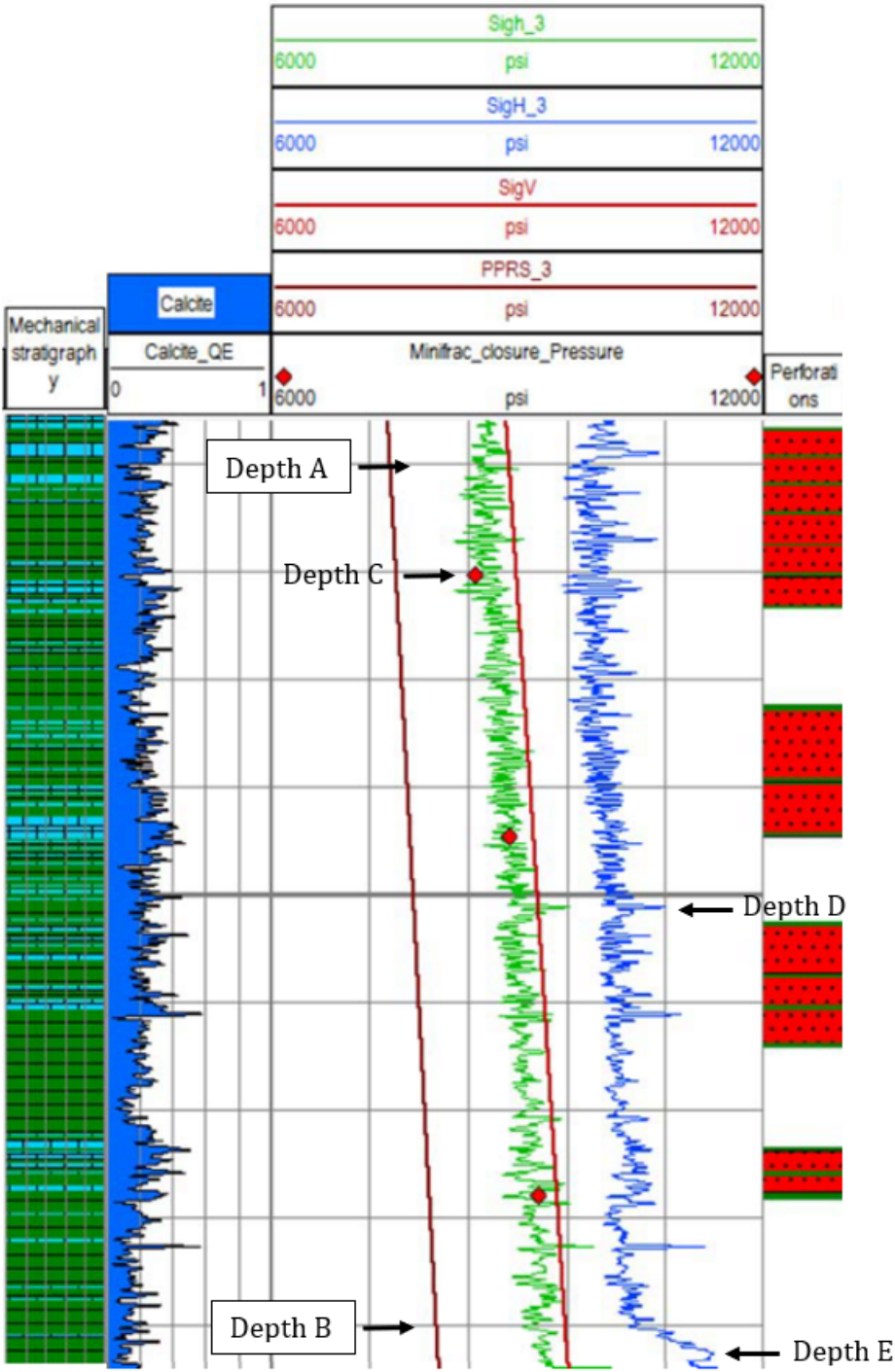
$$P_{mud} = P_W$$


Sigh_3
6000
psi
12000
SigH_3
6000
psi
12000
SigV
6000
psi
12000
PPRS_3
6000
psi
12000
Calcite
Mechanical stratigraphy
Calcite_QE
0
1
Minifrac_closure_Pressure
6000
psi
12000
Perforations
Depth A
Depth C
Depth D
Depth B
Depth E

