

## Lecture 14 – Marine Sediments

(1) The CCD is:

- (a) the depth at which no carbonate secreting organisms can live
- (b) the depth at which seawater is supersaturated with respect to calcite
- (c) the depth at which calcite is no longer preserved in marine sediments
- (d) none of the above

The CCD will be deepest in areas that have:

- (a) shallow waters with high carbonate dissolution rates and low settling rates
- (b) deep waters with high carbonate dissolution rates and low accumulation rates
- (c) the CCD is approximately constant everywhere
- (d) up-welling zones of high surface production

The oozes on the seafloor mostly consist of:

- (a) boulders and cobbles from glaciers
- (b) bones and teeth of fish
- (c) fine mud washed down from the continent
- (d) microscopic hard parts of single celled surface living organisms

Siliceous sediments are abundant on the deep ocean floor at high latitudes because:

- (a) radiolarian are more abundant in high latitude waters
- (b) diatoms are more abundant at the nutrient rich high latitudes
- (c) cold water promotes the preservation of silica
- (d) much of the carbonate gets dissolved in the cold deep water
- (e) all of the above
- (f) b, c, and d but not a

What are the controls for calcium carbonate distribution in marine sediments?

- o overlying productivity
- o kinetics: e.g. amount of time that tests remain in sediments exposed to seawater.
- o water depth
- o temperature
- o non-CaCO<sub>3</sub> flux including opal and clays
- o all of the above

What controls the distribution of detrital sediments? Detrital sediments will be most abundant:

- (a) close to continental margins
- (b) only at river mouths
- (c) in the deep basins at mid latitudes
- (d) in upwelling areas
- (e) at the location where continental glaciers arrive at the sea

(2) What are hydrogenous sediments and where would these be abundant?

These are sediments formed by chemical precipitation in the ocean the most abundant are Fe-Mn oxyhydroxides

In what way do the controls on silica deposition differ from those of carbonate deposition?

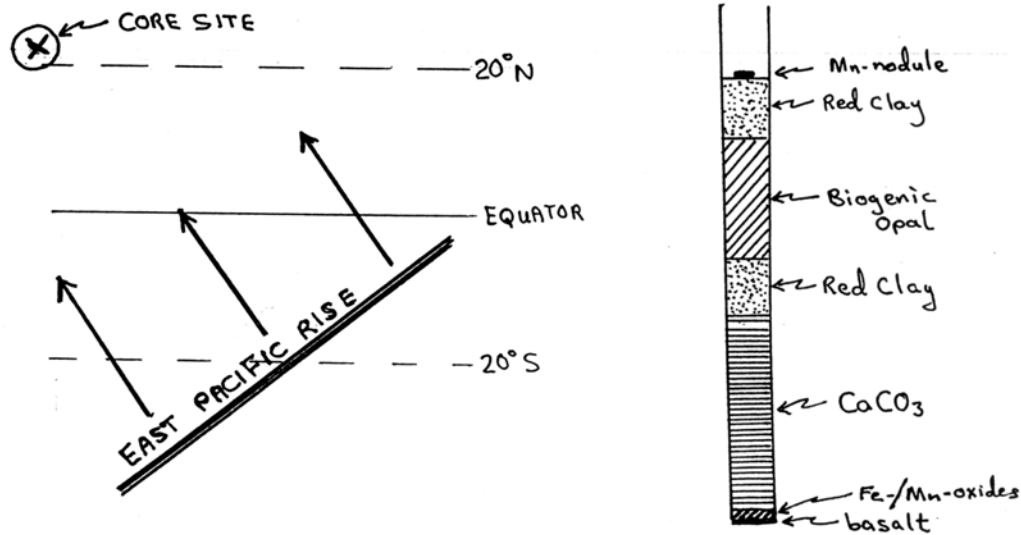
Silica preservation is mainly controlled by the flux of Si to the sea floor while for carbonates depth (pressure) plays a more important role.

What are the major controls on carbonate content in marine sediments?

production, dissolution and dilution

Which metal of the following is NOT typically found in manganese nodules: iron, uranium, nickel, cobalt, copper

(3) In the figure below, the geologic setting of a core taken by the deep sea drilling program is presented along with the composition of sediments in the core obtained. Starting with the basalt at the base of the core, describe the processes and setting which led to the marked variations in sediment types



The bottom sediments represent the oceanic crust formation at the EPR and the associated Fe-Mn oxide rich sediments at ~2,500m. As the core moved with the plate carbonates accumulate since the depth of the site is shallower than the CCD but with time the crust cools and contracts and the ocean floor is now below the CCD red clays accumulate. The biogenic opal deposition occurs as the core passes through the high productivity equatorial region and then once again deep waters in the north Pacific dominated by red clay and Mn nodules.

