Introduction to Marine Chemistry

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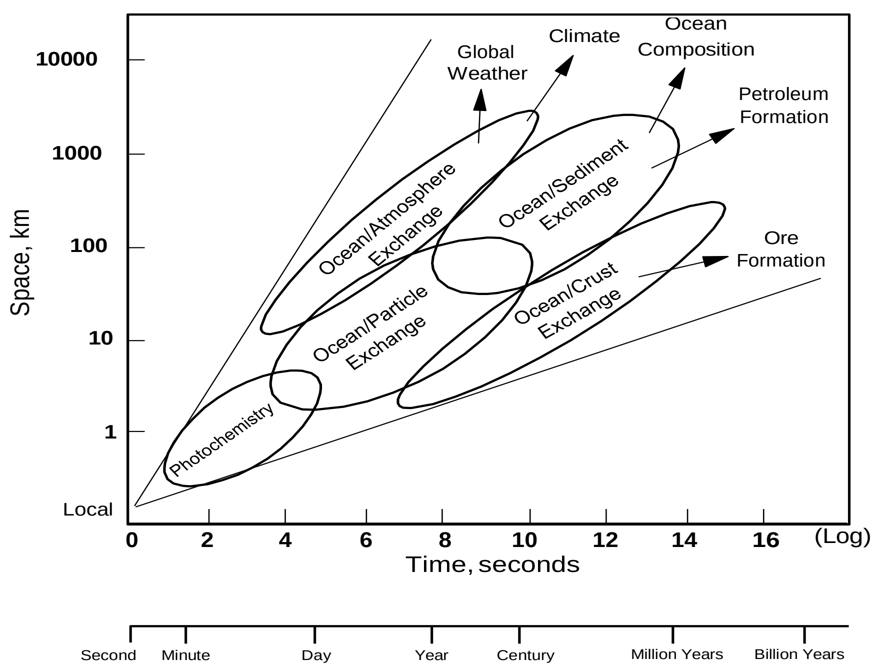
The Timetable of This Course

1 Oct	**1st Lecture**	**26**	
8		**3 Dec**	
15		**10**	
22		**17**	
29		**24**	
5 Nov		**31**	**2ND Exam**
12	**1St Exam**	**7 Jan**	**Last Lecture**
19			

Chemical oceanography is the study of everything about the chemistry of the ocean based on the distribution and dynamics of elements, isotopes, atoms and molecules. This ranges from fundamental physical, thermodynamic and kinetic chemistry to two-way interactions of ocean chemistry with biological, geological and physical processes. It encompasses both inorganic and organic chemistry, and includes studies of atmospheric and terrestrial processes as well. Chemical oceanography includes processes that occur on a wide range of spatial scales; from global to regional to local to microscopic dimensions, and temporal scales; from geological epochs to glacial-interglacial to millennial, decadal, interannual, seasonal, diurnal and all the way to microsecond time scales. The field by its own nature is very much an interdisciplinary field.

