UNDERSTANDING SUBSURFACE PRESSURE AND ITS PREDICTION

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Headlines

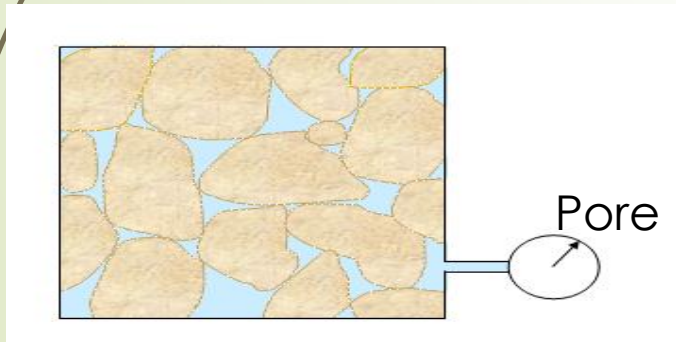
- Introduction
- Types of formation pressure
- Stress in the subsurface
- Manage Reservoir
- Seismic Data
- Study Area in Abu Dhabi
- Data well

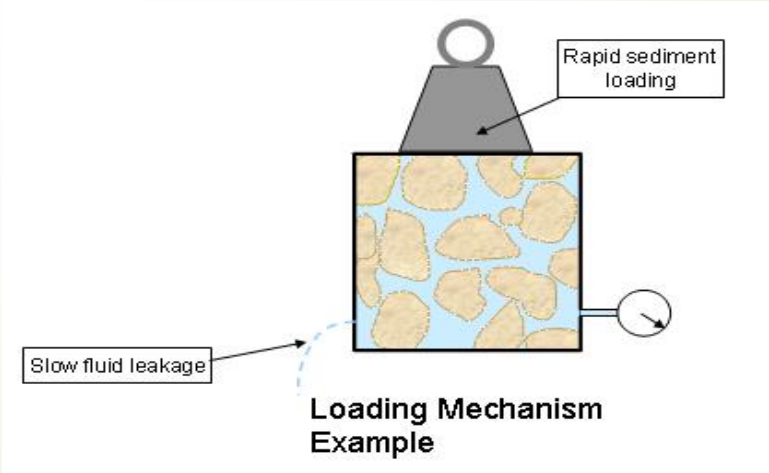
Introduction

- Pressure measurement is essential to optimized hydrocarbon recovery.
- Accurate formation pressure can be determined at almost any time in a well's life cycle.
- Drilling Data and seismic Data give us optimizing well location prediction.
- Pore Pressure gradients are variable depending on subsurface temperature and pressure conditions
- The transition zone is an interval which exhibits a gradual change in pore pressure from hydrostatic to abnormal, or from abnormal to even a higher pressure

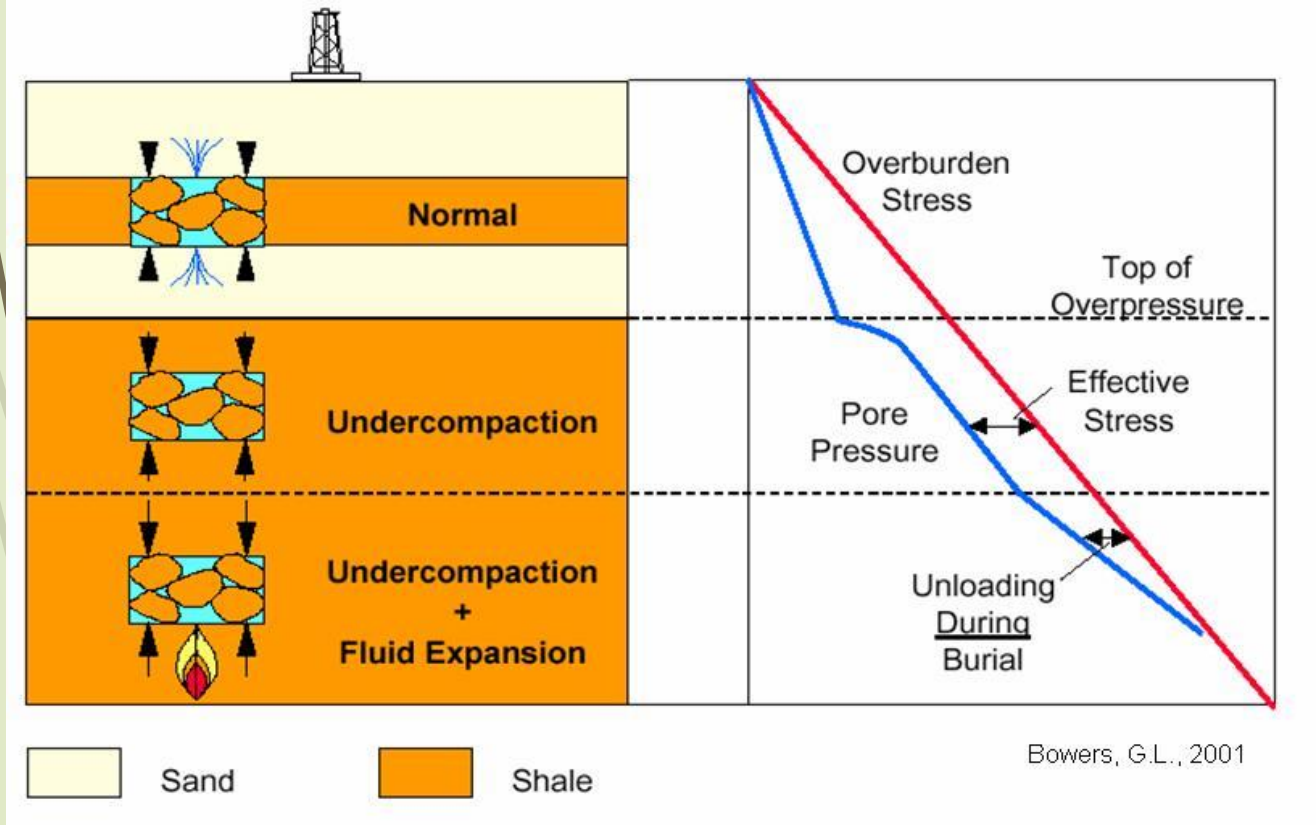
Types of Pressure formation

- **Subnormal pressure**: Pressure below hydrostatic, Areas where water table is low (arid and mountainous areas)
- **Normal pressure:** (Pore pressure = Hydrostatic pressure) Hydrostatic pressure is the pressure exerted by the weight of a static column of fluid
- **Abnormal pressure:** Overpressure always involve a particular zone becoming sealed.





Lithostatic pressure



Lithostatic pressure(overburden pressure): pressure exerted by the weight of overlying sediments, including the weight of the contained fluids.

