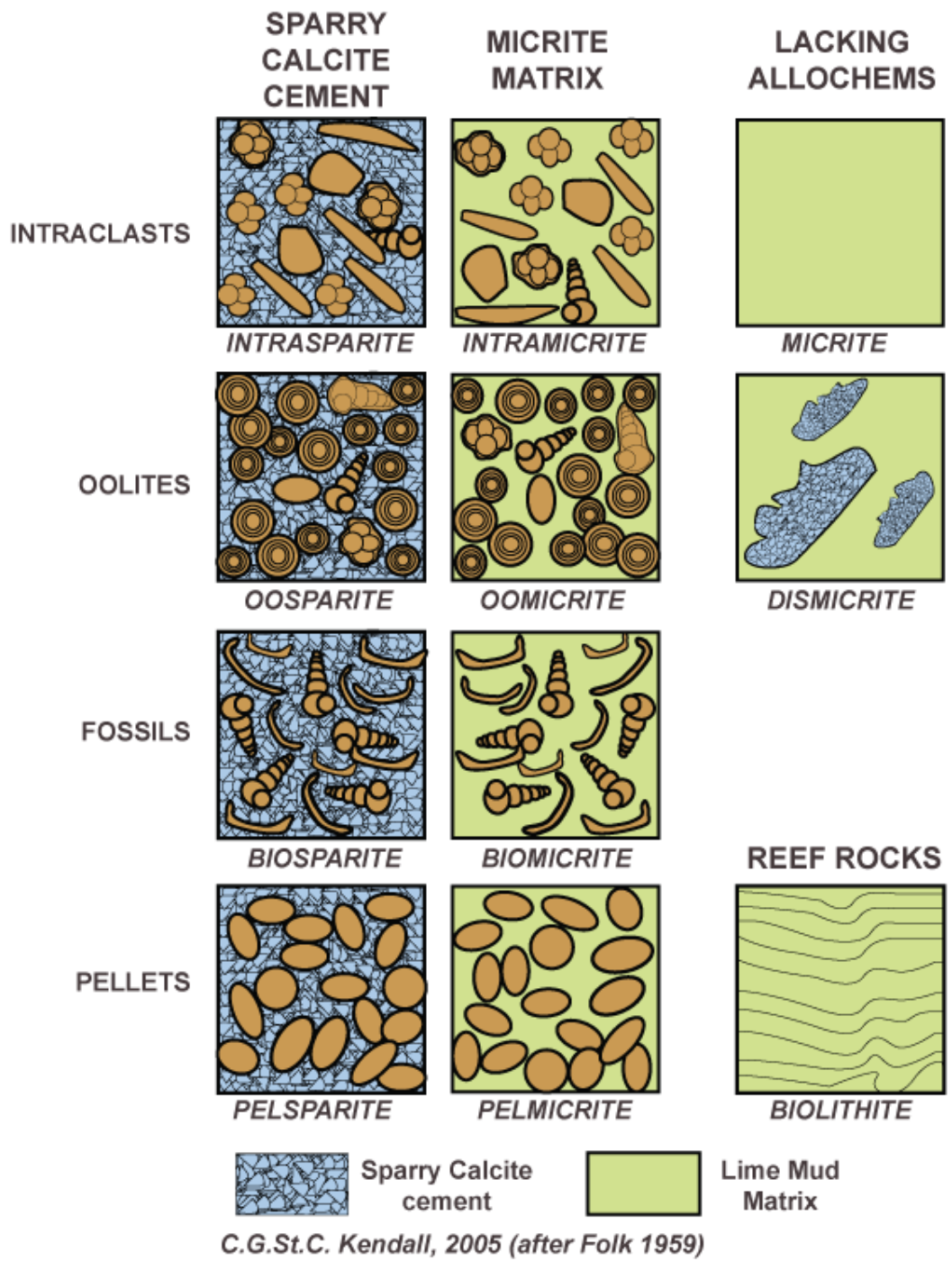
Boundstone (typical of reef structures)

Stromatolitic boundstone
(Green R. Fm., Eocene, Wyoming)



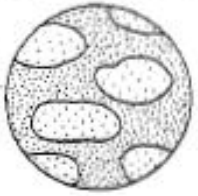
Coral boundstone

All images from: http://www.eos.ubc.ca/courses/eosc221/sed/carb/classification.html



R. L. Folk classification of carbonates

Folk versus Dunham

	GRAIN TYPES			
MUDSTONE < 10% grains	Lime mud, micrite, calcilutite, chalk			
	PELLETS	SHELL DEBRIS	OOLITHS	INTRACLASTS
WACKESTONE > 10% grains, mud supported	 Pelmicrite	Biomicrite	Oomicrite	Intramicrite
PACKSTONE > 5% mud, grain supported	Pelmicsparite	 Biomicsparite	Oomicsparite	Intramicsparite
GRAINSTONE < 5% mud	Pelsparite	Biosparite	 Oosparite	Intrasparite
BOUNDSTONE original components bound together	Reef rock, biolithite			