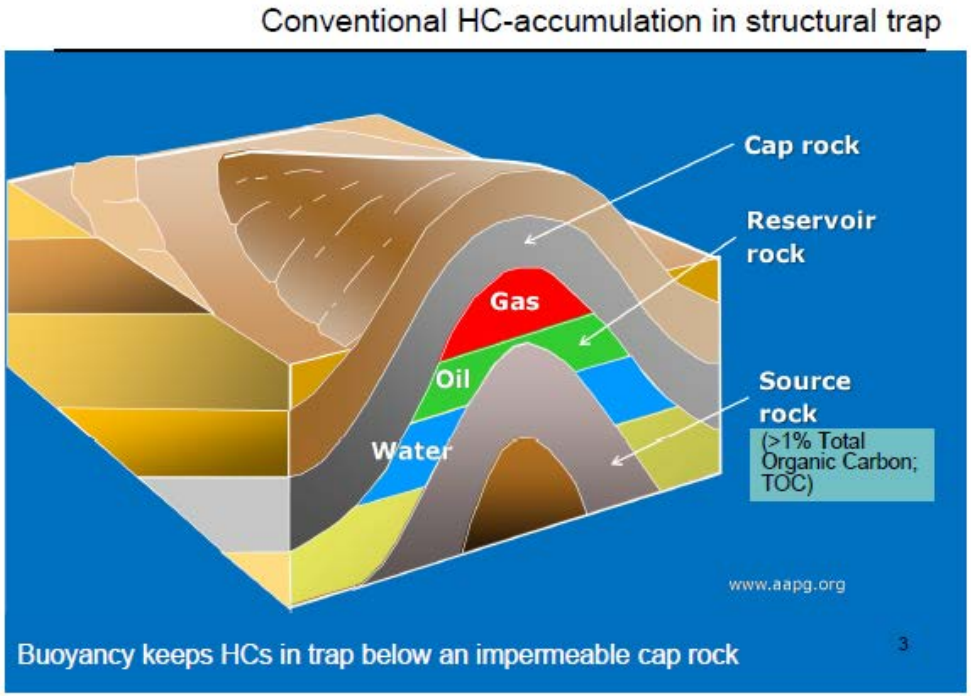
Traps

Velledits Felicitász

Definition of the trap

„The place where oil and gas are barred from further movement, and allowing them to accumulate.” Levorsen 1967.

Includes the reservoir rock and the impermeable cap rock.



Sachsenhofer 2017

Critical Components of a Trap

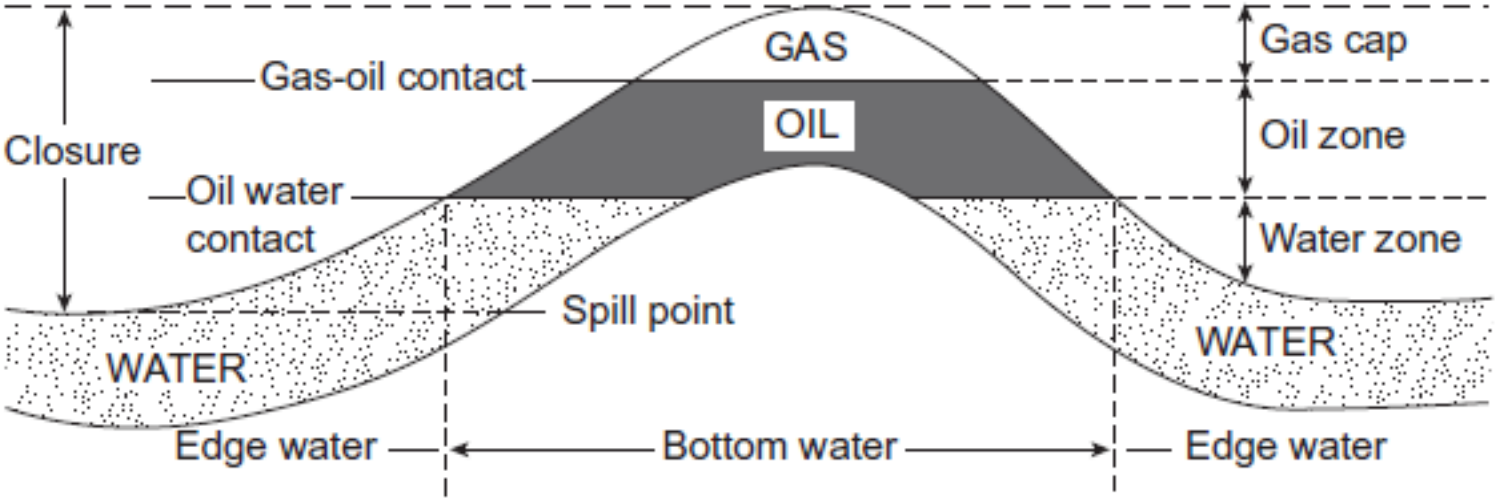
Reservoir rock

- **Porosity** – storage space for hydrocarbons – must be high enough to provide accommodation of significant amounts of hydrocarbon/fluids
- **Permeability** – transmitting and exchanging fluids effectively.
- **Reservoir rocks** are most often heterogeneous containing rocks with different porosities and permeabilities.

This leads to intervals within a reservoir unit that do not contribute to the volume that produce hydrocarbons effectively and will be uneconomical.

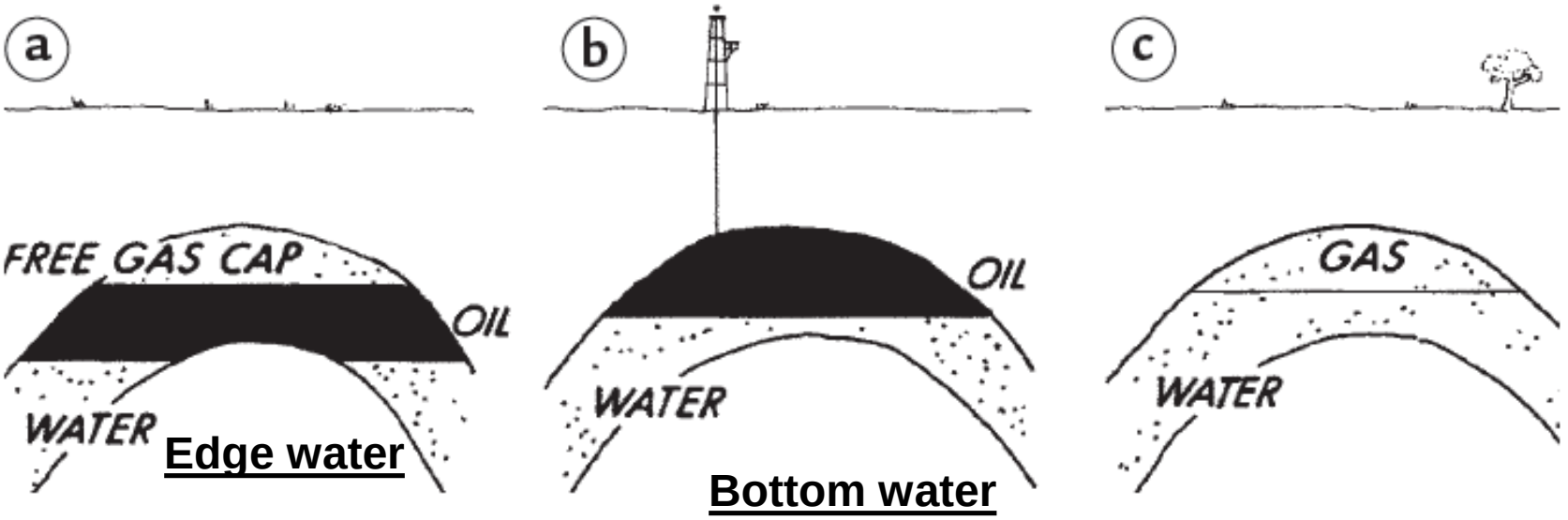
Compartmentalization of reservoirs with separate gas-oil-water contacts and different pressure distributions.

Parts of the traps



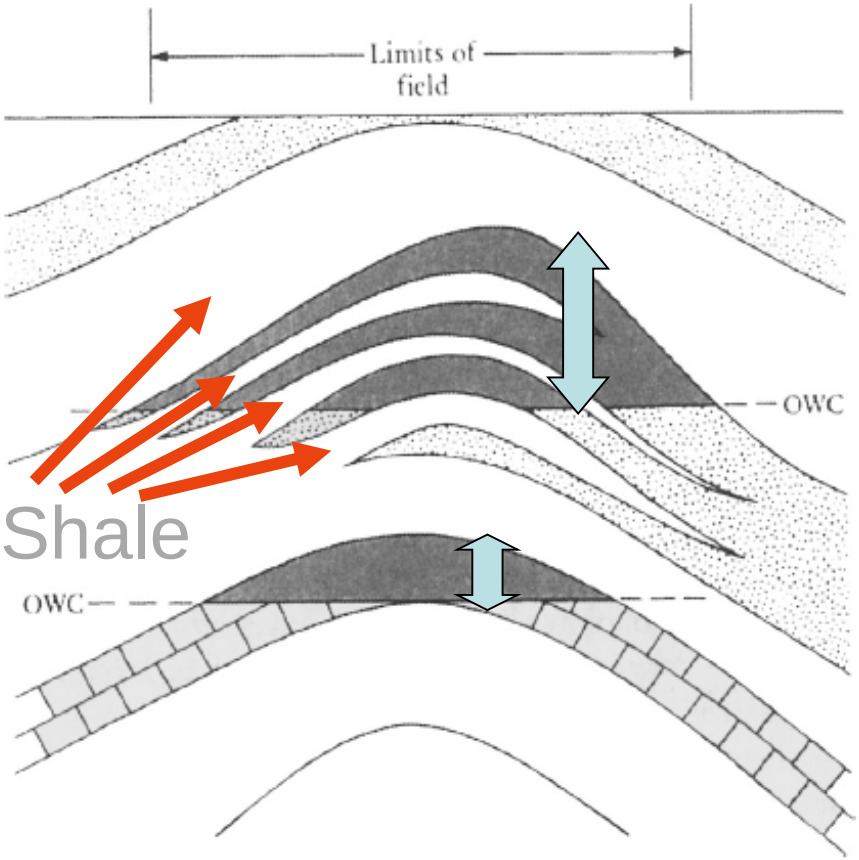
Crest, or culmination: the highest point of the trap.
Spill point: the lowest point at which hydrocarbons may be contained in the trap.
The closure of the trap: the vertical distance from crest to spill plane is.
Bottom water : water located in the reservoir below the oil
Edge water: water located in the reservoir to the side of the oil.
Pay: a part of reservoir containing economically producible petroleum.
Gross pay: including non-productive zones.
Net pay: including only productive zones.

Types of hydrocarbon traps

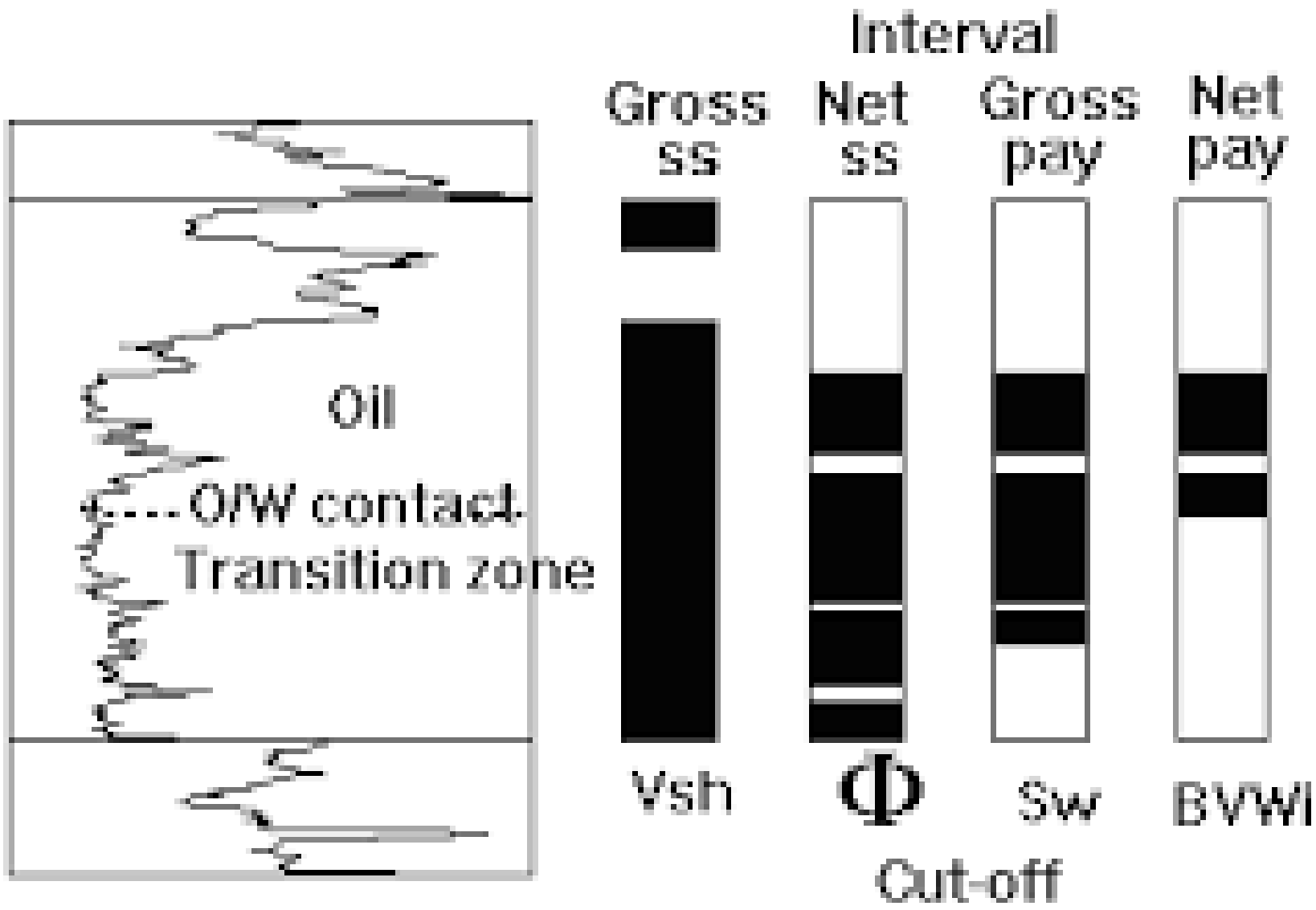


(a) saturated pool (b) undersaturated pool (c) gas reservoir Hyne 2012

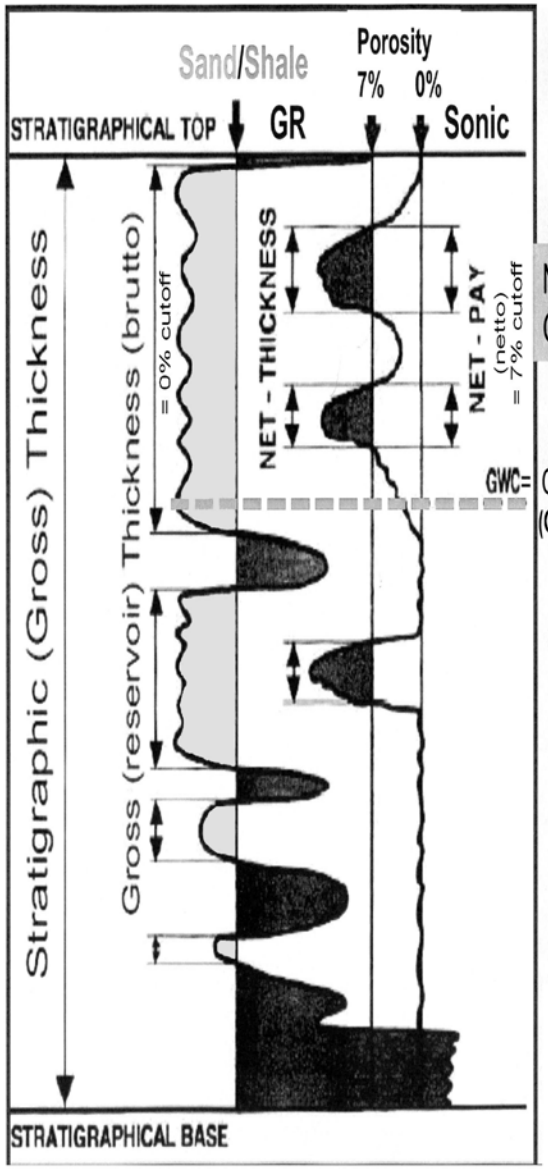
Gross/net pay



This field contains two pools, that is, two separate accumulations with different oil:water contacts (OWC).
In the upper pool the net pay is much less than the **gross pay** because of nonproductive shale layers.
In the lower pool the **net pay** is equal to the gross pay.


Interval
Gross ss
Net ss
Gross pay
Net pay
Oil
O/W contact
Transition zone
Vsh
Φ
Sw
BVWI
Out-off

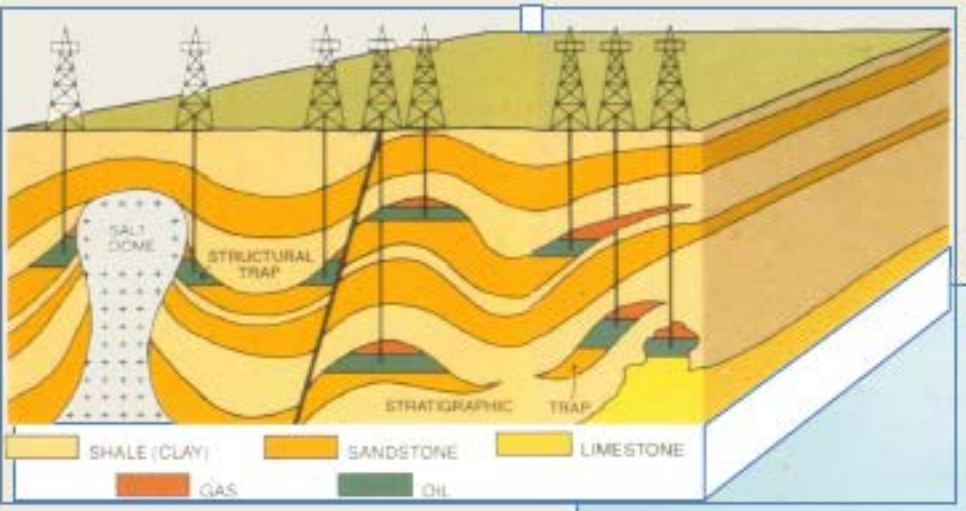
Reservoir Thickness Terms in Gamma-Ray (GR)-Log and Sonic Log



Net Pay = net above GWC or OWC

GWC = Gas Water Contact
(OWC = Oil Water Contact)

Types of Oil and Gas Accumulations



STRATIGRAPHIC TRAPS may occur where the reservoir rock thins laterally or is 'pinched-out' into surrounding seal rocks

STRUCTURAL TRAPS are often found along the edges of salt domes, in the crests of 'anticlirial' folds or along fault lines.



Anticlinal folds exposed in sea cliffs south of Cardigan, West Wales

Classification of Hydrocarbon Traps

I. Structural traps: caused by tectonic processes

are created by the deformation of rock strata within the earth's crust.

Can be caused by horizontal compression or vertical movement which results in the folding, tilting and faulting within sedimentary rock formations.