Types of formation pressure

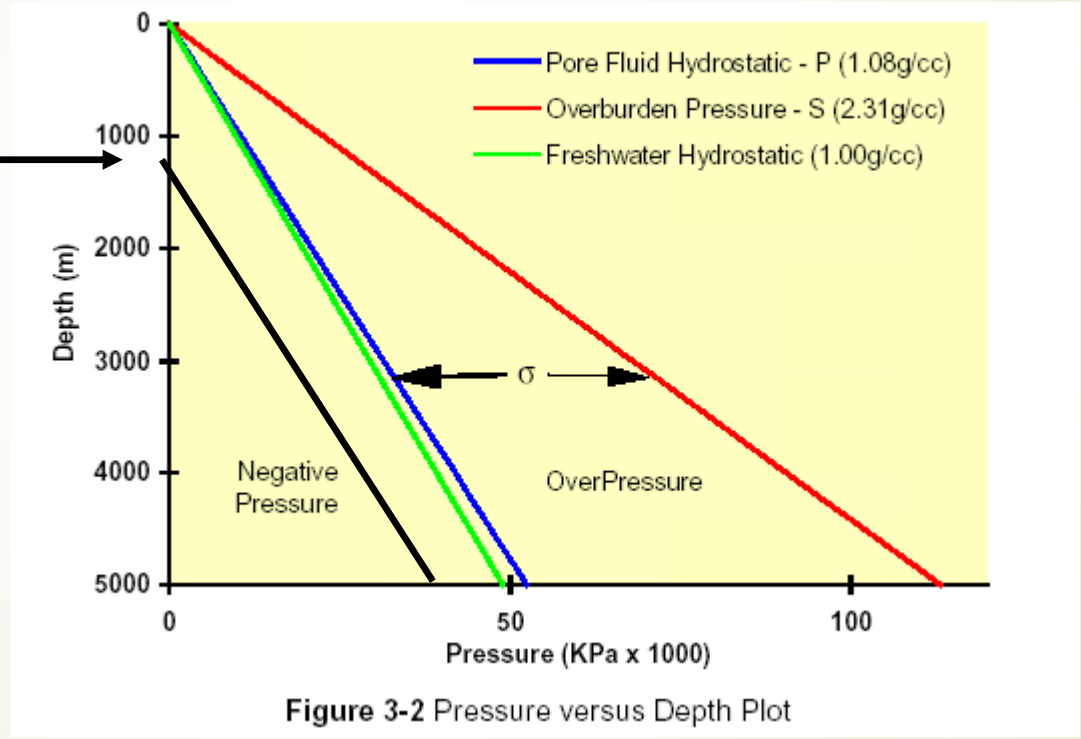
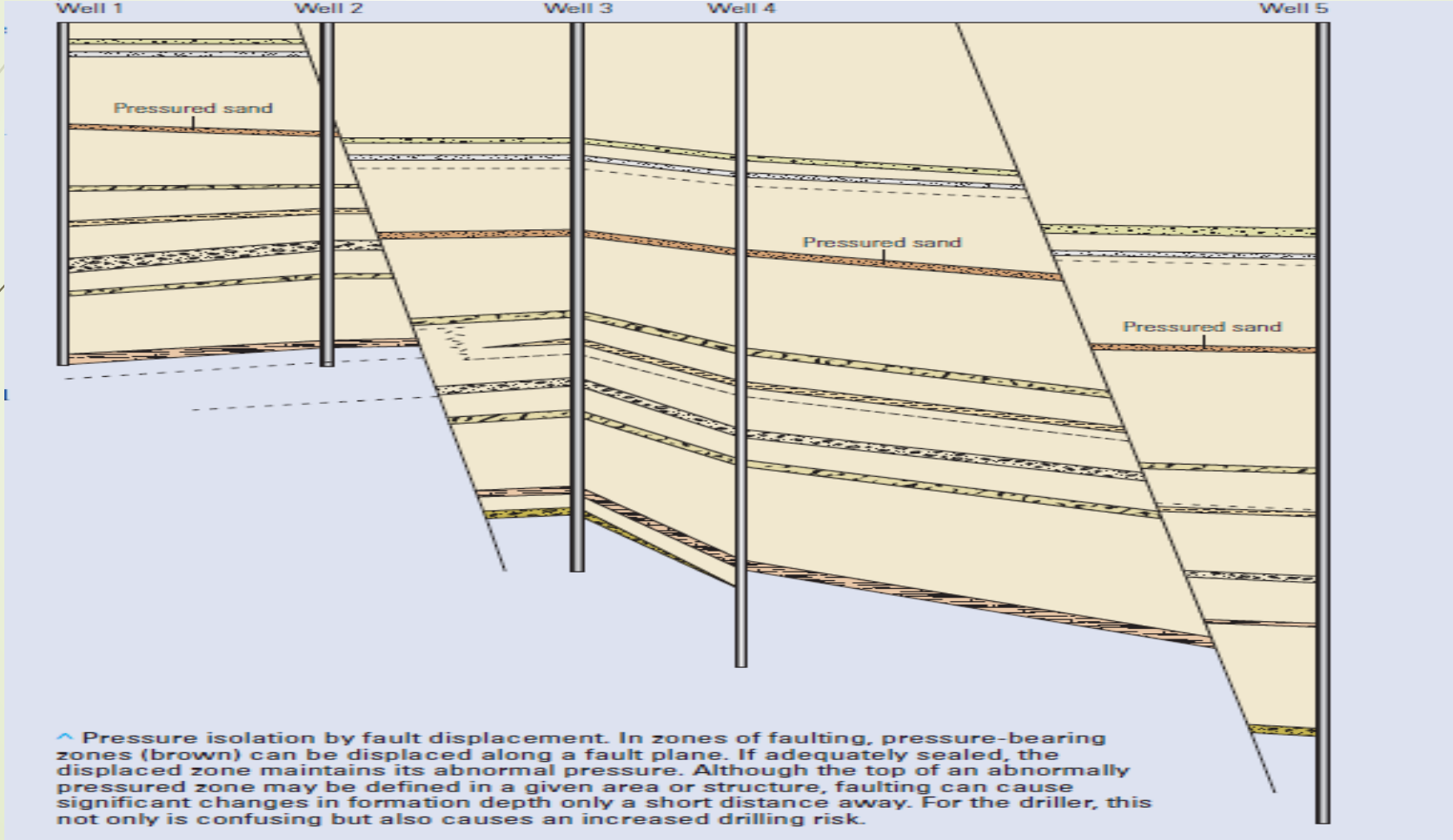


