Geology & Geophysics

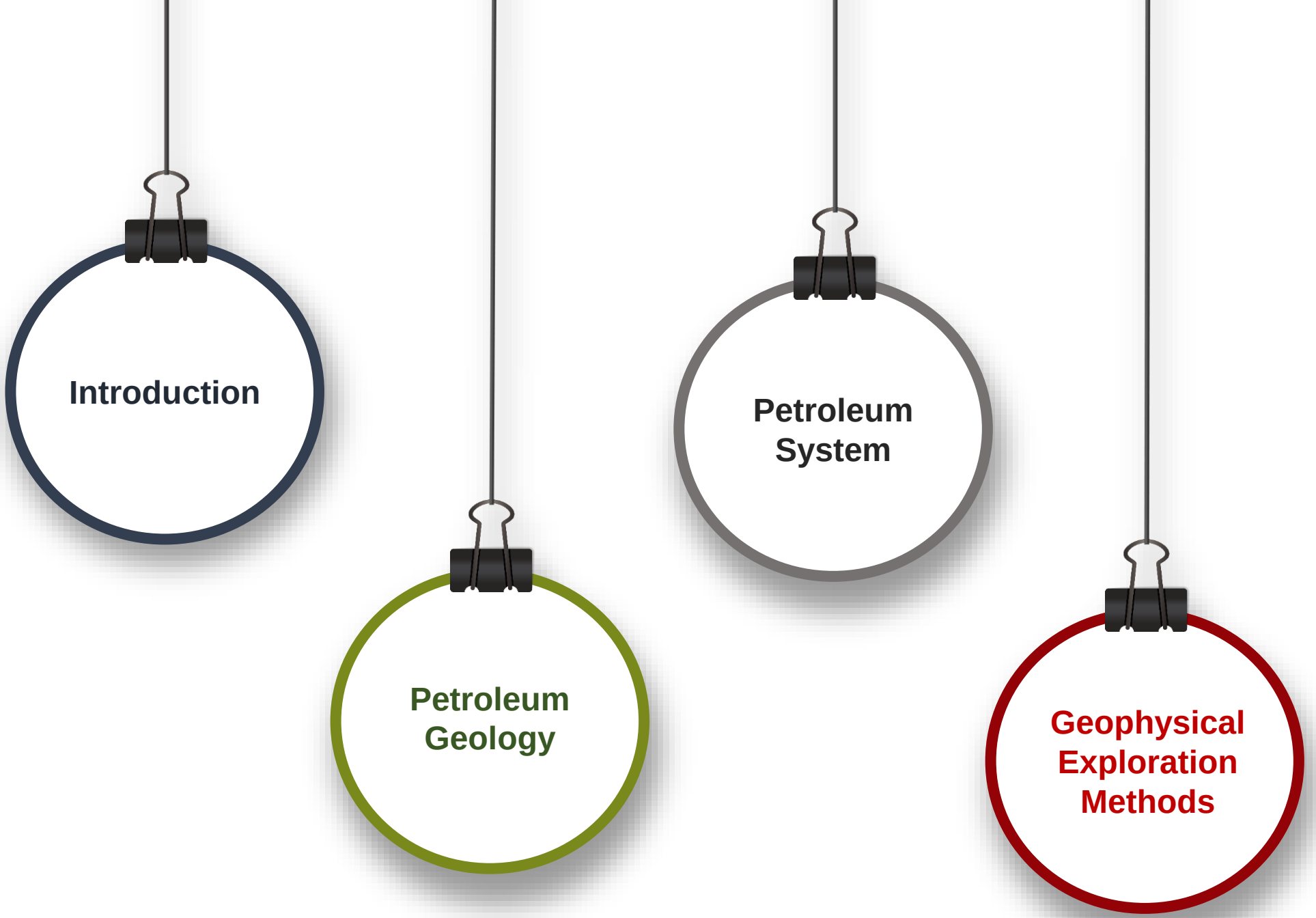
The Science of Oil & Gas Exploration

Ahmed Selem
Upstream Oil and Gas Consultant
AMS Oil and Gas Consultancy
ahmed.selem@amsconsultancy.co.uk

SPE Seminar: Introduction to E&P
28 November 2019
The Geological Society of London

London Section

Outline


Introduction
Petroleum Geology
Petroleum System
Geophysical Exploration Methods

Geoscience in Oil and Gas Exploration

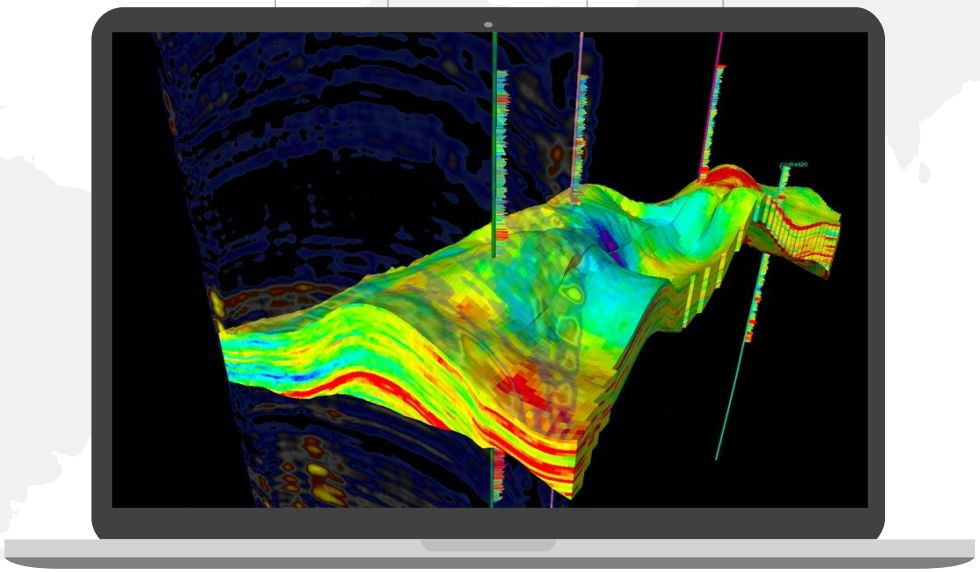
Scientific Multitasking

Geological Data
Field analysis to find the elements of a petroleum system
(scale of 10s - 100s of miles)

Geophysical Data
An image of the subsurface formations and structures
(scale of miles)

Regional Data
Satellite imaging
(scale of 100s of miles)

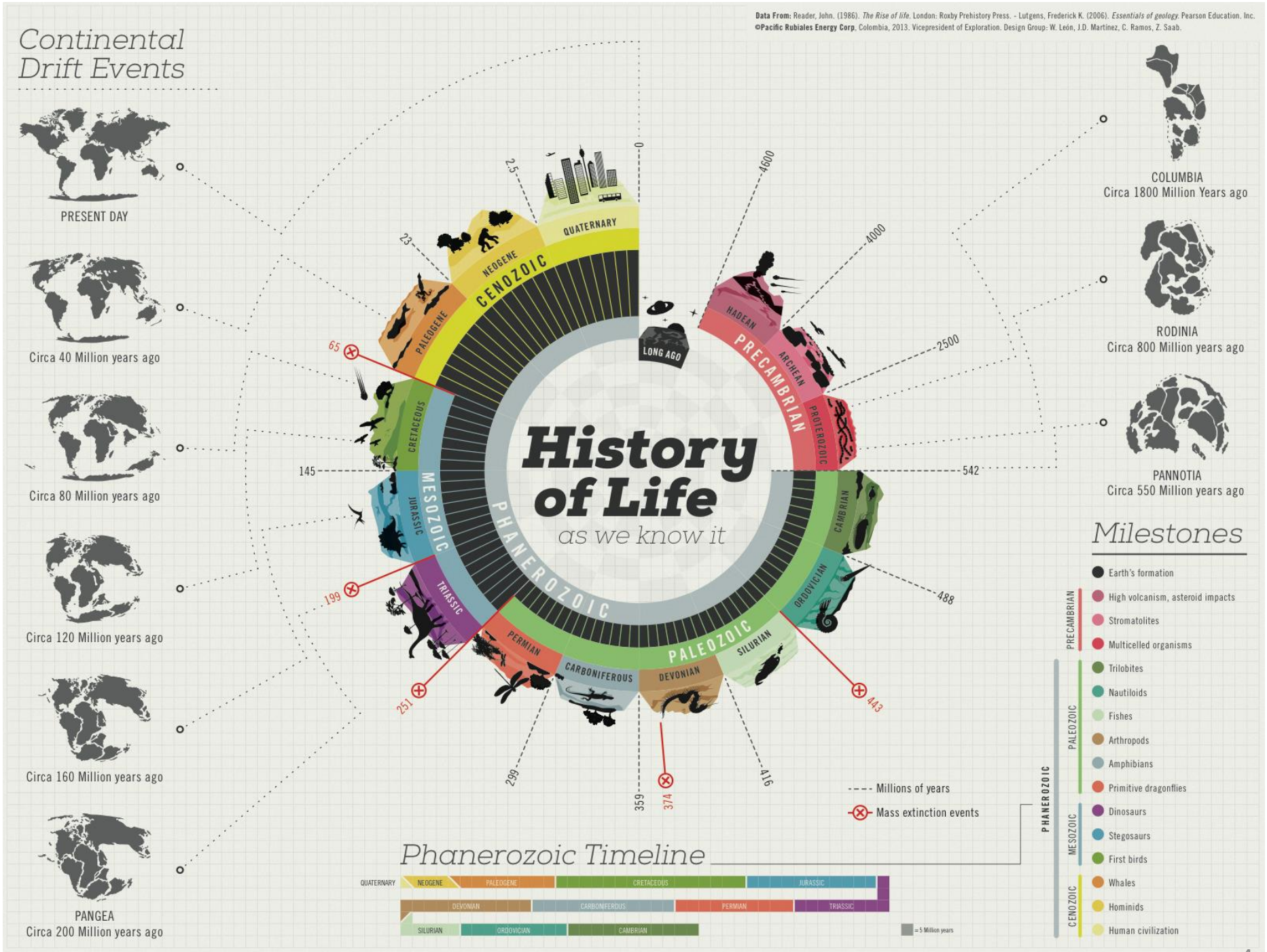
Well Data
Detailed description of the reservoir rock
(scale of inches to microns)



Petroleum Geology

Geological Time Scale

- GTS is used by geologists to describe the timing and relationships of events that have occurred during Earth's history.
- Most oil deposits existing today were formed in the Mesozoic age.



Rock Types and Cycle

Igneous

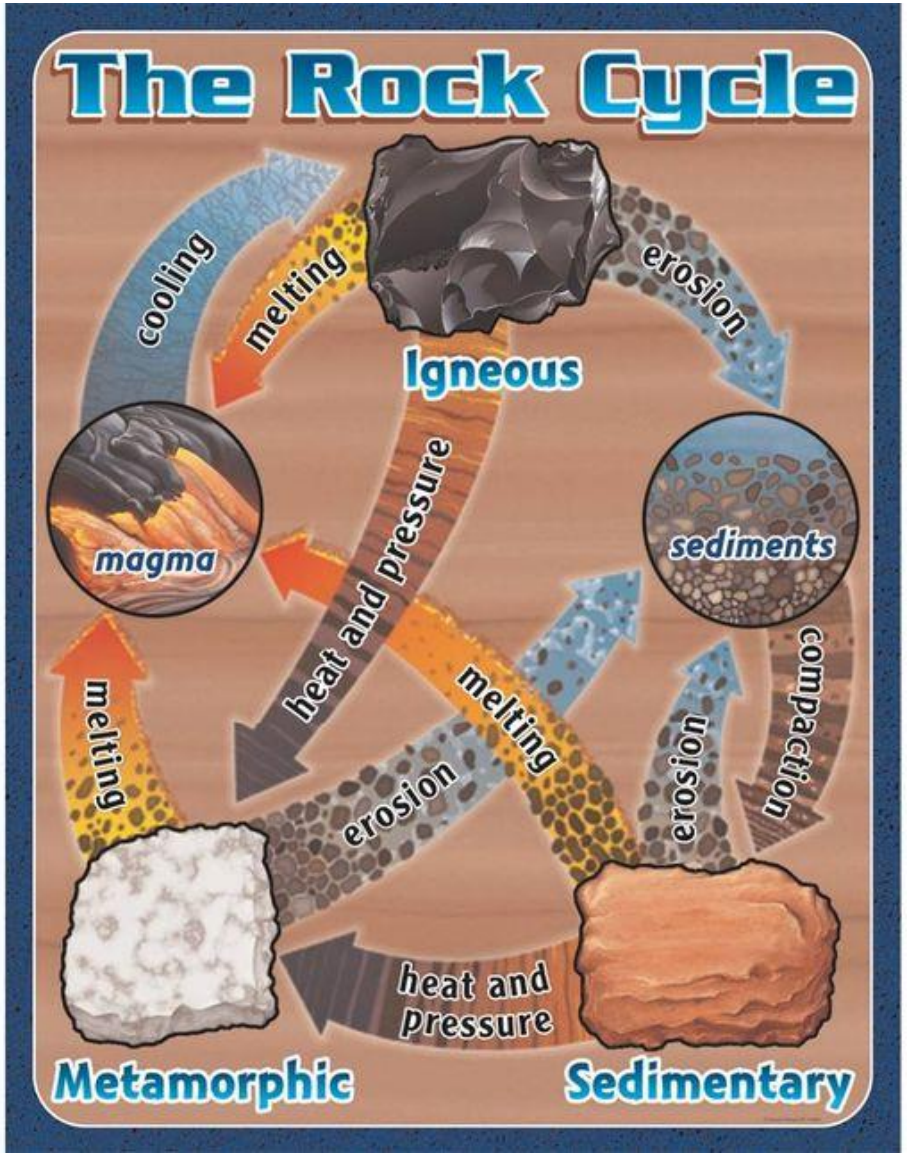
Igneous rocks are formed when magma (molten rock deep within the earth) cools and hardens.

