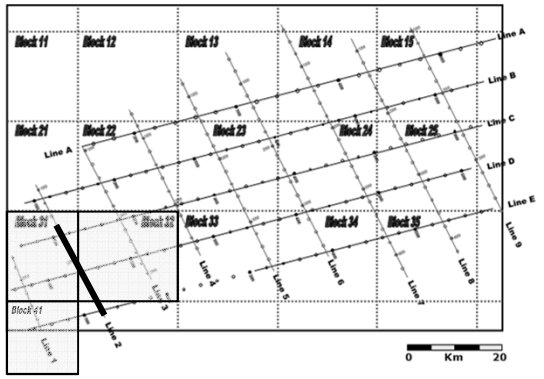
Lecture 4

The Tiger Field

NOTE: These materials are for educational purposes for undergraduate and graduate students ONLY. If you are not a student or faculty member, please do not use these resources.

Ross Licensing Round

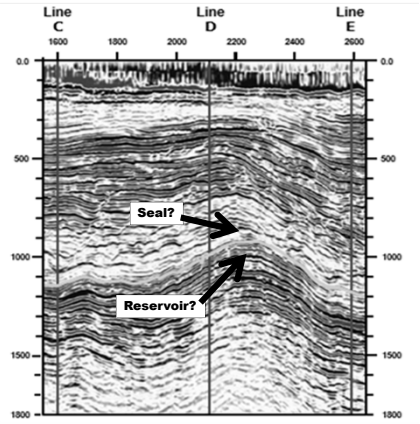
The fifteen (15) blocks open for bids:



Our Best Lead

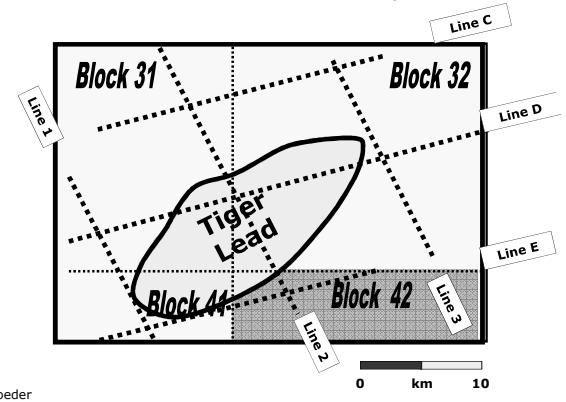
The Tiger lead:

- Huge Anticline
- Res = High Amp, Continuous
- Seal = Low Amp, Discontinuous



Our Blocks

We obtained leases for Blocks 31, 32 and 41



Summary: HC System

Source Rock
- Coals and coastal plain coaly shales in the Amundsen Fm.
- Dominantly terrestrial plant origin with high total organic carbon.

Reservoir
•The Ross Fm fluvial to nearshore sandstones are the primary reservoirs.

Trap
•Extensional fault blocks associated with Late Cretaceous rifting.

Seal
•Mostly marine shales and marls of the Shackleton Member.
•Some shales within the Ross Fm act as intra-Ross seals.

Maturation and Migration
•The major generation and expulsion was initiated in the Miocene.
•Peak generation at depths of 4-5 km for oil and 5-6 km for gas.

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Lecture 6

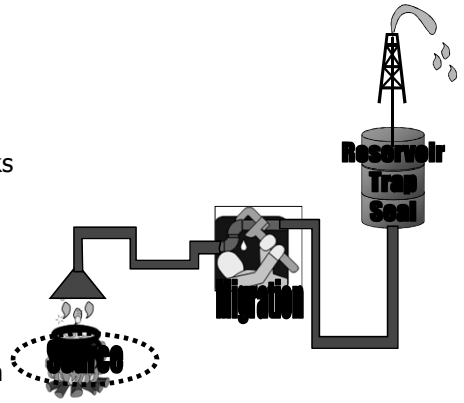
Source Rocks and HC Generation

NOTE: These materials are for educational purposes for undergraduate and graduate students ONLY. If you are not a student or faculty member, please do not use these resources.