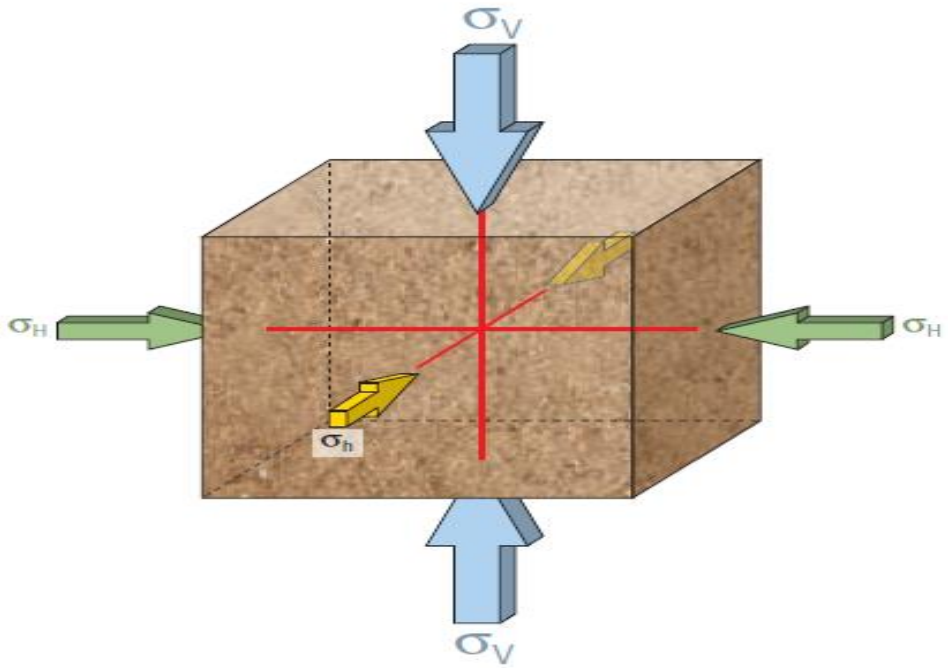
Figure 3-2 Pressure versus Depth Plot

Causes of Abnormal pressure



^ Pressure isolation by fault displacement. In zones of faulting, pressure-bearing zones (brown) can be displaced along a fault plane. If adequately sealed, the displaced zone maintains its abnormal pressure. Although the top of an abnormally pressured zone may be defined in a given area or structure, faulting can cause significant changes in formation depth only a short distance away. For the driller, this not only is confusing but also causes an increased drilling risk.

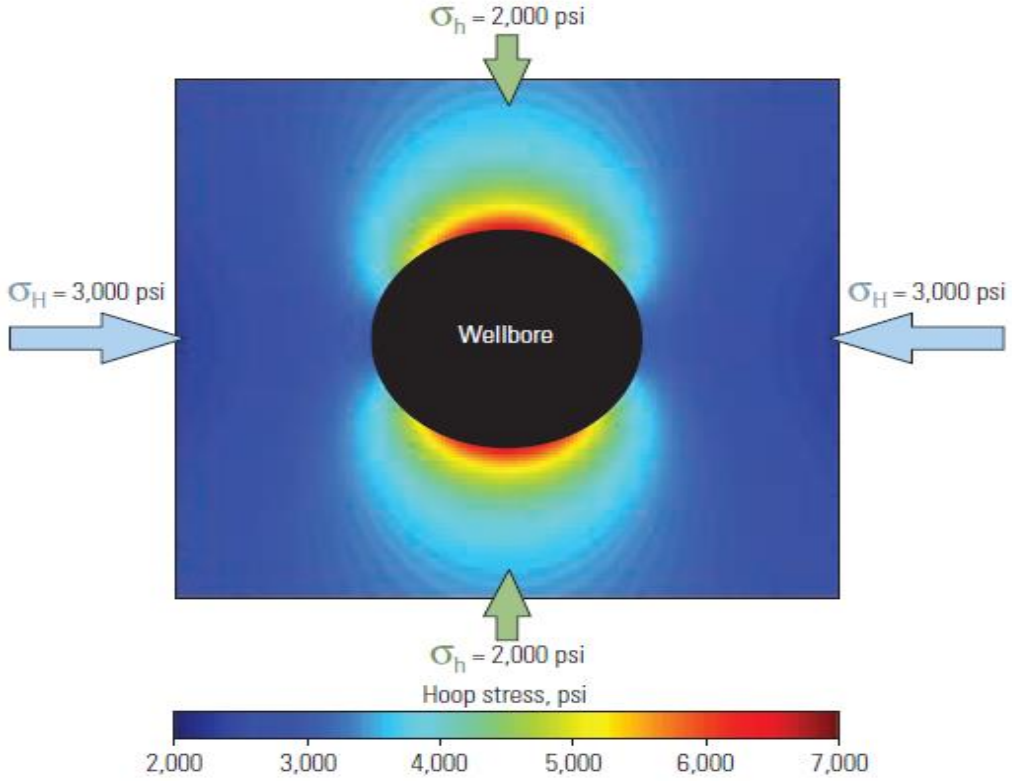
Stress in the subsurface



^ In-situ stresses and principal stresses. Stresses on a cube of material buried in the earth are given the designation σ_V, σ_H and σ_h, where V indicates vertical, H indicates the direction of the larger horizontal stress, and h that of the smaller horizontal stress. For simplicity, it is often assumed that these are the principal stress directions, but the principal directions of stress can be rotated significantly from these three axes. The principal stresses are generally indicated as σ_1, σ_2 and σ_3, in decreasing order of magnitude. When the principal stress directions do not coincide with the vertical and horizontal directions, there will also be shear stresses on the cube faces in the orientation shown.

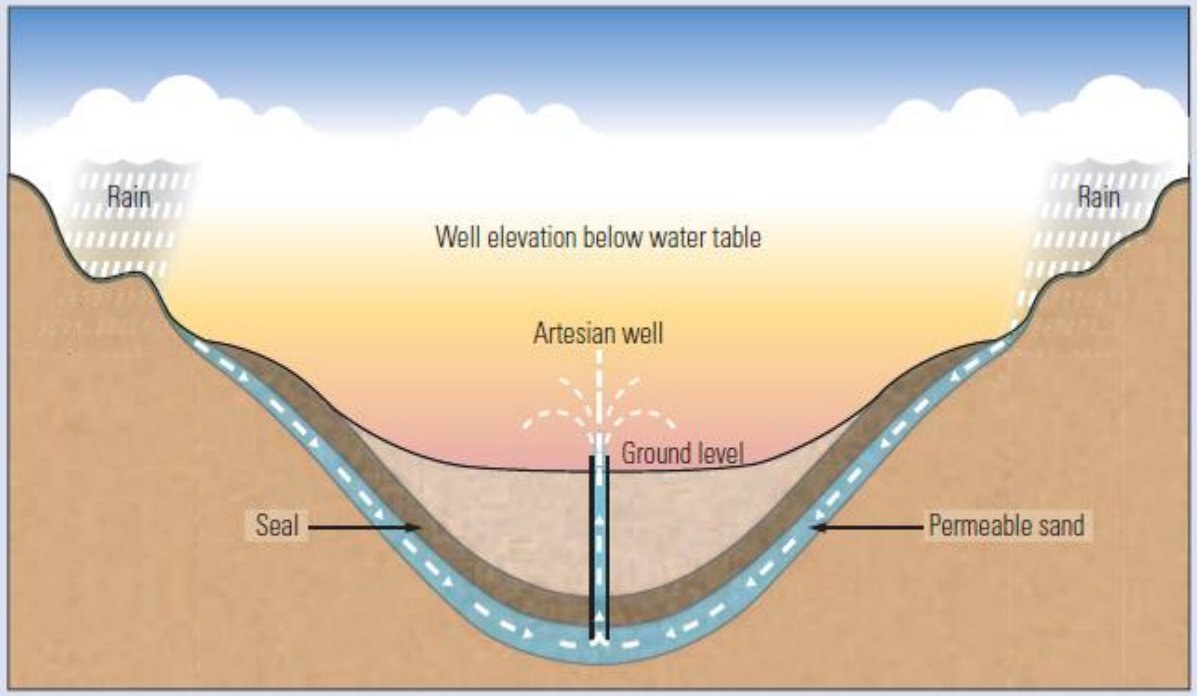
Natural, the vertical stress s stem primarily from the weight of overburden. Horizontal stresses also have a gravitational component that many be enhanced by tectonics, thermal effects and geological structure.

