Naturally Fractured Reservoirs

Specific Features of Carbonate Fracture Reservoir

Shahab Gerami, Fall 2010

Naturally Fractured Reservoirs

- Naturally fractured reservoirs occur worldwide.

- Although fractured reservoir are scattered throughout the world, one of the areas where the highest concentrations of reserves of this type can be found, is in south-west Iran and east to north of Iraq.

- The oil in place in the Middle East fractured reservoirs represents 25-30 % of the total oil in place in that region. This percentage may well represent the contribution of fractured reservoirs to the total oil in place on a world wide scale (Saidi 1987).

- About 90% of Iranian reservoirs are fractured reservoirs.

Fracture, Fracture Set, Fracture Network?

➢A fracture is a surface of discontinuity of mechanical origin. The fracture is the failure of a rock (= deformation) resulting from applied forces (= stress).

➢ A fracture is characterized by its attributes (dip, strike, length, aperture, morphology and origin)

➢A fracture set (or fracture family) is a set of fractures with similar attributes

➢The fracture network involves the description of the fracture attributes and investigates the relationship between the different fracture sets.

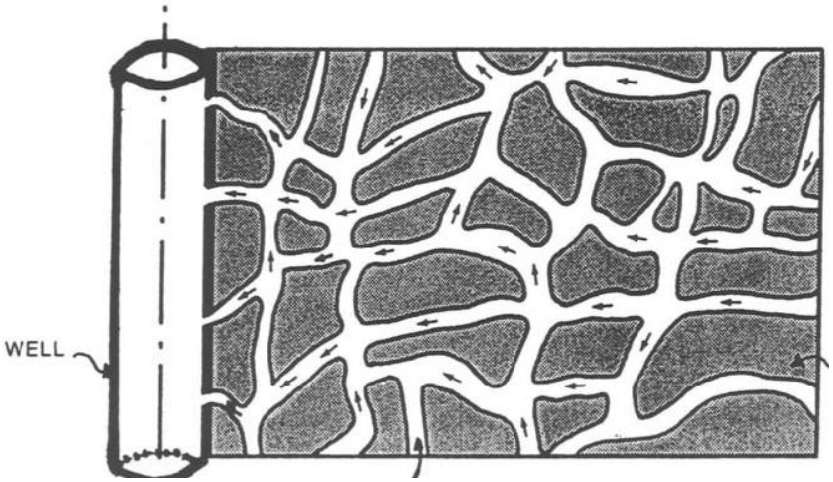
➢The fracture network is characterized by the spatial properties of fractures, such as the number of fracture sets, their relative fracture density, the fracture connectivity.

What is a fractured reservoir?

For geologists:
A fractured reservoir is first and foremost a reservoir with structural discontinuities resulting from a given paleostress history.

For reservoir engineers:
A fractured reservoir is first and foremost a reservoir with structural discontinuities affecting flows.

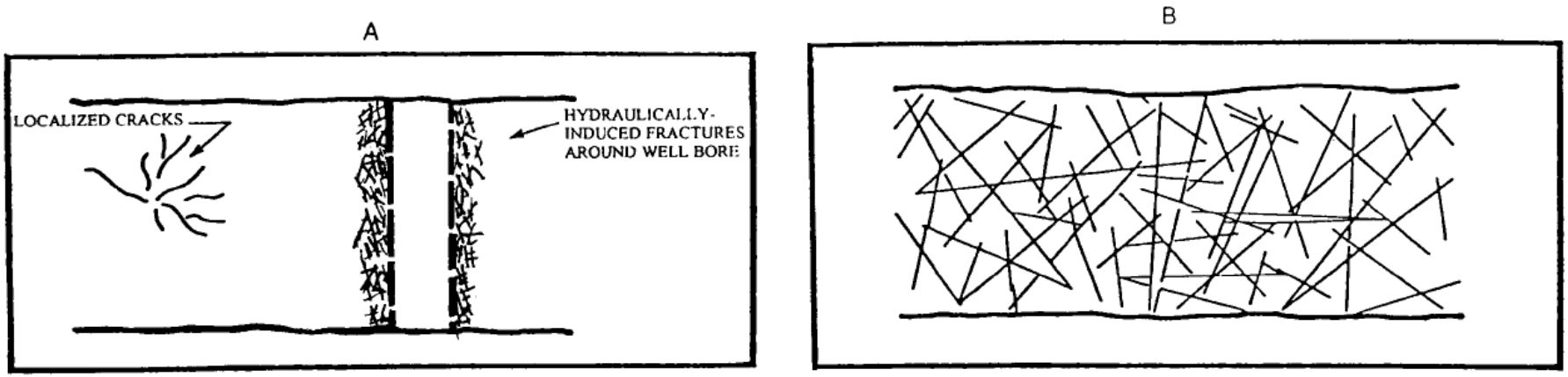
[R.A. Nelson, in Geologic Analysis of Naturally Fractured Reservoirs, Quotes:
" A fractured reservoir is defined as a reservoir in which naturally occurring fractures either have, or are predicted to have, a significant effect on reservoir fluid flow either in the form of increased reservoir permeability and/or porosity or increased permeability anisotropy" **]**



Carbonate Fracture Reservoir

➢A carbonate reservoir is defined as being "fractured" only if a continuous network of various degrees of fracturing is distributed throughout the reservoir. Such fractures formed naturally during the specific geological circumstances of reservoir history.

➢On the other hand, the presence of some dispersed fractures induced by engineering stimulations in a carbonate rock will never transform a carbonate reservoir into a natural "fractured carbonate reservoir"



Carbonate reservoir: (a) artificially fractured; (b) naturally fractured.

Identification of a Continuous Fracture Network in Carbonate Reservoirs

(1) Significant mud losses during drilling operations,
(2) Special behavior of transient pressure analysis (e.g., double-slope curves),
(3) Cores examination, etc.