Metamorphic

Metamorphic rocks are formed under the surface of the earth from the metamorphosis (change) that occurs due to intense heat and pressure (squeezing).

Sedimentary

Sedimentary rocks are formed from particles of sand, shells, pebbles, and other fragments of material. Together, all these particles are called sediments.

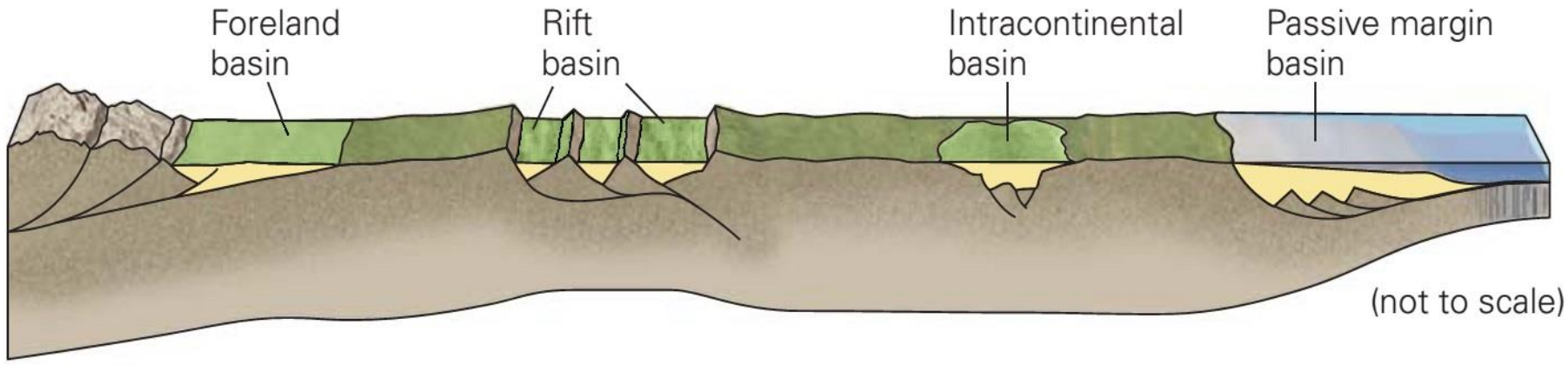


Hydrocarbons are associated with sedimentary rocks.

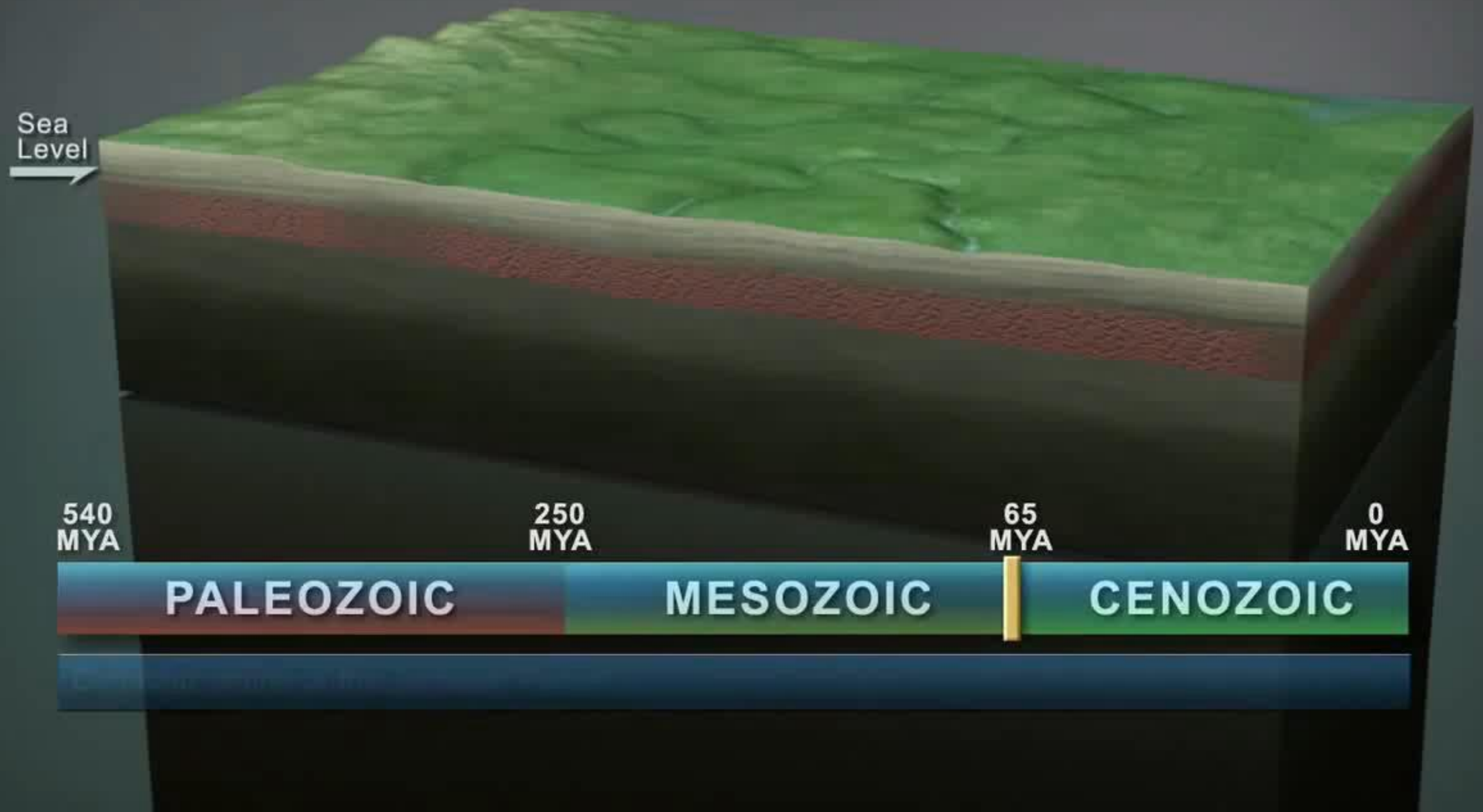
Sedimentary Basins: Home of Hydrocarbons

Most of the world's hydrocarbons are concentrated in sedimentary basins created by tectonic activity in diverse geological settings.

Sedimentary basins are regions of Earth of long-term subsidence creating accommodation space for infilling by sediments.

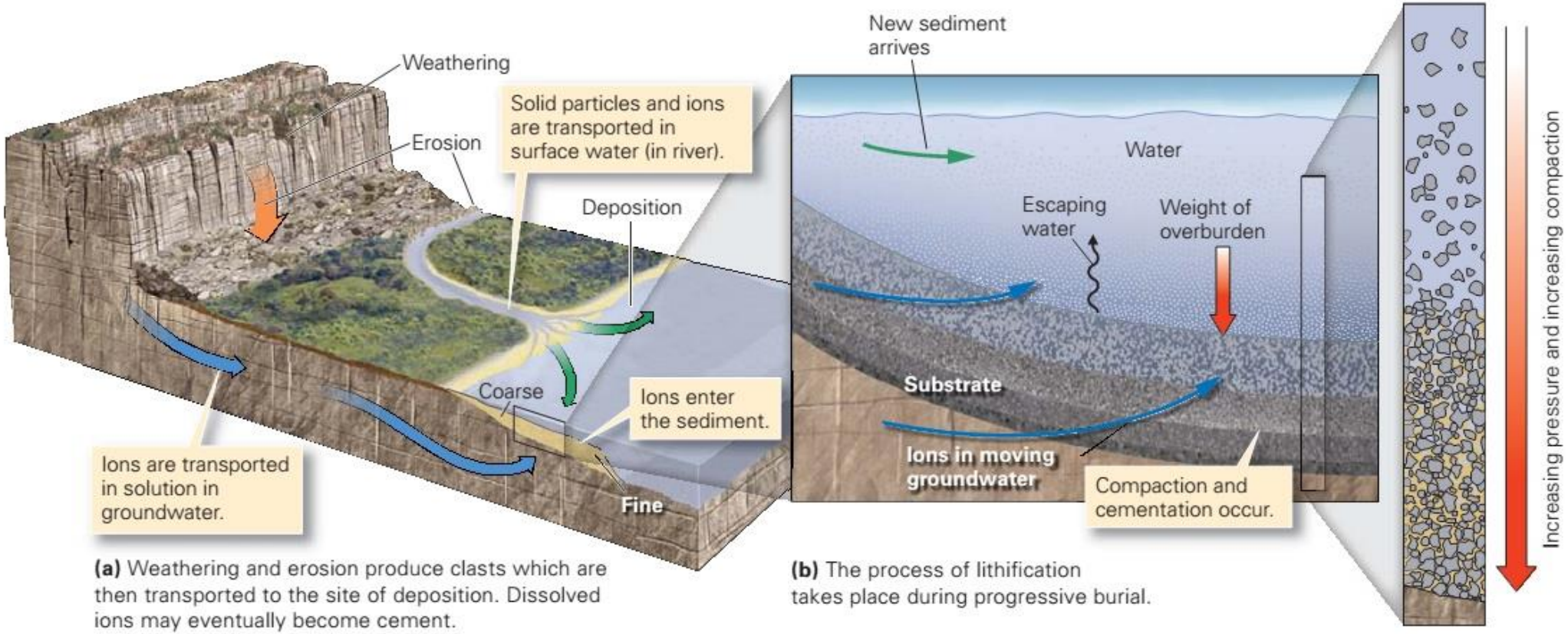


geologylearn.blogspot.com/2016/03/sedimentary-basins


Sea
Level
540
MYA
250
MYA
65
MYA
0
MYA
PALEOZOIC
MESOZOIC
CENOZOIC

Formation of Sedimentary Rocks
Clastic Rocks

- They form by the cementing together or consolidation of grains derived from pre-existing rocks.
- Examples: Sandstones and shales



(a) Weathering and erosion produce clasts which are then transported to the site of deposition. Dissolved ions may eventually become cement.

