Geology and seismic

Energy workforce oil and gas 101
October 5, 2022

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The Wave, rock formation in Coyote Buttes North, Paria Canyon-Vermilion Cliffs Wilderness, Utah, Arizona, USA

Agenda

01 Definitions

02 Brief history of oil exploration

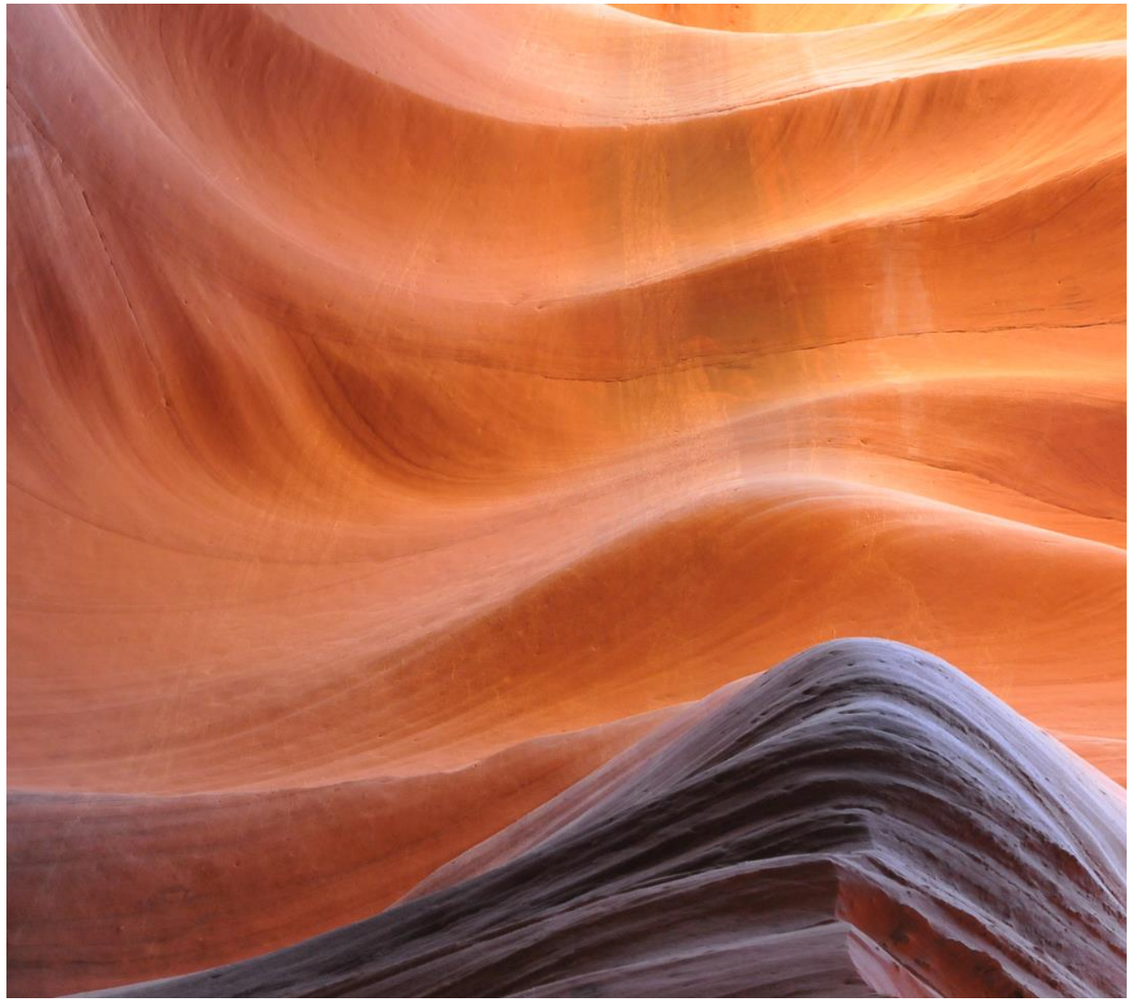
03 Play and petroleum systems analysis

04 Introduction seismic technology

05 Basic concepts of petroleum geology

06 Exploration evaluation example

07 Final remarks

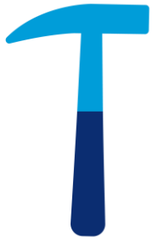


Source: Chevron Image Library

Section 1

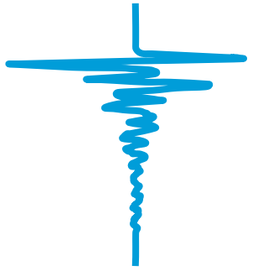
Definitions

Definitions



Geology

The science that deals with the dynamics and physical history of the earth, the rocks of which it is composed, and the physical, chemical, and biological changes that the earth has undergone or is undergoing.



Geophysics

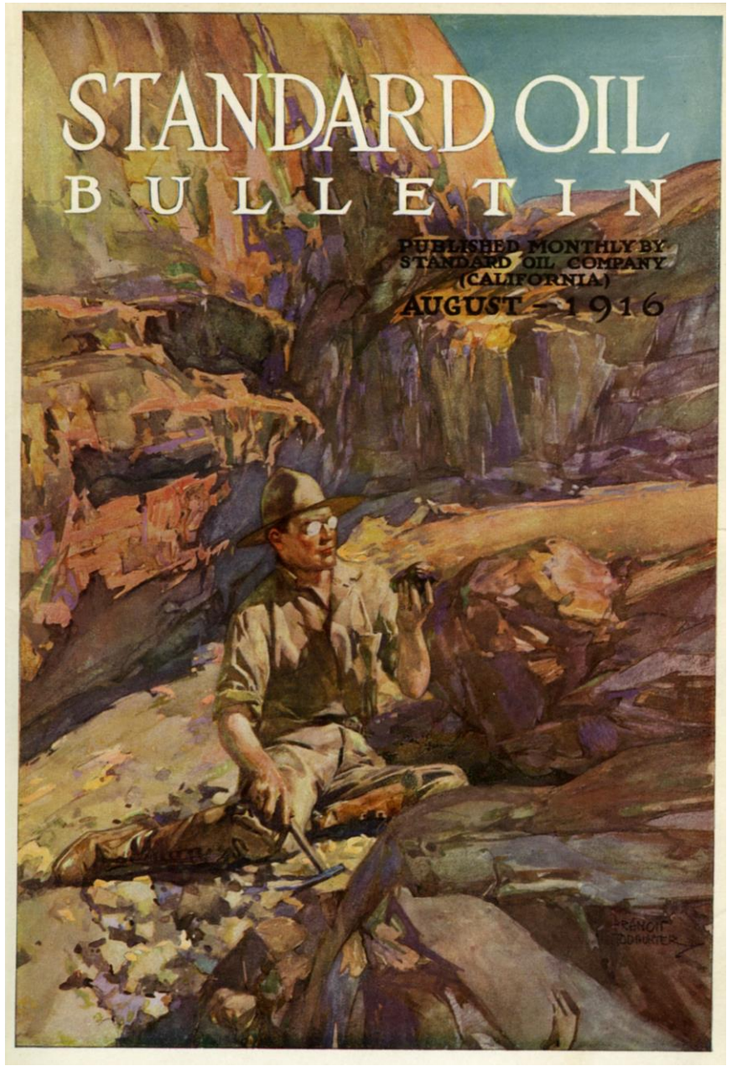
The branch of geology that deals with the physics of the earth and its atmosphere, including oceanography, seismology, volcanology and geomagnetism.

Source: https://www.dictionary.com

Section 2

Brief history of oil exploration

Early exploration

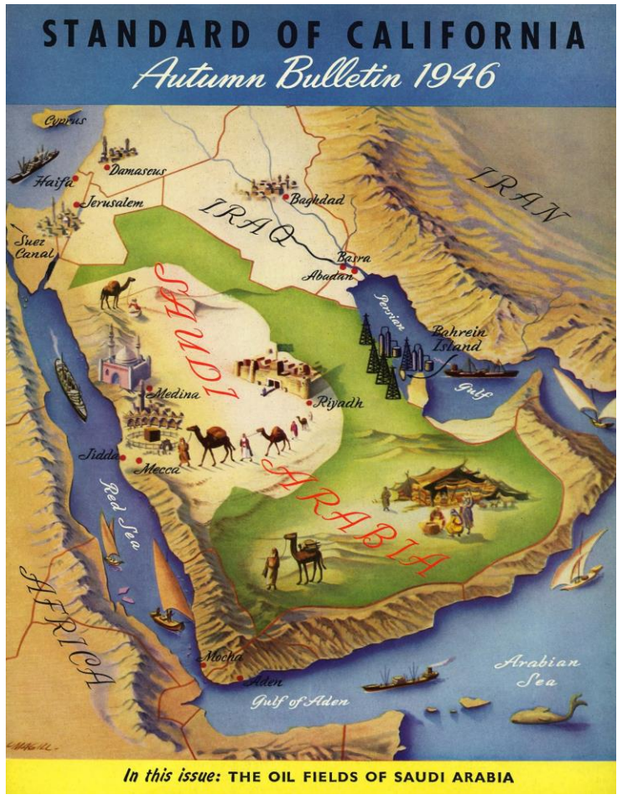


Source: Chevron Image Library, Standard Oil Co. Publication, 1916

Source: Chevron Archives, 1934, four geologists on the Arabian Peninsula

Mid-20th century technology changed the game

Rapid technological advances opened the door to new onshore oil plays across the world



