Reservoir-Pressure and Its Applications

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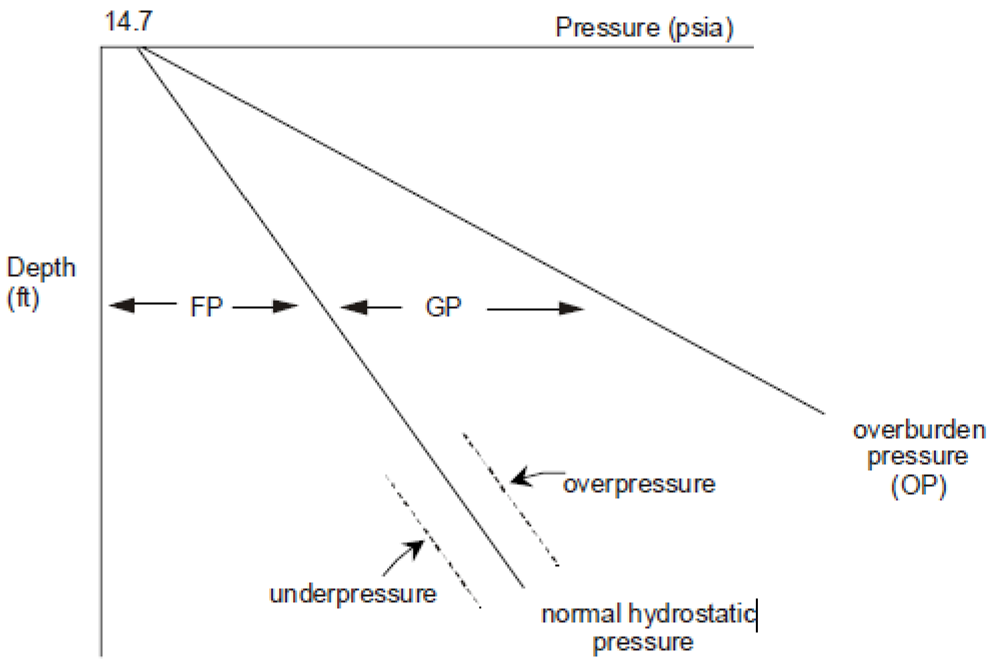
Content

- Reservoir pressure
- Typical pressure gradients
- Determination of fluids contacts
- Applications of reservoir pressures

Refs: Applied Petroleum-Reservoir Engineering, Craft & Hawkins
Fundamentals of Reservoir Engineering, Dake
Lecture notes of Wim Swinkels

Reservoir Pressure

- Formation pressure is defined as total fluid pressure in pore space.
- Total pressure at any depth, resulting from the combined weight of the formation rock and fluids, whether water, oil or gas, is known as the overburden pressure.



Reservoir Pressure

- Overburden pressure is constant at given depth, thus:
- d(FP) = -d(GP)
  - Reduction in fluid pressure leads to corresponding increase in grain pressure
- Fluid pressure regimes in hydrocarbon columns are dictated by the prevailing water pressure in the vicinity of the reservoir.
- $P_{res} = \left(\frac{dP}{dh}\right) \times H + 14.7\ (psia)$
- Water-pressure gradient depends on chemical composition (salinity), for pure water, it is 0.4335 psi/ft

