MICRITES and CHERTS: a very simple introduction to carbonates in ocean waters

notes from lecture: a quick summary

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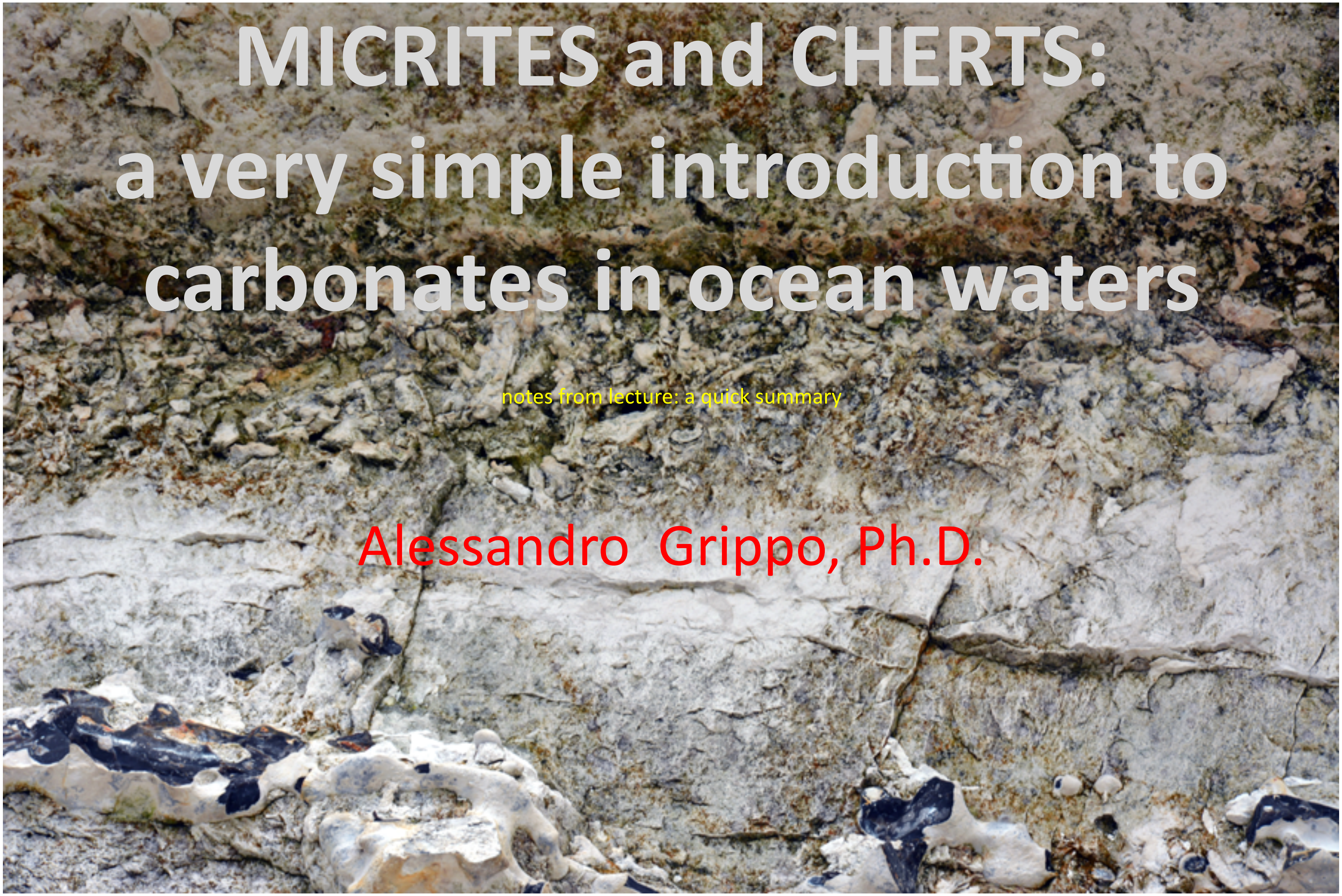


Chalk (in white) and Chert Nodules (in black)
at the Cretaceous/Paleogene boundary at Stevns Klimt, Højerup, Støre Heddinge (Sjælland, Denmark)

previously:

- Clastic Sedimentary Rocks

- Chemical Sedimentary Rocks
  - Phosphates
  - Ironstones (Hematite, Limonite, Magnetite, Siderite, Goethite, and more)
  - Evaporites (Halite, Gypsum, Anhydrite, and many more)
  - Carbonates
  - Cherts

Carbonates

- Inorganic
  - form directly in water because of changing chemical equilibrium in solution
    - Travertine, Tufa, Oolitic Limestone
- Biochemical/Bioclastic
  - form because of the biological activity of an organism (biochemical) and successive mechanical weathering of remains (bioclastic)
    - Coral Reefs and Stromatolites, Fossiliferous Limestone, Coquina, Chalk, Micrite

Carbonates in shallow waters: neritic deposits

- neritic deposits are in general dominated by sediments that come form land (gravel, sand, silt, clay)

- in certain areas, particularly in shallow tropical waters, carbonate deposits are abundant
  - Carbonate minerals containing CO_3
  - Marine carbonates primarily limestone – $CaCO_3$
  - Most limestones contain fossil shells
    - Suggests biological origin
  - Ancient marine carbonates constitute 25% of all sedimentary rocks on Earth.