Stress in the subsurface



^ Plan view of hoop stresses surrounding a vertical wellbore. In this model, pore pressure and wellbore pressure are equal, while maximum and minimum effective stresses within the formation equal 2,000 psi and 3,000 psi [13.8 and 20.7 MPa], respectively. However, hoop stress, which varies as a function of radius and azimuth, is strongly compressive along the azimuth aligned with minimum horizontal stress (σ_h) (red shading above and below the wellbore), where it reaches almost 7,000 psi [48.3 MPa]. Wellbore failure will be more likely to occur along this axis. (Adapted from Sayers et al, reference 9.)

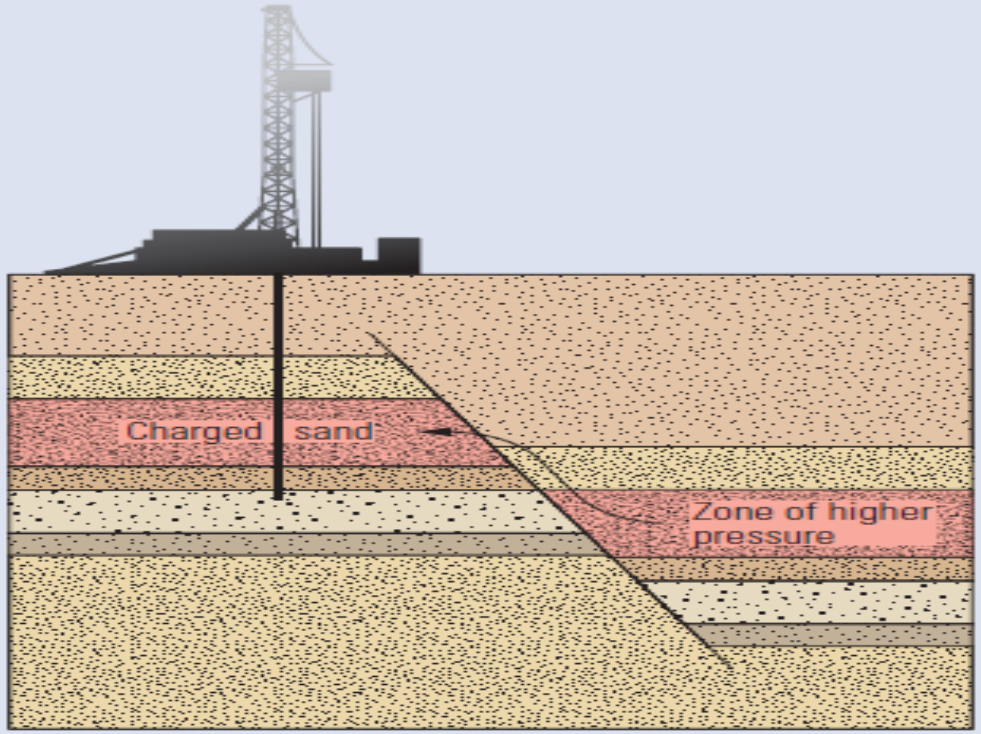
Manage Reservoir



^ Artesian pressure system. In these systems, the surface elevation of the well is below sea level or below the water table. This commonly occurs when drilling in a valley or basin surrounded by hills or mountains—locations where a connected water table is charged by water from higher locations.

In formation pore spaces, stress is transmitted to liquids or gases in the form of pressure. The magnitude of pressure applied in any one direction is the same for all directions.
If a fluid is compressed, it reacts by exerting an equal and opposite pressure outwards.
Cap-rock zone.

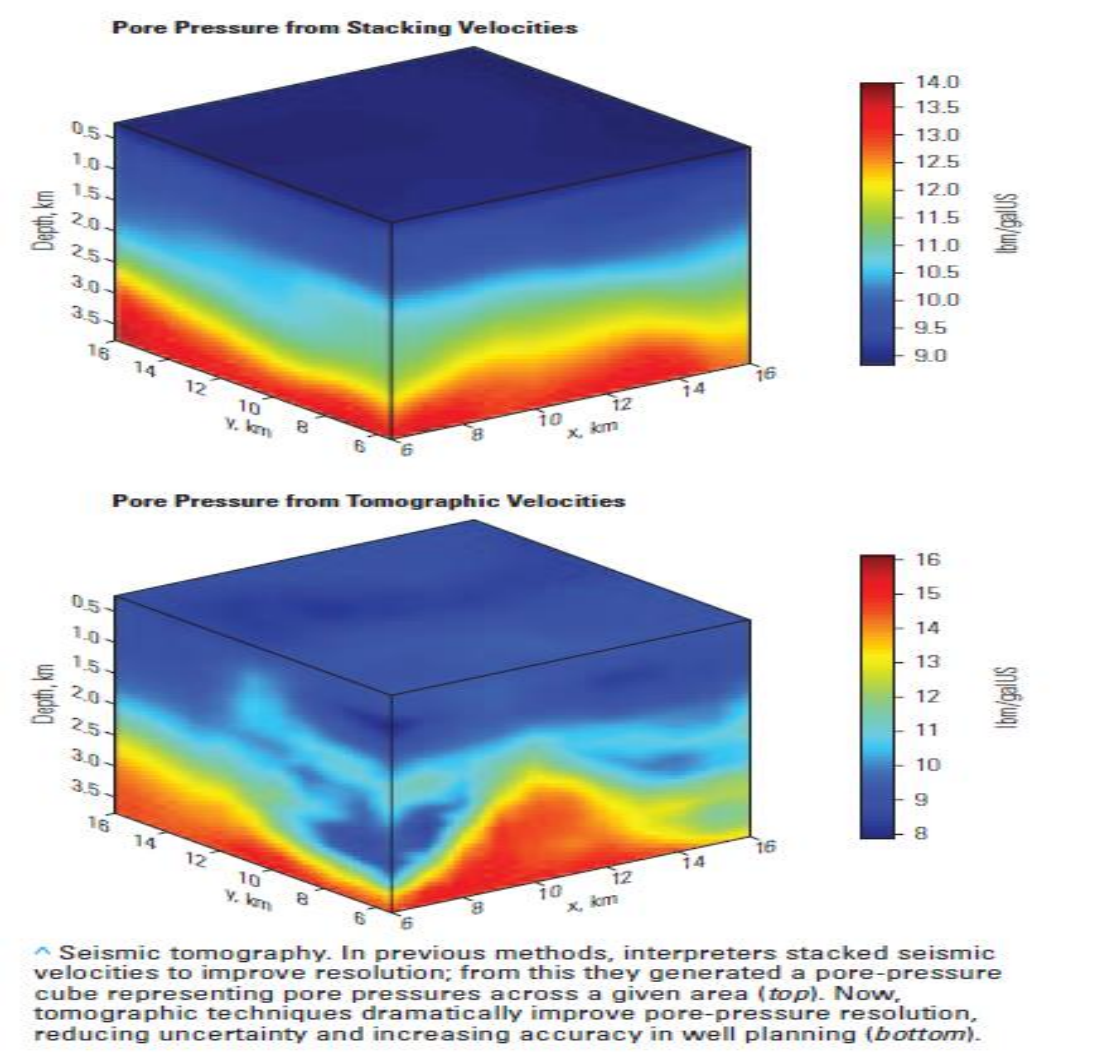
Manage Reservoir



^ Fracture migration. Fault planes may allow pressure transmission from a zone of higher pressure to a more shallow, lower-pressured zone. This results in an abnormally pressured, or charged, sand. These effects are common in tectonically stressed environments and adjacent to salt domes.

