Hydrocarbon Fluids Properties, Models and Applications

Fluids/DHI consortium, Oct. 26, 2015

D. han (UH) &. M. Batzle (CSM)

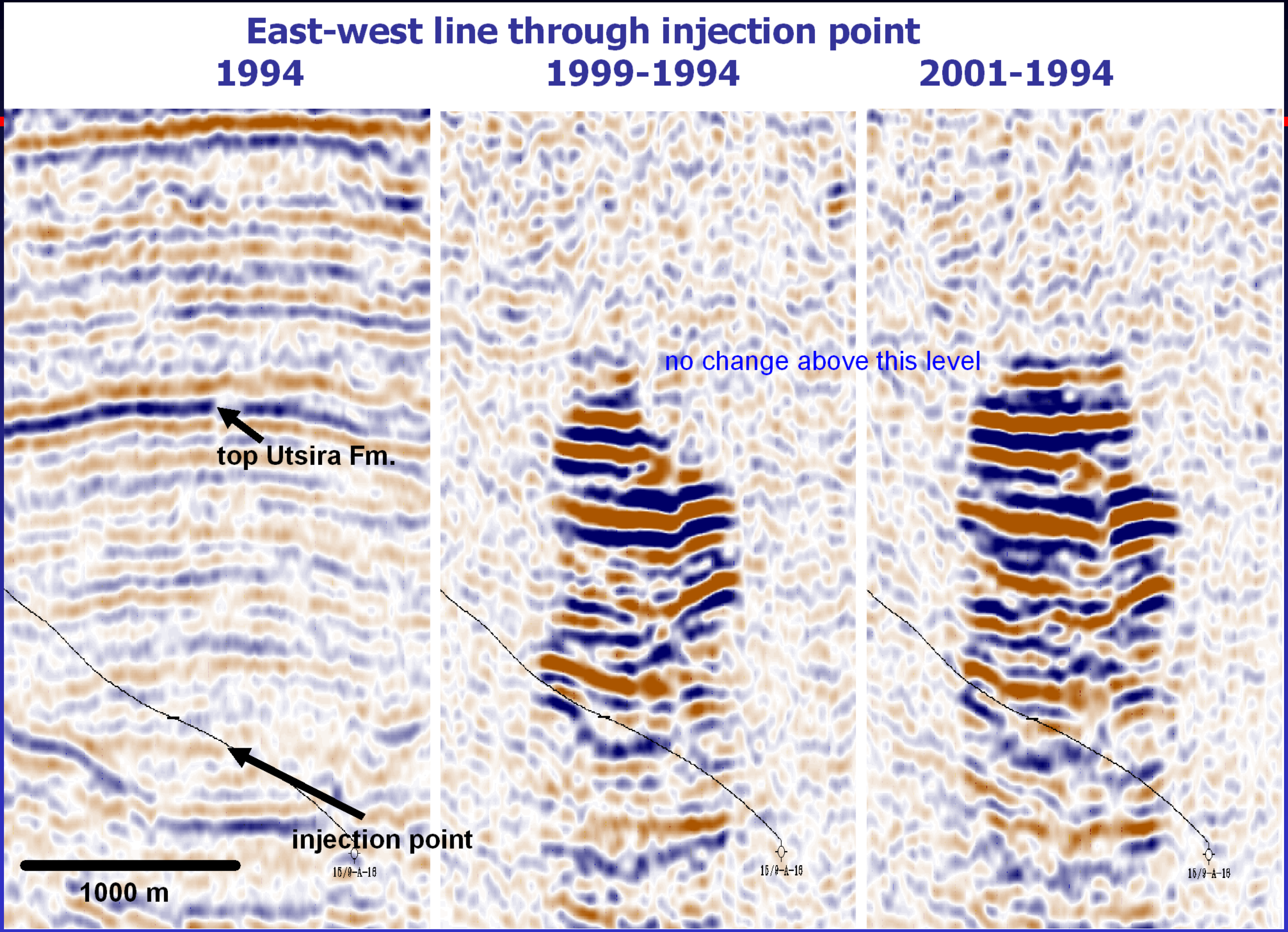

FLUIDS
PROPERTIES and BEHAVIOR of PORE FLUID
for GEOPHYSICAL APPLICATIONS
IV. GENERAL FLUID PROPERTIES
FOR ROCK
CENTER
ABUSE

IT’s ALL ABOUT

FLUIDS

GEOPHYSICAL PROPERTIES of FLUIDS

Colorado School of Mines - University of Houston
“ FLUIDS” Consortium



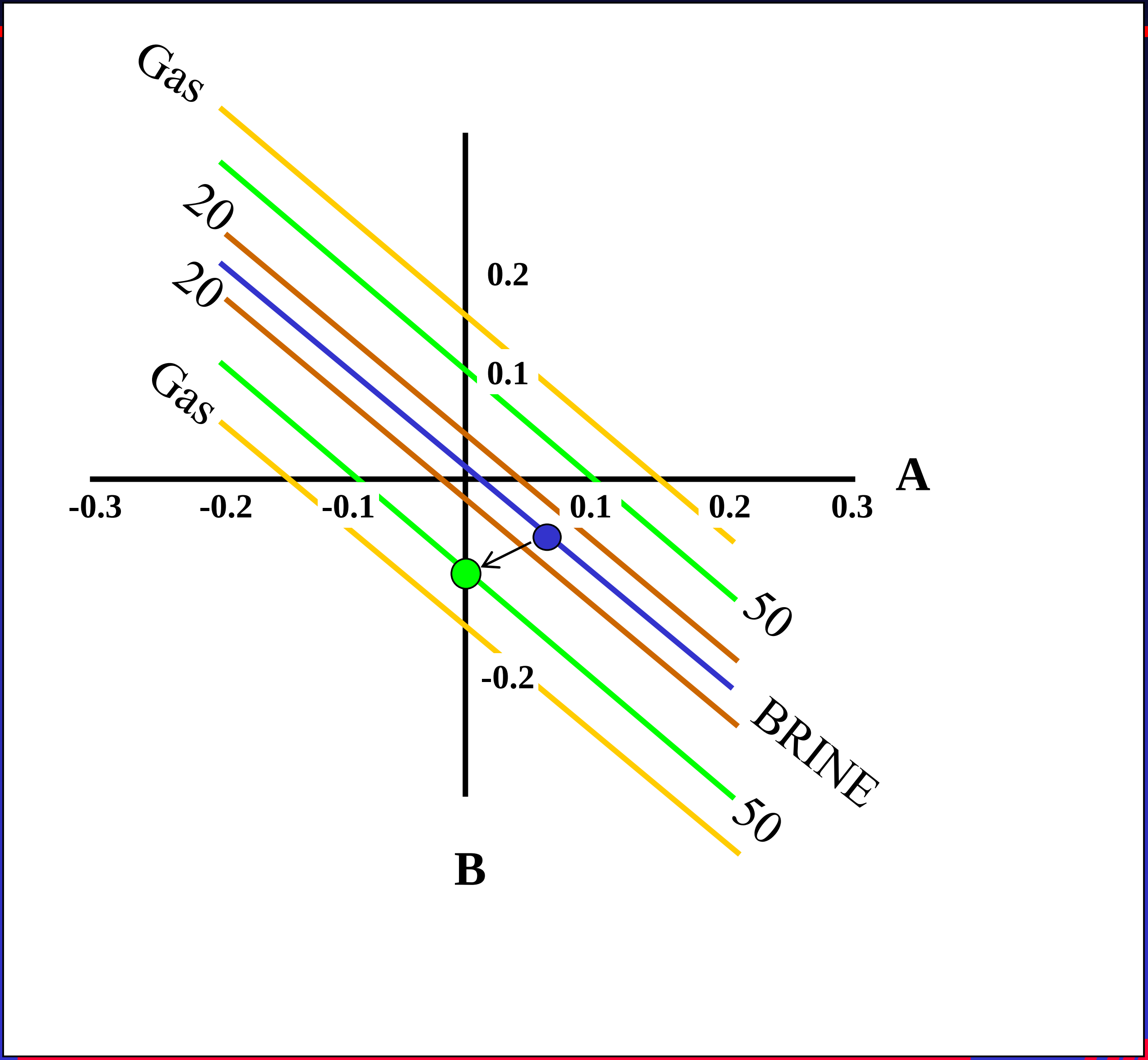
From Ivar Brevik, STATOIL

UH&CSM

CO_2 Injection, Sleipner Field, Norway

Fluid /DHI

General A–B Trend with Fluid

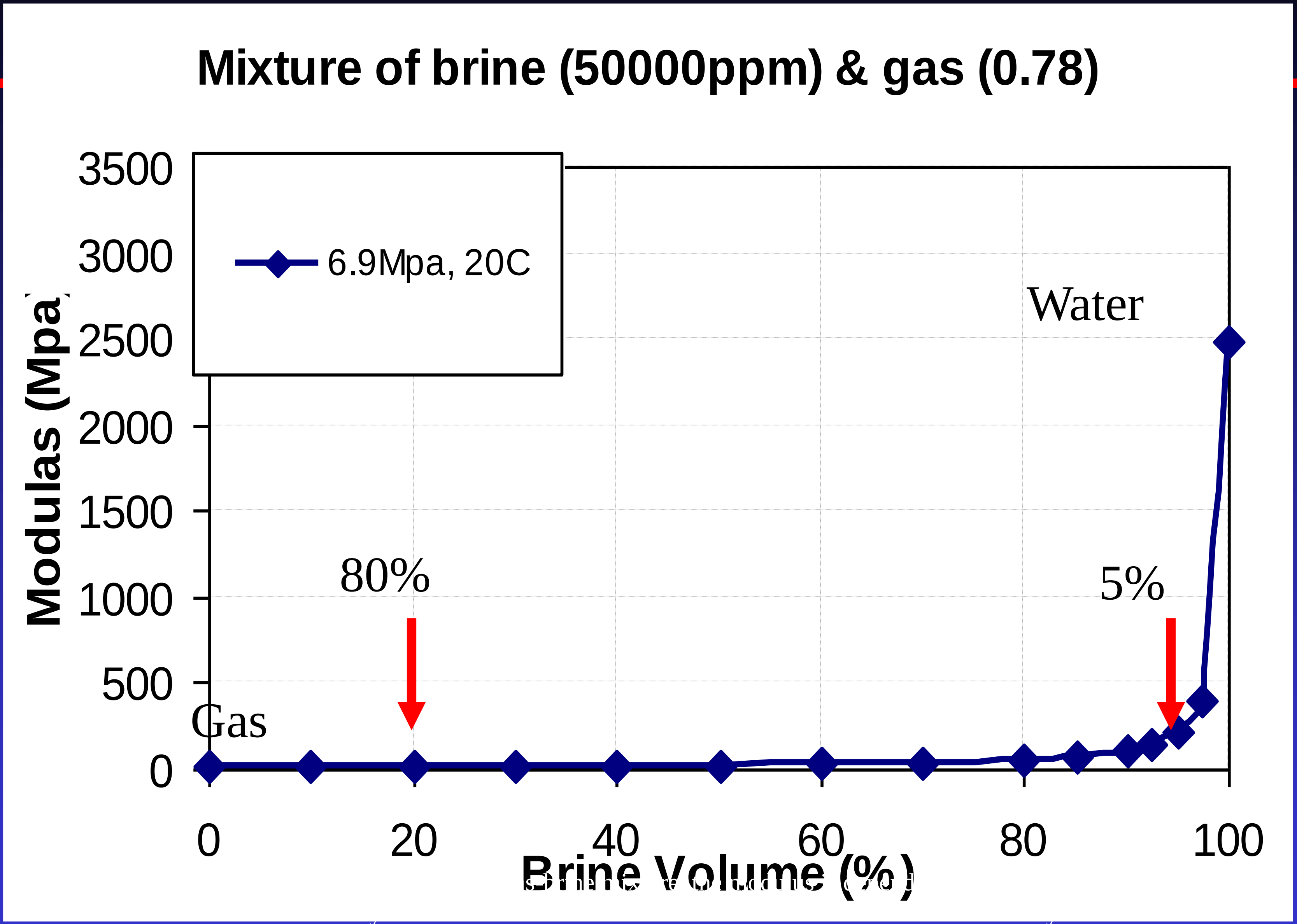


King Kong vs. Lisa Anne

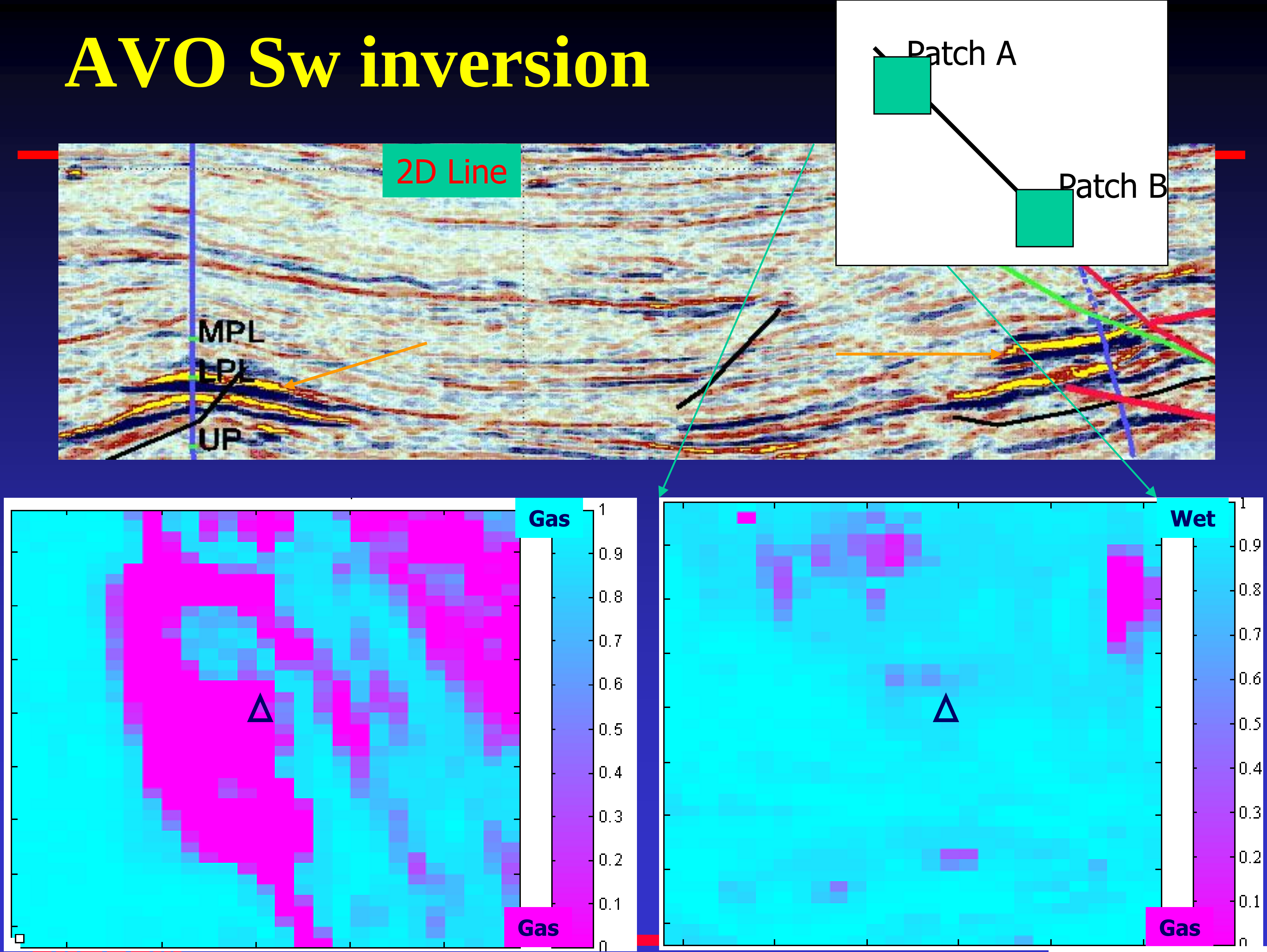
- Green Canyon, GOM
- Plio-Pleistocene
- Target TVD 11800ft, OB 4100ft

No one escape to drill dry holes.
We are in risk business

(O'Brien, 2004)


Mixture of brine (50000ppm) & gas (0.78)
6.9Mpa, 20C
Modulas (Mpa)
Brine Volume (%)
0
500
1000
1500
2000
2500
3000
3500
0
20
40
60
80
100
Water
Gas
80%
5%

AVO Sw inversion



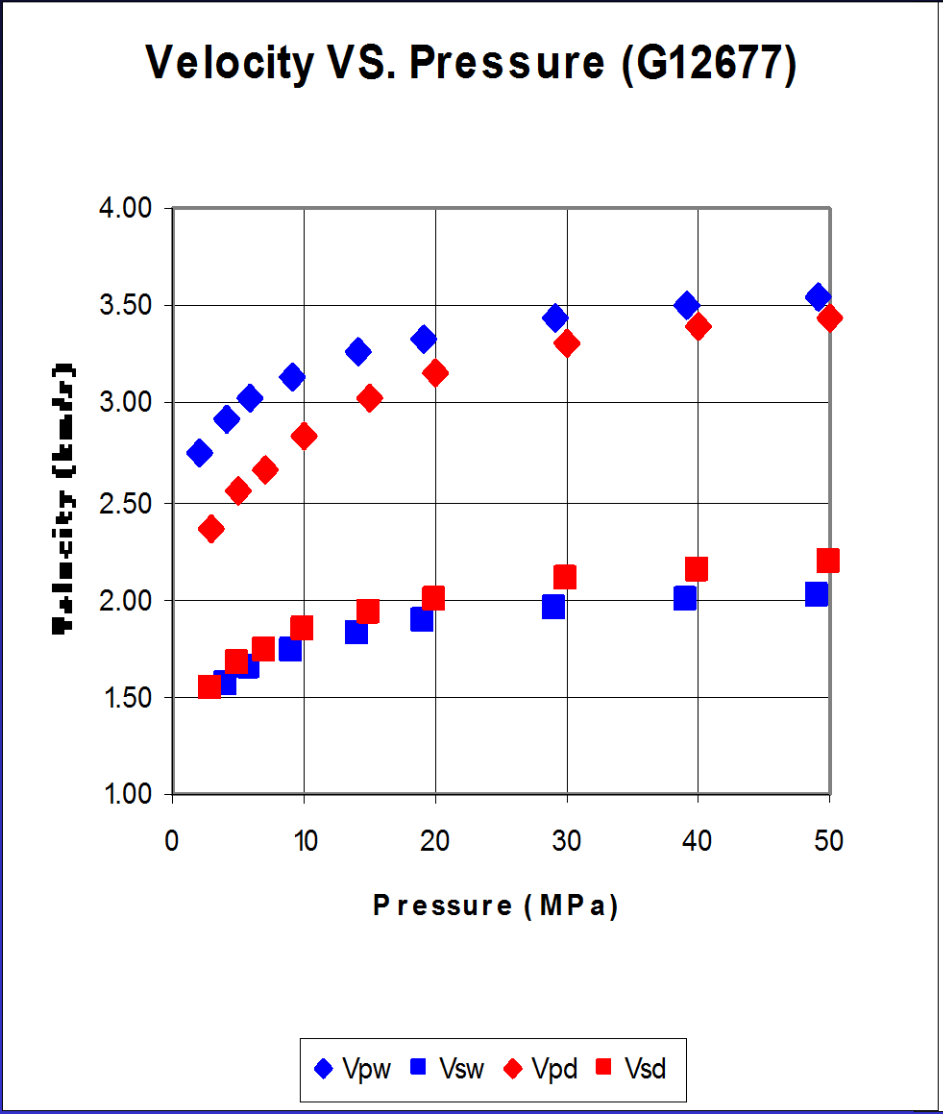
Chi and Han, 2007

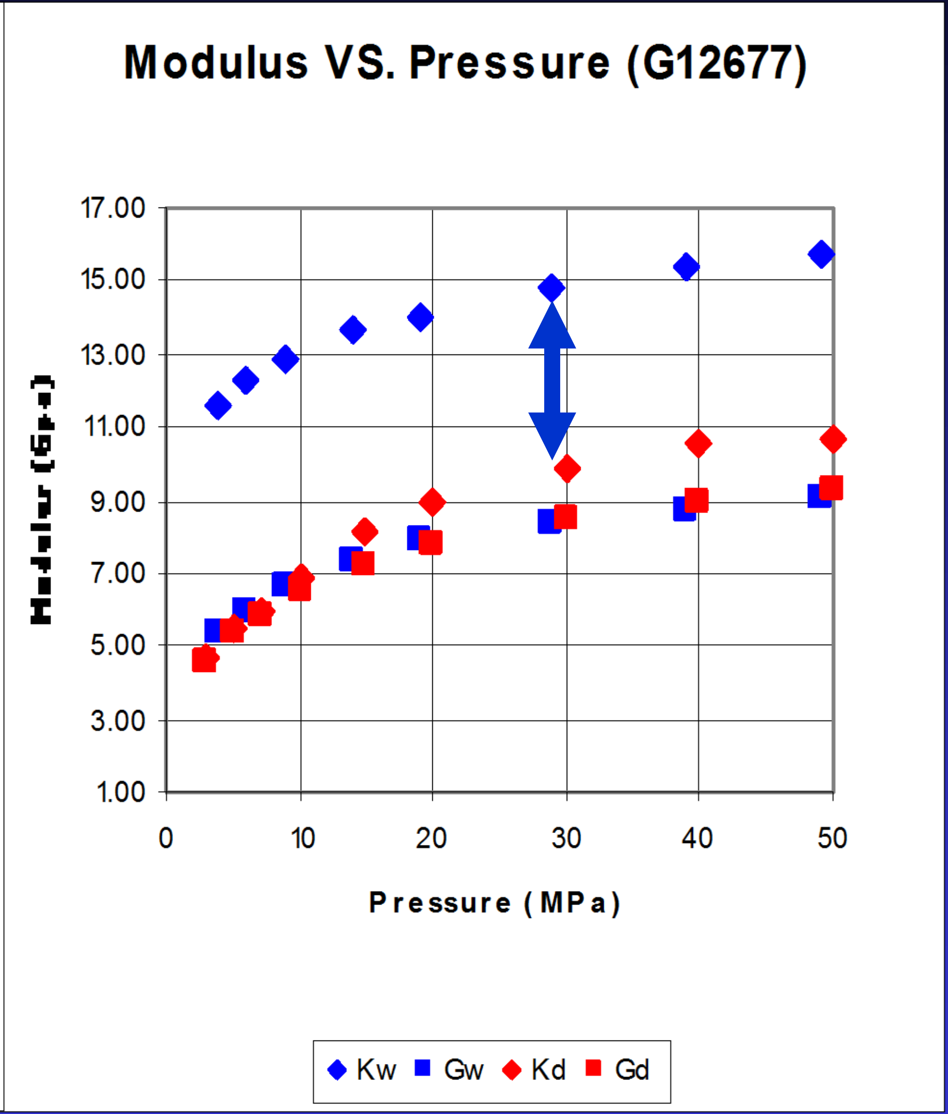
Rulers

Understand Physics

Fluid is our target

Fluid Effects





Model Constrain: Gassmann's Equation

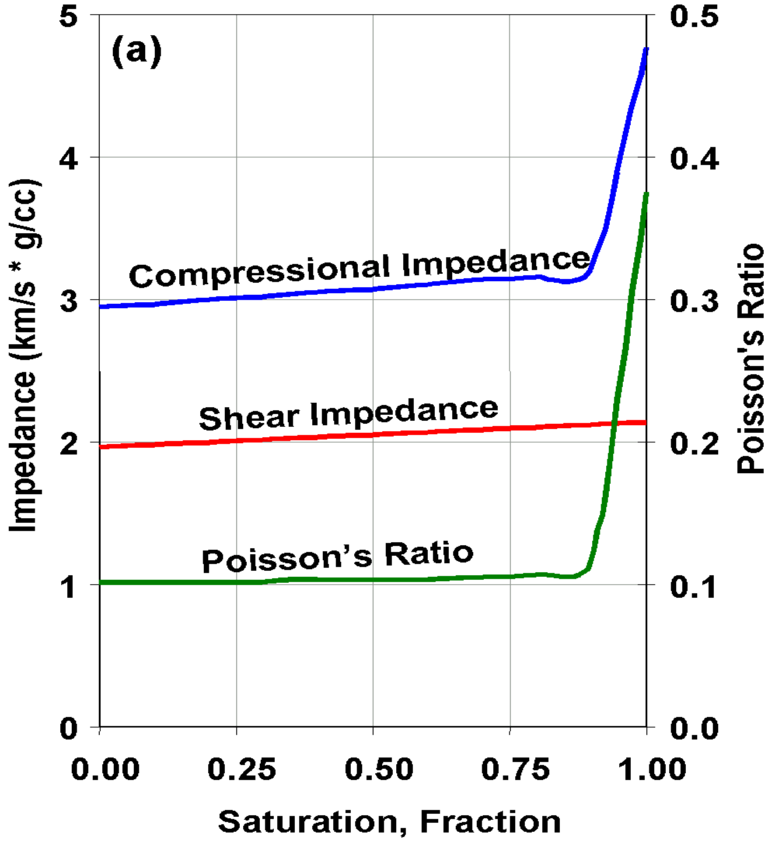
P-wave modulus (φ > 15%)

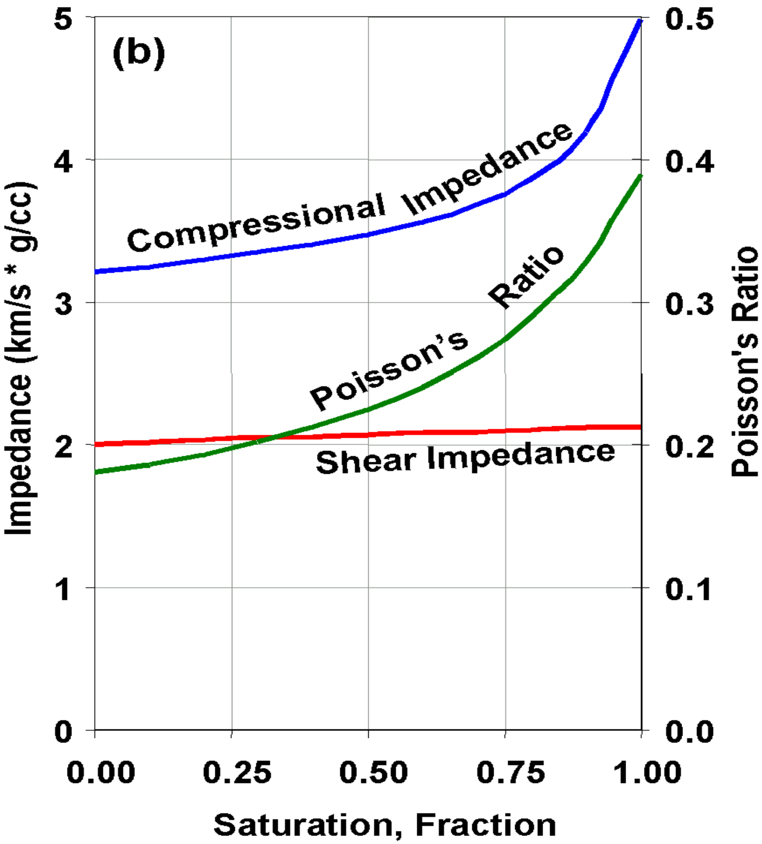
ρVp^2 | M_d | Gain | Fluid

$$M_s = K_d + 4/3 * \mu + G(\phi) * K_f$$

Han & Batzle (2004)