Elements and Processes

Essential Elements
- Source rocks
- Reservoir rocks
- Seal rocks
- Overburden rocks

Major Processes
- Trap formation
- Hydrocarbon
  - Generation
  - Migration
  - Accumulation



Source of Oil & Gas

ORGANIC MATERIAL		REACTION CONDITIONS		OIL - GAS GENERATION
Plant or Animal Remains sugar $C_6H_{22}O_{11}$	+	Time Burial Temperature	=	Oil & Gas Molecules Methane Gas CH_4

Image Courtesy of ExxonMobil

Organic Matter Types

Type I
- Algal remains deposited under anoxic conditions
- Deep lakes
- Generate waxy crude oils

Type II
- Planktonic & bacterial remains
- Marine anoxic conditions
- Generate both oil and gas

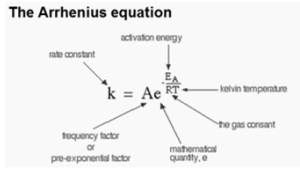
Type III
- Terrestrial plant matter
- Decomposed by bacteria and fungi, sub-oxic
- Generate gas with some light oil

Source Rock Properties

- **Total Organic Content (TOC)**
  - Weight % organic carbon
  - Greater than 1% to be considered a source
  - Can exceed 15% - world class source
- **Hydrogen Index (HI)**
  - The density of hydrogen in the rock relative to that of water (# H atoms per unit volume/# H atoms/vol in water)
  - It is the key factor in the response of a neutron porosity log

We Need More than High TOC

- We need the raw material, organic matter, to generate oil and gas molecules
- We also need the chemical reaction that converts plant & animal remains into HCs
- Temperature is a primary control on the chemical reaction that we need
- Temperature is controlled by the temperature gradient and depth of burial
- We (geochemists) can model the reaction using an Arrhenius equation



http://www.chemguide.co.uk/physical/basicrates/arrhenius.html

From Organic Matter to HCs

Deposition

Proteins, lipids & carbohydrates are deposited with sediment

Diagenesis

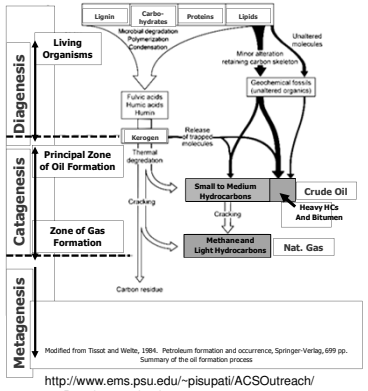
Compaction under mild temperature and pressure converts the organic material into kerogen, a dewatered waxy material

Catagenesis

The thermal degradation of kerogen to form HC chains. As burial depth and temperature increases, longer HC chains (oil) is cracked to shorter HC chains (gas)

Metagenesis

Hydrogen is driven off leaving residual carbon

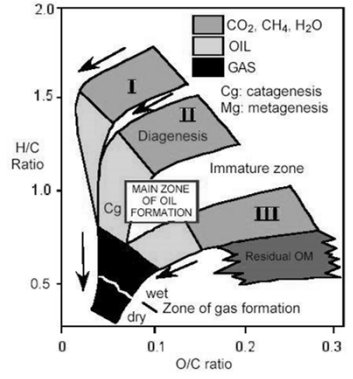


http://www.ems.psu.edu/~pisupati/ACSOutreach/Petroleum_2.html

Van Krevelen Diagram

If we plot the O/C ratio vs. the H/C ratio:

- The three organic matter types (OMTs) can be distinguished
- The degree of diagenesis to catagenesis can be determined



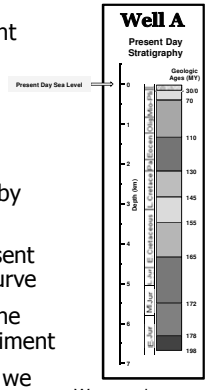
https://geochemist.wordpress.com/2009/01/08/evolusi-termal-material-organik-2/

Basin Modeling

- We can use computer software to model a basin's history
- This modeling can be:
  - 1-D – modeling a well location (or pseudo-well)
  - 2-D – model a cross-section (between wells)
  - 3-D – use a series of grids to model a region
- We start with present-day stratigraphy
- We back-strip from present to past times (geohistory)
- We calibrate with temperature data and current indicators of HC generation states
- Then we can model forward through geologic time to get source and reservoir properties