- Anticlines
- Fault traps
- Growth faults and rollover anticlines
- Drag folds in overtrust belts
- Salt domes (according to some classification)

II. Stratigraphic traps:

II/A. Primary:caused by depositional morphology

- Reefs, Beaches, River channels, Pinch-outs, Incised valley fills.
- Compactional anticlines

II/B. Secondary: under or above an unconformity surface:

- Truncation, Onlap

II/C. Diagenetic

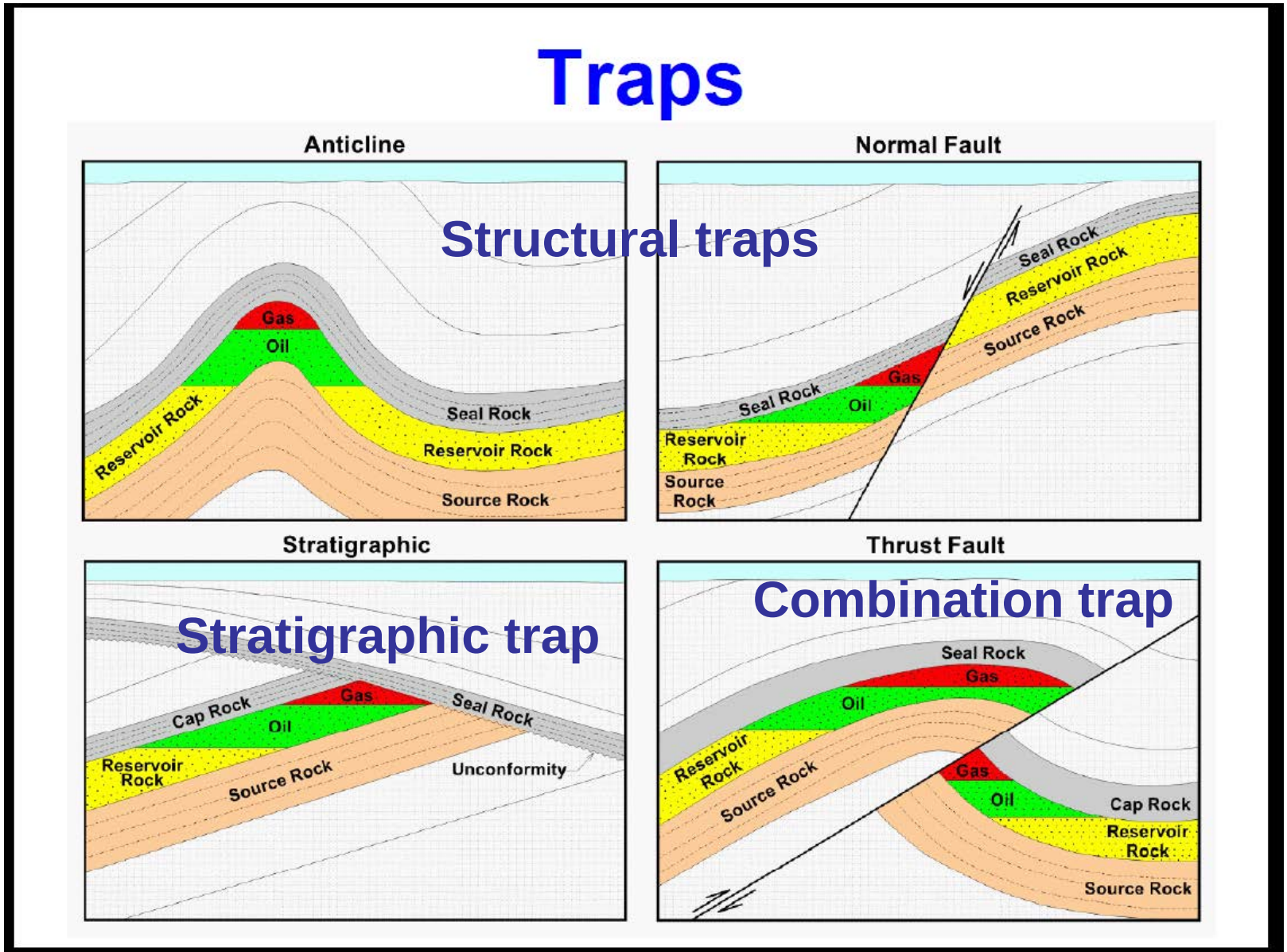
III. Hydrodynamic

flow of water updip and downdip can create pockets of trapped oil

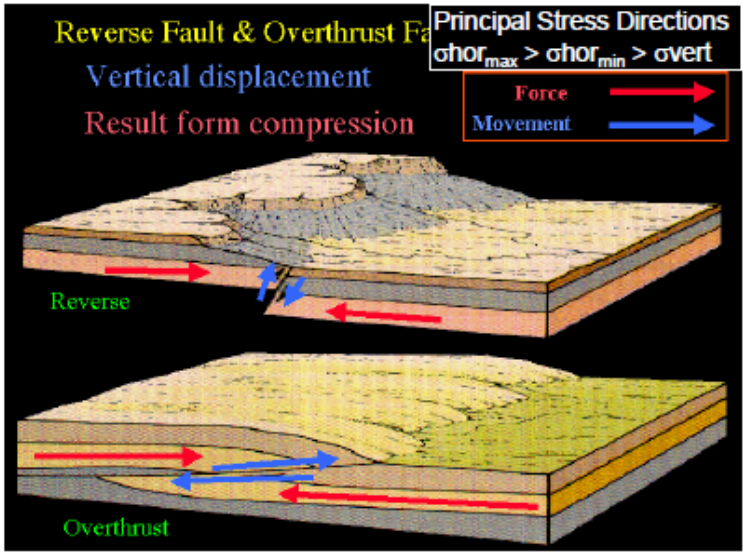
IV. Combination traps: have both structural and stratigraphic trapping elements

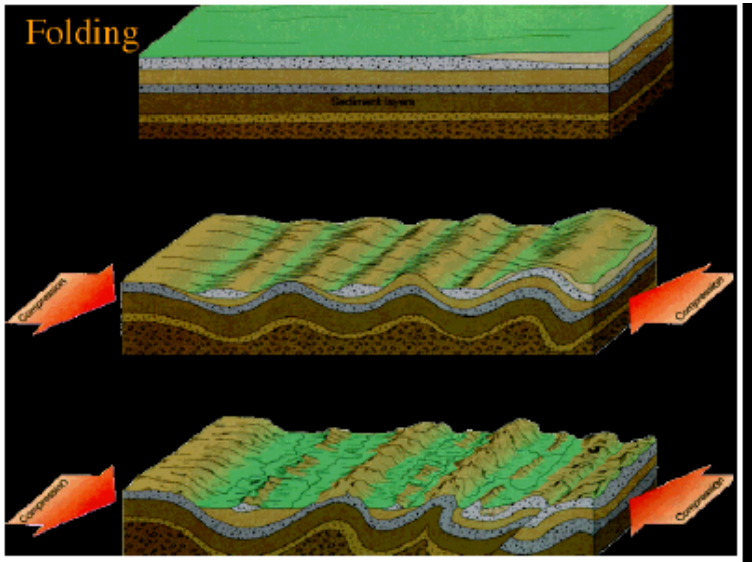
- Salt domes
- Bald headed structures
- Faulted anticline

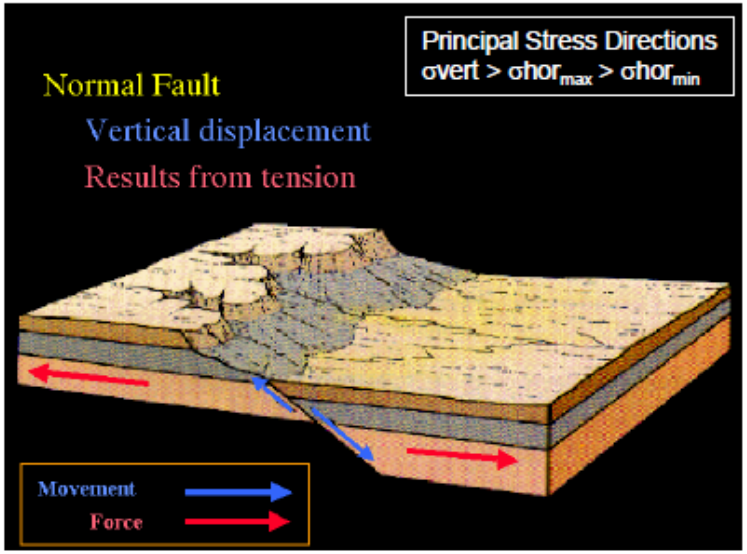
The three main trap classes

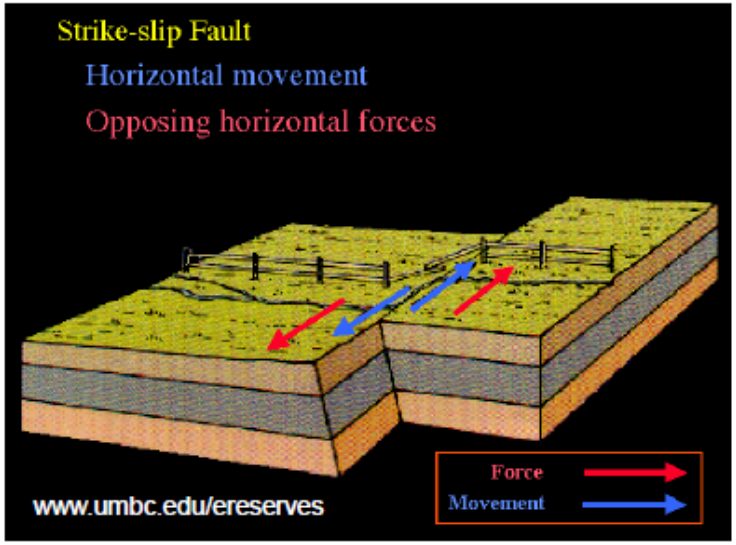


Tectonic movements



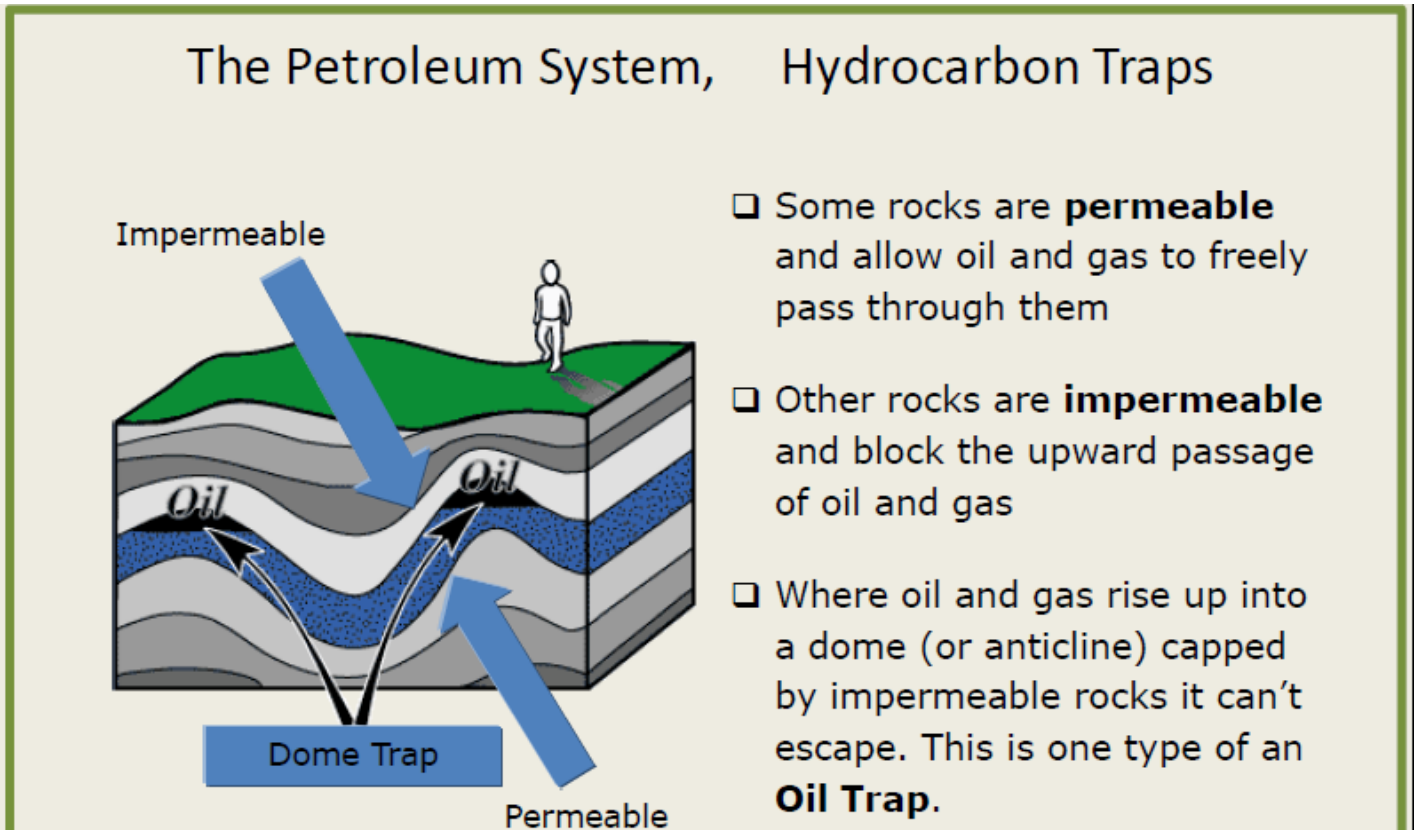


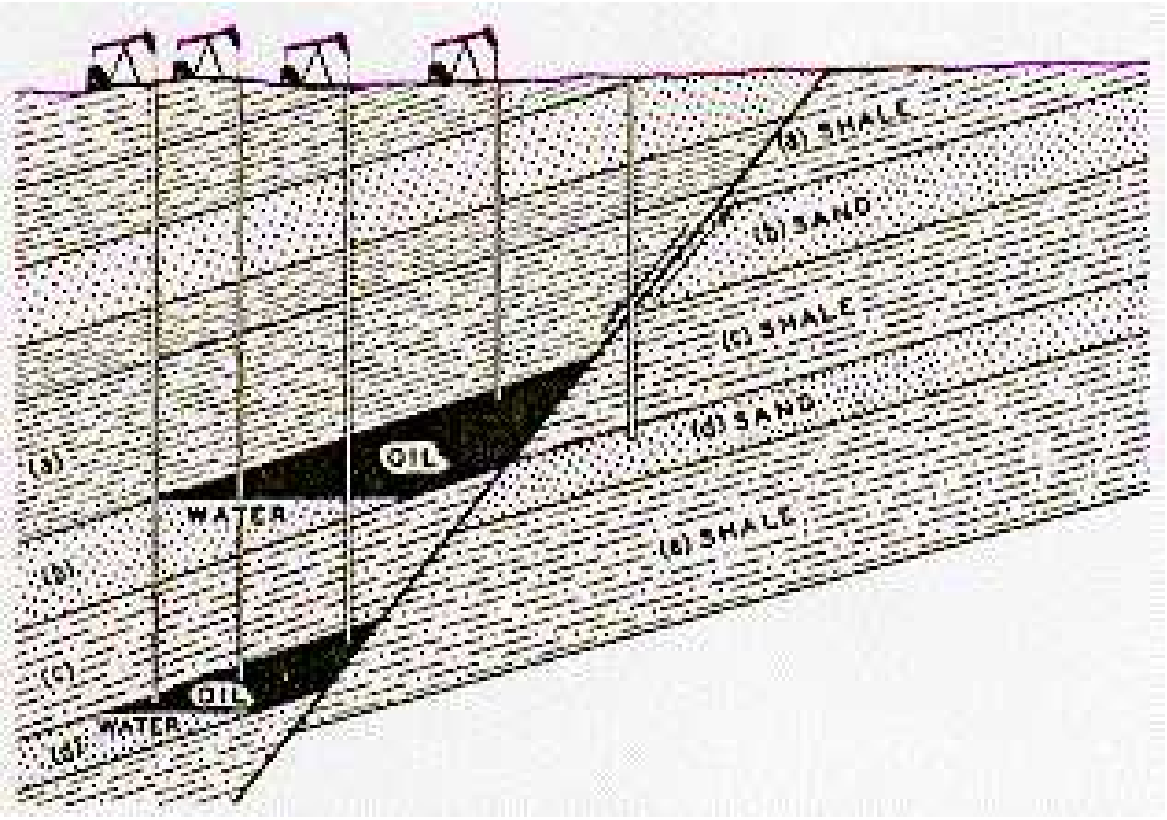




I/1. Anticlinal trap

The rock layers in an anticlinal trap were originally laid down horizontally then folded upward into an arch or dome. Later hydrocarbons migrated into the porous and permeable reservoir rock. A cap or seal (impermeable layer of rock) is required to permit the accumulation of the hydrocarbons.

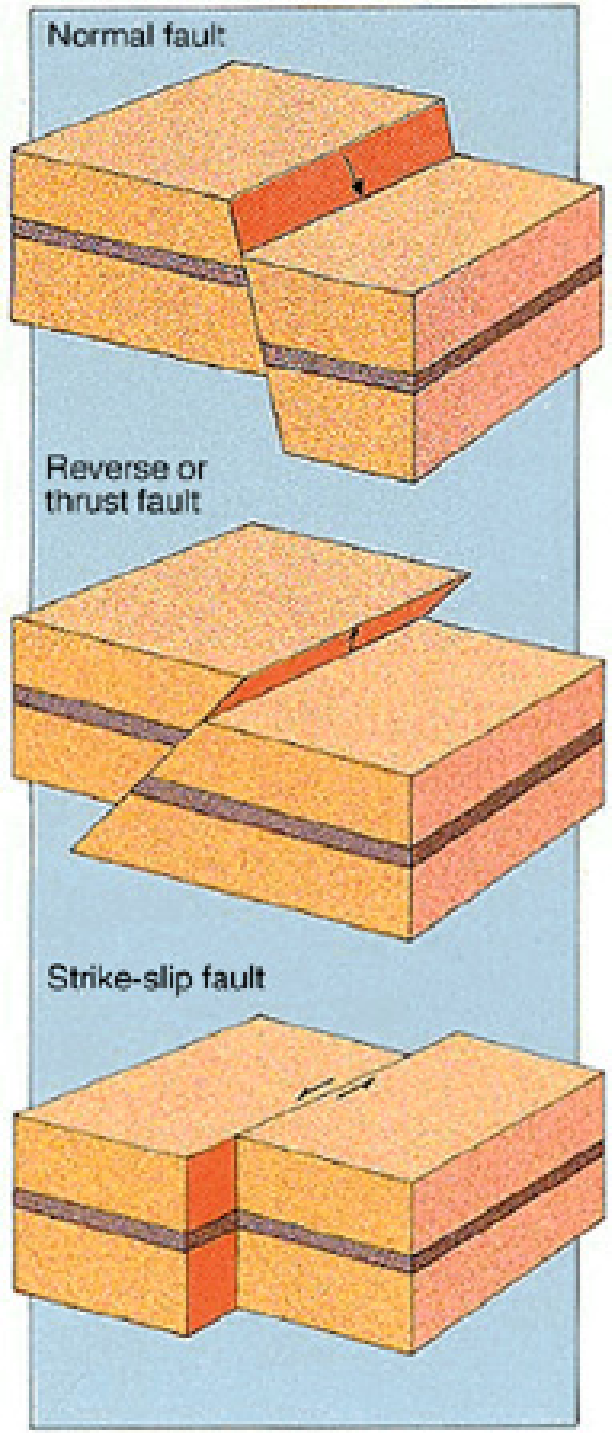




I/2. Fault trap

The faulting of stratified rock occurs as a result of vertical and horizontal stress.
At some point the rock layers break, resulting in the rock faces along the fracture moving or slipping past each other into an offset position.