Source: Chevron Image Library, Standard of California, 1946

Source: Chevron Archives, 1934, Fairchild aircraft used for oblique photography of Arabian Peninsula

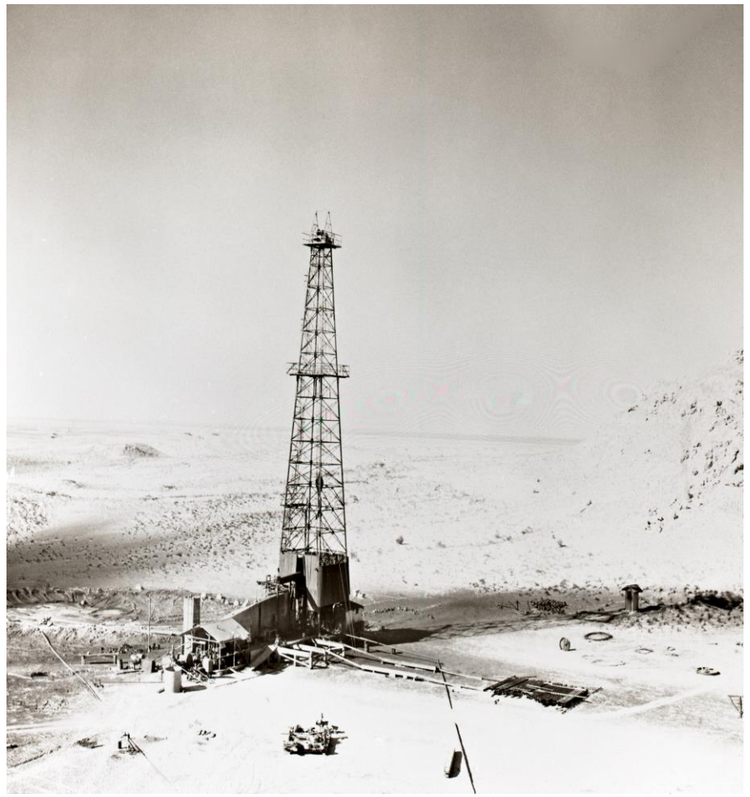


Plate tectonics

Unifying theory of geosciences (formalized in the 1960s) revolutionized our understanding of how sedimentary basins form and where prospective oil and gas deposits may reside

Source: Google Earth

Section 3

Play and petroleum systems analysis

Play and petroleum systems analysis

The “play” is the bedrock of exploration – a conceptual model/style of hydrocarbon accumulations that explorationists use to develop prospects in a basin

Regional geology

Source: Chevron Image Library - Hormuz

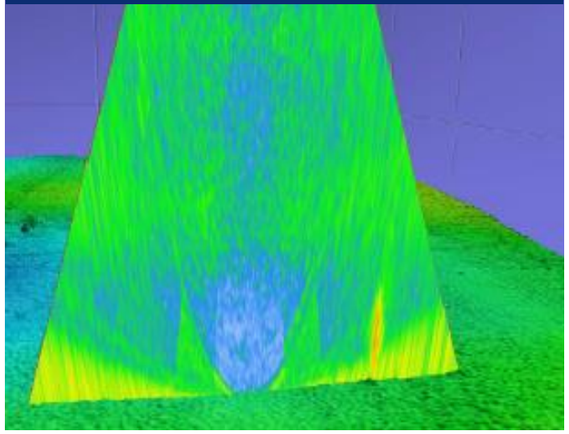
Outcrops

Source: A.A Kulpecz, Western Ireland

SAR – seep detection

Source: Chevron Image Library - Satellite

Multibeam/bathymetry



Source: Chevron-CSIRO Great Australian Bight Marine Survey II (2017)

Petroleum systems/play analysis

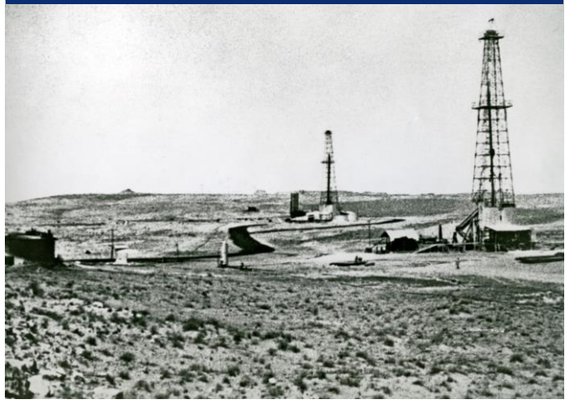
- Super integrated
- Technology plays a major role
- Search for “leading” indicators
- Macroscale (tectonics and paleoclimate) down to microscale (micropaleontology)
- Many successful ideas are adaptations from prior failures

Piston cores

~1m

Source: Chevron-CSIRO Great Australian Bight Marine Survey II (2017)

Old well data



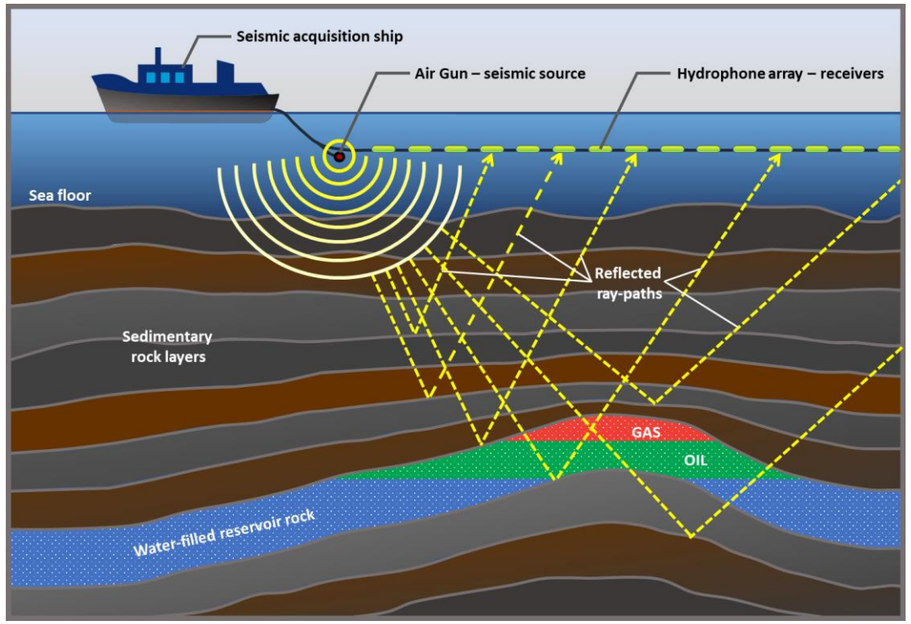
Source: Chevron Image Library – Arabian Peninsula 1938

Section 4

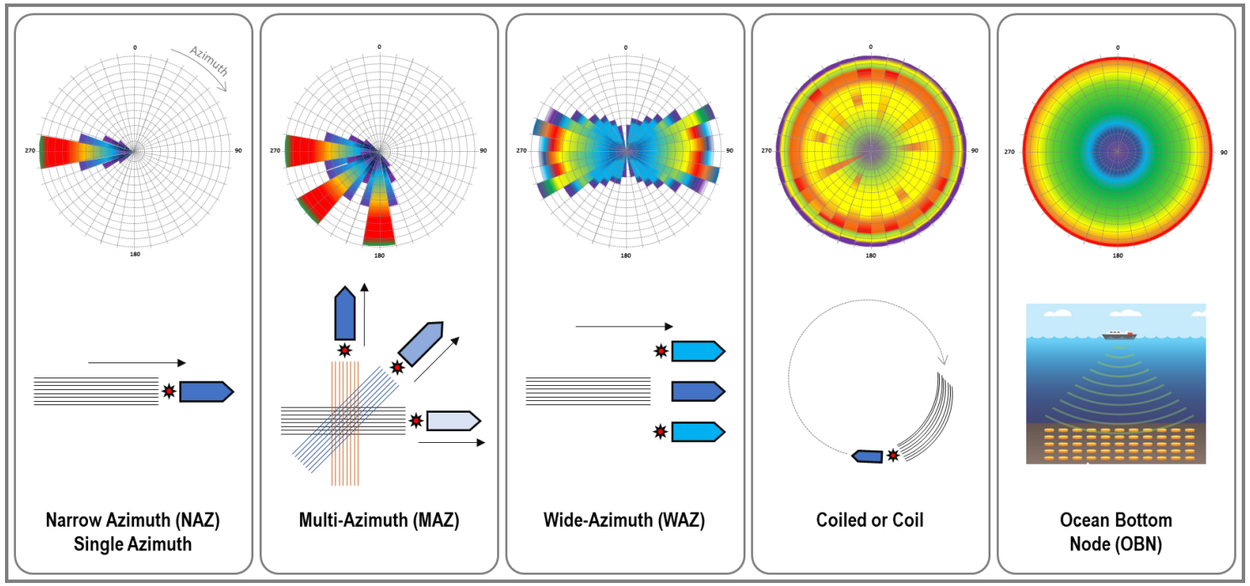
Introduction seismic technology

Basics of seismic data and acquisition

Seismic data is collected by “shooting” a source into a set of receivers and recording through **time** the **amplitude** of the energy received while documenting the **physical position** of the source and receiver. This organization of the data is shot ordered.