The true confirmation of the fractured character of a given reservoir results from certain specific features observed during the initial stage of field discovery as well as during the field development and production phase.

Full-diameter whole core compared to plug-size sample (round hole to the left) for fractured rocks. Plug size is 2.5 cm (1 in.) diameter.

RESERVOIR CLASSIFICATION SCHEMES

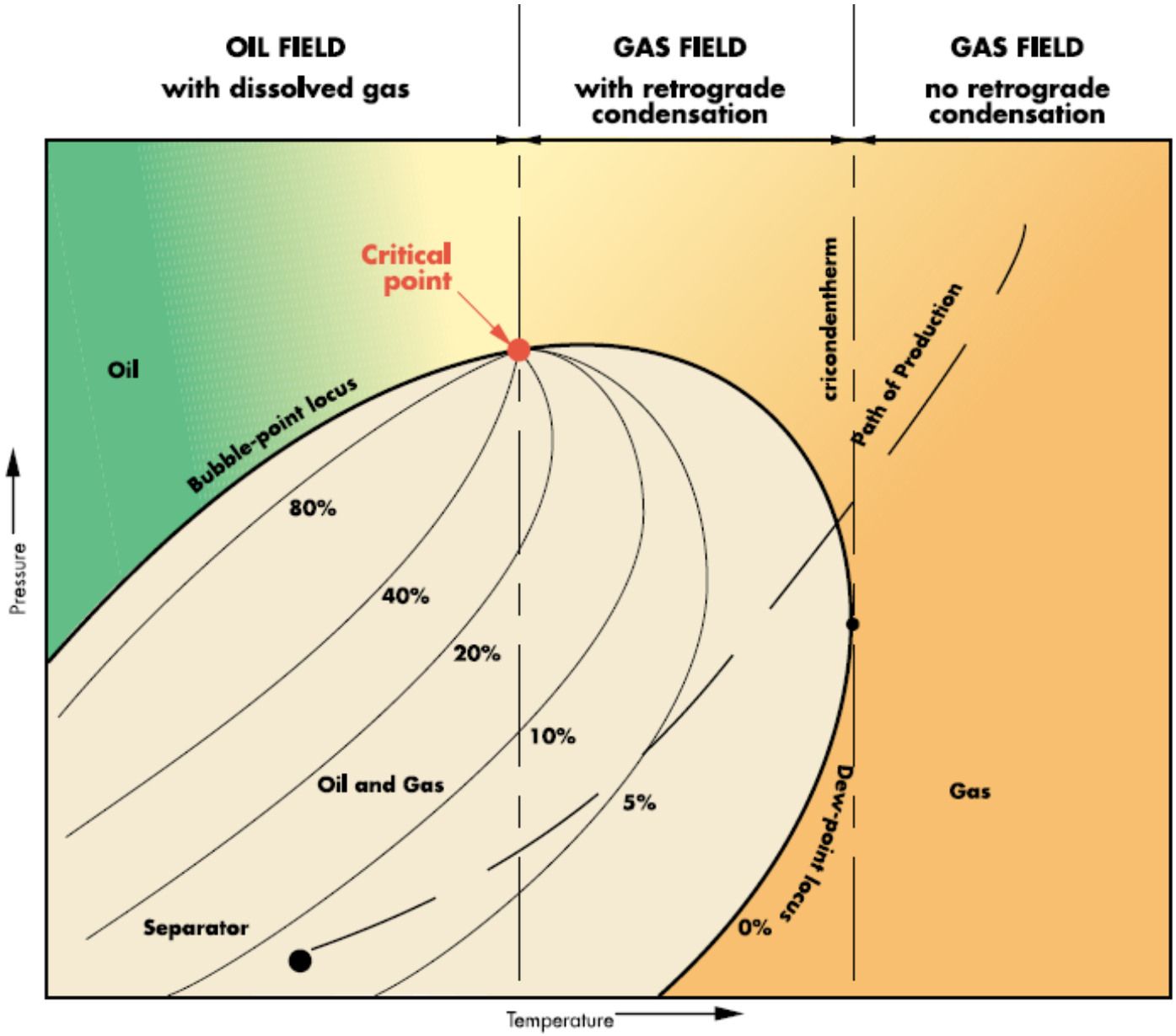
(1) fluid composition in the reservoir

(2) type of available reservoir energy (drive mechanism)