Structural situations in which highly dipping permeable formations
Allow pressure transmission from a higher- pressured deep zone to a shallower depth.

Seismic Data

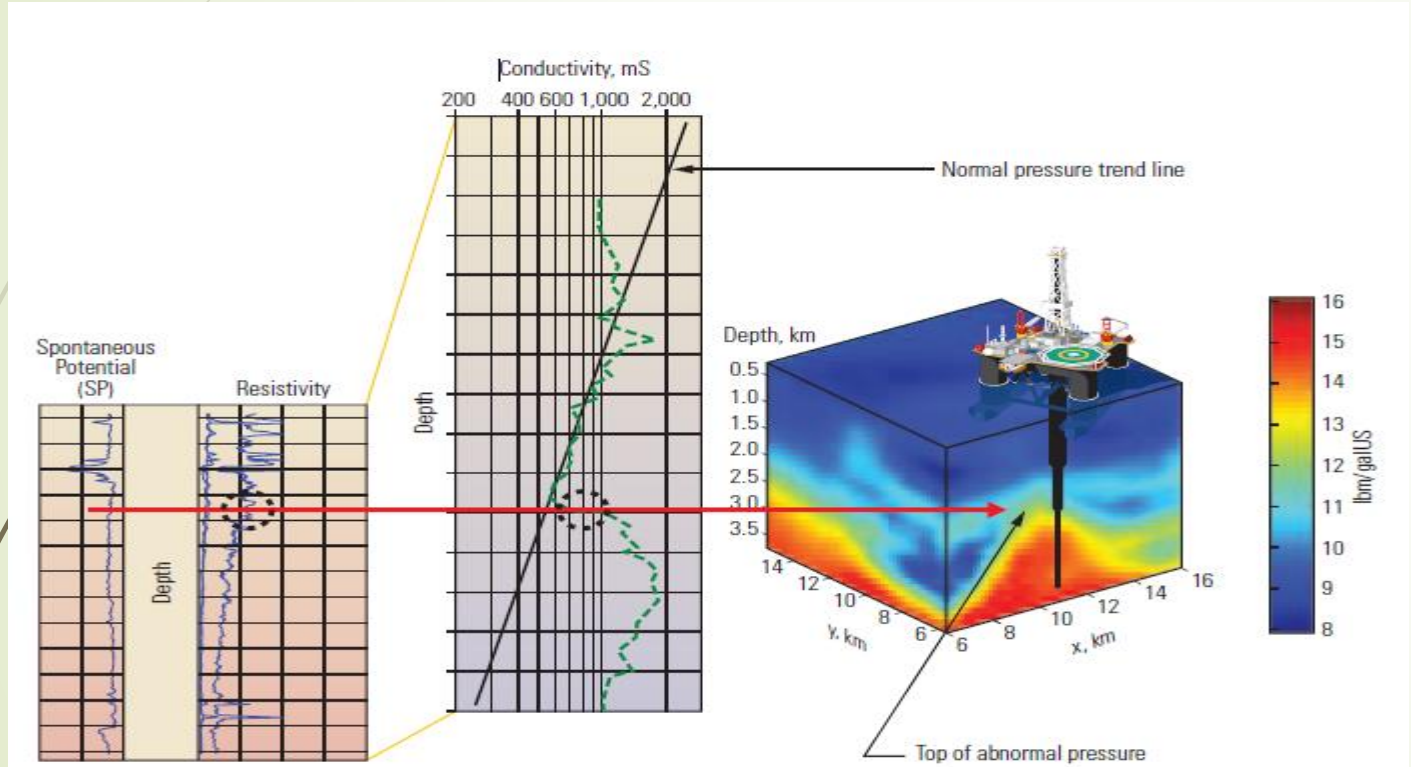


^ Seismic tomography. In previous methods, interpreters stacked seismic velocities to improve resolution; from this they generated a pore-pressure cube representing pore pressures across a given area (*top*). Now, tomographic techniques dramatically improve pore-pressure resolution, reducing uncertainty and increasing accuracy in well planning (*bottom*).

Reflection tomography offers significant advantages compared with conventional seismic data but reflection tomography replaces the low resolution, conventional velocity analysis.

More information including, Drilling Data, mud data, mudlogging, formation samples, wire line and while-drilling logs.

Seismic data & Drilling Data



^ Electric log analysis to reduce the uncertainty of seismic-based pore-pressure predictions. In normally compacted sediment, electrical conductivity will decrease with depth as water is squeezed from pore spaces. A deflection in conductivity from the normal trend (dashed circle, *left and middle*) may indicate a change in pore-water concentration, hence the potential for abnormal pressure. Using both seismic and electric log data, computer processing refines the data and generates three-dimensional predictive models that help engineers and drillers visualize pore-pressure trends (*right*).