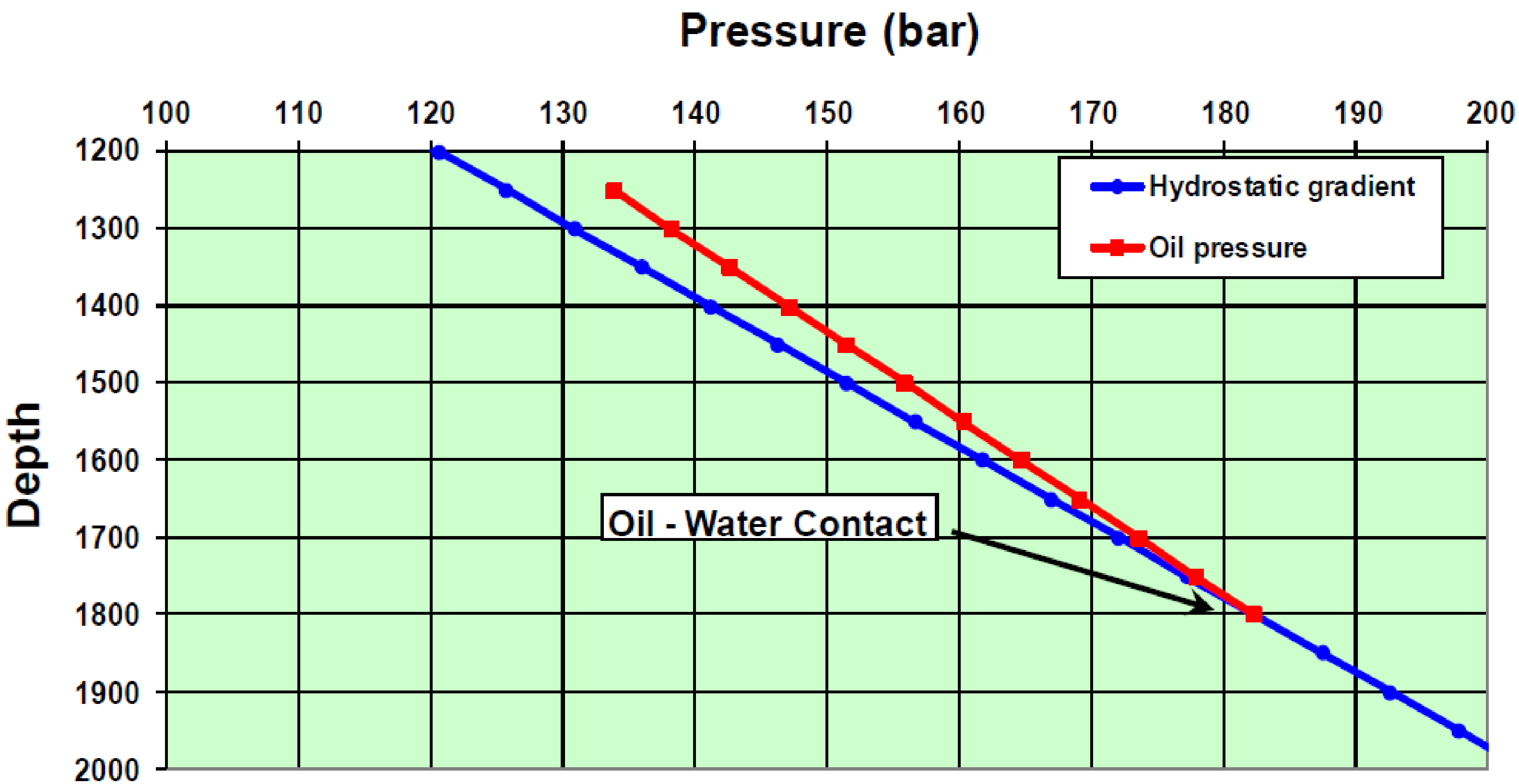
Abnormal Hydrostatic Pressure

- When sand is effectively sealed off from surrounding strata so that hydrostatic-pressure continuity to the surface cannot be established, abnormal pressure occurs:
- $P_{res} = \left(\frac{dP}{dh}\right) \times H + 14.7 + C\,(psia)$
- C is constant and positive for over-pressured situation and negative for under-pressured situations
- Geological changes such as uplifting of reservoir, or equivalent surface erosion result in reservoir pressure being too high for its depth of burial
- Opposite effects occur in downthrown reservoir in which abnormally low fluid pressure can occur.