(3) type of pore system

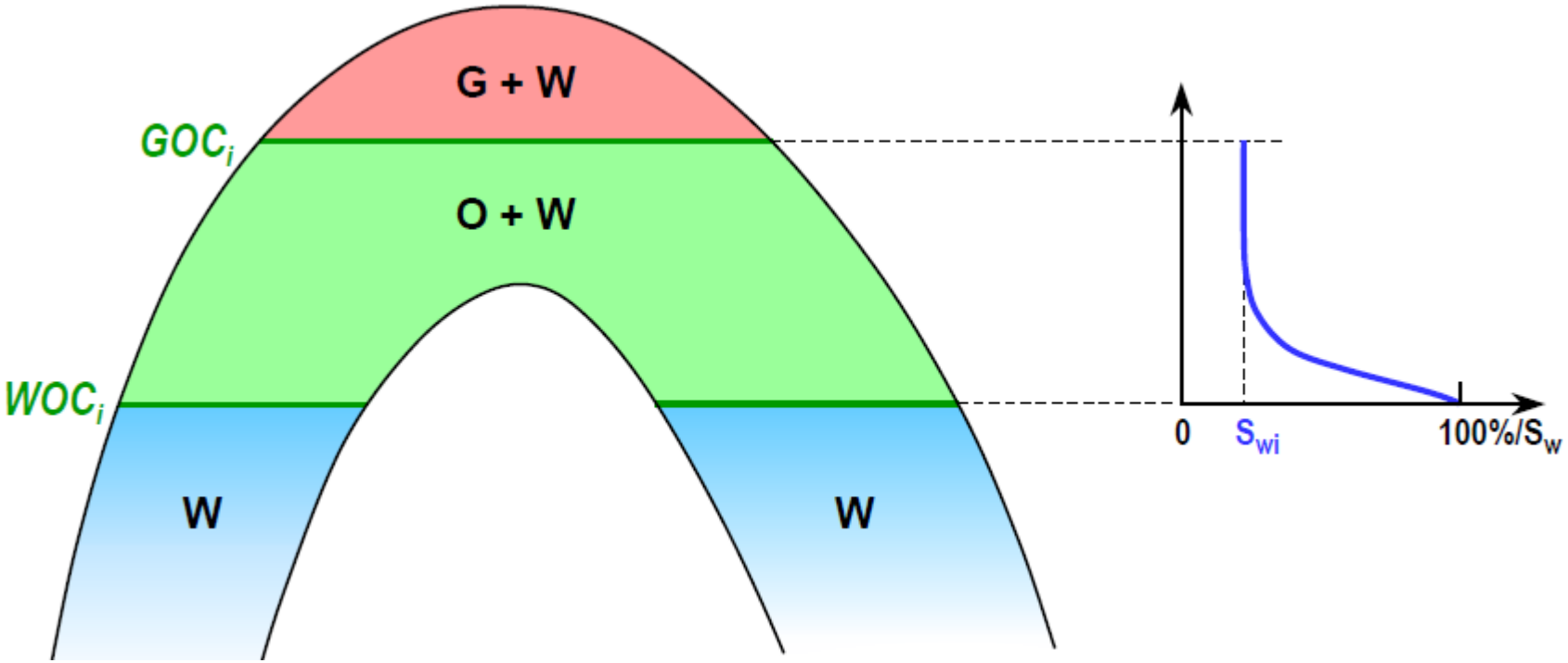
(4) geological nature of the reservoir

Generalized P-T diagram of a gas and oil



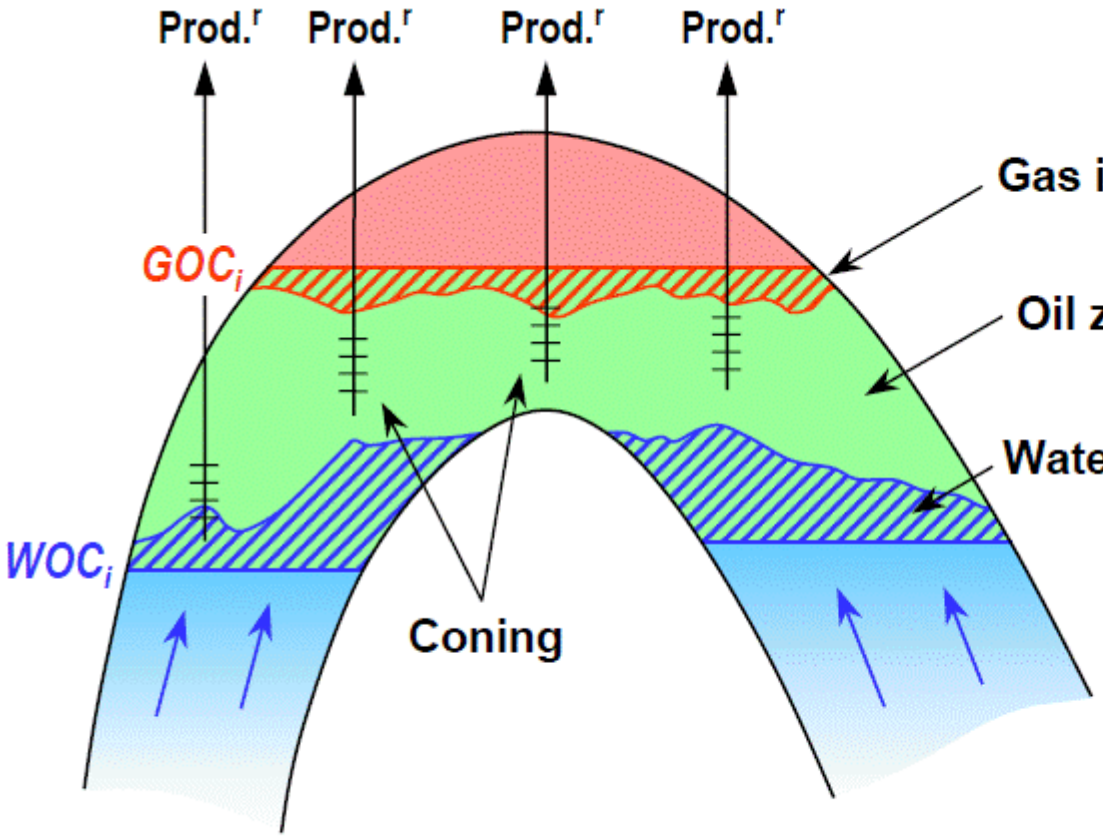
Conventional Oil Reservoirs

Production Mechanisms- Initial Conditions



Conventional Oil Reservoirs

Production Mechanisms Status During Development



Gas invaded zone : S_{org}, k_{rog}

Oil zone : S_{oi} ($P_{CDr.}$)