- Coral Reefs
  - Massive structure of carbonate
  - Warm, crystal-clear, shallow waters
  - Atolls, Barriers, Fringing Reefs
- Stromatolites
  - Fine layers of carbonate
  - Warm, shallow-ocean, high salinity
  - Cyanobacteria

(a)

The Great Barrier Reef of Australia

from Cyanobacteria to Stromatolites

- Some filamentous cyanobacteria float as greenish scum on lake, streams, or ocean waters

- Others form “algal” mats on the seafloor that can trap sediment to produce distinctive 3-D structures (stromatolites)

Modern Stromatolites from Shark Bay, Australia

Stromatolites

in four “simple” steps

① **Accretionary organosedimentary structures**

the structure build up (accretes), and forms a structure through interaction of biological and physical processes

② **commonly thin-layered, megascopic, and calcareous**

made of thin, stacked laminae, visible to the naked eye, partially composed of calcium carbonate minerals

③ **produced by the activity of mat-building communities of mucilage-secreting microorganisms**

microscopic organisms living together generate mats, or layers by secreting sticky gelatin-like slime

④ **mainly filamentous photoautotrophic prokaryotes such as cyanobacteria**

most organisms are developing threads (and not spheres), are photosynthetic, are Bacteria and Archaea, and most of the times are cyanobacteria

Fossil Stromatolites

from Glacier National Park, Montana

Micrite and Chert

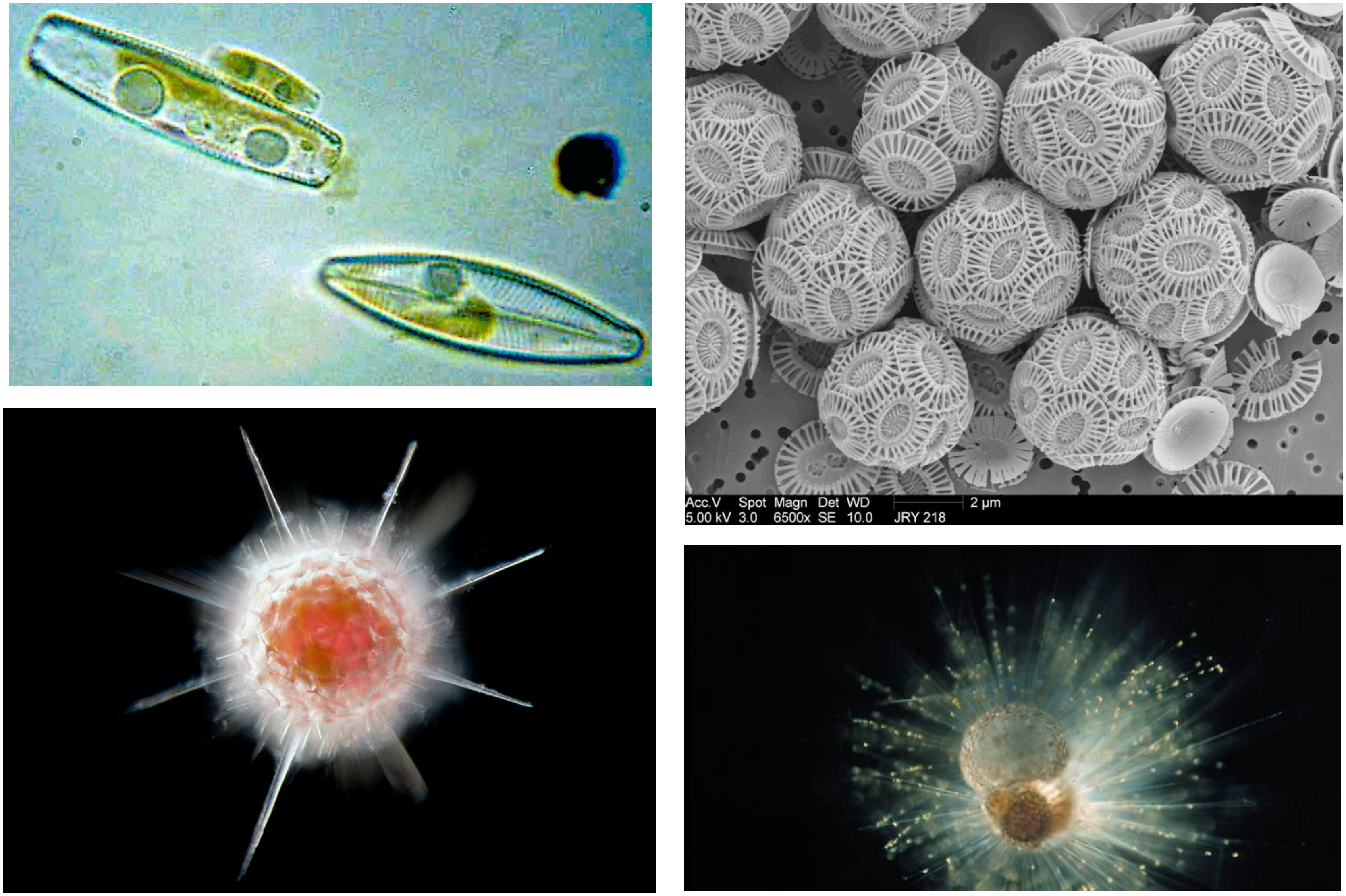
- Micrite (microcrystalline calcite) and Chert (microcrystalline silica) can have various origins