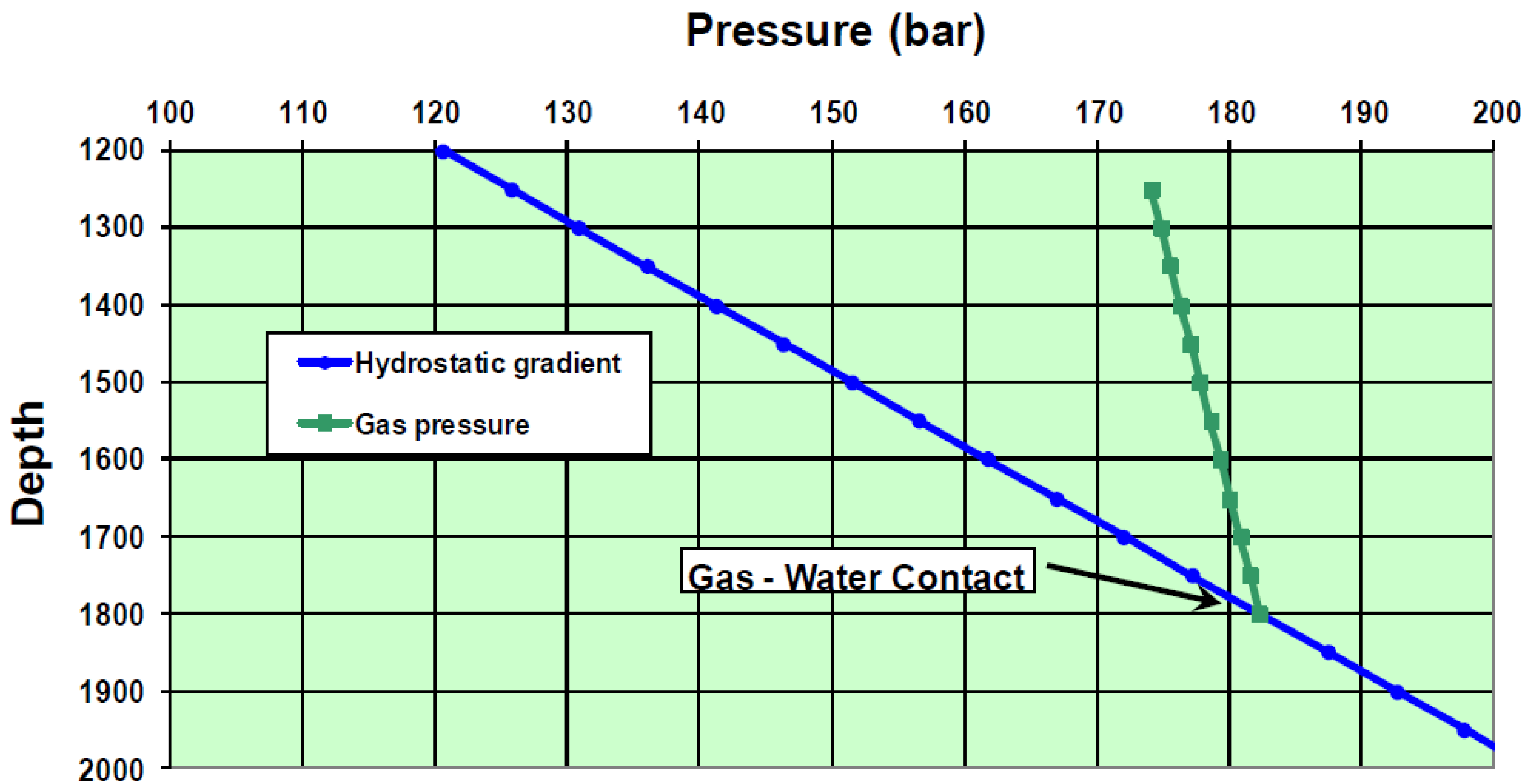
Typical Pressure Gradients

- For water: 0.45 psi/ft
- For oil: 0.35 psi/ft
- For gas: 0.08 psi/ft

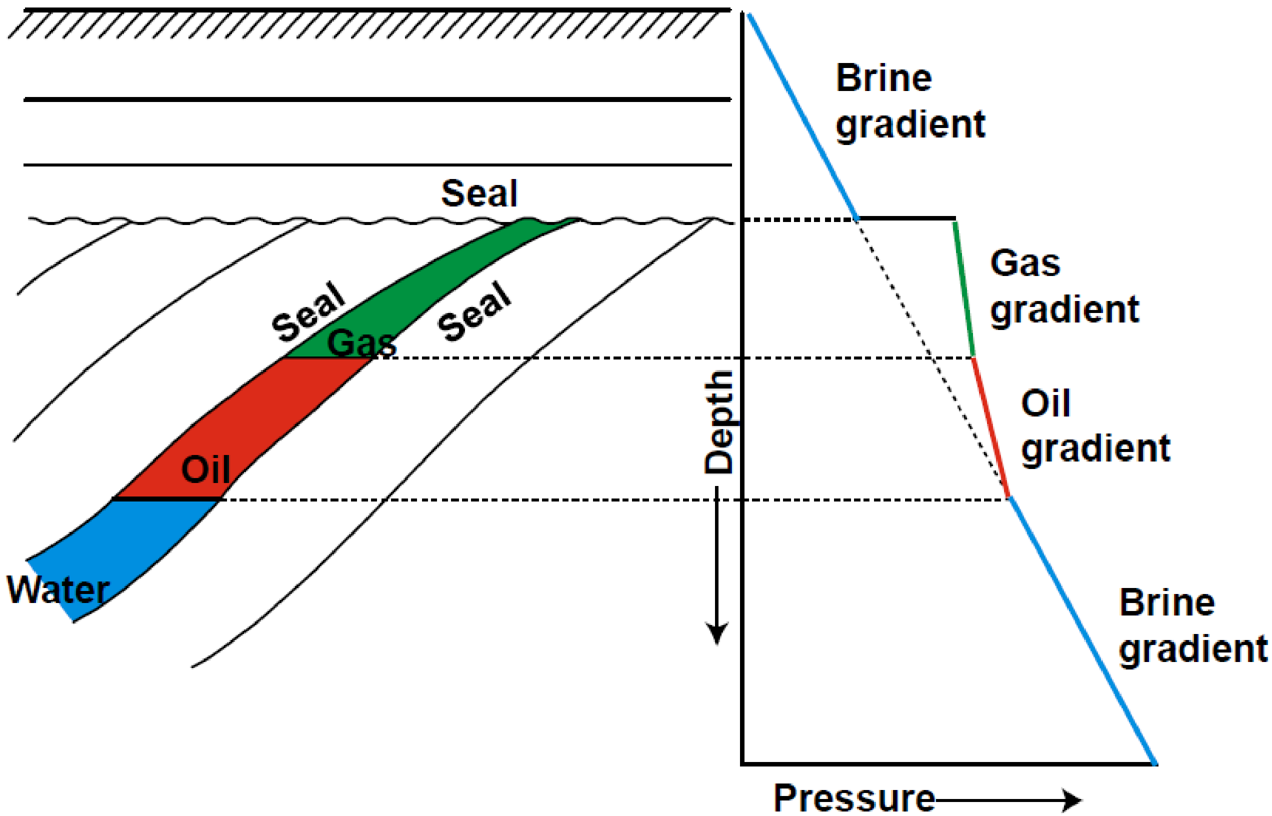
Pressure Gradients in Oil Reservoirs



Pressure Gradient in Gas Reservoirs



Pressure Gradient

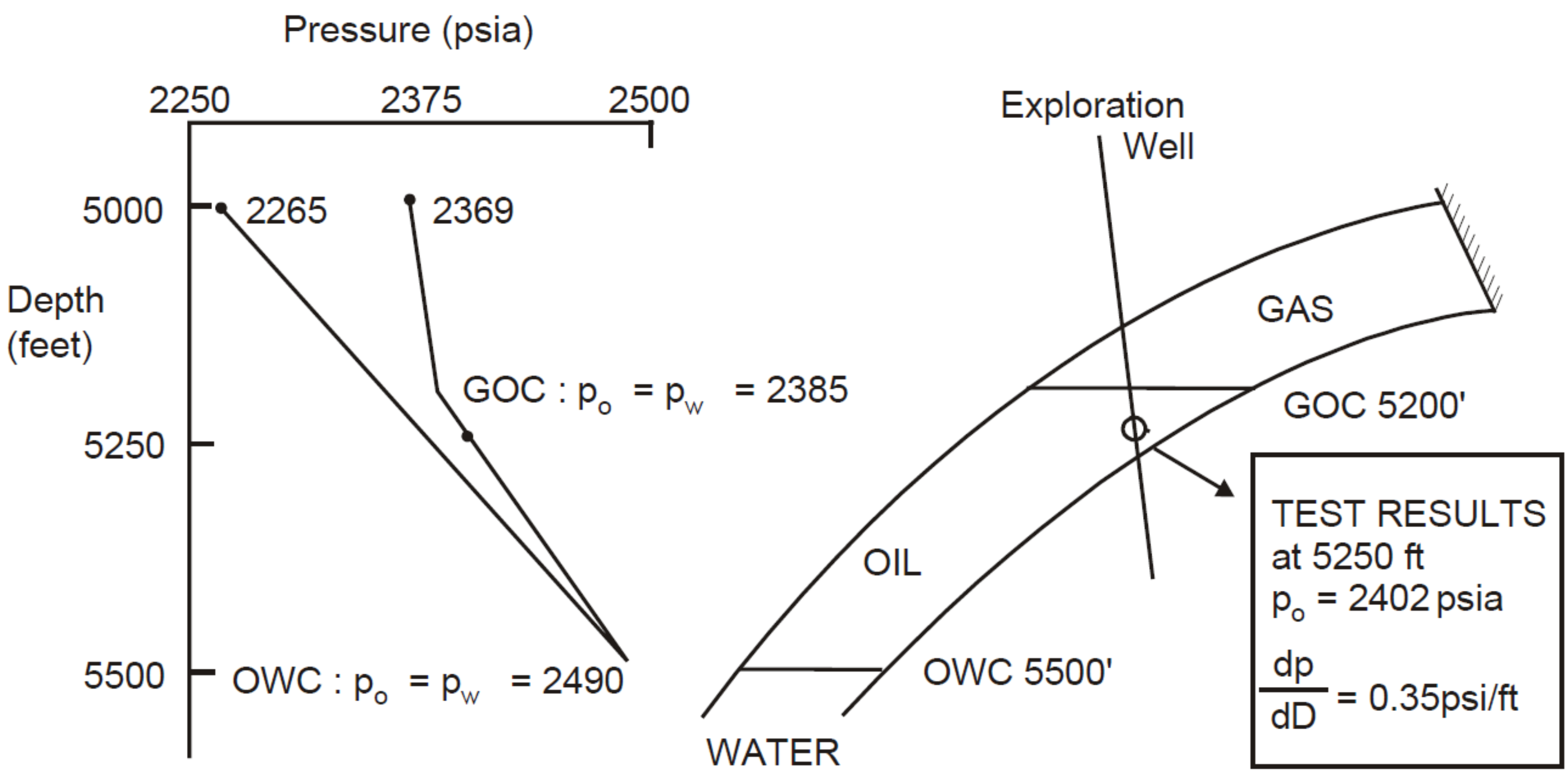


Reservoir Pressure

- At top of structure, gas pressure exceeds normal hydrostatic pressure
- In well drilling through sealing shale on very crest of structure, there will be sharp pressure kick
- Magnitude of pressure discontinuity on drilling into hydrocarbon depends on vertical distance between point of well penetration and hydrocarbon/water contact.
- For given value of distance, pressure discontinuity will be much greater if reservoir contains gas only

Determining Fluid Contacts

- At time of drilling exploration well, one aim is to determine position of fluid contacts



Determining Fluid Contacts

- GOC = 5200 ft on logs run in well
- Since OWC cannot be seen by well, OWC can only be inferred as result of well test (e.g., drill stem or wireline formation test)
- With these tests: P_o at 5250 ft is 2402 psia and oil gradient 0.35 psi/ft, which are sufficient to specify

$$P_o = 0.35H + 565 \text{ psia}$$

- Extrapolation of this line to meet normal hydrostatic pressure leads to OWC at 5500 ft