Example acquisition geometries

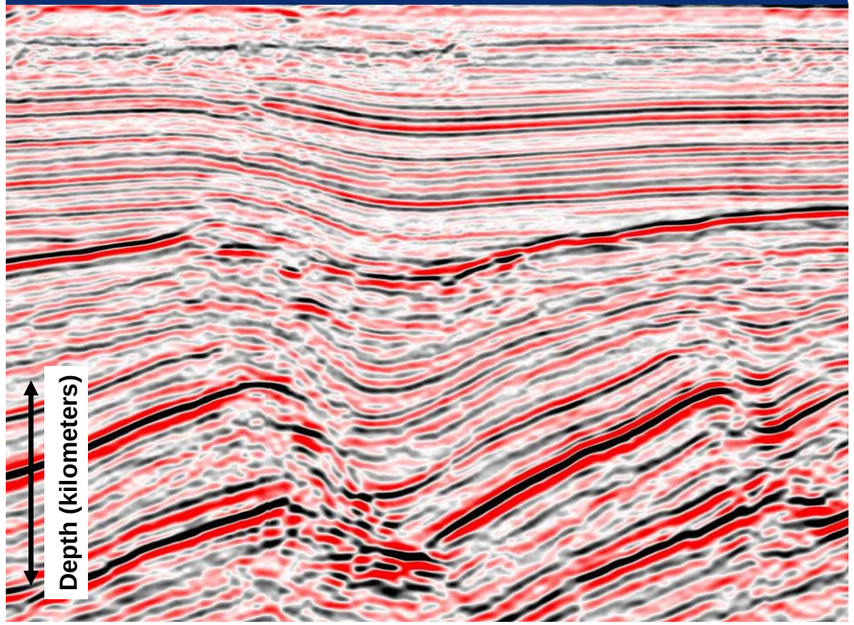


Seismic data and imaging has greatly evolved over the last 30 years due to advances in acquisition techniques as well as computing power and speed.

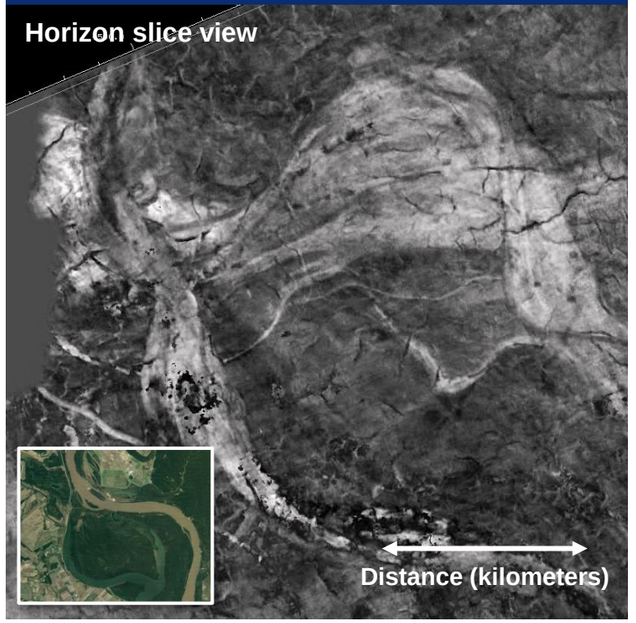
Seismic technology is critical to unlock new plays and define prospects

Seismic acquisition

2D seismic data



3D seismic data



Source: Barents Sea Open File Seismic, Google Earth

2D spec data:

- Low cost
- Acquired by vendors, governments as multiclient to grow industry interest
- Broadly spaced lines (~5–20 km)
- Regional coverage
- Good for early evaluation

3D data cube:

- Higher cost – more focused on specific prospects
- Acquired by companies and vendors
- Excellent coverage of smaller area (prospect)
- Excellent resolution
- High-powered seismic processing
- Generally required in order to drill

Understanding the scale of seismic data

Observation:

Harbour View Tower in Ho Chi Minh City gives us an example of **seismic resolution**

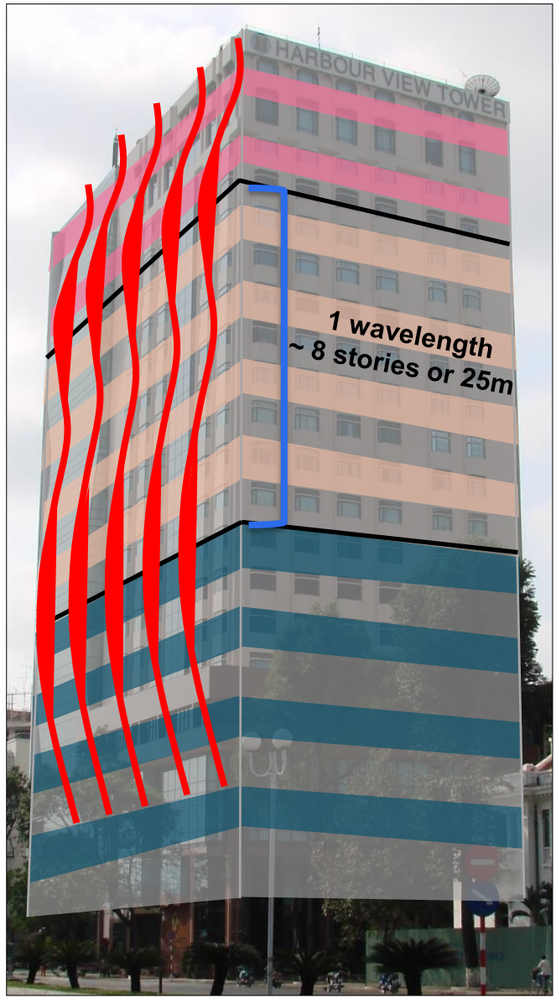
- The wavelength is about 8 stories or 25 meters.
- Assuming a 2,000 m/s velocity, the equivalent frequency is 80 hz (relatively high-resolution for seismic data)

Relevance:

If the windows and the walls between them represent rock layers, many impedance contrasts would be included in one seismic wavelength

Impact:

Special attention is needed to appropriately understand what can be interpreted and ultimately resolved using seismic data



Source: Photo – Bob Kieckhefer

Section 5

Basic concepts of petroleum geology

Prospect: a subsurface feature that may hold commercial quantities of oil and gas