(b) The process of lithification takes place during progressive burial.

geologylearn.blogspot.co.uk/2016/03/sedimentary-basins

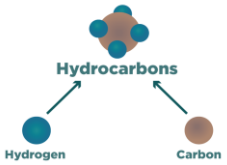
Formation of Sedimentary Rocks

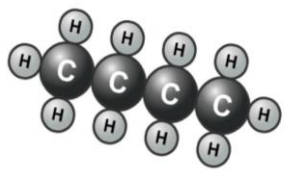
Carbonate Rocks

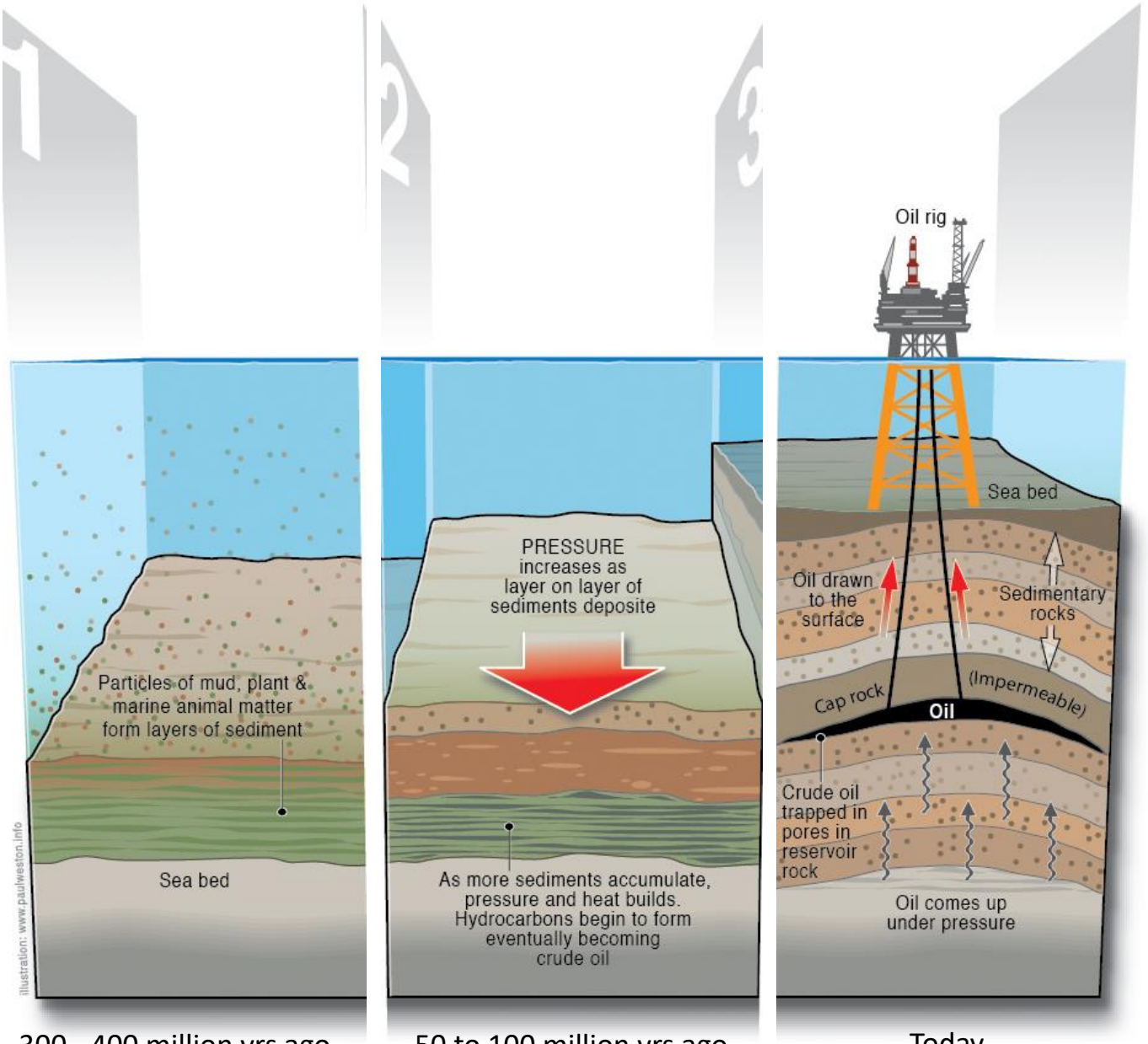
- Formed by chemical & physical processes.
- Composed mainly of carbonate minerals.
- Carbonates form mainly in tropical marine environments.
- Examples: limestone and dolomite.

Hydrocarbons Formation

- Hydrocarbons form as a result of the degradation of plant material and bacteria.
- The process takes millions of years.
- It requires deep burial, high temperature and pressure.
- Hydrocarbons are chains of hydrogen and carbon.







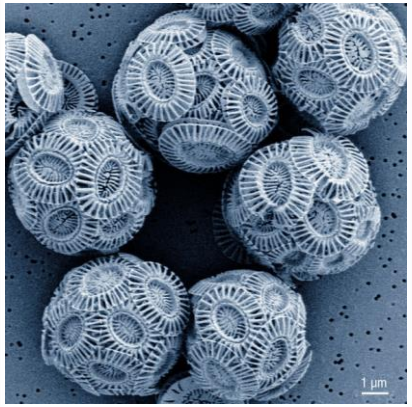
300 - 400 million yrs ago

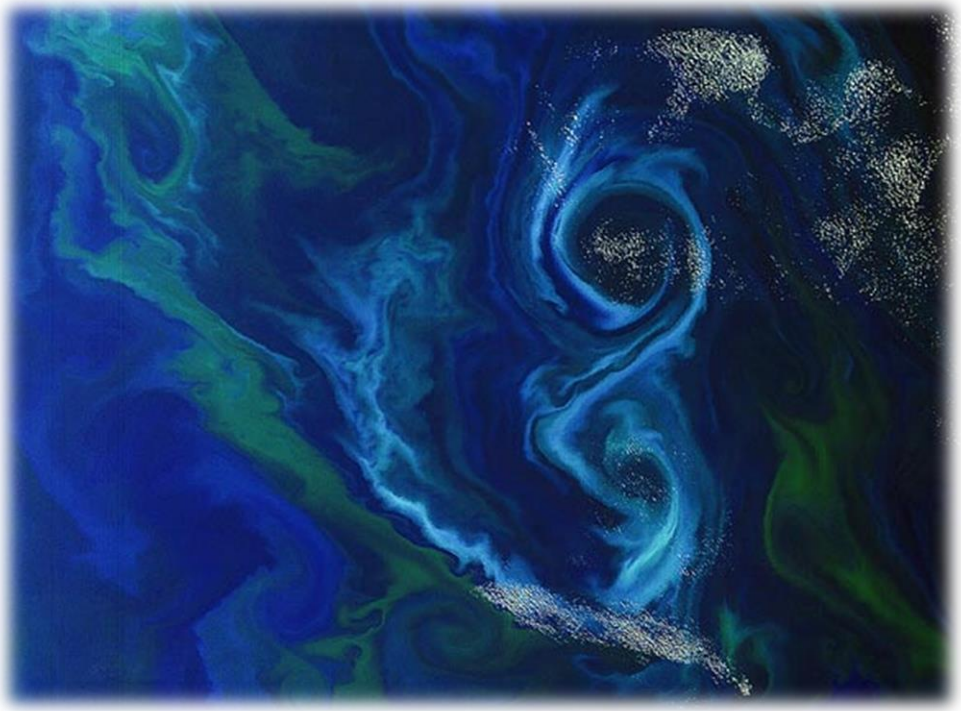
50 to 100 million yrs ago

Today

Algae Blooms: The Source of Hydrocarbons

Coccolithophores are colouring the water of the Atlantic Ocean bright blue.





An algae bloom in the shape of a figure 8 in the south Atlantic Ocean.

Algae: tiny sea organisms

The Petroleum System

A concept that includes all the geologic elements and processes that are essential if an oil and gas accumulation is to exist.

Petroleum System

Elements & Processes

❑ Petroleum System Elements

- Source rock
- Reservoir rock
- Seal rock
- Overburden rock

❑ Petroleum Systems Processes

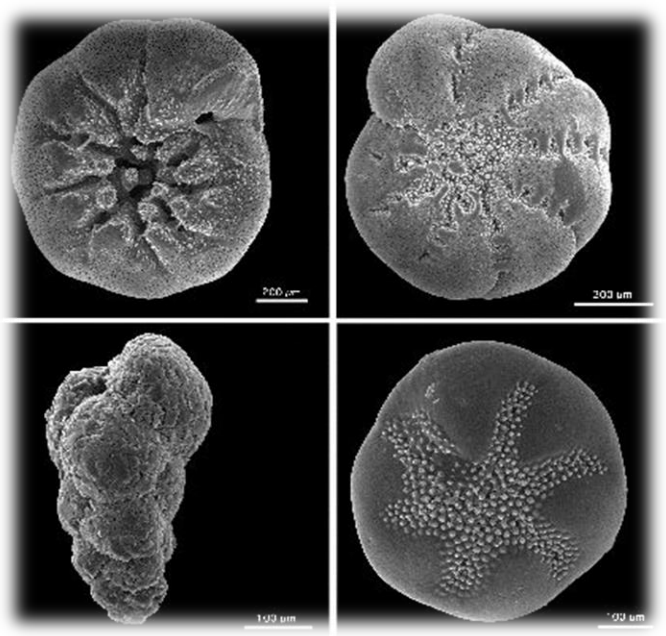
- Trap formation
- Generation, migration, accumulation of hydrocarbons

Petroleum System Elements
Source Rock

- Source Rock conditions:
  - Abundance of organic matter
  - Lack of oxygen
  - Deep burial

- Most of the organic matter found in sediments is contained in shales.

Microscopic marine animals



Kimmeridge Clay - World Class Source Rock

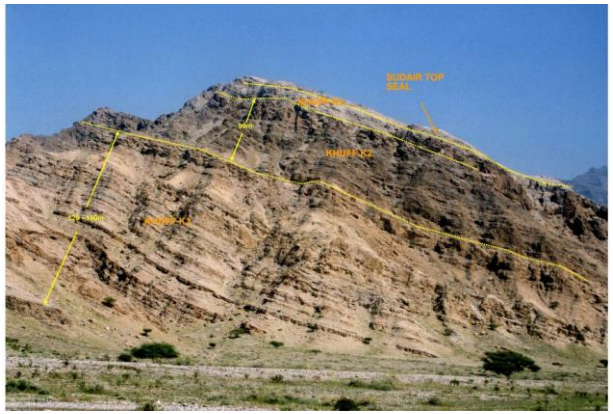
www.southampton.ac.uk/~imw/Kimmeridge-Bay

Petroleum System Elements
Reservoir Rock

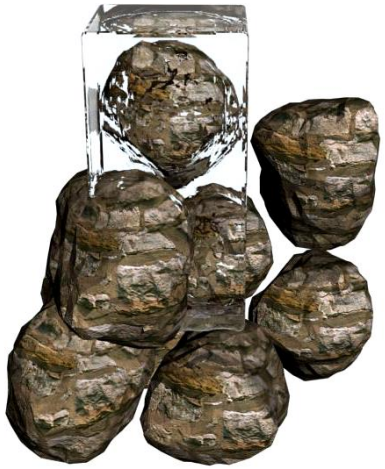
- Reservoir rocks are any porous and permeable rocks capable of containing hydrocarbons and producing them.