- They can indicate deep-marine environments (with exceptions)

- Microscopic organisms that live in the ocean and make a shell (test) of either calcite or silica are the main contributors to the formation of Micrite (Chalk) and Chert (Diatomite and Radiolarite)

Deep-marine carbonates and cherts

- Two most common chemical compounds:
  - Calcium carbonate ($CaCO_3$)
  - Silica (SiO_2), often found in its hydrated form Opal ($SiO_2 \cdot nH_2O$)
- Include many kinds of single-celled organisms and a few kinds of simple multicellular organisms
- Plant-like protists (algae) are photosynthetic
  - dinoflagellates, diatoms, coccolithophorids
    - all these are very important in the fossil record
- Animal-like protists (or protozoans)
  - amoebas, zooflagellates, ciliates
    - radiolarians and foraminifera are amoeba-like protists that are also very important in the fossil record



Clockwise from upper left: live Diatoms; Coccolithophorids; live Foraminifer; live Radiolarian

Nekton, Benthos, Plankton

- Organisms that live in the ocean can be classified as:
  - **Nekton**: swimmers
      - example: dolphins, octopuses, squids, whales
  - **Benthos**: bottom dwellers
    - sessile (standing in one place, like a tree on land)
      - example: sea lilies
    - mobile (on the surface – **epifauna**; digging into the substrate – **infauna**)
      - example: crabs and lobsters
  - **Plankton**: floaters

Important Planktonic Protists in the fossil record

- **Phytoplankton** (plant-like)
  - Diatoms and Coccolithophorids

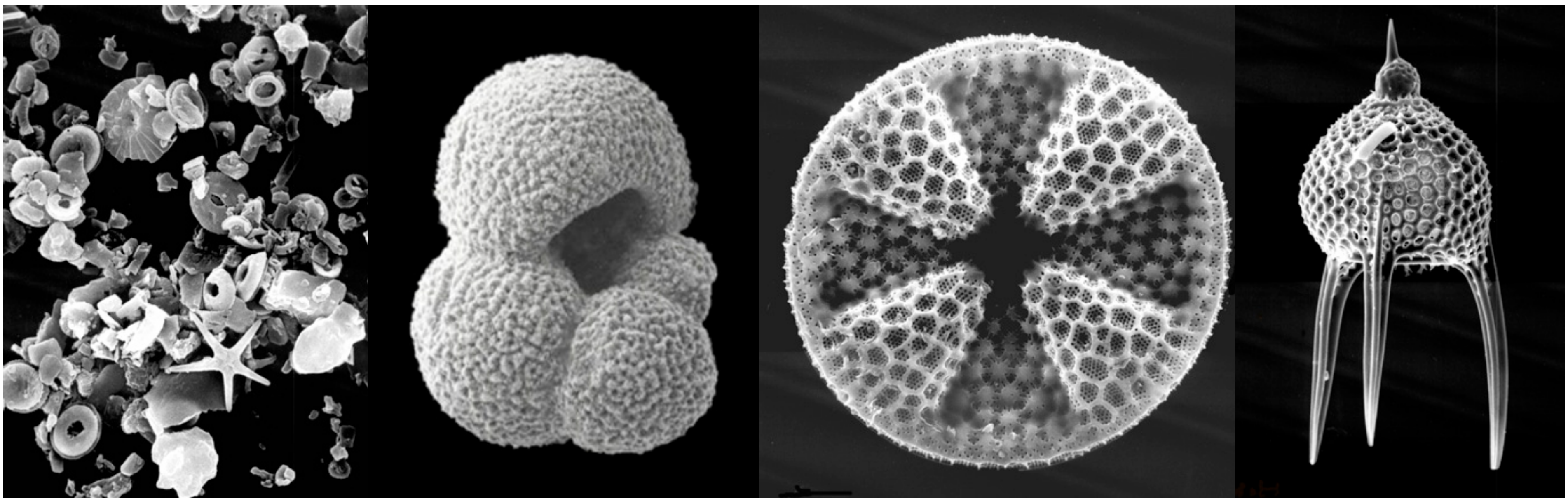
- **Zooplankton** (animal-like)
  - Radiolarians and Foraminifera

- These organisms secrete a skeleton (also called a “test”, or a shell)

- When they die, these skeletons sink to the bottom of the ocean and form a rock

All these organisms are microscopic: they can only be observed under a microscope.
Coccolithophorids are so small that they can only be imaged with a SEM (Scanning Electron Microscope)