Determining Fluid Contacts

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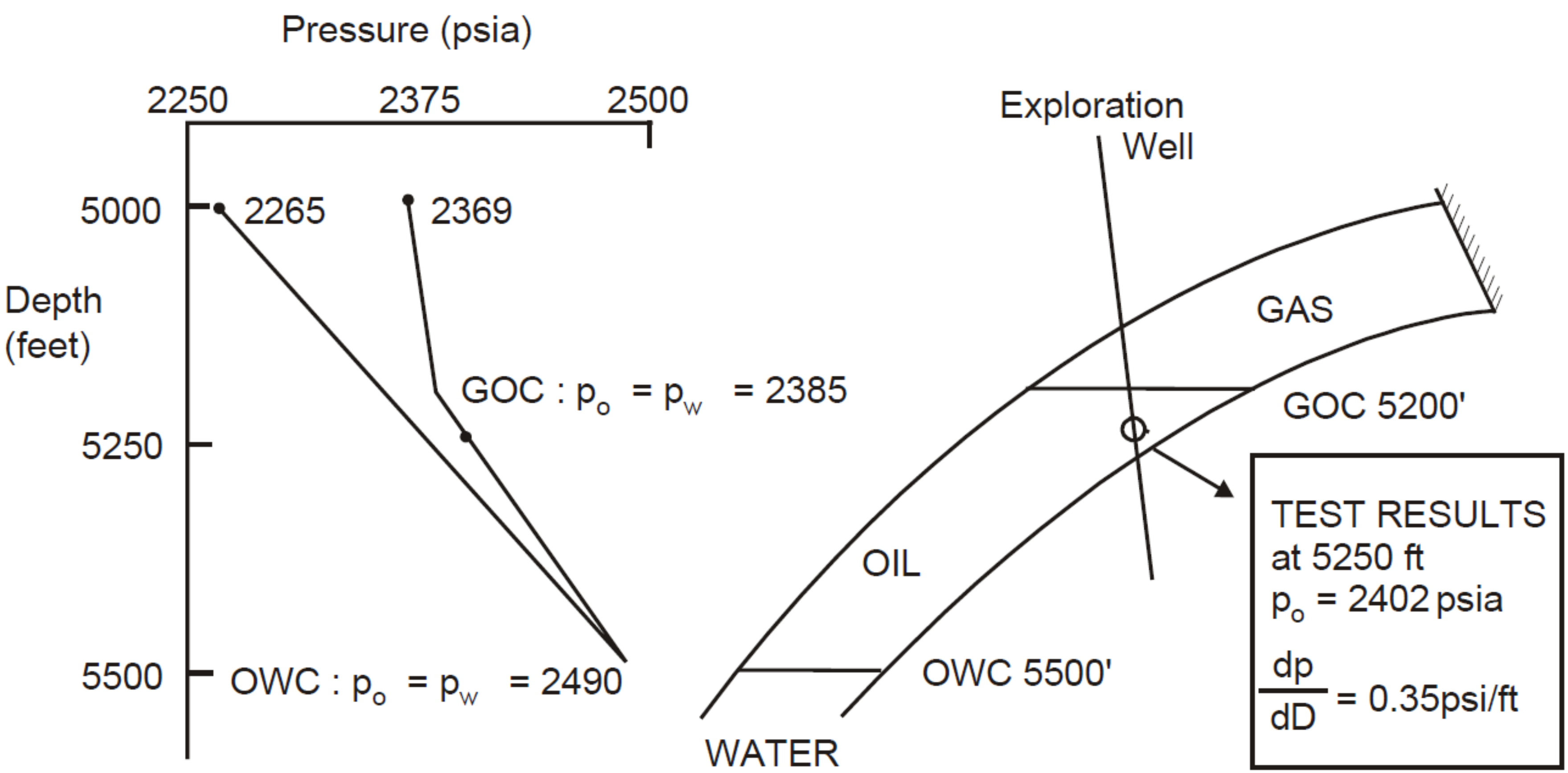
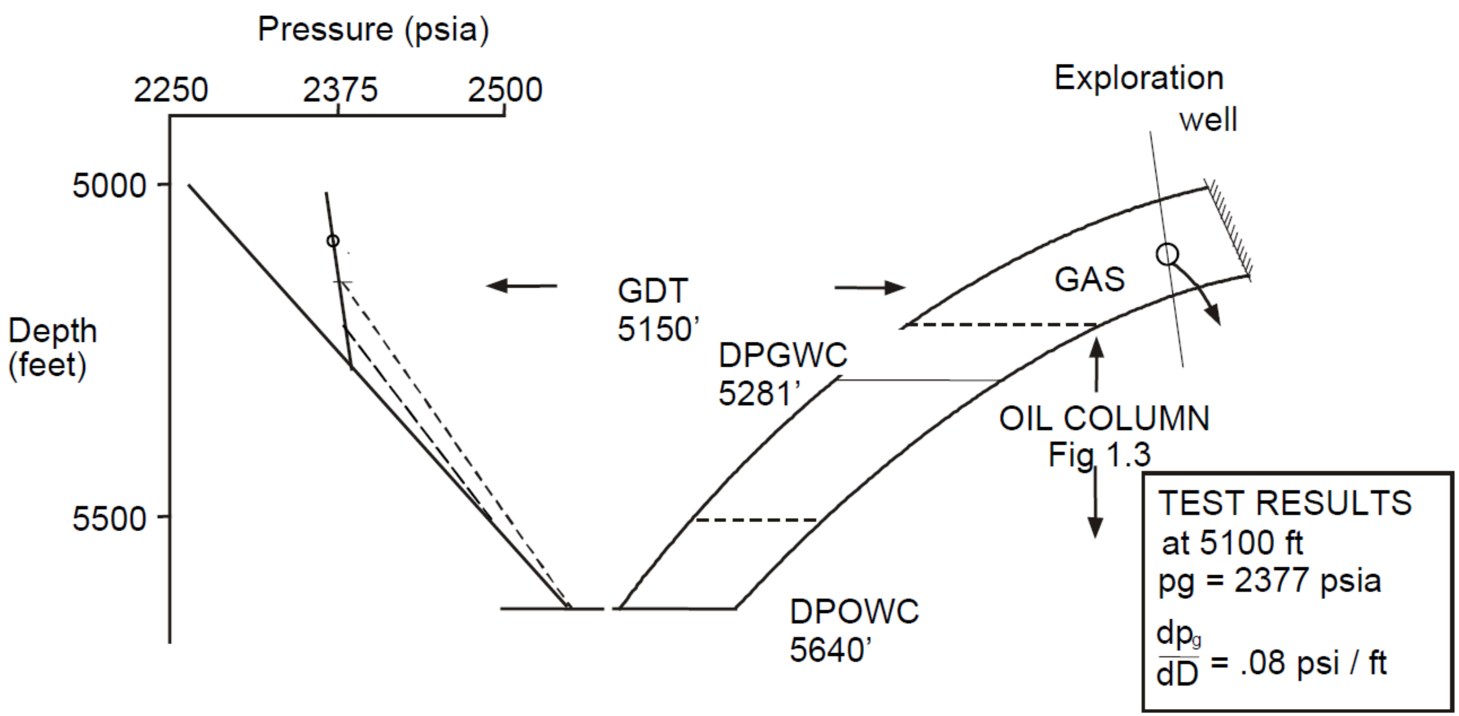


Determining Fluid Contacts

- This type of analysis critically relies on knowledge of hydrostatic pressure regime.
- For instance, if water is over-pressurized by 20 psi, then OWC becomes 5300 ft, difference of 200 ft in position of contact makes enormous difference in oil-in-place
- Therefore, it is essential to define hydrostatic pressure regime in new fields
    - One simple way doing this is to run a series of wireline formation tests in which pressures are deliberately measured in water bearing sands both above and beneath hydrocarbon reservoir