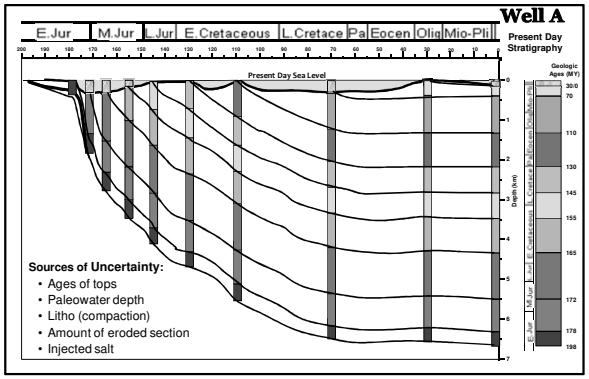
Back-Strip for Burial History

- From an existing well, we can get present day stratigraphy:
  - Age-depth pairs (e.g., 198 Ma, 6725 m)
  - Lithology of each major interval
  - Paleo data for ages and water depths
- Software allows us to step back in time by progressively removing the top layer
- We datum each time step based on present day sea level (SL) or our favorite SL curve
- This method gives us a model for how the basin subsided and was filled with sediment
- We also "de-compact" the sediments as we move back through geologic time

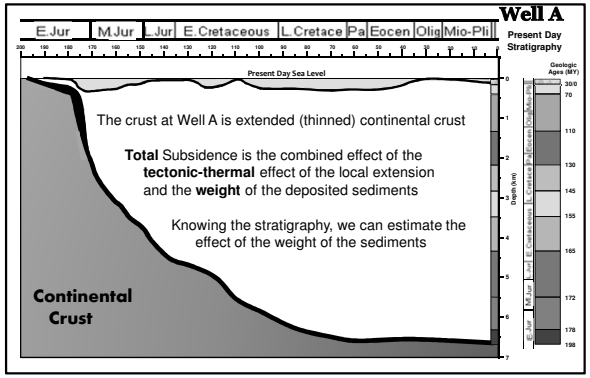


We can also use seismic-derived stratigraphy to model pseudo-wells

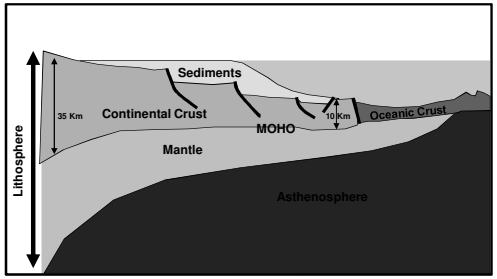
Back-Strip for Burial History

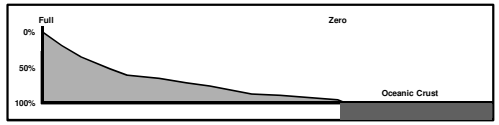


Components of Total Subsidence



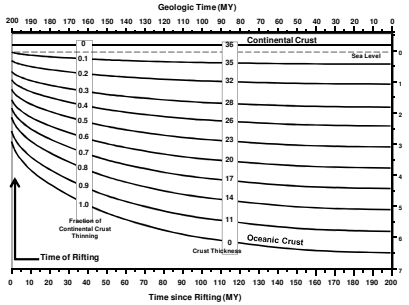
Extensional Margins





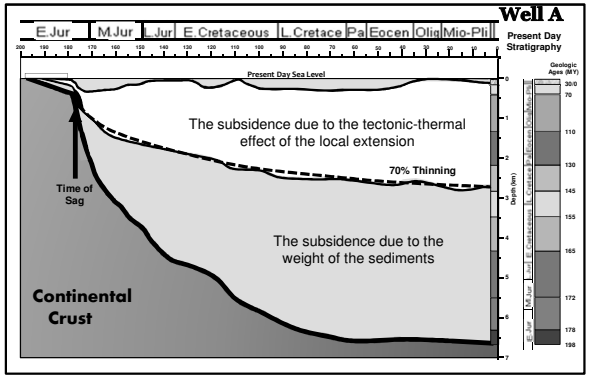
Theoretical Post-Rift Thermal Subsidence

- Royden et al. (1980) used the subsidence of oceanic crust (100% extension) to develop several models of how extended continental crust would subside in the absence of sediment load
- The curves shown below are for their dike injection model