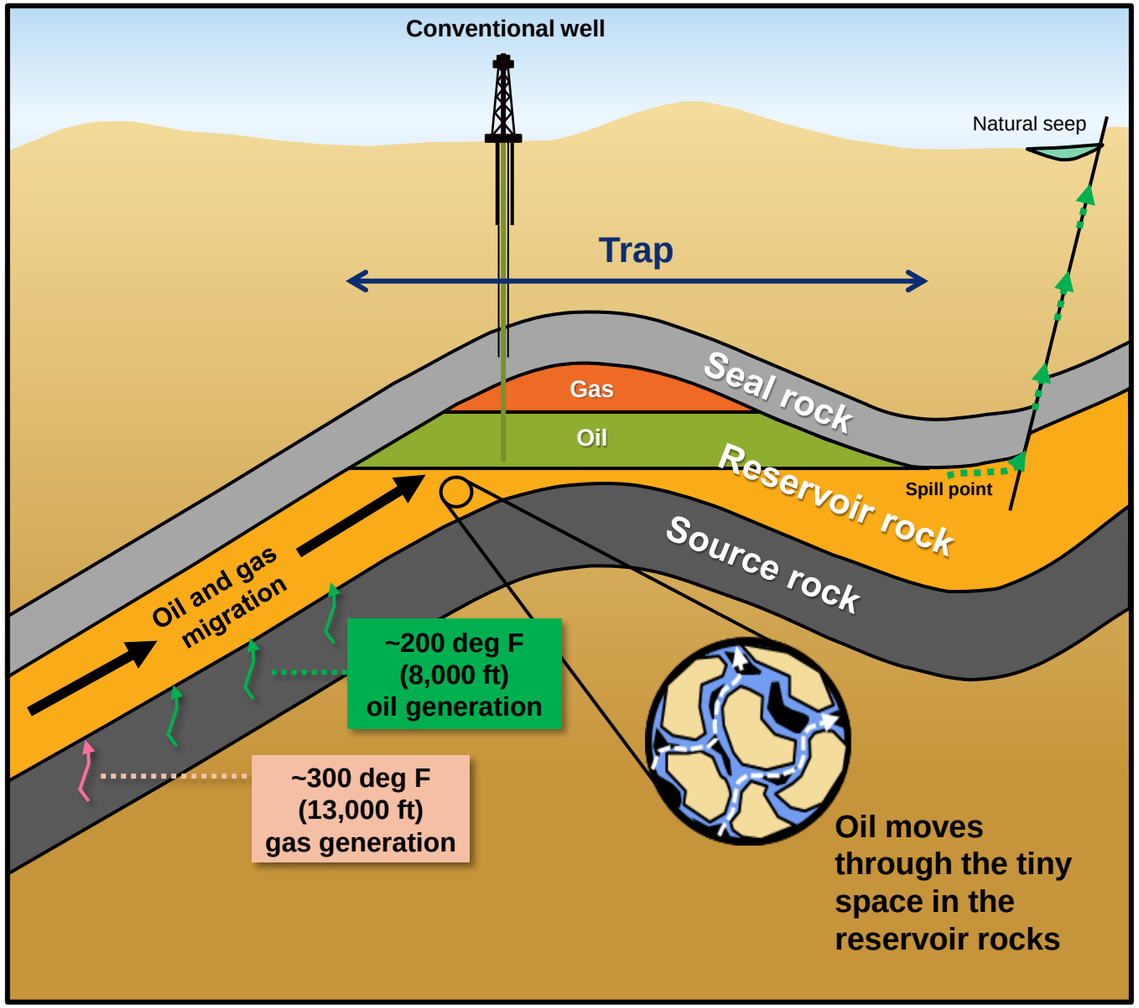
Four key elements to a prospect

Charge (source rock) — Organic-rich rock where oil and gas is generated

Reservoir — Porous rocks through which oil and gas migrates and resides

Seal — Impermeable rock that traps oil and gas

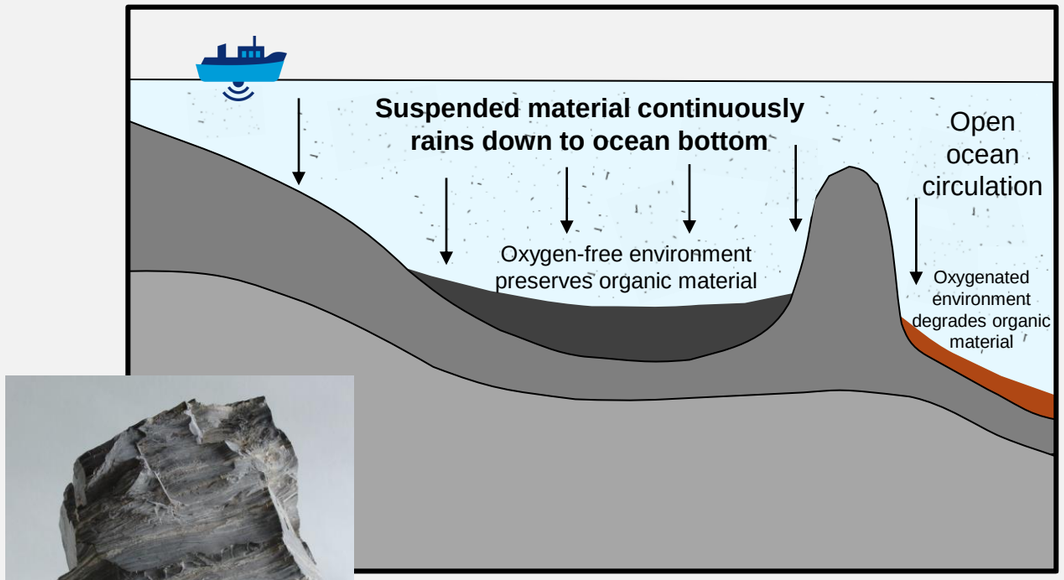
Trap — Geologic container where oil and gas is trapped



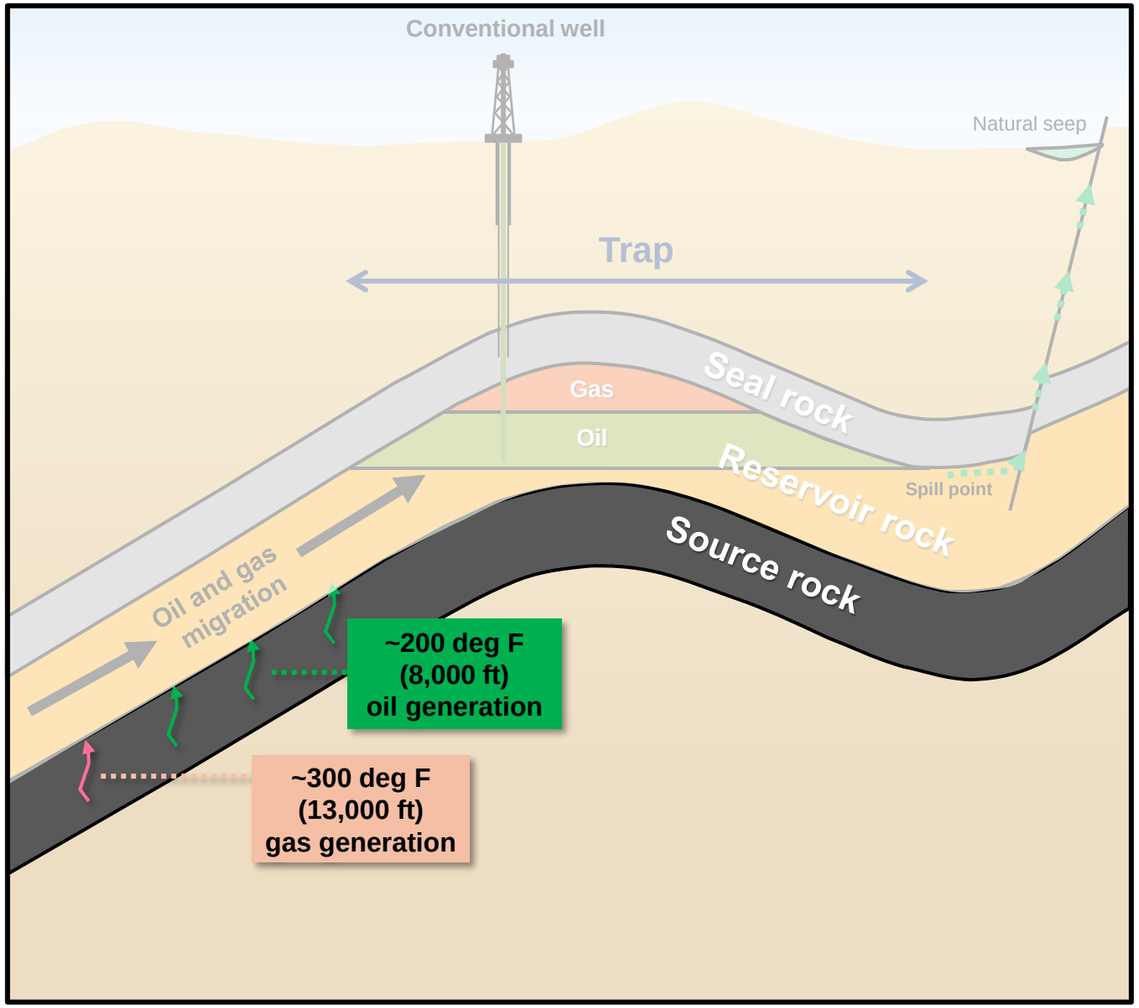
Components of a prospect: source and charge

Organic material that accumulates and is preserved over millions of years is buried and heated, generating oil or gas.

Rocks, usually fine-grained shale, in which organic material has accumulated and is preserved in the rock record.



Source: Chevron Image Library



Components of a prospect: reservoir

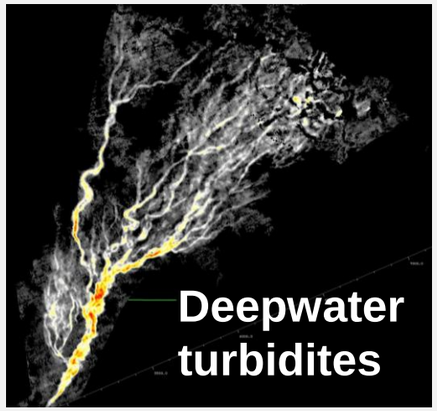
Oil and gas migrate from “the kitchen” upward into porous rocks known as “reservoirs.”

Common reservoir types

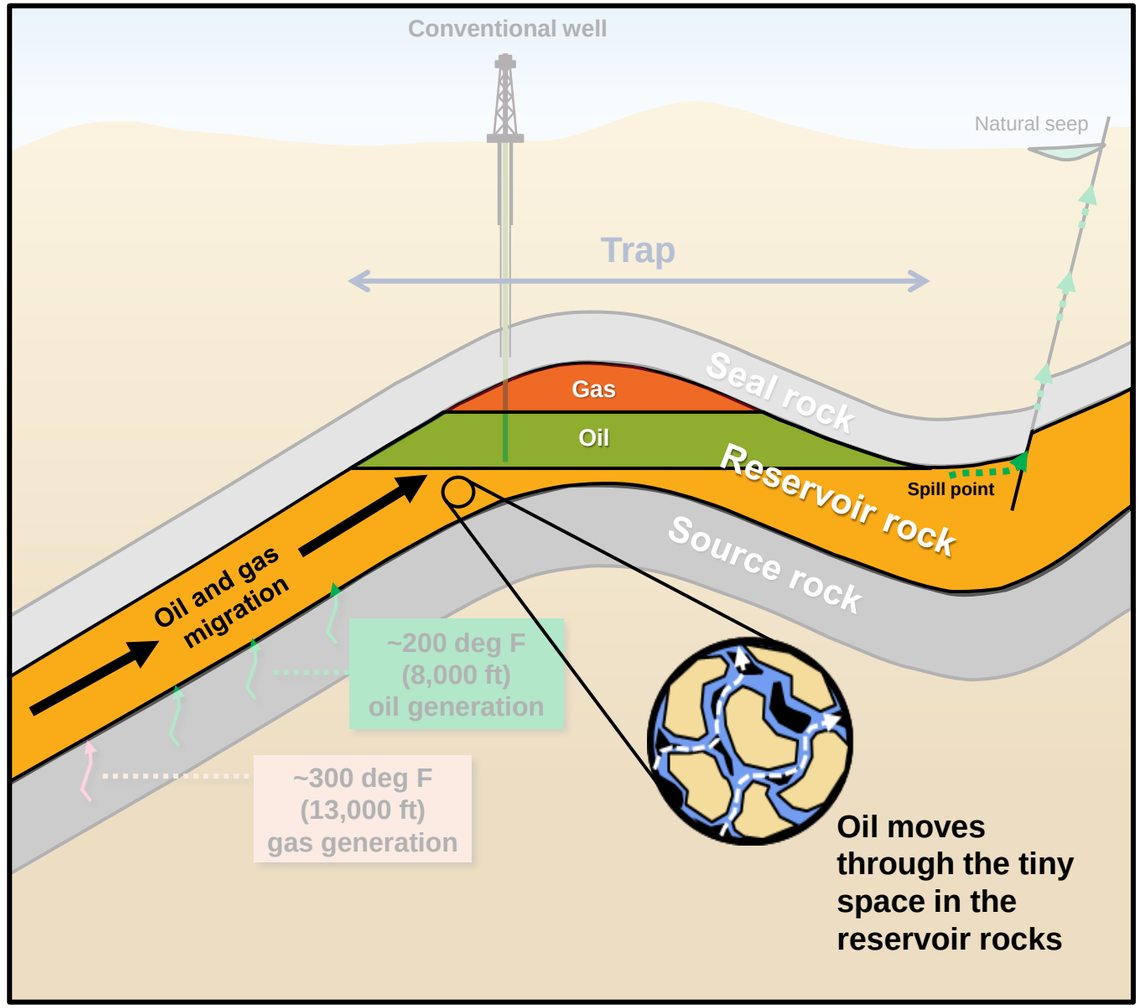
Death Valley, CA (Janet Yun)