p

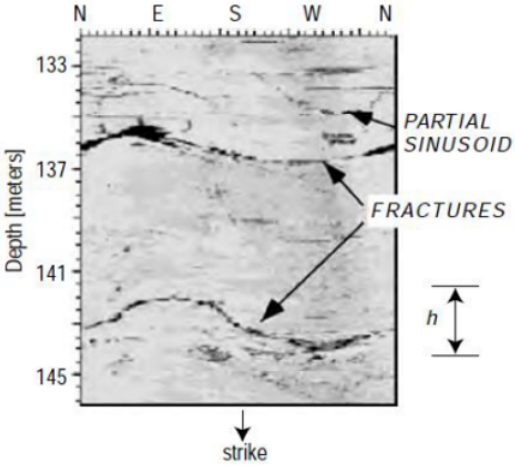
q

I_1

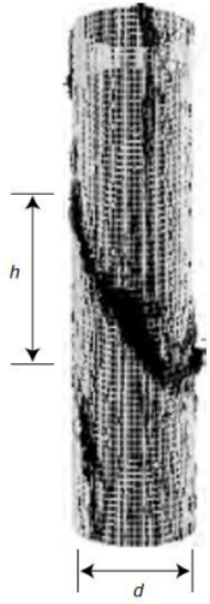
τ

σ_n

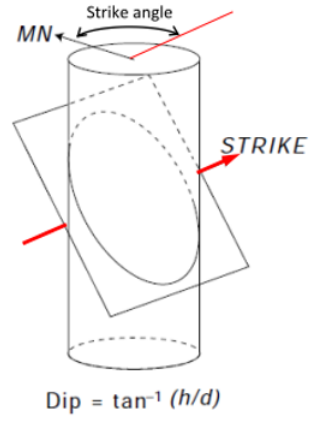
Un-wrapped image
(ultrasonic)



3D-representation



Interpretation



(Zoback 2013, RM, Ch 5.3)

(σ_n, τ)