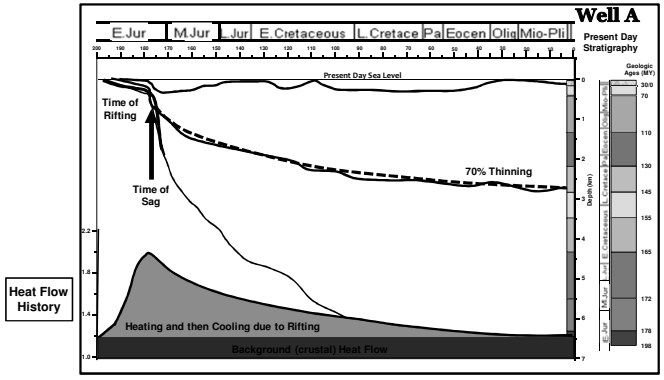


Modified from Hardenbol, Vail and Ferrer (1981)

Components of Total Subsidence

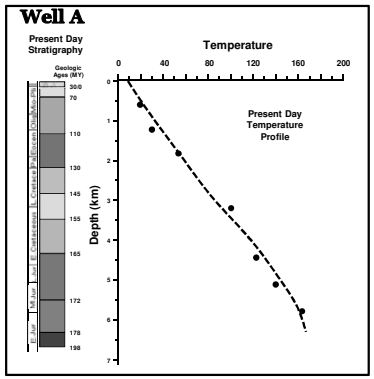


Heat Flow



Heat Flow History

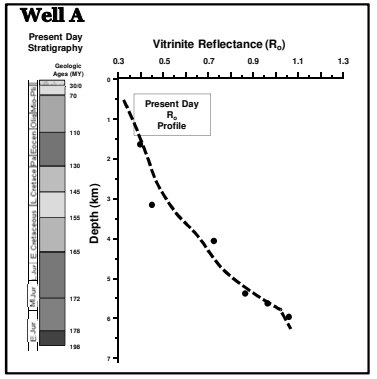
Temperatures



- Software allows us to model the temperature history of each depositional unit
- Present temperatures from well data can be used to calibrate the thermal model
- In this case, we have a reasonable match between measured and predicted temperatures
- Thus we can model the HC generation history of our source unit(s)

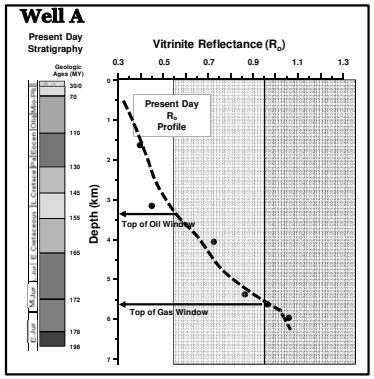
Vitrinite Reflectance

- Organic material from cores or cuttings can be examined under a microscope
- Specialists can determine how shiny the vitrinite particles are
- Vitrinite reflectance is a measure of how hot the rocks have been – a paleo-thermo-meter
- Thus we can also calibrate our temperature history using this type of data



Hydrocarbon Generation

- R_o can be linked to when oil and gas are generated
- The oil window is about R_o values of 0.55 to 0.95
- The gas window is about R_o values of 0.95 to 2.2
- For each modeled location (real or pseudo-well) we can get a depth for the tops and bases of these windows
- If results are fairly consistent, we can use depth maps to outline oil and gas generation areas



Source & Generation Analysis

1. Use available data to identify intervals that could be potential source rocks
2. Collect TOC, HI, temperature and R_o data in and around your area of interest
3. Select locations to model subsidence, fill and temperature histories
   - Actual well locations
   - Pseudo-well locations using seismic-derived stratigraphy
4. Run initial models
5. Calibrate models using temperature data, R_o data, and areal consistency
6. Develop a depth vs. R_o relationship
7. Use this relationship and depth maps for the top/base of the source interval(s) to map the oil generation 'window' and the gas generation 'window'

Lecture 7

Reservoir Rocks

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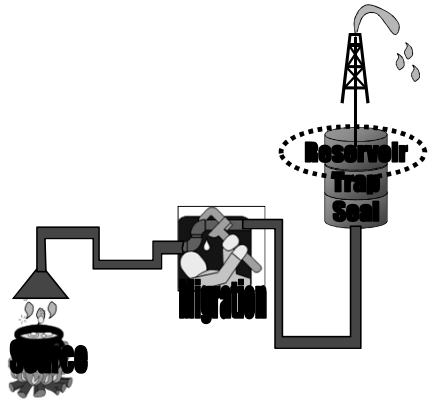
Elements and Processes