Nile Delta (Google Earth)

Coral Reef, Maldives (A.A. Kulpecz)



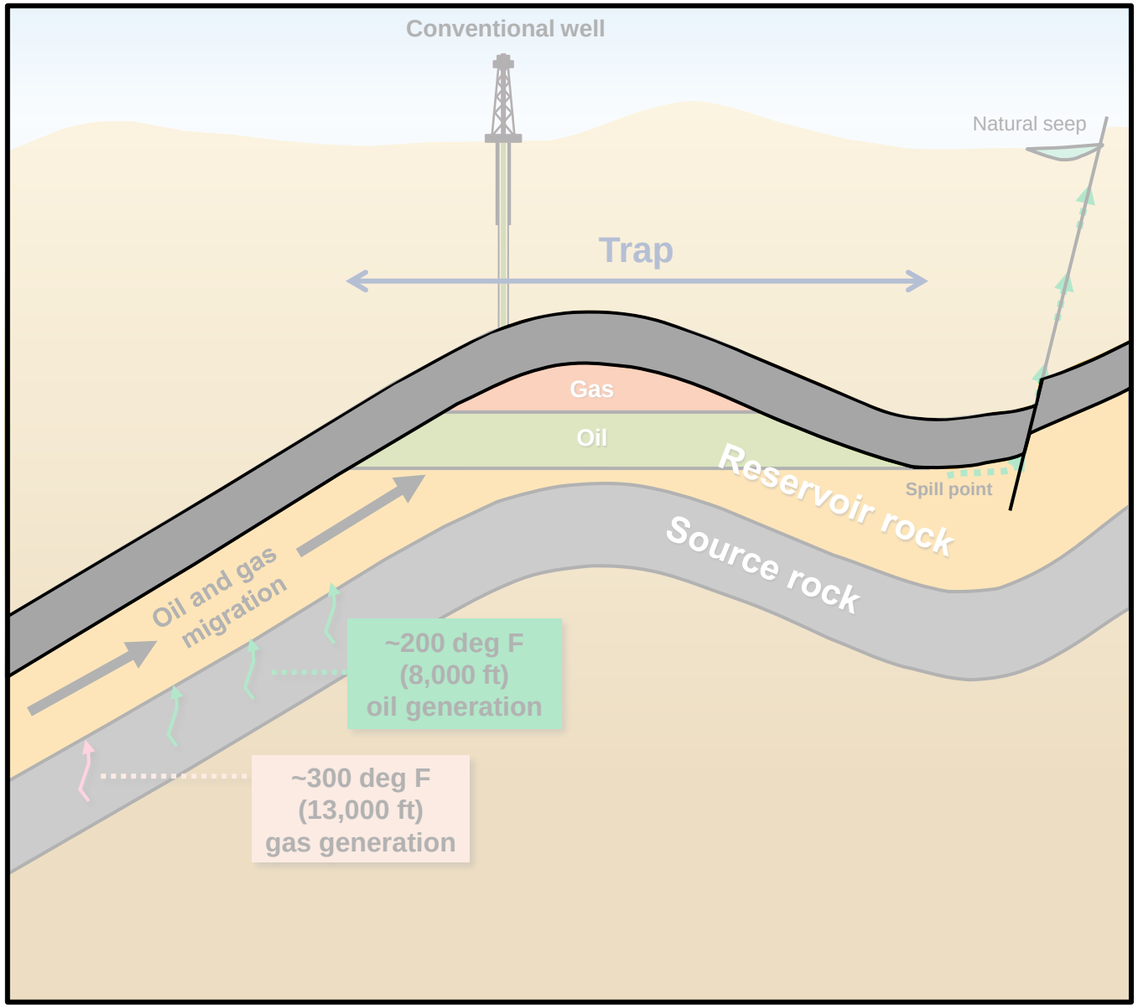
Deepwater System, Norway (NPD open file)



Components of a prospect: seal

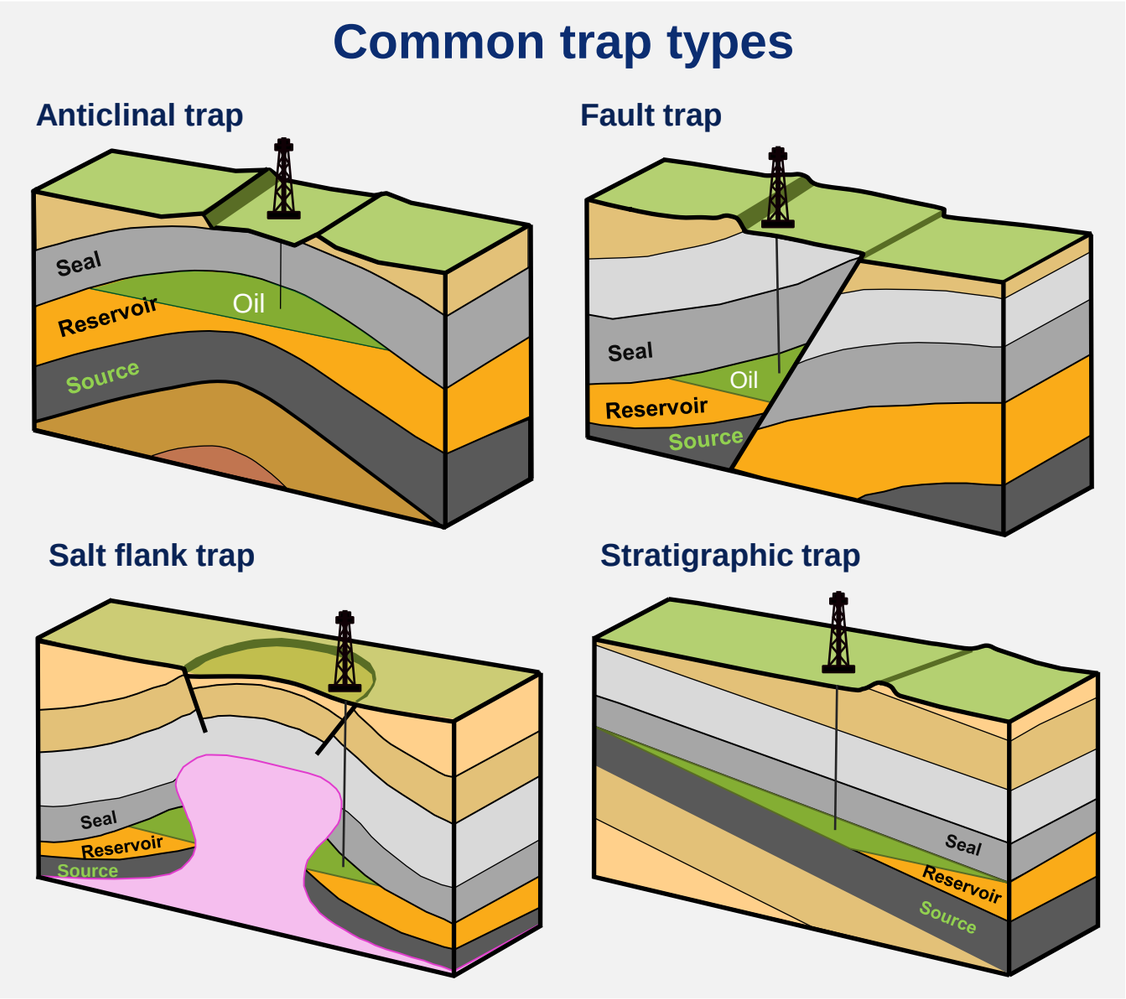
Impermeable rock that keeps oil and gas trapped (e.g., prevents it from migrating onward and upward to the earth's surface)