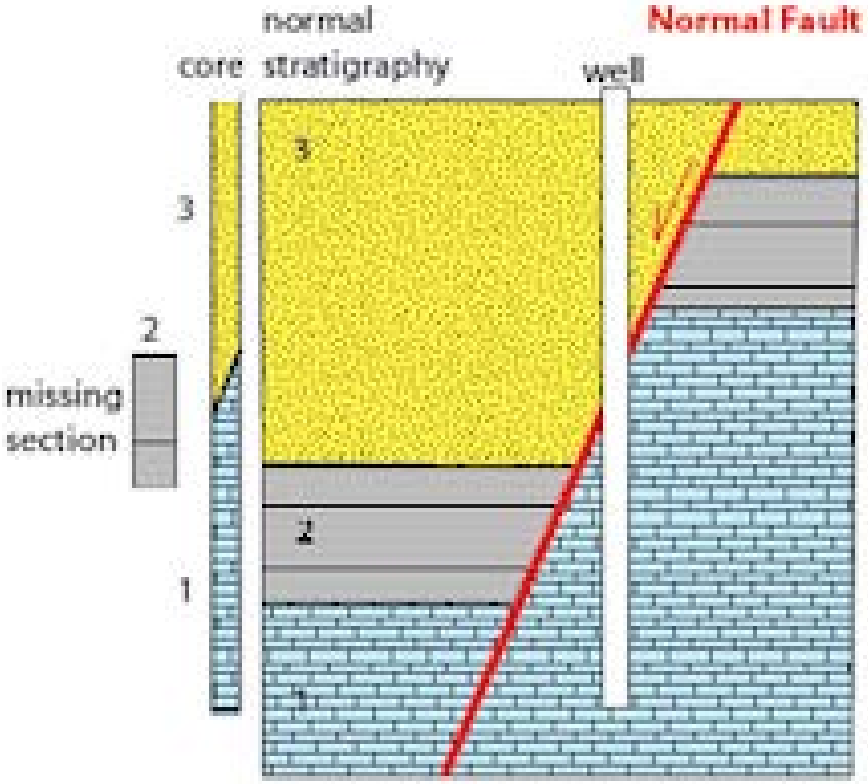
Faulting in the earth has caused vertical movement of the rock layers. When a non-porous rock is moved opposite to a porous rock than it seals off the natural flow of the hydrocarbons. Gas and oil cannot pass through the fault boundary, they are trapped and they can accumulate.



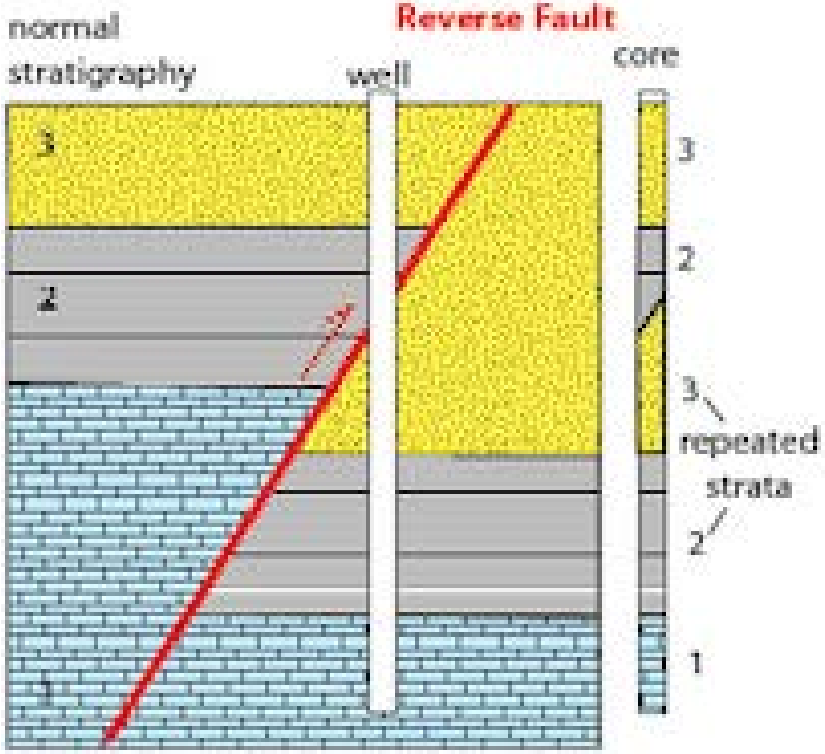
Normal fault

Reverse of thrust fault

Strike slip fault

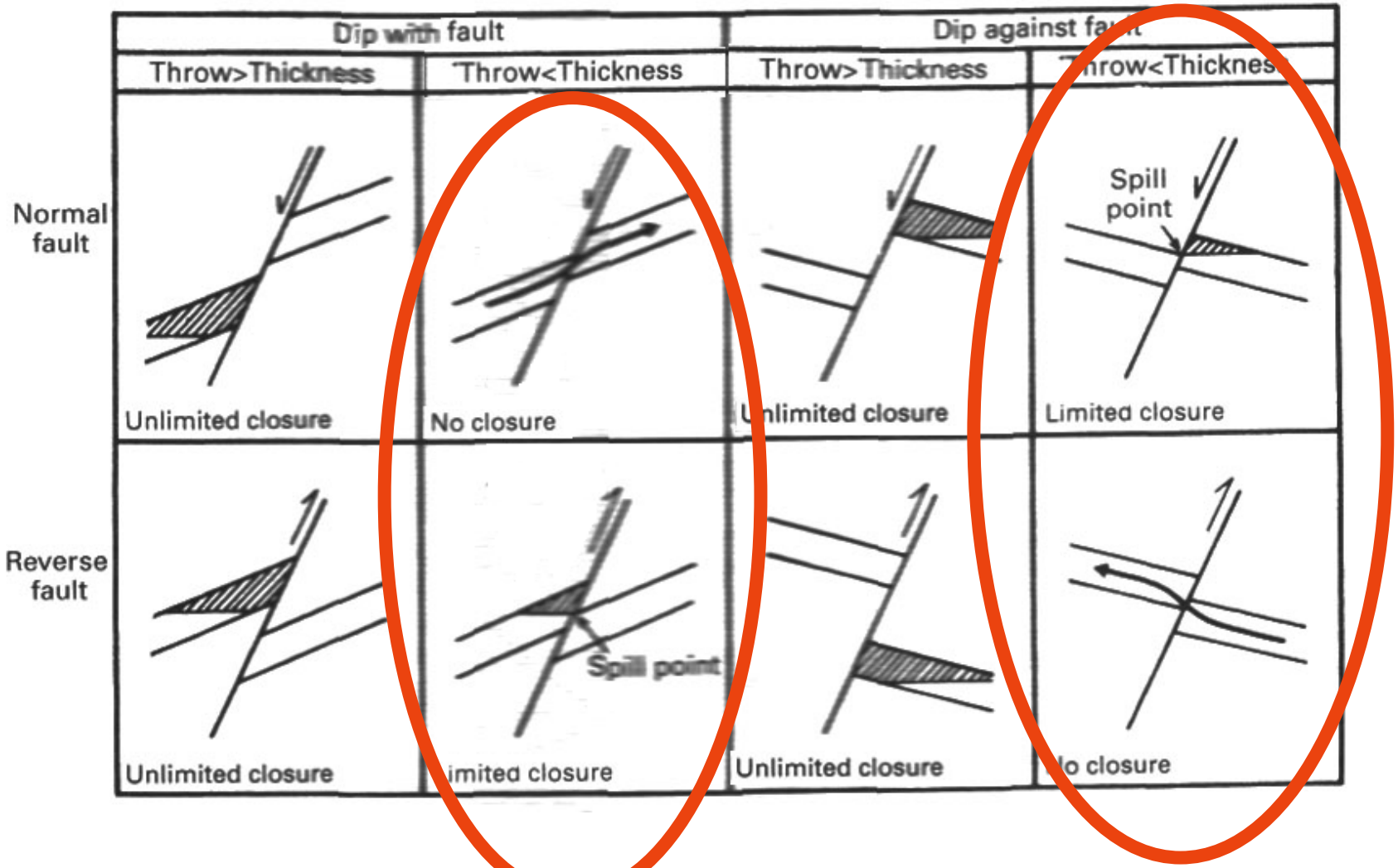


A vertical well drilled within the fault may not intersect all horizons



A vertical well penetrating a reverse fault can encounter repeated section.

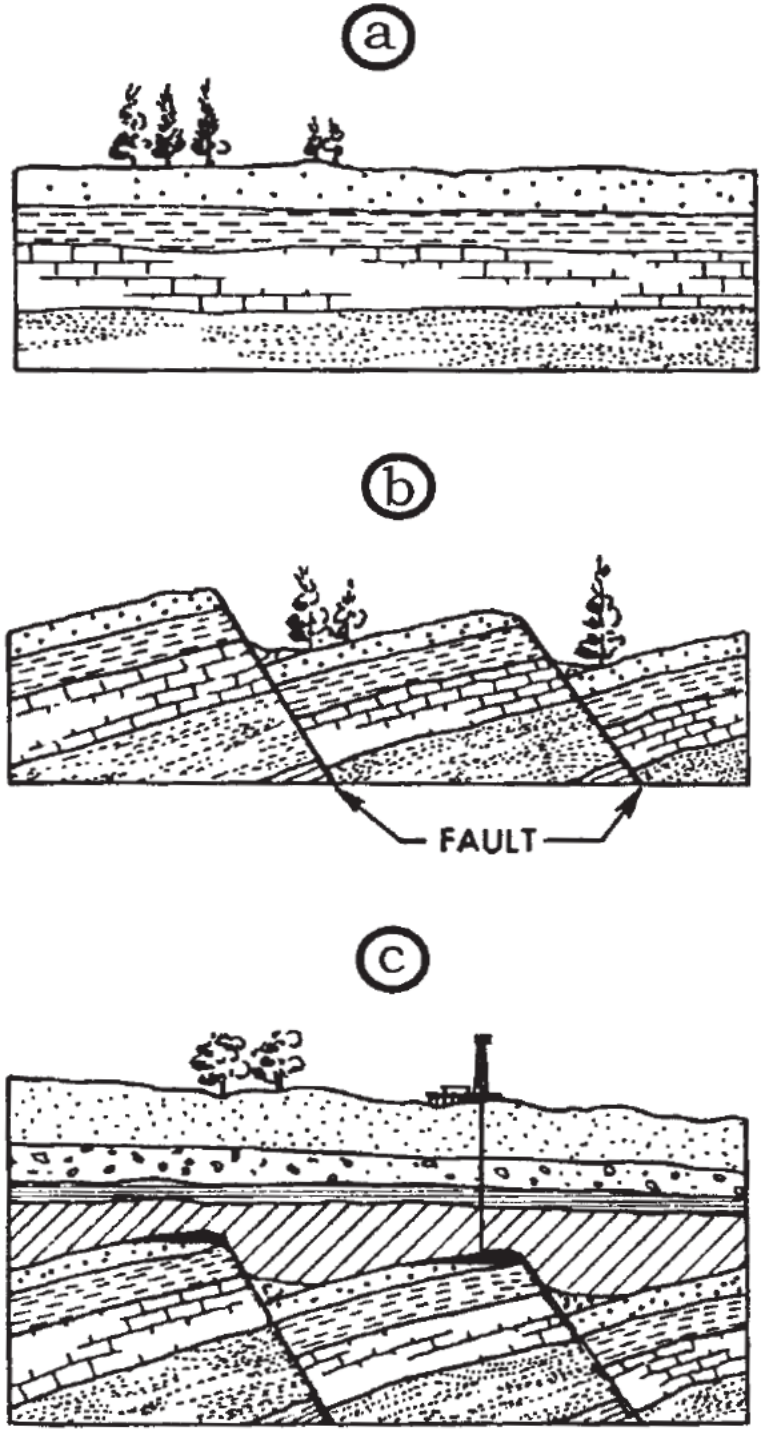
but in some cases faults allow the flow of oil and gas



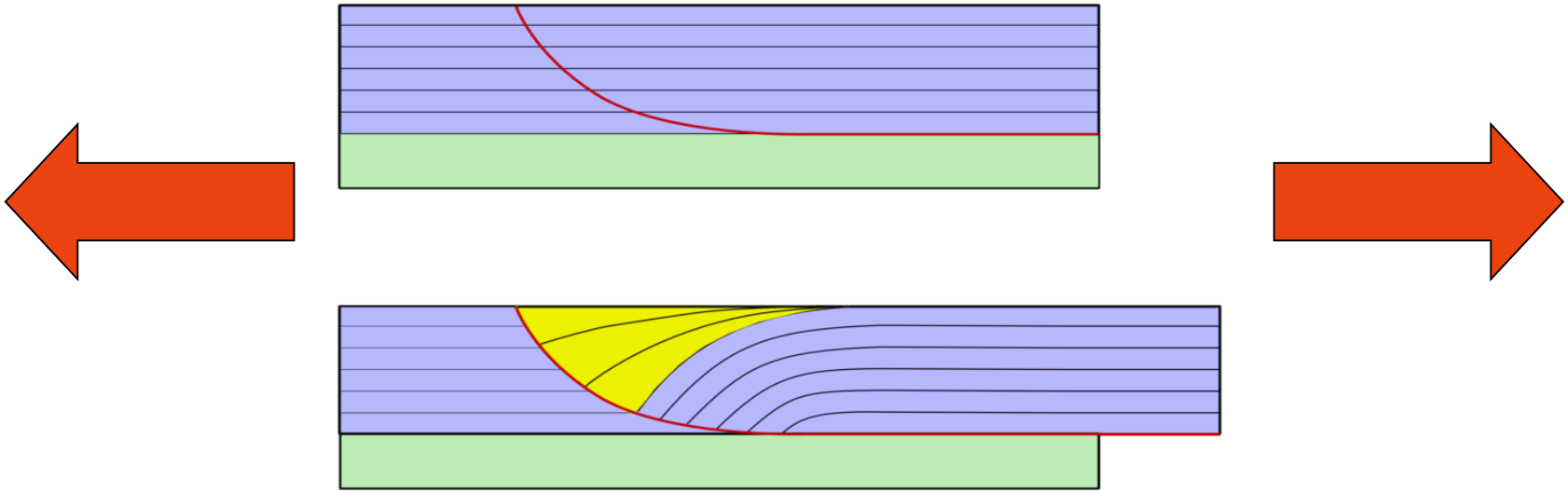
Tilted fault blocks

Buried, tilted fault blocks can form large petroleum traps.

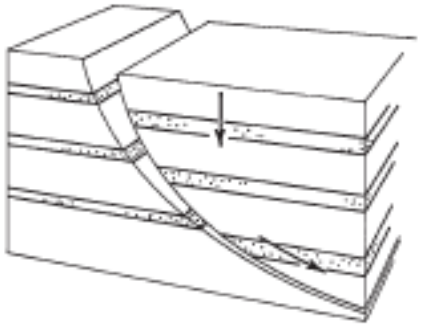
1. Horizontal sedimentary rocks were broken by normal faults into large blocks,
2. They were tilted.
3. Some of the blocks can contain reservoir rocks.
4. Later, the seas covered the tilted fault blocks and deposited caprocks of shale or salt on them.
5. The oil and gas then formed and migrated up along the reservoir rock to below the sealing fault or caprock.

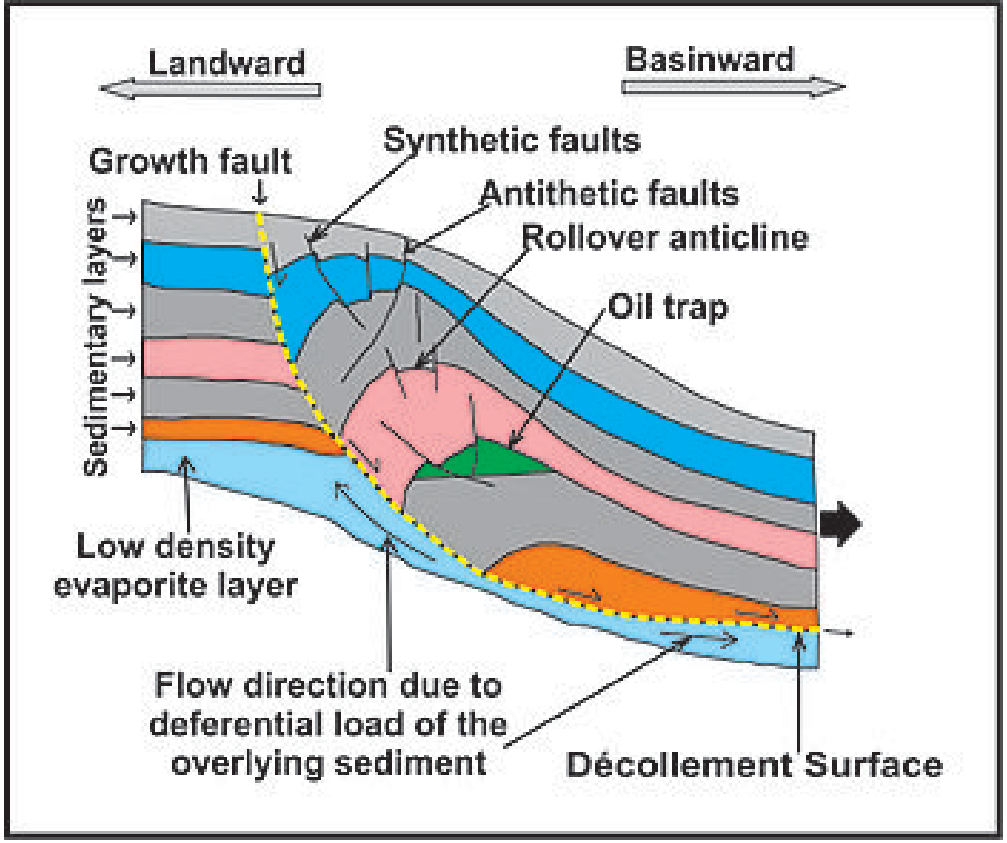


I/3: Growth fault – rollover anticline



<u>Rollover anticlines</u> related to extension. It is a syn-depositional structure (develop during sedimentation) developed within the hanging wall of large listric normal faults. Listric faults flatten with depth. Due to the extension a void is created between the two blocks. The layers of the hanging wall filling this void and experiences flexural.





- Each layer shows thickening toward the controlling fault.
- Rollover structures are often associated by large river deltas, and are favorable traps for hydrocarbons.

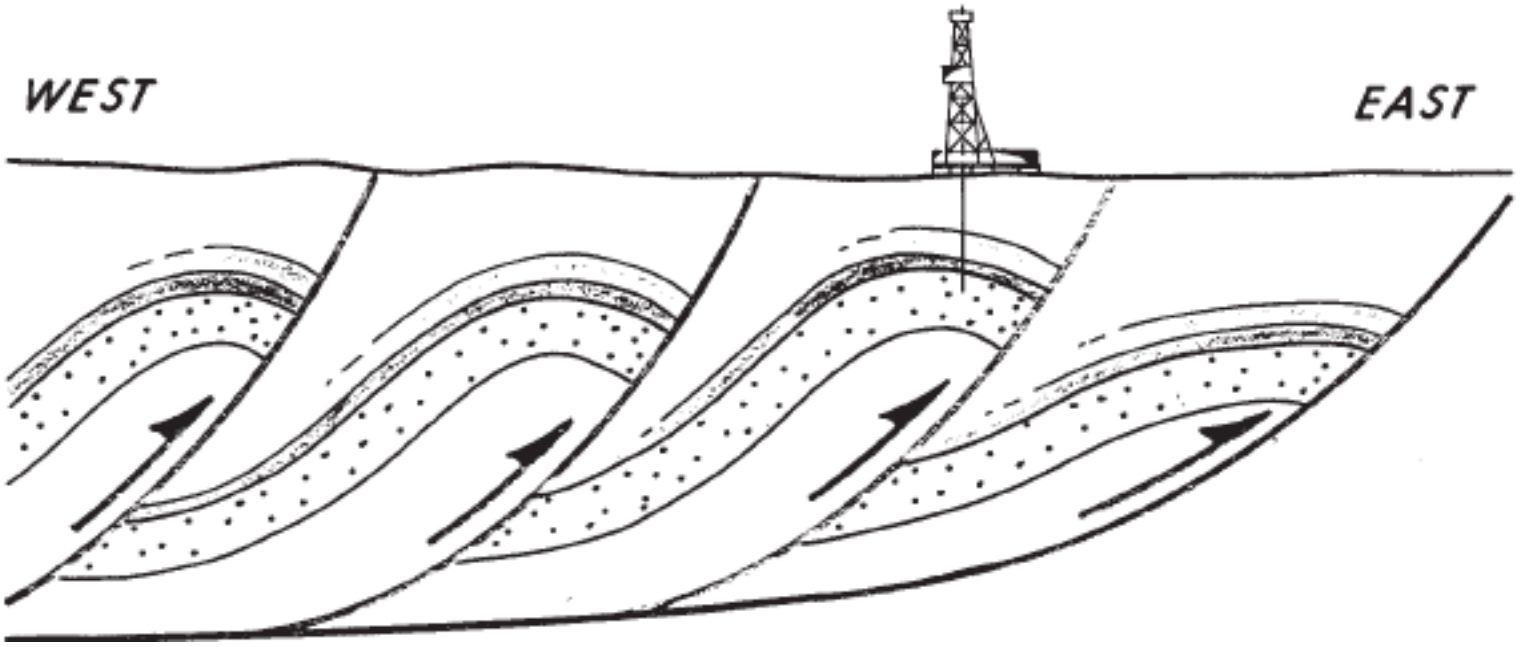
I/4: Drag folds

- Most mountain ranges on land were formed by compressional forces, and the rocks display compressional features such as folds, reverse faults, and thrust faults. The thrust faults occur in zones called *overthrust belts* that parallel the mountain ranges.