- Reservoir lithologies include:
  - Sandstone
  - Limestone (Carbonates)

Sherwood Sandstone

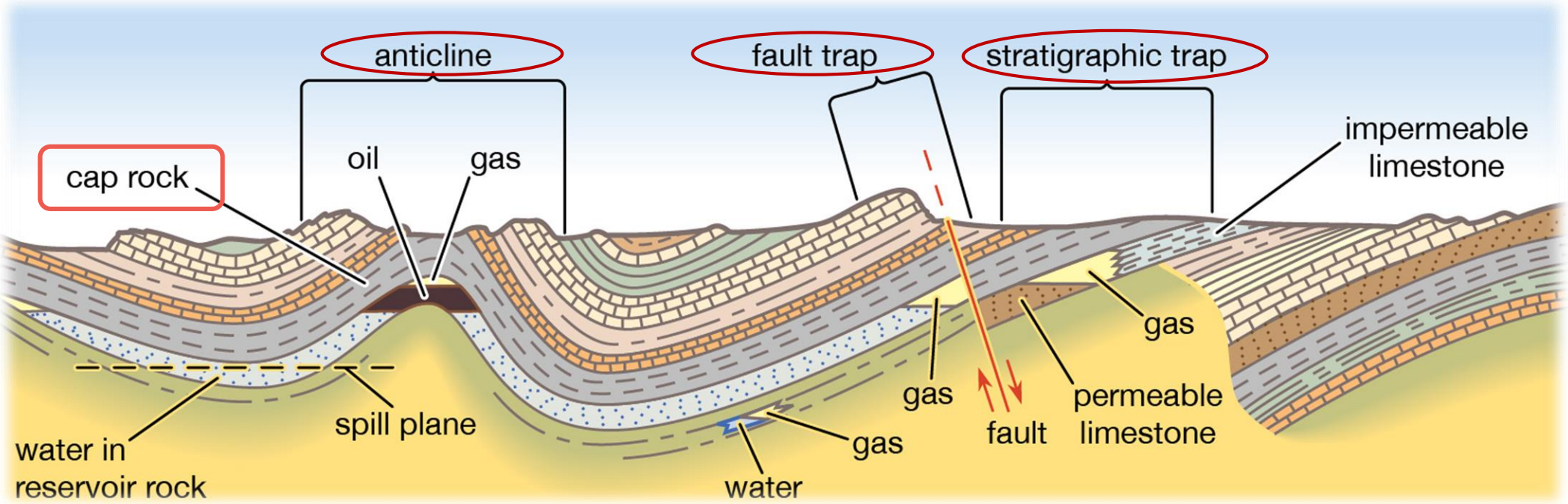


Khuff Carbonates: A major Reservoir



Petroleum System
Seals and Traps

- **Seal/cap** rocks are impermeable to prevent leakage from the trap.
- Shales and Evaporites are the most common seal rocks.
- Traps are 3-D configurations that pools the hydrocarbons.



Source: Encyclopedia Britannica

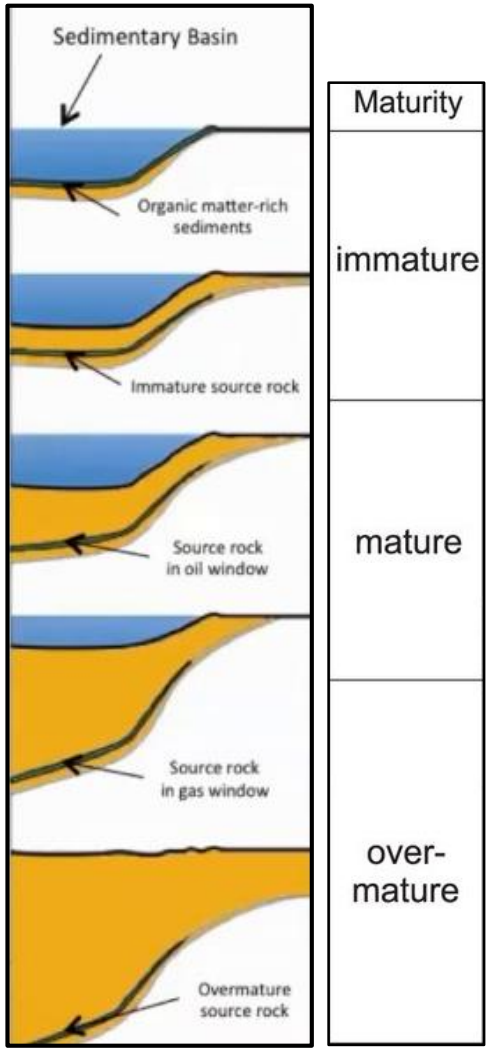
Petroleum System Processes
Trap Formation

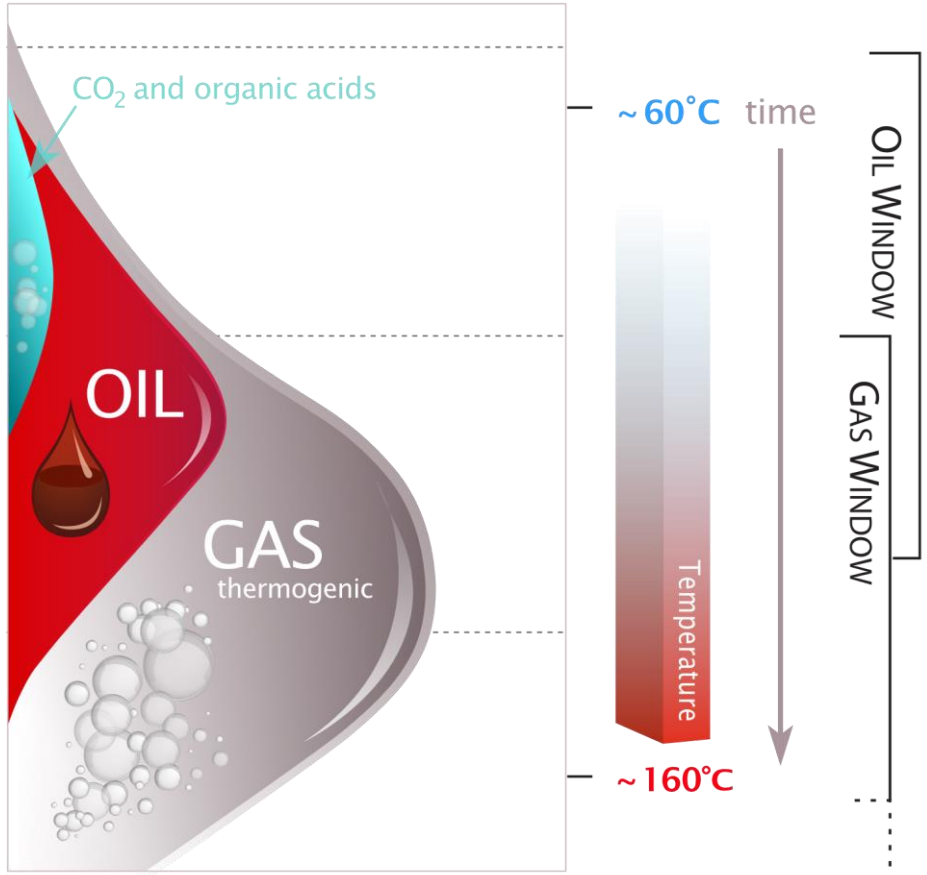
- Structural traps are formed by structural features, usually as a result of tectonics.
- Stratigraphic traps are formed by changes in rock type/quality.
- The development of salt domes can deform rock units into traps that hold oil and gas.

Courtesy of dome energy

Petroleum System Processes
Generation & Maturation

- As the source rock is buried, it is heated.
- Organic matter is first changed by the increasing temperature into Kerogen (a solid form of hydrocarbons).
- And then, with increased pressure and temperature, it is changed into a liquid state – oil.

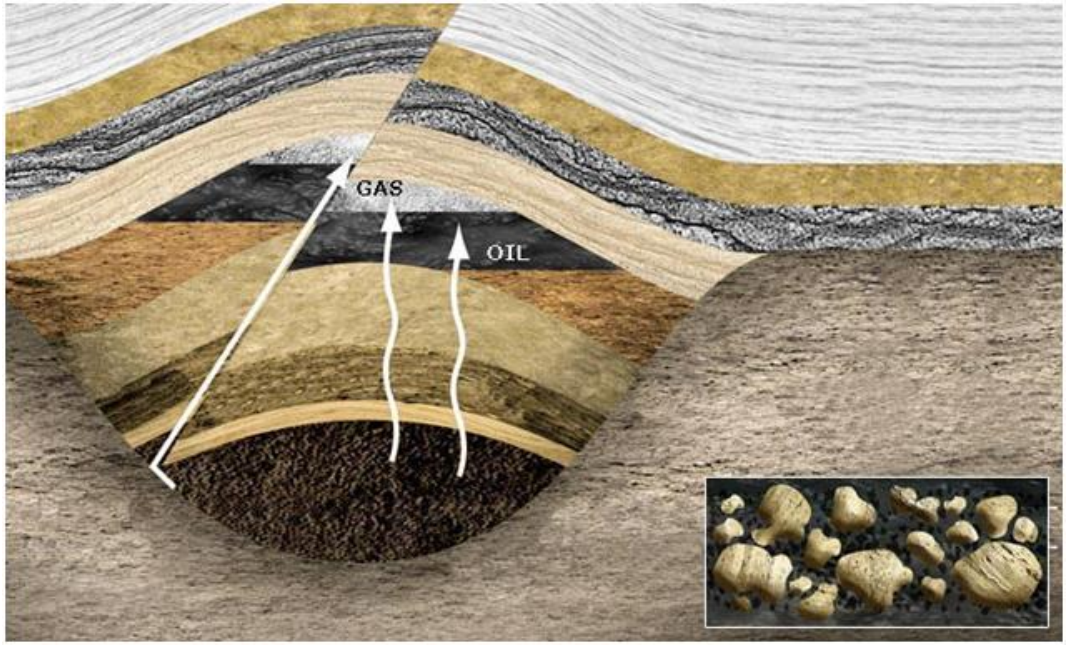




Petroleum System Processes
Migration & Accumulation

- Oil is less dense than water and will rise through the fluid system of the surrounding rock.
- Carrier beds are rock layers that allow fluids to pass through them.
- Oil will move up until it is stopped by a ”seal” and it is collected in a reservoir rock.

Oil on the move

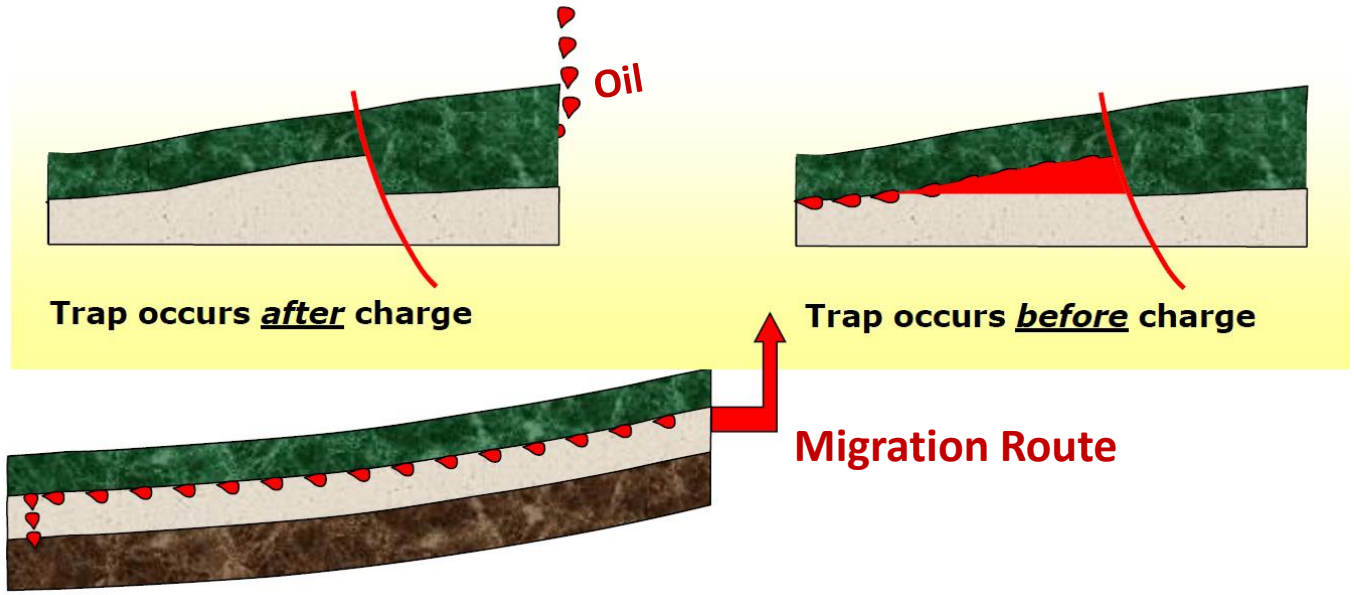


This takes a very long time!

