History of Ocean Exploration

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• See http://www.uaf.edu/cfos/people/faculty/detail/index.xml?id=146
THEN: Darwin left London for Plymouth on 16 October 1831 to prepare for the start of the voyage. A few of the scientific items he brought with him included:
1 microscope (a single lens model by Bancks & Son, London)
1 geological compass, 1 plain compass
2 pistols (with spare parts), 1 rifle (with spare parts)
1 telescope
1 geological hammer
5 simisometers [probably sympiesometer, a lightweight barometer]
3 mountain barometers
1 clinometer
1 camera obscura
1 hygrometer (belonged to FitzRoy)

NOW:
Darwin was given quarters in the chart room, one deck above Capt. FitzRoy's quarters, at the stern of the ship. It was 9 feet by 11 with 5 feet of headroom with bookshelves, cabinets, an oven, and a wash stand, plus a 4 x 6 chart table in the middle. There was about 6 feet by 8 feet of room to work in. Darwin lived in this room, on and off, for nearly five years setting the stage for his the theory of evolution.
A study of history uses the past to better understand the present.
Where are we?
The early Polynesians knew about the ocean, without latitude and longitude, clocks, or sat navigation.
Estimating one’s latitude was done by the navigator who observed the sun’s height at noon. At night, the position of the North Star and the orientation of major constellations helped determine a ship’s location.

Solutions to finding the correct latitude begin with the Arab navigators who used the “Kamal,” a length of cord attached at the center to a rectangle of wood. The cord had knots in it that corresponded to the latitude of known ports. The navigator held the knot to his eye, lined up the lower edge of the board with the horizon and the upper edge corresponded to the correct latitude when it aligned with the noon sun.
The Cross-staff, invented around 400 B.C., was proposed for navigation by Johann Werner in 1514.

The cross-staff’s single vane was moved to align the horizon and the sun or other celestial body.

It had two critical problems. First, the user was looking directly at the blinding sun, and second, trying to sight it and the horizon at the same time meant having to focus on two objects simultaneously, an impossible task for the human eye.
The Quadrant, a device for measuring the altitude of a celestial body, was first recorded in use in 1461. The Quadrant did not require sight of the horizon. It did require staring into the Sun in order to find its altitude.
The Astrolabe was adapted for marine navigation around 1480. It was held by the thumb ring at the top, above eye level and the *alidade*, the pointer in the center, was aligned to point to the sun. The altitude was then read off the wheel and that corresponds to the longitude.
Longitude is a different problem, and depends on knowing the time, which was measured by a sandglass. Not until the invention of the chronometer in early 1700s did estimating longitude begin to be reliable.

Measuring time at sea, hence measuring longitude, was solved with the invention of the chronometer in early 1700s by John Harrison. Once local time was known as an offset from Lisbon (or one’s home port), then estimating longitude was possible.

James Cook had two Harrison chronometers on board the *Endeavor* during his first Pacific navigation in 1768.
Determination of Longitude and Latitude

- Axis of rotation AND direction to Polaris
- Observers latitude
- Equator
- Your latitude
- To horizon
that the Antimeridian Time Zone ±12. Its half is zone -12; its half is zone +12. The both halves is the that the day differs.

11:00 UTC

next two hours, it will same day nearly all the around the world.

this hour (Sunday, 12:00, UTC), it is everywhere, except in zone -12, where it is still hour of Saturday.
NOW: GPS provides positioning to within a meter or less.
Early ocean exploration focused on mapping the world and expanding the known boundaries.

At left is Cook’s drawings of Tahiti made while observing the Transit of Venus in 1769. At right is a satellite view of Tahiti from GoogleEarth. GoogleEarth uses Landsat imagery nearly 250 years later to show an improved picture of Moorea. Both images show the shallow beaches surrounding the islands. GoogleEarth image has better inland details.
I have had occasion to satisfy myself with the Subterraneous Air, and other subjects I was led of, I think I should deliver much more then I shall now proceed for the reason newly my being particularly any thing that hinders a man, I was not solicitous of mines; yet after ha-

perature of the Air at may not be impro-

something of the Tem-

eall Regions; and of the
1665: Robert Hooke’s instrument for measuring pressure (depth)

Robert Hooke’s instrument for collecting water samples
A Fundamentally Important Oceanographic Expedition from 1872-1876

The HMS Challenger, a sailing ship of 2,300 tons with auxiliary steam power, conducted one of the major expeditions ever with funding from the The British Royal Society.