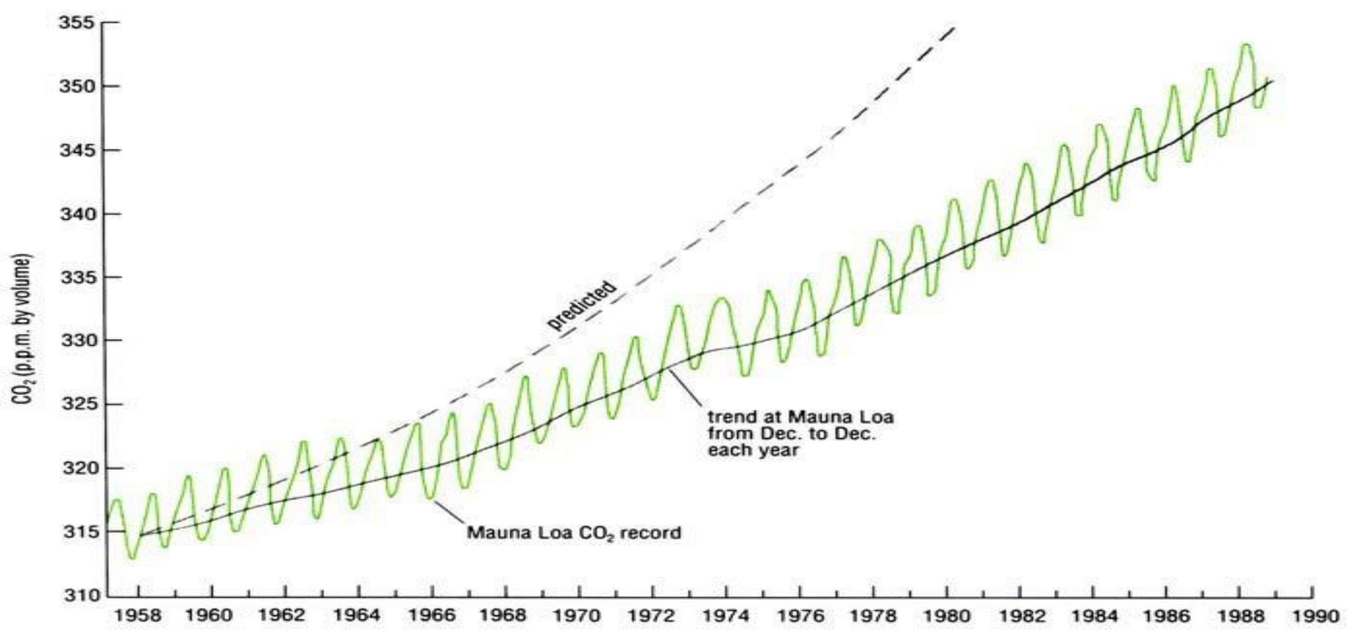


The advantages of the chemical perspective include:

1. Huge information potential due to large number of elements (93), isotopes (260), naturally occurring radioisotopes (78) and compounds (innumerable) present in the ocean.
2. Chemical measurements in the ocean are highly representative, reproducible and predictable (statistically meaningful). One drop of water is about 1/20th of a milliliter or 0.05 g, this is 2.8×10^{-3} moles or 1.7×10^{21} molecules.
3. Quantitative treatments are possible (stoichiometries, balances, predictions of reaction rates and extents).
4. We can learn about processes from chemical changes. Seawater composition integrates multiple previous events, this is important because most of the ocean is inaccessible to direct observation.

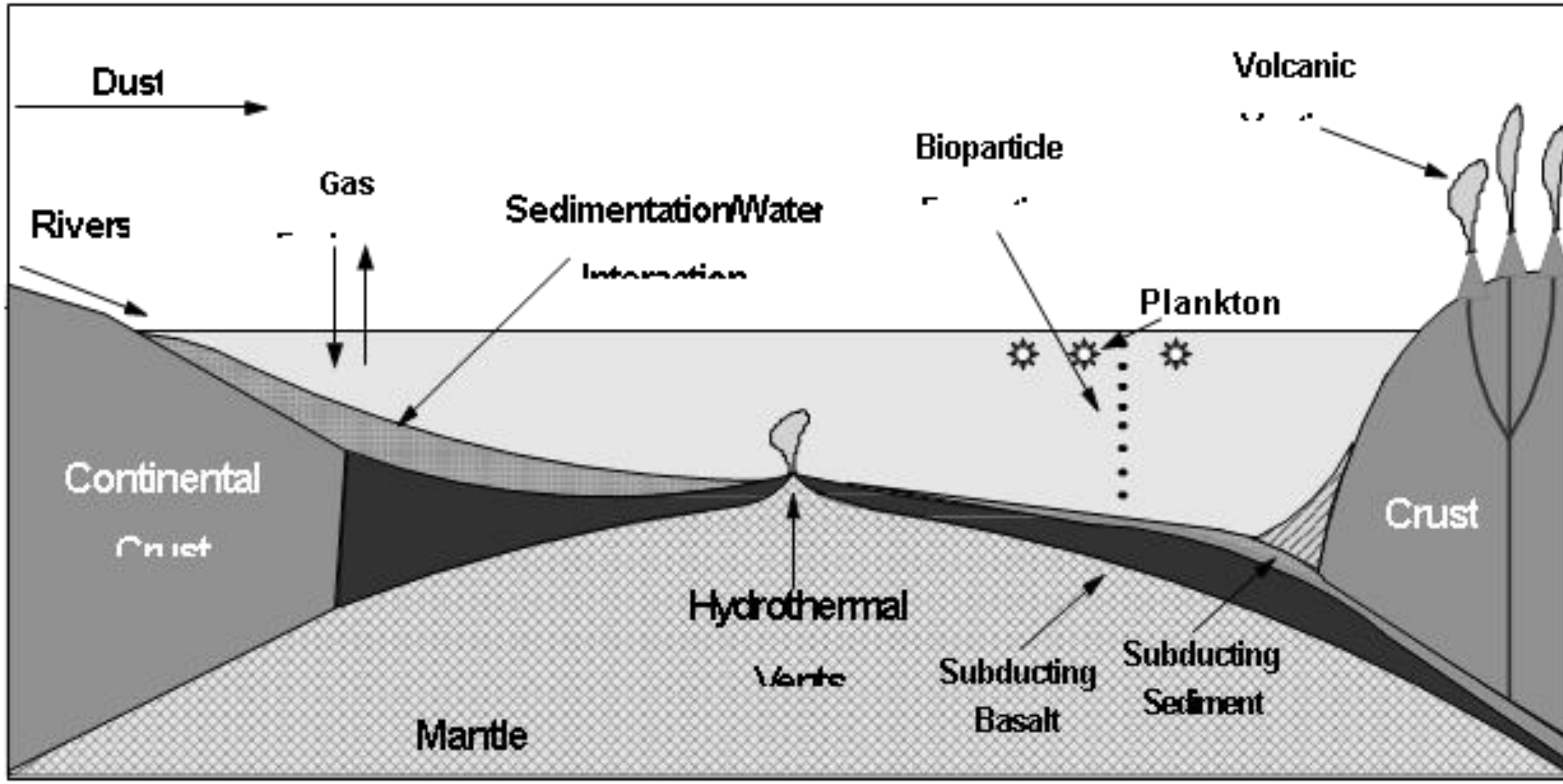
How and Why is This Field Relevant?