Essential Elements

- Source rocks
- Reservoir rocks
- Seal rocks
- Overburden rocks

Major Processes

- Trap formation
- Hydrocarbon
  - Generation
  - Migration
  - Accumulation



Reservoir Rocks

A **Reservoir Rock** is one from which oil & gas can be extracted from wells and brought to the surface

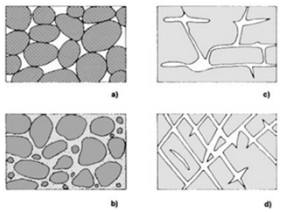
It must have:

1. Void space in the rock for HC molecules to occupy
   Porosity
2. Sufficient "plumbing" so the HC molecules can escape from the rock
   Permeability

Porosity

Porosity (commonly symbolized as Φ) is a measure of the void (i.e., "empty") spaces in a material, and is a fraction of the volume of voids over the total volume (between 0 and 100%).

From Wikipedia



http://echo2.epfl.ch/VICAIRE/mod_3/chapt_1/main.htm

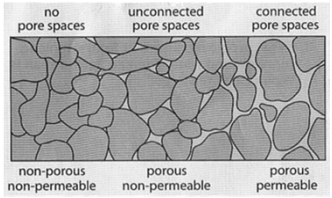
Influence of structure and texture of a porous medium on porosity:
a) poorly graded uniform granular material in which particles have their own porosity system;
b) well graded granular material with small particles filling the big pores;
c) partially closed discontinuity systems appeared in an intact porous rock due to active water;
d) open discontinuity systems appeared in an intact rock due to mechanic fracturing.

(from Freeze and Cherry, 1979 after Meinzer, 1923)

Permeability

Permeability (commonly symbolized as κ) is a measure of the ability of a porous material (often, a rock or an unconsolidated material) to allow fluids to pass through it.

From Wikipedia



http://petroleum101.com/what-is-a-petroleum-reservoir/

Without enough permeability in the rock, the oil and gas would not be able to flow and it would remain trapped in the reservoir rock. Permeability is really an expression about how interconnected the pores and natural fractures in the rock are.

Permeability and porosity are the two most important characteristics of a reservoir, and are studied intensely by asset evaluation teams.

Types of Reservoirs

Conventional Reservoirs

- Clastic
- Carbonate

Unconventional Reservoirs

- Tight Oil/Gas Sands
- Shale Oil/Gas
- Coal Bed Methane

Traditional methods are used to extract HCs from reservoir-quality rocks within some type of trap

New methods are used to extract HCs from non-reservoir-quality rocks often within source intervals

Clastic Reservoirs

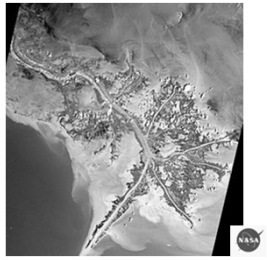
Conventional Reservoirs

- Clastic
  - Alluvial Fans
  - Aeolian Dunes
  - Fluvial
  - Shoreline
  - Delta ☑
  - Deep Water ☑
- Carbonate

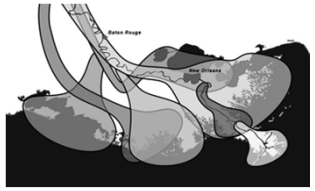
Deltas

A river **delta** is a landform that forms at the mouth of a river, where the river flows into an ocean, sea, estuary, lake, or reservoir. Deltas form from deposition of sediment carried by a river as the flow leaves its mouth. Over long periods, this deposition builds the characteristic geographic pattern of a river delta.

From Wikipedia

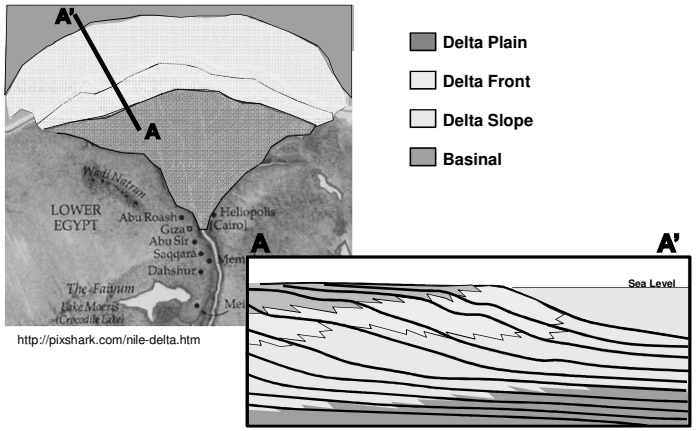


http://en.wikipedia.org/wiki/File:Mississippi_delta_from_space.jpg



http://en.wikipedia.org/wiki/File:Mississippi_Delta_Lobes.jpg

Delta – Envir. of Deposition (EODs)