Determining Fluid Contacts

- Now we consider this situation, well only penetrates gas zone



Determining Fluid Contact

- Well test conducted at 5100 ft, from which P_g = 2377 psia, gas gradient = 0.08 psi/ft
  - This leads to $P_g = 0.08\ H + 1969$ (psia)
  - Having seen no oil, one may suspect that there is gas alone, using normal hydrostatic pressure line ($P_w = 0.45H + 15$) at depth 5281 ft $P_w = P_g$, this is deepest possible GWC (DPGWC)

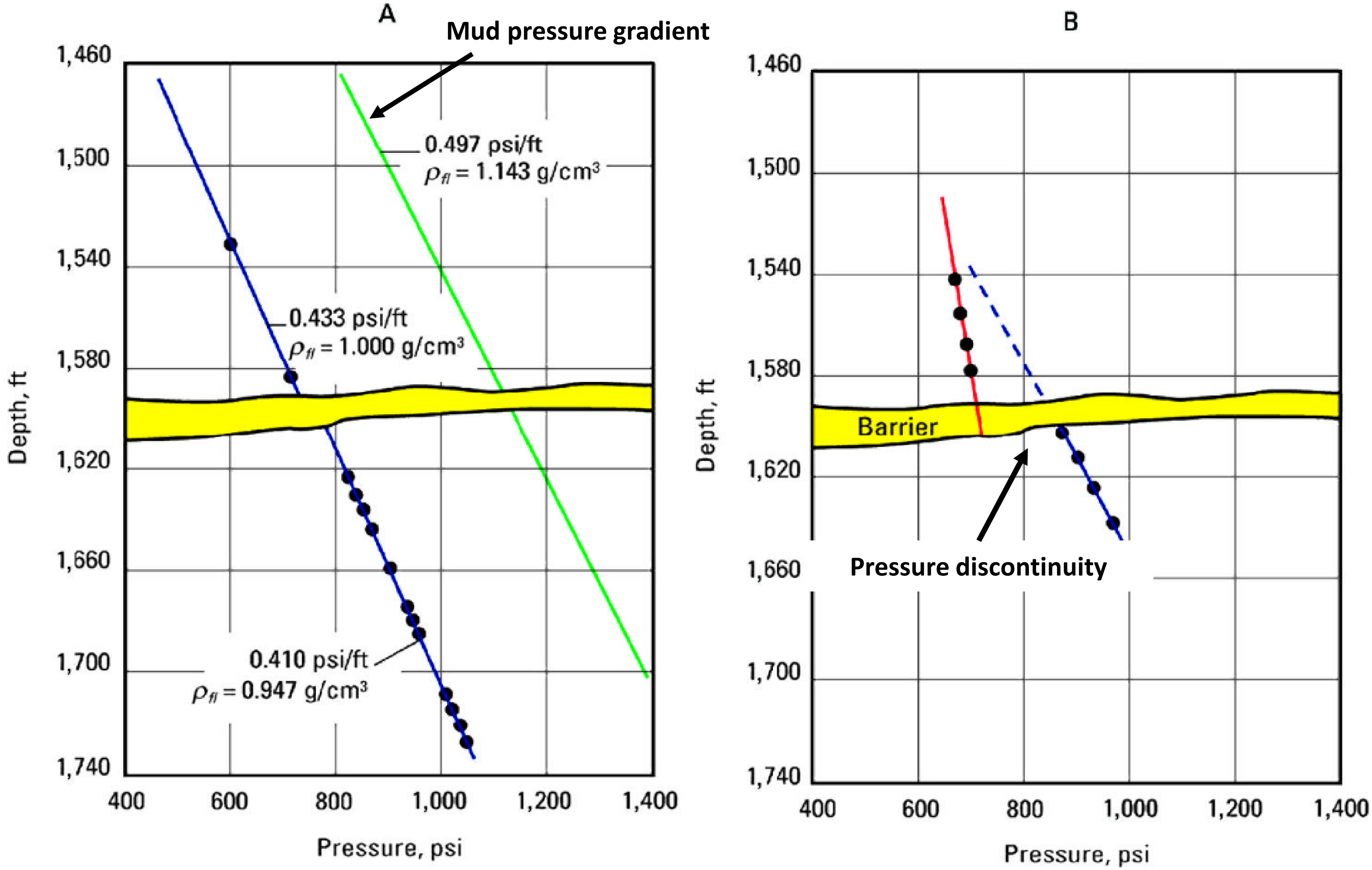
- Alternatively, since deepest point gas seen is 5150 ft (GDT), there is no physical reason why oil column should not exist.
  - It leads to $P_o = 0.35H + 579$ and using hydrostatic line, we get OWC = 5640 ft, this is deepest possible OWC(DPOWC)

- Therefore, despite fact that well carefully tested, high degree of uncertainty remains as to extend of any oil column

Is there oil column?