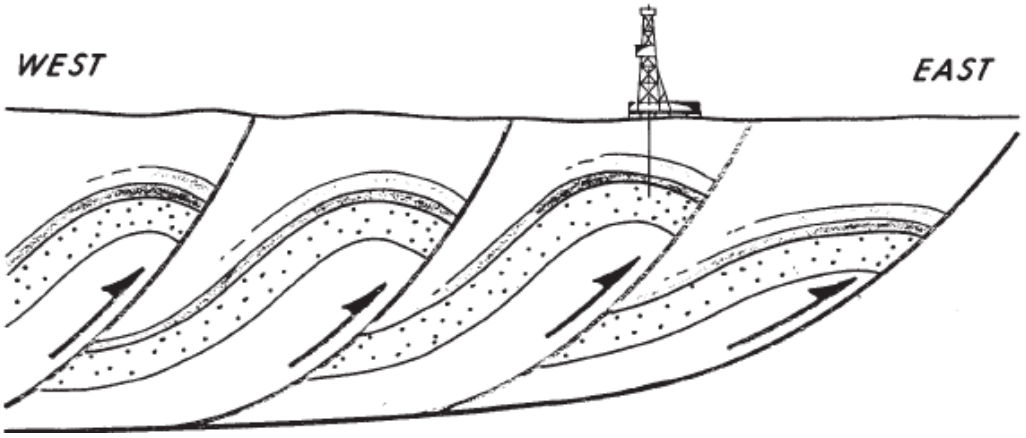
Map of Rocky Mountain

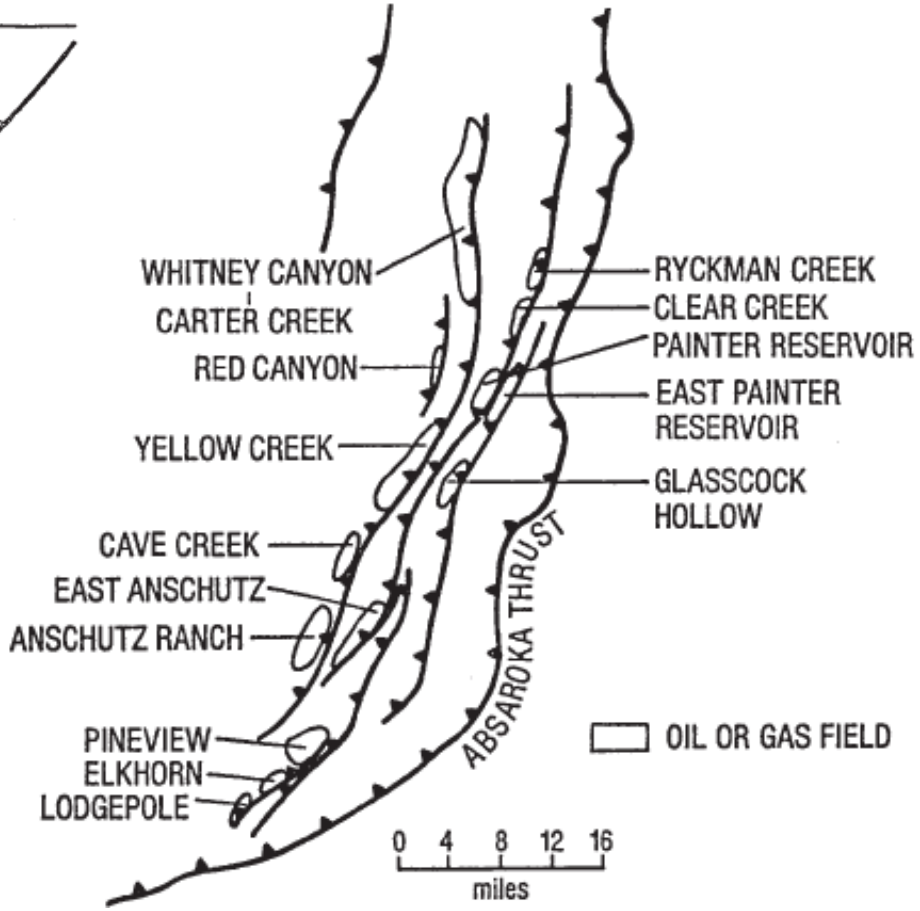
A west-to-east cross section shows the deformation of the earth's crust. Several of the thrust faults moved tens of miles horizontally.In Wyoming and Utah, the 1,000 ft (305 m) thick Jurassic age Nugget Sandstone has been deformed into large subsurface **drag folds** along the thrust faults. These are the targets for Rocky Mountain overthrust drilling.



East-west cross section of overthrust belt

Each drag fold field is located just to the west of a thrust fault





Map of oil and gas fields in the Western overthrust belt of Wyoming and Utah.

II. Stratigraphic traps

Formed by changes in rock type, due to sedimentary facies changes or diagenetic processes

II/A. Primary:caused by <u>depositional morphology</u>

- Reefs, Beaches, River channels, Pinch-outs, Incised valley fills.
- Compactional anticlines

II/B. Secondary: <u>under or above an unconformity surface</u>:

- Truncation, Onlap

II/C. Diagenetic

These traps do not occur as a result of movement of the strata.

II/A. Primary or depositional stratigraphic traps: caused by facies change

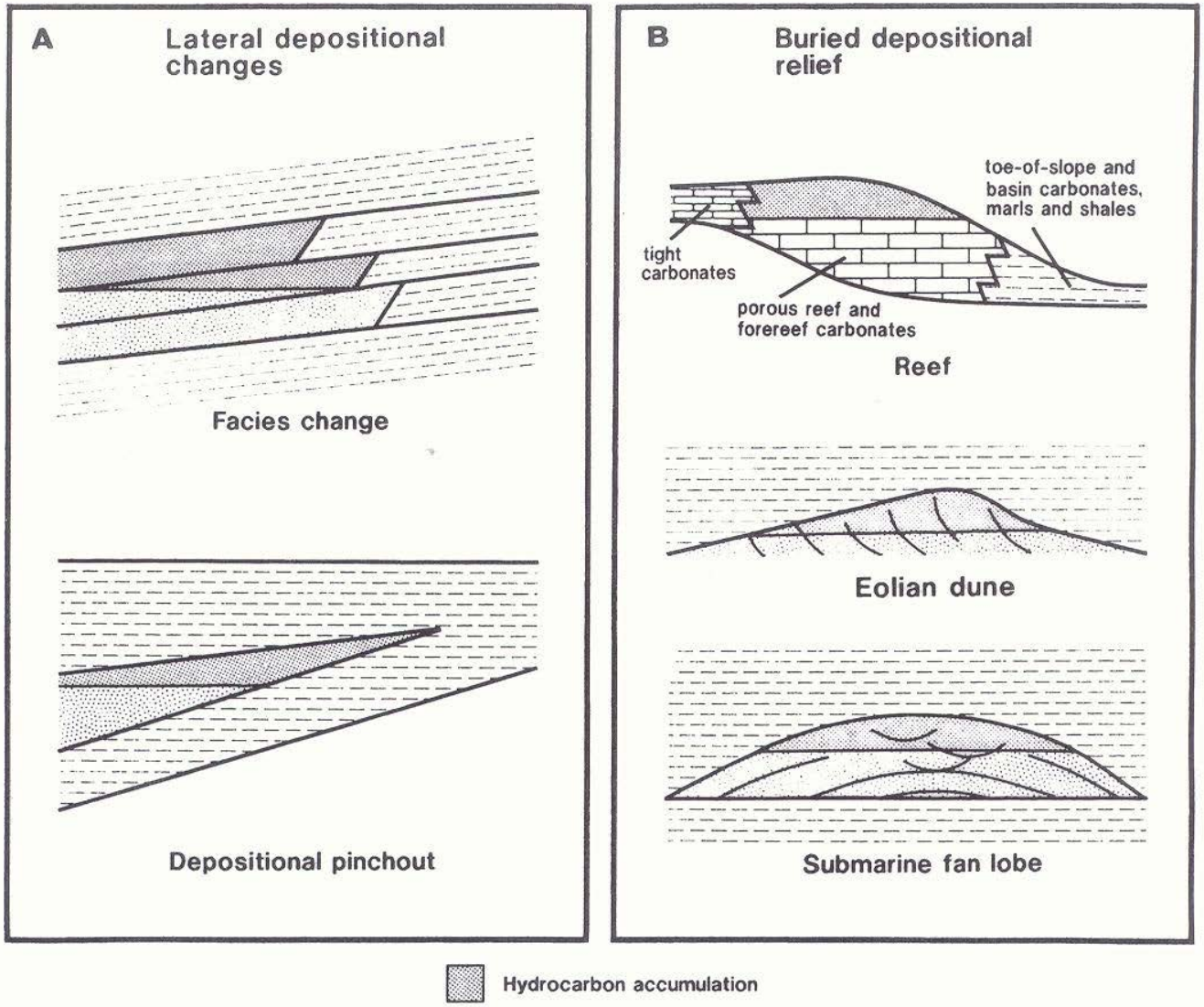
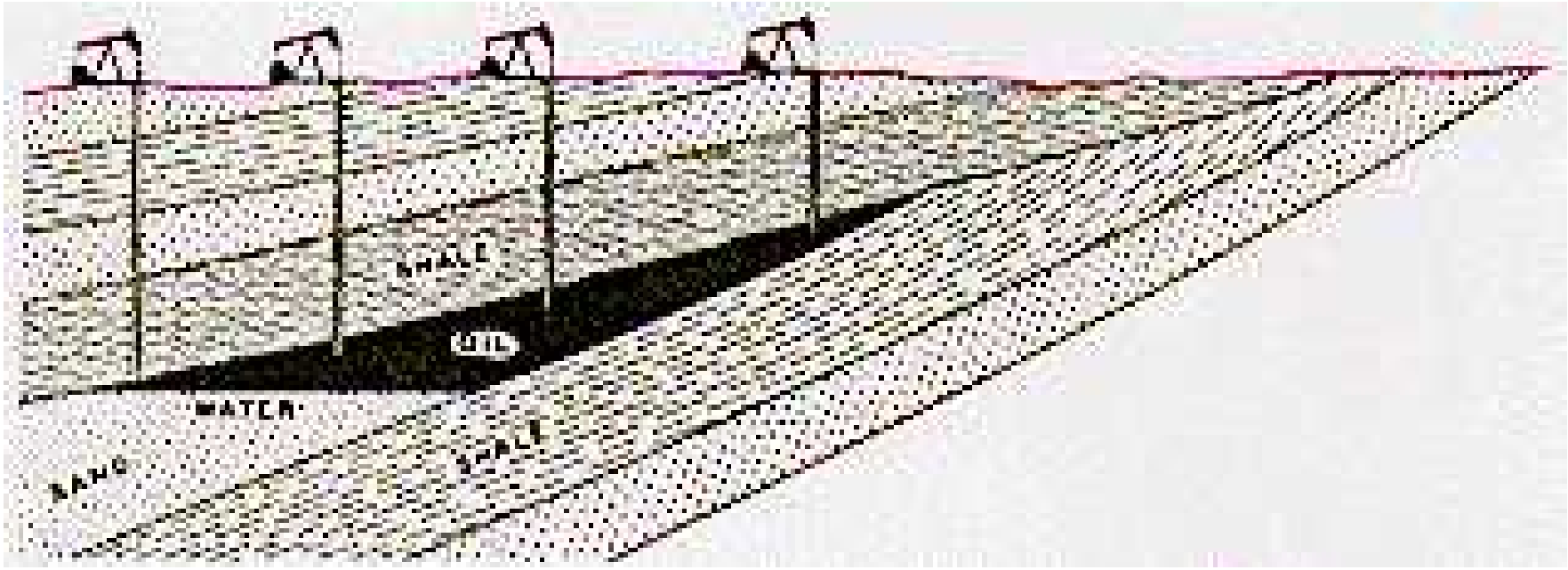


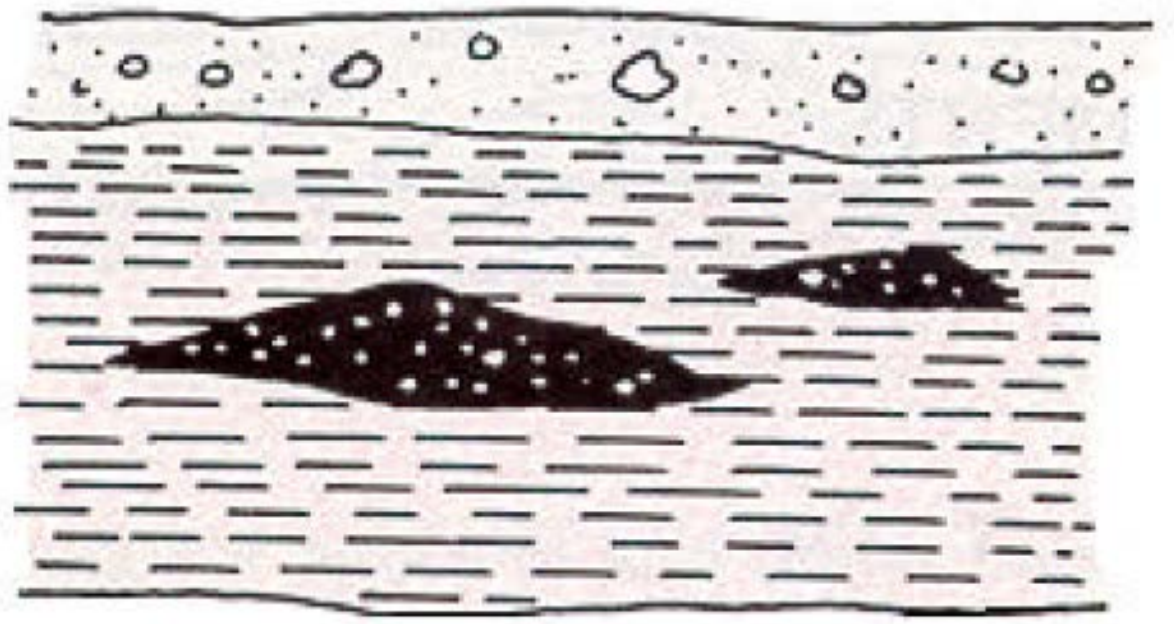
Figure 13.7. Primary or depositional stratigraphic traps. (A) Traps created by lateral changes in sedimentary rock type during deposition. Top: juxtaposition of reservoir and seal caused by lateral facies changes. Bottom: reservoir termination due to the depositional pinchout of porous and permeable rock units. (B) Traps formed by buried depositional relief. In each example, sedimentary processes form a potential trapping geometry, but require burial by younger impermeable section to create the required top seal.

II/A/1: Pinch-out trap



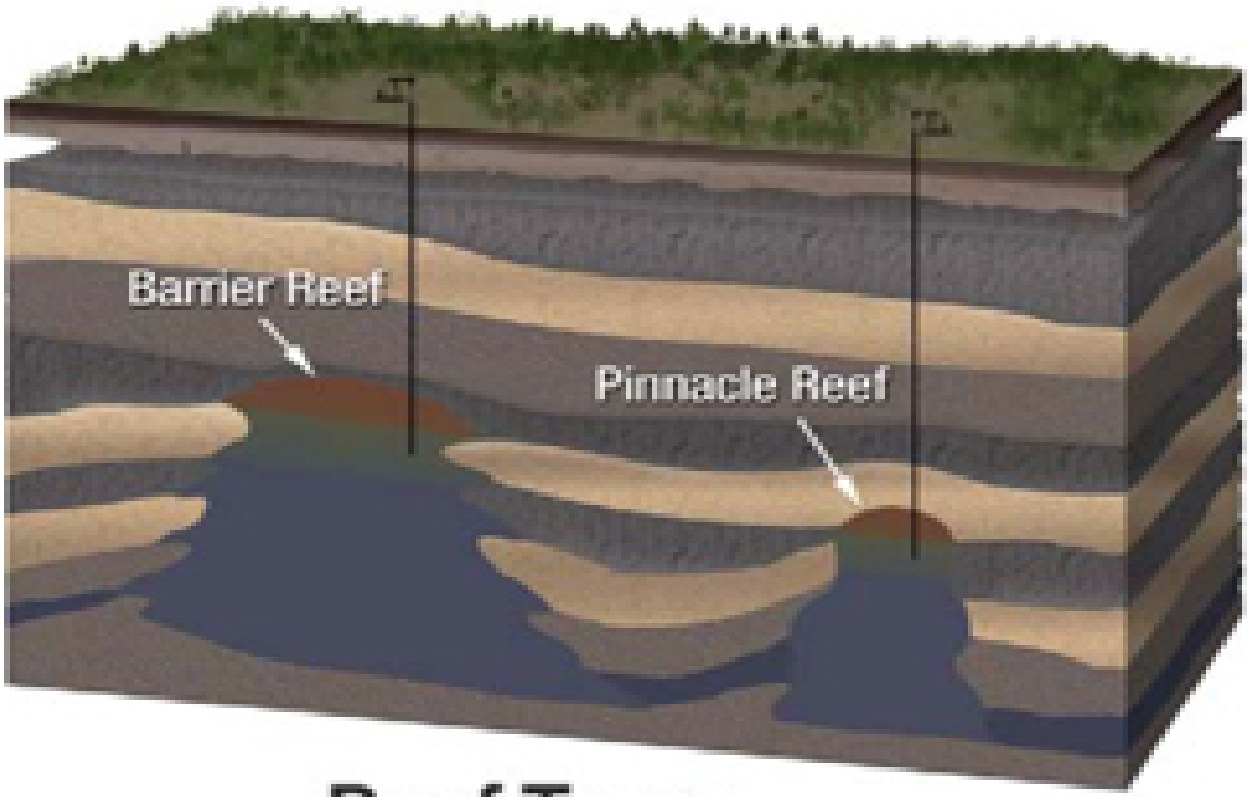
Pinch-out trap: thinning out of a reservoir rock against an impermeable seal rock. Created by **depositional environment (facies) changes up-dip.**

II/A/2: Lenticular trap



A porous area surrounded by non-porous strata. They may be formed from ancient buried **river sand bars, beaches**, etc.