http://pixshark.com/nile-delta.htm

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Seismic Line through a Delta

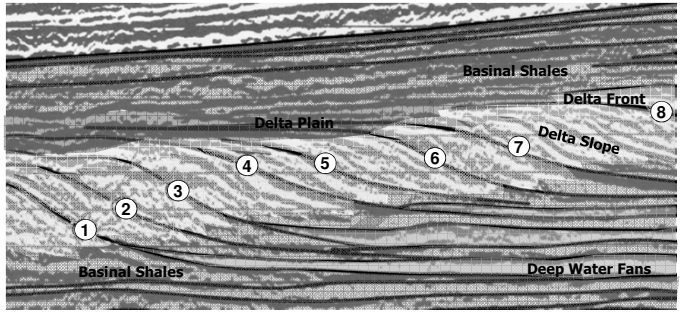

Image Courtesy of ExxonMobil

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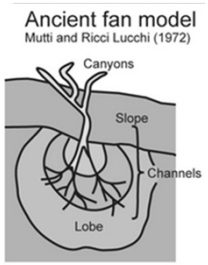
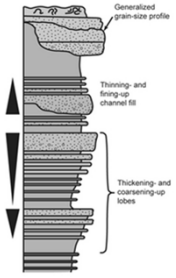
Deep Water Sands

A **turbidite** is the geologic deposit of a turbidity current, which is a type of sediment gravity flow responsible for distributing vast amounts of clastic sediment into the deep ocean.

From Wikipedia





Ancient submarine fan model of Mutti & Ricci Lucchi (1972) (left), based on vertical stacking of sedimentary rocks (right).

Modified from Mutti & Ricci Lucchi (1972) and Mutti (1992).

Both from:
http://www.nature.com/scitable/knowledge/library/submarine-fans-and-canyon-channel-systems-a-24178428

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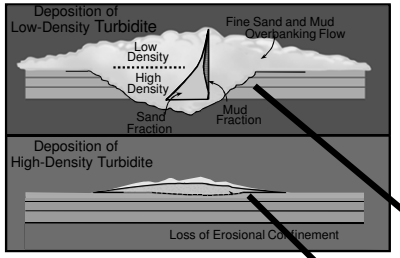
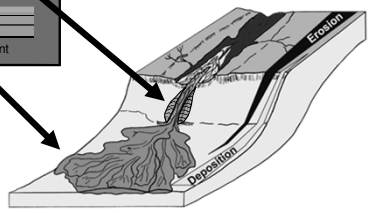
Deep Water Sand Deposition



Reservoir quality sands can be deposited as part of a confined to semi-confined channel system within canyons on the slope and rise

Reservoir quality sands also can be deposited as part of a unconfined sheet sands on the basin floor (abyssal plain)



Adapted from Beaubouef et al, 1999

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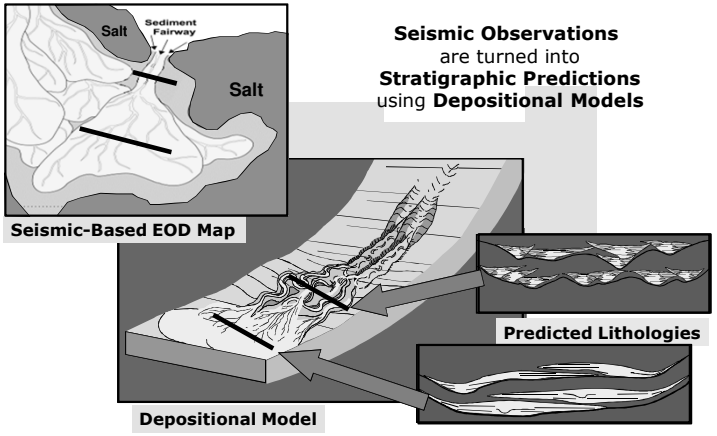
Making Predictions