Critical Moment

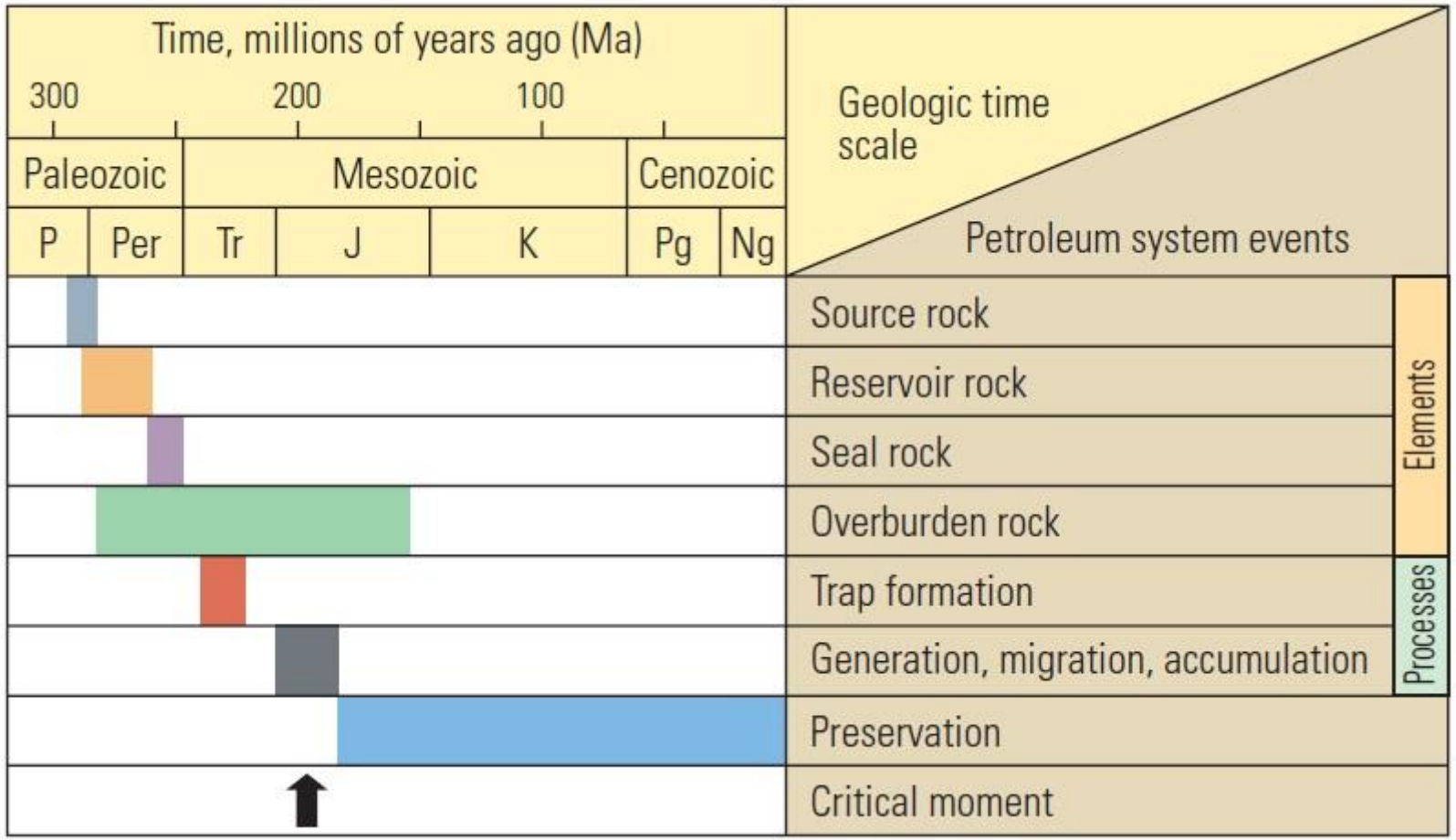
- This is the time of generation, migration and accumulation of most of the hydrocarbons.

- The critical moment occurs when 50 - 90% of source rock organic matter has transferred to hydrocarbons.

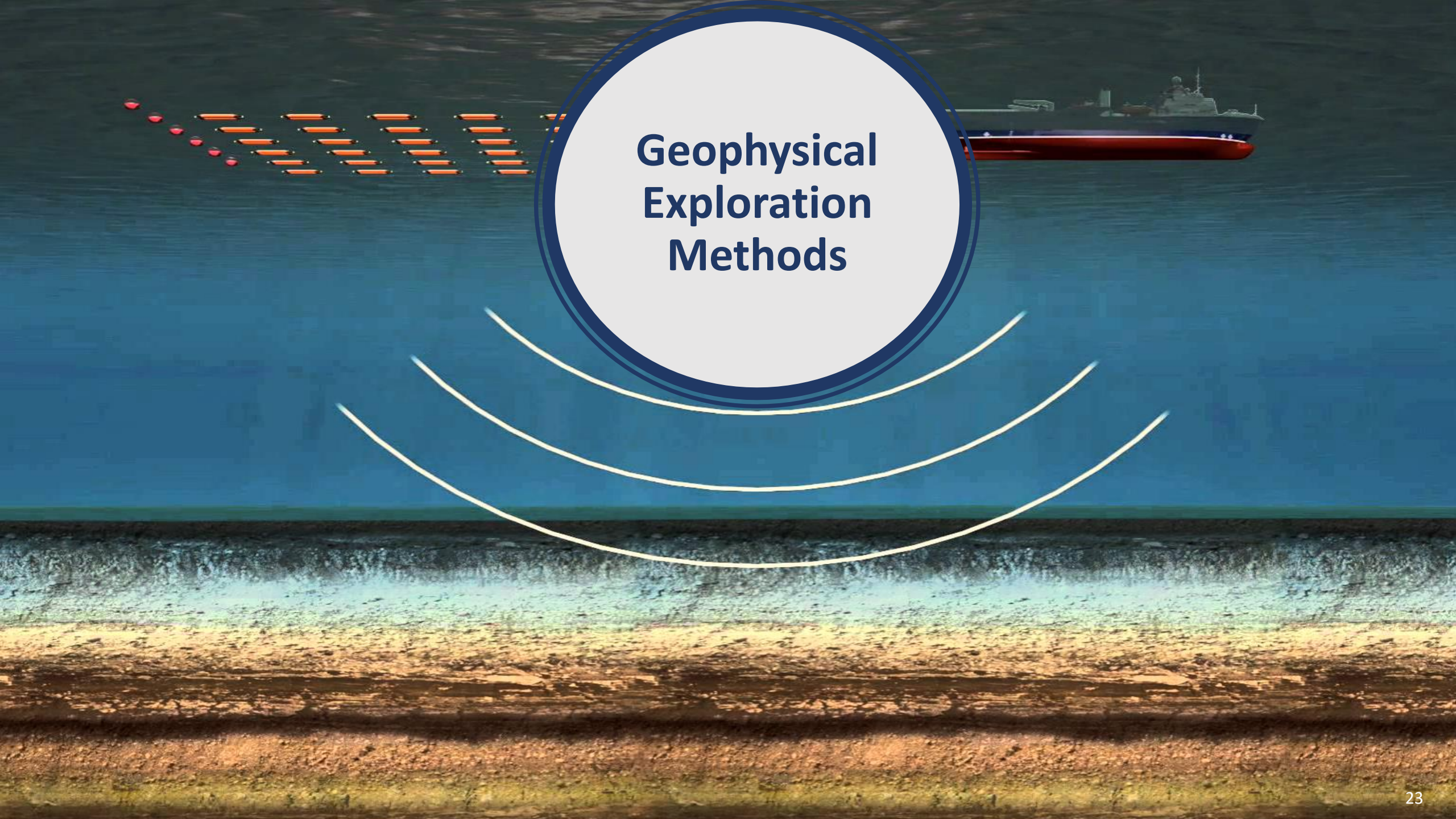


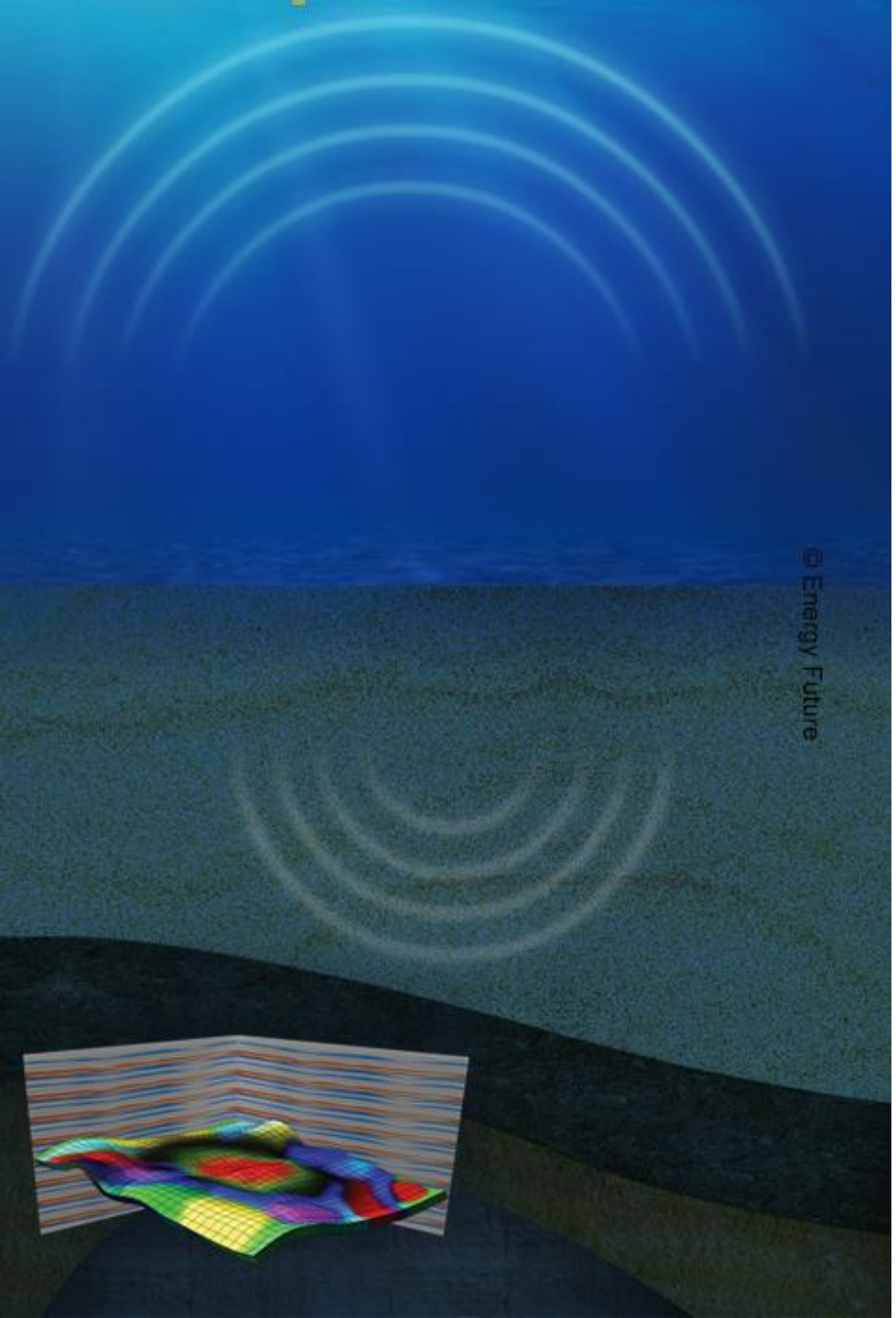
Petroleum System Timing

An events chart depicting timing of a petroleum system. Each of the coloured horizontal bars represents the time span of an event.



Source: Schlumberger Oilfield Review: Basin and Petroleum System Modelng


Geophysical
Exploration
Methods



Seismic
The sound of the subsurface

- Seismic data from acoustic waves is one of the most important tools for discovering new oil and gas-bearing reservoirs.
- Sound waves are bounced off underground rock formations.
- The waves that reflect back to the surface are captured by recording sensors.
- Analysing the time the waves take to return provides valuable information about rock types and possible fluids in rock formations.

Seismic Applications in E&P

❑ **Exploration**

To determine structures and stratigraphic traps to be drilled and accurately plan locations for wells.

❑ **Appraisal and Development**

For reserves estimation and formulation of field development plans.