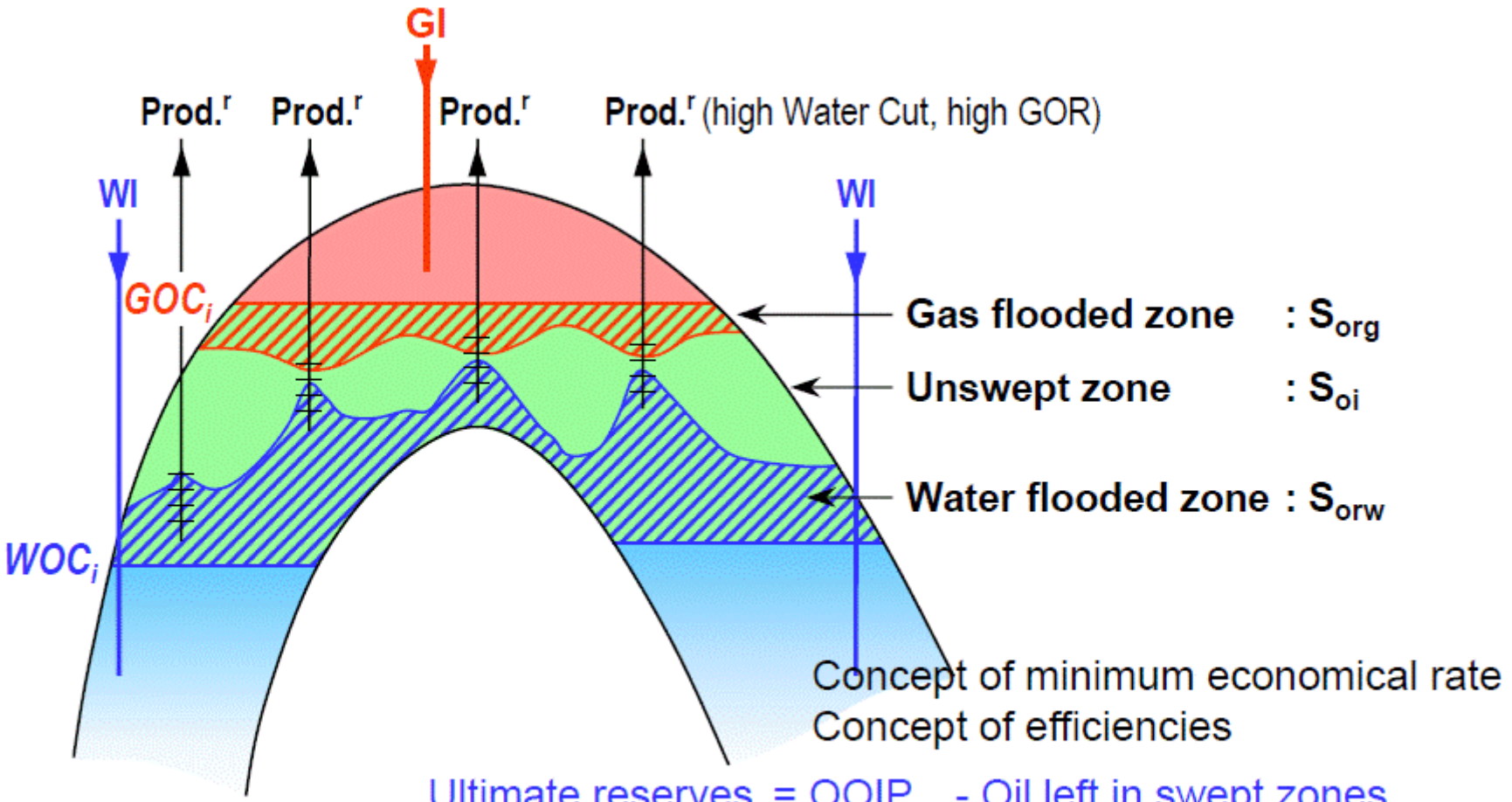
Water invaded zone : S_{orw},k_{row}

At t

- $N_p = \sum^{t} \sum^{n} q_{oi}$
- $\overline{P_r} < P_i$
- Saturation changes
- X phase flow (O, W, G)
- End saturation