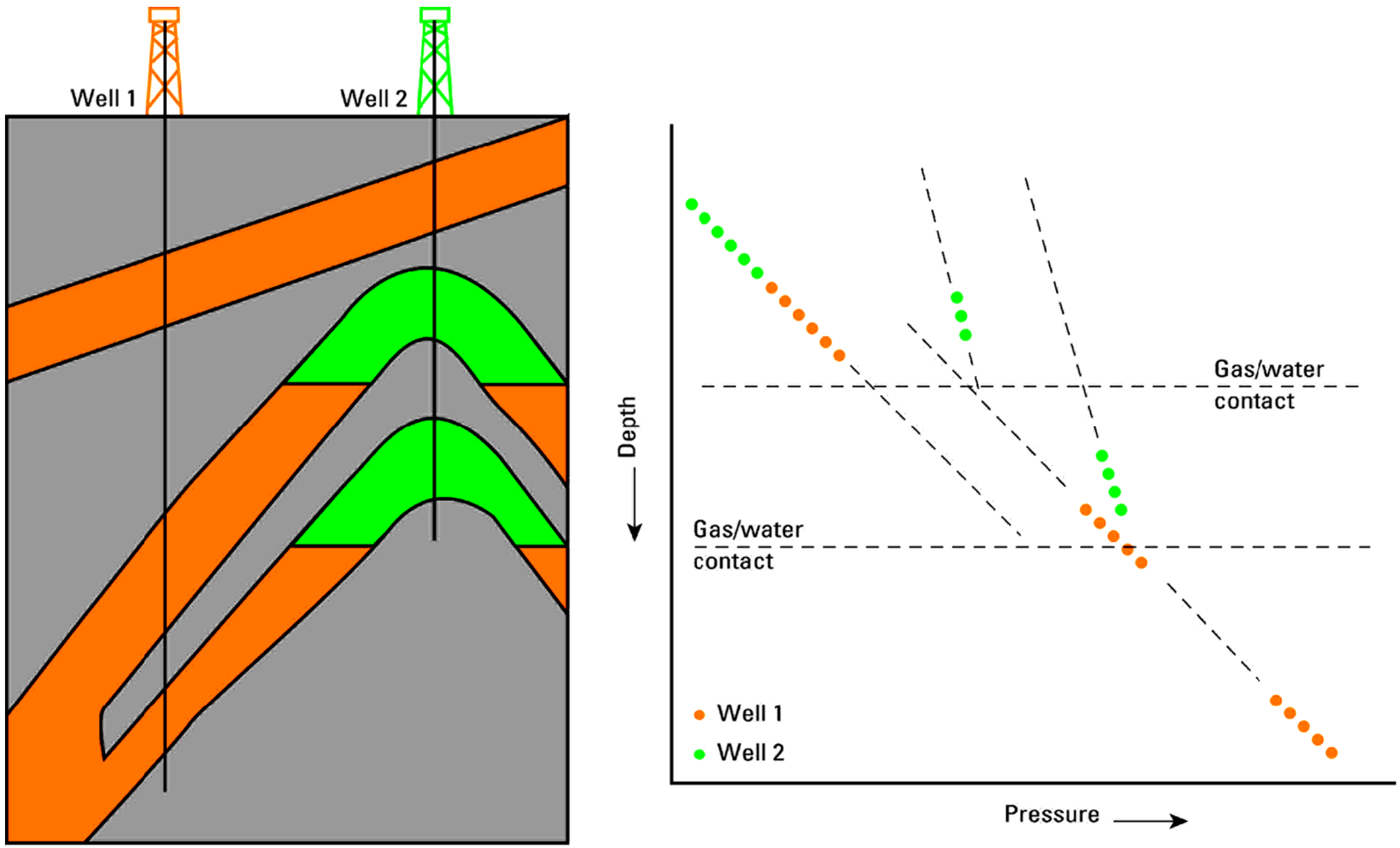
- Only sure way is to drill well further down-dip on structure
- If mechanically feasible, deviate from original hole
- Therefore, when planning exploration well it is not always beneficial to aim well at highest point of structure.
- Doing so tends to maximize chance of finding hydrocarbons but opposes one of primary aims of exploration wells (gaining as much information about reservoirs and contacts as possible)

Detecting Permeability Barriers



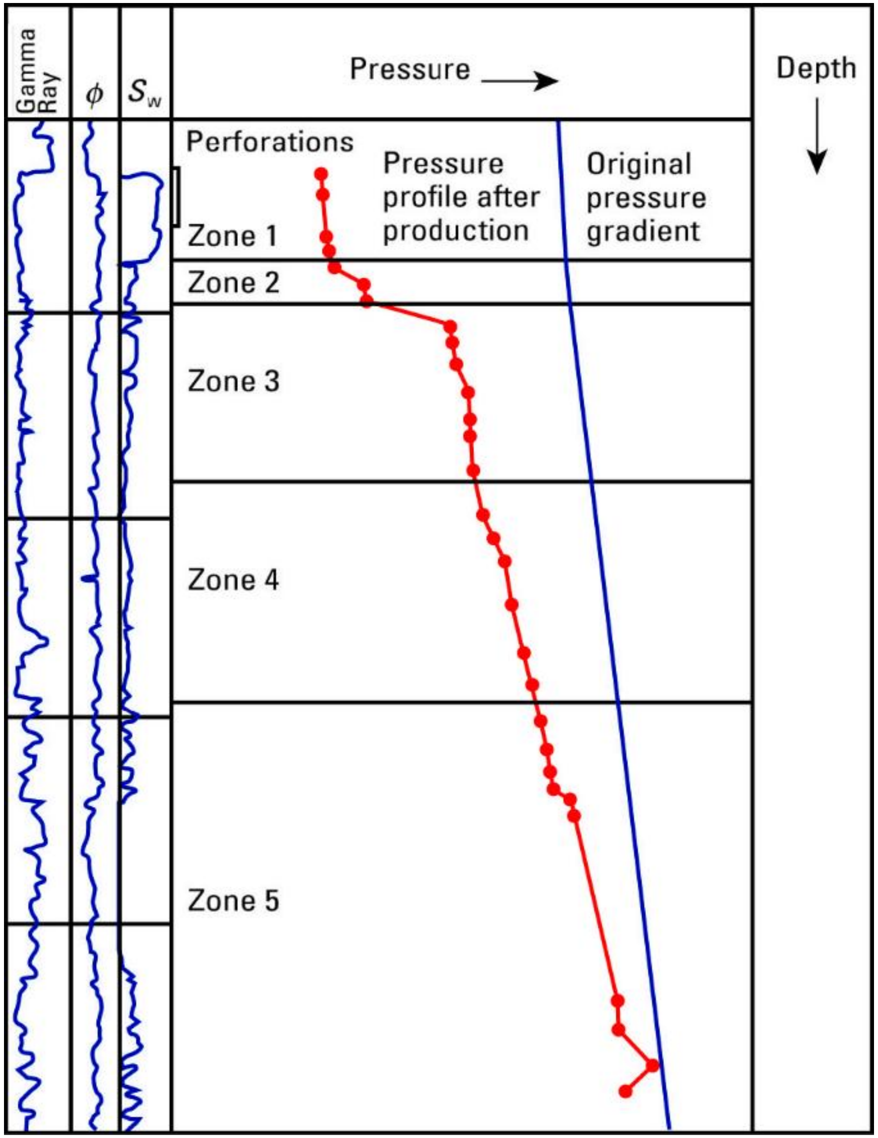
Yellow layer is barrier (no flow); otherwise, pressure would have equilibrated on both sides of yellow layer over geologic time