Challenger was tasked to systematically collect observations of the oceans every 200 miles and measure the depth to the seafloor and measure temperature at various depths. Using a sounding rope, they collected water samples and dredged the bottom for rocks and deep-sea marine life. The Challenger expedition established the general protocol for all expeditions to follow in the next 50 years. The results from the expedition fill a staggering 50 volumes.
Modern Oceanography

• Four main disciplines
  – Biological
  – Chemical
  – Geological
  – Physical
**NISKIN BOTTLE**

- Used to collect water samples from specific depths.
- The “messenger” triggers the valves to close.
Advances in Geological Oceanography

The development of the theory of Plate Tectonics was a scientific revolution dating to Wegner's theory of continental drift from the 1920s.
A major advance in geological Oceanography is the reconstruction of the earth's paleo-climates from deep sea cores.
Prior to World War II, biological oceanography had two central themes. Fisheries science was the first theme, focusing on finding where the great fisheries were located, why they varied in space and time, and attempted to find where more resources be found. Today this field is really “fisheries oceanography.”

The second major theme was simply new discoveries where the goal was increasing knowledge for the sake of knowledge. After WWII, the problems of pollution and its transport required that we know how the ocean functioned so it could be managed and the concept of sustainability became more widespread.

After WWII, one of the most important biological oceanographic discoveries was the unexpected finding of chemosynthetic hydrothermal vent communities.

Instead of sunlight, these communities relied on bacteria. They were first discovered in 1977 near the Galapagos islands.
This hydrothermal vent community, located on the Galapagos Rift, includes giant tubeworms (*Riftia pachyptila*), mussels (*Bathymodiolus thermophilus*), and crabs (*Bythograea thermydron*) at a depth of 2,500 m depth. (Photo by Fred Grasslel, WHOI)

Autotrophic bacteria (able to form nutritional organic substances from simple inorganic substances such as carbon dioxide) oxidize hydrogen sulfide in vent water to obtain energy, which is then used to produce organic material for growth. The primary producers (plants in our photosynthetic world) in the vents are chemosynthetic bacteria that form the base of vent food webs. All vent animals ultimately depend on these bacteria for food.

Chemosynthetic ecosystems have turned up everywhere in the ocean: on the continental shelves and slopes, in the deep sea, at plate margins, and ridge crests.
In 1978, the Coastal Zone Color Scanner (CZCS) was launched and showed, for the first time, the coherence of ocean biology, revealing its patterns, variability, and complexity, to the oceanographic community.

CZCS was followed in 1997 by an improved U.S. ocean color satellite Sea-Viewing Wide Field of View Sensor (Sea WiFS).

Ocean color showed that (1) the ocean is very under sampled, (2) mesoscale (basin) physical processes determine the spatial distribution of phytoplankton, (3) bottom topography or bathymetry influences plant biomass, (4) there is complexity in the seasonal phytoplankton signal, and (5) the magnitude of interannual variability is better known.
Specific advances in biological oceanography

1. Understanding of deep-sea diversity in the late 1960s fueled debates on how diversity is maintained in a large, monotonous environment.

2. The landmark achievement by Dugdale and John Goering (1967) showing that primary productivity in the ocean can be divided into locally recycled nutrients, regenerated production, and new nutrients transported into the euphotic zone as new production. This is driven by the physical processes of mixing and upwelling.

3. Determining that zooplankton swim, feed, breed, and live in a viscous, highly structured medium.
In 1998, a major oceanographic discovery oceanography came from estimates of subseafloor sedimentary microbial abundance which suggested microbes may account for 27–33% of Earth’s living biomass.