We are all aware of the CO_2 and other greenhouse gases increase in the atmosphere since the beginning of the industrial revolution. This is seen in the classic data from C.D. Keeling (1976) showing the seasonal oscillations and the steady annual increase of CO_2 at the Mauna Loa Observatory. Most experts conclude that we are already witnessing the impact of this as global warming, and the signal is expected to become increasingly more pronounced.



The inventory of dissolved inorganic C in the oceans is 50-60 times greater than that in the atmosphere, so a small perturbation of the ocean carbon cycle can result in a substantial change in the concentration of CO_2 in the atmosphere. The ocean carbon cycle influences atmospheric CO_2 via changes in the net air-sea CO_2 flux that are driven by differences in the partial pressure of CO_2 between the surface ocean and atmosphere. This exchange process is dominated by two interdependent "carbon pumps" that deplete the surface ocean of total CO_2 relative to deep water. Because the solubility of CO_2 increases with decreasing temperature, the **SOLUBILITY PUMP** transfers CO_2 to the deep sea during formation of cold deep water at high latitudes. **This is a link of the ocean carbon cycle to physical processes (circulation)**. At the same time the **BIOLOGICAL PUMP** removes carbon from surface waters by settling of organic and inorganic carbon derived from biological production to the deep sea. **This is a link of the ocean carbon cycle to biological processes**.

Understanding the natural processes that affect the global carbon cycle is an important requisite for correctly predicting the effects of global warming. For this we need a sound descriptive and quantitative background in all aspects of chemical oceanography and a good understanding of the coupling between chemical oceanography, tectonics, climate, and physical, and biological oceanography. As illustrated in the figure below the oceans are in continues contact with the atmosphere, lithosphere and biosphere.