Conventional Oil Reservoirs

Production Mechanisms Status at Abandonment Conditions



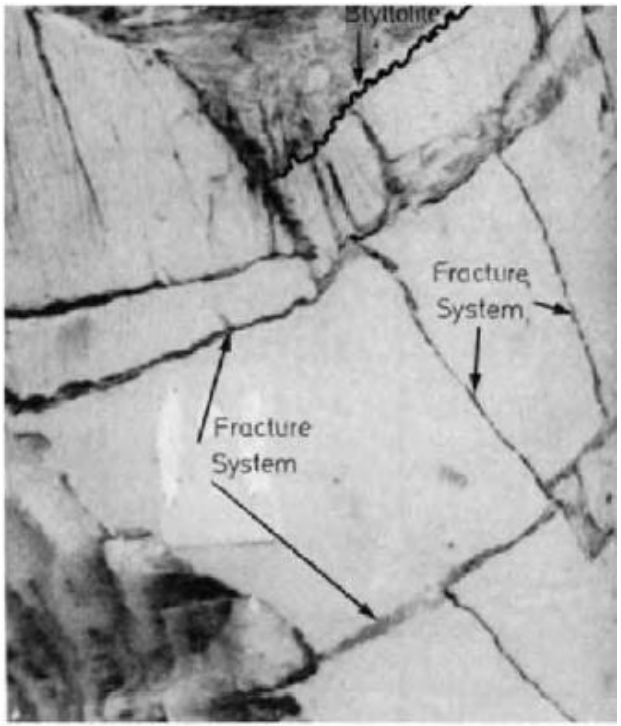
Concept of minimum economical rate

Concept of efficiencies

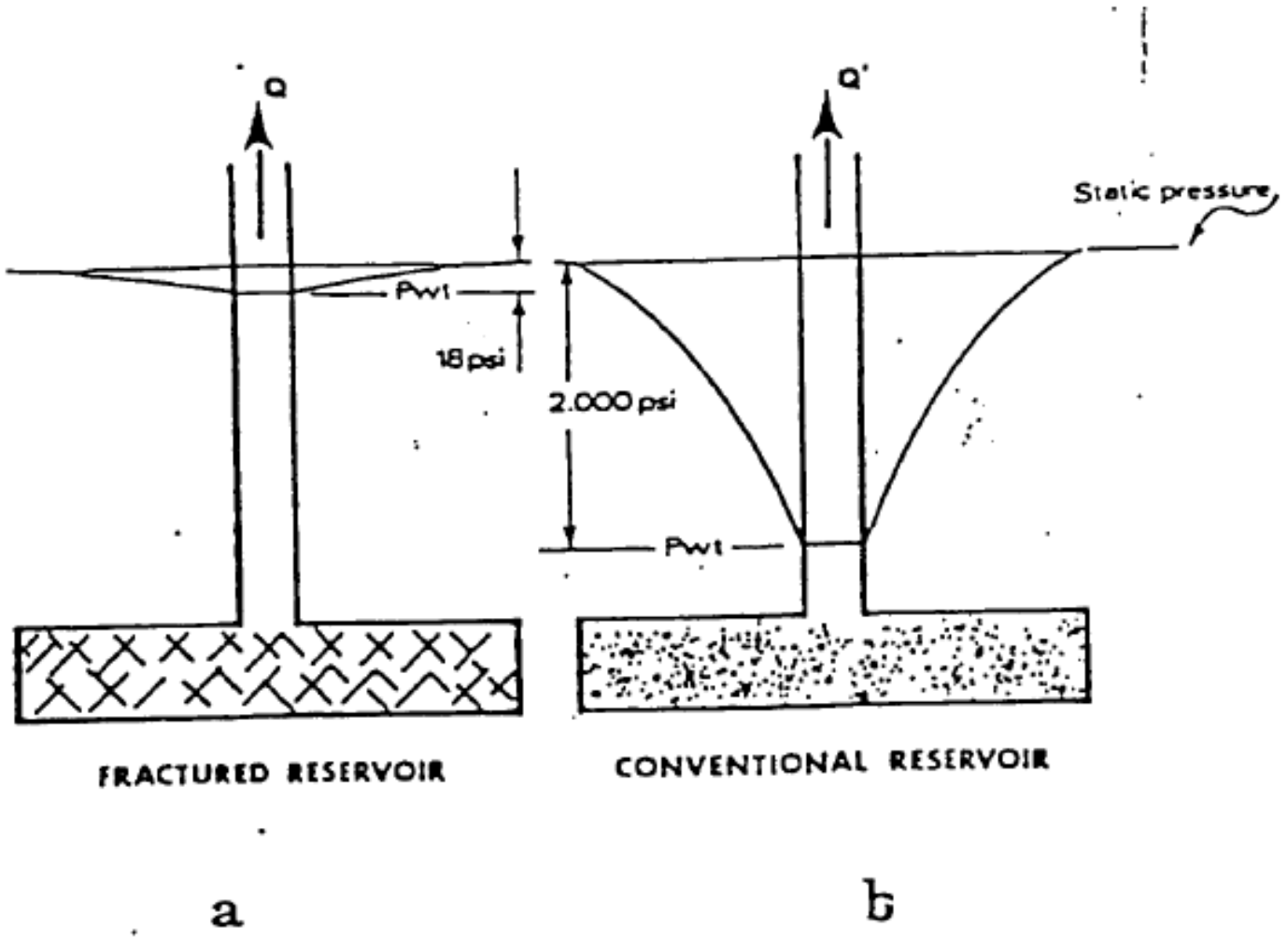
Ultimate reserves = OOIP - Oil left in swept zones
- Oil left in Unswept zone
= $N_1 + N_2 + N_3$

Why fractured reservoirs behave differently and need to be treated differently ?

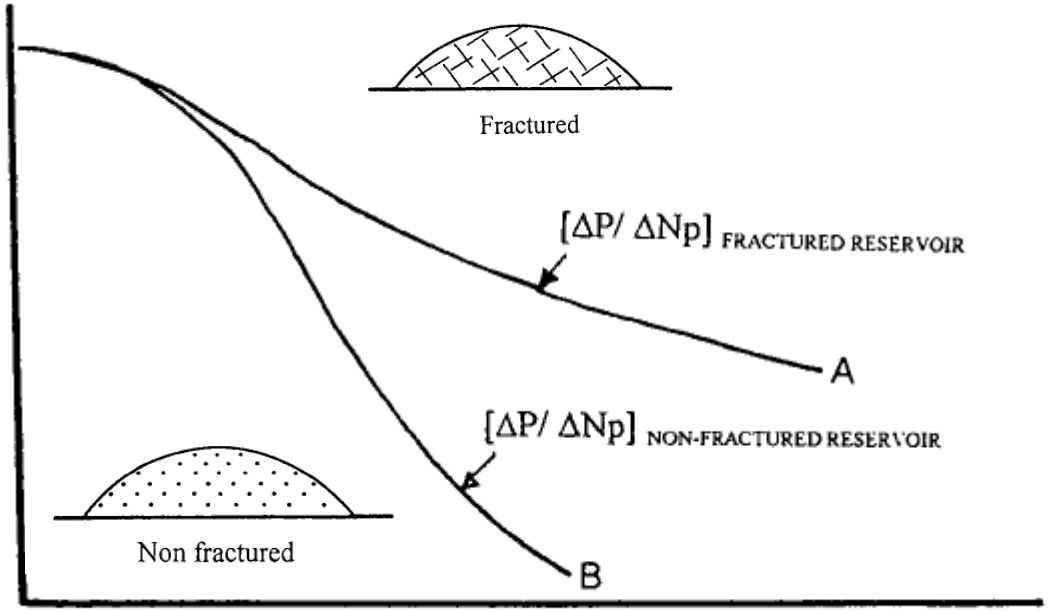
- High permeability – low porosity fractures in a low permeability - higher porosity matrix provides the mechanism for recovery of hydrocarbons. However, this dual-porosity system adds a measure of complexity that is absent in conventional reservoirs. The production characteristics of fractured reservoirs differ from those of conventional reservoirs in several fundamental ways.