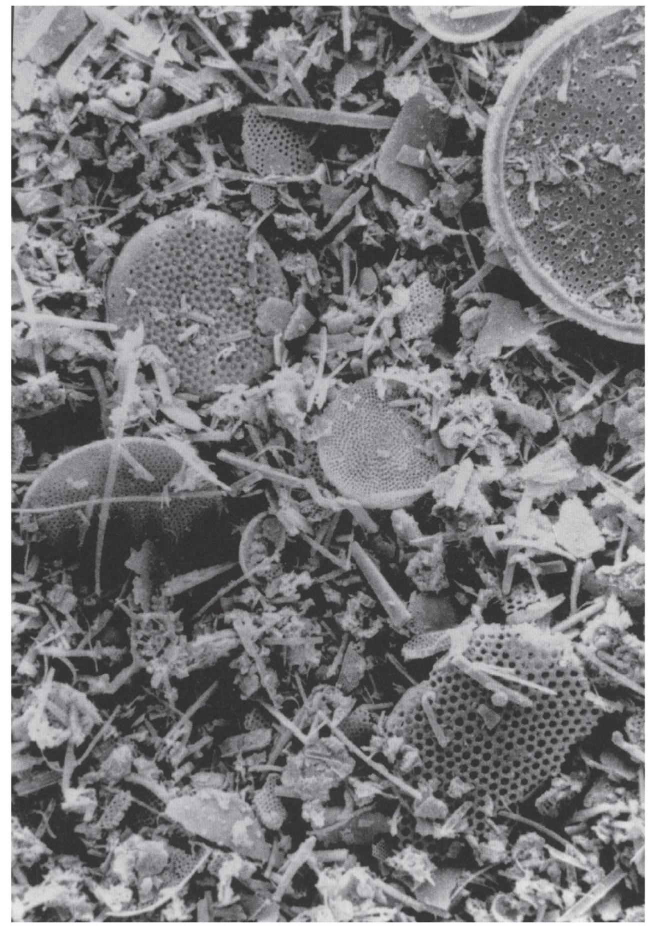
	$CaCO_3$ shell	SiO_2 shell
Phytoplankton	**Coccoliths** (disks from Coccolithophorids)	**Diatoms**
Zooplankton	**Foraminifera**	**Radiolarians**



Coccoliths Foraminifer Diatom Radiolarian

Silica in Biogenous Sediments

- Tests from diatoms and radiolarians generate siliceous ooze.
- Siliceous oozes lithify into diatomaceous earth and radiolarites



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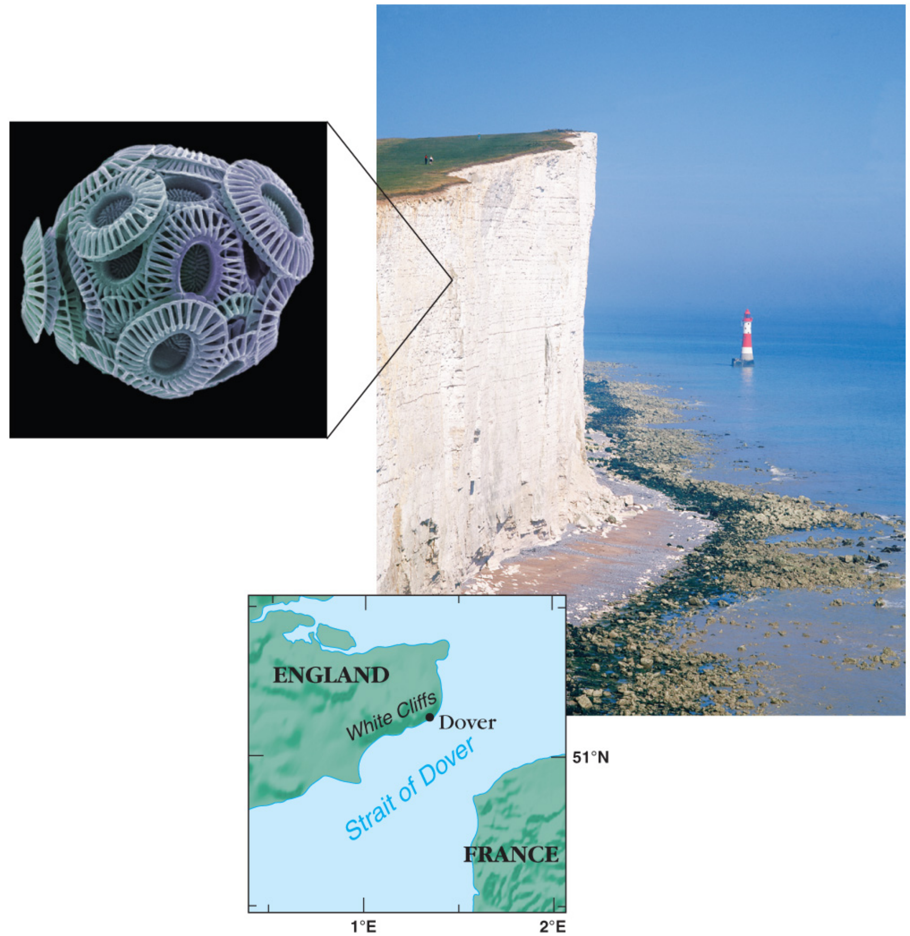
Calcium Carbonate in Biogenic Sediments

