OCN 201: Shelf Sediments

Rockall Plateau

Squid 2000 & CSP3000 at 2200J
Scale Lines at 100 mS
Site water depth: 700 - 1000m
July 2000
Classification by Mode of Formation

- **Detrital sediments**
  - Transported and deposited as particles
  - Derived from weathering of pre-existing rocks
    (igneous, metamorphic or sedimentary)
- **Chemical sediments**
  - Precipitated from solution
Terrigenous Sediment Cycle

- Land (terra) born (-genous)
- Land source **identifiable**
- Participates in sediment cycle…
  - Erosion
  - Transport
  - Deposition
  - Recycling in deep earth
Chemical Sedimentary Rocks

- Limestone: calcite = CaCO$_3$
- Dolomite: CaMg(CO$_3$)$_2$
- Evaporites: evaporation of seawater: CaCO$_3$, CaSO$_4$.2H$_2$O, NaCl, KCl, borates

Bristol Lake, Mojave Desert
Passive Margins (East USA)

- Faulted blocks of rifted continental crust
- Triassic rift valley sediments in faulted blocks
- Overlain by Jurassic marine sediments/salt
- Overlain by thick (shelf, slope, rise) sediments (Cretaceous and Cenozoic) that buried ancient reef
- Whole coastal plain still subsiding and accumulating.
Origin of salt beds by evaporation when the ocean basin was young.
Pockmarks on the floor of the Gulf of Mexico

- Sediment from Rockies carried by Mississippi.
- Overlies salt (~180 Ma).
- Weight of sediment causes domes of salt to rise, spread out and dissolve.
- Collapsed salt domes create “pockmarks”.
Thick deposits of salt form in the ocean
a) because rivers carry sediment to the sea.
b) from evaporation of seawater.
c) in young ocean basins, which are long and narrow.
d) both b) and c).
e) all of the above.
Sea Level Changes: I

- Deduced from sediment packets on continental margin using seismic methods.
- Use of one or two ships
- Earlier used dynamite, now use airguns.
- *reflection* (layering) vs *refraction* (speed of sound in layers)
Sea Level Changes: II

- **Transgression:** Progressive flooding of land, high sea level stand
- **Regression:** Progressive draining of land, low sea level stand
Sea Level Change

• **Local causes**
  – Water in motion
  – Storm surges, wind driven, currents along shoreline
  – Tectonic uplift or subsidence

• **Global causes**
  – Change in ice volume
  – Change in mean seafloor spreading rate (fast = younger seafloor, sea level rises, slow = older seafloor, sea level falls
  – Change in mean ocean T (water expands on warming)
Sea Level Summary

- Sea level is rising!
  - Sea level fell from 125 Ka to ~20 Ka due to ice buildup.
  - Sea level has been (generally) rising for the past 20 Ka. (evidence from drowned reefs).
  - Global sea level has risen about 20 cm over past century, largely due to melting of glacial ice.
  - There is a local effect of Hawaiian geology on sea level rise.
Why is sea level rising?

Domingues et al., 2008, Nature

Sea level (mm)

- Alpine glaciers
- Greenland and Antarctica
- Thermal expansion (shallow)
- Thermal expansion (deep)
- Water in reservoirs

Sea level (mm)

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Sea Level in Hawaii

- Two causes:
  - Local: Hawaiian Arch
  - Global: overall sea level rise

Every island has its own rate of sea-level rise

- The young Big Island is so heavy it bends the lithosphere
- Downward push at hotspot causes upward bulge under Oahu
- As the Pacific Plate moves, every island rides over the bulge causing uplift

Source: NOAA tide gauge network
Effect of Sea Level on Coasts: I

Estuary Development through a Transgressive Sequence
Effects of Sea Level on Low Areas

- Rise of only a few 10’s of cm can be critical.
- Pacific Atolls (Marshall, Micronesia, Tuamotu, etc.)
- Indian Ocean (Maldives… shown here!)
- Also important for low continental areas (Florida, New Orleans, London, Venice)
Effect of Sea Level on Coasts: II

Low sea level at ~20 ka increased dry land (from reef banks and continental shelf) as much as 200 km seaward.