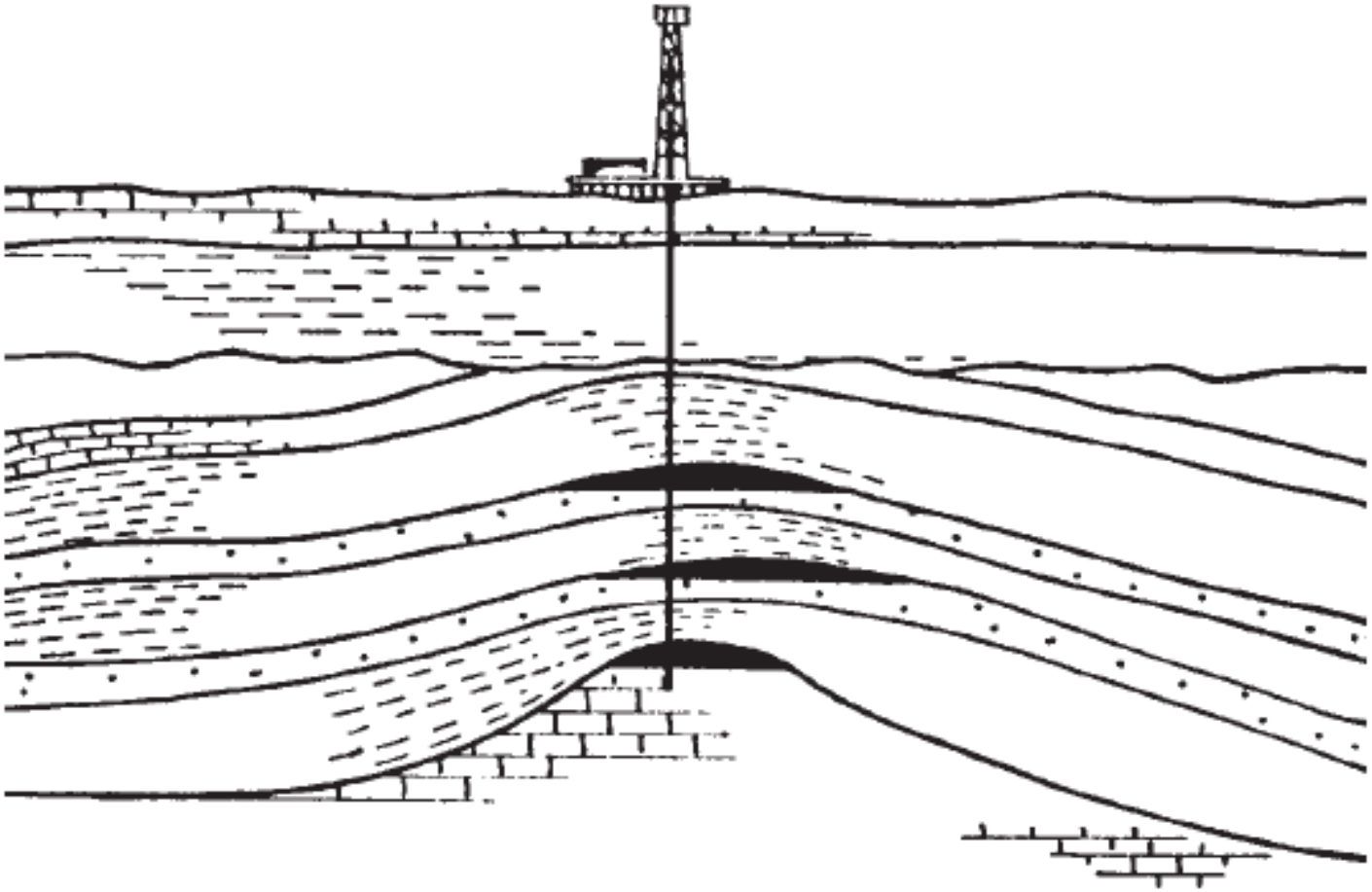
II/A/3: Reefs



Reef Traps

Reefs are prolific gas and oil traps

- Petroleum production can come not only from the reef but also from a *compaction anticline* overlying the reef (see later)



compaction anticline

Reef on seismic section

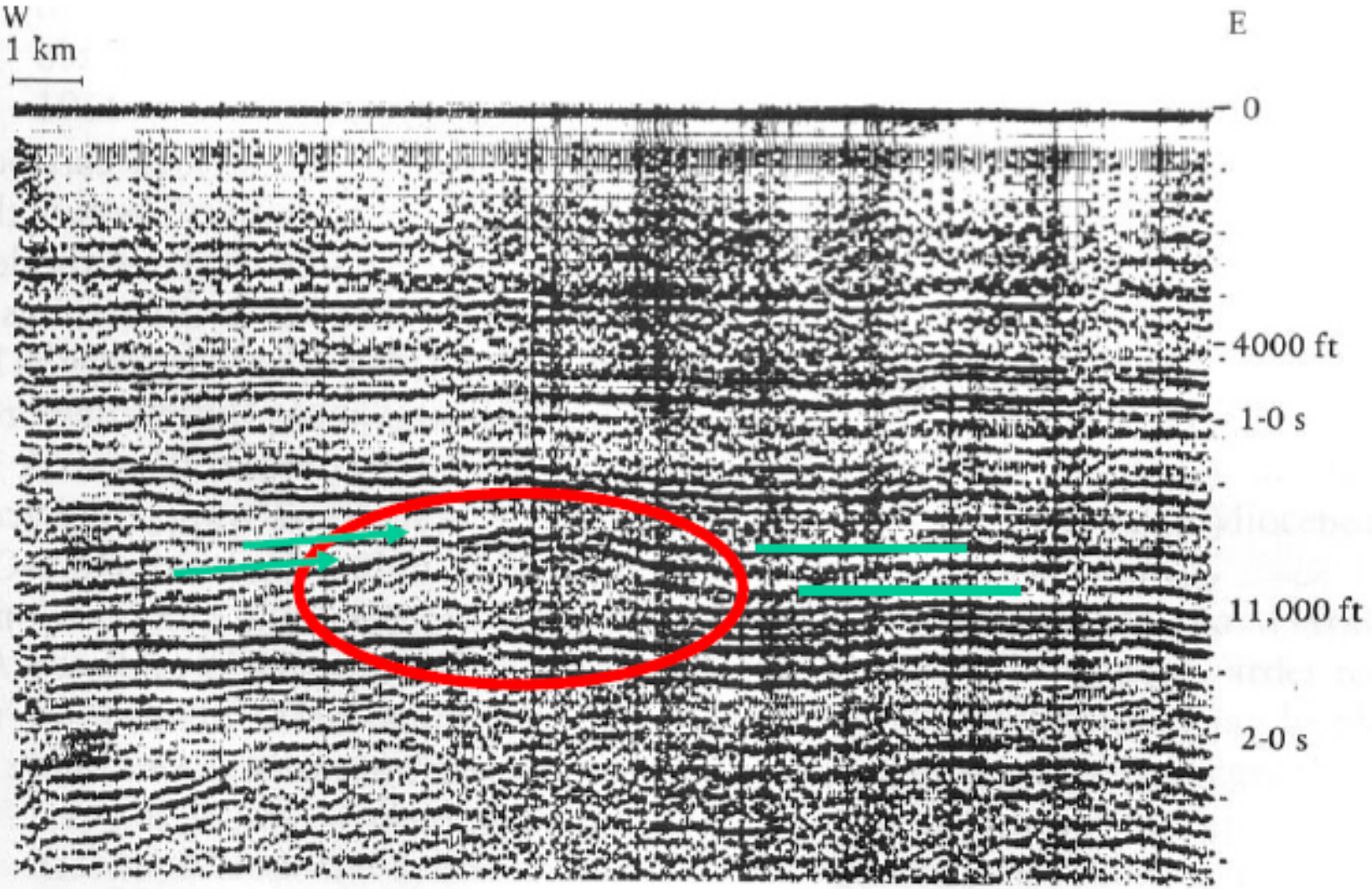
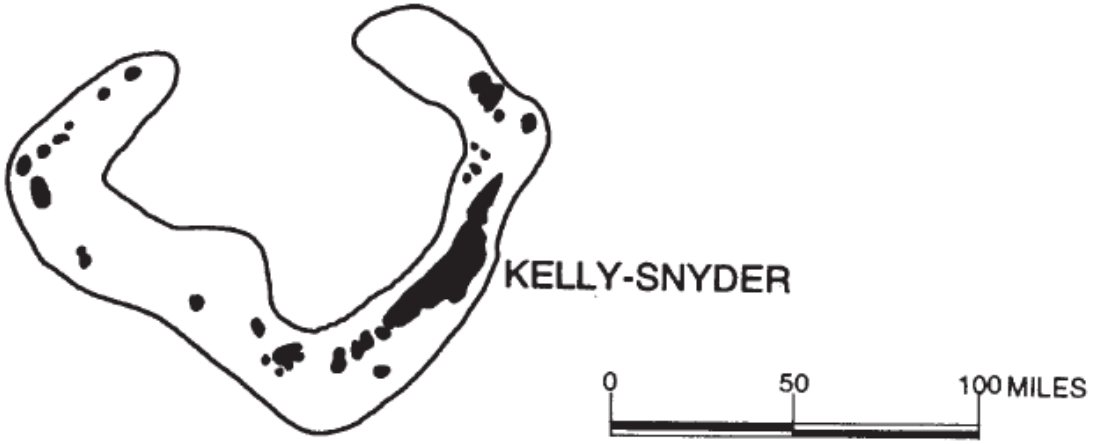


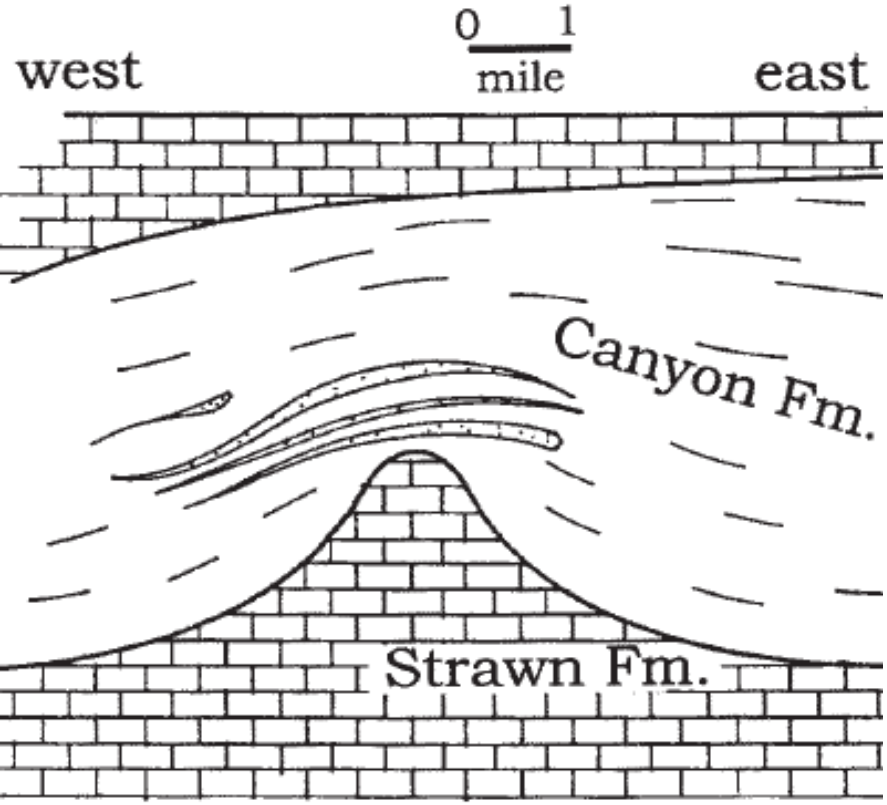
FIGURE 7.39 Seismic line through a limestone reef or build-up, clearly visible as a characterless lense at 11,000 feet. Note regular reflectors of back reef lagoonal sediments to the east, and basinal reflectors onlapping the reef from the west. (From Fitch, 1976.)

II/A/3:Atoll

(a special reef)



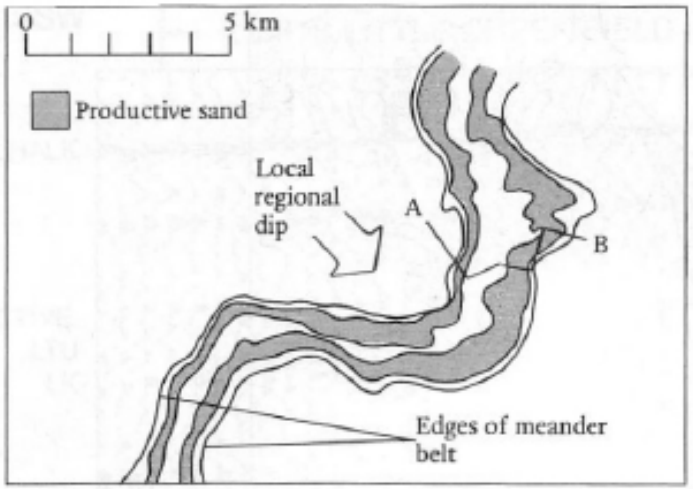
Map of the Horseshoe atoll, Texas, showing oil fields

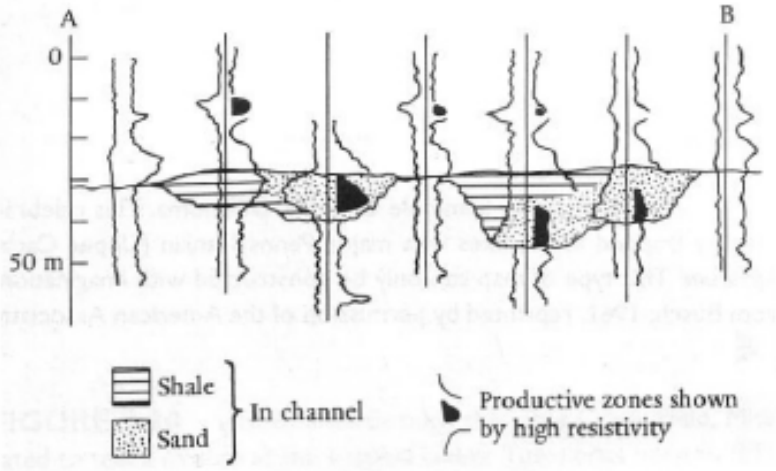


The major production comes from the reef that has pores enhanced by solution. Production also comes from the compaction anticline in thin sandstone layers in the overlying shales of the Canyon Formation.

East-west cross section of Snyder field, Texas

II/A/4: River Channels



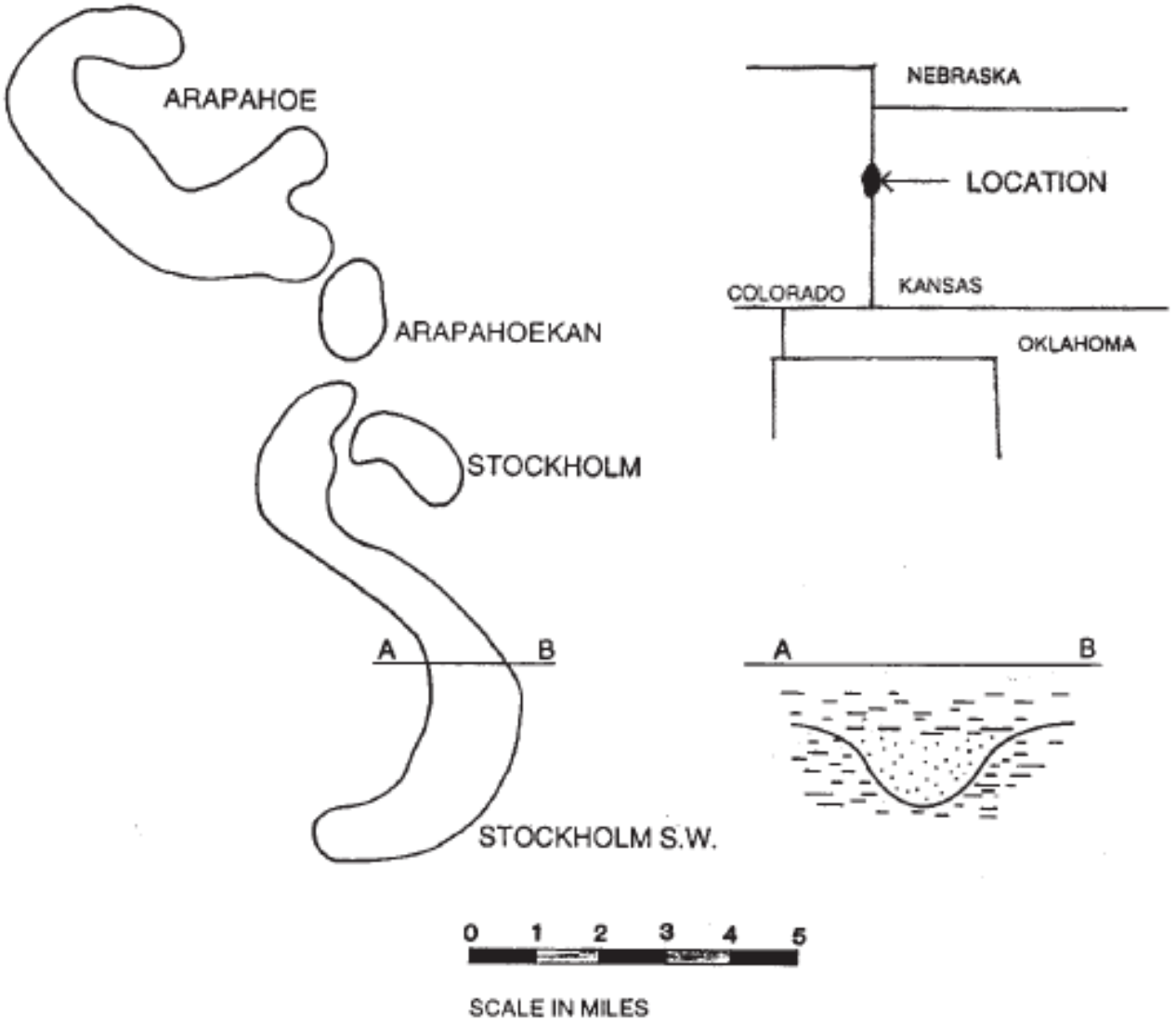


„Shoe-string traps“

Map and cross-section of the Cretaceous South Glenrock oil filed, Powder River basin, Wyoming.
Note the small dimensions of the reservoir and that not all of the channel contains sand.