Study Abu Dhabi Area

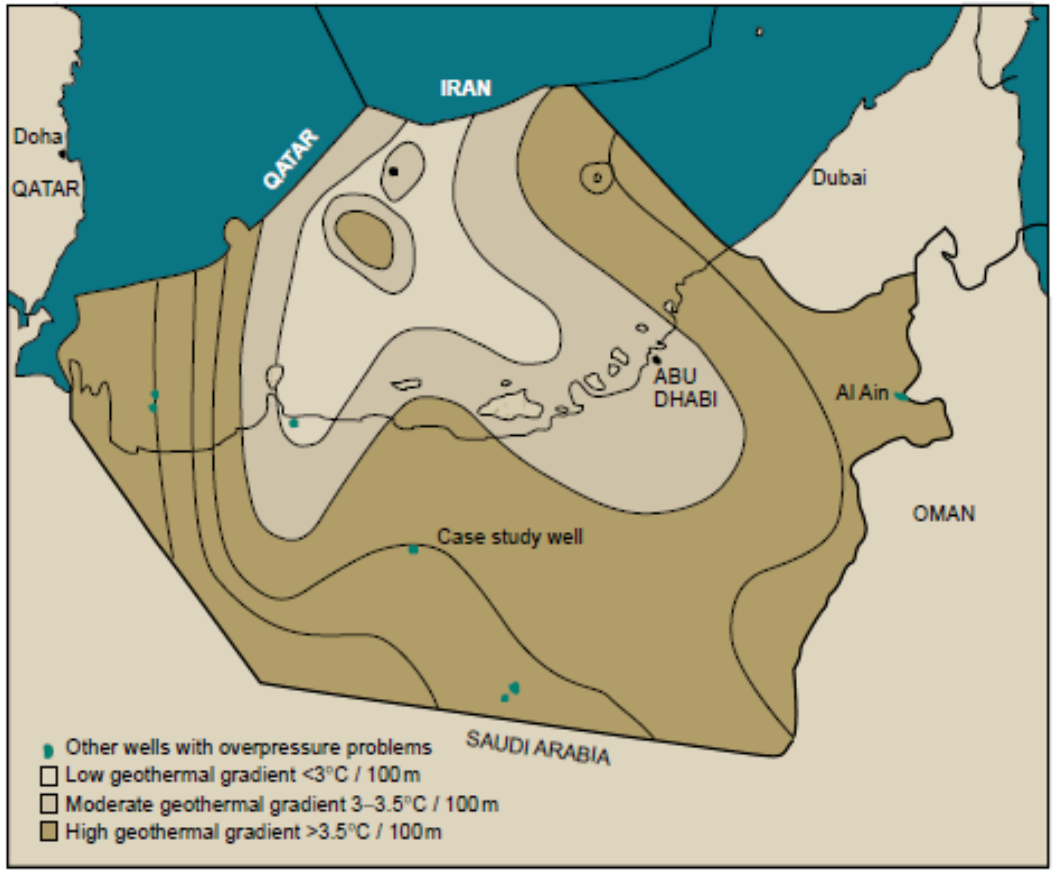


Figure 1.9: The first stage coincides with hydrocarbon maturation at the depocenters, particularly in areas with high geothermal gradients, which creates abnormal increases in fluid volume and pore pressure. From: A Rahman, Al-Tawil and I Azzam, SPE36297

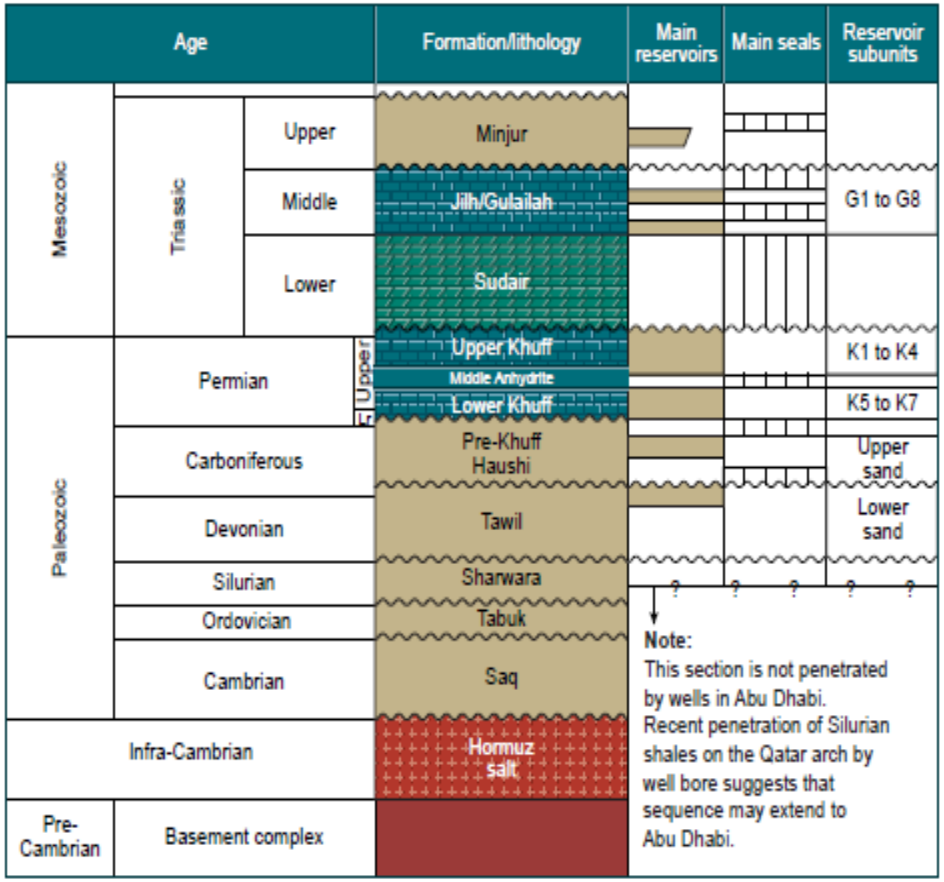
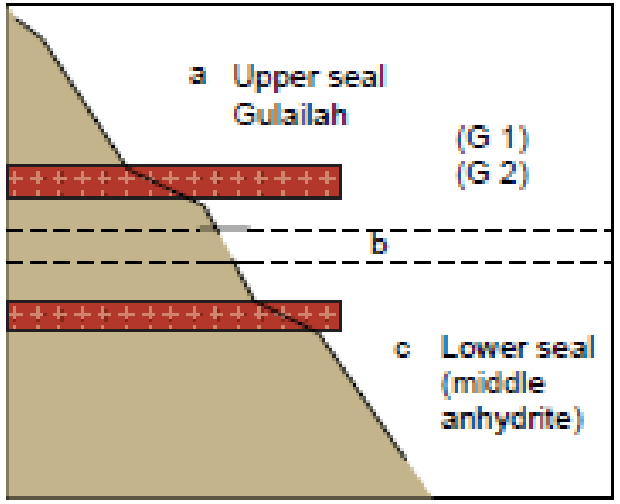