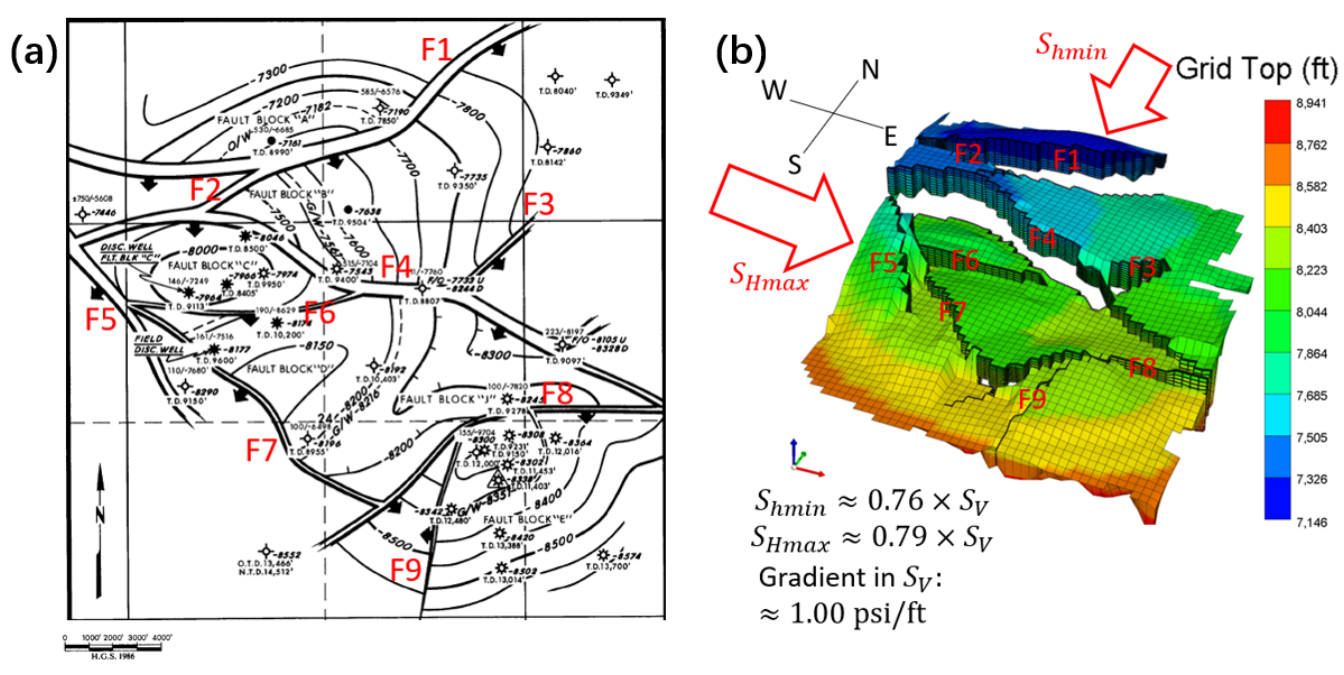
$\mu = 0.5 \pm 0.1$

$60^\circ \pm 10^\circ$

$80^\circ \pm 5^\circ$

$10^\circ \pm 10^\circ$

$60^\circ \pm 5^\circ$


(a)
F1
F2
F3
F4
F5
F6
F7
F8
F9
FAULT BLOCK "A"
FAULT BLOCK "B"
FAULT BLOCK "C"
FAULT BLOCK "D"
FAULT BLOCK "E"
FAULT BLOCK "J"
DISC. WELL
FLT. BLK "C"
FIELD
DISC. WELL
N
0 1000' 2000' 3000' 4000'
H.G.S. 1986
(b)
N
W
E
S
S_{hmin}
S_{Hmax}
Grid Top (ft)
8,941
8,762
8,582
8,403
8,223
8,044
7,864
7,685
7,505
7,326
7,146
$S_{hmin} \approx 0.76 \times S_V$
$S_{Hmax} \approx 0.79 \times S_V$
Gradient in S_V:
≈ 1.00 psi/ft