Future sea level will rise up to 70 m if polar ice caps melt, flooding the reef platform and continental shelf of the SE USA . . .

Loss of Greenland ice cap = 7 m rise
Sea level is rising today because
a) Earth’s climate is warming.
b) glacial ice is melting.
c) the oceans are warming, and water expands as it warms.
d) all of the above.
Value of Physical Resources from the Sea (2001)

Oil and gas: $200B
Cable laying: $10B

Placers: diamonds $800M
gold $200M

Sand and gravel: $500M

Salts (including Mg): $500M
Political regime: UN Law of the Sea

• **Nearshore:**
  – 12 mile territorial zone and 200 mile Exclusive Economic Zone.
  – These two zones account for 40% of the ocean area!

• **Offshore:**
  – International Seabed Authority (leases, royalties)
Origin of Oil and Natural Gas

1. **Deposition** of organic carbon in sediments (bodies of small organisms)
2. **Burial and heating** to convert to oil and gas (\(=\) *hydrocarbons*)
3. **Migration** through permeable sediment (e.g., sandstone)
4. **Trapping** to form an underground pool
Nature of **Source Rock**

- Rich in organic carbon
- Thick, as found along continental margins (but NOT in the deep sea!)
- Buried to >2 km to heat sediment (= *maturation*)
  (Natural gas rather than oil is made below ~7 km.)
- Overlain by permeable rocks for fluid migration
- Caprock/natural traps in which to accumulate (folds, faults, salt domes)
Formation of an Oil or Gas Deposit

Large amounts of organic carbon produced by marine organisms in near-surface waters

Carbon-rich sediments deposited in protected environment.

Later sediments buried and sealed the carbon-rich deposits

Carbon in deeply buried sediments transformed by heat and pressure into oil and gas.

The pressure of additional sediment deposits expels the oil and gas into porous rocks where they formed oil and gas fields
Structure of Fossil Fuel Deposits

- Hydrocarbons are not present as large liquid pools; rather:
- Oil and gas adhere to particles of enclosing rock.
- Oil and gas ascend until trapped by an impermeable caprock.
Geologic Traps for Oil and Gas
Economic Considerations

- Drilling for oil is costlier in ocean than on land. (also true of any marine mining operation)
- Most marine oil deposits are tapped from platforms in less than 100 m water depth.
Oil

- Most of the oil on Earth was produced during episodes of extreme warmth between 90 and 150 million years ago.
- Algae proliferated in warm sunlit tropical waters, and the hot surface water prevented normal circulation such that stagnant anoxic conditions occurred at depth.
- We will burn most of this oil within a single human lifetime (Ours!)
- A grown man working at hard physical labor for a month burns the amount of energy in a gallon of gasoline.
- Each American has available to them the energy equivalent of ~200 slaves. *Energy is the source of our wealth!*
The Peak in Oil Production: the USA

US peaked in 1970, as predicted by M. King Hubbert in 1956. Peak was 11 MBrl/day.

Today we use 20.

Drill, Baby, Drill?

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World crude oil production peaked in 2005-2008 (so far).
Implications of “Peak Oil”

• The production curve is called a “logistic curve”.

• The peak in production follows the peak in discovery by 30-40 years (USA: 1930’s, 1970; global discovery peak was 1964.)

• At the peak, ~half of the resource is gone—and it is the good half! (easy to find and cheap to recover)

• Production falls rapidly and inevitably from the peak, regardless of demand. A long plateau produces a steeper drop.

• As of 2009, 64 countries are past-peak and 35 are not.
UK OIL PRODUCTION FORECAST: 1950 to 2050

- **Discovery Peaks:** 1970
- **Piper Alpha Disaster:** 1999
- Production peaked in 1999

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The peak year of global oil discovery was 1964.
In the next 25 years, crude oil production from existing wells will decline from the current 74 Mbarrels/day to only 16 Mbarrels/day (IEA, 2010).

= Severe shortfall!

74 + 10 = 84 million barrels per day
(135 needed in 2030!)
Aloha, see you next time...
Exclusive Economic Zone

- EEZ’s of some countries overlap.
- Multiple claims to same areas
- Leads to boundary disputes.