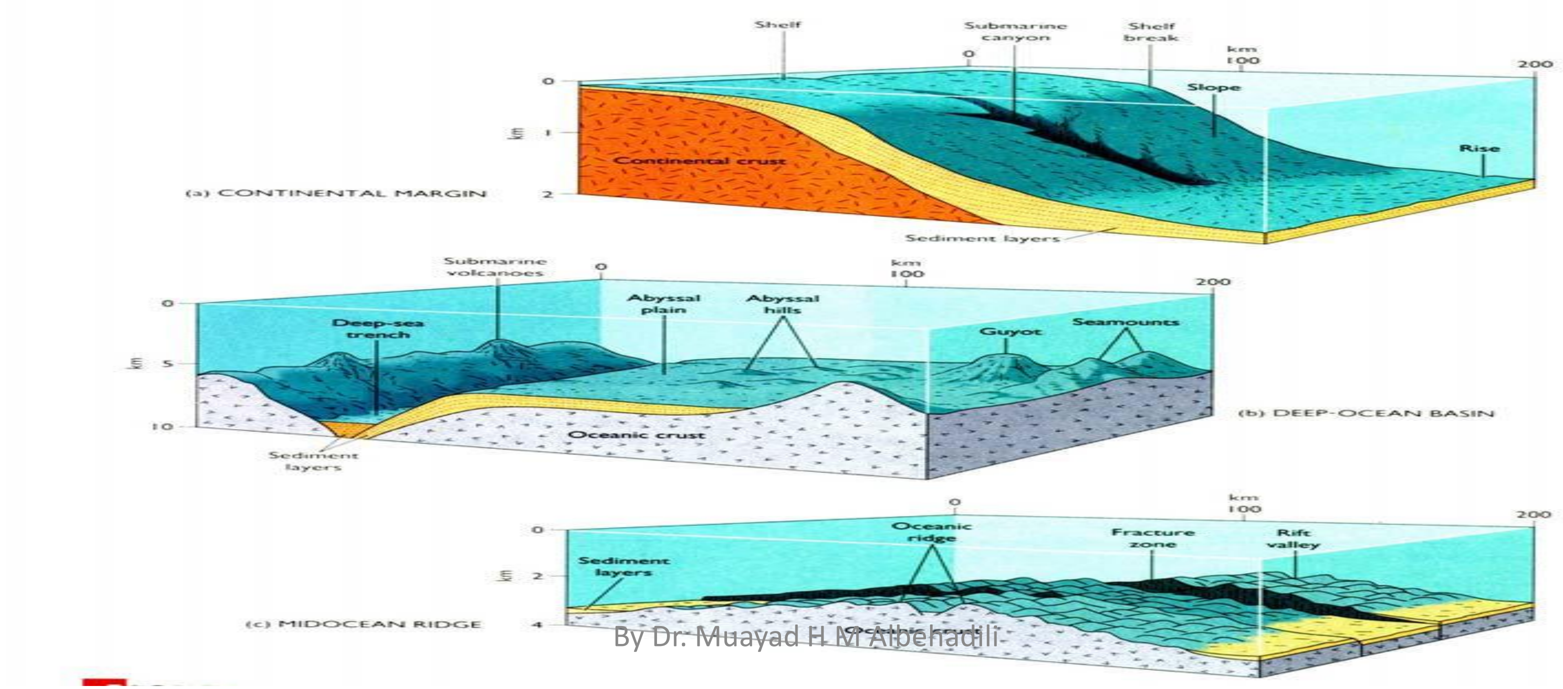
In addition to the major role the ocean plays in the global carbon cycle the world's ocean is also a resource for minerals, energy (gas and petroleum), fisheries, and is the ultimate water source.