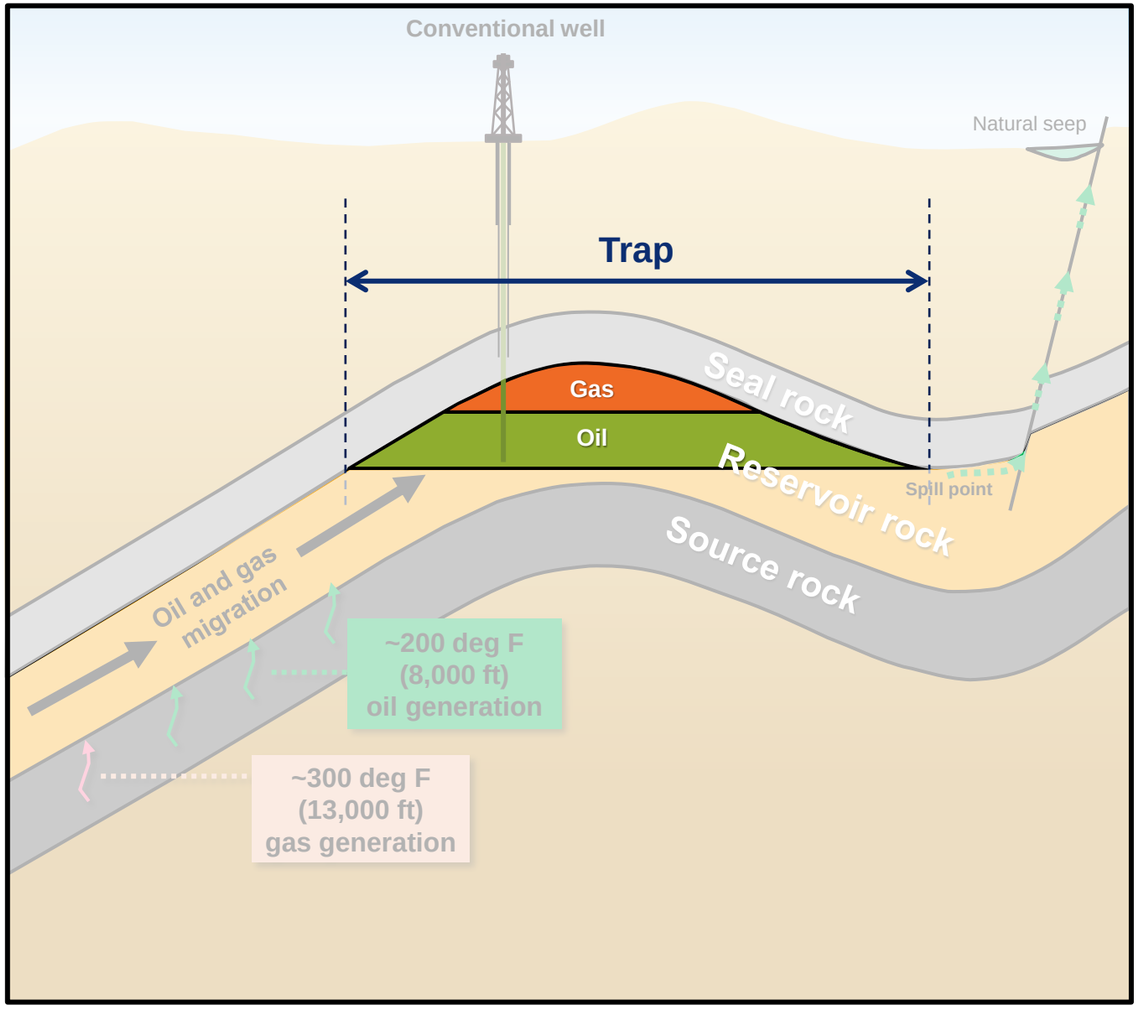
A seal is **impermeable rock** – which means it is very difficult for liquids or gases to move through it. Usually very fine grained and it holds back or "traps" hydrocarbons below it.



Components of a prospect: geometry/trap

A geologic feature that “traps” hydrocarbons – the “container” of a future oil or gas field





Section 6

Exploration evaluation example

Exploration is a portfolio investment business

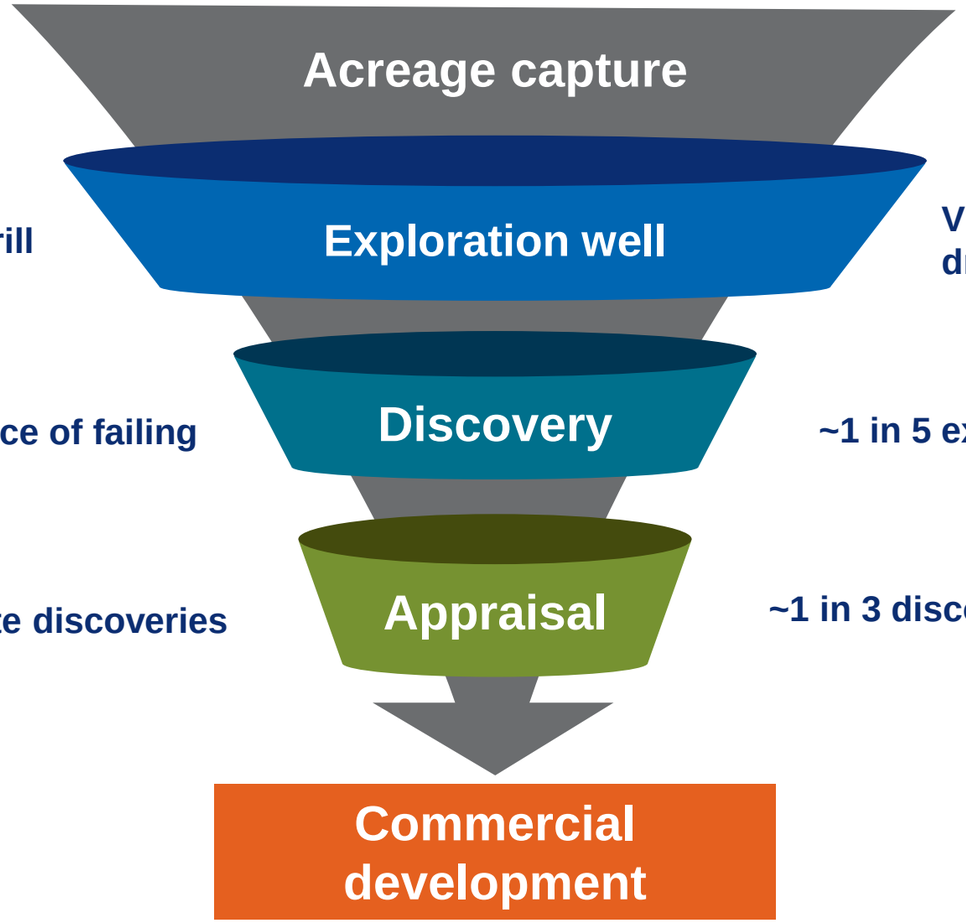
Only a fraction of new opportunities will be successful

Develop concept, capture acreage, and identify opportunities

Select best opportunities to drill

Exploration wells have an ~80% chance of failing

Evaluate discoveries



Viable prospects are high graded for drilling

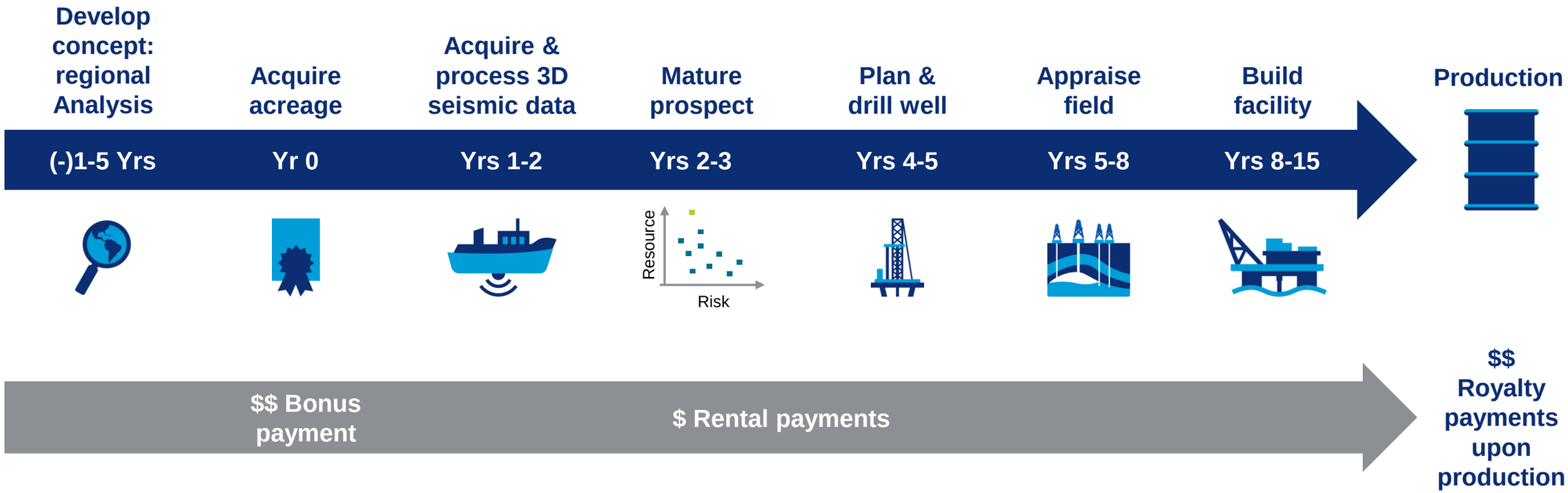
~1 in 5 exploration wells results in a discovery

~1 in 3 discoveries commercially viable

Statistics from deepwater Gulf of Mexico acreage
Sources: Wood Mackenzie, ESA GOMsmart

Exploration is a long-term business

10 to 15+ years from idea & concept to first production



Disruptions at any point of the cycle impacts the ability to explore and consequently, the ability to secure resources for the future.