Shallow (1000 ft) and Deep (20,000 ft) Gas Effect





(a) Gas Modulus (Kg) = 0.00387Gpa

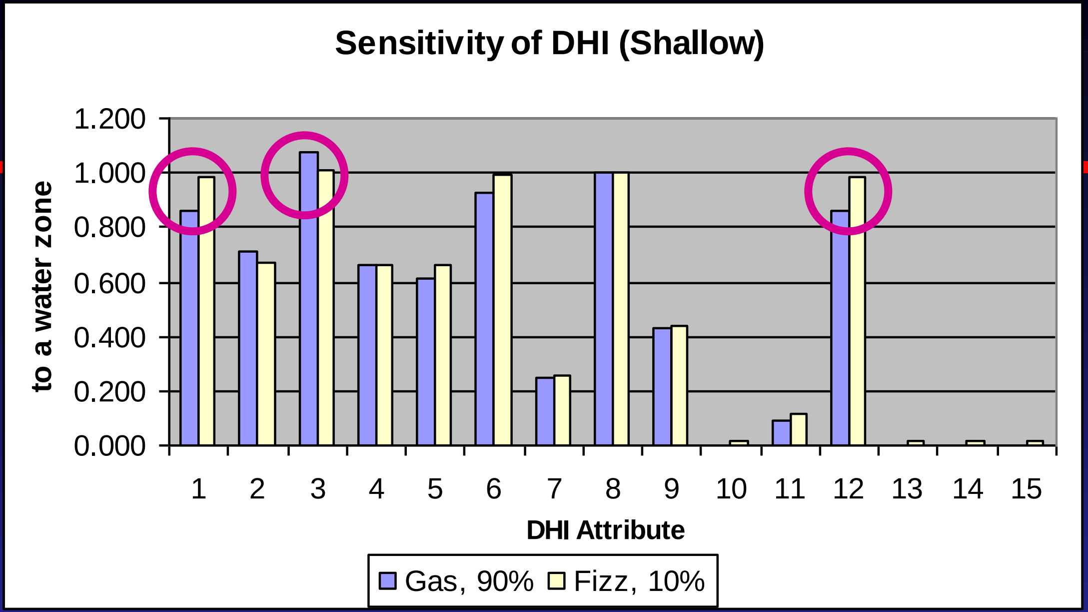
Water Modulus (Kw) = 2.435Gpa

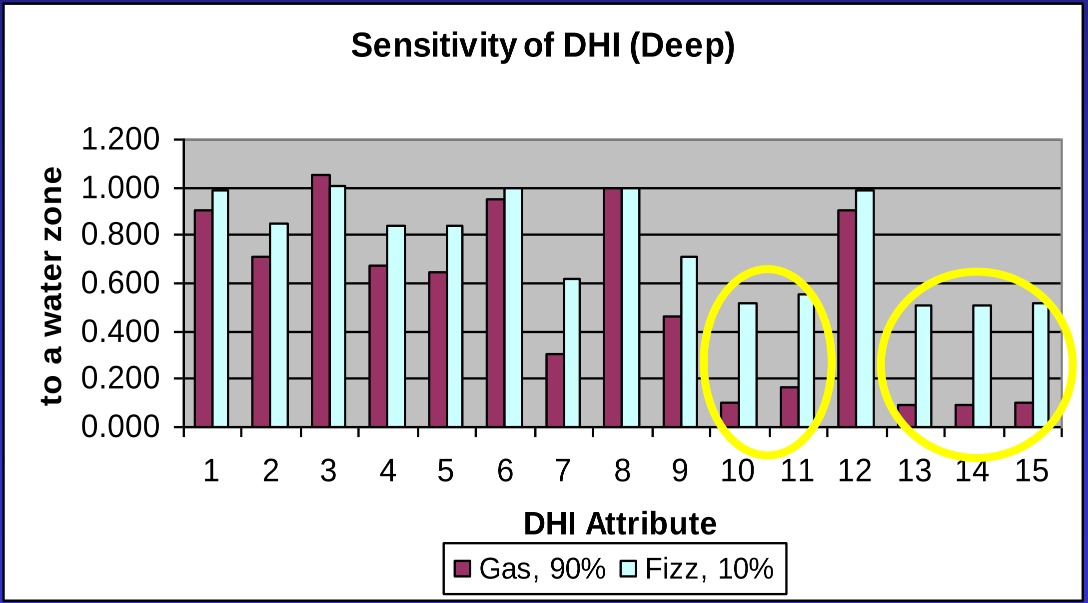
(b) Gas Modulus (Kg) = 0.248 GPa

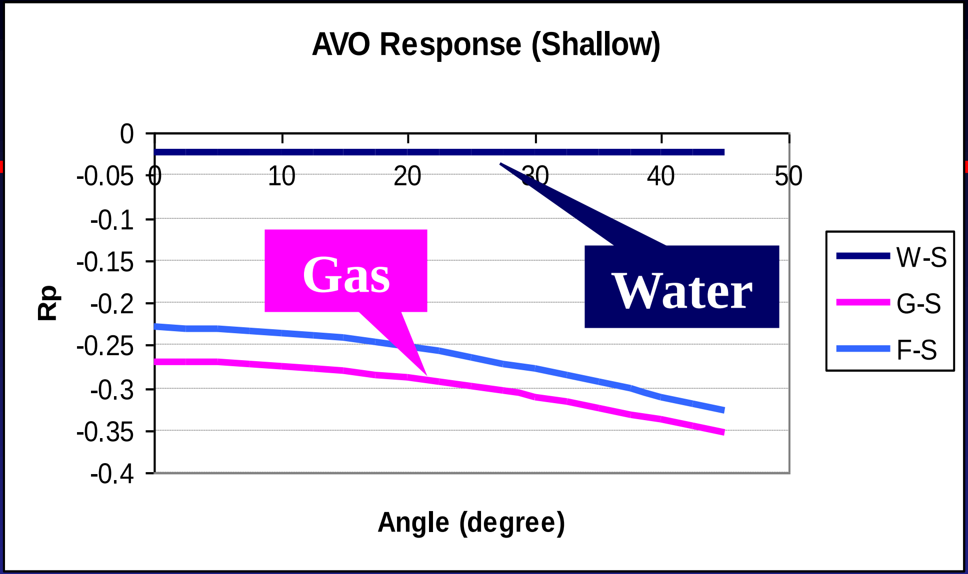
Water Modulus (Kw) = 2.905 GPa

15 attributes

1. Den
2. Vp
3. Vs
4. Vp/Vs
5. Zp
6. Zs
7. K
8. μ
9. M
10. ΔK
11. λ*ρ
12. μ*ρ
13. ρ*ΔK
14. ρ*Kf
15. Kf



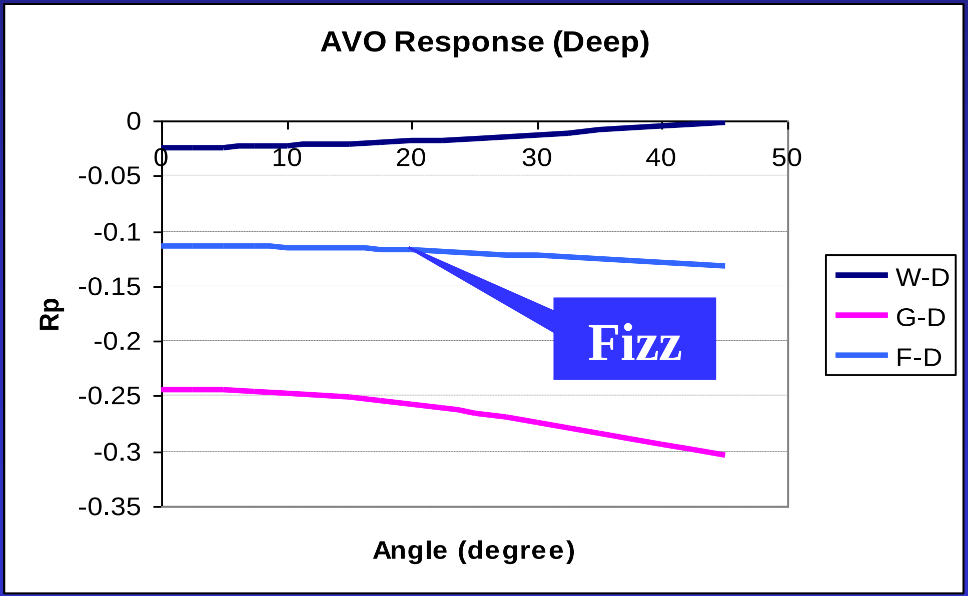




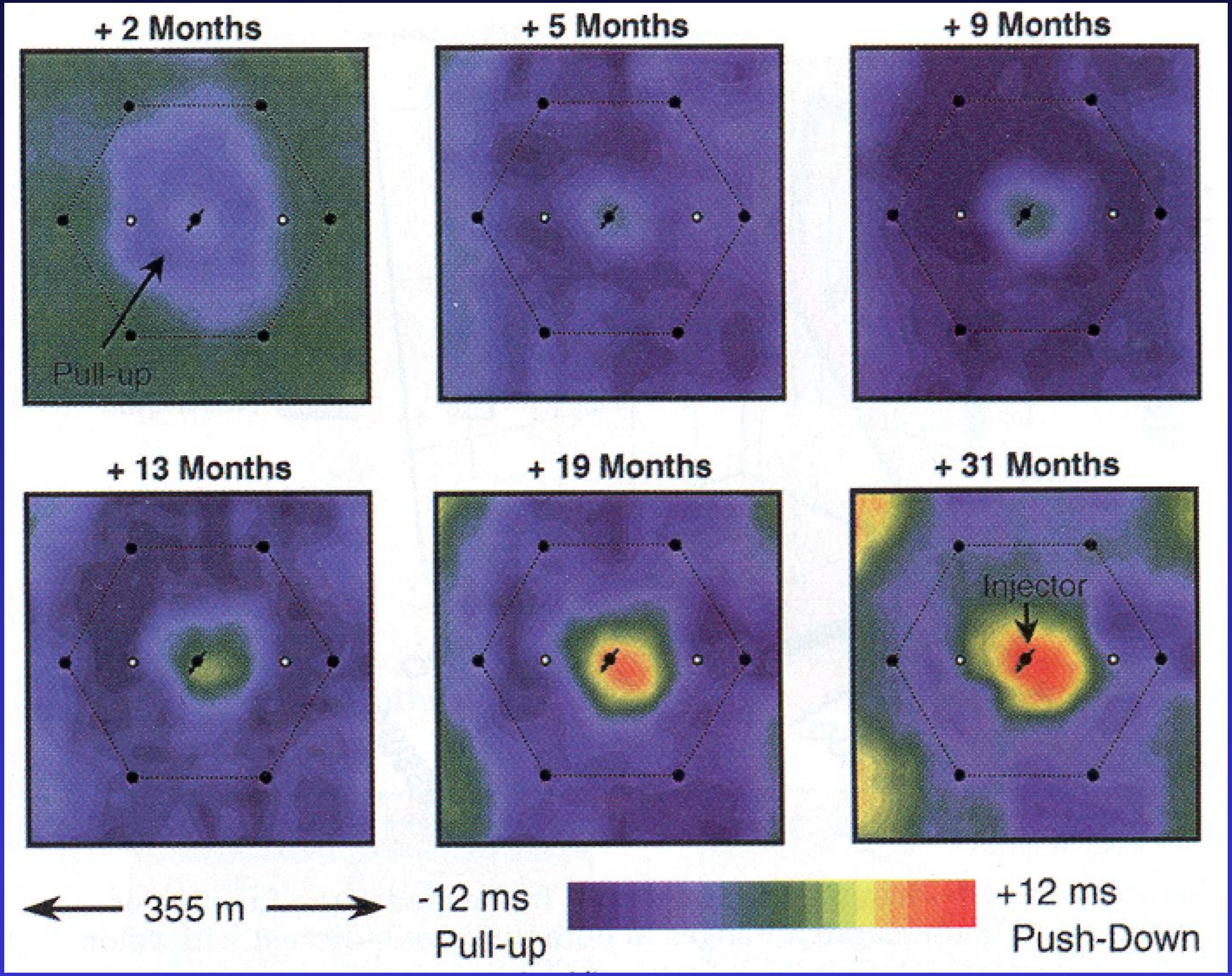
Shallow

Deep

$$R_0 = 0.5*(\frac{\Delta V}{V} + \frac{\Delta \rho}{\rho})$$



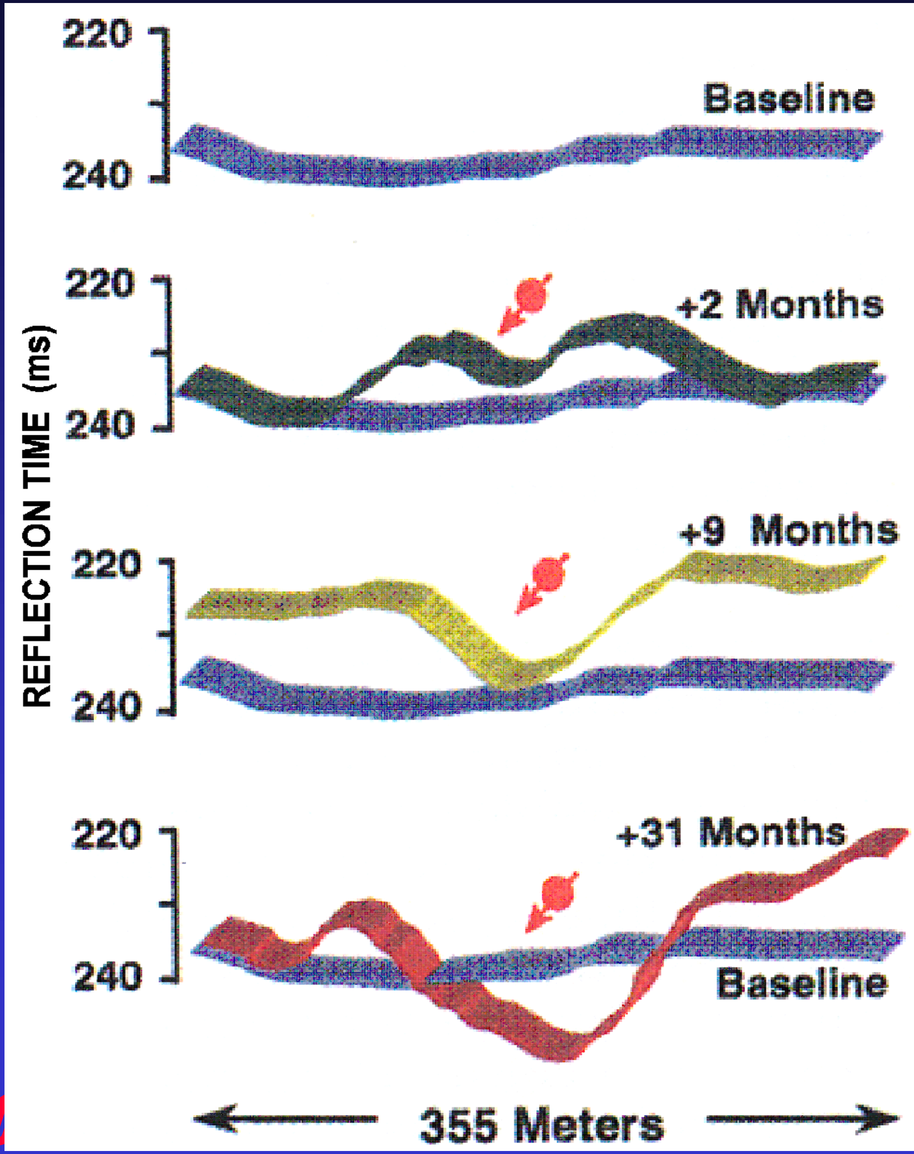
DURI FIELD STEAM FLOOD, SEISMIC TIME LAPSE



UH&CSM

Jenkins et al. (1997)

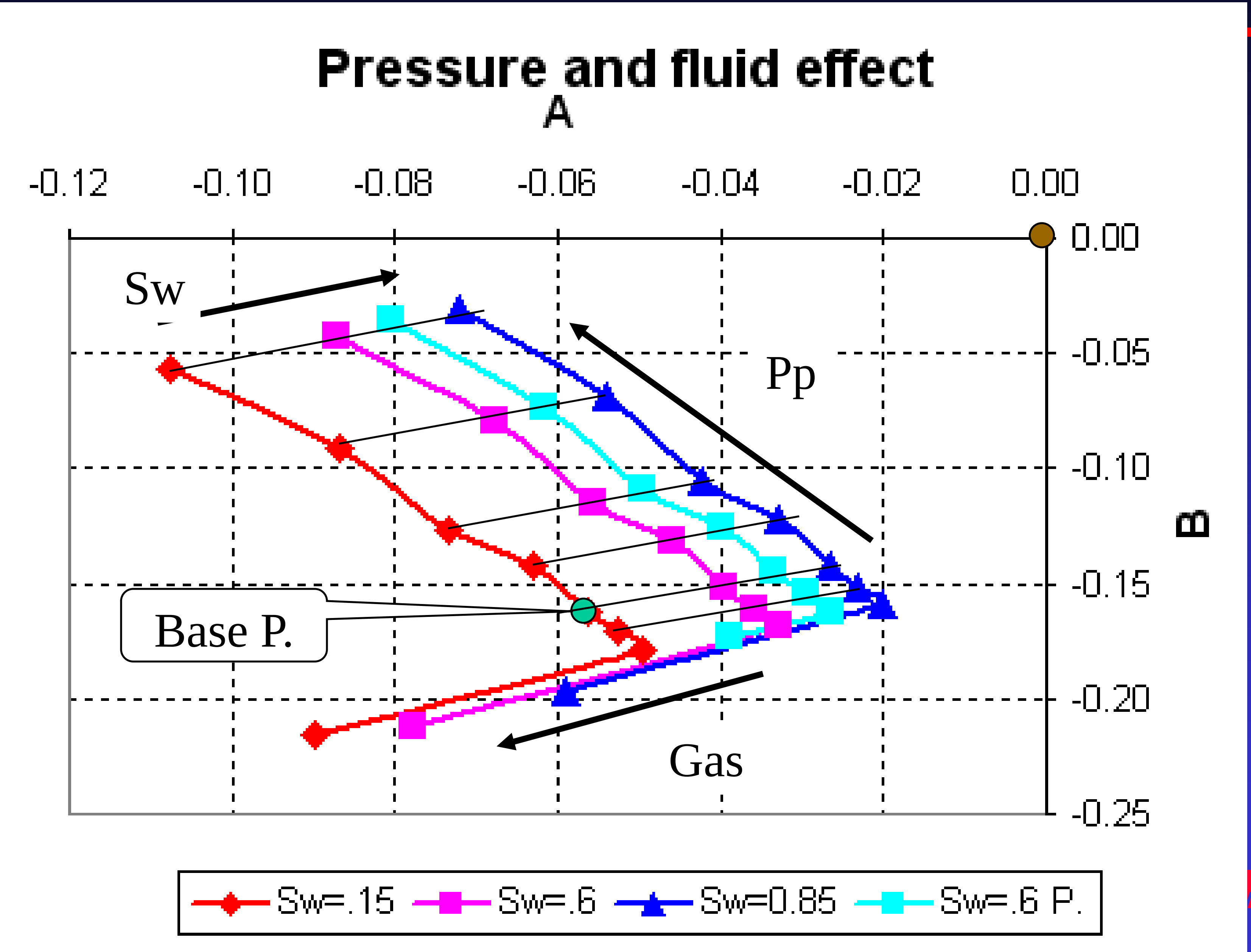
DURI FIELD STEAM FLOOD, SEISMIC TIME LAPSE



P , T variation with steam, oil, gas phase transition

Jenkins et al. (1997)

AVO Response



Fluid Properties

-- It is the Key

Working Hypothesis

Uniformity (scaleless)

- - Small sample

Dynamic elasticity of fluids

-- Can not obtained from PVT data

-- Can be measured ultrasonic

Working Hypothesis

Investigate velocity & density
of single phase fluid with constrain of the phase boundary

Calculate velocity
of multi-phase fluids with the wood equation

Working Hypothesis

Calculate velocity

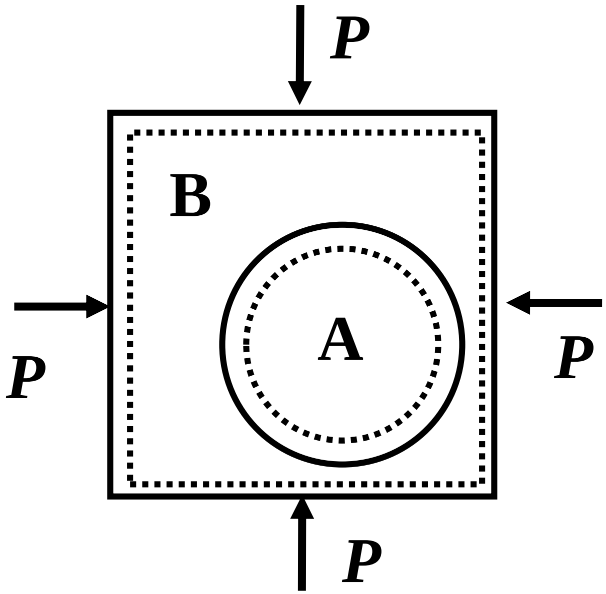
of multi-phase fluids with the wood equation

Calculate density

of multi-phase fluids with the Linear mixing law

EFFECTIVE FLUID MIXTURE BULK MODULUS

WOOD'S EQUATION (Reuss bound)



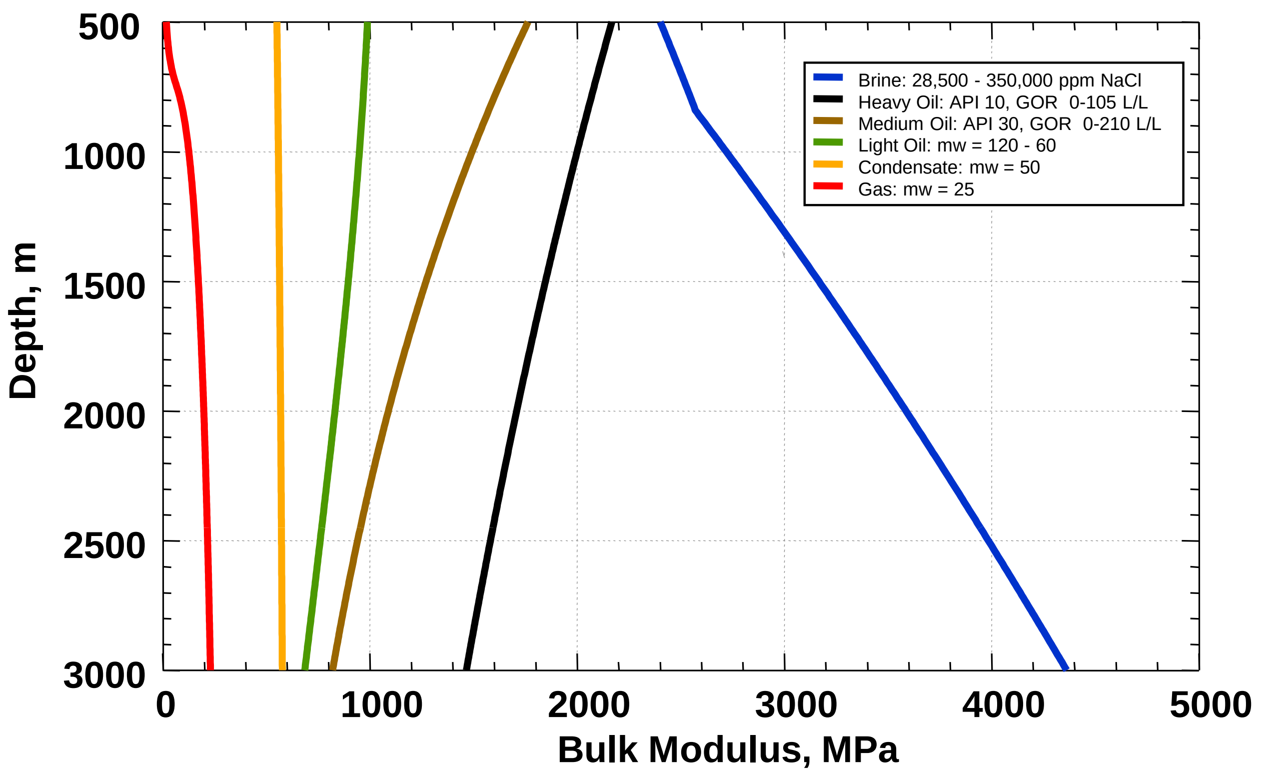
$$\frac{1}{K_A} = \frac{-1}{V_A}\frac{\Delta V_A}{\Delta P}$$

$$\frac{1}{K_{mix}} = \frac{A}{K_A} + \frac{(1 - A)}{K_B}$$

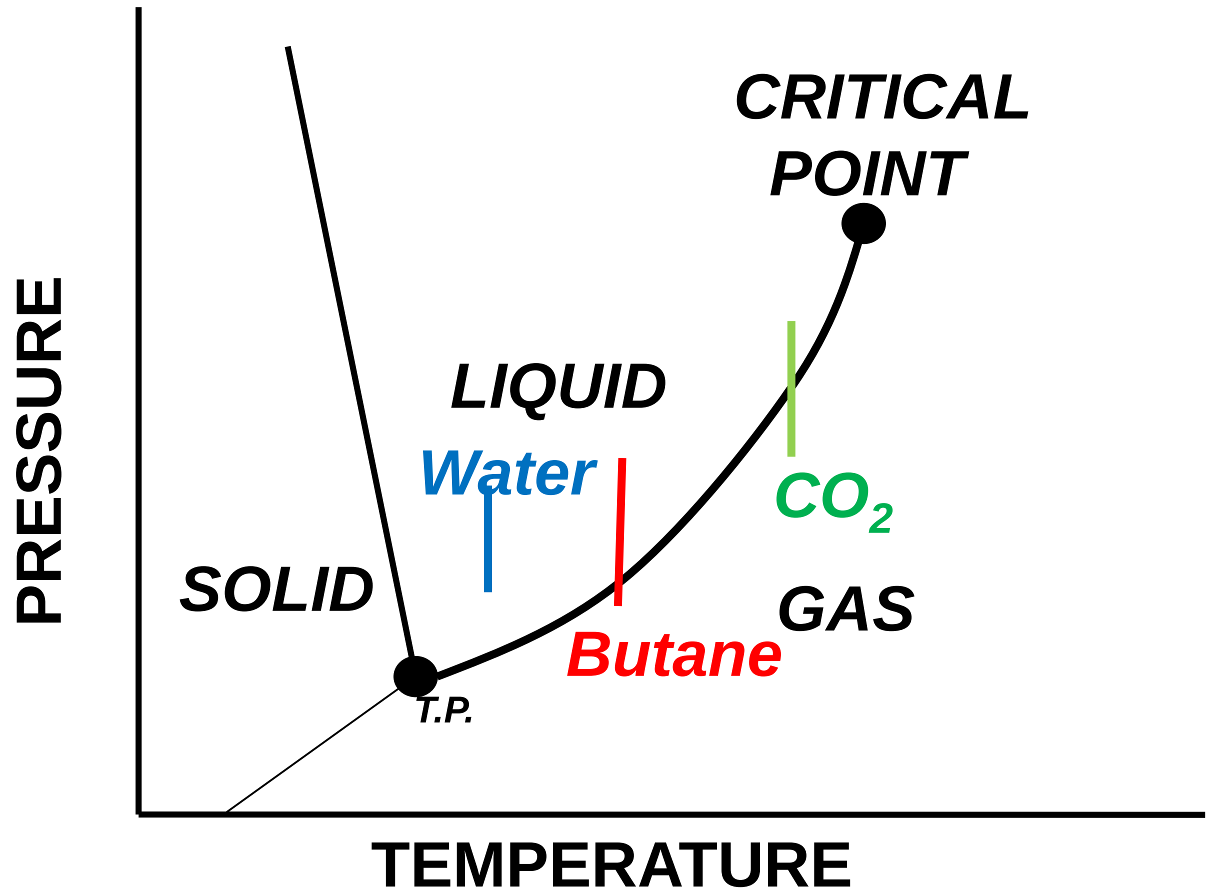
Fluid mixtures can be calculated under the presumption of equal pressure.

