Ocean 201 week 6 Lecture 2: Physical Resources from the Sea (M.J. Mottl)

Text from slides

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)

Exclusive Economic Zone

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

Offshore Oil and Gas

- Generated ~$200 Billion in 2001(worldwide)
- 35% of crude oil and 26% of natural gas produced in 2000 was from seabed.
- About 1/3 of world reserves is in continental margins.
- **Little to no oil or natural gas on deep seafloor!**

US Oil and Gas Potential

Alaska, S. California borderlands, and Gulf of Mexico are most promising US areas.

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

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

Origin of salt in salt domes

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.

Deep Water Oil Drilling Platforms
Oil Company tension-leg platform Ursa, deployed in 1998 in 1160 m depth offshore Louisiana. Tallest offshore rig
Platform Mars (deployed in 1996) superimposed on Houston skyline
Both platforms are anchored by vertical and lateral cables to seafloor and can withstand 22 m (71ft) waves and 225 km/h (140 mph) winds.

Gas Hydrates (Methane = CH_4): I
- Abundant in nature (Arctic regions and marine sediments)
- Crystalline solid of gas molecules (e.g., CH_4) surrounded by a cage of water molecules = methane-water ice
- Also known as “clathrates”; consist of two dissimilar molecules mechanically intermingled but not truly chemically bonded.
- One molecule forms a framework that traps the other molecule.

Gas Hydrates (Methane): II
- Look much like water ice; stable in ocean floor sediments at water depths > 300 m (high pressure, low temperature).
- Known to cement loose sediments in a surface layer up to several hundred meters thick.
- May impact climate!

Gas Hydrates (Methane): III
- Amount of carbon bound in gas hydrates worldwide is estimated to total twice the amount of carbon to be found in all known fossil fuels on Earth.

- Large accumulations of methane hydrates off North Carolina and South Carolina in US waters
- Volume of gas and richness of the deposits make methane hydrates a candidate for development.

Gas Hydrates (Methane): IV
Recently sampled hydrates off Pacific NW (Cascadia Margin)

Gas Hydrates (Methane): V
- Top right: Gas hydrate plug in a Brazilian pipeline
- Bottom Right: Gas hydrate in a core, dissociating
- Bottom: schematic showing how decomposition can cause slope failure

Issues Associated With Hydrates

Submarine Placer Deposits
- ***Placers*** are ores concentrated as particles by the action of water.
- Diamonds
  --$800 M in 2003
  --second only to oil and gas
  --mainly from offshore South Africa
- Gold
  --$200 M in 2003
  --mainly from offshore South Africa

Sand and Gravel
- Third in dollar value to oil and gas and diamonds
- More than 1 G tons mined in 1998
- Valued at more than $ 500 M
- Most is dredged from continental shelves.
- About 20% of Japan/England sources from seafloor
- Largest operation (Ocean Cay) in Bahamas recovers oolite (largely aragonite) sand.
- Used in concrete, construction, glass, animal feed supplements, and to reduce soil acidity.
- US deposits mostly Alaska, Calif, Wa, Mid-Atlantic
- Alaskan oil rigs are built on gravel platforms.

Magnesium
- $MgCl_2$ and $MgSO_4$ salts from seawater
- 50% of world production of Mg is from seawater.
- 60% of Mg compounds produced in US use Mg from a single plant in Texas…
- Value of Mg to US economy was $350 M in 2002.
- Mg compounds are used in chemical processing, food, medical applications, agriculture, and for lining high T furnaces. Mg metal is used in alloys.

Salts

- Ocean is 3.5 wt.% salt.
- Evaporation leads to CaCO3, CaSO4, NaCl and complex mix of Mg and K salts.
- Table salt is 78% of evaporative residue salts.
- Recovered from large artificial ponds worldwide.
- Production of selective salts by shifting brine from pond to pond based on density
- K salts for fertilizers
- Br for medicine, chemical processing, antiknock agents
- Gypsum for wallboard
- 1/3 of world salt by evaporation
- US produced 4.7 M tons (2002) by evaporation ➔ $155 M

Phosphorites

- Rock with high P (> 40% P2O5) content
- Used for fertilizer, phosphoric acid
- Host to many other useful substances (U, V, F, REE)
- Biogenic deposits, often on continental slope/rise
  (S. Africa, Peru, Florida) in upwelling zones
- Formed by decay of biogenic remains.
- Best deposits are in shallow waters.
- US production is mainly in Florida.
- Nauru: guano deposits: biogenic but of a different type . . .

Future Prospects

- Mn nodules (Cu, Ni) and crusts (Co)
- Polymetallic sulfides (Cu, Zn, Ag, Au) from submarine hot springs
- Energy from:
  --tides
  --waves
  --Ocean Thermal Energy Conversion (OTEC)

Marine Polymetallic Deposits

- Deep-sea Fe-Mn nodules
  - on abyssal (4000-6000 m) seafloor
  - Found in red clay provinces
  - Diagenetically/hydrogenetically produced
  - Slow sediment accumulation rates necessary
  - Resource value is in Cu, Ni (and other metals)
- Fe-Mn Crusts (Co-rich Crusts)
  - Precipitated directly from seawater on seamount outcrops
  - Very slow growth rates
  - Best ore-grade found in depth range of 1000-2000 m
  - Rich in cobalt

Other Polymetallic Deposits

- Hydrothermal deposits (MOR, island/back arcs, and hotspots):

- Precipitate from hot water (typically polymetallic sulfides, anhydrite, barite, metalliferous Fe-rich sediments)
- Sulfides are rich in Zn, Cu, Ag, Au, and other metals.
- This is how many land-based deposits formed.

Marine Mineral Values

- Marine mining is more expensive than land mining.
- Need high metal prices to make economically viable.
- Metal (commodity) prices fluctuate a lot.
- Peak in price in 1980's due to political pressures.
- Current values rising again.
- May make marine minerals interesting again…

Freshwater

- Only 0.017% of world surface water is fresh and ready for use "as is".
- Additional 0.6% is available as ground water (but much is polluted).
- Availability of potable water determines maximum population of any geographic area, use of other natural resources, and lifestyle.
- Because of scarcity desalination is becoming a viable exploitation option (Middle East, W. Africa, Peru, FL, TX, CA).
- >1500 desalination plants worldwide
- Produce about 13.3 GL/day
- Saudi Arabia alone produces ~114 ML/day.
- Some wild ideas (drag icebergs to desert areas)

Marine Energy

- Wind power: renewable source
  - Wind farms in Denmark, compare to land based windfarms in CA, OR, WA
- Waves and Currents
  - No large scale wave harnessing to date
  - Some small experimental installations in Japan, Norway, UK, Sweden, US, Russia
  - One device uses rush of air trapped by waves entering breakwater caissons
  - Ocean currents also potentially harnessable (…Gulf Stream and Hammerfest, Norway)

OTEC

- Ocean Thermal Energy Conversion
- Closed or open cycle systems
- Based on T differences between surface and deep water
- Use warm water to volatilize working fluid (e.g., NH3).
- Volatilized fluid used to turn turbines.
- Use cold water to condense working fluid.