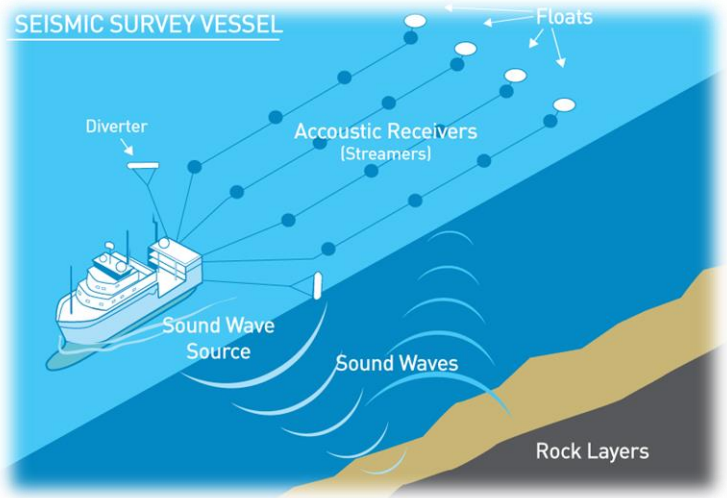
❑ **Production & Reservoir Management**

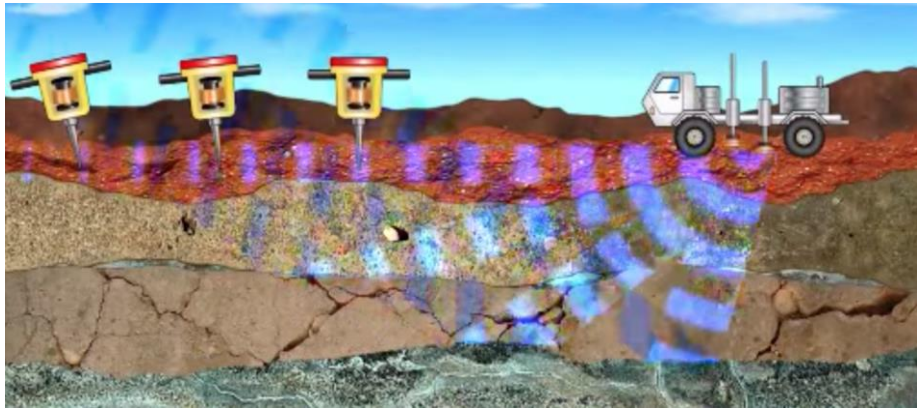
For reservoir surveillance purposes such as:

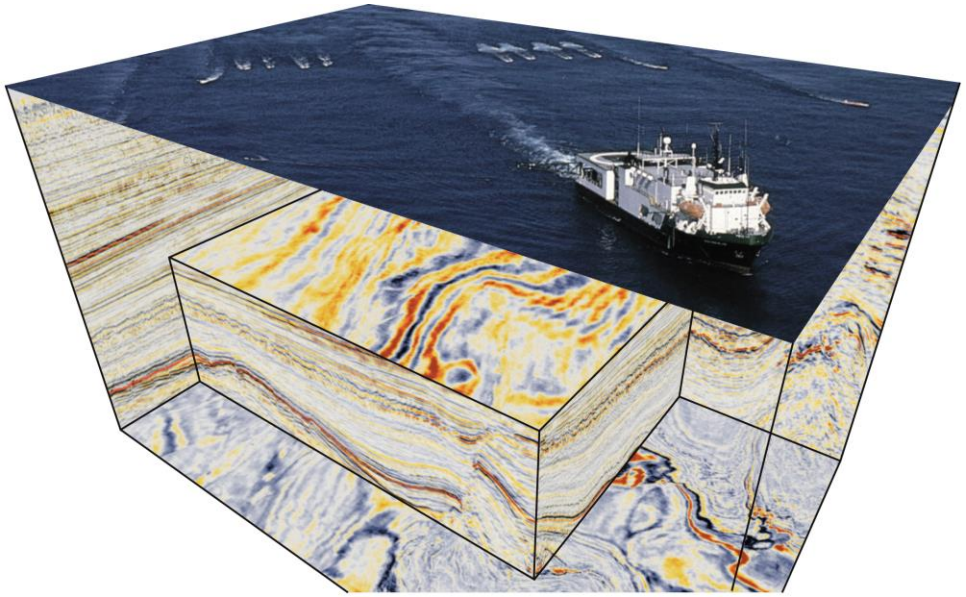
- Observing movement of fluids contact
- Understanding how the reservoir reacts to waterflooding or gas injection
- Locating untapped pockets of hydrocarbons within the reservoir

Seismic Surveys
Land & Marine


Courtesy of Schlumberger



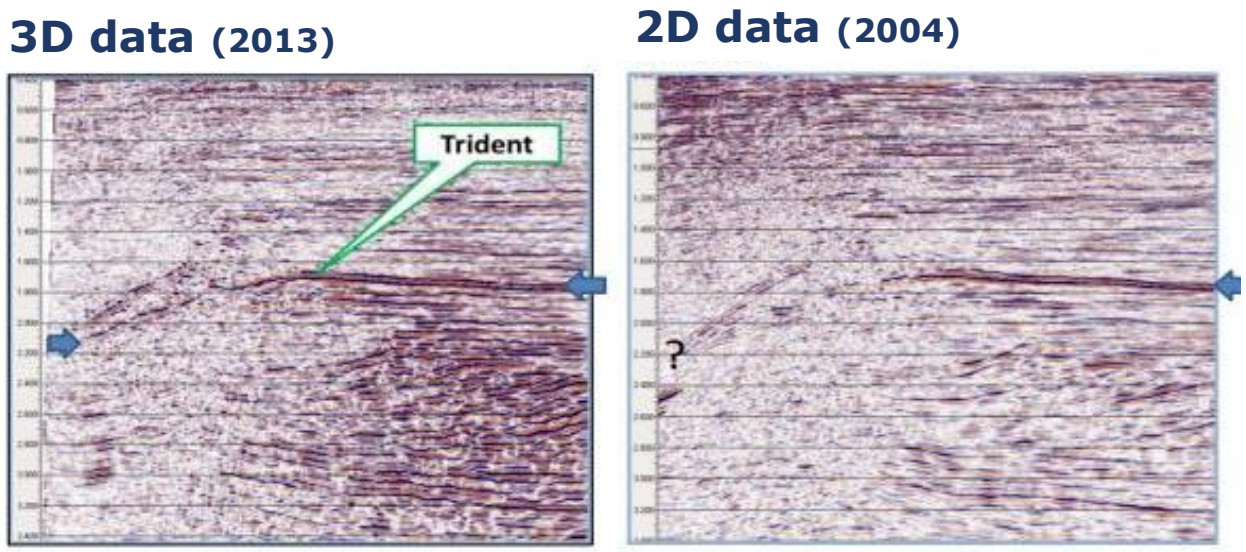

Courtesy of Queensland resources Council


www.iris.edu/gallery3/research/lrsp/SB13

2D/3D Seismic

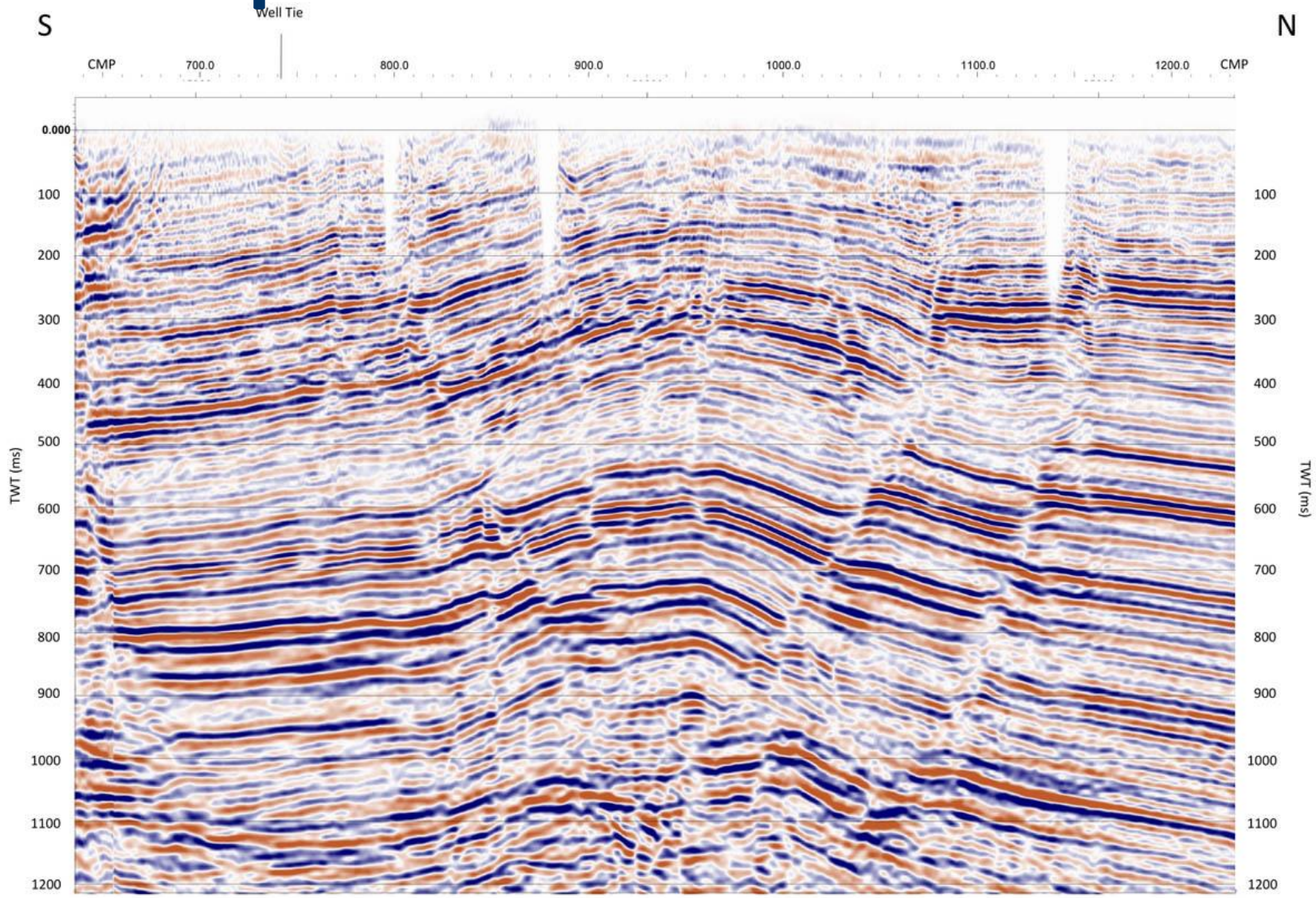
- **2D seismic** survey produces a 2D plane (slice) of data representing the formations directly below the line of geophones.
- **3D seismic** consists of a uniform grid of criss-crossed lines of geophones. A cube-shaped model of the subsurface structures can be built.