This result is often called Wood's equation.

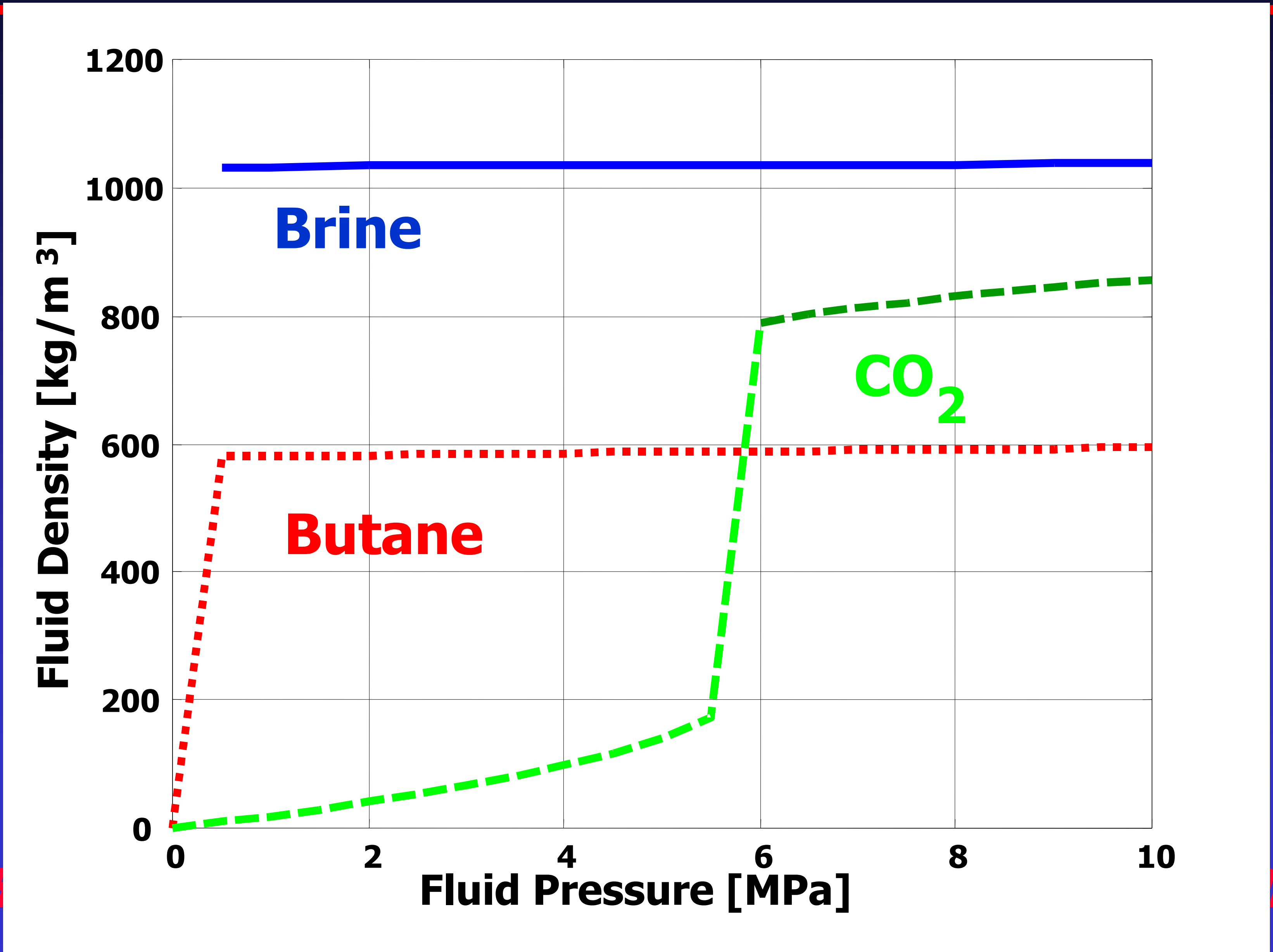
Fluid Property Control
GoM Fluid properties with Depth



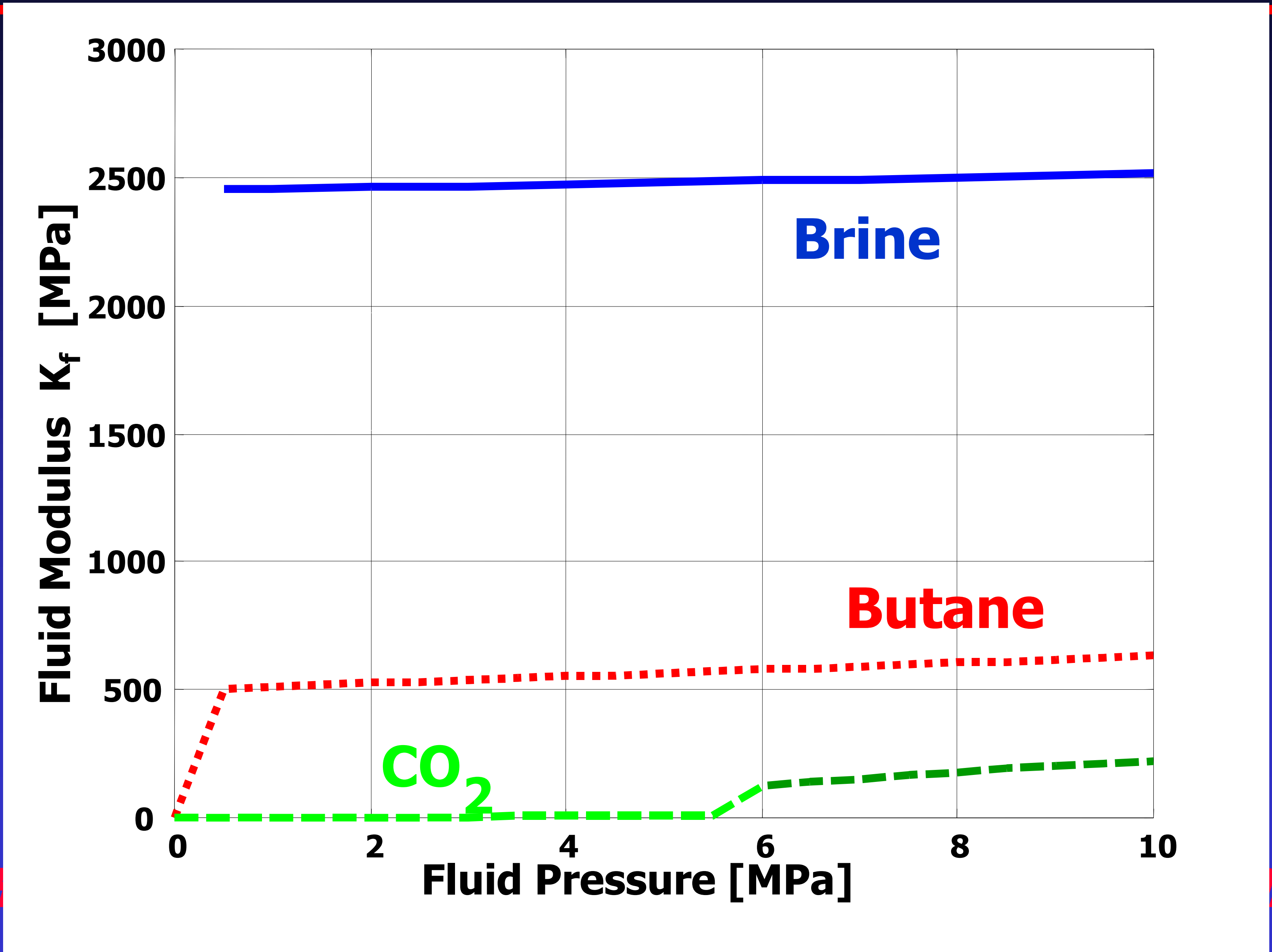
GENERAL PHASE BEHAVIOR: *PURE COMPOUND*



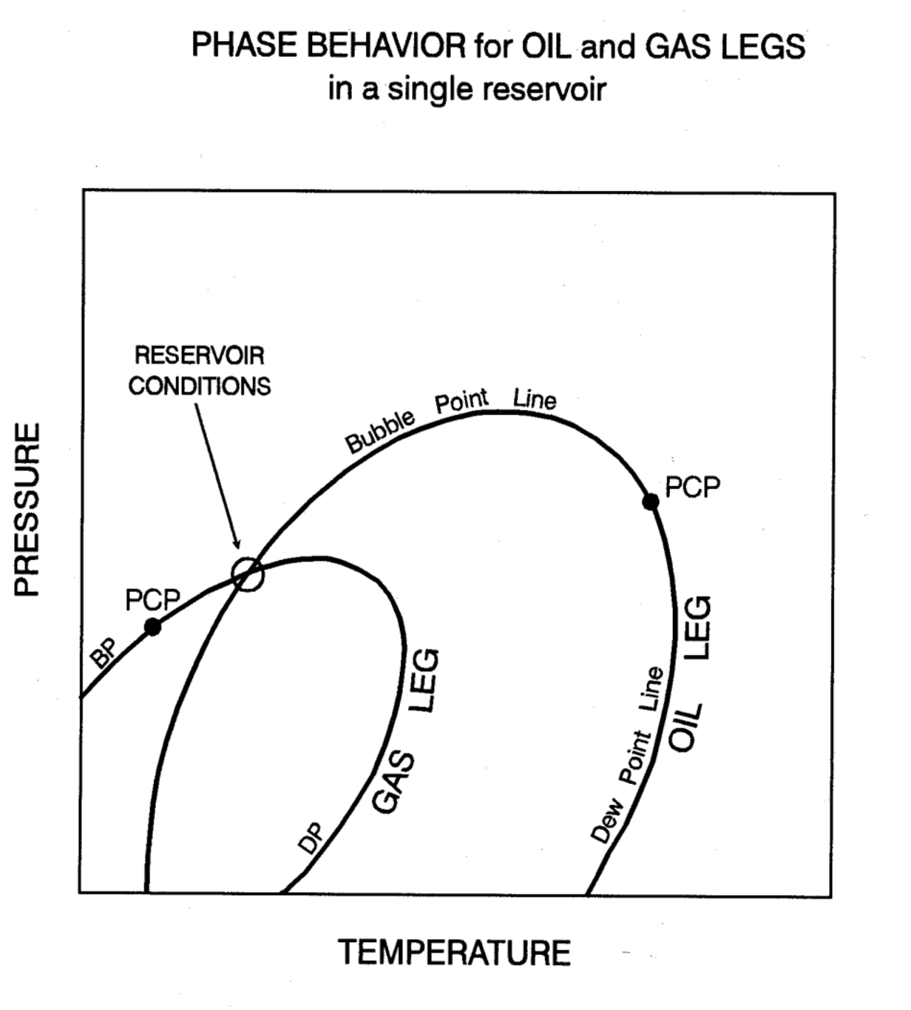
Fluid – Density

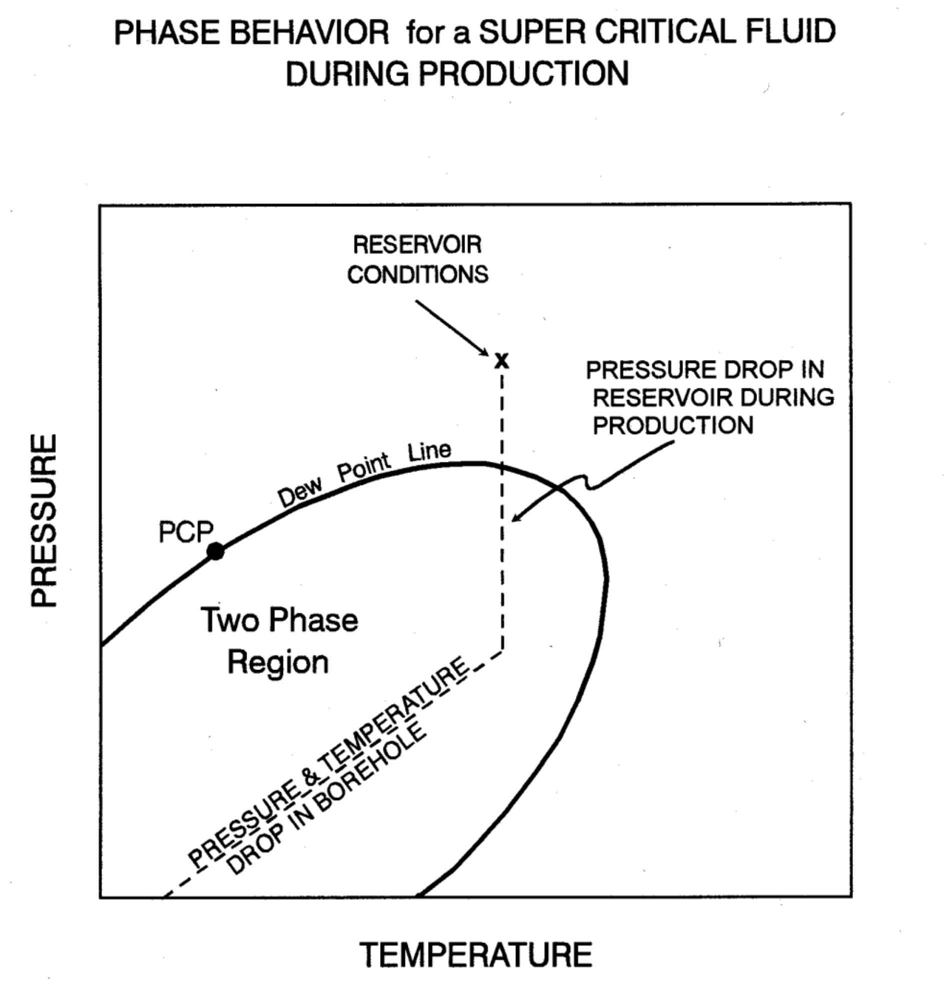


Fluid – Modulus

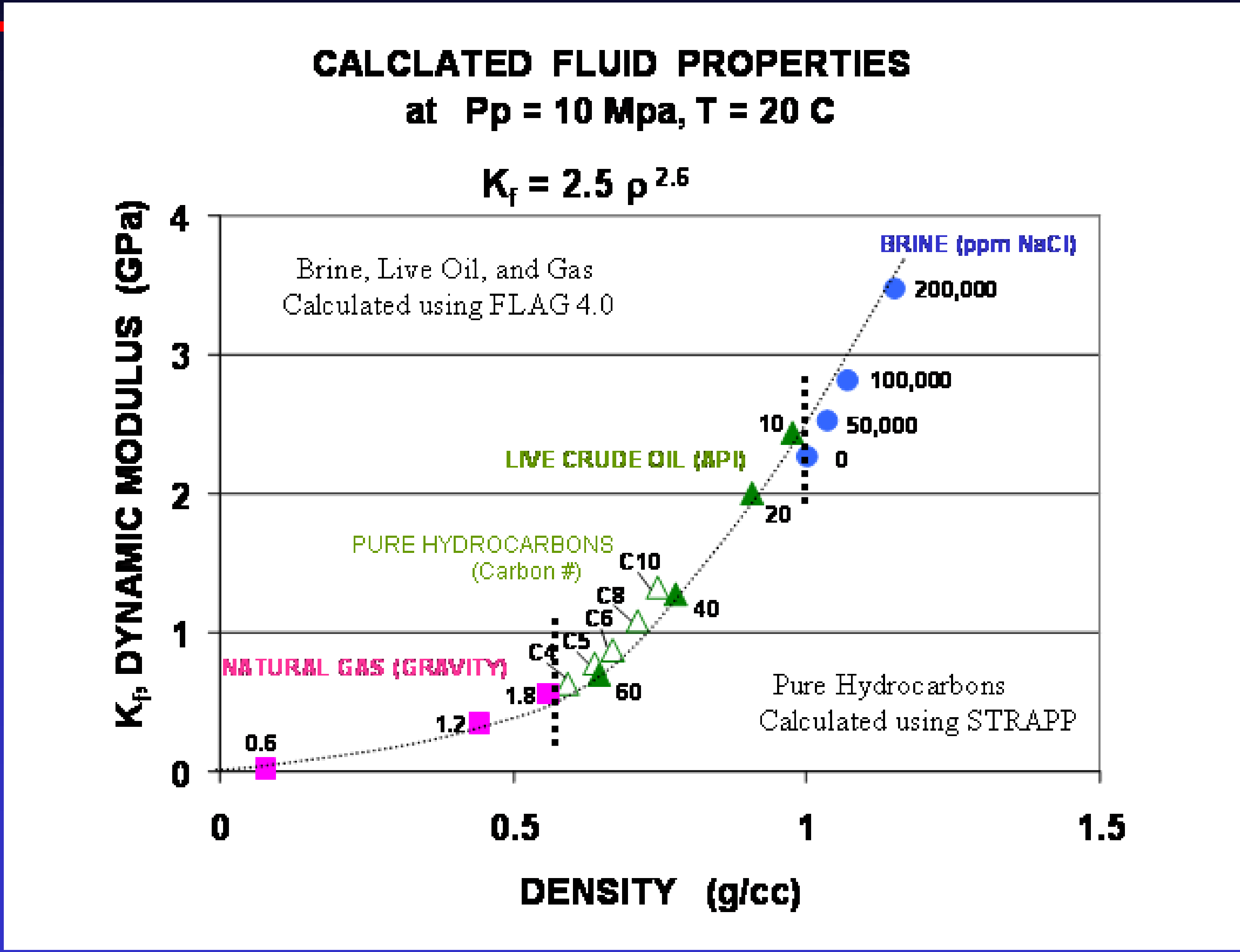


In situ Phase Relation





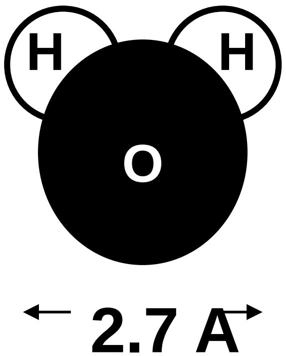
Fluid Trend (Density Control)

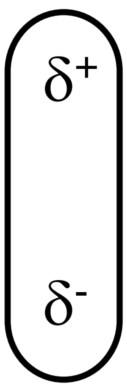


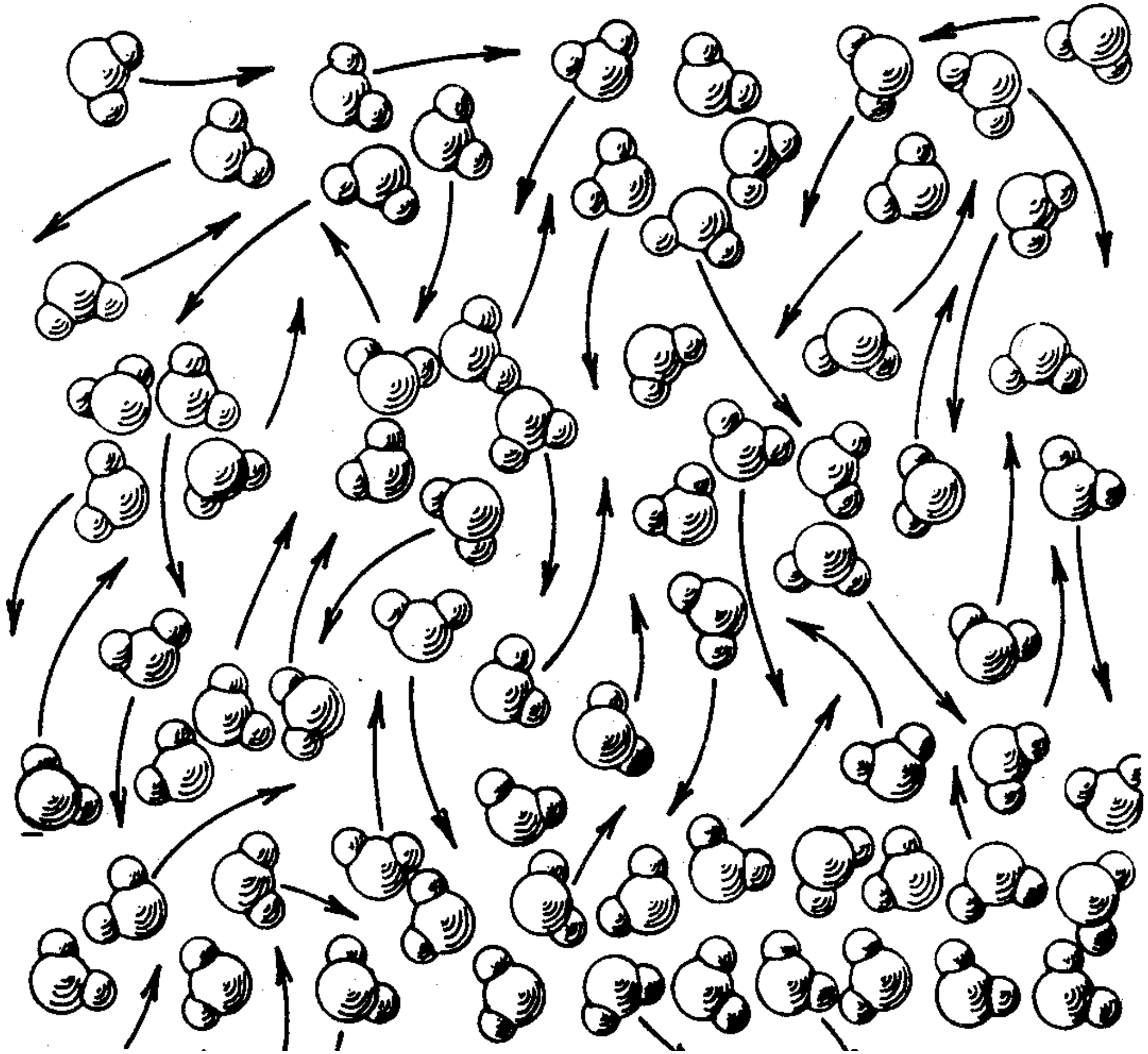
TYPES of PORE FLUIDS

- ***WATER and BRINE***
  (BRINE = H_2O + Salt)
- ***HYDROCARBONS***
  Oil
  Gas
  Mixtures
- ***HEVEY OIL***
- ***DRILLING MUD FILTRATE***
- ***PRODUCTION FLUIDS***
  Steam
  Miscible Injectants
  (CO_2, Dilute, …)
  Frac Fluids