- Tests from Coccolithophorids and Foraminifera will form a calcareous ooze
- Coccolithophorids
  - Also called *nannoplankton*
  - Photosynthetic algae
  - Coccoliths – individual plates from dead organism
  - Chalk
    - Lithified coccolith-rich ooze



- Foraminifera
  - Protozoans (zooplankton)
  - Use external food
  - Also form foraminifer ooze
  - Can be mixed up with coccoliths

  - Micrite, or micritic limestone
  - If mixed 35-65% with abyssal clay, rocks are called Marls

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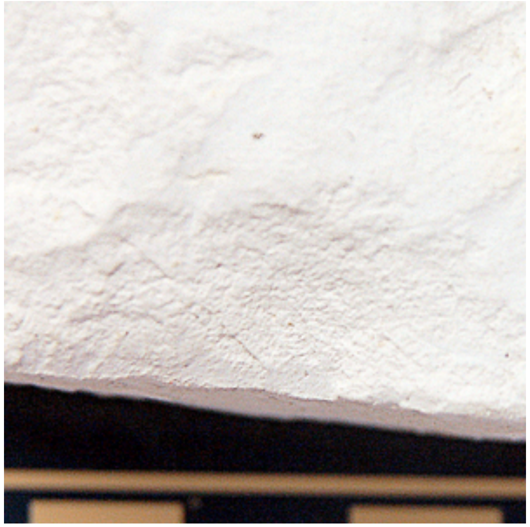
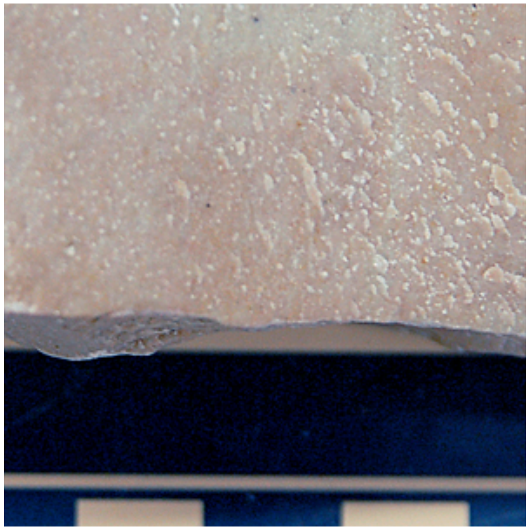


Chalk

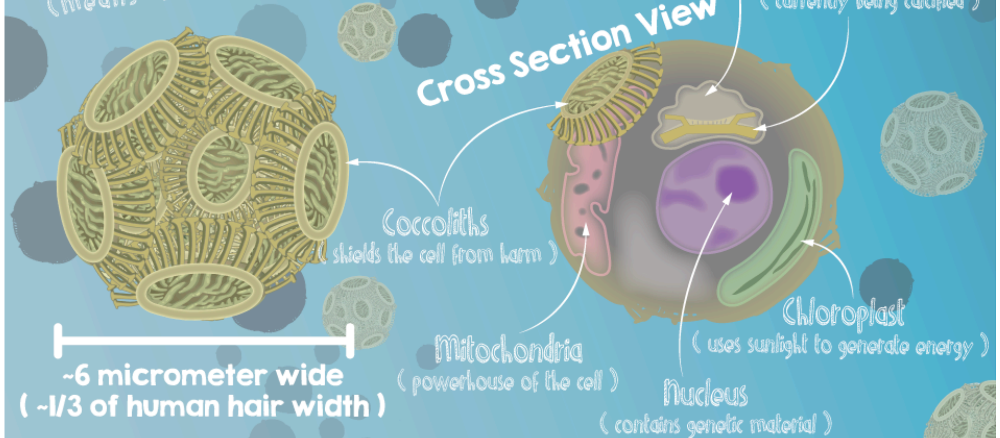


Micrite

Chert

ANATOMY OF THE Coccolithophore

(means "round stone bearer" in Latin)



Protective Shields

Coccolithophores are microscopic unicellular phytoplankton that use photosynthesis (similar to plants). Though more research is needed, the coccoliths may provide protection from UV rays, grazers, and turbid water currents.[1]

Turning CO_2 into Chalk

When coccolithophores die, it sinks and carries the absorbed CO_2 to the deeper ocean. Tectonic movement, however, has since lifted coccolithophores from 65 million years ago, forming the Cliffs of Dover.

Cliffs of Dover are located in England. The white chalky materials are the remains of ancient coccolithophores

Source:
1. Young, J.R. (1994). Functions of coccoliths. In: Winter A and Siesser WG (eds). *Coccolithophores*, pp. 63-82. Cambridge: Cambridge University Press.
2. Moheimani, N.R., Webb, J.P., and Borowitzka, M.A. (2012) Bioremediation and other potential applications of coccolithophorid algae: A review. *Algal Research*. 2, 120-133.
3. Jordan, R.W. (2012) Haptophyta. In: eLS. John Wiley & Sons, Ltd: Chichester.