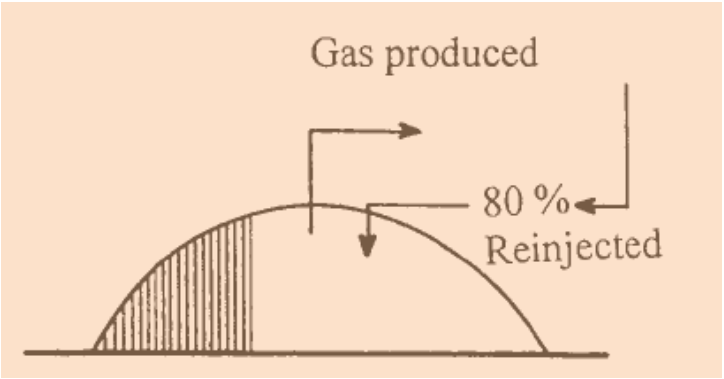


1. Because of the high transmissivity of the fracture network, pressure drop around a producing well is very low and pressure gradients do not play a significant role in production. Production is driven instead by complex mechanisms that govern fracture/matrix-block communication.



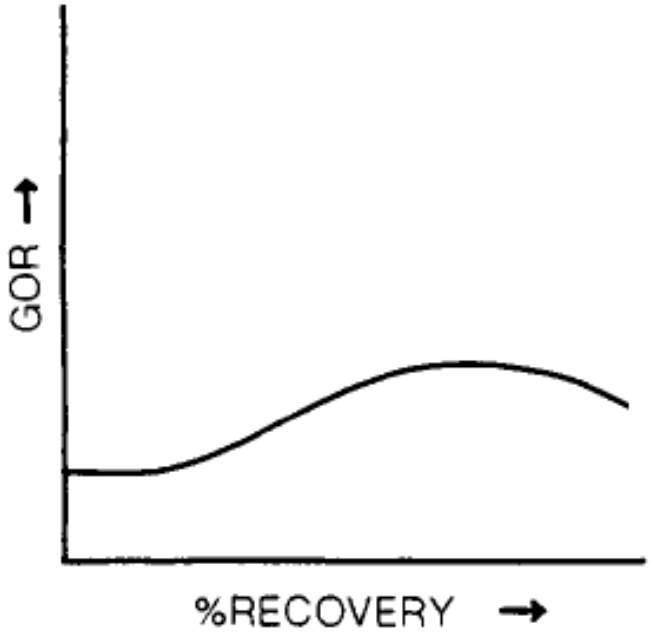
2. In fractured reservoirs with some matrix permeability, the pressure decline per barrel of oil produced is low compared to conventional reservoirs. This occurs because fluid expansion, gravity drainage, and imbibition provide a continuous supply of oil from matrix blocks into the fractures during production.



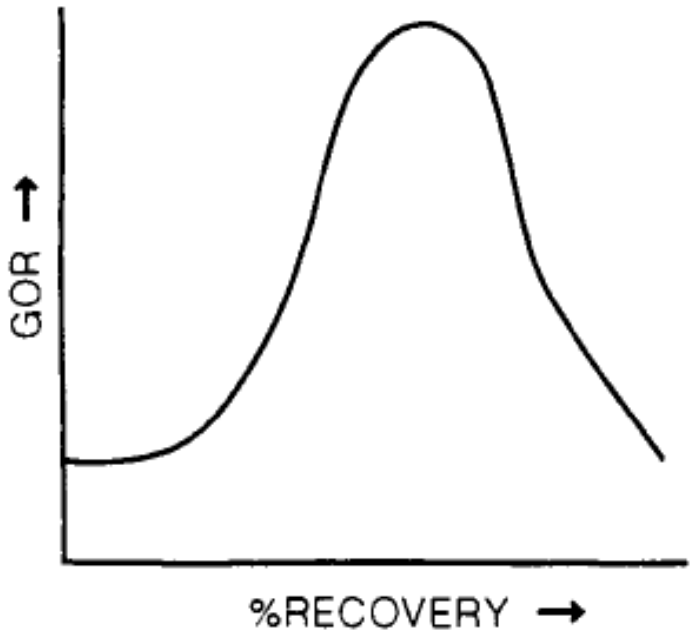


Pressure decline becomes equivalent to fractured pressure decline if 80% of gas produced is reinjected into the reservoir.

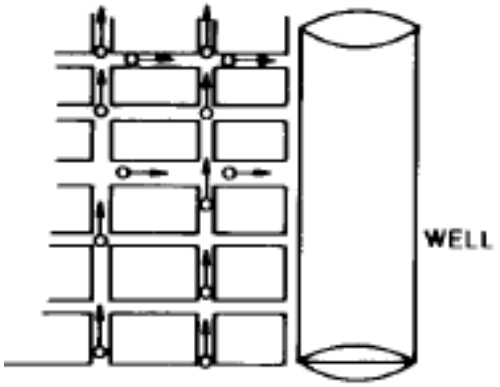
3. The GOR of fractured reservoirs normally remains lower throughout production, if the reservoir is properly managed. This occurs because liberated gas flows preferentially upward through fractures to the top of the reservoir rather than horizontally toward the nearest well bore as in a conventional reservoir. The liberated gas creates a secondary gas cap, or expands an existing gas cap, and the gas content of produced oil is lowered accordingly.