WATER a.k.a. H_2O

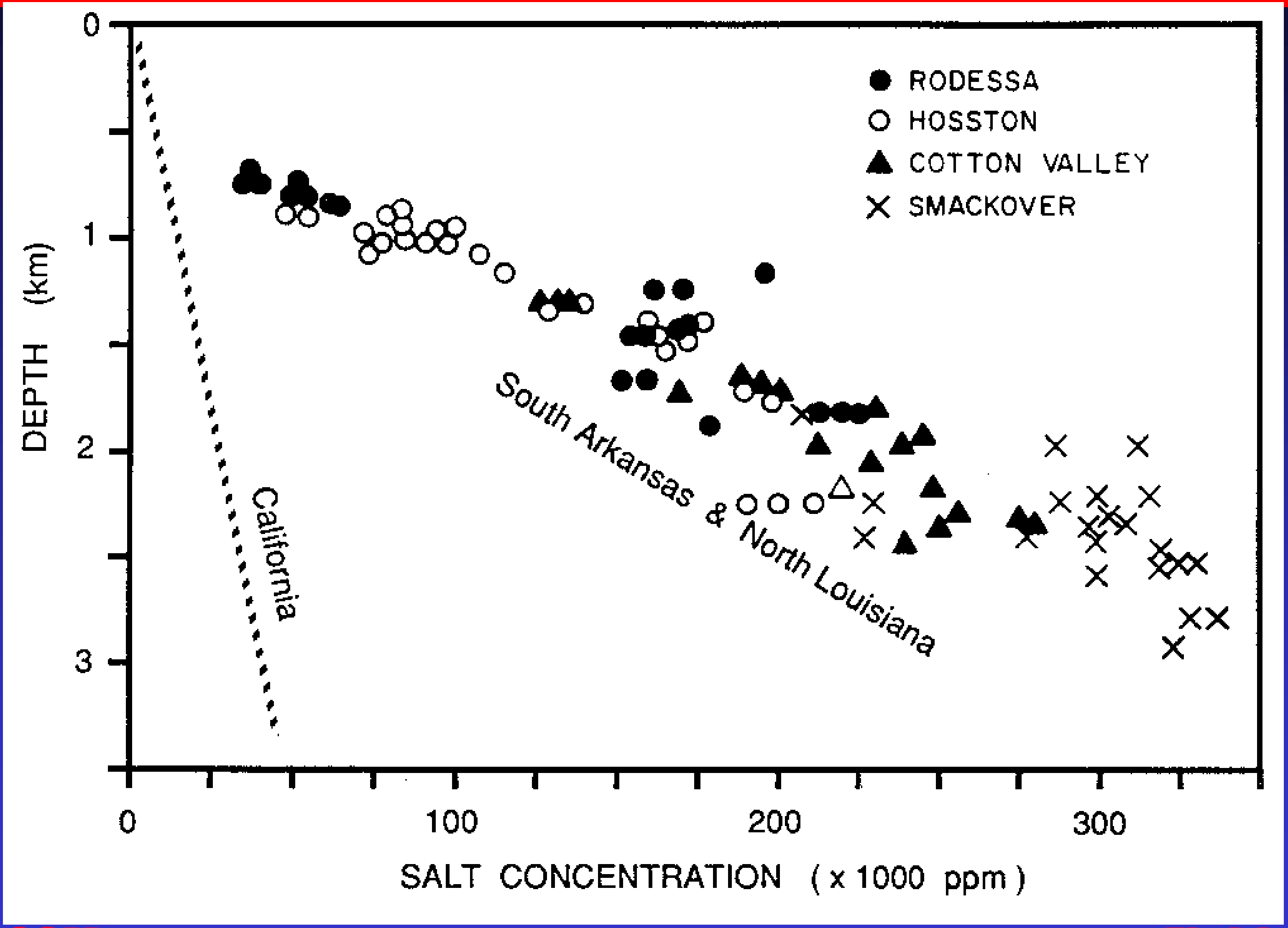






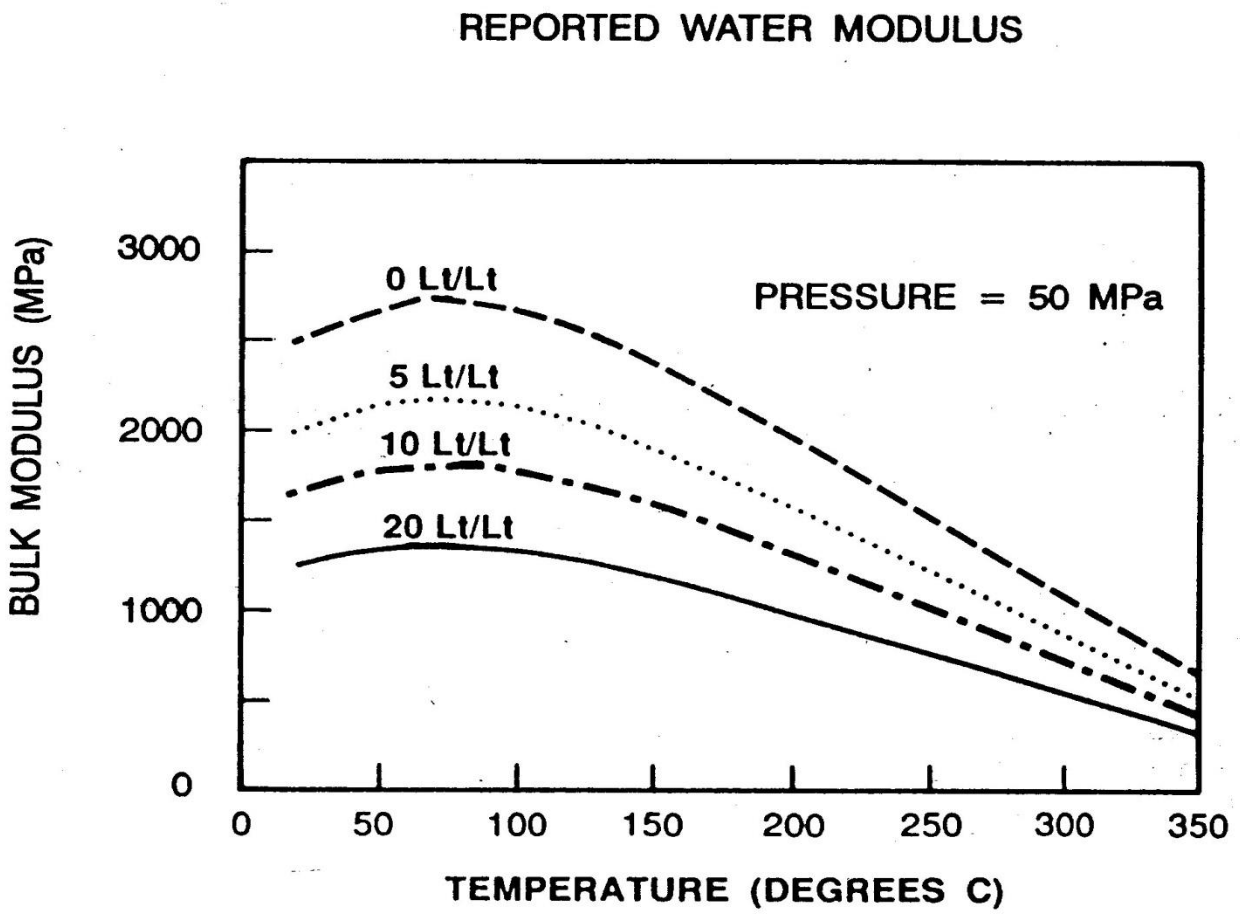
Hinch, 1980

localized brine Properties



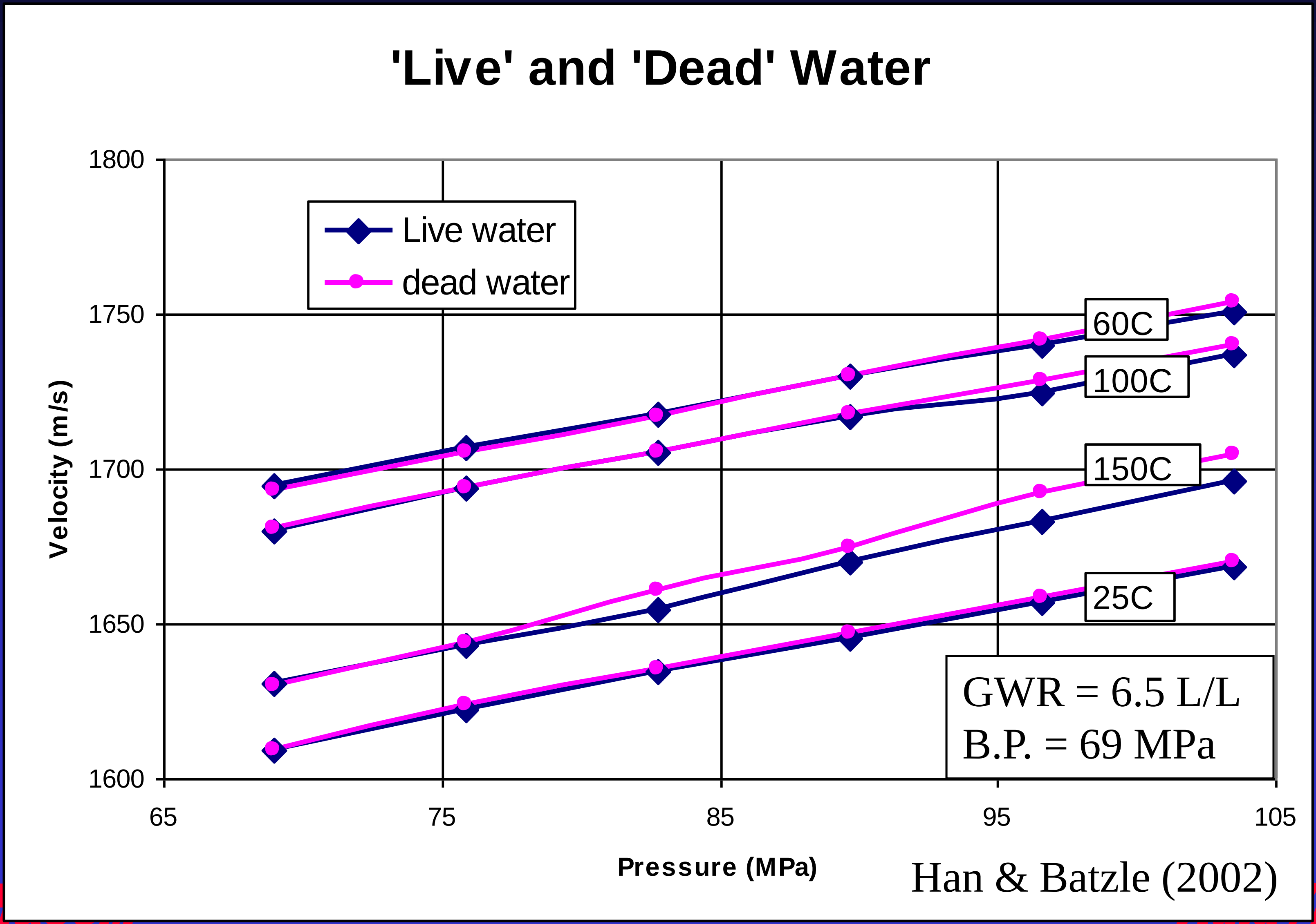
False DHI

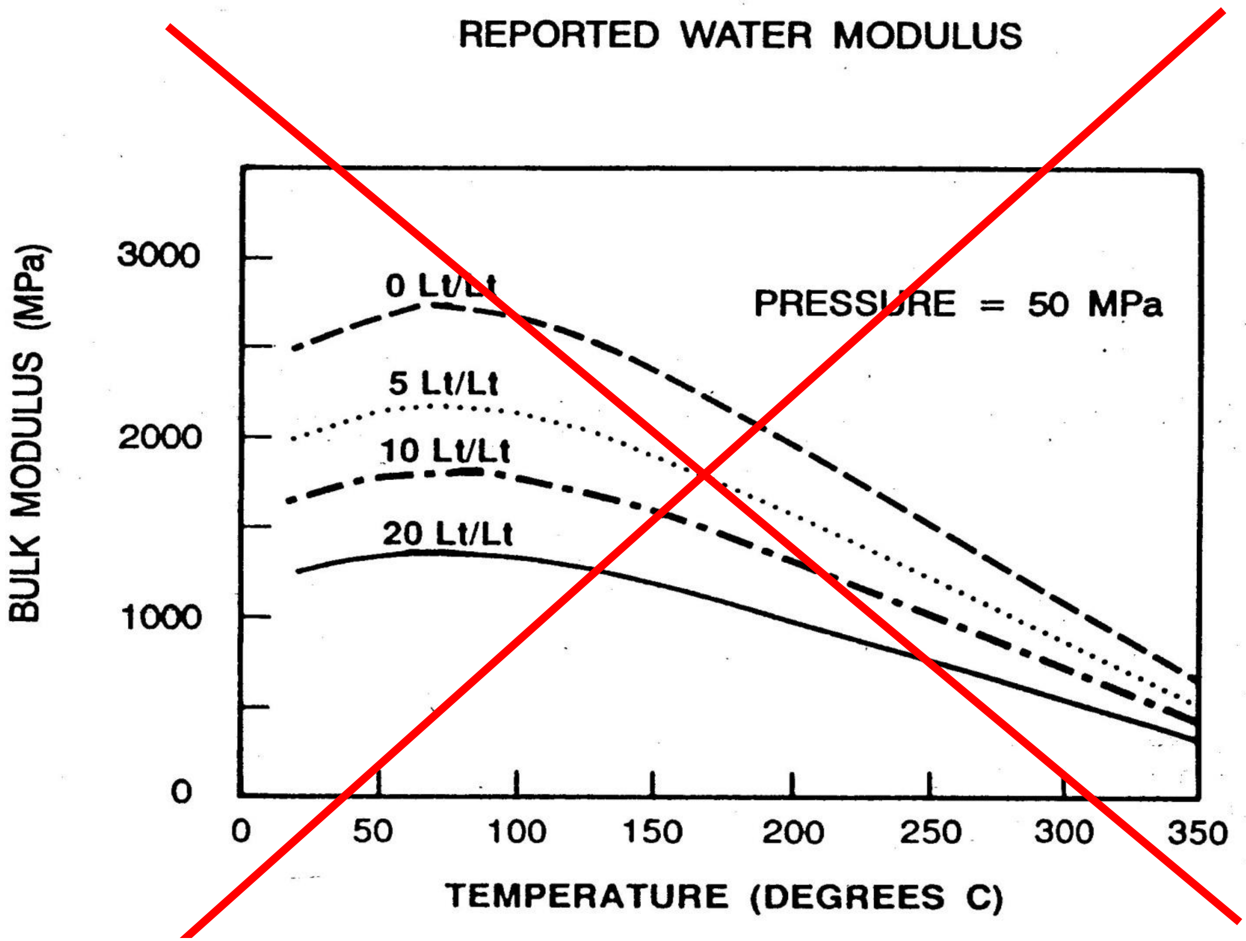
Is dissolved gas reduce modulus of water and causes DHI?



Baztle&Wang, 1992

Gas effects

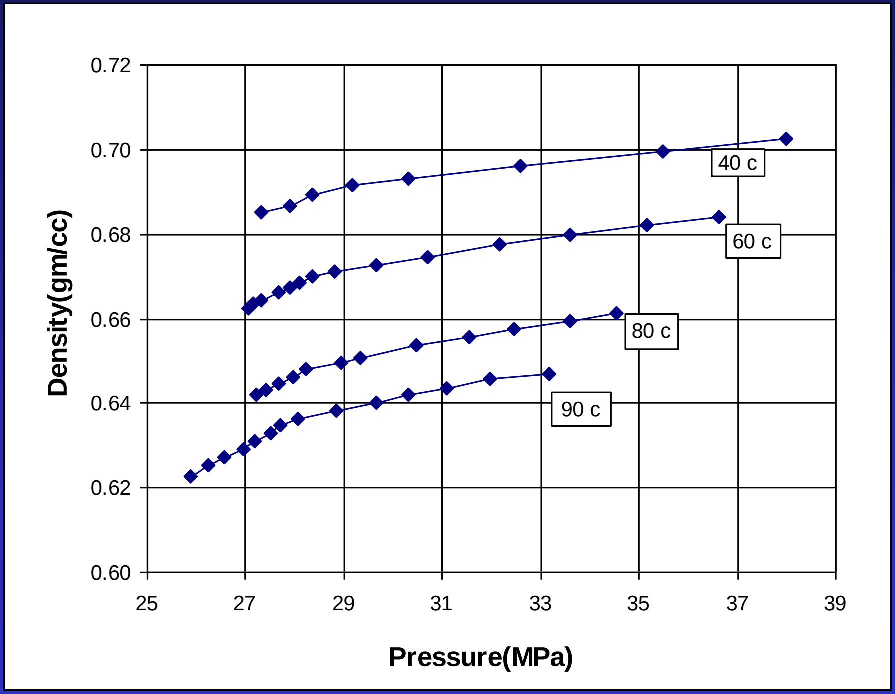

'Live' and 'Dead' Water
Velocity (m/s)
1800
1750
1700
1650
1600
65
75
85
95
105
Pressure (MPa)
Live water
dead water
60C
100C
150C
25C
GWR = 6.5 L/L
B.P. = 69 MPa
Han & Batzle (2002)

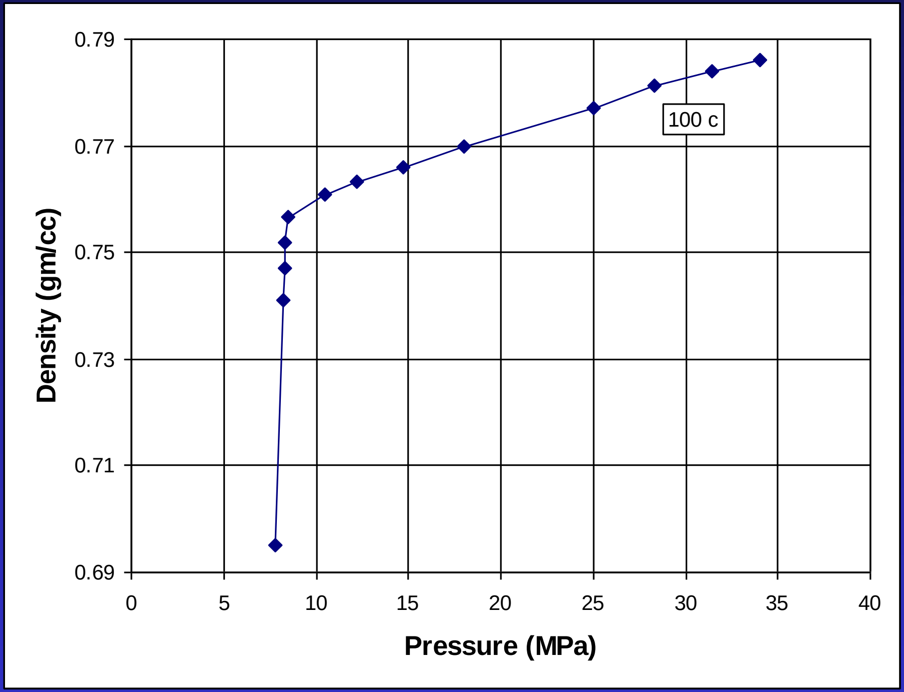


Baztle&Wang, 1992

Gas Phase near the Bubble Point

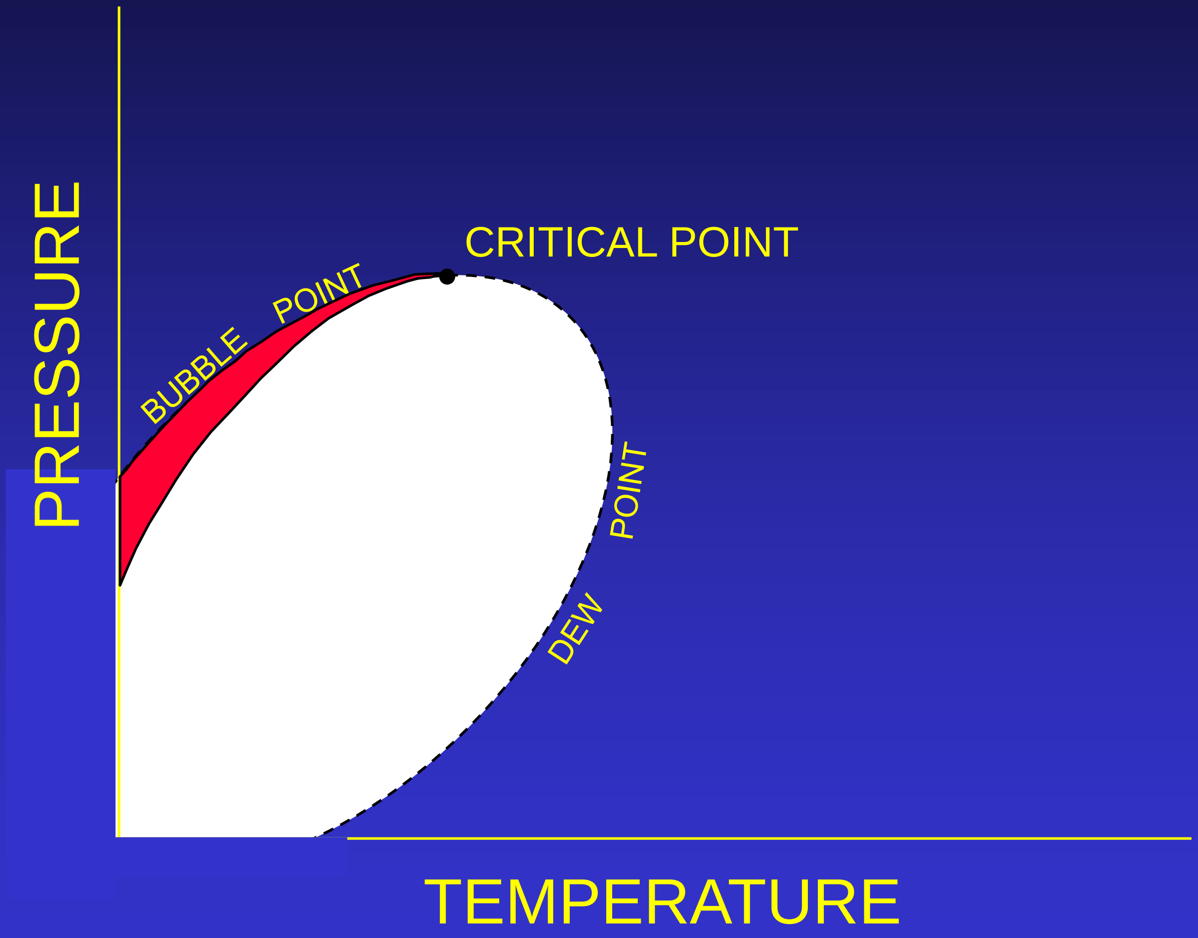
Density as a function of pressure for live oils





Seismic Gas Effect

IMPORTANCE OF PHASE TRANSITION
To Seismic Data



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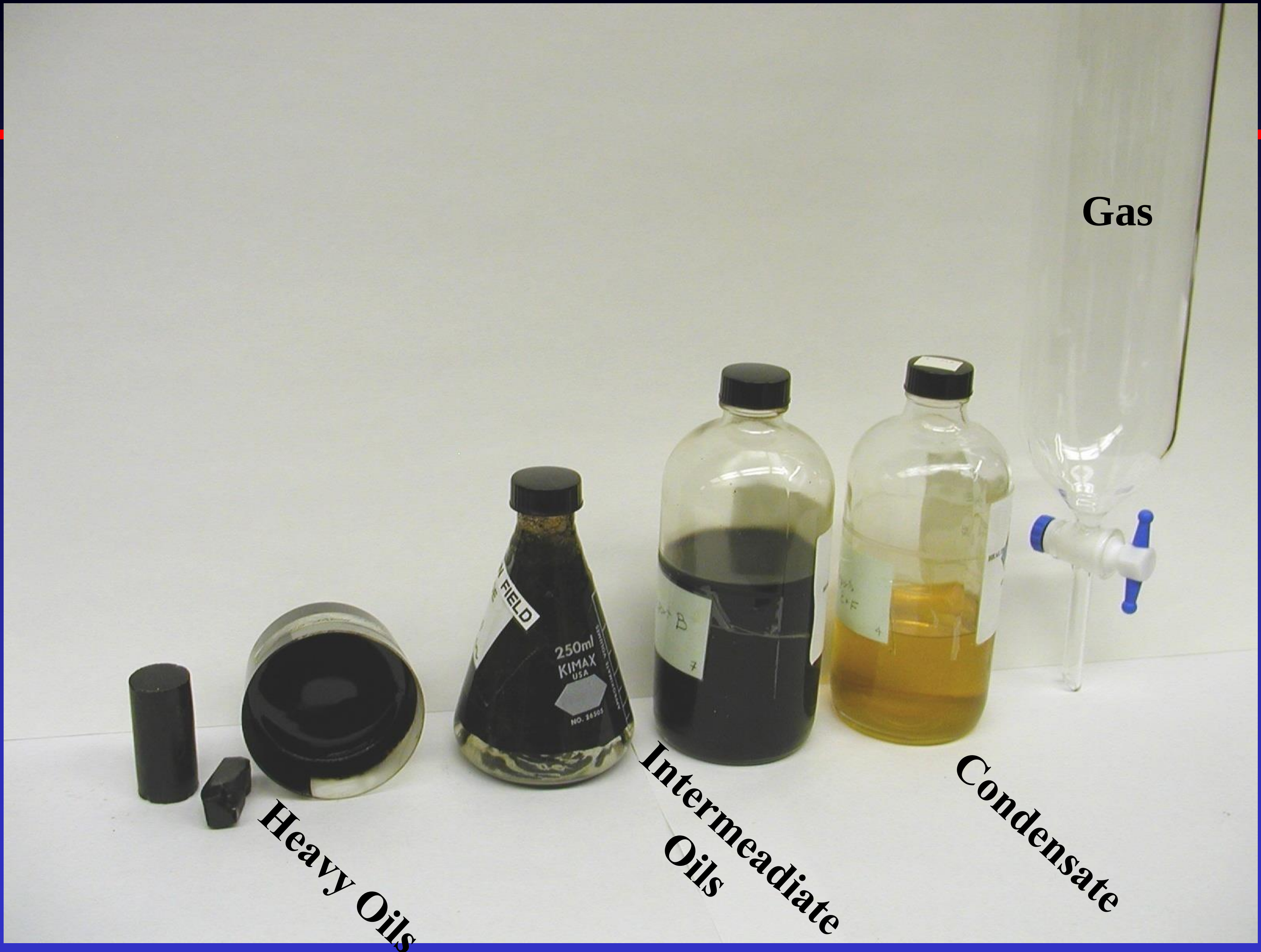
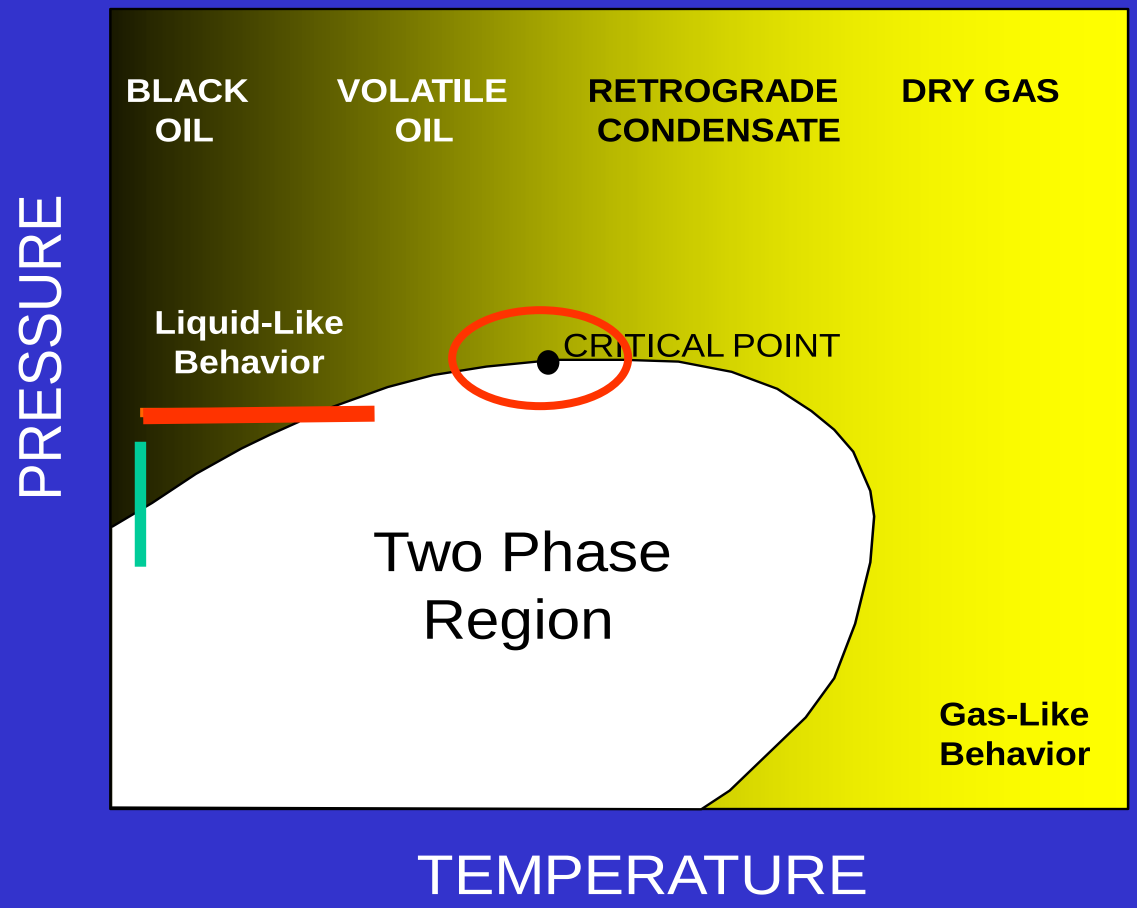
  - ***Gas***
  - ***Mixtures***
- ***HEAVY OIL***
- ***DRILLING MUD FILTRATE***
- ***PRODUCTION FLUIDS***
  - ***Steam***
  - ***Miscible Injectants (CO$_2$, Dilute, …)***
  - ***Frac Fluids***

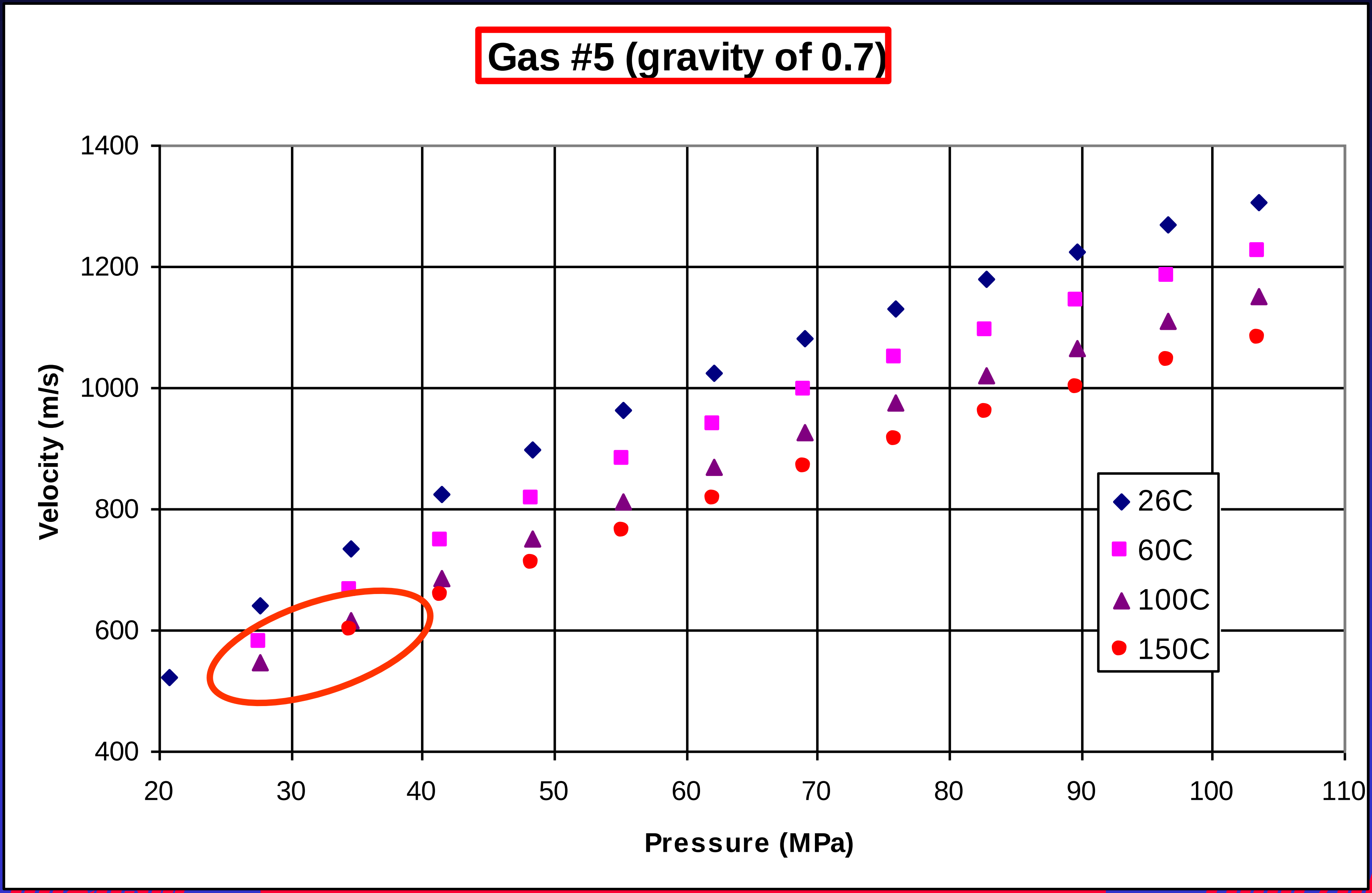


Hydrocarbons come in many flavors, each with specific properties. In addition, complex mixtures of thes components will change composition under differing conditions.