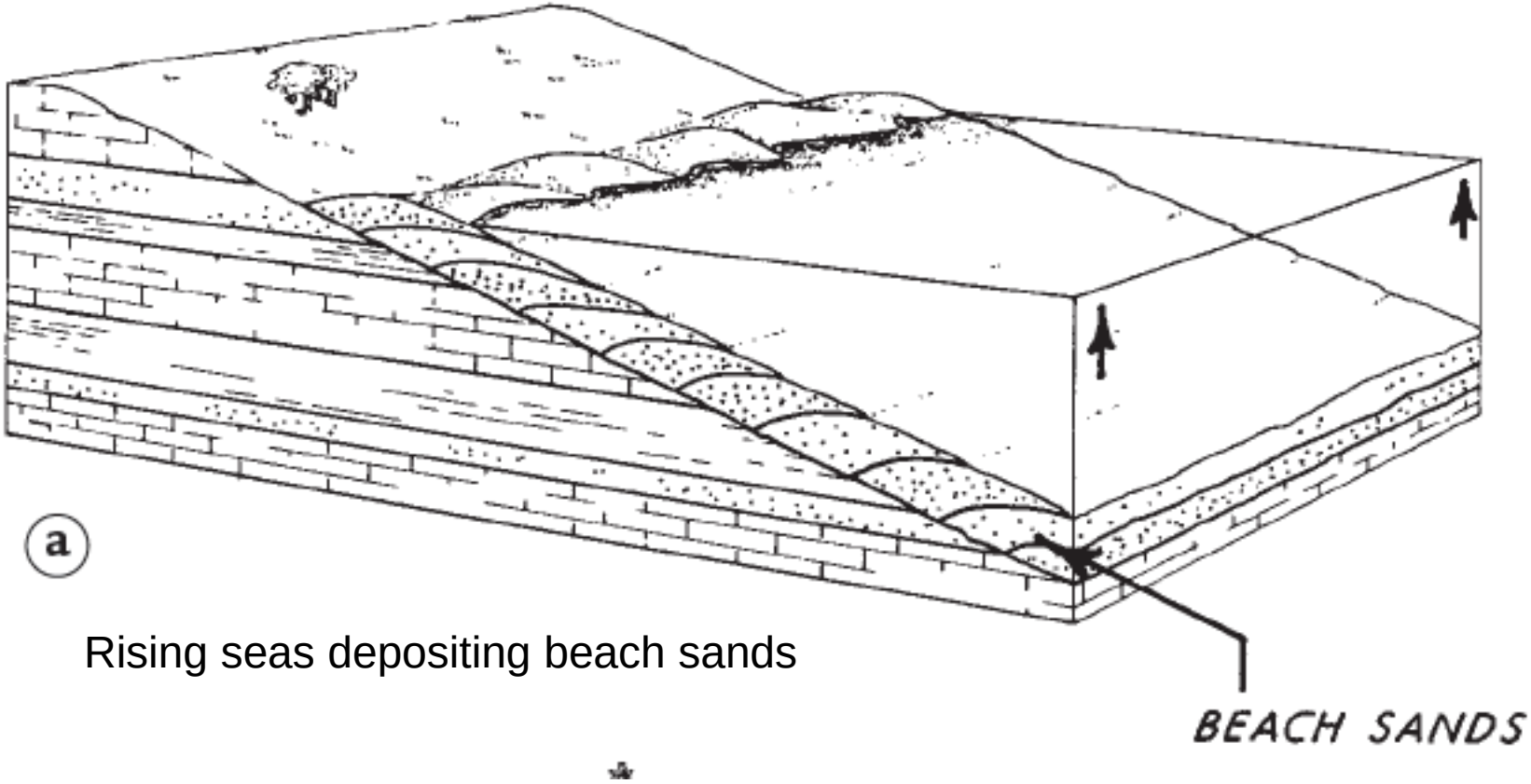
Arranged „perpendicular“ to coast-line

Selley (1997)



Map of Pennsylvanian age sandstone fields, Colorado and Kansas, and west-east cross section of Stockholm southwest field.

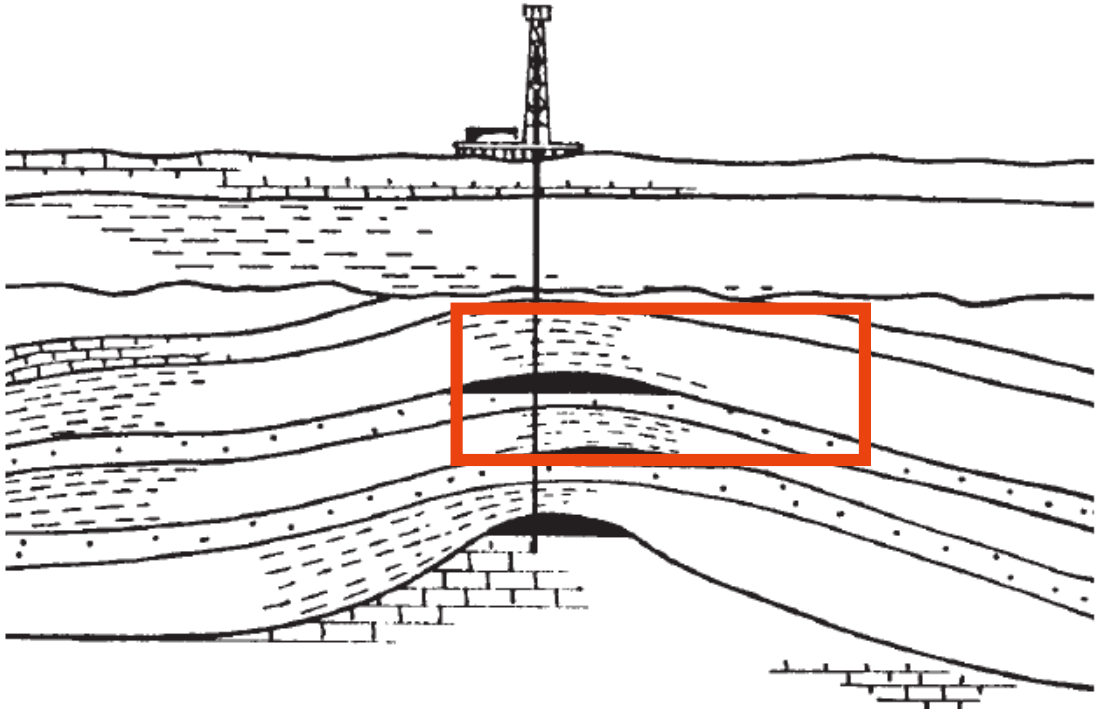
II/A/5: Beach sands



Rising seas depositing beach sands

Beach sands can be deposited on an angular unconformity during rising seas and form giant oil and gas field reservoirs.

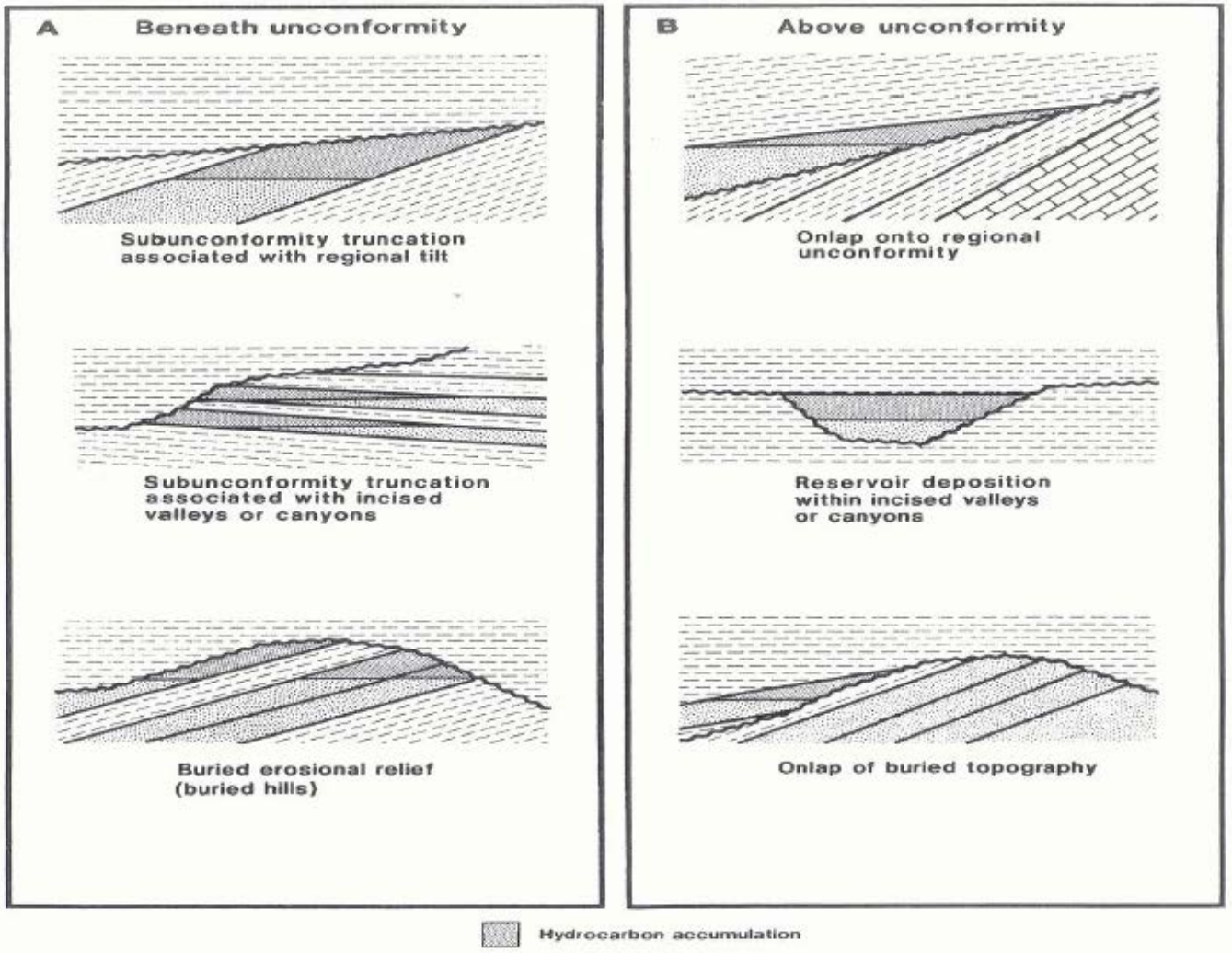
II/A. Primary traps: Compactional anticlines



It forms in porous sediments, such as sands and shales, deposited on a hard rock mound or ridge, such as a limestone reef.
The sediments are deposited thicker to the sides of the reef than directly over the top. When the sediments are buried deeper, the weight of the overlying sediments compacts the loose sediments. The reef, composed of resistant limestone, compacts less. Because more compaction occurs in the thicker sediments along the flanks of the reef, a broad anticline forms in the sediments over the reef. Any reservoir rocks in the sedimentary rocks overlying the reef can trap petroleum.

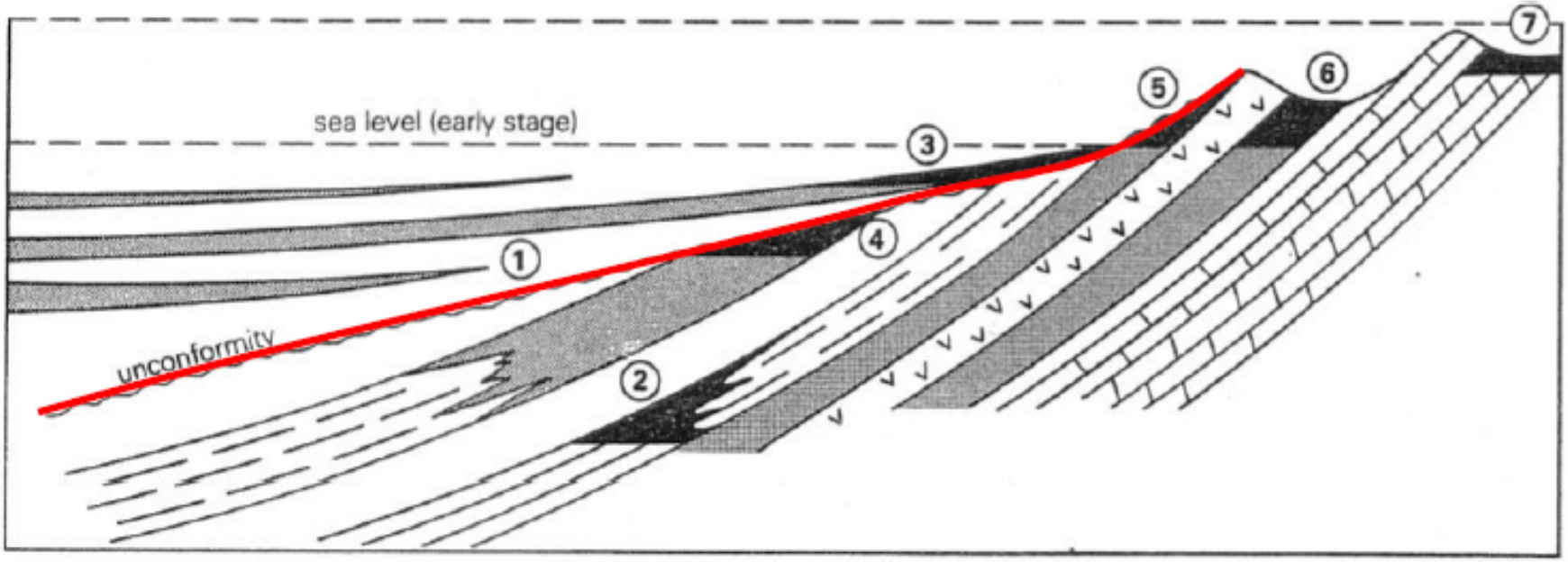
II/B. Secondary: <u>under or above an unconformity surface</u>:

Truncation, Onlap



Stratigraphic – Unconformity – Truncation/Onlap

Traps dependant on the presence of buried hills during basinal subsidence and marine transgression (= *Paleogeomorphic traps*)

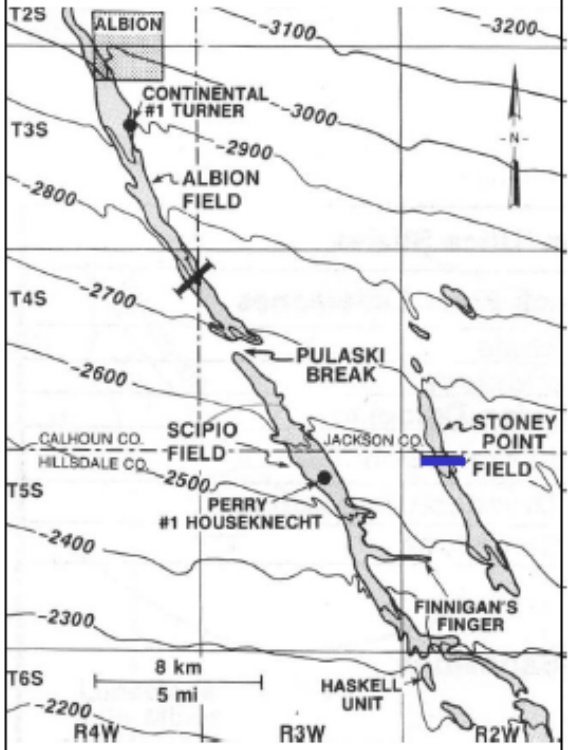


1, 2 pinch-out traps (not related to unconformity)
3 Unconformity traps above the unconformity (onlap)
4 Unconformity traps below the unconformity (truncation)
5-7 paleogeomorphic traps (buried hills; truncation)

North (1990)

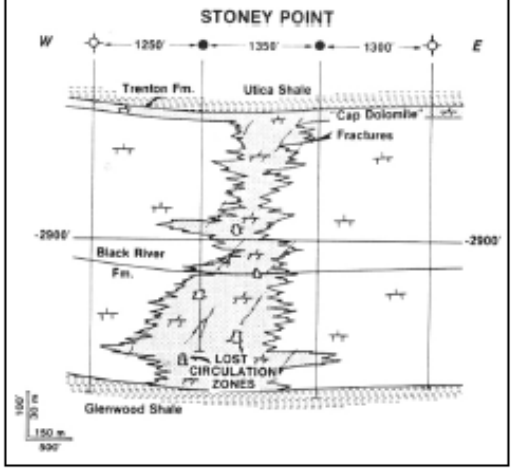
II/C Stratigraphic traps: Diagenetic

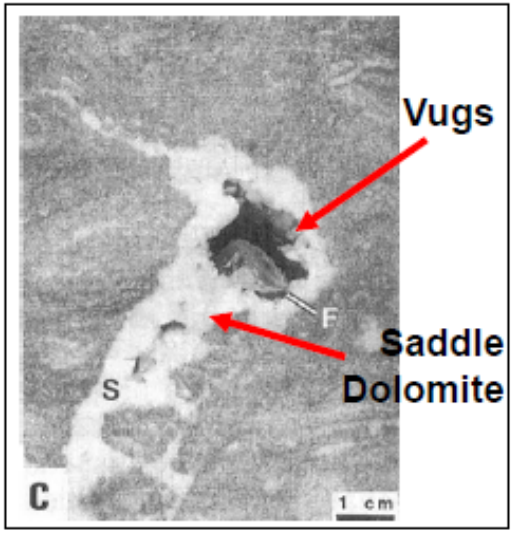
Structure map on Top of Trenton Group



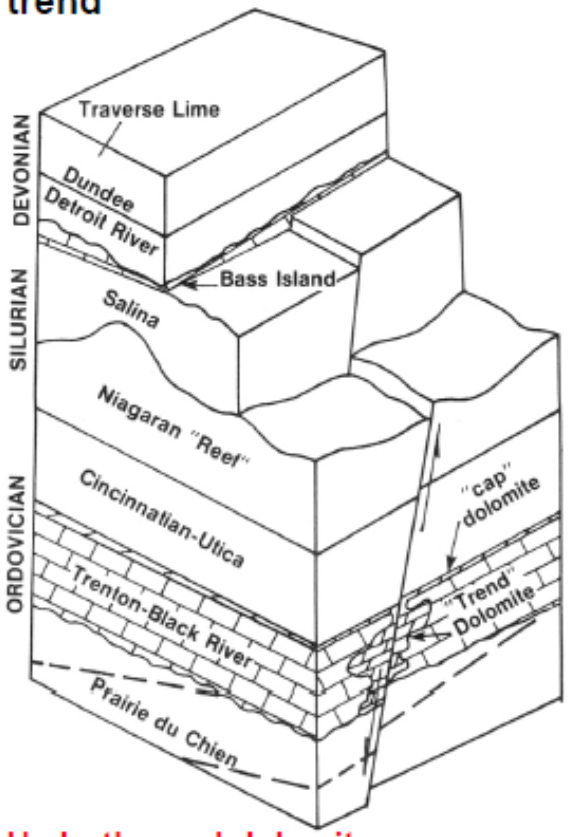
- **uniform regional dip**
- **synclinal depressions** over the long, linear Albion-Scipio and Stoney Point trends.
- **en echelon arrangement** of traces of syncline axis
- **Strike-slip fault** with some vertical (extensional) movement

- **abrupt transition** from regional limestone to reservoir dolomite





Interpretation of Albion-Scipio trend



Hydrothermal dolomite

- Hot fluids ascending along faults changed calcite ($Ca[CO_3]$) into dolomite ($Ca/Mg[CO_3]_2$).