This is an astonishing and previously unheard amount of biomass, although more recent estimates reduce this estimate somewhat.
Aristotle considered the origins of salt in the sea, and, since Aristotle's time, many scientists have made significant contributions to understanding the chemistry of the oceans. In 1647, Robert Boyle wrote "Observations and Experiment About the Saltiness of the Sea", which established him as the founder chemical oceanography.

It was William Dittmar who undertook the analyses of seawater to establish the constancy of ratios of the major ions in seawater. Dittmar's report on seawater chemistry based on the 77 water samples of the 'Challenger' expedition was the most extensive seawater analysis performed at that time.

The focus today is on use of geochemical tracers and quantifying rates and fluxes, particularly of carbon as CO2 and radionuclides.

**Table 16.5: Ionic Constituents of Seawater Present in Concentrations Greater than 0.001 g/kg (1 ppm)**

<table>
<thead>
<tr>
<th>Ionic Constituent</th>
<th>g/kg Seawater</th>
<th>Concentration (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride, Cl^-</td>
<td>19.35</td>
<td>0.55</td>
</tr>
<tr>
<td>Sodium, Na^+</td>
<td>10.76</td>
<td>0.47</td>
</tr>
<tr>
<td>Sulfate, SO_4^-</td>
<td>2.71</td>
<td>0.028</td>
</tr>
<tr>
<td>Magnesium, Mg^{2+}</td>
<td>1.29</td>
<td>0.054</td>
</tr>
<tr>
<td>Calcium, Ca^{2+}</td>
<td>0.412</td>
<td>0.010</td>
</tr>
<tr>
<td>Potassium, K^+</td>
<td>0.40</td>
<td>0.010</td>
</tr>
<tr>
<td>Carbon dioxide*</td>
<td>0.106</td>
<td>2.3 x 10^-3</td>
</tr>
<tr>
<td>Bromide, Br^-</td>
<td>0.067</td>
<td>8.3 x 10^-4</td>
</tr>
<tr>
<td>Boric acid, H_3BO_3</td>
<td>0.027</td>
<td>4.3 x 10^-4</td>
</tr>
<tr>
<td>Strontium, Sr^{2+}</td>
<td>0.0079</td>
<td>9.1 x 10^-5</td>
</tr>
<tr>
<td>Fluoride, F^-</td>
<td>0.0013</td>
<td>7.0 x 10^-5</td>
</tr>
</tbody>
</table>

*CO_2 is present in seawater as HCO_3^- and CO_3^{2-}.

Minor constituents: Many other elements are dissolved in seawater in concentrations less than one part per million (ppm) and we call them trace elements.

**Principle of constant proportion or principle of constant composition**

Water is well mixed and the ratio of one major constituent of seawater to another remains nearly constant. What circumstances could give rise to exceptions?
Achievements in Physical Oceanography

In the 1940s and 1950s a general understanding of the abyssal circulation was laid-out.

In the 1950s, the basic currents were so well known that the surface currents were on handkerchiefs given to pilots should they need it. See http://www.escape-maps.com/escape_maps/map_list_wwii_us_liferaft.htm
The Ekman Spiral
All students of oceanography learn about the Ekman spiral, an elegant early-century mathematical solution to the wind-driven current profile.
Achievements in Physical Oceanography

During the 1950s and 1960s, the development of the “Hydrographic method” allowed oceanographers to determine currents based on measurements of Temperature, Salinity, and Pressure.
Achievements in Physical Oceanography

Advances in our thinking:

Pre-1970 the ocean was viewed as “steady state”.

After 1970 the focus was on mesoscale (basin scale) variability where 99% of the kinetic energy is found. This includes internal waves, edge waves, mixing events, and other time-dependent processes. The ocean is MUCH more energetic than we realized.

Today, we ask where is the ocean energy supplied by the wind dissipated?

How an ocean productivity be sustained?

What role do ocean currents play in transporting heat around the planet?
Acoustic Thermometry
Today, many of the scientific efforts are focused on restoring or maintain environmental health.
5 PLASTIC GYRES
Concentration of Microplastic, Great Pacific Garbage Patch