Chalk from pelagic coccolith oozes:
The K/Pg boundary at Stevns Klimt, Denmark

Distribution of Biogenous Sediments

- Depends on three processes:
  - Productivity
    - Number of organisms present in surface waters
    - depends on availability of food and light (photosynthesis can be effective only in the photic zone, that is the first 100 m of the ocean form the surface)
  - Destruction
    - Many tests are dissolved at the bottom or even before reaching it
  - Dilution
    - When other kinds of sediments are present, they *dilute* the oozes
    - Typically it is lithogenous sediment that dilutes oozes
    - Since lithogenous sediment is common in coastal areas, biogenous sediment is more indicative of deep-waters

Calcareous Ooze and the CCD

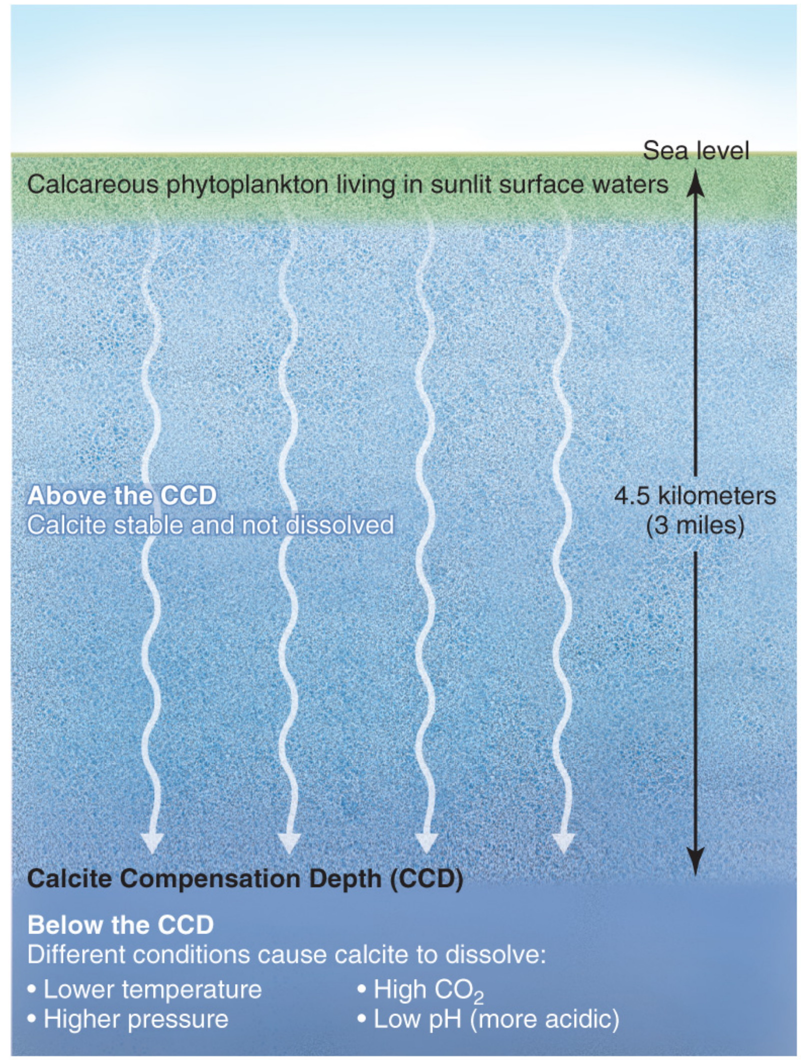
- CCD – Calcite (or Carbonate) compensation depth
  - Depth where $CaCO_3$ readily dissolves
  - *Rate of supply = rate at which the shells dissolve*