II/C. Stratigraphic: Diagenetic Traps

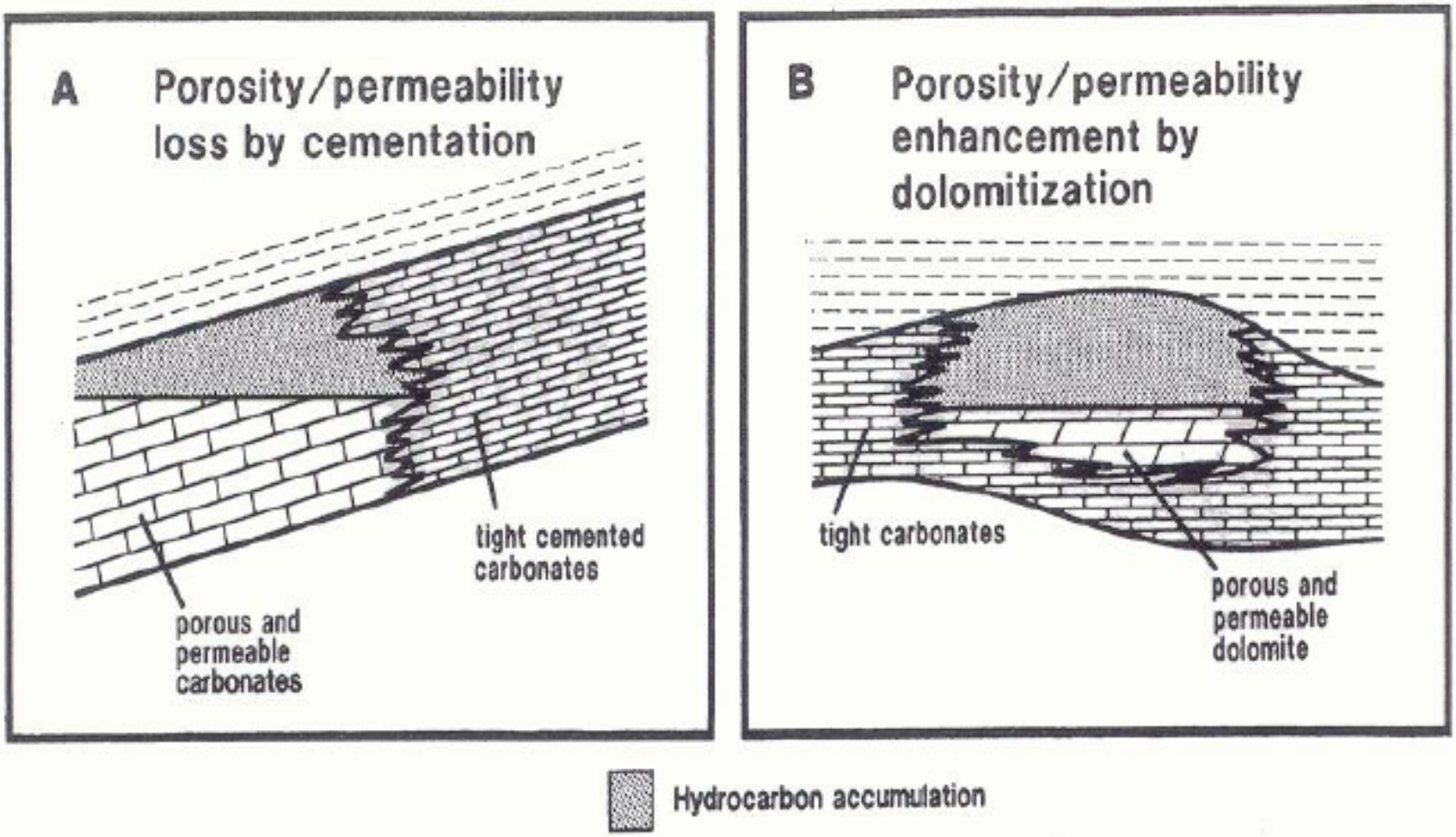
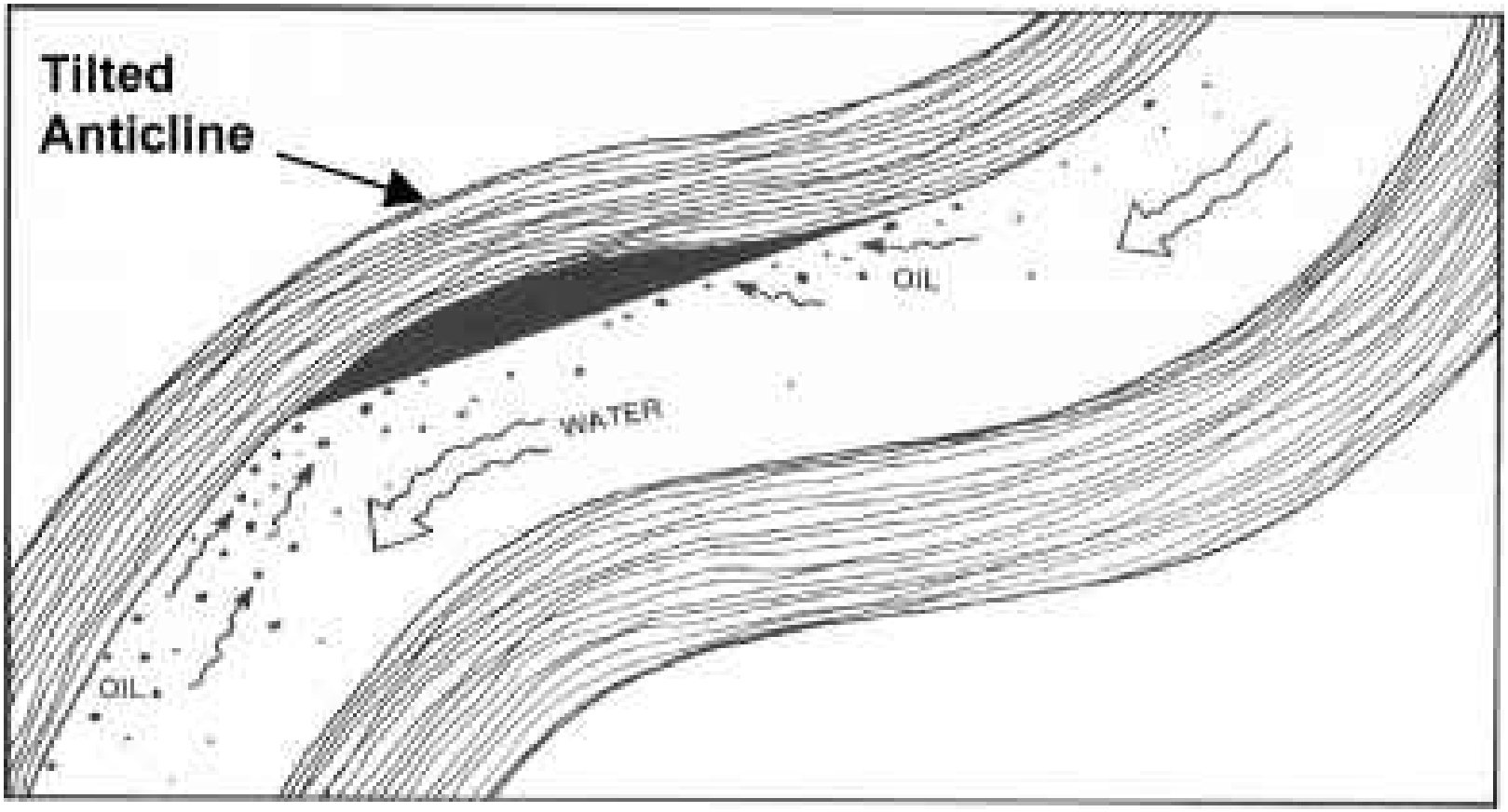


Figure 13.9. Secondary diagenetic stratigraphic traps. (A) Traps created by postdepositional updip porosity occlusion. (B) Traps created by postdepositional porosity and permeability enhancement.

III. Hydrodynamic traps

flow of water updip and downdip can create pockets of trapped oil

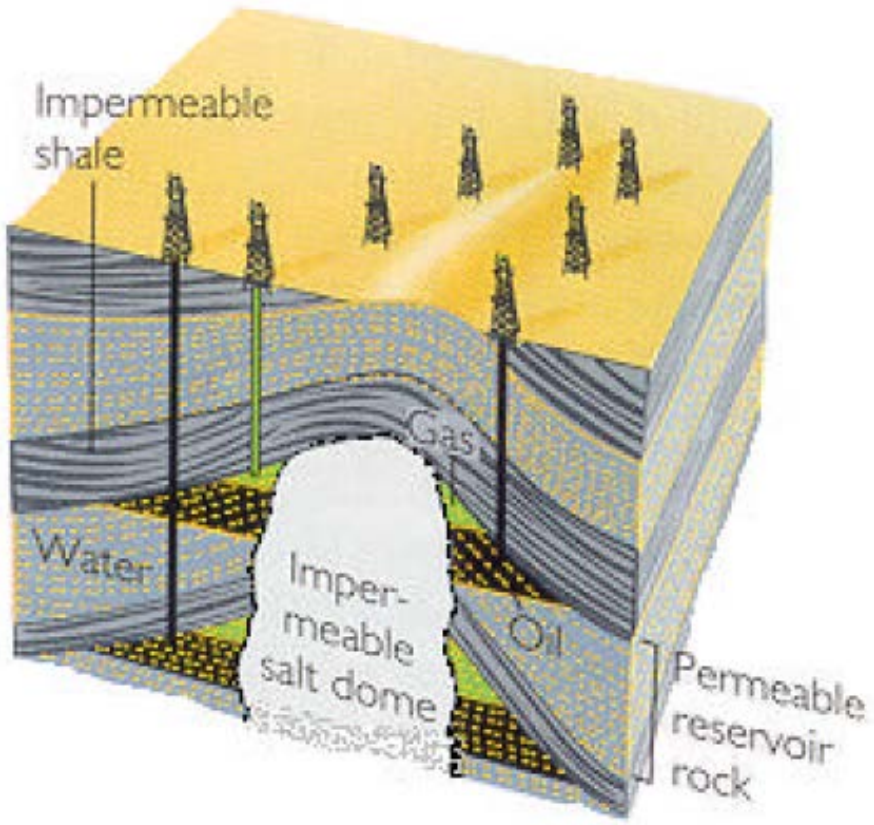


IV. Combination traps

have both structural and stratigraphic trapping elements

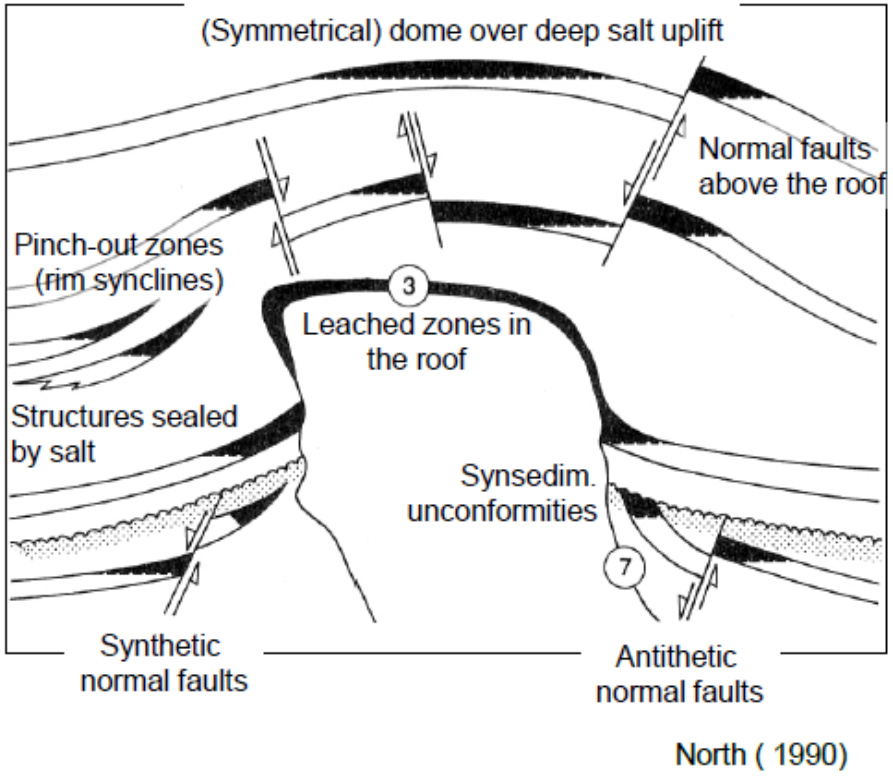
- Salt domes
- Bald headed structures
- Faulted anticline

IV/1: Salt Dome Trap



A trap created by piercement of stratified rock layers due to intrusion of salt from below.
The lower formations, nearest the intrusion are uplifted and truncated along the sides of the intrusion, while layers above are uplifted creating a dome or anticlinal folding. Hydrocarbons migrate into the porous and permeable beds on the sides of the column of salt.
Hydrocarbons accumulate in the traps around the **outside of the salt plug** if a seal or cap rock is present.

Traps associated with salt domes



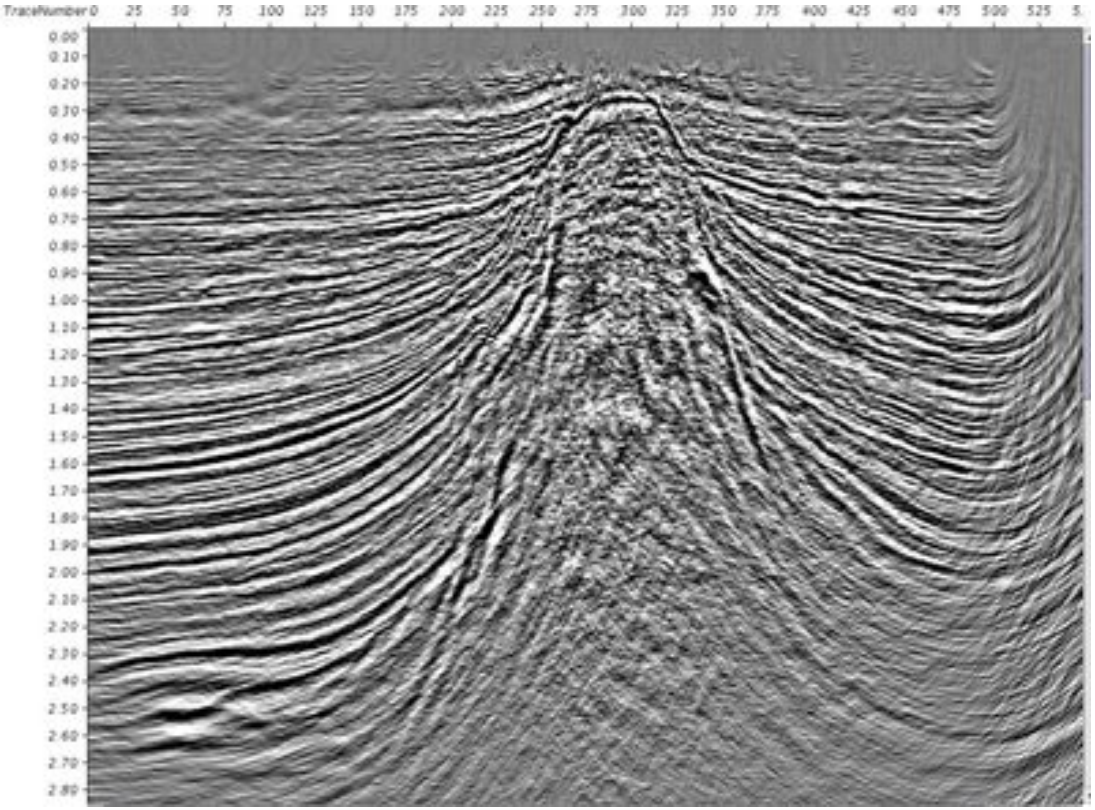
North (1990)

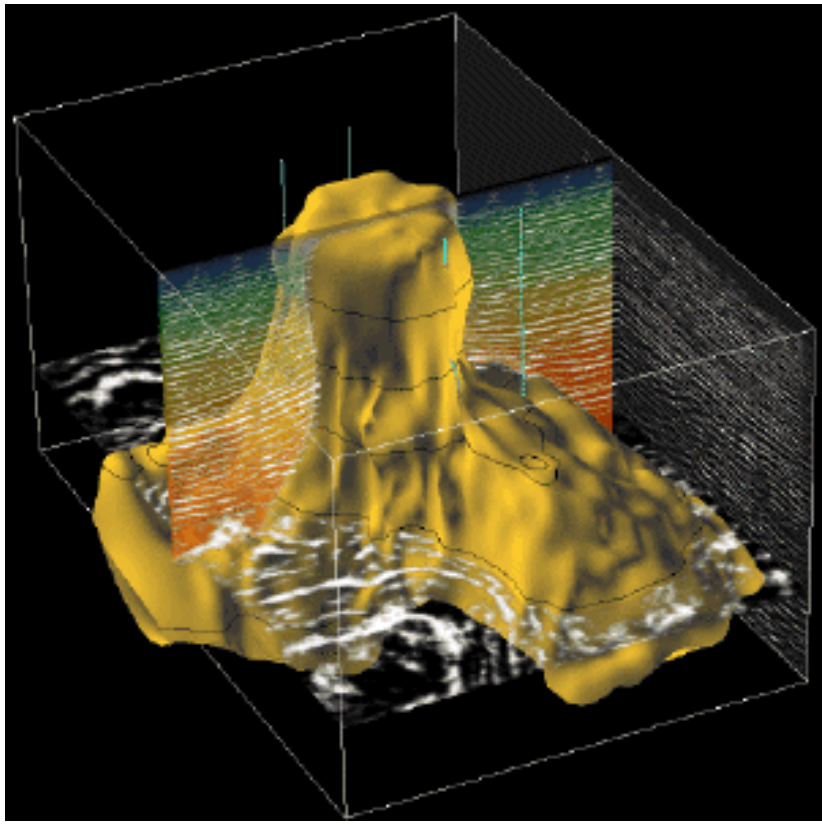
- There are two areas for drilling on salt domes.
- 1. **<u>Above the salt dome</u>**, any shallow reservoir rocks such as sandstones are domed.

  Near the top of the salt dome, uplift has caused the overlying sedimentary rocks to be faulted with normal faults that sometimes form grabens. These form fault traps. Because the caprock is often fractured and porous, it can be productive reservoir rock.

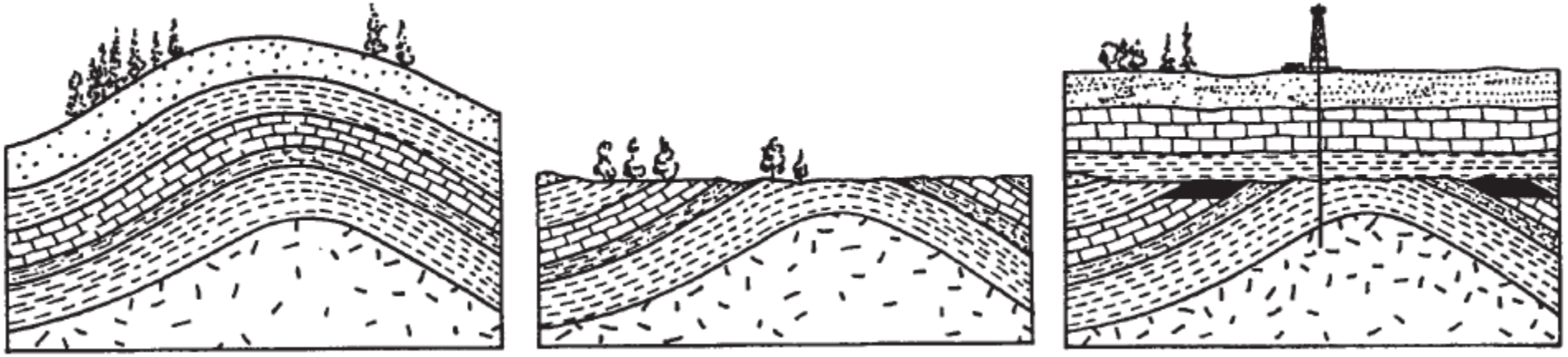
  2. <u>Along the flanks of the salt dome</u>, reservoir rocks that were uplifted and pierced form traps against the impermeable
- salt dome.