Trident Prospect



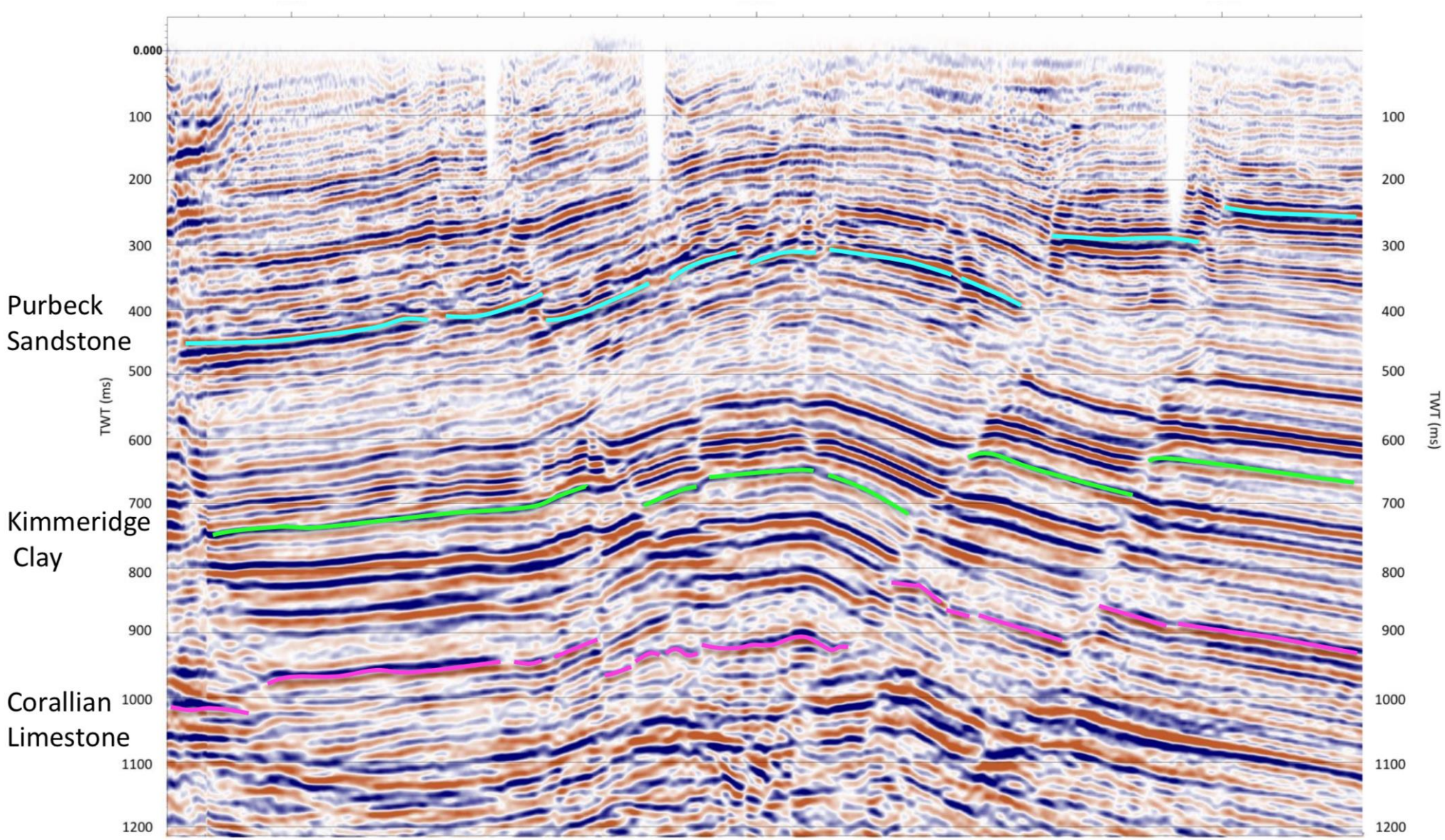
Source: Tangiers Petroleum

Seismic Interpretation

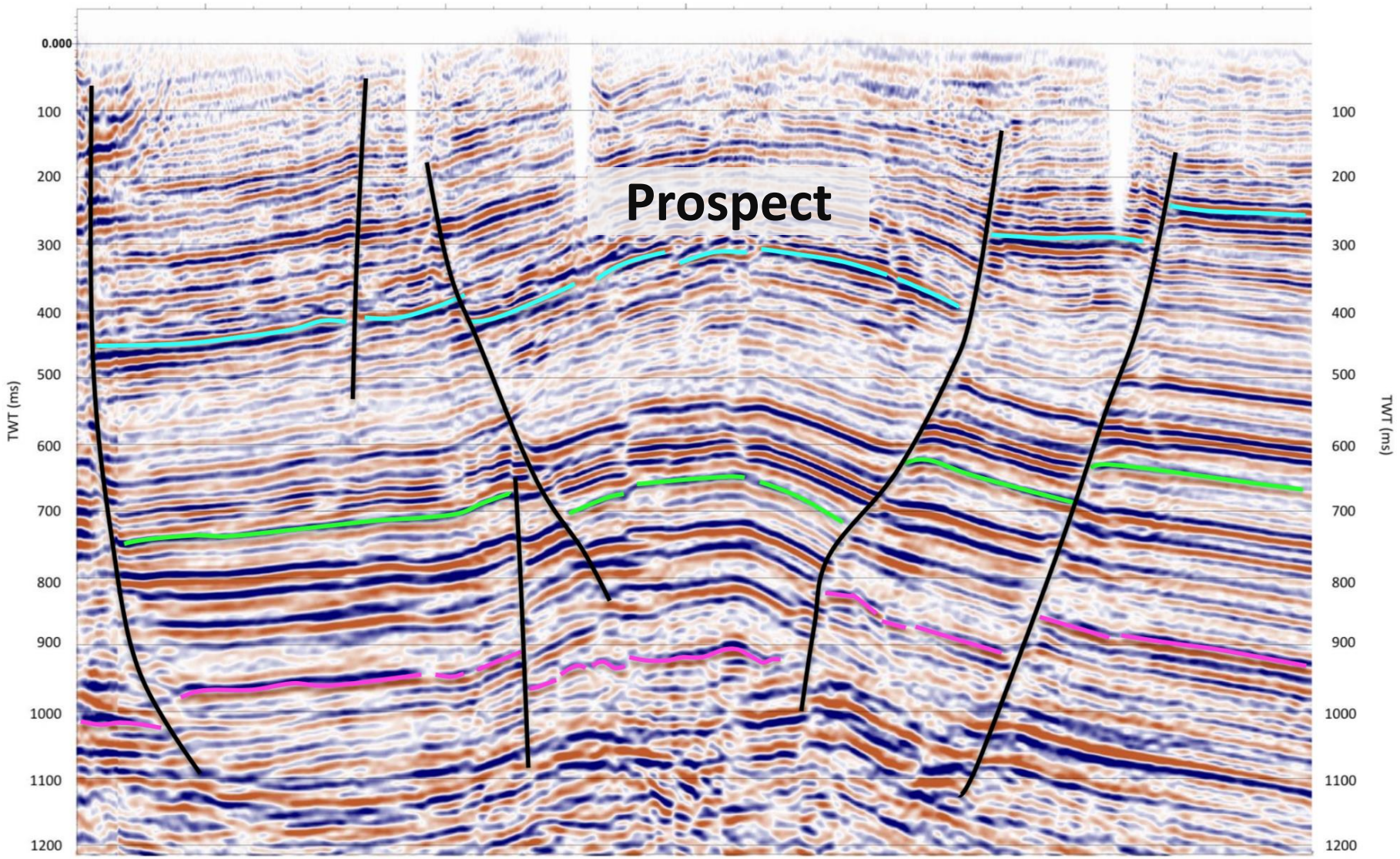


Courtesy of sub-surf rocks

Horizons


Purbeck Sandstone
Kimmeridge Clay
Corallian Limestone
TWT (ms)
0.000
100
200
300
400
500
600
700
800
900
1000
1100
1200

Faults

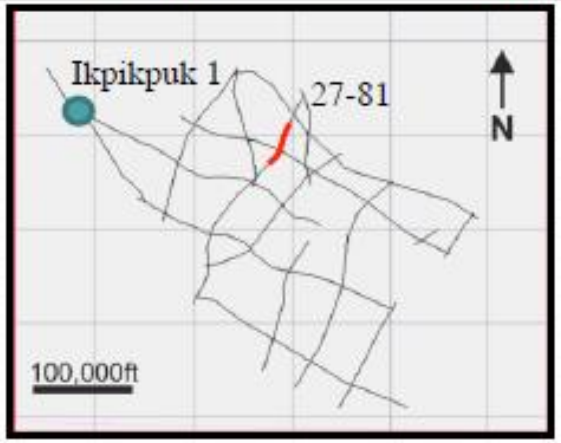


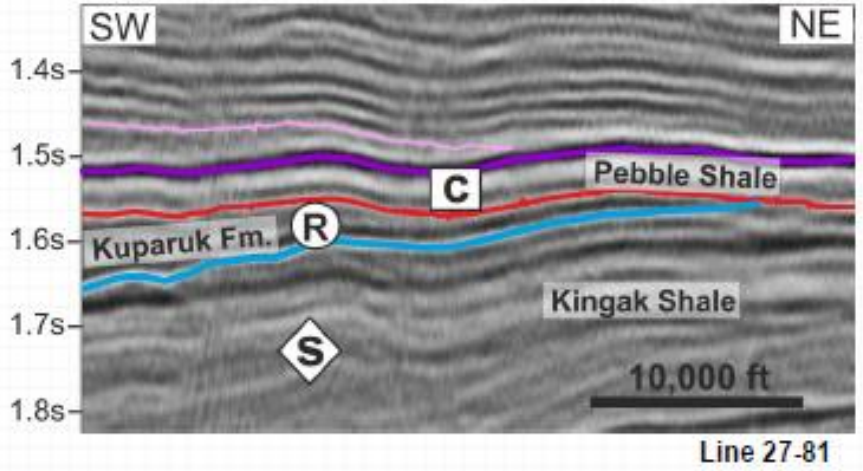
A prospect is a potential hydrocarbons target that is recommended for drilling based on geological and geophysical indications/evidence.

Prospect Evaluation

Source Presence	0.75
Charge Access	0.8
Reservoir Presence	0.7
Reservoir Deliverability	0.8
Trap Presence	0.65
Seal Presence/Column	0.8

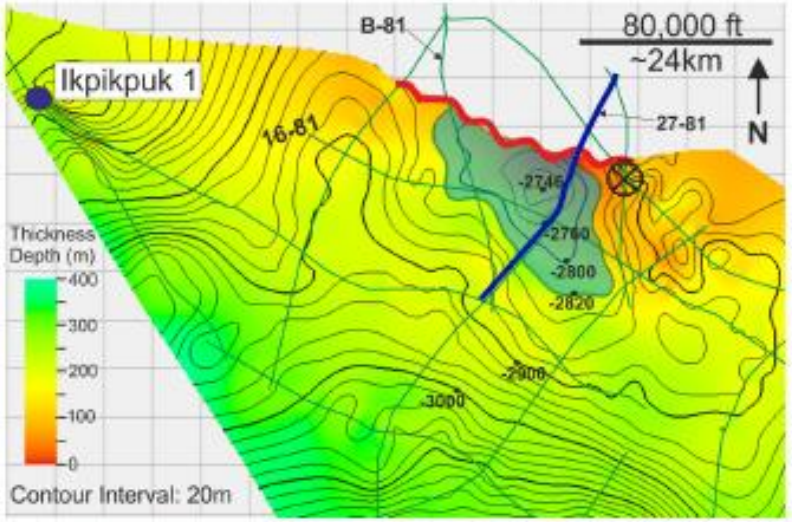
Probability of Success = **17.5%**





Line 27-81

Volumetrics	P50 Value
GRV ($km^2.m$)	23961
Recovery Factor	35.9%
Oil in Place (mmstb)	1227
Recoverable Oil (mmstb)	**427**



Combination Trap: truncation,/ 3-way dip

Exploration Drilling

To Drill or not to Drill?