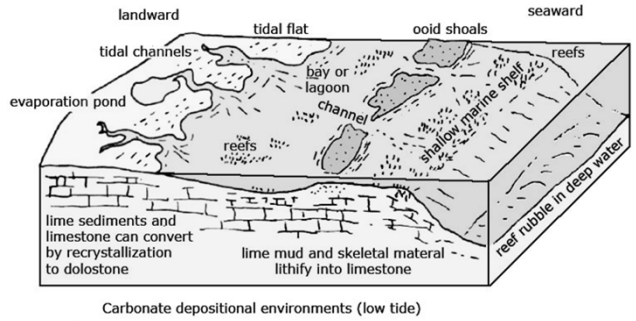
Seismic Observations are turned into **Stratigraphic Predictions** using **Depositional Models**

Carbonate Reservoirs

Conventional Reservoirs

- Clastic
  - Alluvial Fans
  - Aeolian Dunes
  - Fluvial
  - Shoreline
  - Delta
  - Deep Water
- Carbonate

Carbonate Depositional Environments

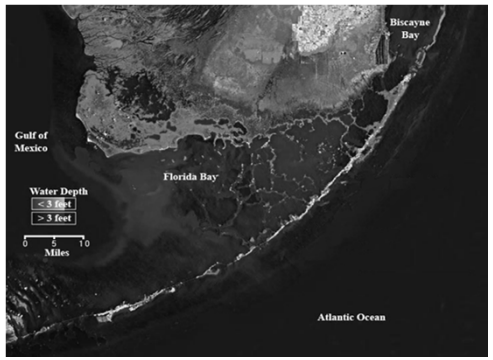


Carbonate depositional environments (low tide)

http://geologycafe.com/images/carbonate_environs.jpg

A Modern Example

South Florida is part of a growing carbonate platform with the Florida Keys consisting of a modern barrier reef complex.



http://geologycafe.com/images/south_florida.jpg

Types of Reservoirs

Conventional Reservoirs

- Clastic
- Carbonate

Unconventional Reservoirs

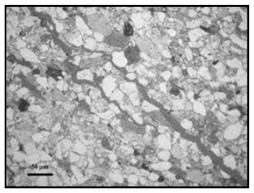
- Tight Oil/Gas Sands
- Shale Oil/Gas
- Coal Bed Methane

What is an Unconventional Reservoir?

CONVENTIONAL → **UNCONVENTIONAL**

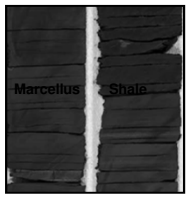
High Porosity (20-40%)
High Permeability

Fluids flow easily through the rock (100' s – 1000' s bbls/day)



Moderate Porosity (10-20%)
Moderate Permeability

Fluids flow poorly through the rock (10' s – 100' s bbls/day)



Ultra Low Porosity (2-10%)
Ultra Low Permeability

Fluids will NOT flow naturally
Fluids will only flow if fracture stimulated (10' s – 100' s bbls/ day when frac' d)

References

Slide 4: http://echo2.epfl.ch/VICAIRE/mod_3/chapt_1/main.htm Figure 1.13

Slide 5: http://petroleum101.com/what-is-a-petroleum-reservoir/ fourth figure

Slide 9: http://pixshark.com/nile-delta.htm image 13

Slide 11: http://www.nature.com/scitable/knowledge/library/submarine-fans-and-canyon-channel-systems-a-24178428 Figure 5, which references:

Mutti, E., and Ricci Lucchi, F., 1972, Le torbiditi dell'Appennino settentrionale: introduzione all'ananisi di facies: Memoirs Soc. Geol. Italiana, v. 11, p. 161-199

Slide 12: Beaubouef, R.T., Rossen, C., Zelt, F.B., Sullivan, M.D., Mohrig, D.C>, & Jennette, D.C. 1999. Deep-water sandstones, Brushy Canyon Formation, West Texas. AAPG Continuing Education Course Note Series #40, The American Association of Petroleum Geologists, Tulsa.

Slide 15: http://geologycafe.com/images/carbonate_environs.jpg

Slide 16: http://geologycafe.com/images/south_florida.jpg