The first hunch

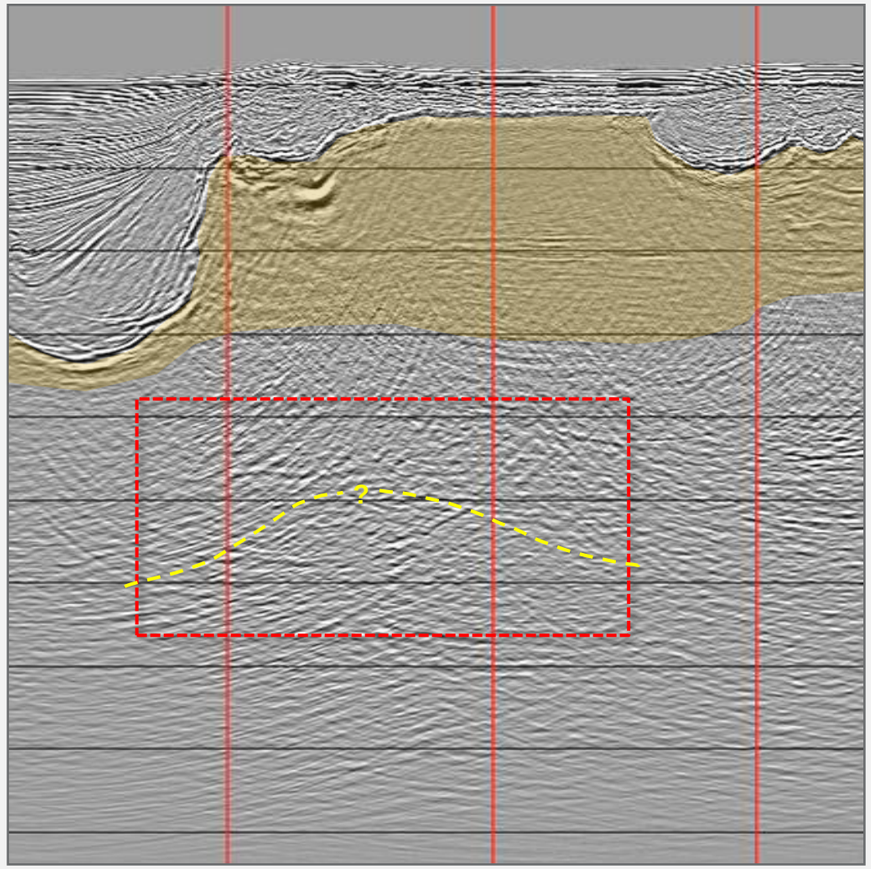
Concept based on seismic data and geologic principles

Key risk elements

Charge (Source rock)	Possible
Reservoir	Possible
Seal	Possible
Trap	Maybe

Early days

Seismic indications of a trap



Veritas DGC Spec Exploration survey (NAZ) 1997-1998 Courtesy of CGG Inc., Houston, Texas

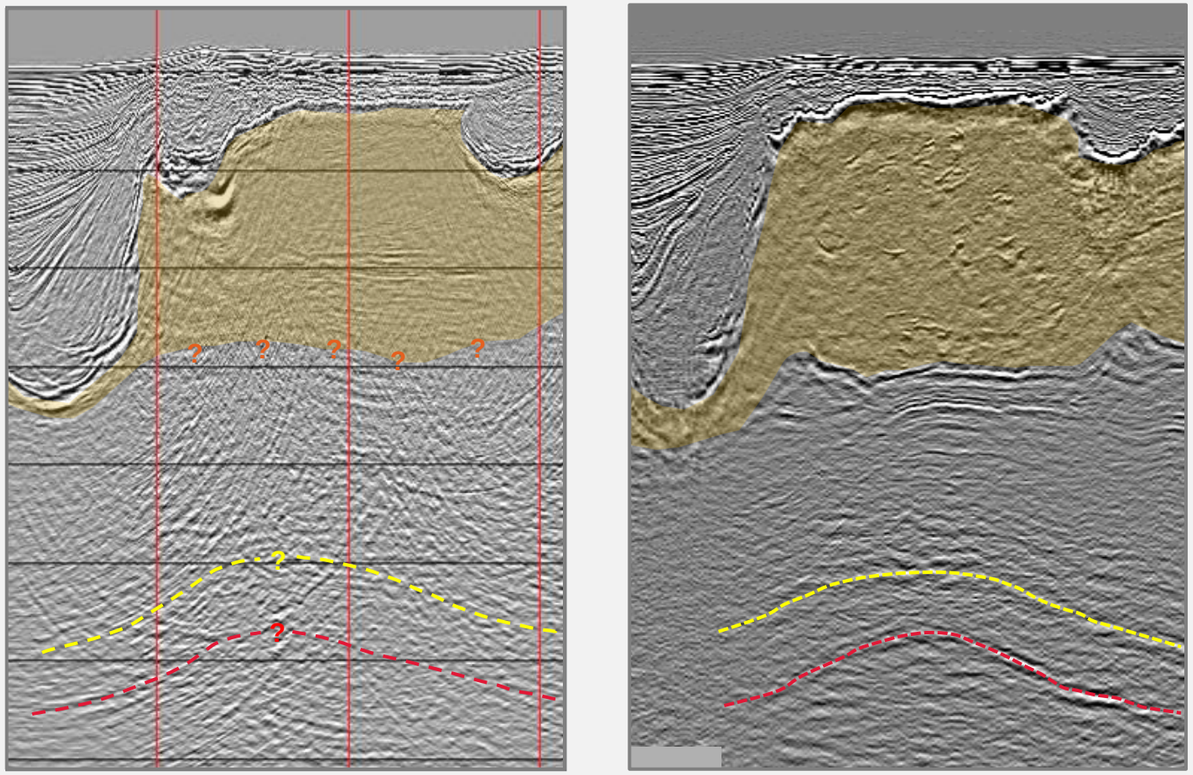
Prospect maturation

Additional seismic data improved interpretation

Key risk elements

Charge (Source rock)	Basin modeling to better define hydrocarbon migration and trap timing
Reservoir	Regional geology and paleogeography to understand reservoir
Seal	Improved 3D seismic imaging of seal-reservoir relationship
Trap	Improved 3D seismic imaging to define trap

Vast improvement in seismic imaging improves trap definition.



Reprocessed Veritas DGC Spec Exploration survey Courtesy of CGG Inc., Houston, Texas

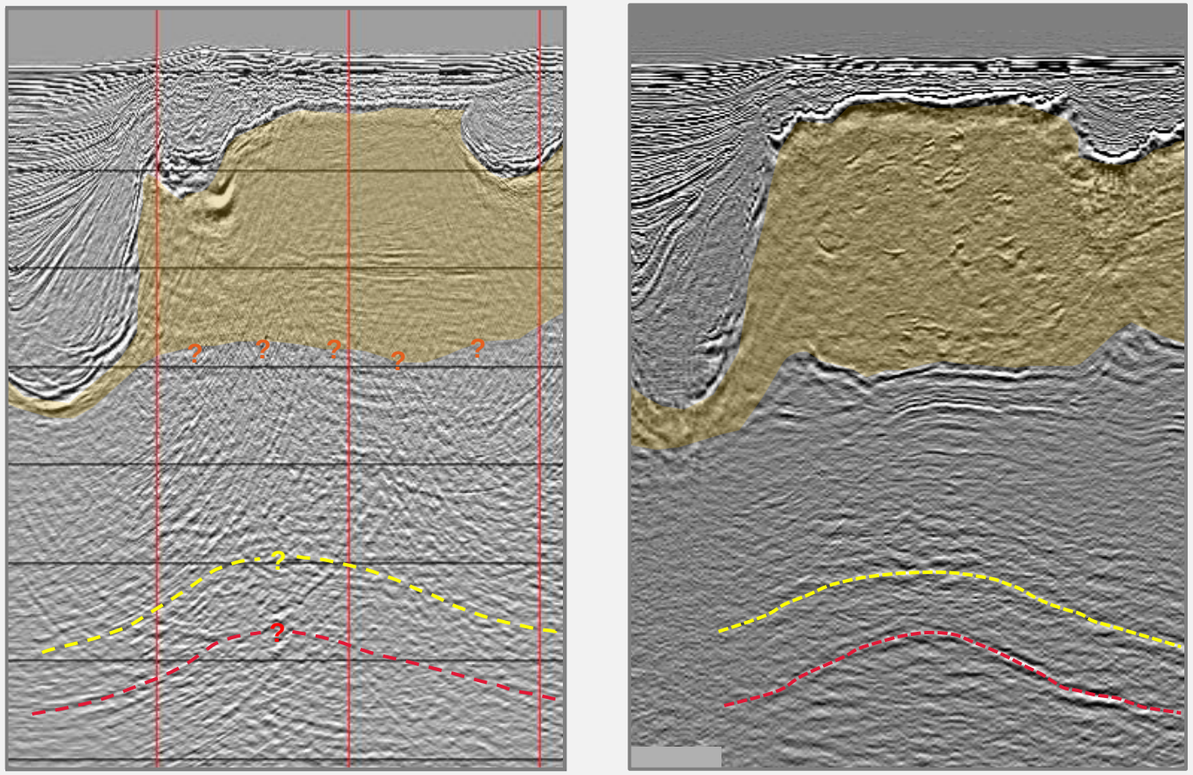
Pre-drill viewpoint

Integration of new data yielded improved chance of success

Key risk elements

Charge (Source rock)	Likely
Reservoir	Probable
Seal	Likely
Trap	Probable

Vast improvement in seismic imaging improves trap definition.