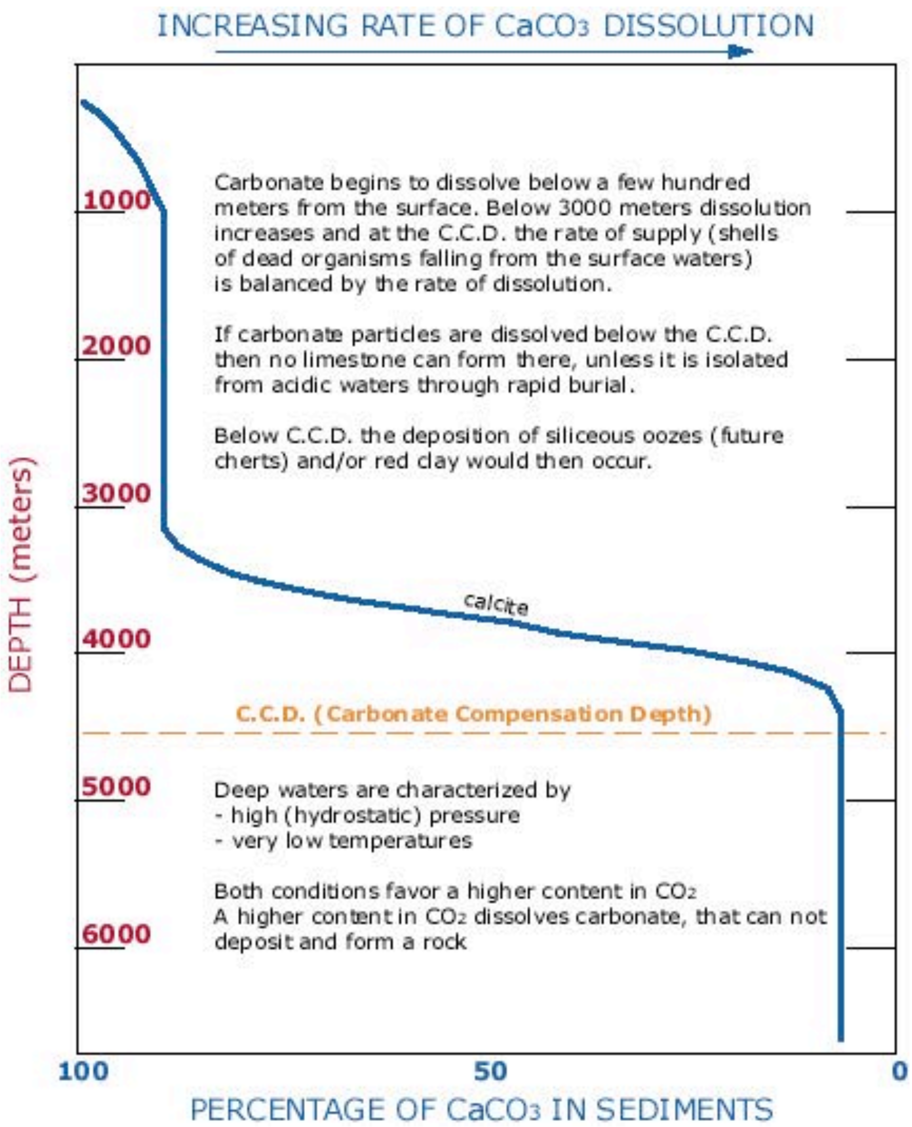
- Warm, shallow ocean saturated with calcium carbonate
- Cool, deep ocean undersaturated with calcium carbonate

- Equilibrium reaction of calcite in water:
  - $CaCO_3 + H_2O + CO_2 \leftrightarrow Ca^{2+} + 2HCO_3^-$

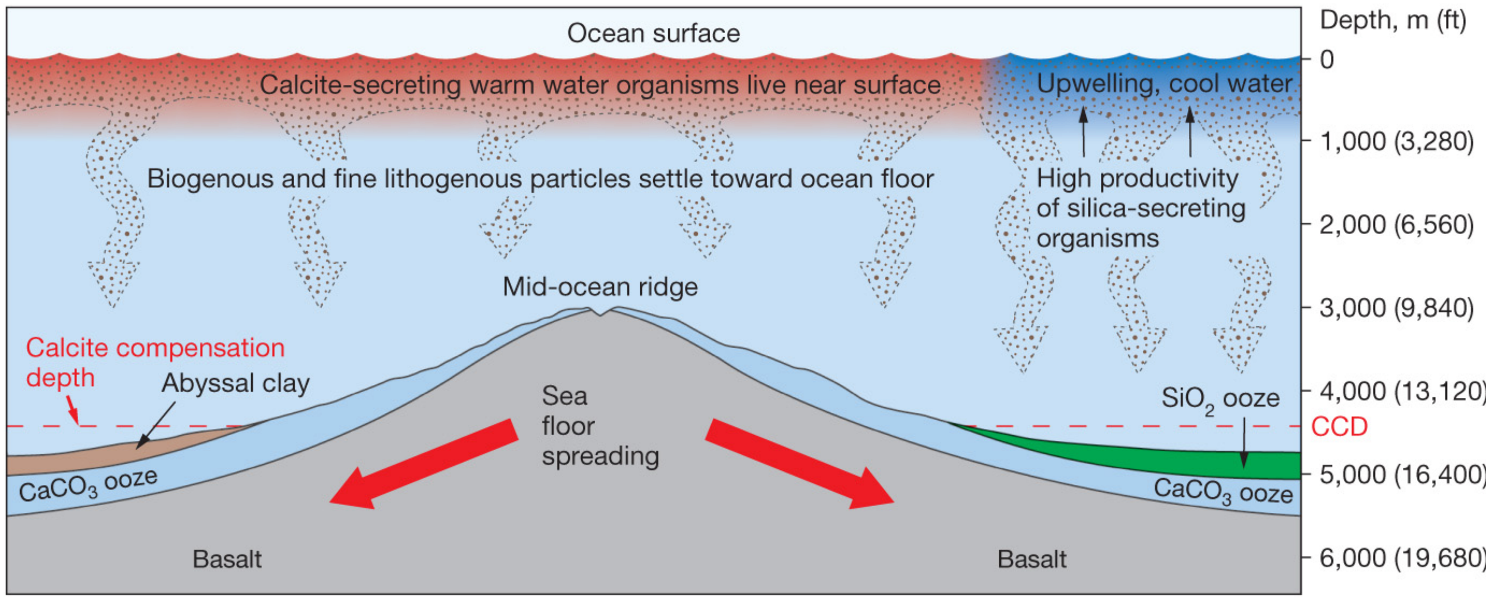
$$CaCO_3 + H_2O + CO_2 \leftrightarrow Ca^{2+} + 2HCO_3^-$$