(4) Both organic carbon and calcium carbonate rain down from the surface ocean and can be important components of marine sediments.

a) How would you expect organic carbon respiration in marine sediments to affect  $\text{CaCO}_3$  preservation in sediments. Why? Write down the important chemical reactions involved that are necessary to understand this system.

b) Would you expect the calcite compensation depth (CCD) to change as a result of respiration? Why?

c) Would the alkalinity of the pore water change as a result of these reactions? Refer to the relevant chemical reactions from part (a) in your answer.

Organic C respiration will reduce the pH in seawater thus increase the solubility of  $\text{CaCO}_3$  preservation will be lower in areas with extensive organic matter degradation.  
 $\text{CH}_2\text{O} + \text{O}_2 \rightleftharpoons \text{HCO}_3^- + \text{H}^+$        $\text{H}^+ + \text{CaCO}_3 \rightleftharpoons \text{Ca}^{2+} + \text{HCO}_3^-$

As a result of respiration the CCD might become shallower (more dissolution).

Respiration will not change the alkalinity but carbonate dissolution will increase the alkalinity.

(5) Where would the sediment column be thicker near mid-ocean ridges or close to continental margins (suggest at least two reasons)?

The sediment will be thicker close to the continental margins. The crust at mid ocean ridges is younger and had less time to accumulate sediments and also near continental margins there is a greater supply of sediment from the continent and also in some cases we can see thickening of the sediment pile due to compaction and formation of a sedimentary wedge near some subduction zones.

(6) In a sediment core recovered from about 2500 meters depth in the Atlantic ocean you get a sequence of sediment dominated by aragonite and calcite on top? What can you say about this site?

It can be said that as the plates moved the location of the core moved from shallow to a deeper area in the ocean, as the aragonite compensation depth is shallower than the calcite CCD. This might also be explained as resulting from a change in sea level as sea level was lower in the last glacial aragonite accumulated (the depth was only 2,400 m) with sea level rise the depth increased resulting in aragonite dissolution and only calcite accumulation.

(7) Arrange these horizons in order of increasing depth:

CCD, calcite saturation horizon, dissolution of some aragonite tests in the sediment is detected, aragonite saturation horizon

Dissolution of some aragonite in sediments; aragonite saturation horizon; calcite saturation horizon, CCD

(8) What do you expect the composition of sediments will be at 2500m in middle of the Equatorial Pacific? How will that change if the depth at the same area is 5000 meters?

The sediment will be foram ooze with siliceous components; it is productive so both will be there but it is above the CCD so carbonate is preserved and there is more of it, it is far from land so little terrigenous material. If the depth is 5000 meters in the same productive area we would expect the sediment to be composed from Radiolaria ooze as carbonate will dissolve at that depth.

(9) Saturation horizon is deepest in the Atlantic Ocean (~4500 m) relative to the Indian Ocean (~3500m) and shallowest in the Pacific (<3000 m). Why? Would you expect the CCD in the Atlantic to also be deeper explain why?

The reason for that is that the pH due to respiration along the conveyor is lowest in the deep Pacific resulting in increased carbonate solubility and shallower CCD

What is the lysocline how is it different than the saturation depth?

There are indications that the lysocline is shallower in the eastern Atlantic compared to the central Atlantic at the same latitude can you explain?

The lysocline depth is the depth at which the effects of dissolution are seen in the sediment below this depth the dissolution is significant.