Extrapolation of Pressure Gradients

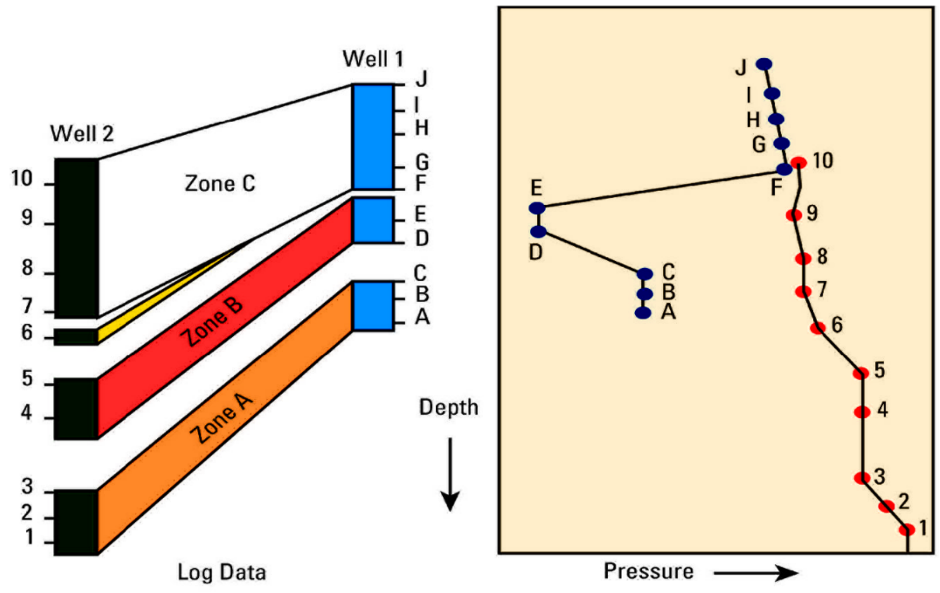


Gas/water contacts cannot be identified by pressure profiles of Well 1 or Well 2. By extrapolating water gradient of Well 1 and gas gradient of Well 2, it is possible to determine position of gas/water contacts

Developed Reservoir



Hydraulic Correlation Between Two Wells



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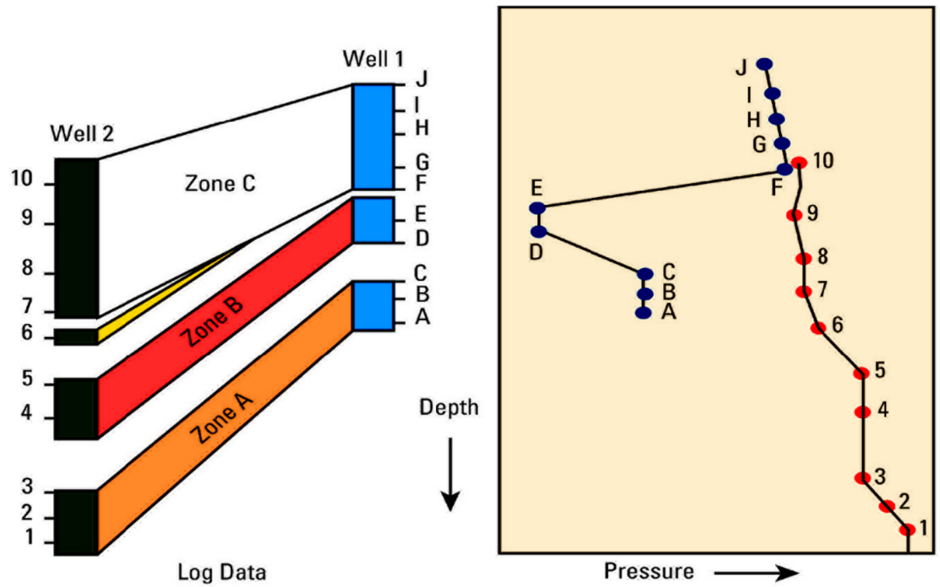

There should be fault between
well 1 and well 2 in zone B and Zone A