Figure 1.6: Permo-Triassic and Paleozoic stratigraphy of Abu Dhabi

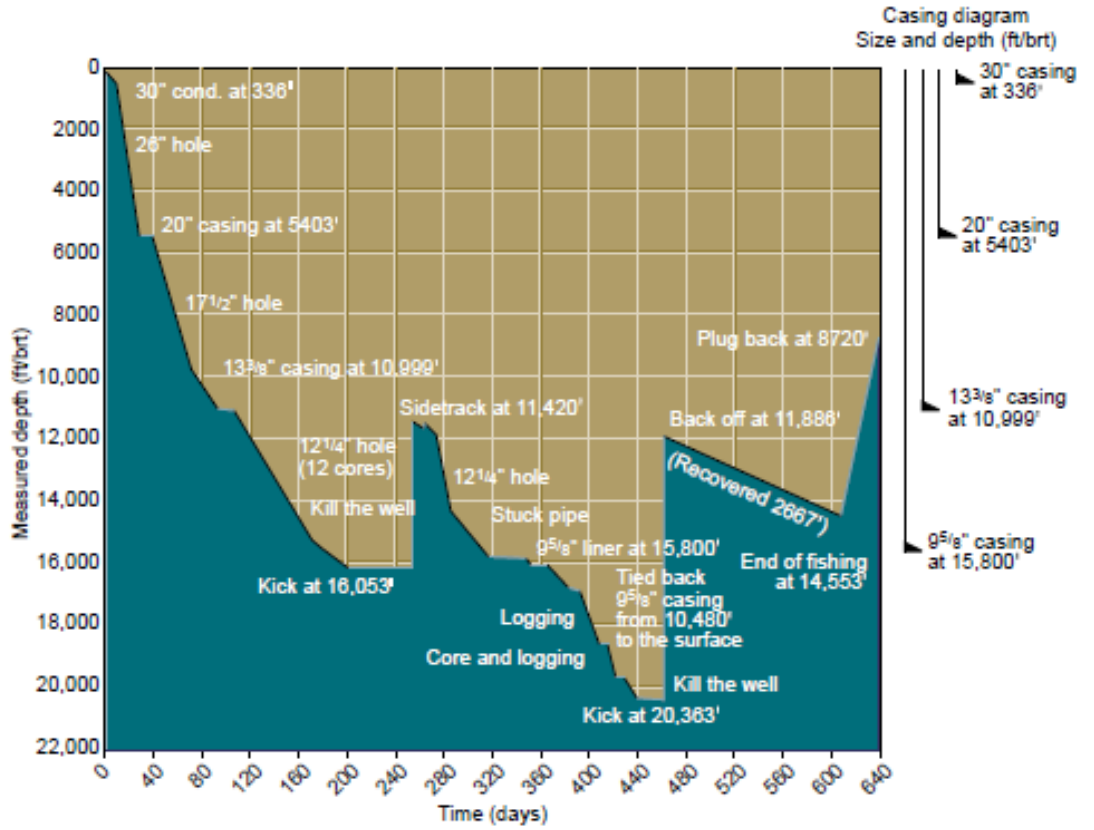
Study Abu Dhabi Area



a) Upper normal pressure
b) Middle overpressure
c) Lower overpressure

Figure 1.7: Complex variations in pressure with depth. Two pressure seals, Gulailah and the middle anhydrite, separate two overpressure systems. From: A Rahman, Al-Tawil and I Azzam, SPE 36297

Figure 1.8: A fish was left in hole which was plugged back and sidetracked at 11,420 ft. Drilling resumed, reaching 15810 ft (above the problem depth) where 9-5/8-in. liner was run and cemented. From: A Rahman, Al-Tawil and I Azzam, SPE 36297



Real Well Data in KSA

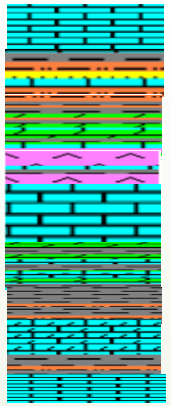
- Operator: SAUDI ARAMCO
- Well: X1
- Location: xxx
- Country: SAUDI ARABIA
- Elevation GL: 730.00 FT
- KB:35.00 FT
- Drilling Rig: X2
- Vertical well
- TD @ 16373 FT
- Gas Reservoir @ Khuff C & Unayzah