σ_n / σ_v

τ / σ_v

$P_p/$

$z = 0.44$

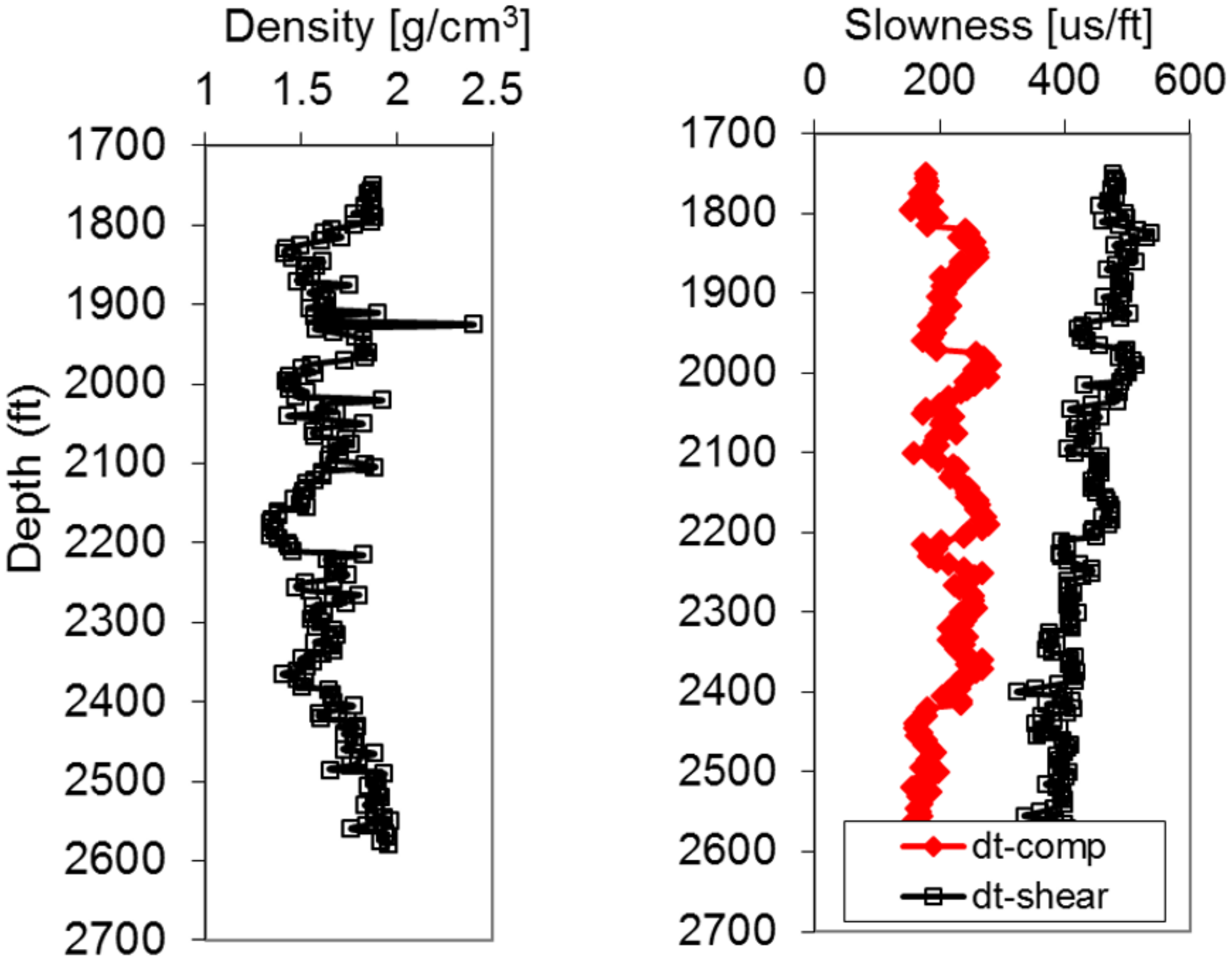
$\mu = 0.6$

$$E_{static} = 0.65 \cdot E_{dynamic}$$

$$E'_{static} = E_{static}/(1-\nu^2)$$

$\varepsilon_{Hmax} = 0.0015$

$\varepsilon_{hmin} = 0$


Density [g/cm³]
1
1.5
2
2.5
Depth (ft)
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
Slowness [us/ft]
0
200
400
600
dt-comp
dt-shear

σ_{xx}

σ_{yy}

ν

UCS

T_s

σ_{rr}

$\sigma_{\theta\theta}$

$\sigma_{r\theta}$

x

y

(r, θ)