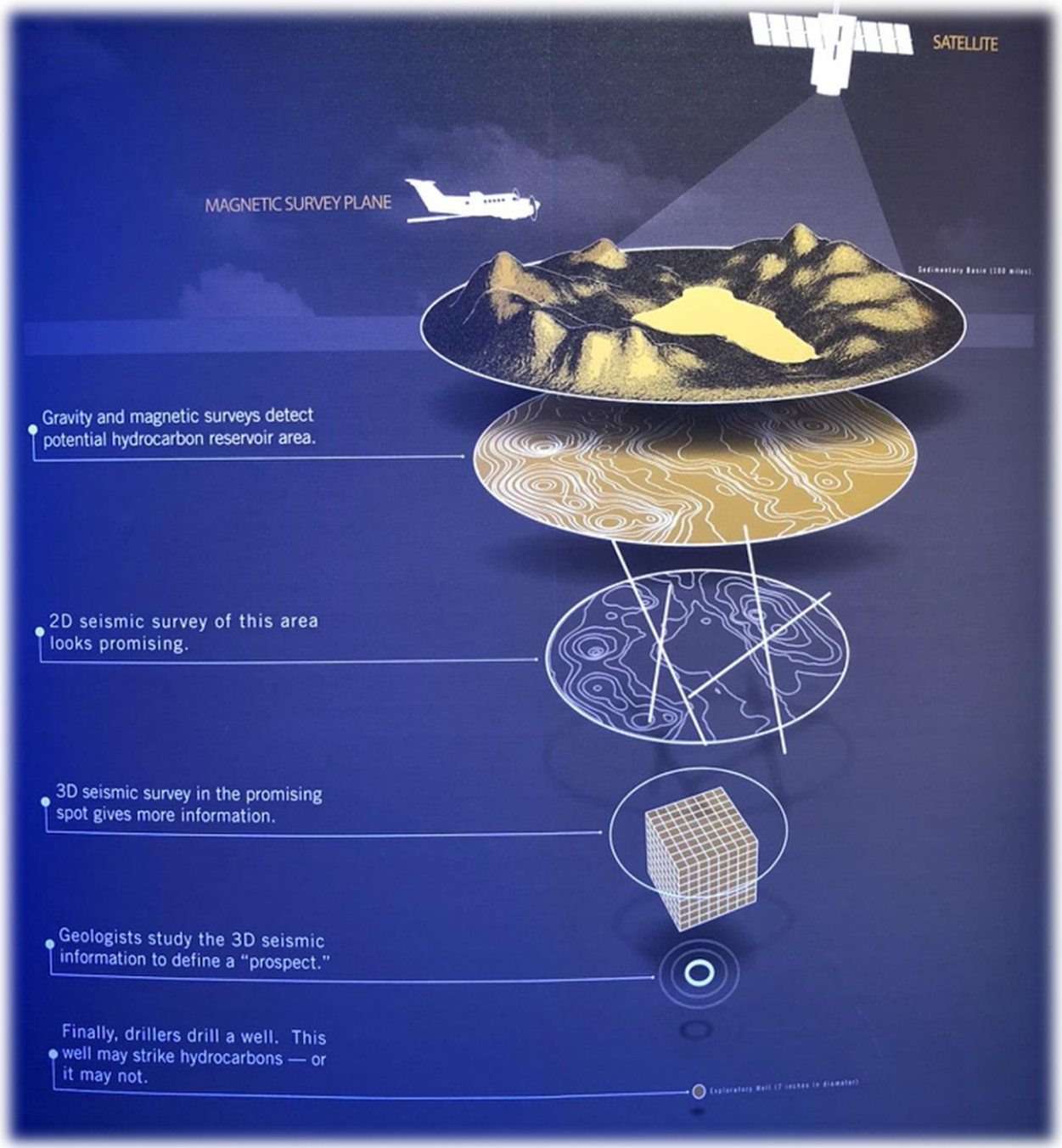
Chance of success of Exploration Wells

- ❑ New areas (no previous exploration):
  10 to 20%
- ❑ Geologically known areas:
  20 to 30%
- ❑ Areas close to production zones:
  60%

Summary

Narrowing Down the Search for Hydrocarbons

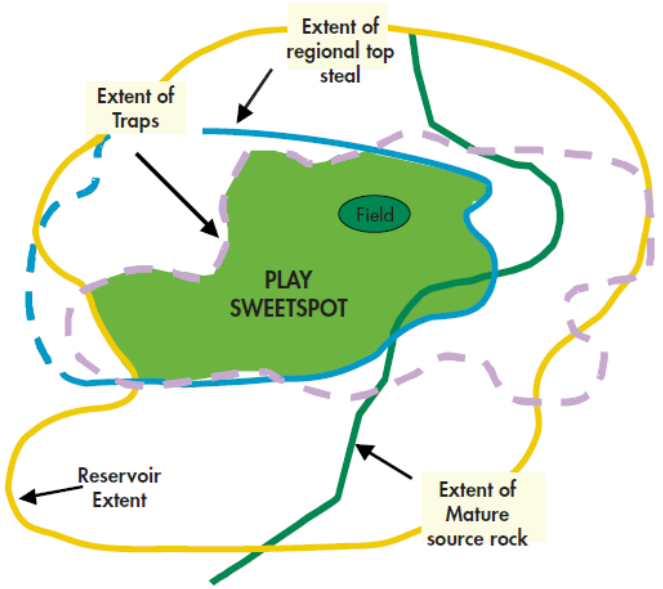
- ❑ Remote Sensing – e.g. Satellite Imaging
- ❑ Geological Mapping
- ❑ Geophysical Surveys
  - Gravity Surveys
  - Magnetic Surveys
  - 2D and 3D Seismic Surveys
- ❑ Exploration Drilling



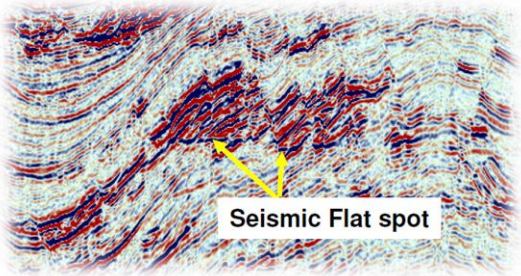
Source: Wiess Energy Hall, Houston

Conclusions

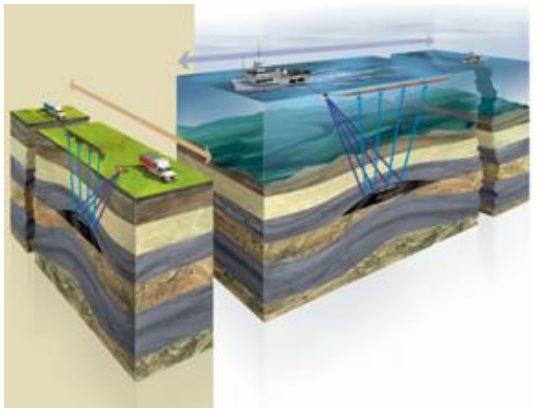
- Characterising the elements of a petroleum system – reservoir rock, seal, source rock and migration pathways is essential to succeed in E&P.



- Geoscientists are “detectives”; they try to solve complex problems from tiny clues to find oil and gas accumulations.



- Exploring for hydrocarbons is a complex process characterised by great subsurface risk and uncertainty.




OK,
NOW WHERE IS THE OIL?

Thank You

ahmed.selem@amsconsultancy.co.uk

+44 (0) 7469 9600 63

London, United Kingdom


BBC

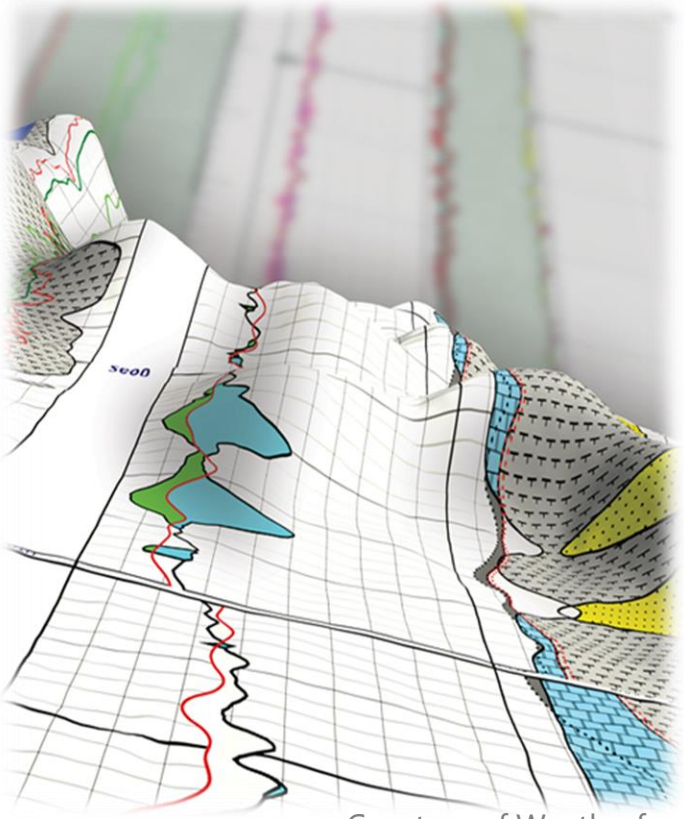
Formation Evaluation

Recognising a commercial well

- Evaluate whether commercial quantities of hydrocarbons are present in formations penetrated by the wellbore.

- Formation Evaluation methods include:
  - Mud Logging
  - Coring
  - Wireline Logging
  - Testing and Sampling

Courtesy of Halliburton



Courtesy of Weatherford

Exploration well is a parametric well

Well Logging

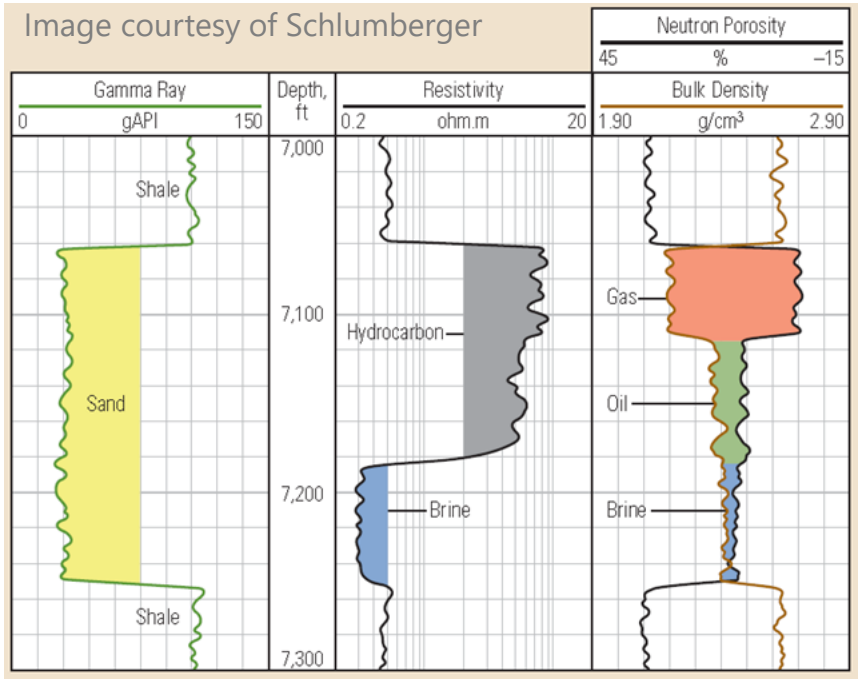
- The well logging is set of borehole investigation methods that are based on special logging tools.
- It is a record of various measurements of the physical properties of rocks recorded while drilling (LWD) or via lowering logging tools into the well (wireline logging).
- **Open hole** logging is mainly used to determine the petrophysical properties of the rocks.
- **Cased hole** logging is used mainly to assess fluid flow into the well.

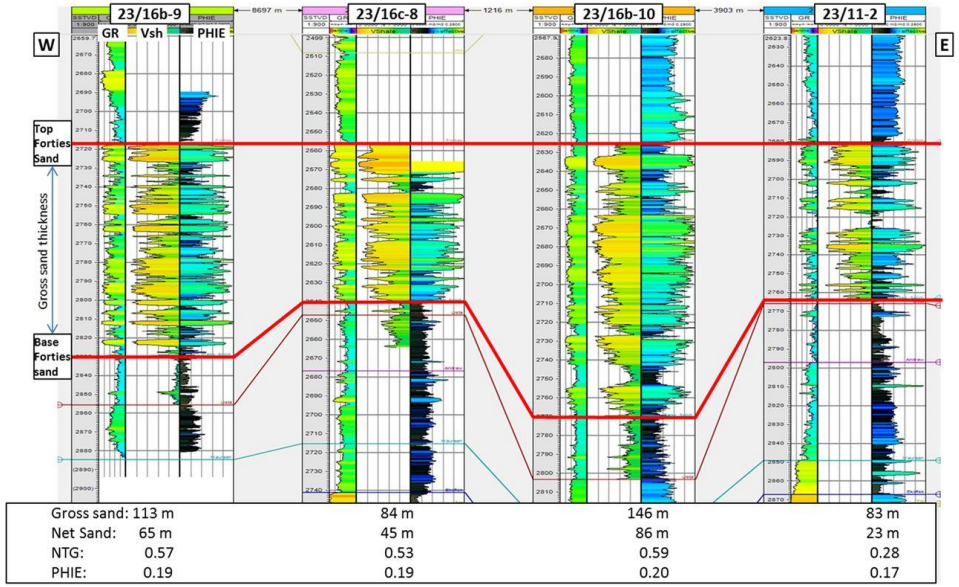
Image courtesy of Schlumberger

Well Log Interpretation

Well logging help geoscientists and engineers to understand:

- ❑ The presence of hydrocarbons
- ❑ The amount of resources present
- ❑ How the subsurface strata correlate
- ❑ The thickness of reservoir layers
- ❑ Reservoir rocks and fluids properties





http://sp.lyellcollection.org/content/403/1/133