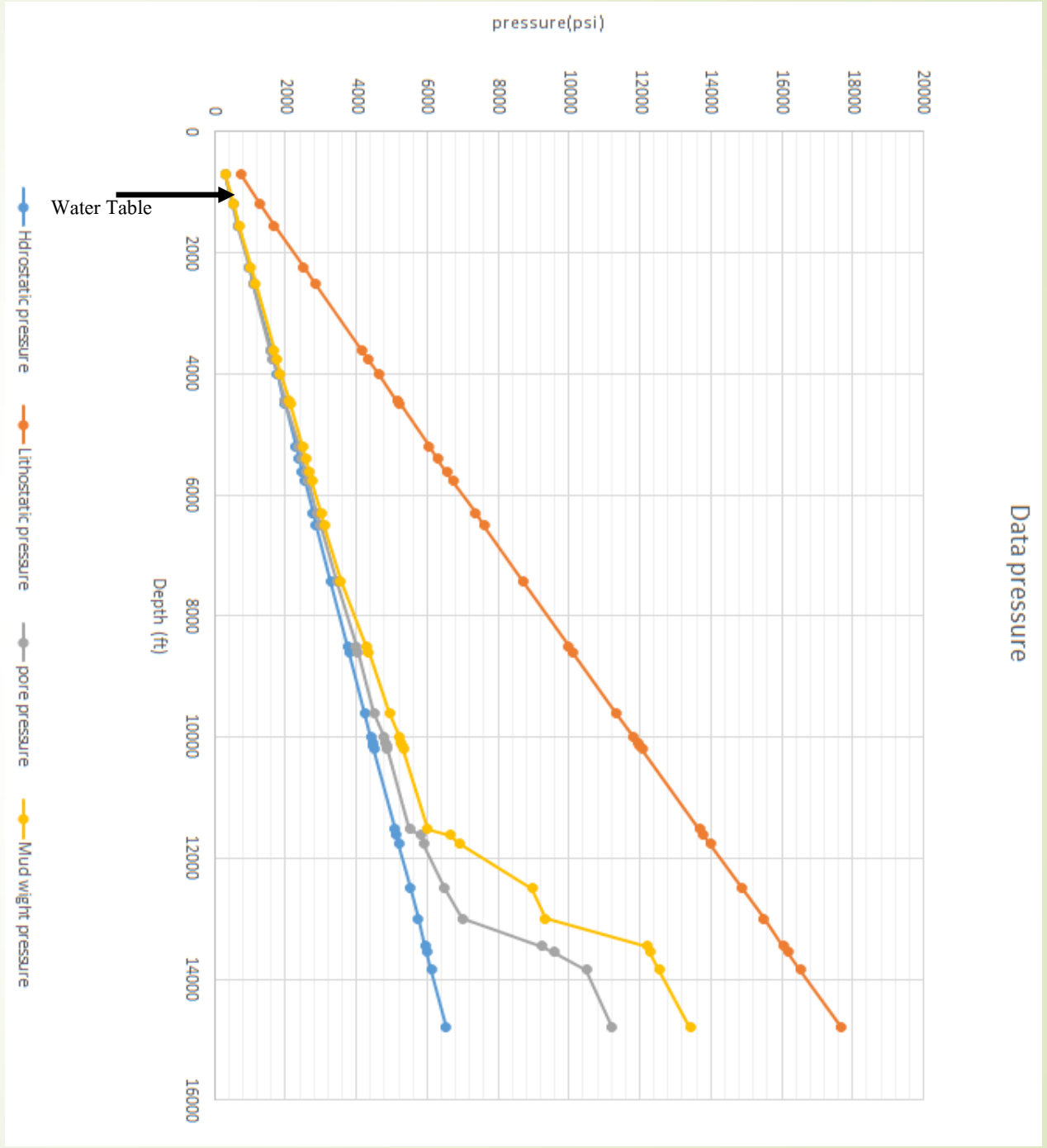
Well Data Pressure

Note

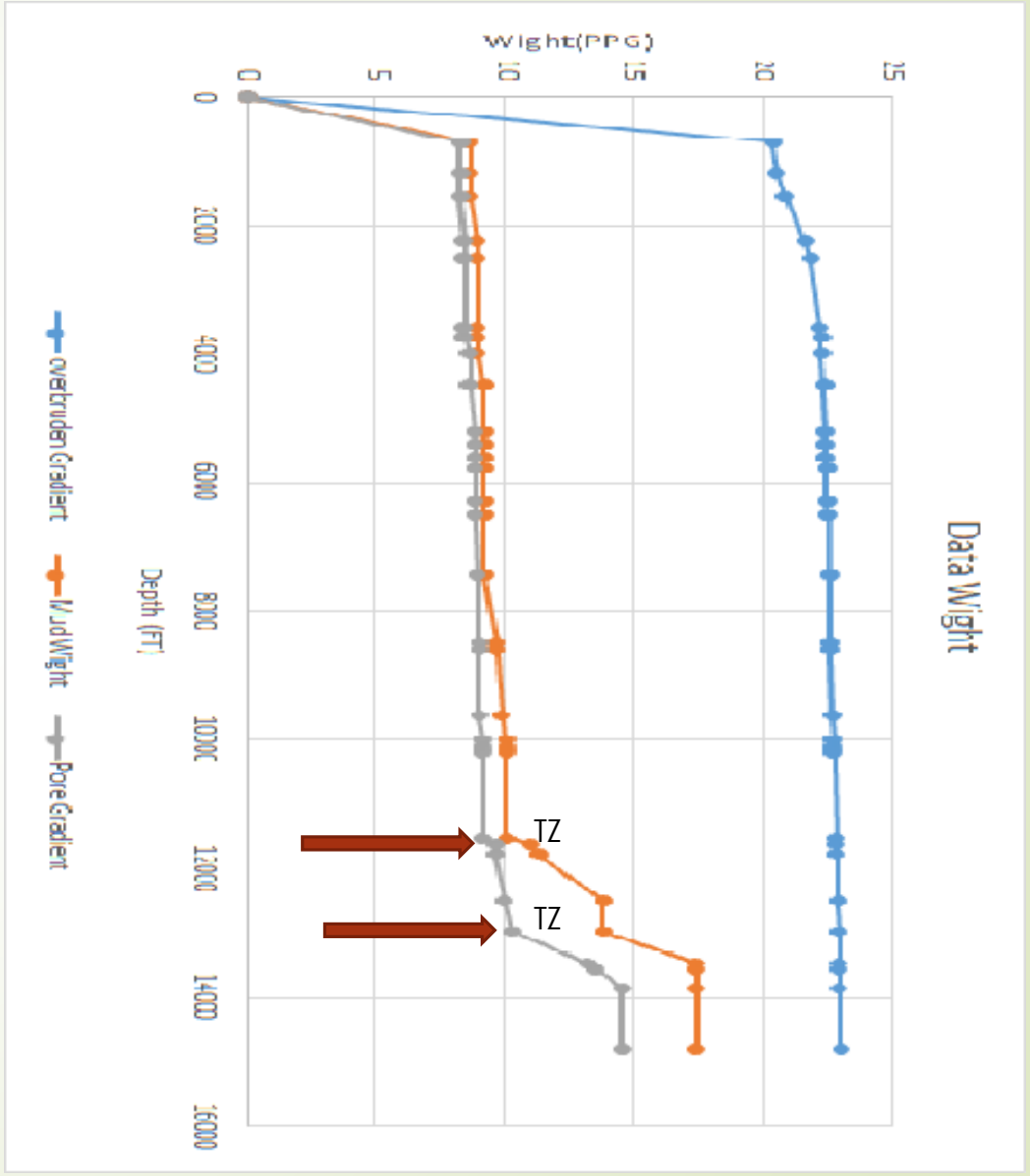
Pore pressure estimation

Lithology





Well Data Weight



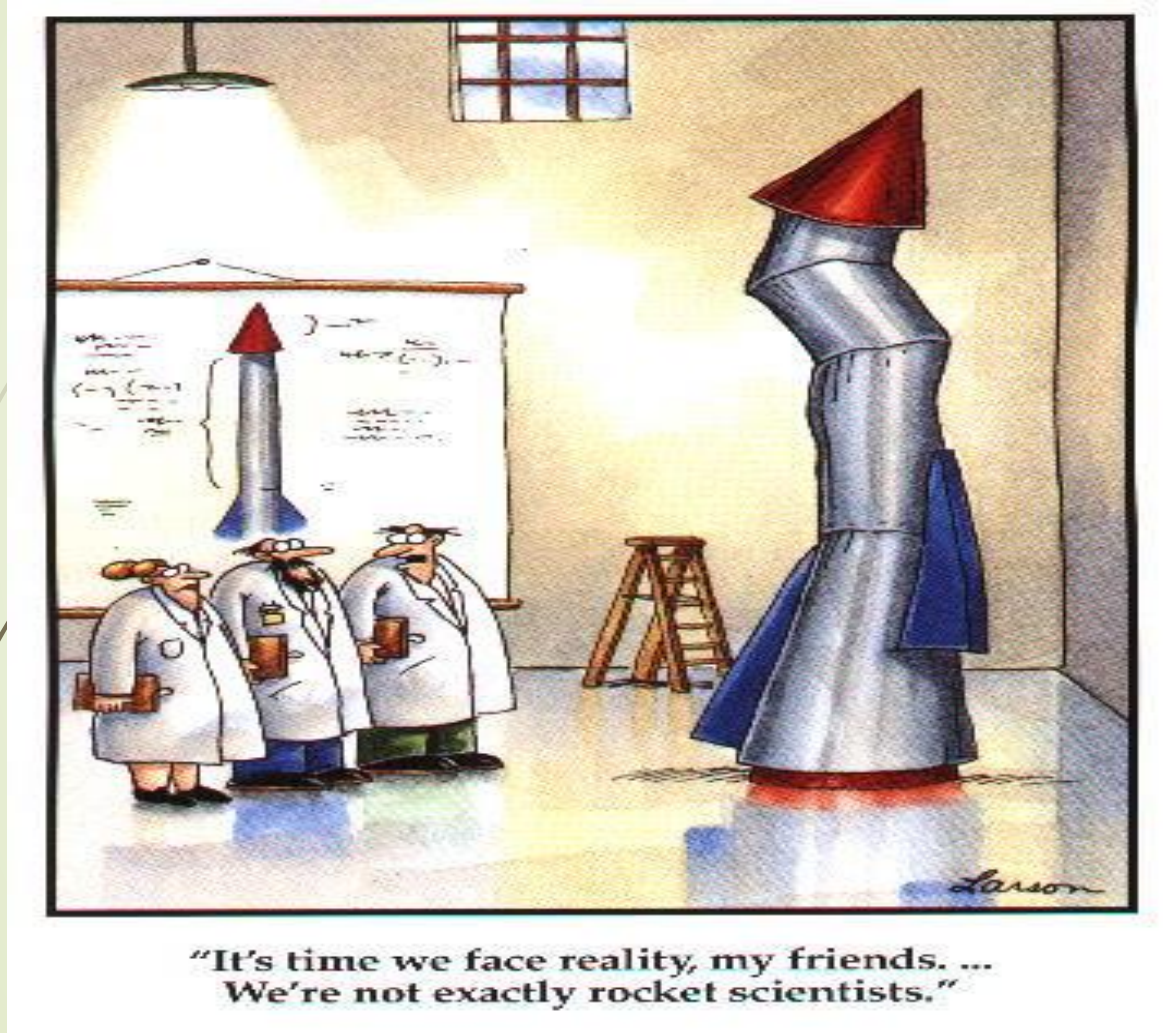
Transition zone

Summary

- Formation pressure Data give us :

1. Water salinities
2. Fluid contact
3. Transition zone
4. Well design
5. Determine good reservoir to production

Thank you



"It's time we face reality, my friends. ...
We're not exactly rocket scientists."