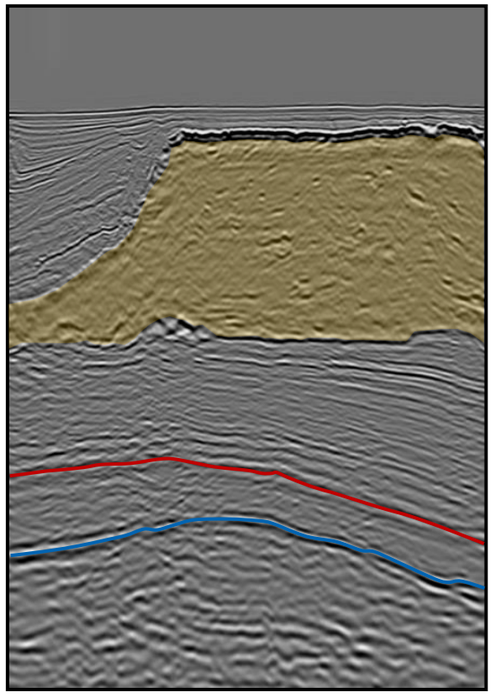
Reprocessed Veritas DGC Spec Exploration survey Courtesy of CGG Inc., Houston, Texas

Discovery

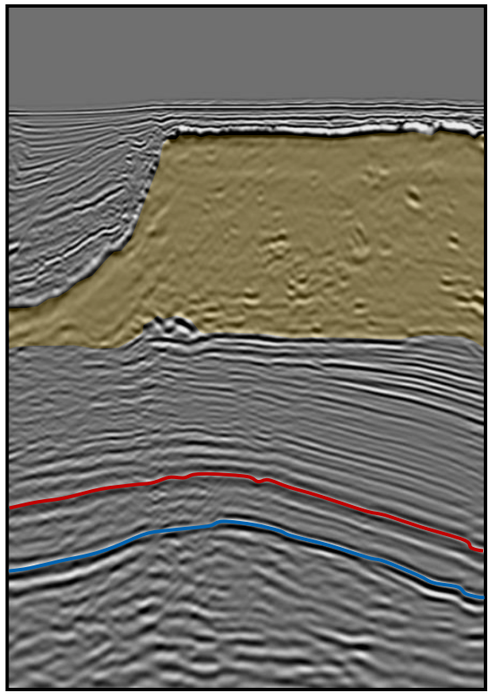
- Ultra deep-water discovery
- Seismic imaging key in defining prospect trap with challenging subsalt geometries
- To get the best image of the subsurface geologists and geophysicists need to work closely together
- Reservoir depth 26,000–29,000 ft TVD
- New technologies needed to deliver resource

Source: Chevron Image Library

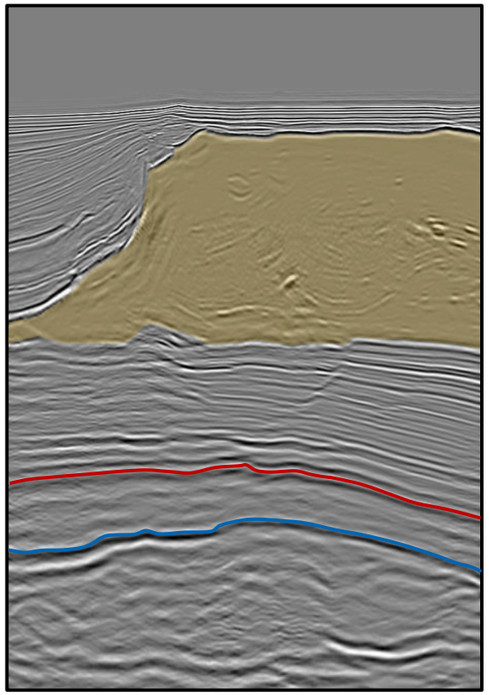
Evolution of 3D seismic from exploration to development



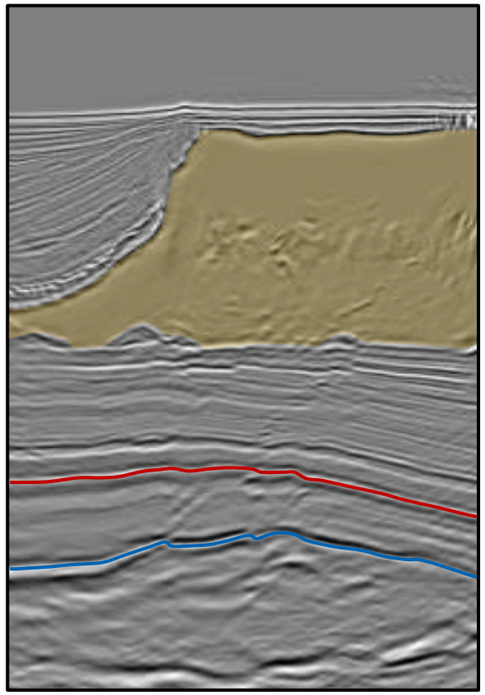
NATS year 1 (SPEC)
Exploration drill



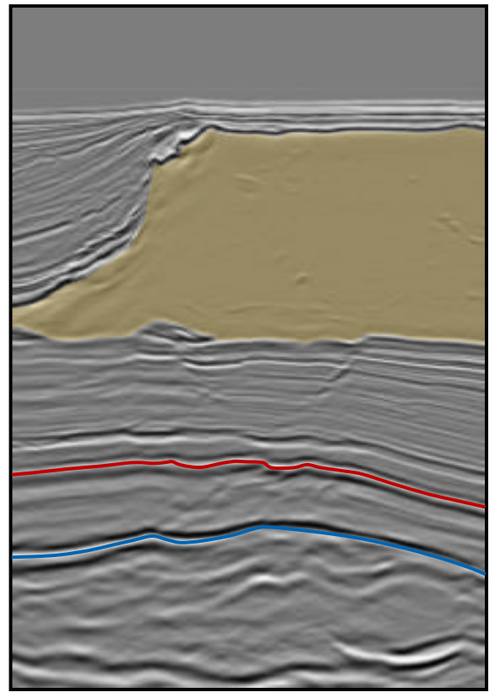
WAZ year 5 (SPEC)
FEED + sanction



WAZ year 8 (Proprietary)
Development stage 1 drilling



OBN year 12
Early out



OBN year 13
Final – current data

OBN provides better structural imaging, fault definition, frequency bandwidth, amplitude fidelity and, therefore, an enhanced understanding of the geometry of the trap and reservoir interval.

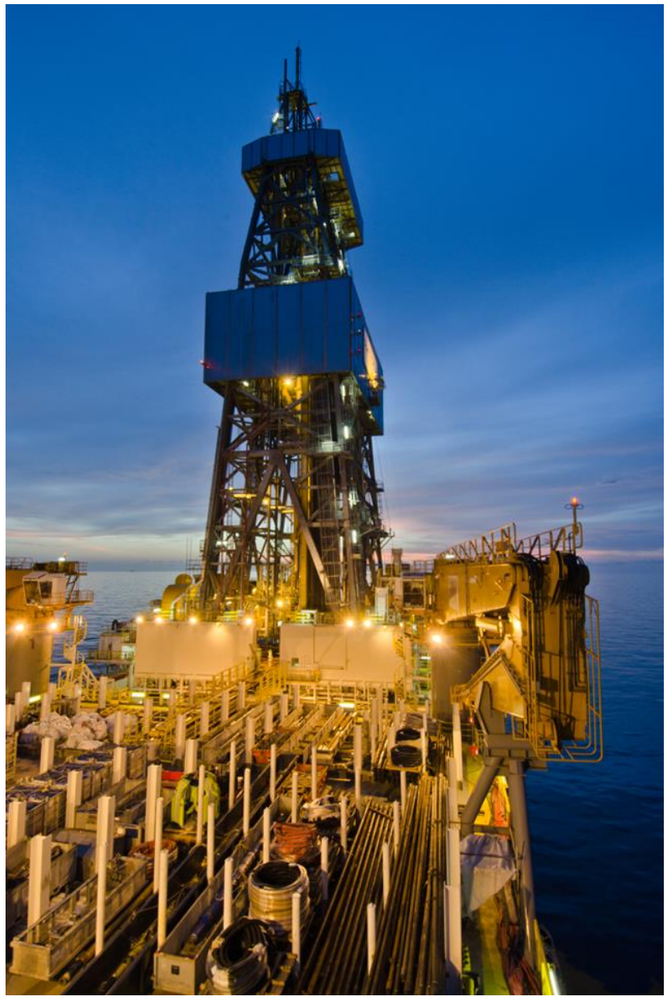
NATS and WAZ Courtesy of CGG Inc.
OBN – Chevron Proprietary

Section 7

Final remarks

Final remarks

- Petroleum geology involves the analysis of hydrocarbon source rocks, geological structures (traps and seals), and the characteristics of porous reservoirs
- Exploration seismology is the key branch of geophysics that allows imaging of the subsurface in order to identify potential structures that may contain hydrocarbons
- Seismic data is the key tool used to identify and de-risk potential prospects
- Technology of subsurface methods has vastly improved over the last 30 years and continues to improve; most recently founded on increased computational power and big data methodologies
- Recent discoveries have outlined how new technologies have allowed geologists and geophysicists to identify structures never seen on previous data – tying conceptual ideas to actual data
- Many successful ideas are adaptations from prior failure(s)



Source: Chevron Image Library

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Thank you