r

σ_{xy}

C

P_c

P_p

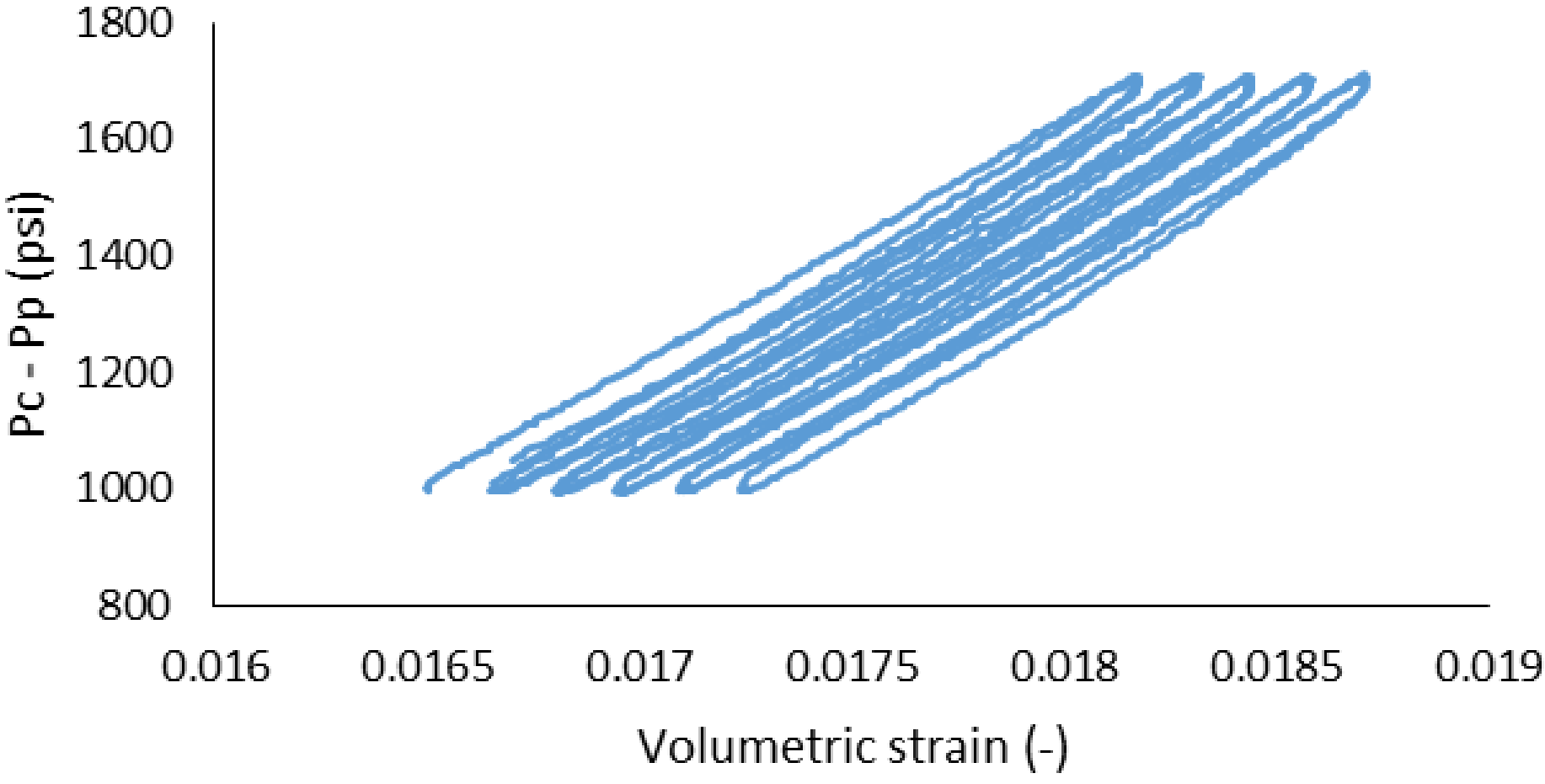
ε_{vol}

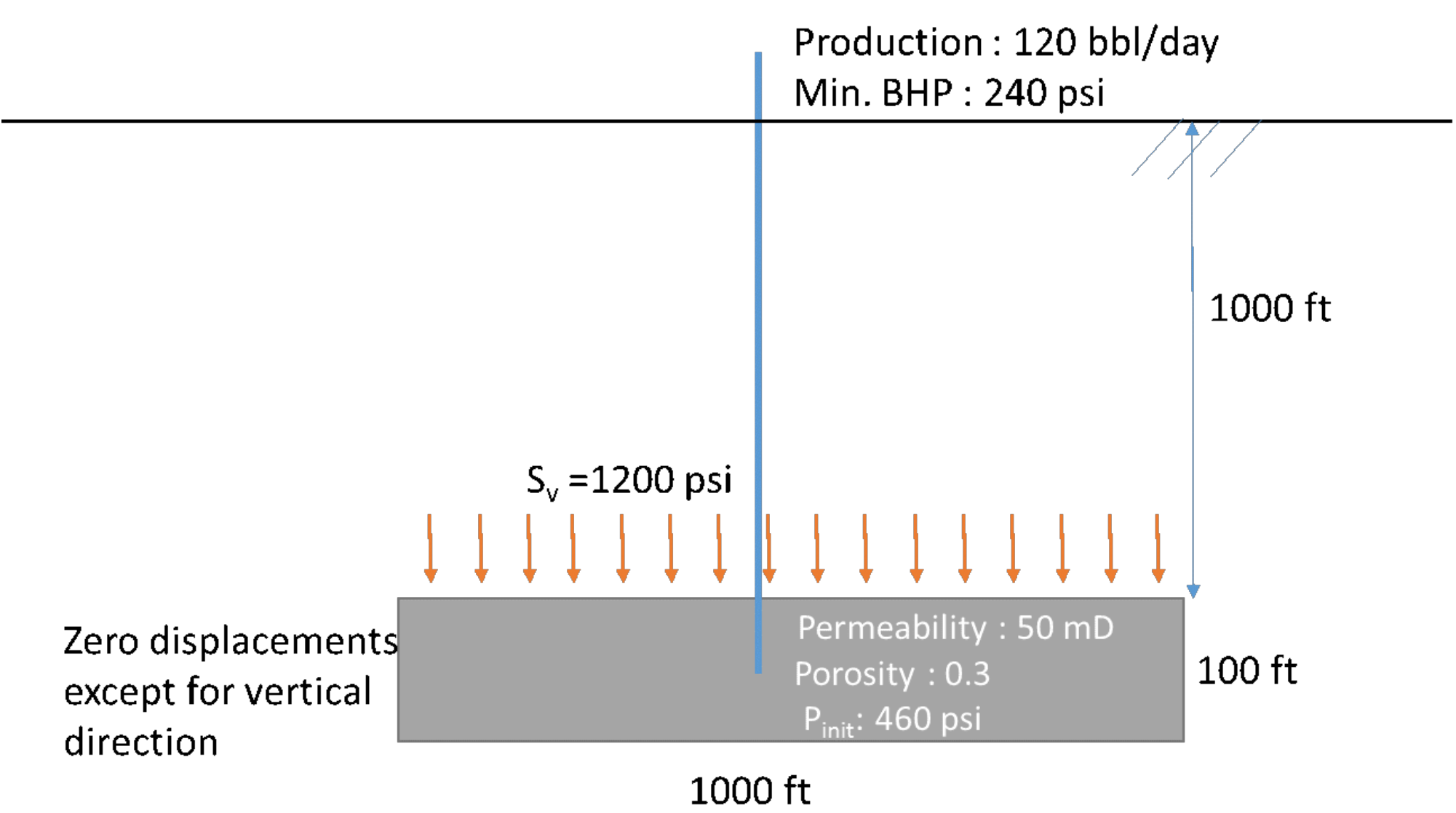
σ_{mean}

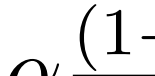
α

α_h

α_v


1800
1600
1400
1200
1000
800
Pc - Pp (psi)
0.016
0.0165
0.017
0.0175
0.018
0.0185
0.019
Volumetric strain (-)


Production : 120 bbl/day
Min. BHP : 240 psi
1000 ft
S_v =1200 psi
Zero displacements except for vertical direction
Permeability : 50 mD
Porosity : 0.3
P_{init}: 460 psi
100 ft
1000 ft



(p', q)

$$\sigma_1 = UCS + q\sigma_3$$

$\left(J_2\right)^{1/2}$

$$P_W = P_p$$

dP_p/dz

dS_v/dz

$$\phi = \phi_0 \exp\left(-\beta \sigma_v\right)$$

$$e = e_0 - C_c \ln\left(\frac{\sigma_v}{1\ \mathrm{MPa}}\right)$$

λ_p

S_v

$\phi_{CS} = 24^\circ$

κ

p'

e

$$d\varepsilon_p^e = \frac{\kappa}{\upsilon}\frac{dp'}{p'};\ d\varepsilon_q^e = \frac{dq}{3G}$$

$$\begin{bmatrix} d\varepsilon_p^p \\ d\varepsilon_q^p \end{bmatrix} = \frac{\lambda-\kappa}{\upsilon p'(M^2+\eta^2)} \begin{bmatrix} M^2-\eta^2 & 2\eta \\ 2\eta & \frac{4\eta^2}{M^2-\eta^2} \end{bmatrix} \begin{bmatrix} dp' \\ dq \end{bmatrix}$$

$v = 1 + e$

$\eta = q/p'$

$$de = \upsilon d\varepsilon_p^p$$

$$dp'_o = d\varepsilon_p^p \frac{\upsilon}{\lambda - \kappa} p'_o$$