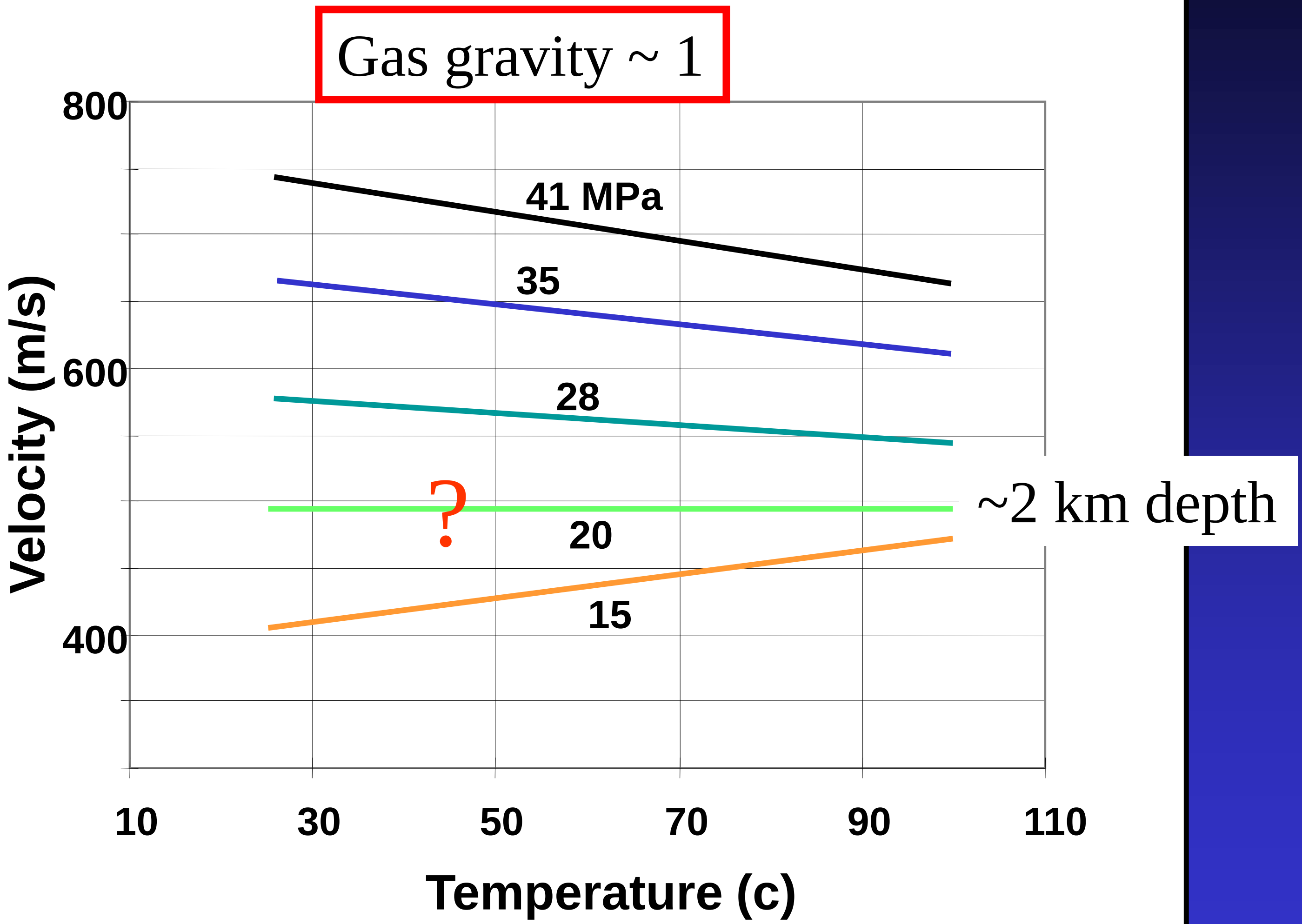
Live Oil Properties API, GOR, G



Gas Properties

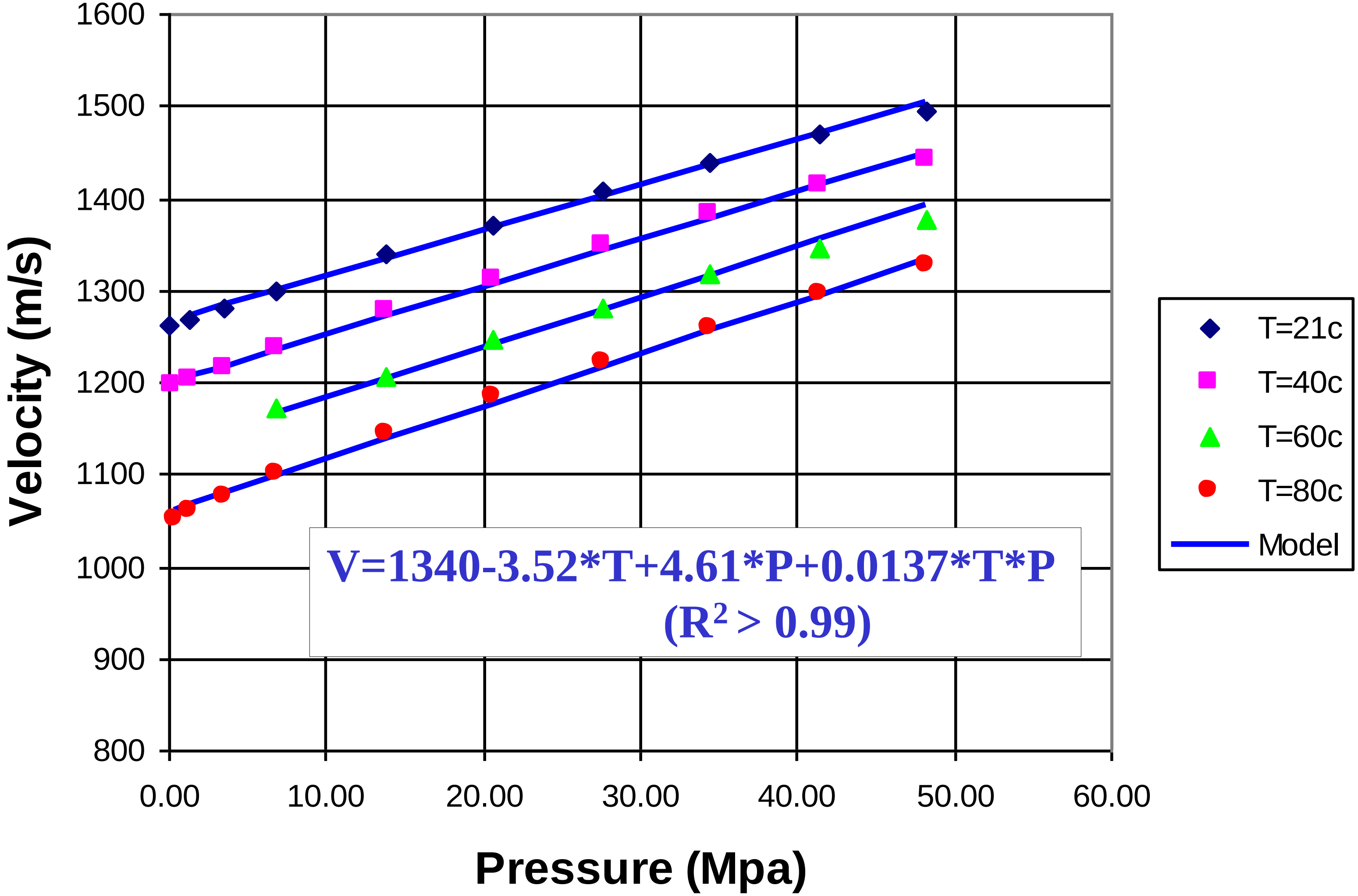


HEAVY GAS COMPRESSIONAL VELOCITY



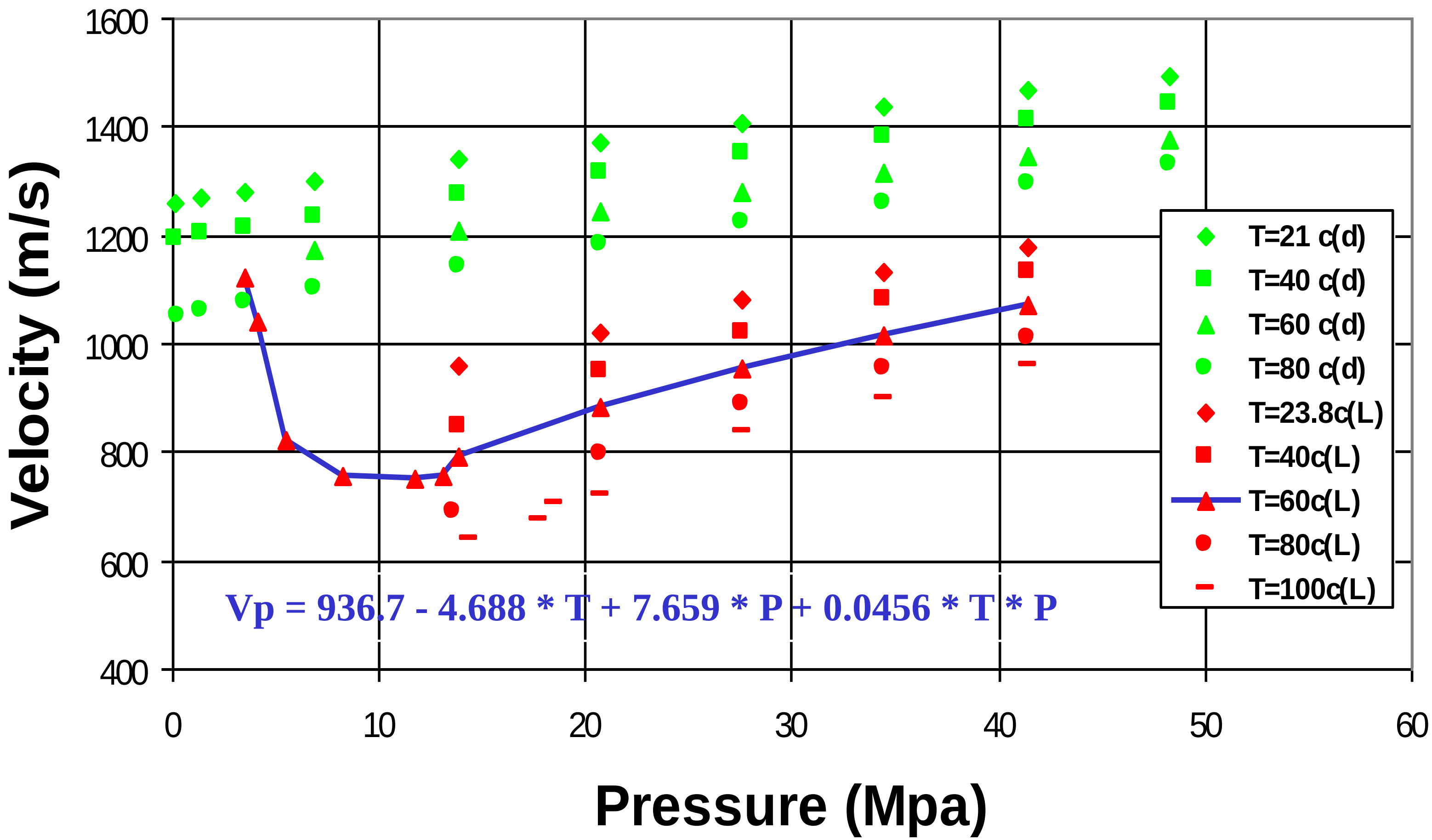
Reinecke (Dead Oil: API 46.6)

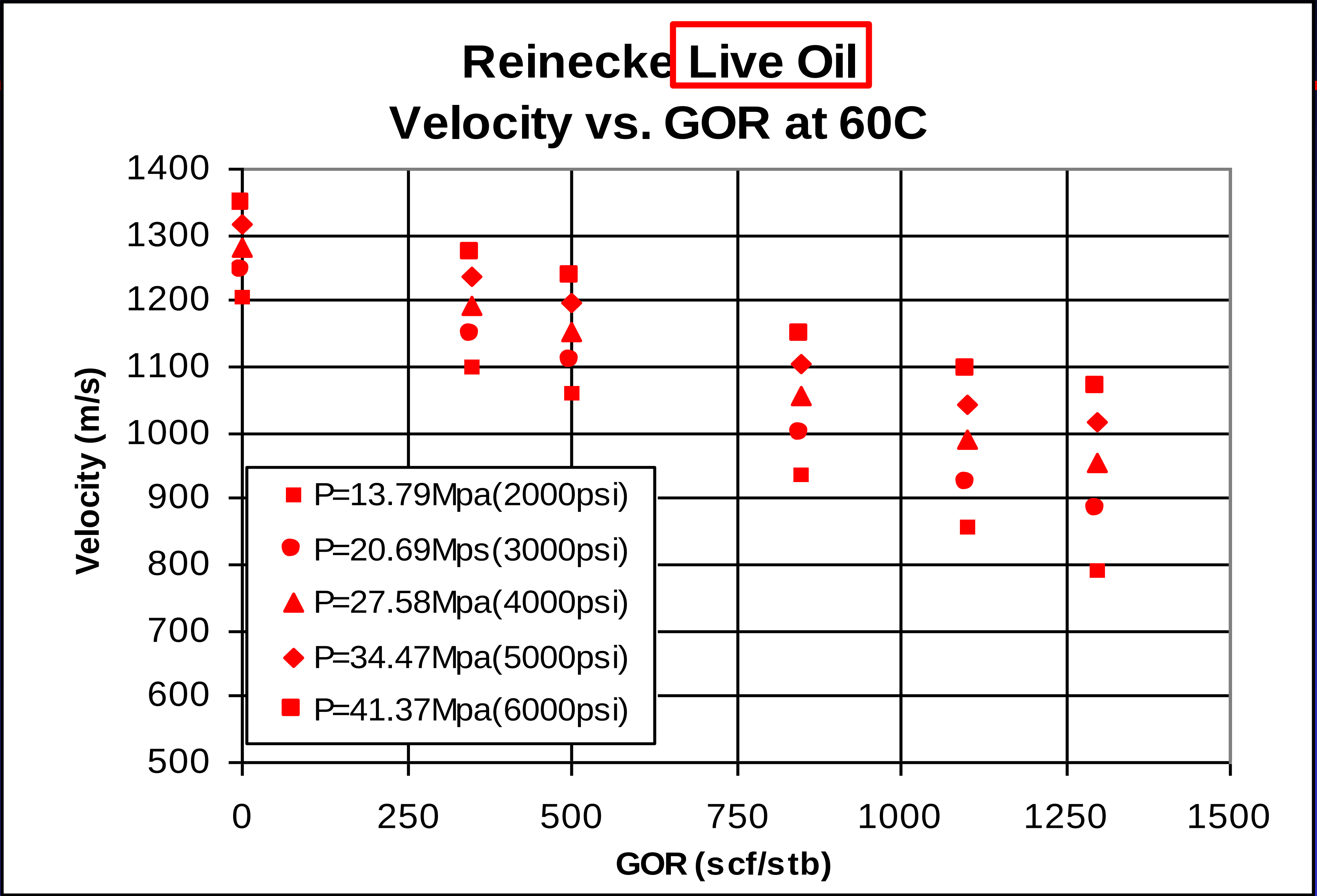
Vp (m/s) = A - B * T + C * P + D * T * P



Reinecke Dead & Live Oil

GOR = 1300 cuft/stb, B.P. = 1900 psi at 60 C

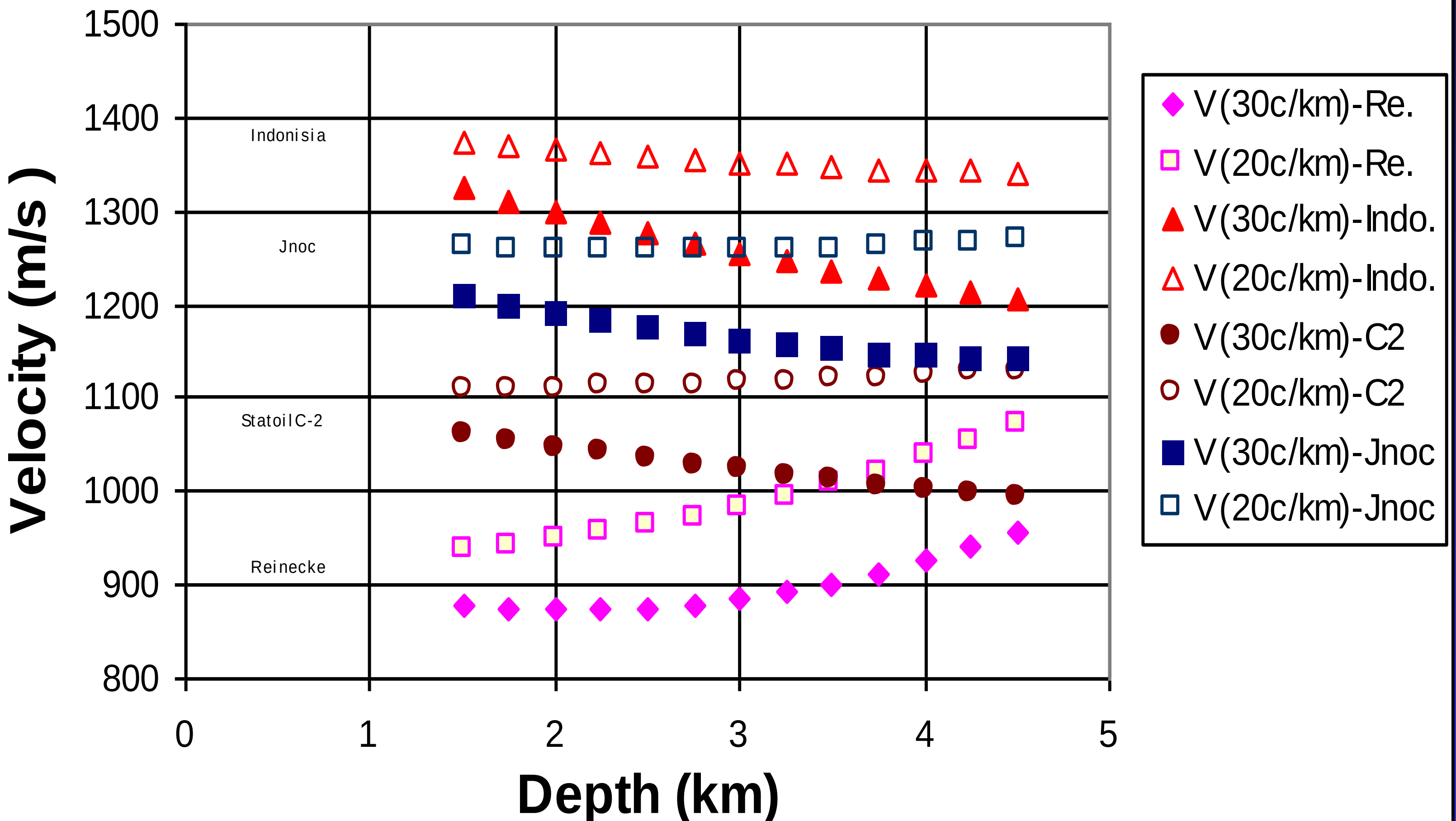




Reinecke Live Oil
Velocity vs. GOR at 60C
Velocity (m/s)
1400
1300
1200
1100
1000
900
800
700
600
500
0
250
500
750
1000
1250
1500
GOR (scf/stb)
P=13.79Mpa(2000psi)
P=20.69Mps(3000psi)
P=27.58Mpa(4000psi)
P=34.47Mpa(5000psi)
P=41.37Mpa(6000psi)

Velocity versus Depth (km)

$$V = A - B * Z * 30 + C * Z * 10.5 + D * Z^2 * 315$$



Velocity Models (H-B 1)