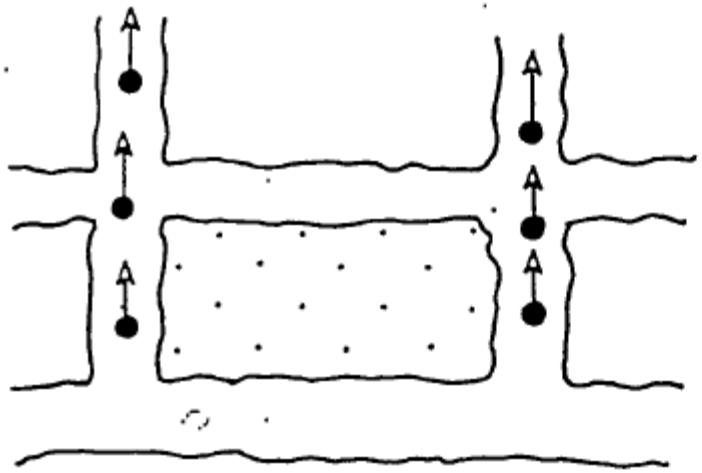
A



B



GAS CAP



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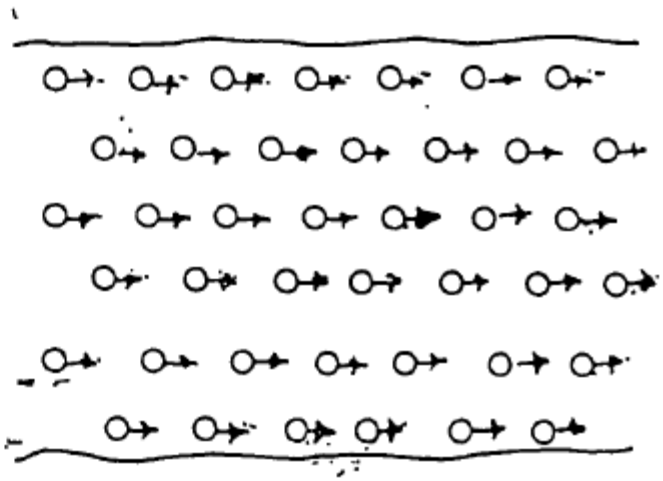
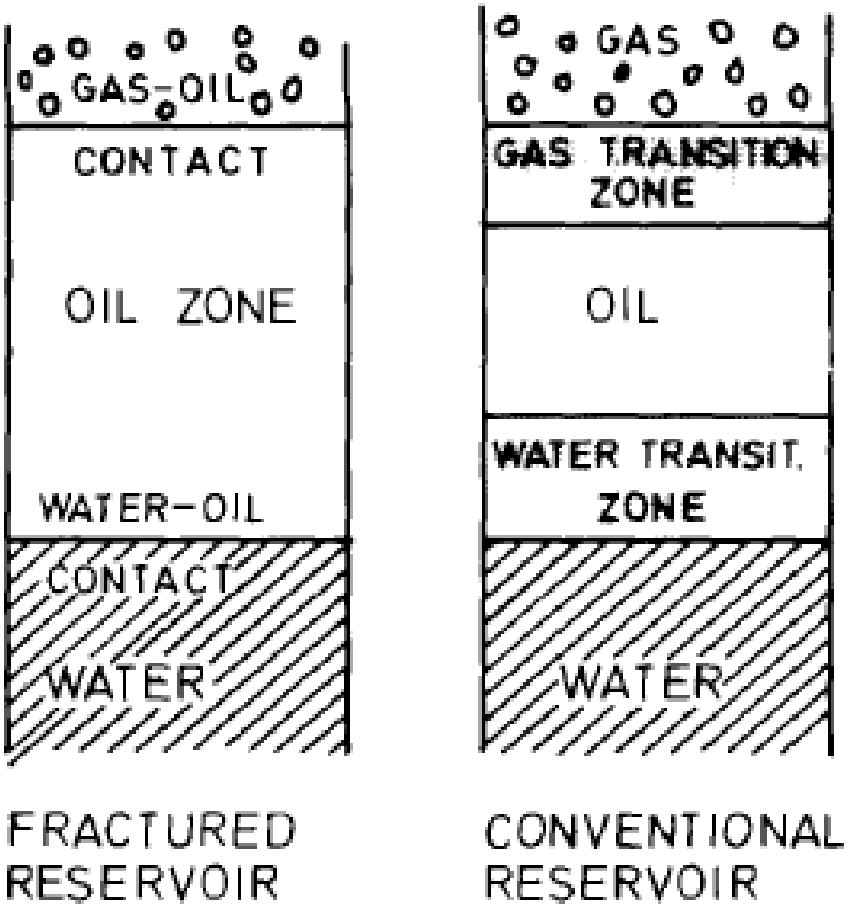
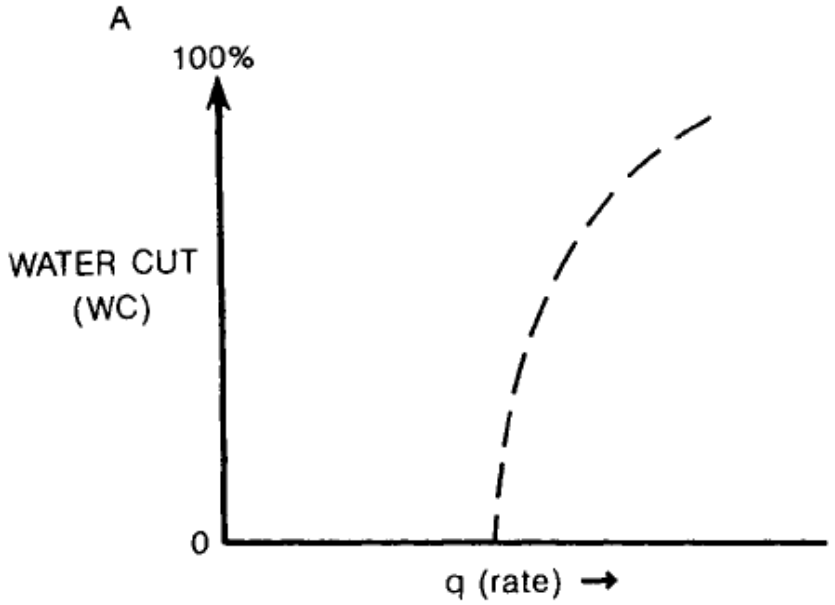