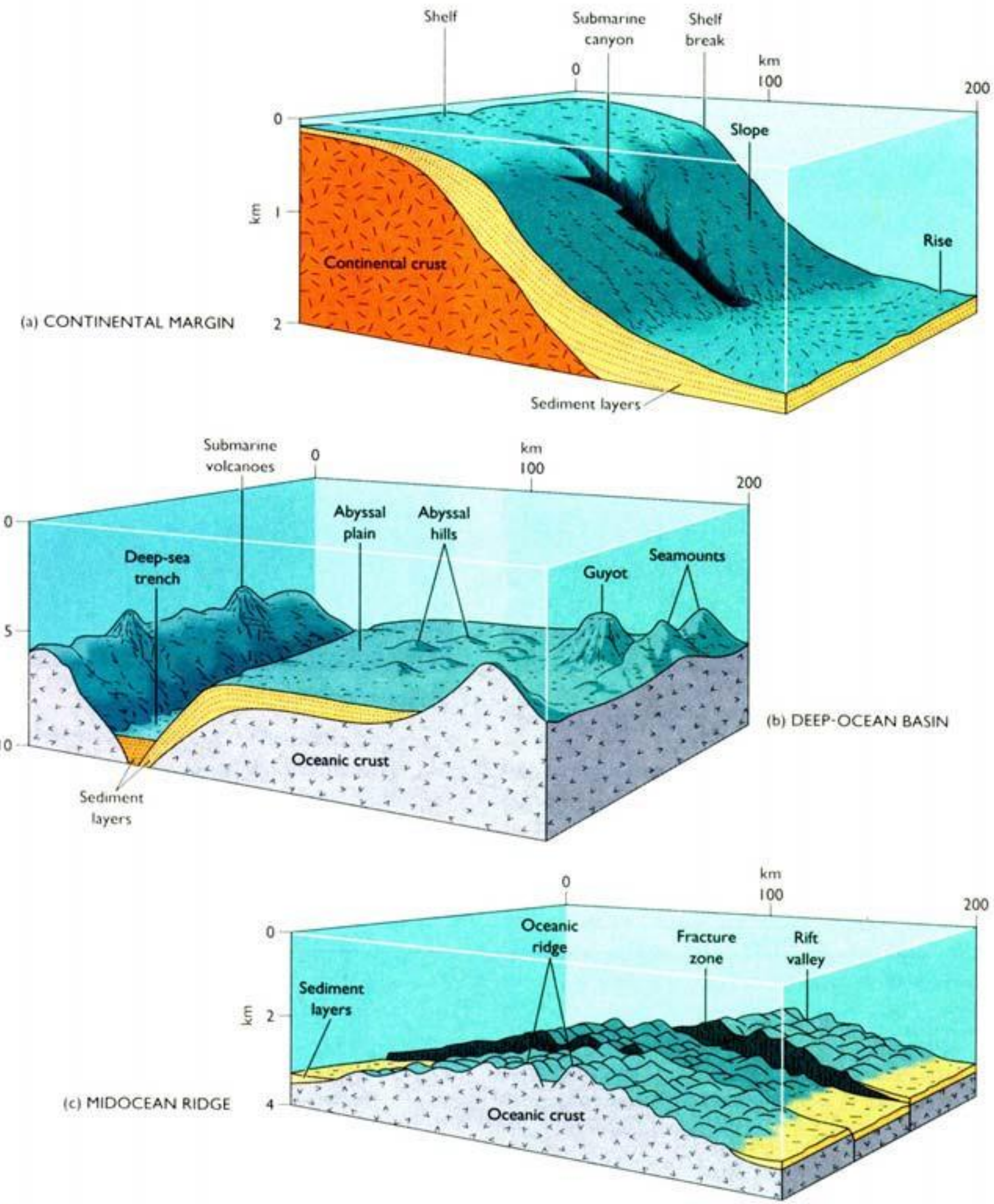
Overview of Ocean Chemistry

- Chemical components of the ocean influence the density of seawater and thus effect its circulation.
- Biological processes in the ocean are controlled by the chemistry (nutrient availability). At the same time biological processes are an important control on chemical distributions. The synergy between biology and chemistry has led to a whole new thriving sub-discipline called biogeochemistry.
- Chemical components are tracers of physical, biological, geological and chemical processes. Understanding what controls chemical distributions helps us understand ocean dynamics.
- Oceanic – Crustal coupling control the distribution of many ions in seawater on time scales of 10^4 to 10^6 years. Thus, we can learn from ocean chemistry about weathering, hydrothermal activity, and other crustal processes.
- Chemical components of marine sediments provide clues necessary to unravel the history of past ocean chemistry and ocean-atmosphere dynamics. Understanding the past should help us predict the future.

Some Descriptive Oceanography

The topography and structure of the ocean floor are highly variable from place to place and reflect tectonic processes within the Earth's interior. These features have varied in the past so that the ocean bottom of today is undoubtedly not like the ocean bottom of 50 million years ago. Even as short as about 5 million years ago Central America did not exist and there was an open seaway between the Atlantic and Pacific. The major topographic systems, common to all oceans, are the continental margins, the ocean-basin floors and the oceanic ridge systems. Tectonic features such as fracture zones, plateaus, trenches and mid-ocean ridges act to subdivide the main oceans into a larger number of smaller basins.




Shelf
Submarine canyon
Shelf break
0
km
100
200
0
Slope
km
1
Continental crust
Rise
(a) CONTINENTAL MARGIN
2
Sediment layers
Submarine volcanoes
0
km
100
200
0
Abyssal plain
Abyssal hills
Deep-sea trench
Guyot
Seamounts
km
5
(b) DEEP-OCEAN BASIN
10
Oceanic crust
Sediment layers
0
km
100
200
0
Oceanic ridge
Fracture zone
Rift valley
Sediment layers
km
2
(c) MIDOCEAN RIDGE
4
Oceanic crust

The Future

Where do we stand today and what does the future hold? Chemical Oceanography will continue to be an exciting, dynamic and vibrant field as the earth's population struggles to deal with the effects of the increase in fossil fuel CO_2 and other anthropogenic trace gases and global warming. A comprehensive discussion on the future of ocean chemistry research in the US (FOCUS) was recently conducted (Mayer and Druffel, 1999).