Two step regression

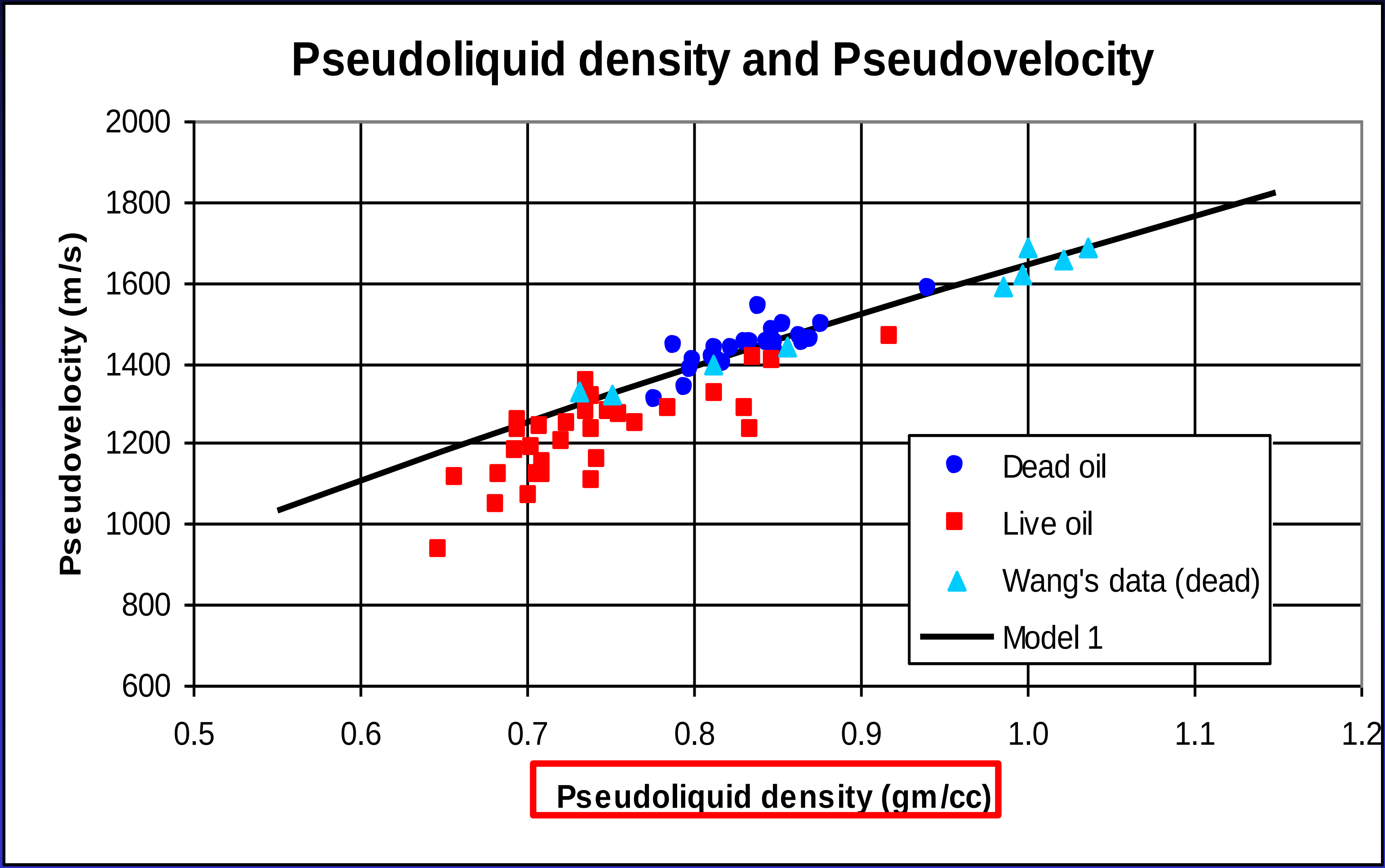
1. Fit velocity data with equation

$$V = A\,(V_{P0}) - B * T + C * P + D * T * P \quad (R \sim 0.99)$$

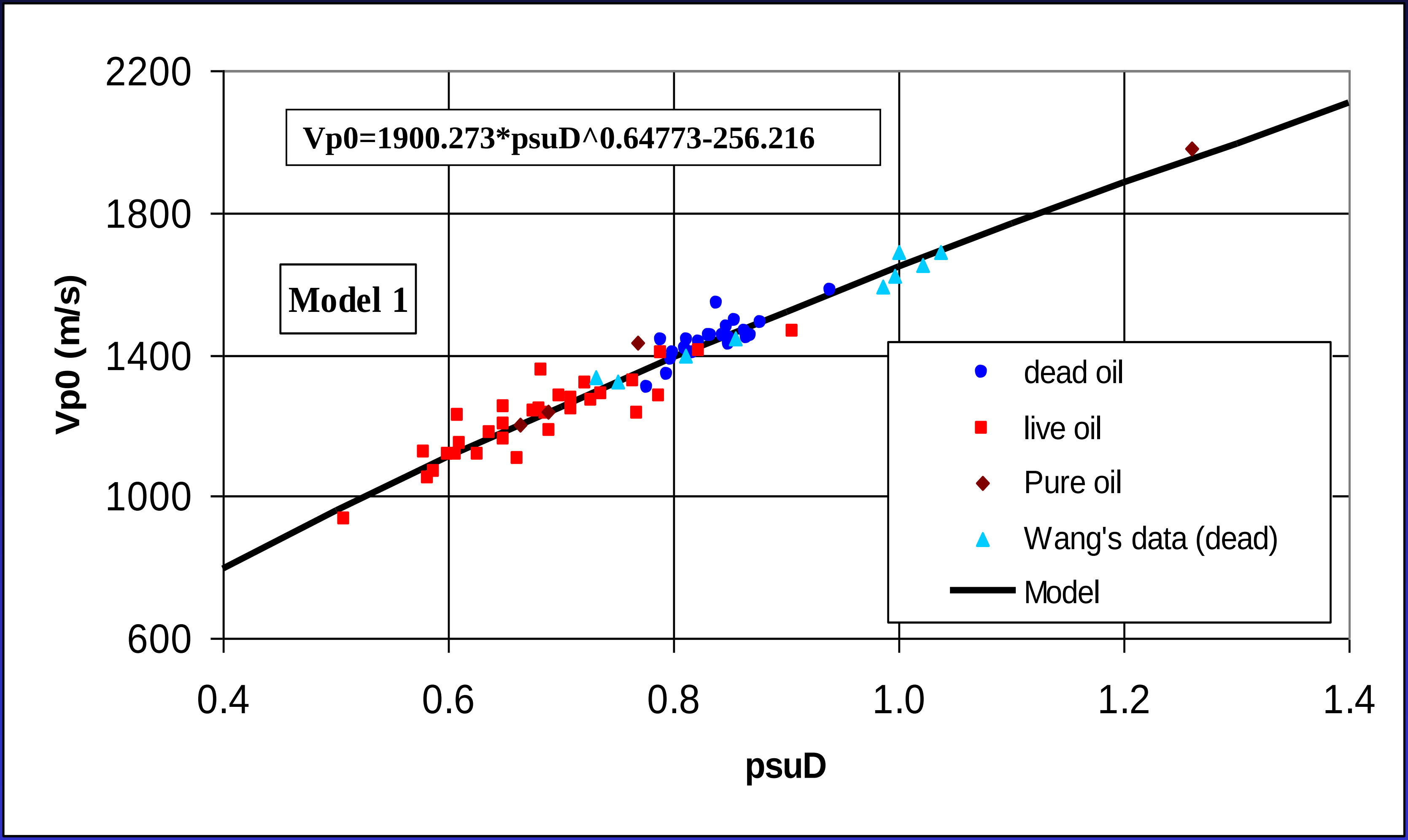
2. Fit coefficient A, B, C, D with GOR, API, and gas gravity

Works for dead oil (no Rs, G), but not for live oil

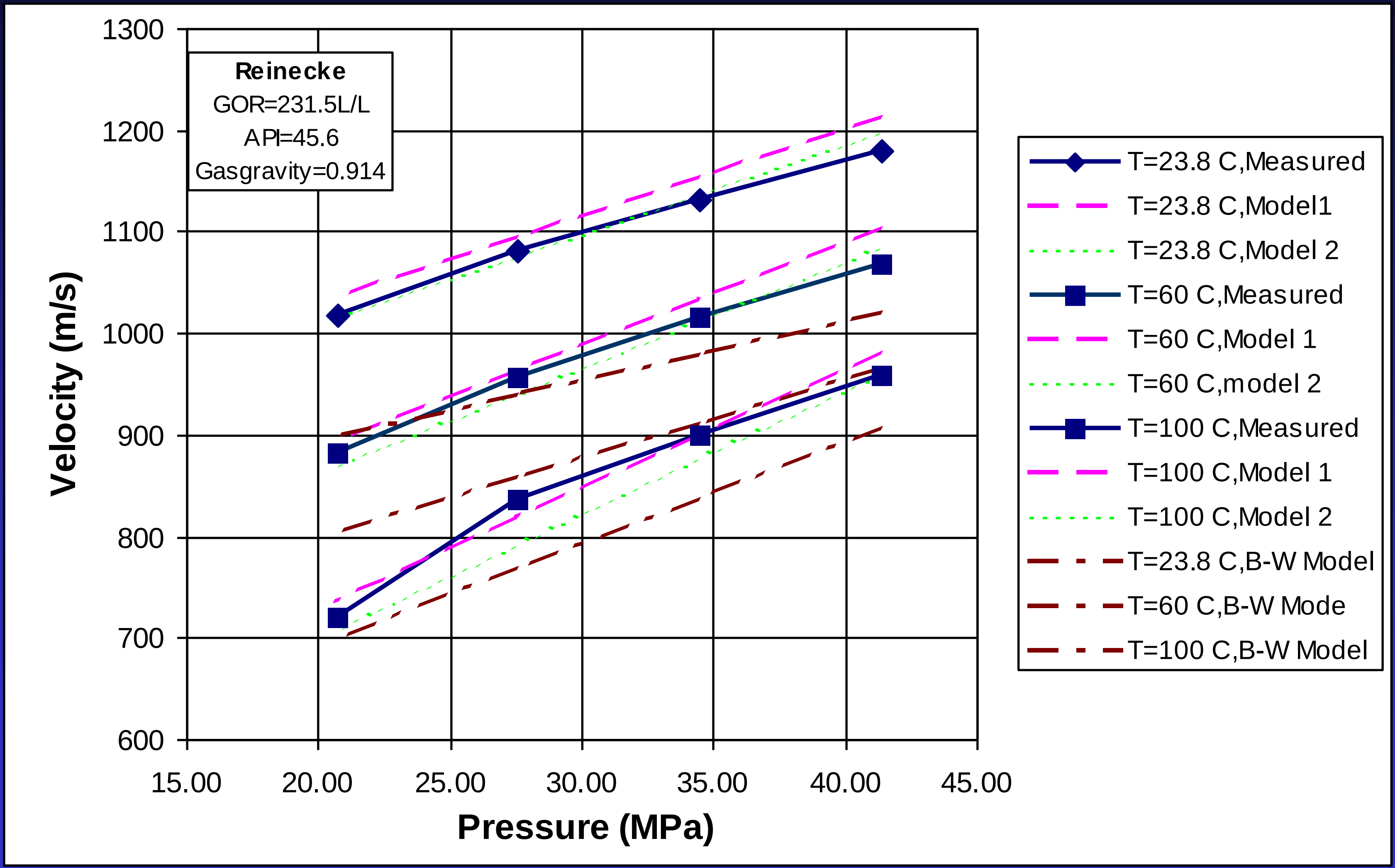
V-Model using Pseudoliquid Density



V_{P0} for H-B Model



Model Comparison



Program Name in FLAG14

***FL*uid *A*pplication of *G*eophysics**

Program name

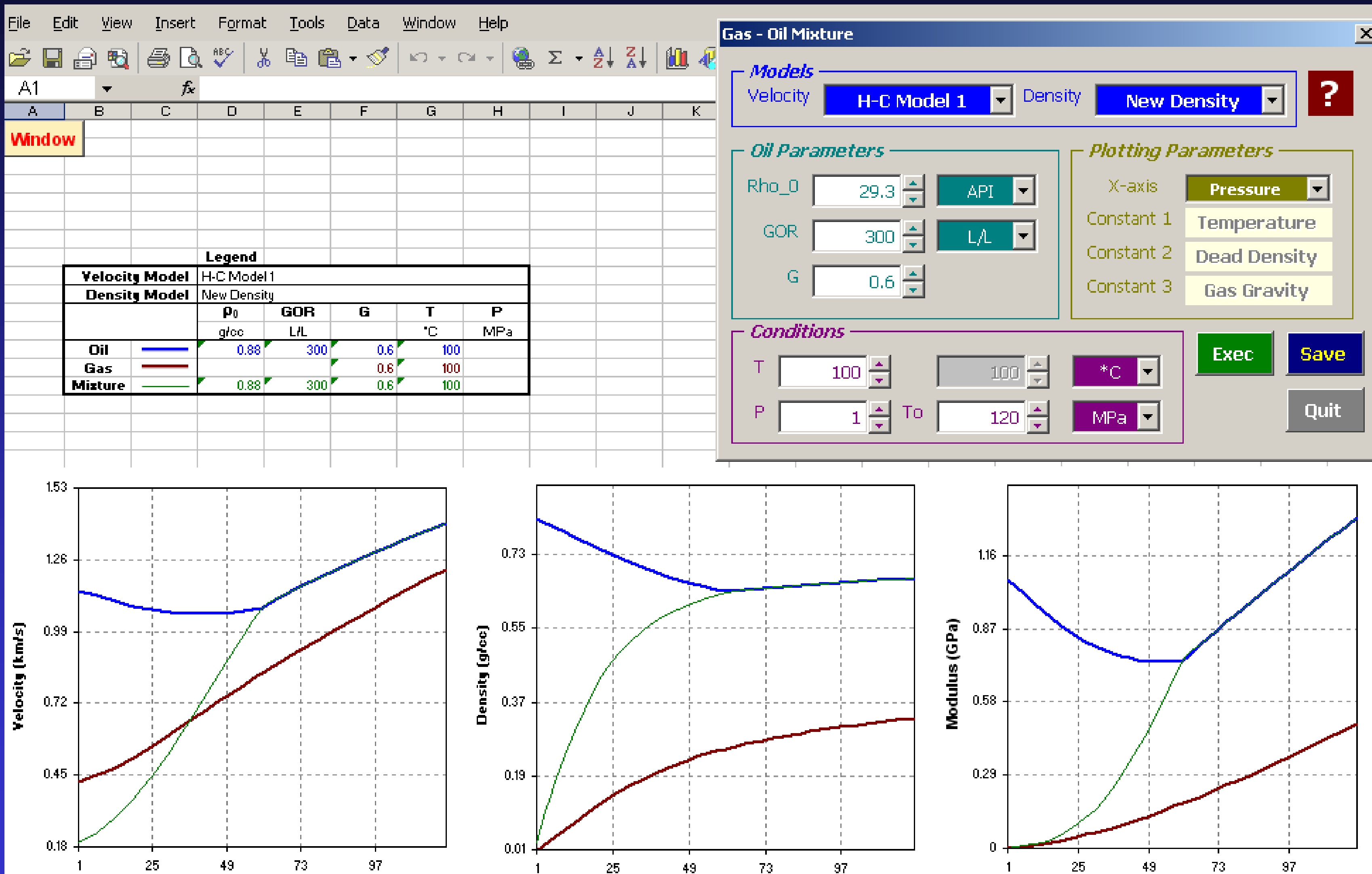
Fluids	Others
Poil14-xyy	EstVs14-xyy
Pgas14-xyy	PAVO14-xyy
Pbrine14-xyy	Pgasm14-xyy
Psteam14-xyy	
VHO14-xyy	

Version Information
The year of the annual meeting for releasing

x is series number. 3 means series 3 (used under EXCEL 2003), and 7 means series 7 (used under EXCEL 2007).

yy is version number

Oil Model with Phase Transition



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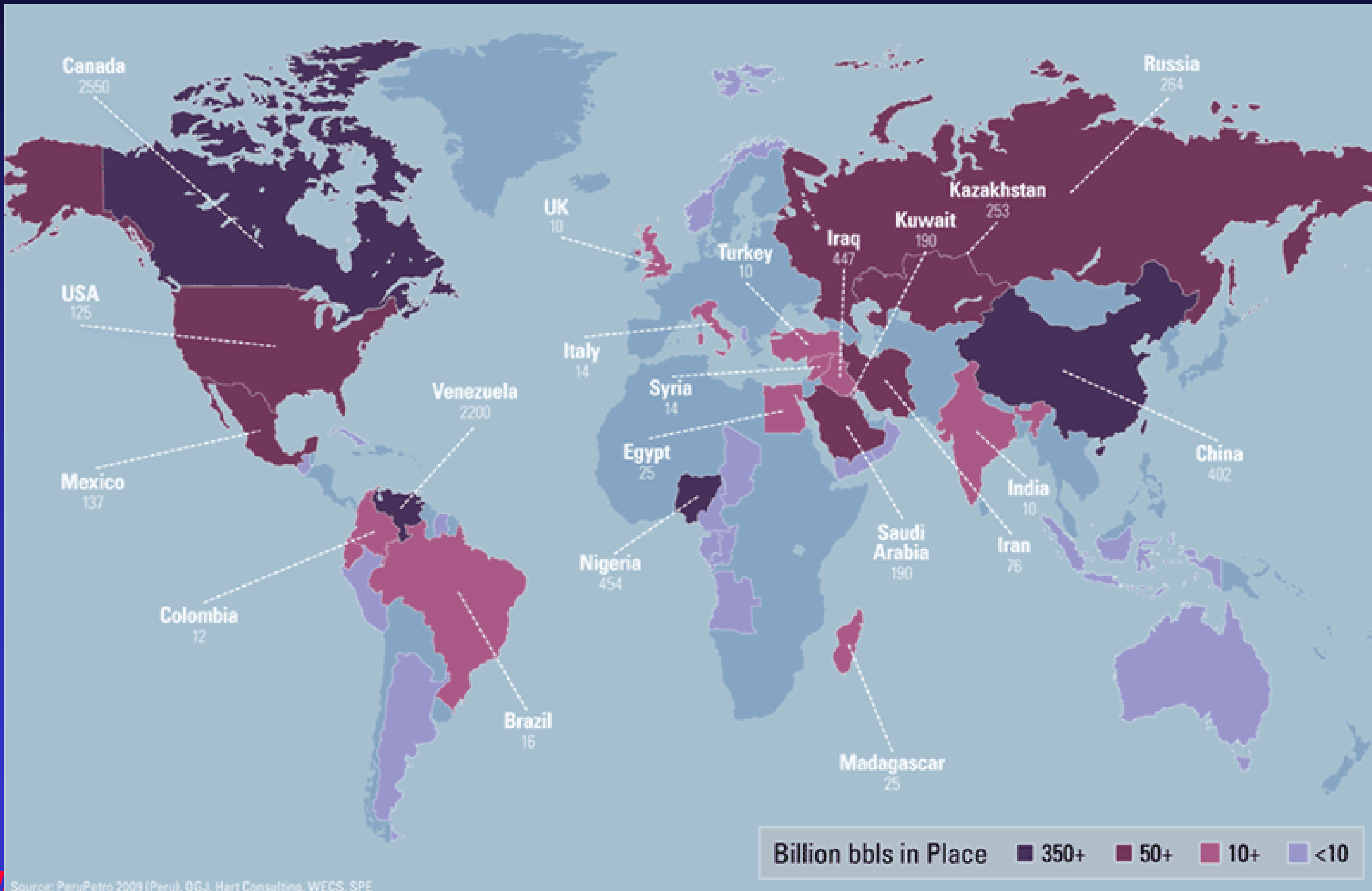
Heavy Oil Map of World



Map courtesy of Schlumberger: slb.com

Heavy Oil

- **High Density**

API gravity

22.3° .... *920 kg/m³*

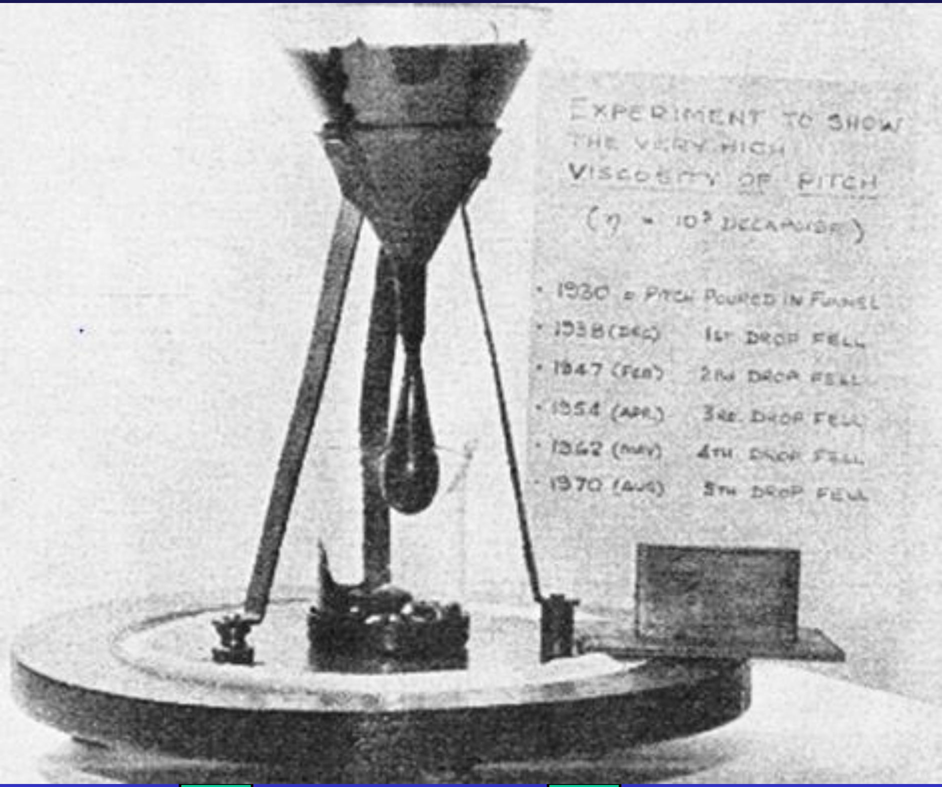
Heavy Oil

10.0° .... *1000 kg/m³*

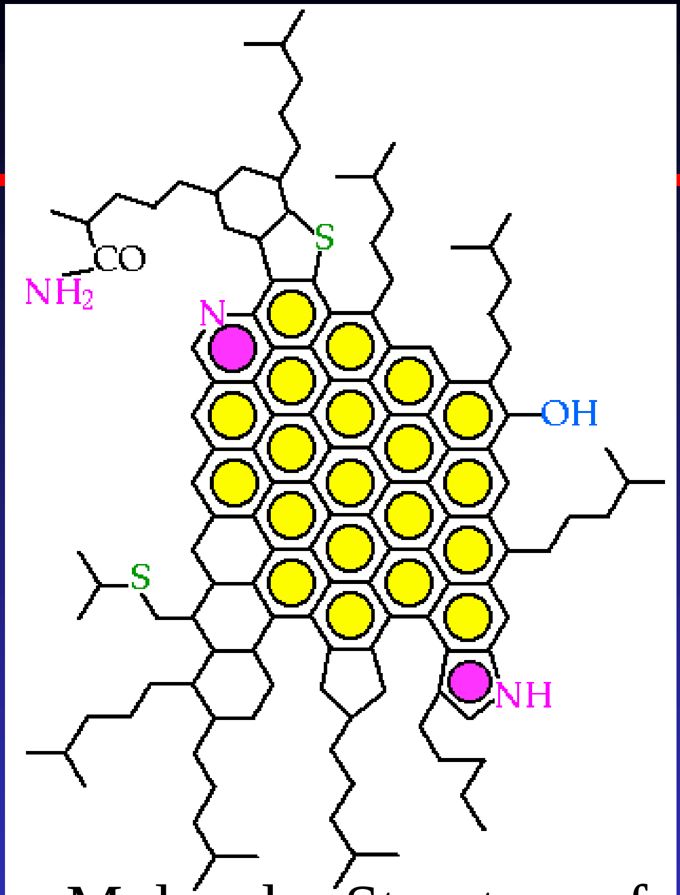
Extraheavy Oil

* Definition by US Department of Energy

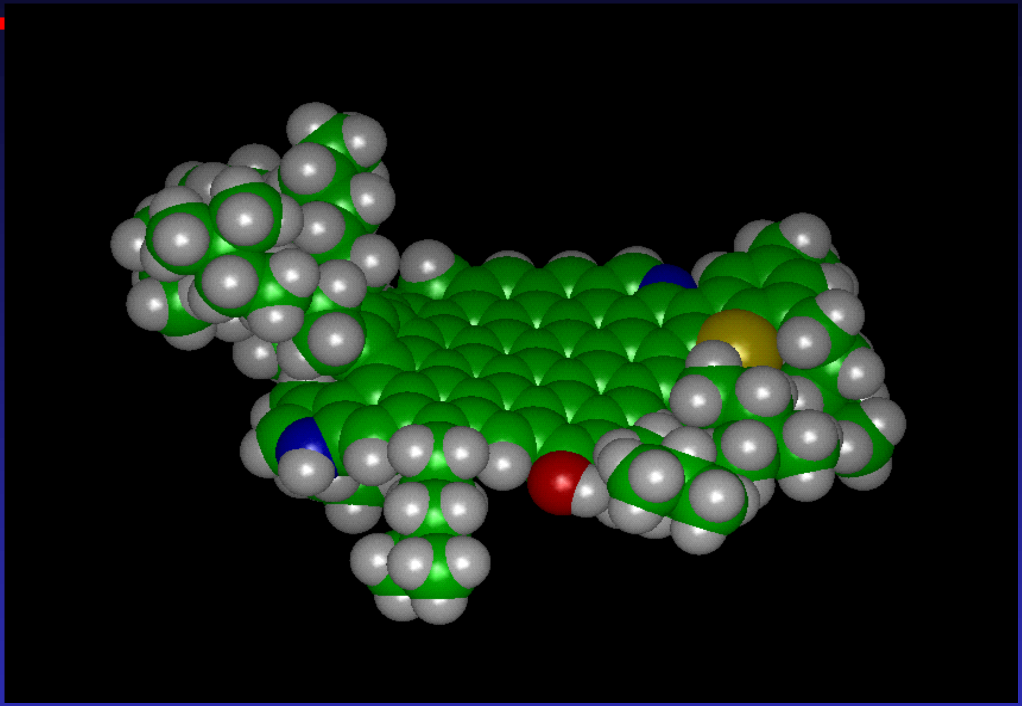
- **High Viscosity**



Thermal **Diluting**



Molecular Structure of Asphaltene Proposed for 510C Residue of Venezuelan Crude by Carbognani [INTEVEP S.A. Tech. Rept., 1992]



3D Picture of Carbognani's Model of Venezuelan Crude Asphaltene Molecule (Courtesy of Prof. J. Murgich)

Michael Jardine

Velocity vs. temperature of heavy oil

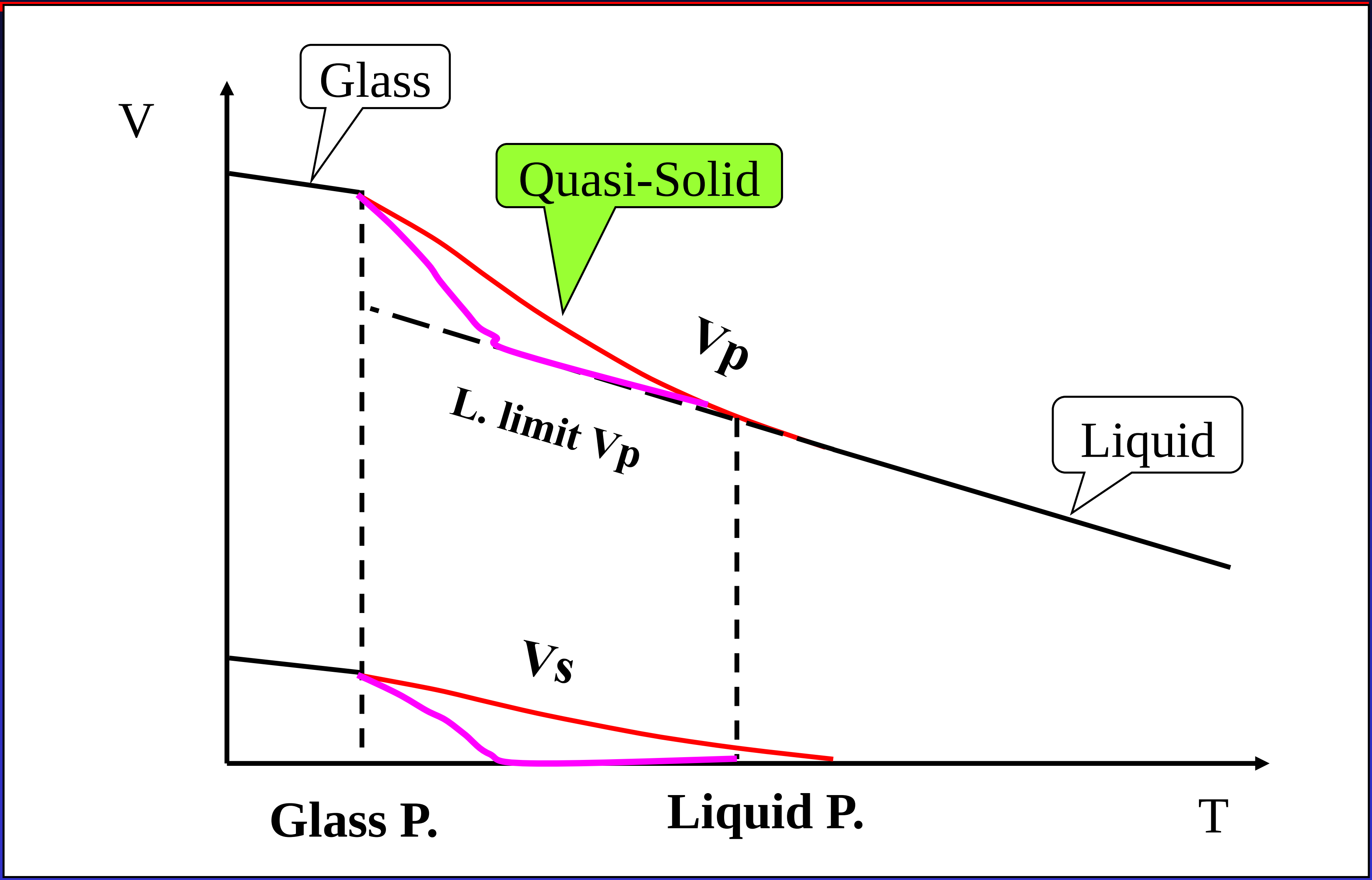


Figure 1. Schematic of Velocity trend for heavy oil.