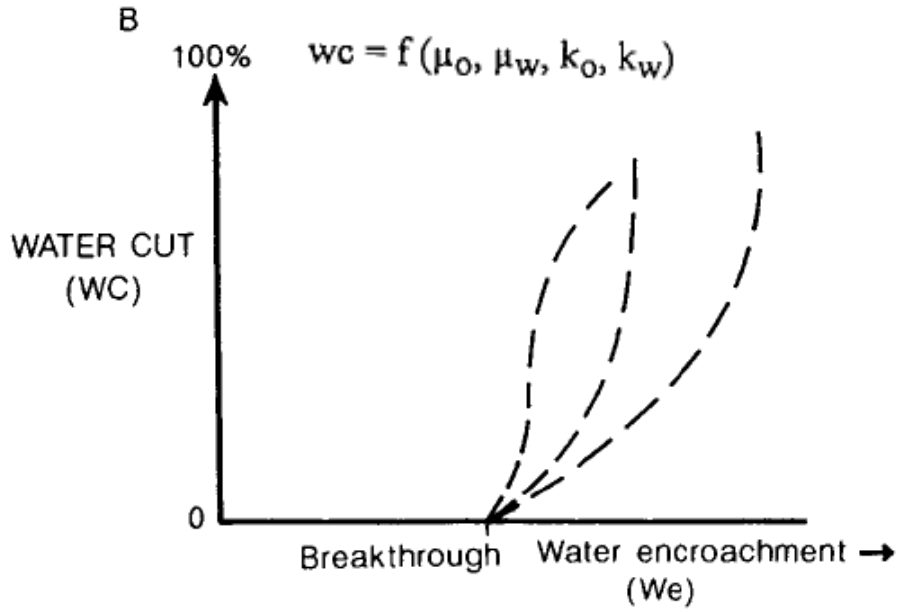
b

4. Fractured reservoirs lack transition zones. The oil-water and gas-oil contacts are knife-sharp surfaces, both prior to and during production, since the high permeability of the fracture network provides a mechanism for rapid re-equilibration of fluid contacts.

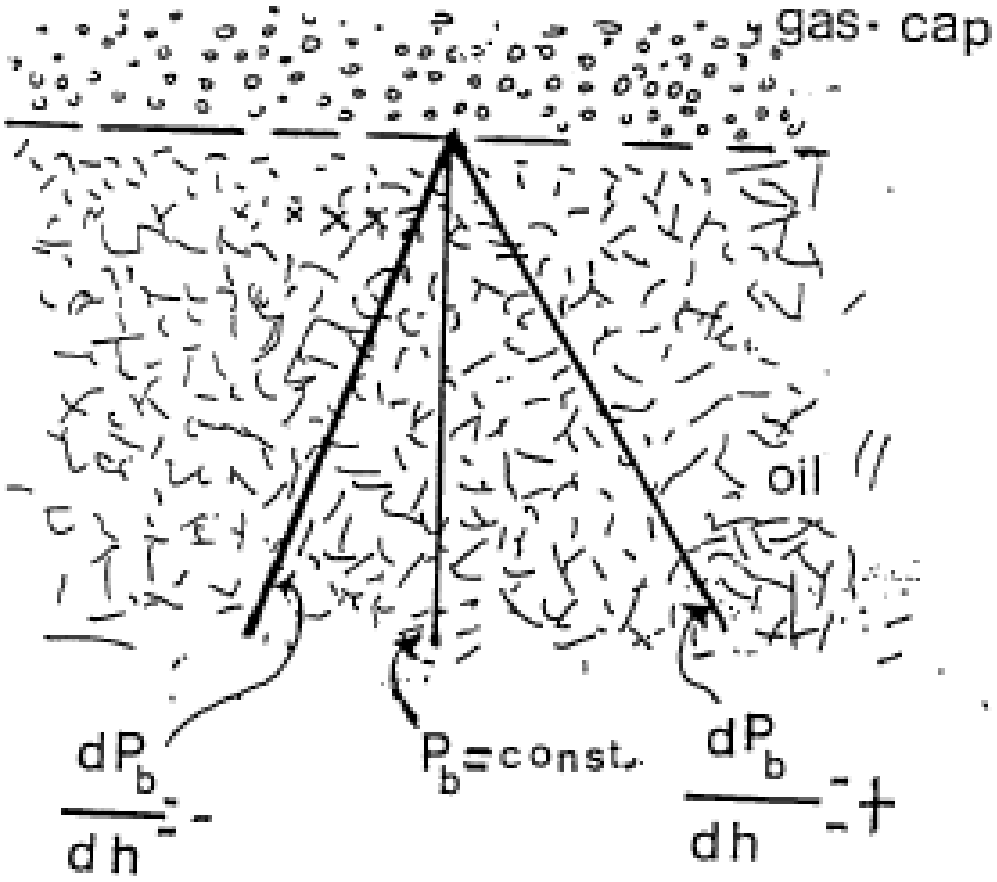


5. Water cut in fractured reservoirs is strictly a function of production rate. The petrophysical characteristics of the reservoir rocks and the PVT properties of the fluids have insignificant effect on water production.





6. Convective circulation occurs during the production of many fractured reservoirs. As a result, PVT properties are constant throughout a fractured reservoir, compared to a conventional reservoir where bubble point varies as a function of depth within the oil column.



A fracture is a surface of discontinuity of mechanical origin.