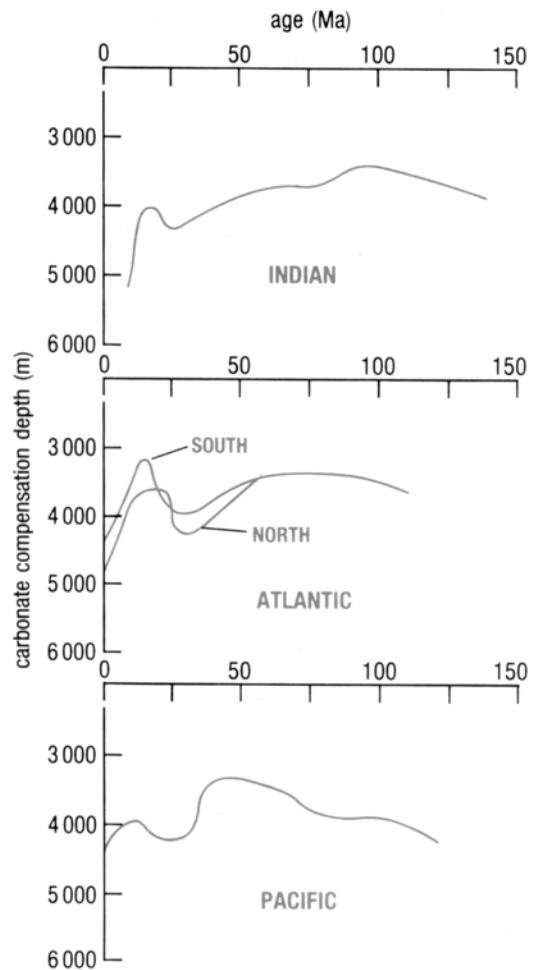
The lysocline is shallower in the Eastern Atlantic due to increased productivity (upwelling area) and organic matter accumulation in the sediment, which results in lower pH and increased dissolution.

(10) Can you suggest a way to reconstruct the rate of plate movement in the Indian Ocean towards Asia using marine sediments?

As the plate passes under the Equatorial area  $\text{CaCO}_3$  and other sediment related to high productivity (barite) will accumulate so if you take a core at a known distance from the equator and date the time when these sediments were deposited the distance from the Equator to the present day position has taken the time between now and the age of these sediments using this information the plate movement rate can be determined

(11) In the figure is the CCD depth in the Atlantic, Pacific and Indian Oceans for the past 150 Ma as reconstructed from ODP cores. Could you suggest why the CCD was shallow in the Cretaceous and got deeper since about 50 Ma?

There could have been a variety of reasons for the shallower CCD in the Cretaceous and we still do not know for sure what the “right answer” is. The important issue is that any explanation should be consistent with paleoceanographic data. One suggestion is that because of higher spreading rates at MOR sea level was higher with larger continental shelf areas. Carbonate was deposited in these extensive shallow marginal seas and thus less carbonate was deposited at depth (a mass balance issue and changes in the focus of sedimentation). Another suggestion is that atmospheric CO<sub>2</sub> levels were significantly higher resulting in more acidic seawater thus increased dissolution of carbonate. We do not know a lot about weathering rate in the Cretaceous but is weathering rates increased in the past 50Ma due to large areas with tectonic uplift (Himalayan, Andeans etc.) may have resulted in increased weathering thus for mass balance we would need to increase the deposition of CaCO<sub>3</sub> too the feedback being deeper CCD. All of this is a lot of speculation and more data about weathering rates, sea level changes, atmospheric CO<sub>2</sub>, oceans productivity etc. are needed to resolve this question.



Changes in the level of the CCD with time for the major oceans, determined from sediment sequences recovered in deep-sea drill cores.

(12) If the rate of seafloor spreading averages about 30 meters per million years, what is the age of the seafloor when it passes through the CCD (assume the ridge crest is at 2500m and the CCD is at 4000m). If the mean rate of non-carbonate accumulation is 0.5cm/1000 years and that of carbonate accumulation is 1.5cm/1000 years how deep would one have to bore into the sediment to reach carbonate bearing sediments at a water depth of 5000 meters?

$(4000-2500 \text{ m}) / 30 \text{ m} \times 10^6 \text{ years} = 50 \times 10^6 \text{ years}$ ; 50 million years of CaCO<sub>3</sub> + non CaCO<sub>3</sub> accumulation  
 $(5000-2500 \text{ m}) / 30 \text{ m} \times 10^6 \text{ years} = 83 \times 10^6 \text{ years}$ ; 83-50 = 33 million years of non CaCO<sub>3</sub> accumulation  
 $50 \times 10^6 \text{ years} \times (1.5 + 0.5 \times 10^{-3} \text{ cm/year}) + 33 \times 10^6 \text{ years} \times (0.5 \times 10^{-3} \text{ cm/year}) = 1165 \text{ meters}$