Temperature Effects

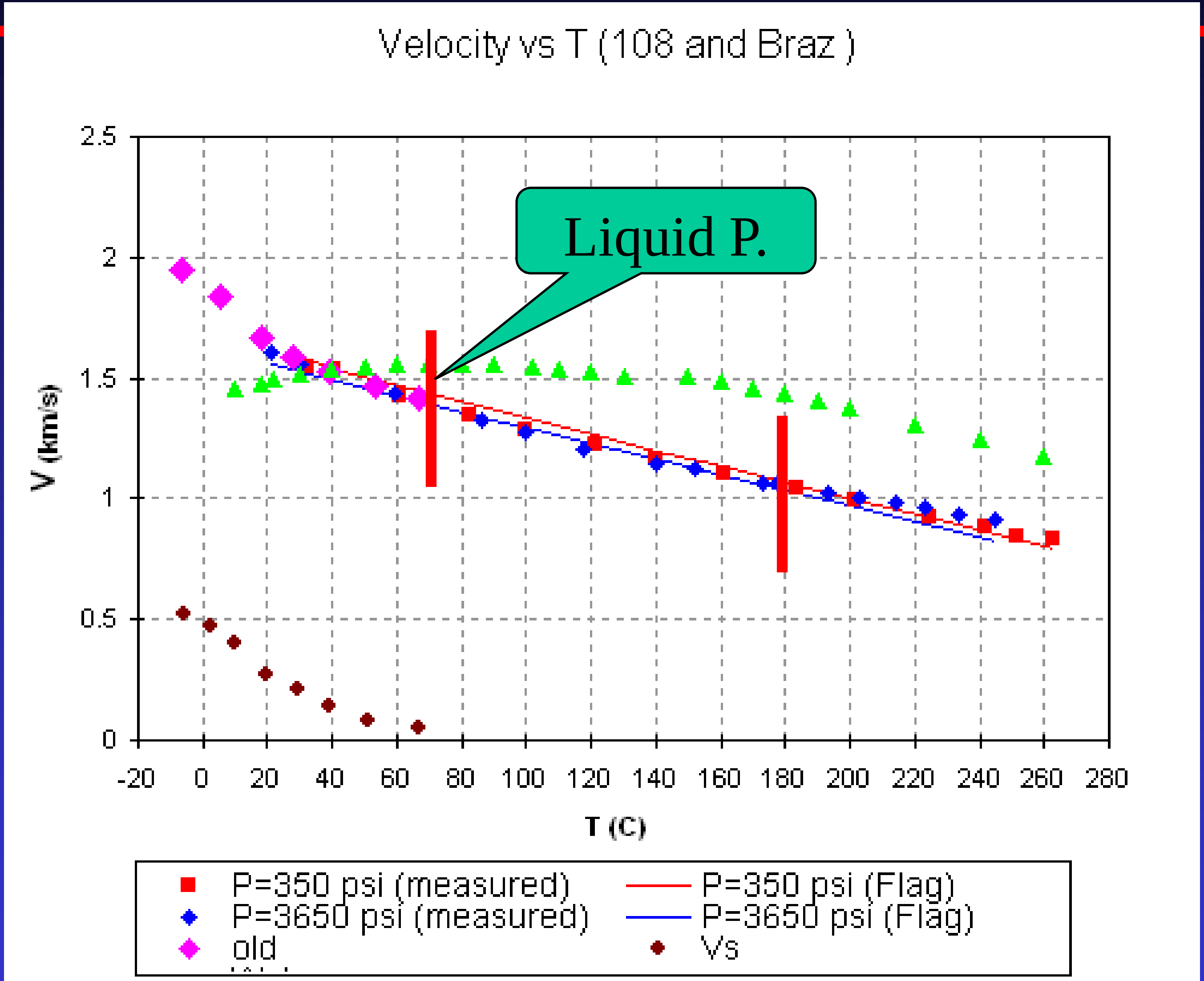
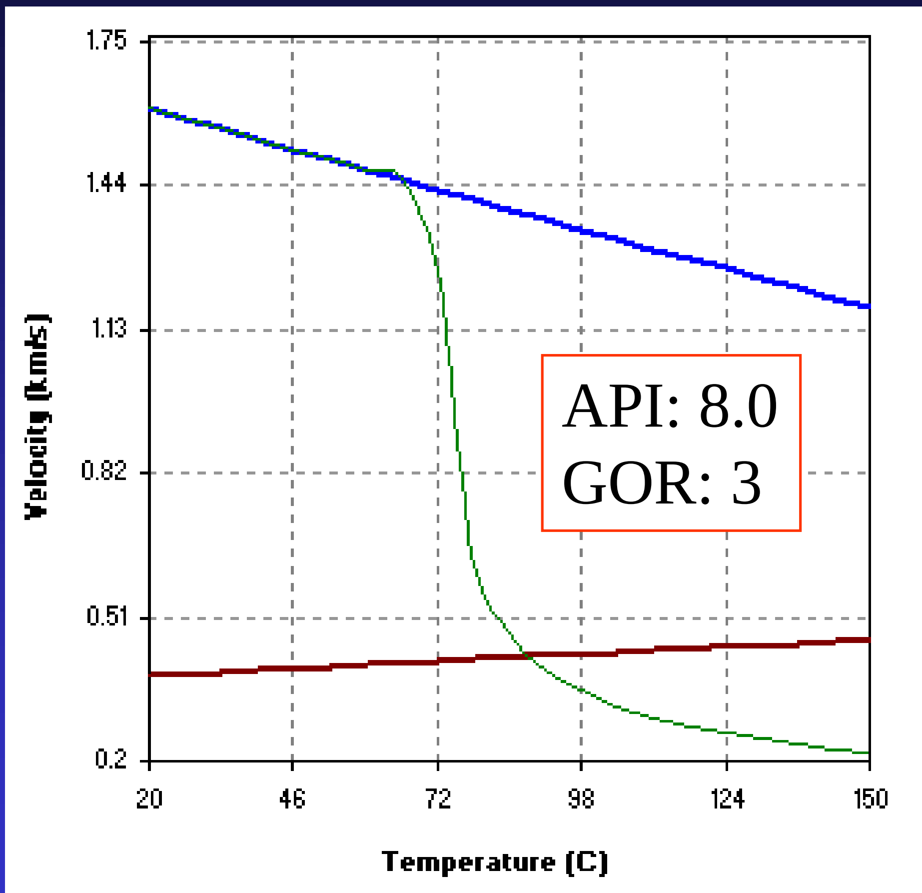
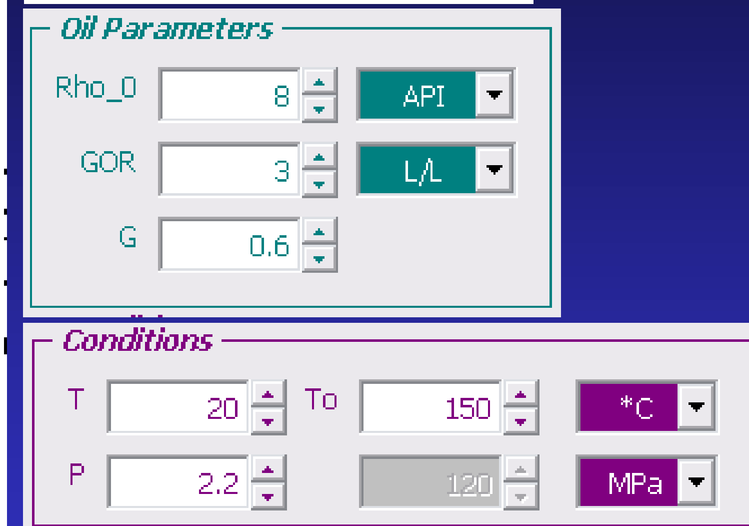


Figure 1. Measure Vp and Vs data versus temperature on two heavy oil sample.

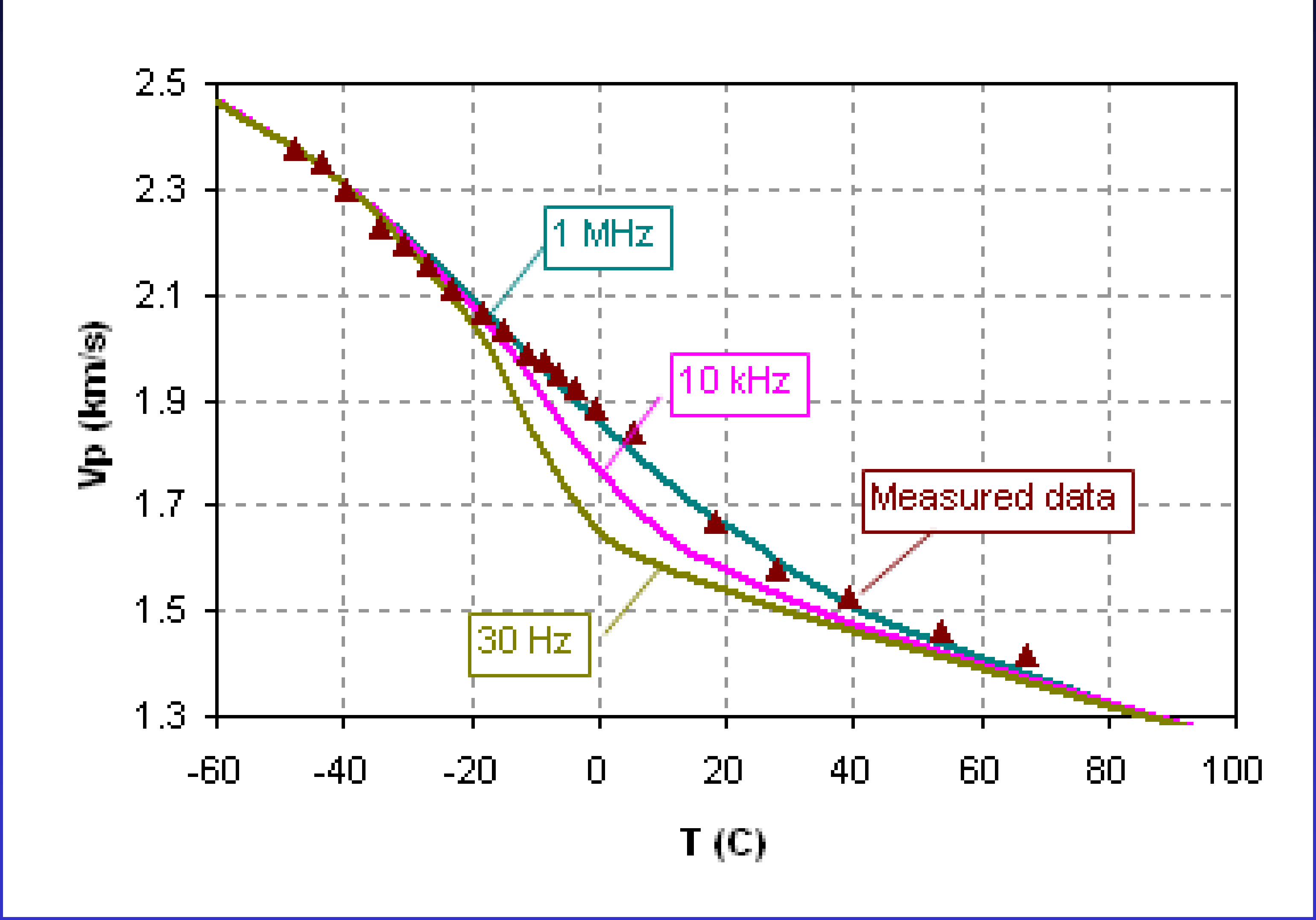
Gas Bubble out at Higher Temperature



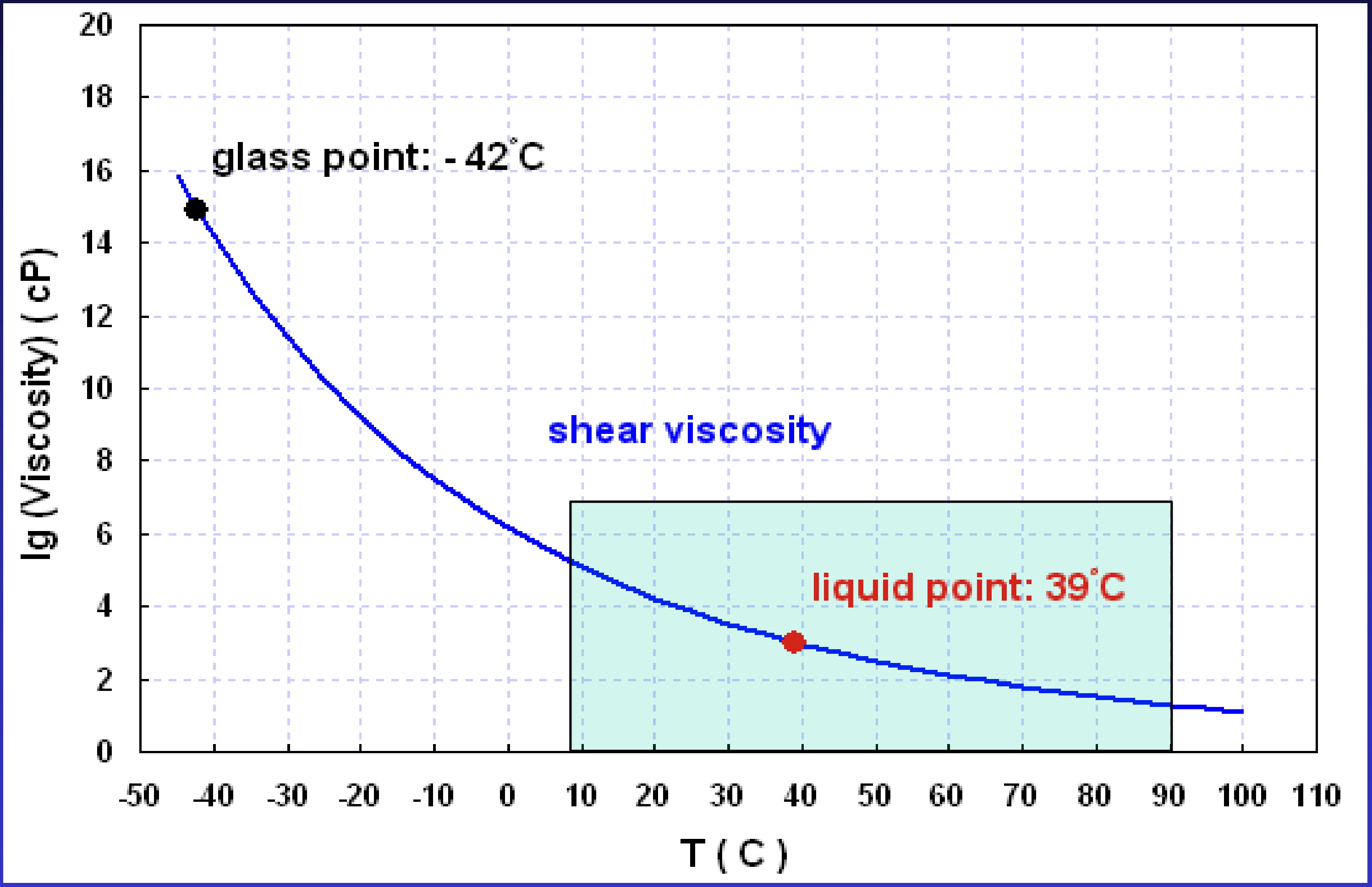
‘Flag’ Calculator



F – T effects on Vp (API = 9.38)



Experiment design

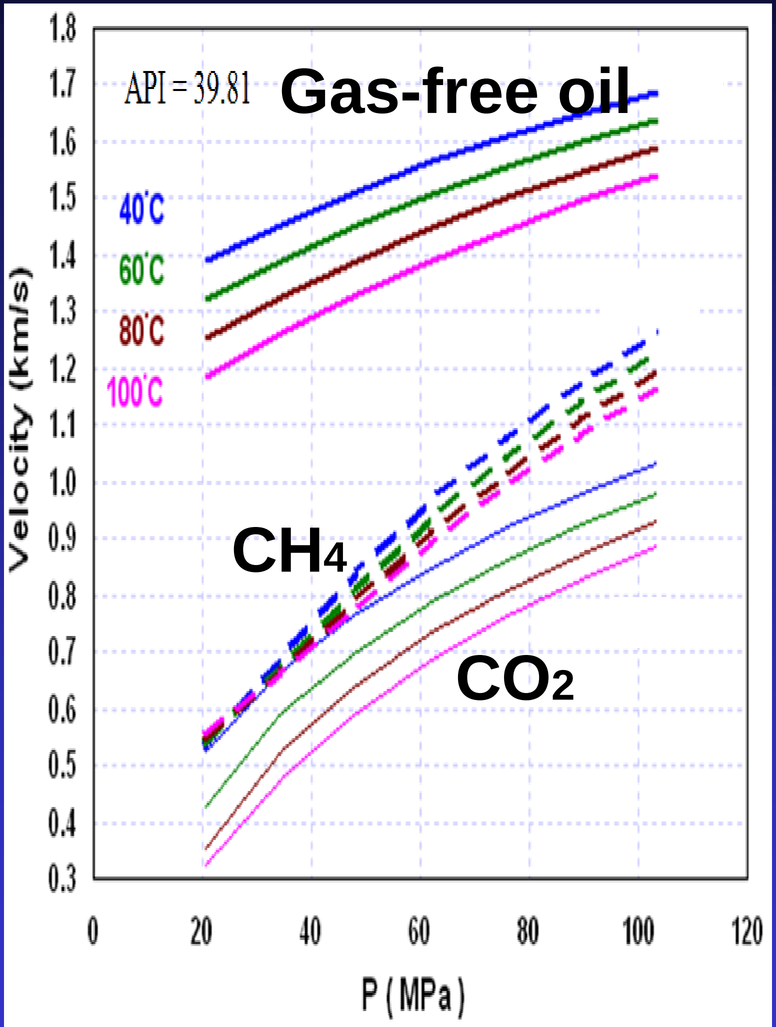


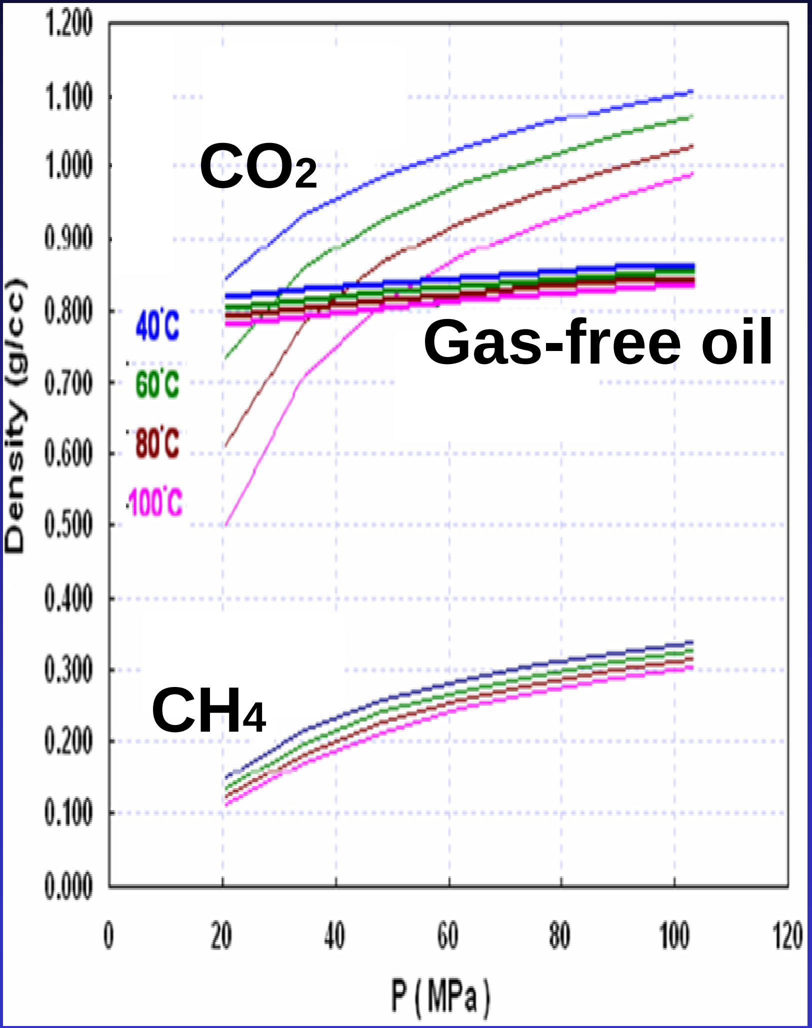
Velocity and density of oil (water) with dissolved CH_4 and CO_2

2013

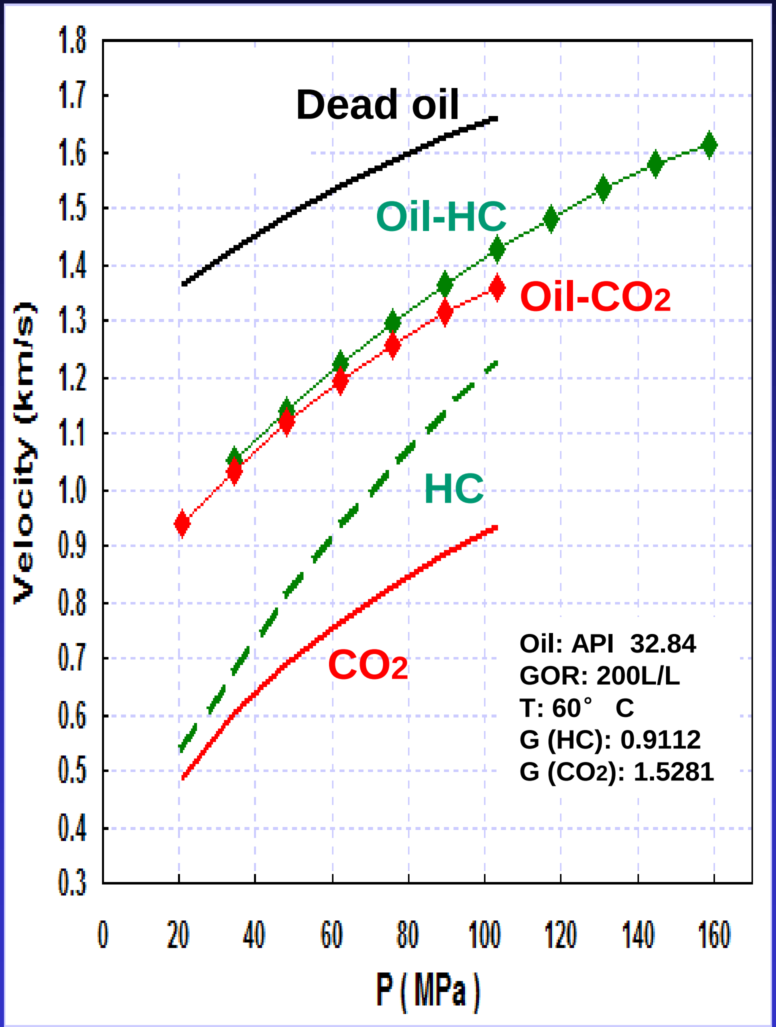
De-hua Han, University of Houston

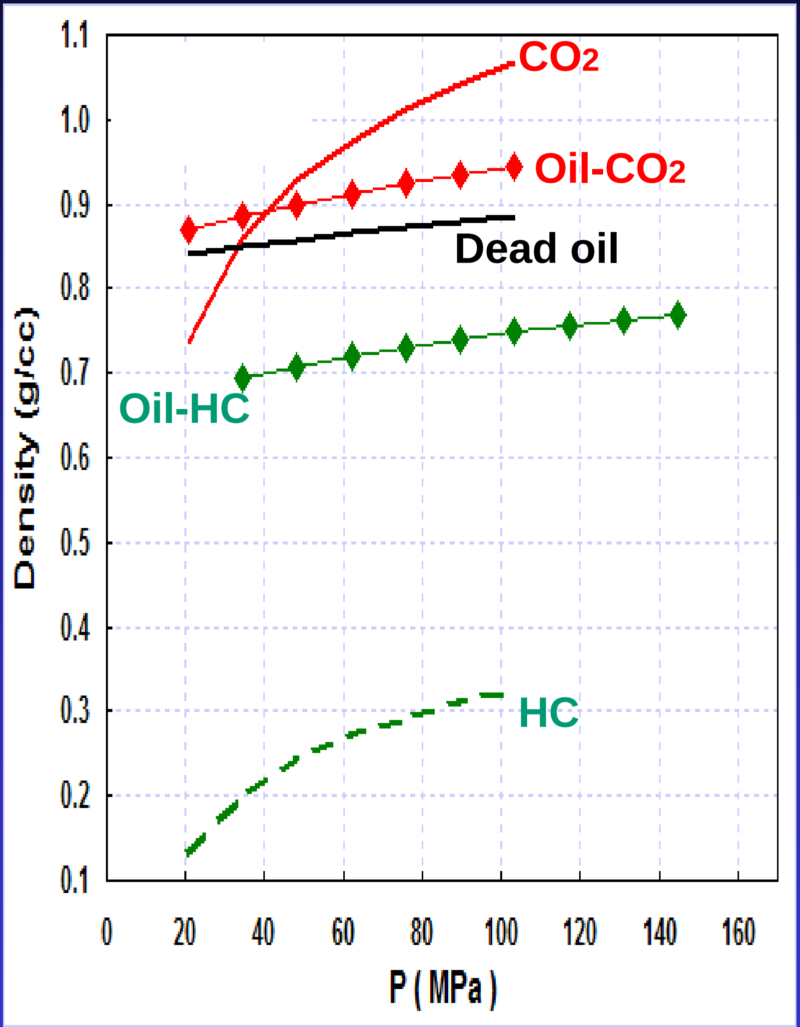
Component property



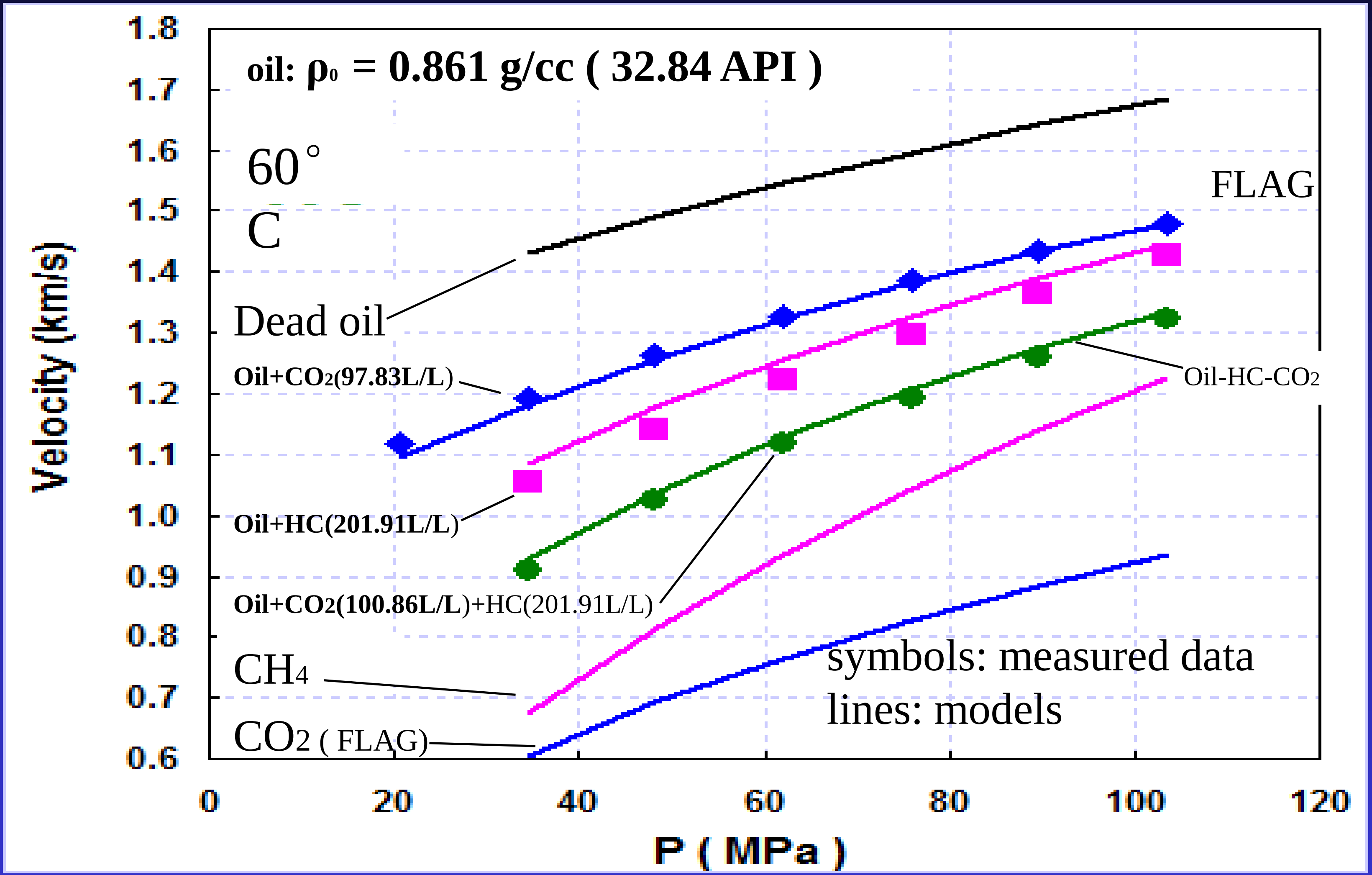


Gas effect comparison: HC vs. CO_2





Our models for oil-HC-CO_2 mixture



Geophysical Characterization Of Tight Oil Reservoirs

July. 2015

De-hua Han (UH), Luanxiao Zhao & Geng Jianhua (Tongji)

Conventional Reservoirs
Small volumes that are

Viscosity : oil > gas*10^3
Modulus: oil > gas*10^4

develop

Fig. 1—The resource triangle.