Salt dome traps





IV/2: Bald-headed anticline

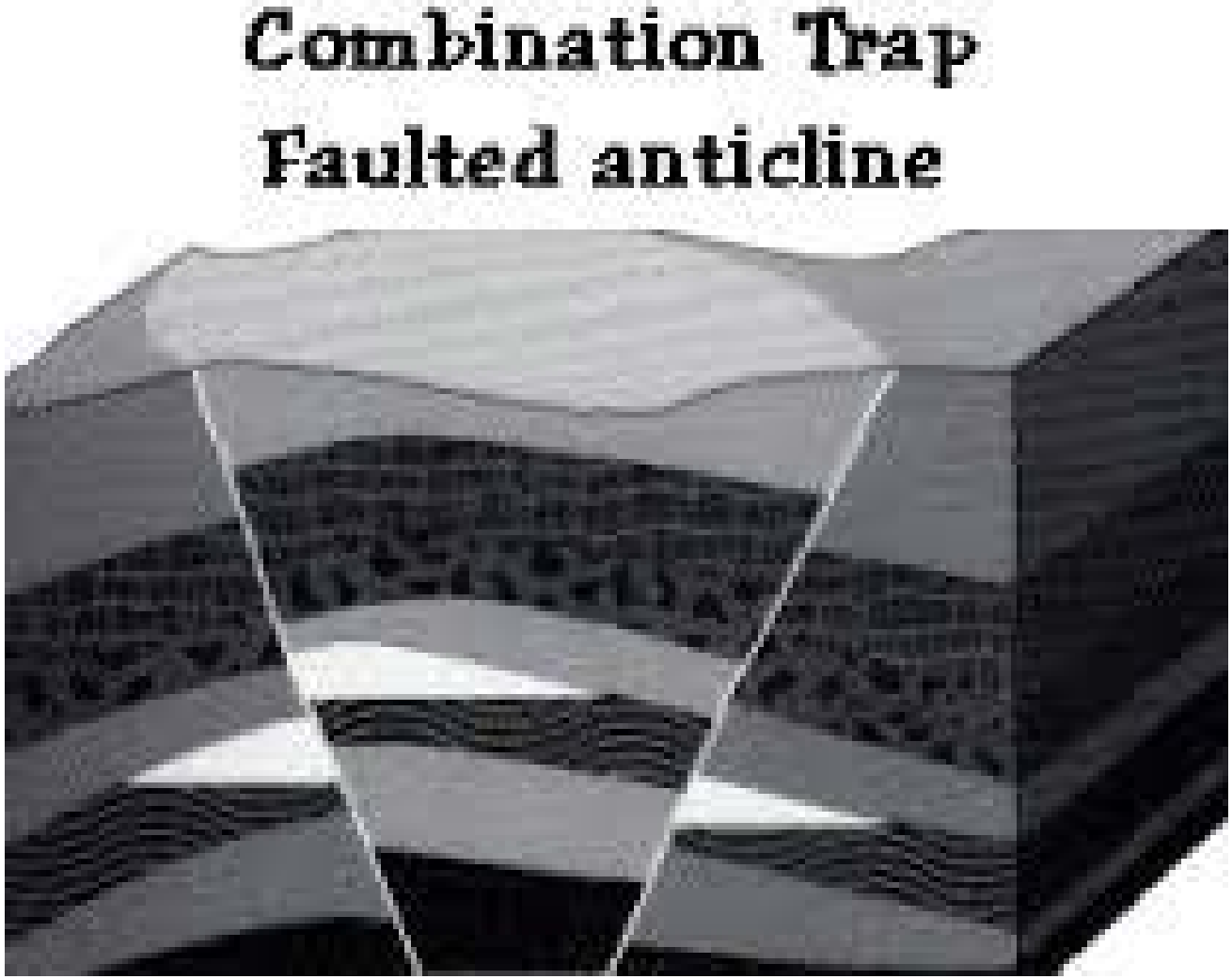


Formation of a bald-headed anticline

1. An anticline or dome is formed
2. The crest of the structure is exposed to erosion. Most of the reservoir rocks can be removed from the top of the structure.
3. Seas later cover the area, and sediments are deposited, burying the eroded structure in the subsurface.

When the petroleum migrates up the reservoir rocks, it is trapped below the angular unconformity. Because the crest of the structure is barren, but the flanks are productive, it is called a *baldheaded structure* or *anticline*.

IV/3: Faulted anticline



Distribution of trap types in large fields

Type of trap	Number of fields (per cent)	Proportion of reserves (per cent)
Structural	66	78
Stratigraphic	22	13
Combination	12	9
Hydrodynamic	—	—

- Structural traps are easy to find
- Large anticline traps have already found

Seal

an impermeable rock layer that doesn't allow fluids to flow through it.

The best seals are: shales, salt.

Well cemented or shaly rocks, micrite, chalk, and permafrost can also be caprocks.

Exersices

Recognizing HC traps

The following 12 geological profiles contain different types of HC-traps.

1. Try to recognize all possible traps within the profiles and show the assumed HC-occurrences. For every profile the type of traps(s) should be noted.
2. Describe the geological conditions and processes, which led to the trap formation (e.g. folding, erosional truncation)

(Sachsenhofer 2017)

Figure 1

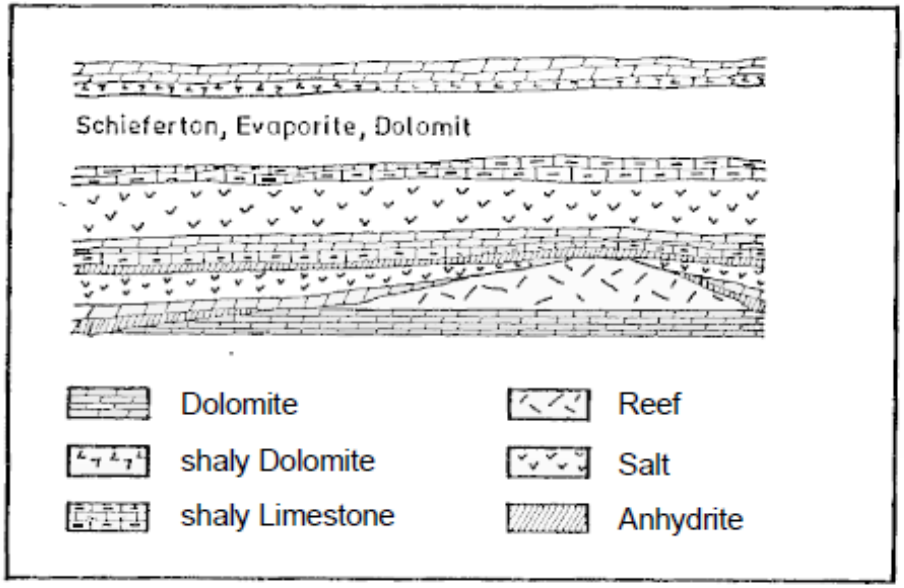


Figure 2

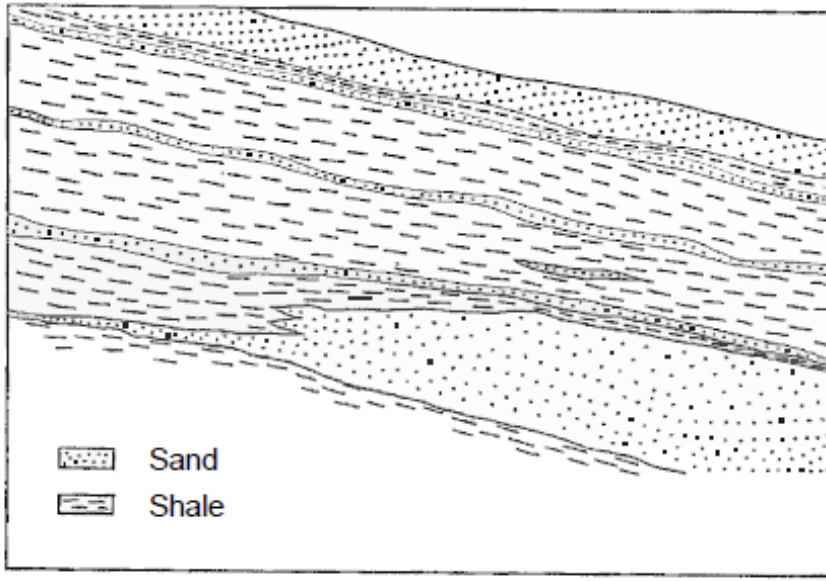


Figure 3

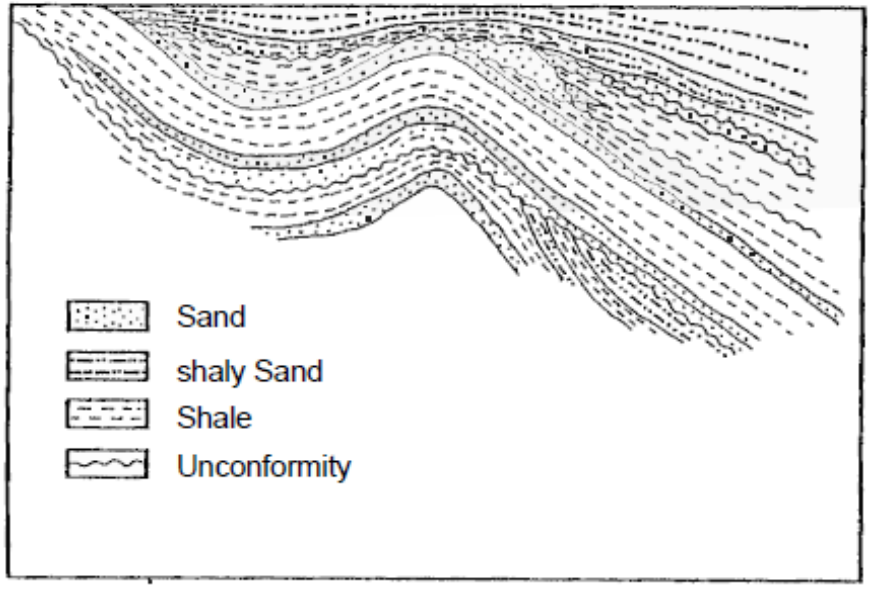


Figure 4

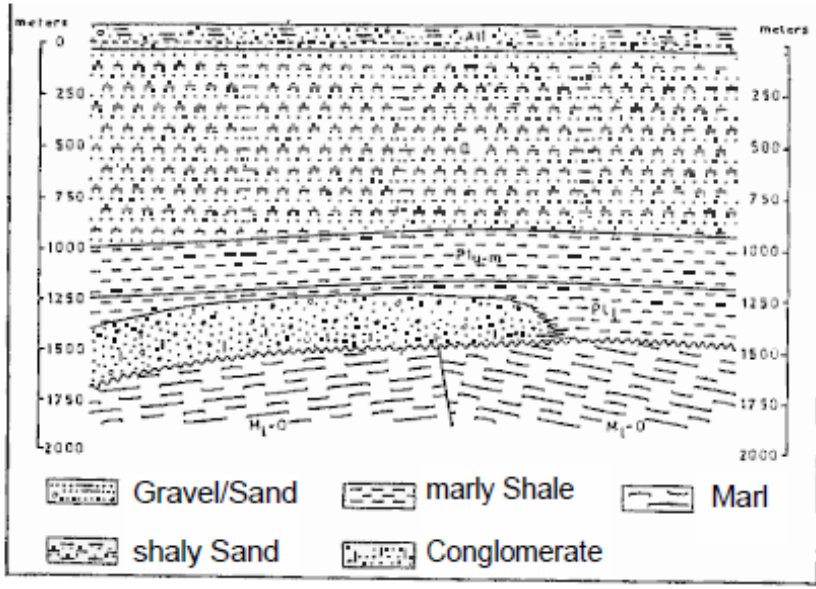


Figure 5

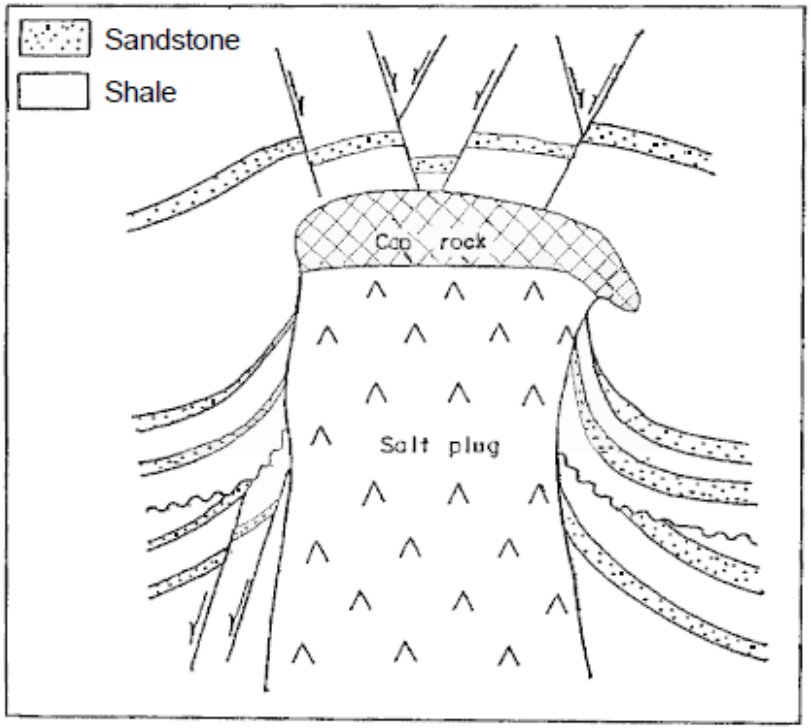


Figure 6

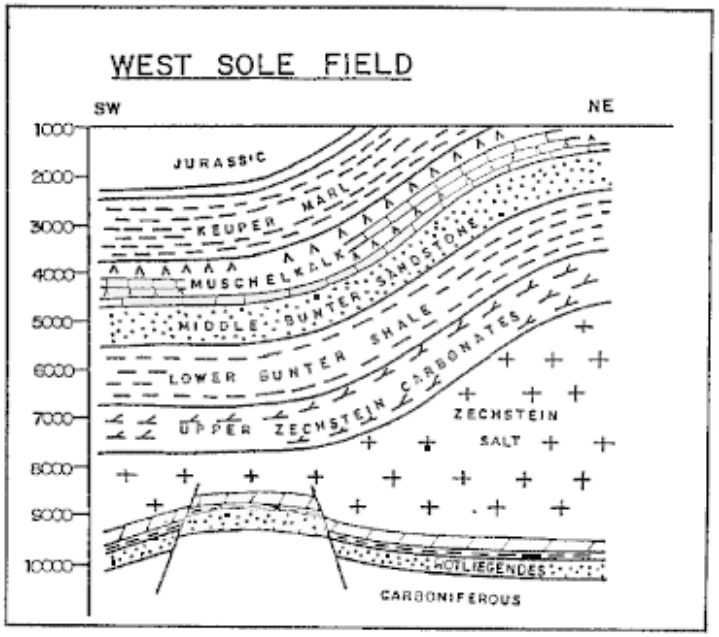


Figure 7

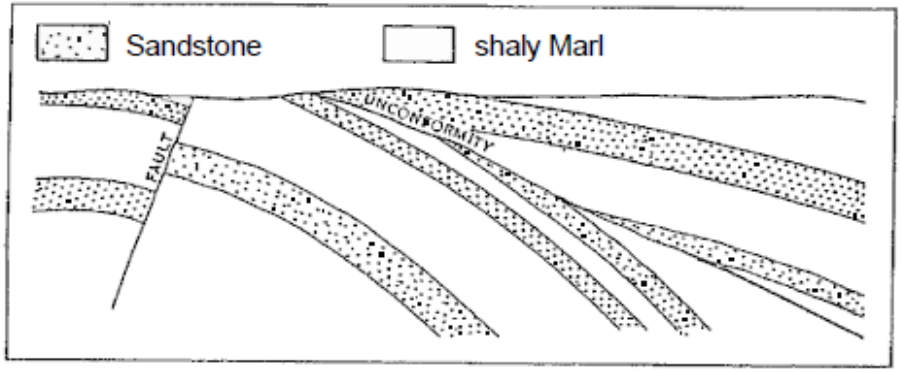


Figure 8

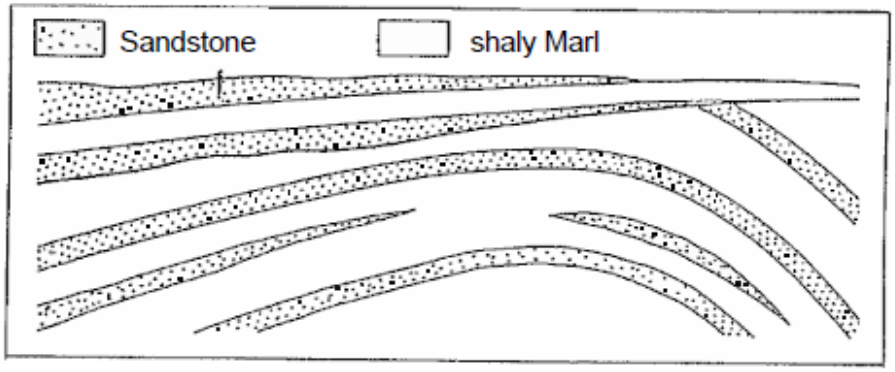


Figure 9

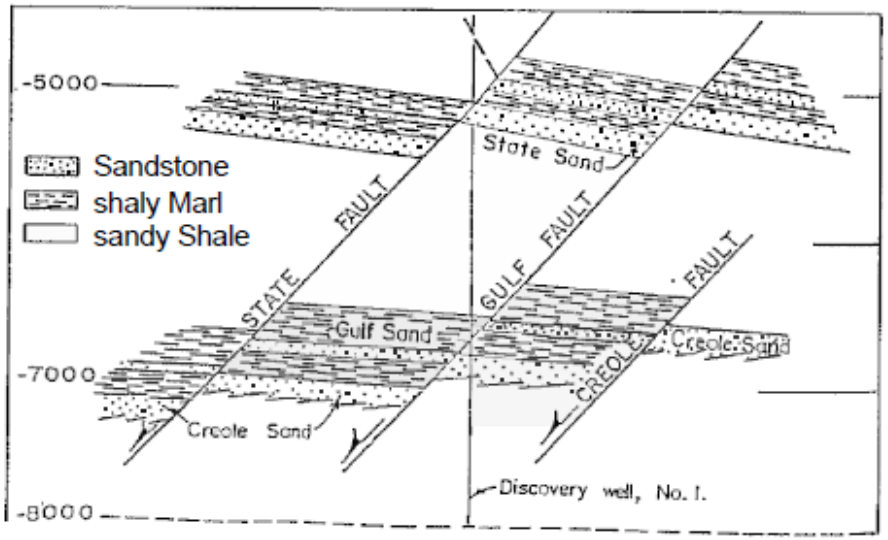


Figure 10

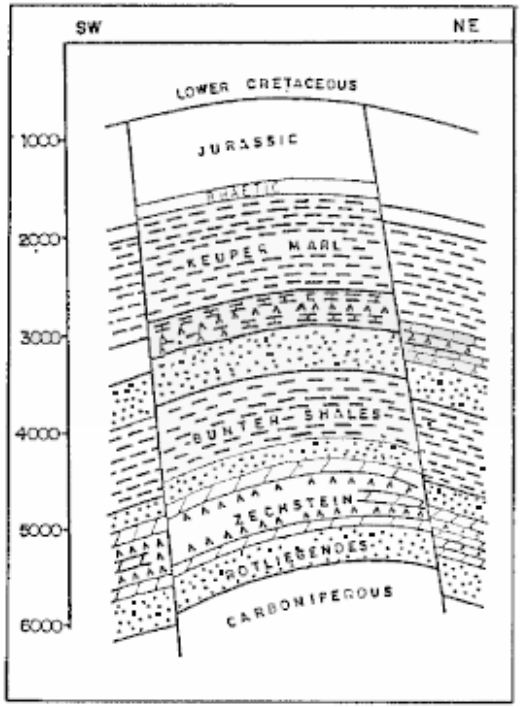


Figure 11

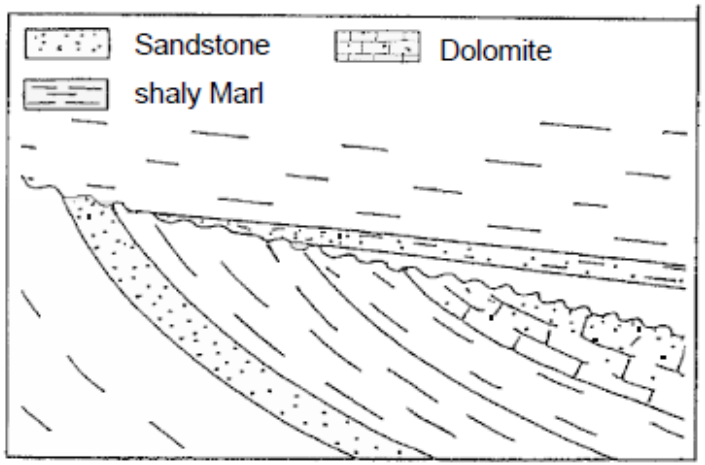


Figure 12