- CO_2 dissolves $CaCO_3$
- CO_2 stays in water with high pressure and low temperatures
  - conditions found in deep-ocean waters and shallow temperate to polar waters
  - $CaCO_3$ shells dissolve
- CO_2 leaves water with low pressure and high temperatures
  - conditions found in shallow tropical waters
  - $CaCO_3$ forms naturally
  - "Carbonate Factory"

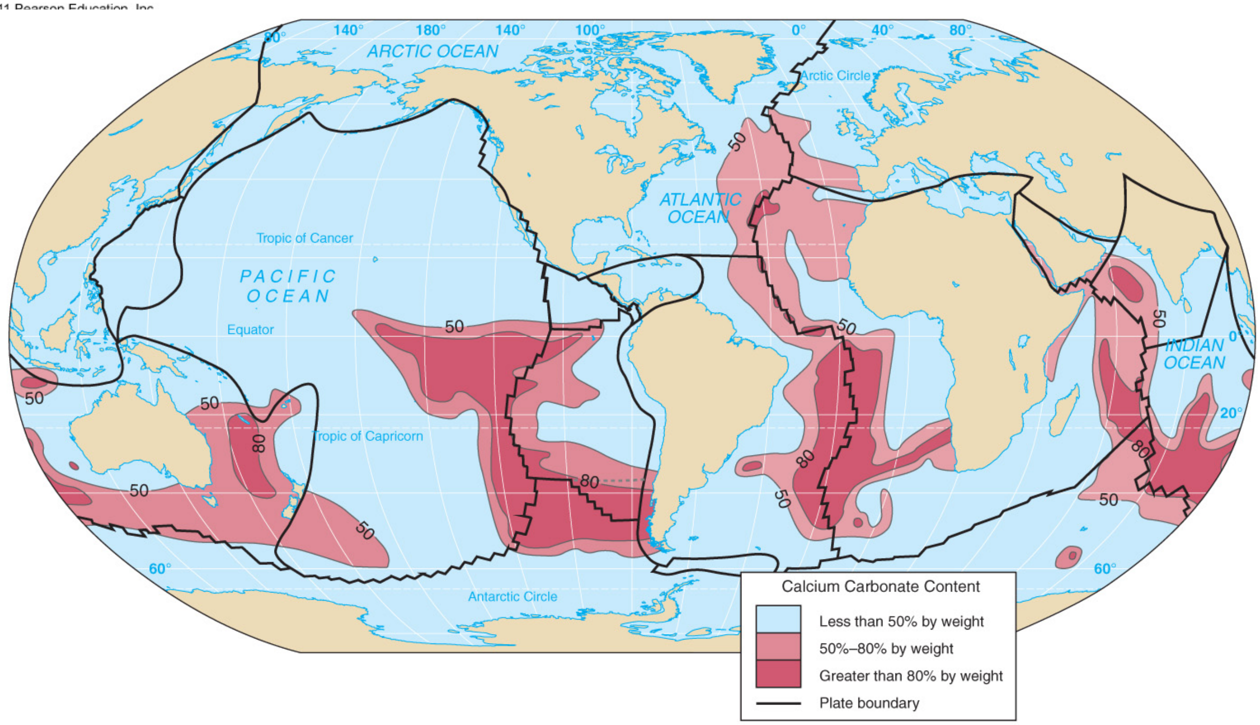




- Lysocline – depth at which *a significant amount of* $CaCO_3$ begins to dissolve rapidly
- Scarce calcareous ooze below 5000 meters (16,400 feet) in modern ocean
- Ancient calcareous oozes at greater depths if moved by sea floor spreading



Ocean surface
Depth, m (ft)
0
1,000 (3,280)
2,000 (6,560)
3,000 (9,840)
4,000 (13,120)
CCD
5,000 (16,400)
6,000 (19,680)
Calcite-secreting warm water organisms live near surface
Upwelling, cool water
Biogenous and fine lithogenous particles settle toward ocean floor
High productivity of silica-secreting organisms
Mid-ocean ridge
Calcite compensation depth
Abyssal clay
Sea floor spreading
SiO_2 ooze
$CaCO_3$ ooze
$CaCO_3$ ooze
Basalt
Basalt



ARCTIC OCEAN
ATLANTIC OCEAN
PACIFIC OCEAN
INDIAN OCEAN
Arctic Circle
Tropic of Cancer
Equator
Tropic of Capricorn
Antarctic Circle
Calcium Carbonate Content
Less than 50% by weight
50%–80% by weight
Greater than 80% by weight
Plate boundary

quick summary

- clastic sediment originate on land and are carried towards the ocean
- evaporites indicate dry conditions, and hence land, or special coastal environment (for instance, sabkha)
- travertine and tufa form on land
- oolitic limestones, reefs, stromatolites, fossiliferous limestones, coquina form in shallow ocean waters, mostly on carbonate shelves
- chalk, diatomite, radiolarite form in deep ocean waters, away from other clastic and chemical sediments
- micrite and chert are microcrystalline rocks that form when the original carbonate or silica component is dissolved and then re-crystallized