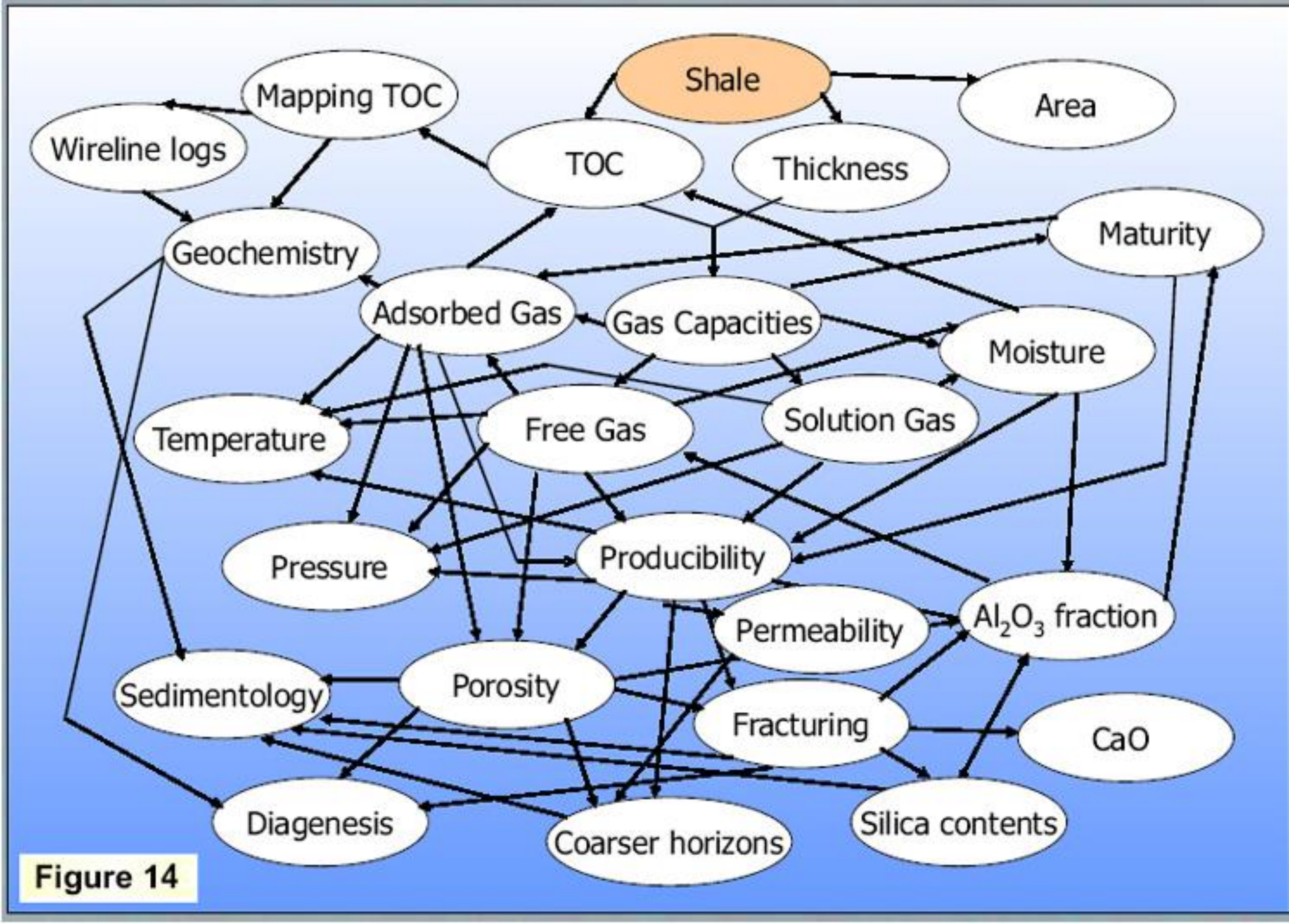
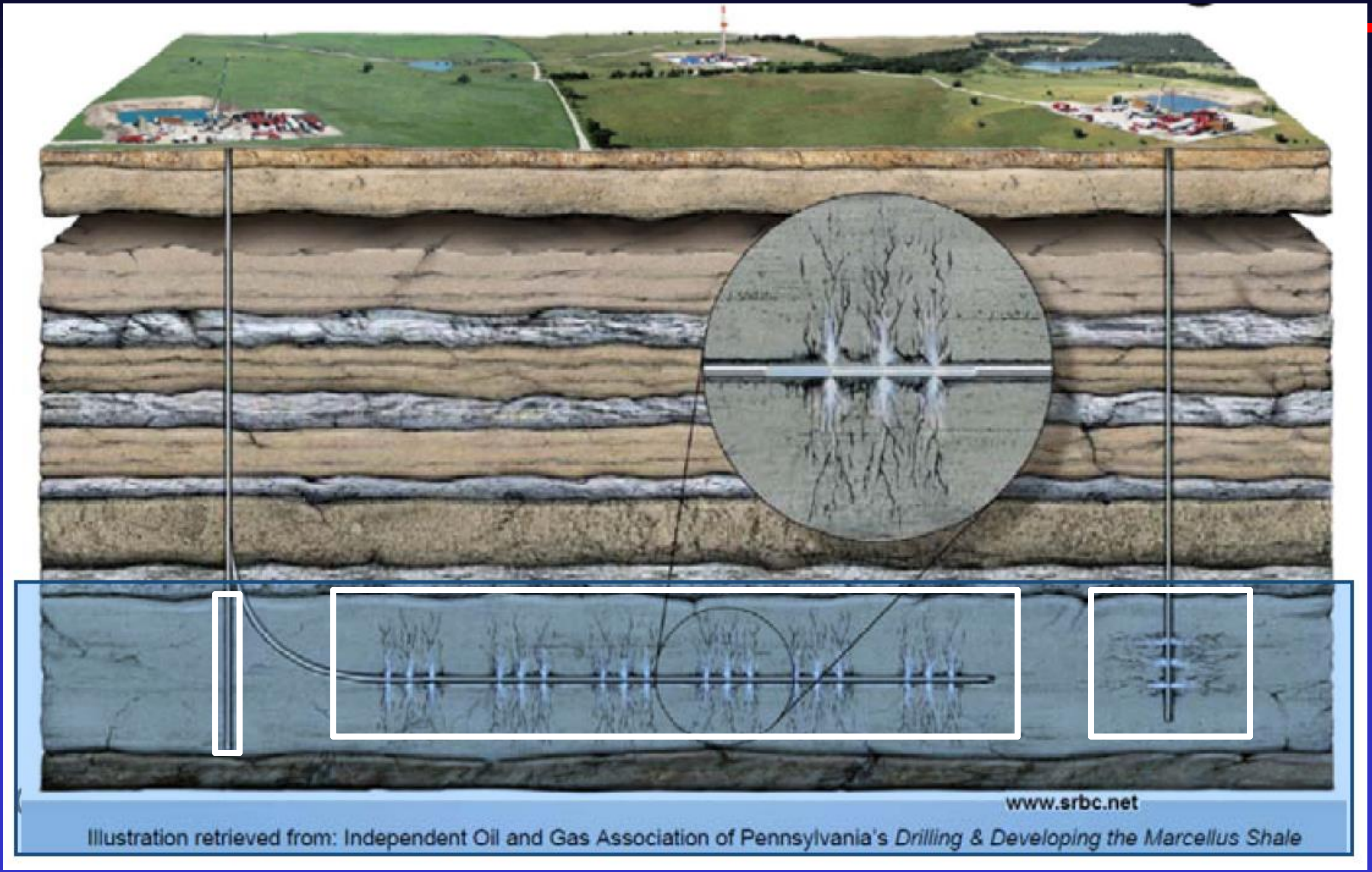


Figure 14. Diagram of important parameters and their interrelationships, along with tools for their depiction.

Production is controlled by Darcy's law

$$Q = \frac{k \cdot \boxed{A} \cdot \Delta P}{\eta}$$

Hydro-frac: key to enhance (A) production



Production is fluid control

$$Q = \frac{k \cdot A \cdot \Delta P}{\eta}$$

Fluid … OR

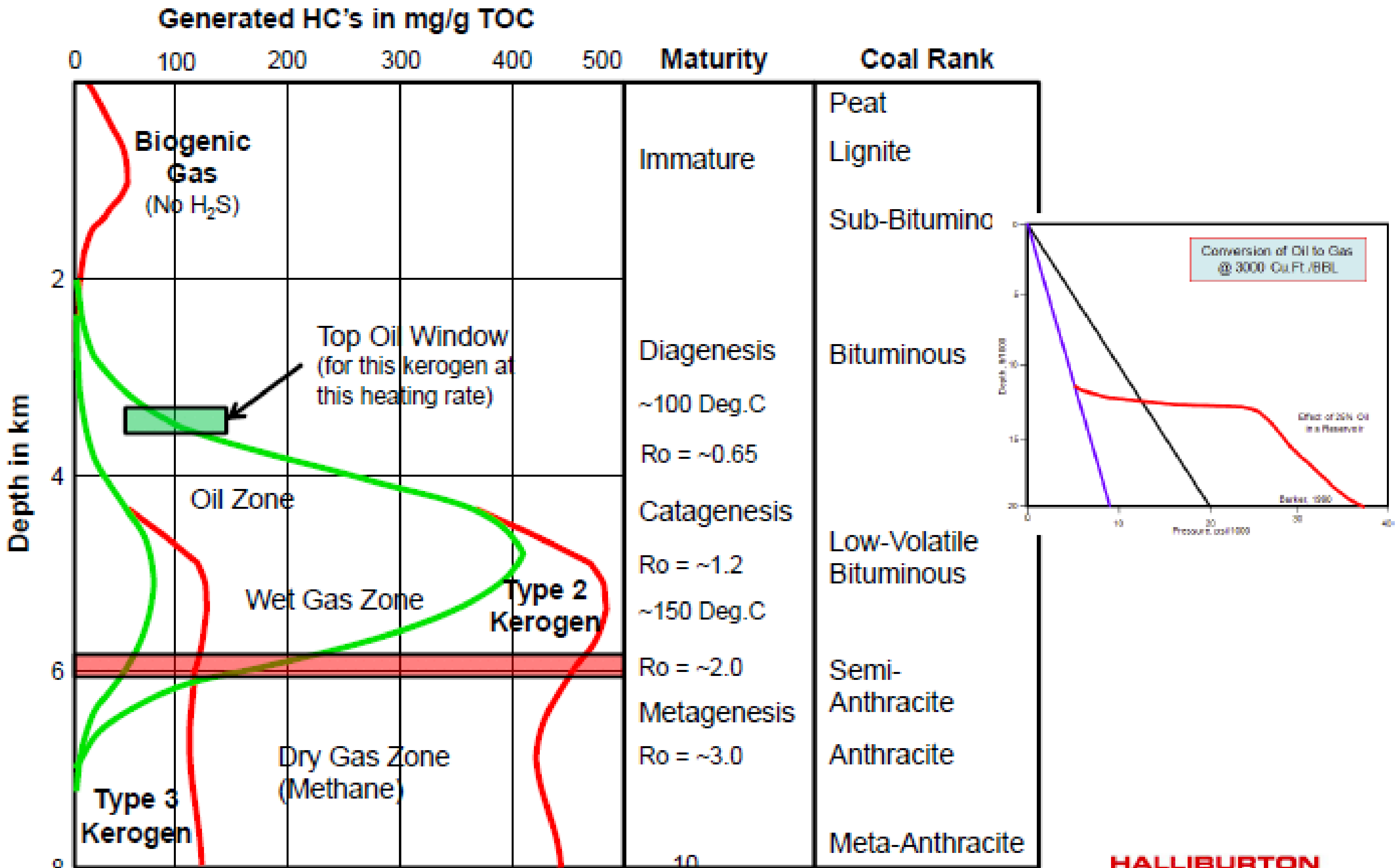
and P…

Perm…

fractures…

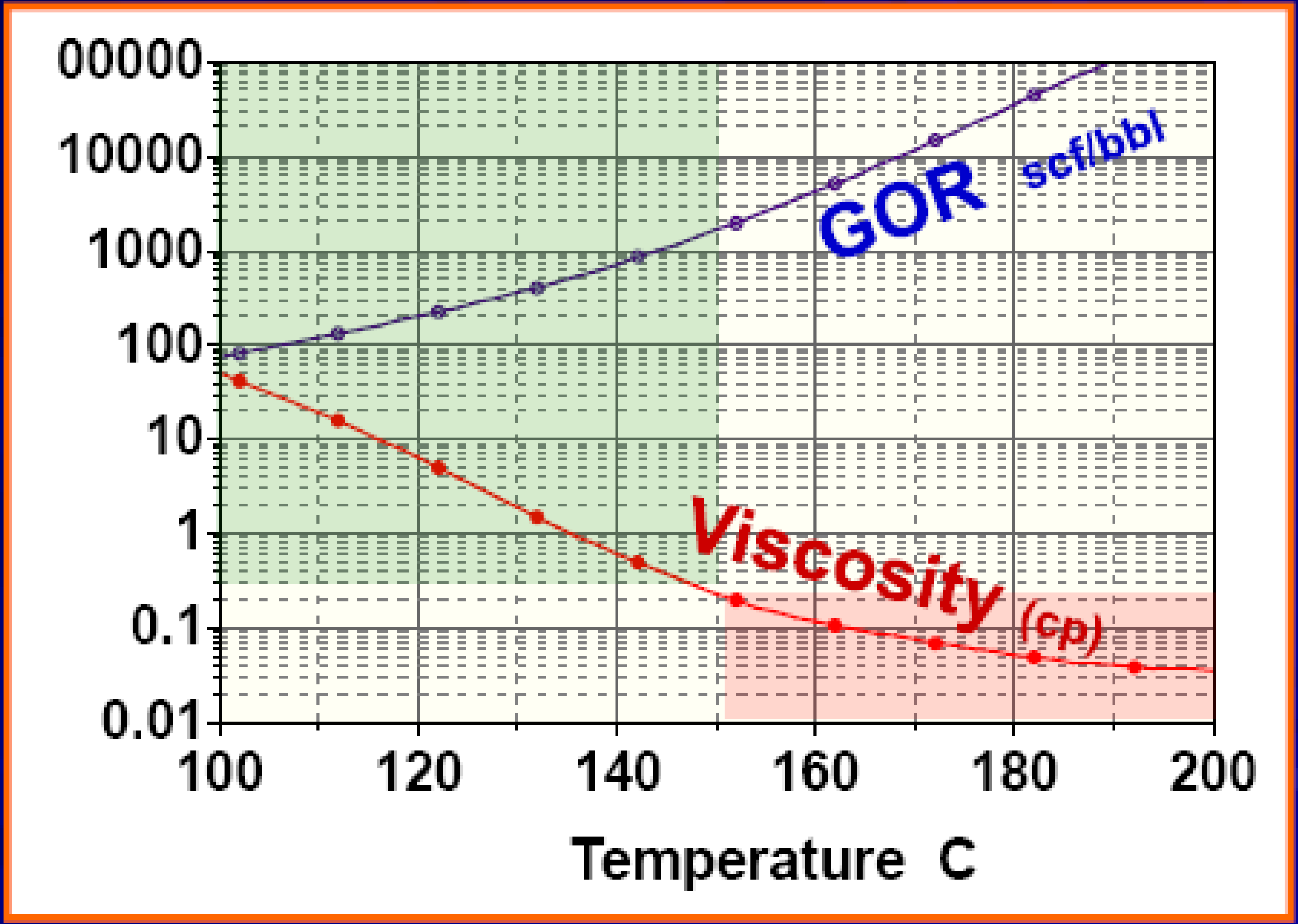
Hydrocarbon Fluid Sweet spots

Hydrocarbon Generation, Maturation and Coal Rank



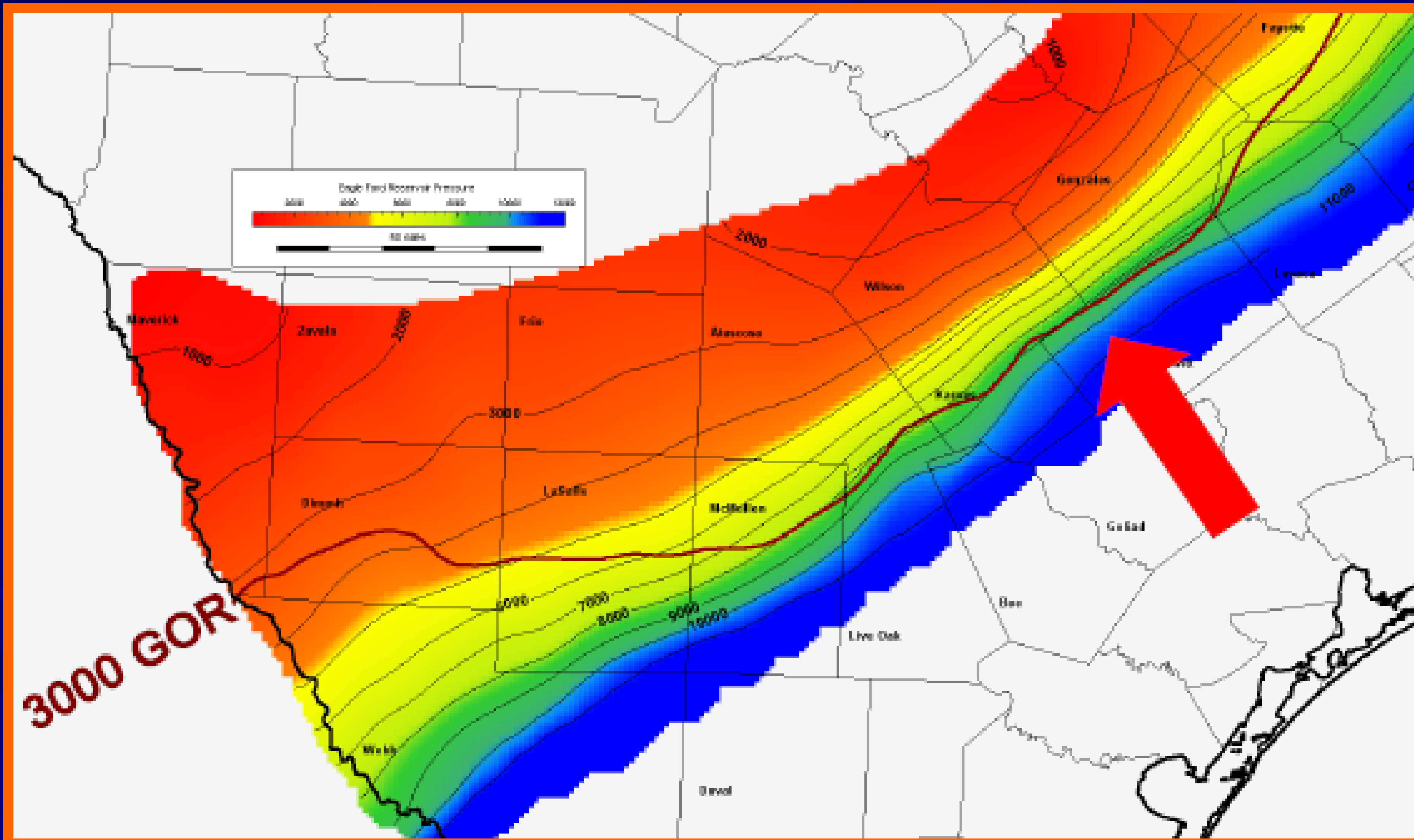
HALLIBURTON

Maturity vs. GOR & Viscosity



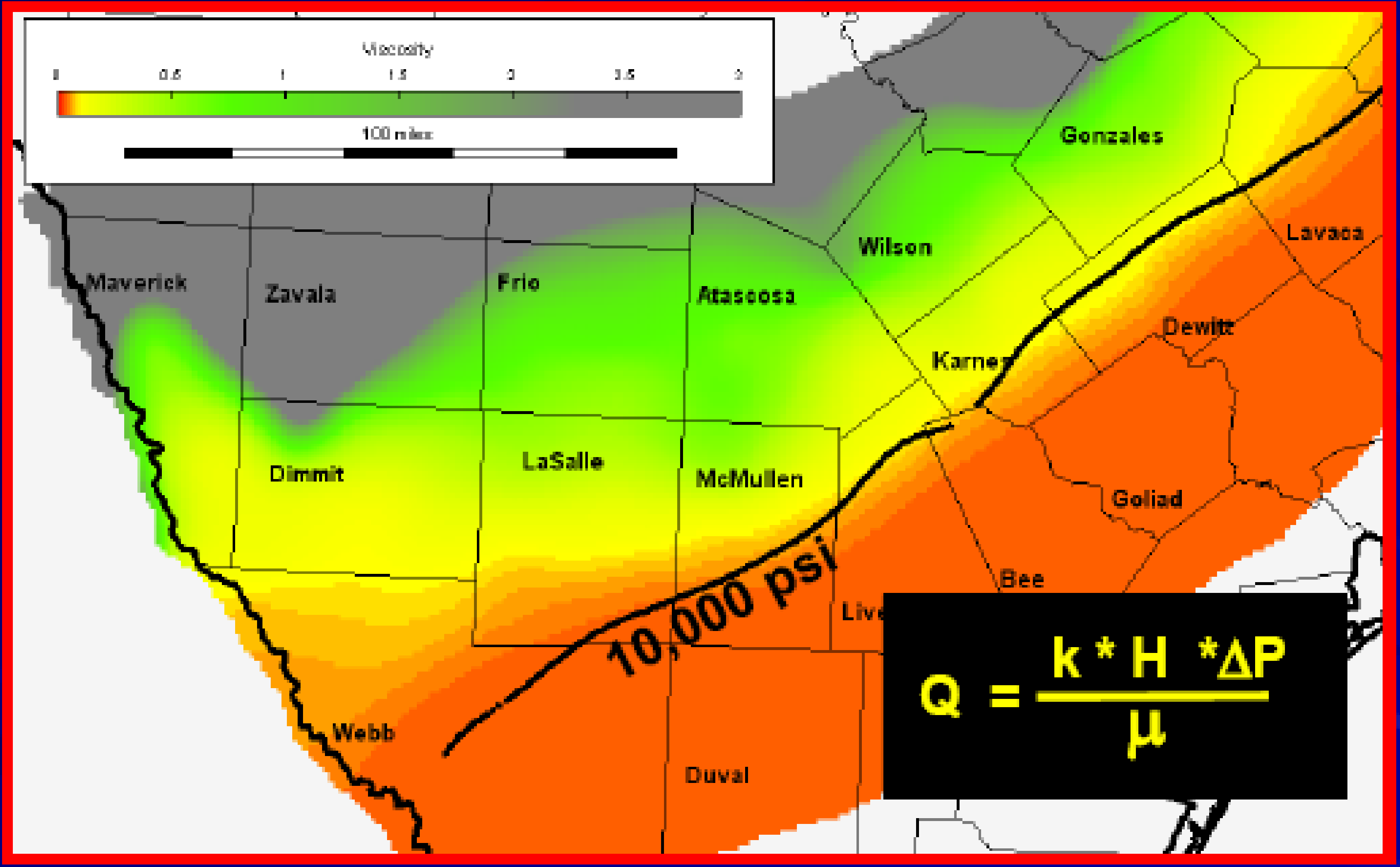
As maturity increases, GOR increases four orders of magnitude and viscosity decreases three orders of magnitude

Eagle Ford liquids sweet spot
How to predict composition and pressure?



H. Cander 2012

Eagle Ford Viscosity
(approximated viscosity estimated from model)



$$Q = \frac{k * H \ * \Delta P}{\mu}$$

High pressure helps mobility of more viscous liquid phase fluids

Thank You！


SO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ic Roc
地震岩
机遇与
mmer Wor
25-29, Bei
ed By


Zhifang Yang

Sponsors (~ 20…)

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