Innovative Applications For Stranded Barrels of Oil

Conference

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DETERMINATION OF HYDRAULIC FRACTURE GRADIENTS FROM LEAK-OFF AND WELL INTEGRITY TESTS

Presentation by
Zoltán Péter Székely
Ms in Petroleum engineering
University of Miskolc

Contents

- Introduction
- Theoretical basics of hydraulic fracturing
  - Formation stress
  - Fracture propagation, containment
- Fracture gradient determination
- Results

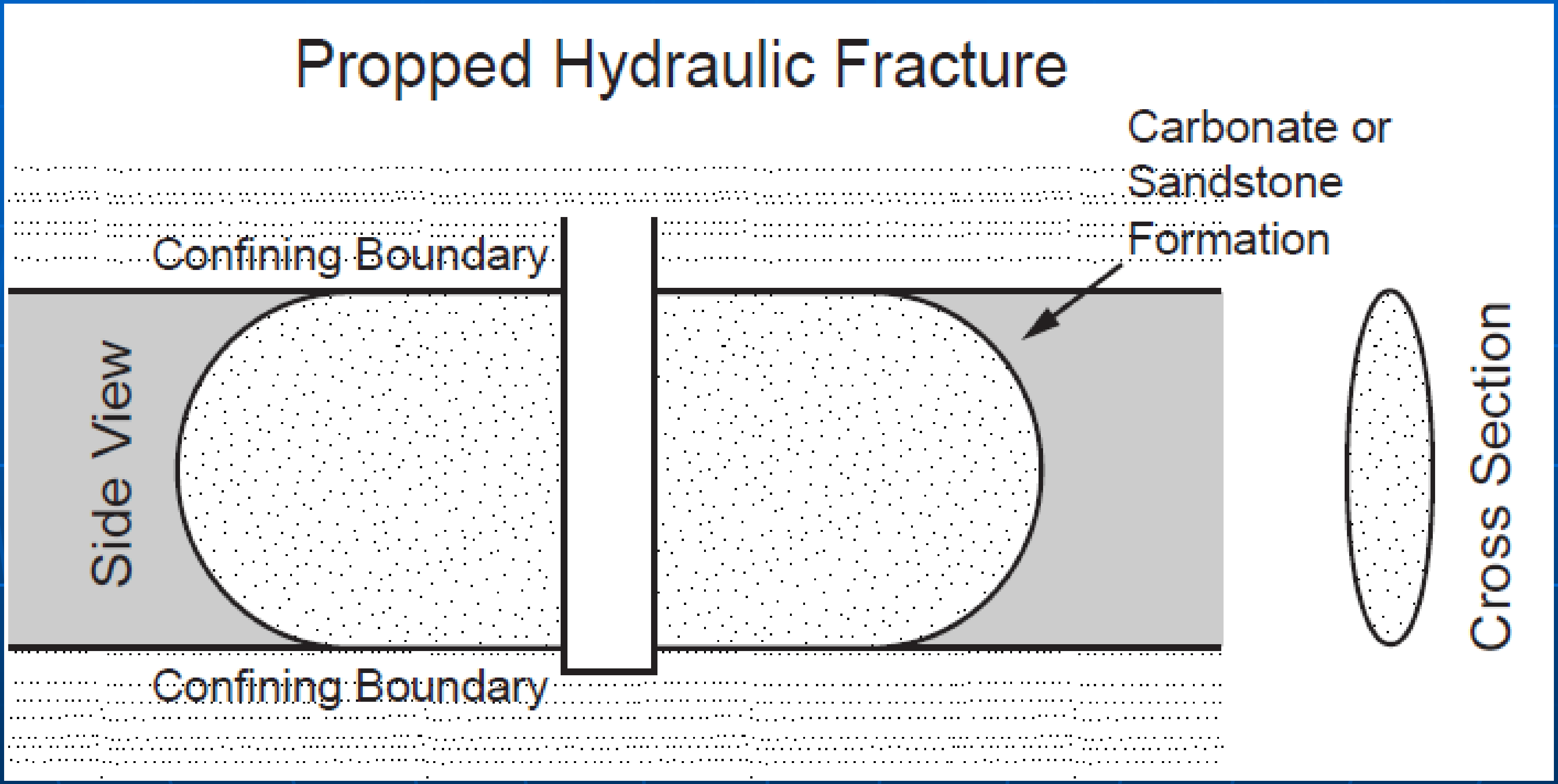
Introduction

- What is hydraulic fracturing?
  - Creates new, highly conductive flow paths
  - Viscous fluid is pumped into the formation
  - Fracture is filled with proppant
  - Significantly better production rate

Introduction

- Width: 5-35 mm
- Length: 100m or more

- Permeability
- Oil wells > 5 mD
- Gas wells > 1 mD

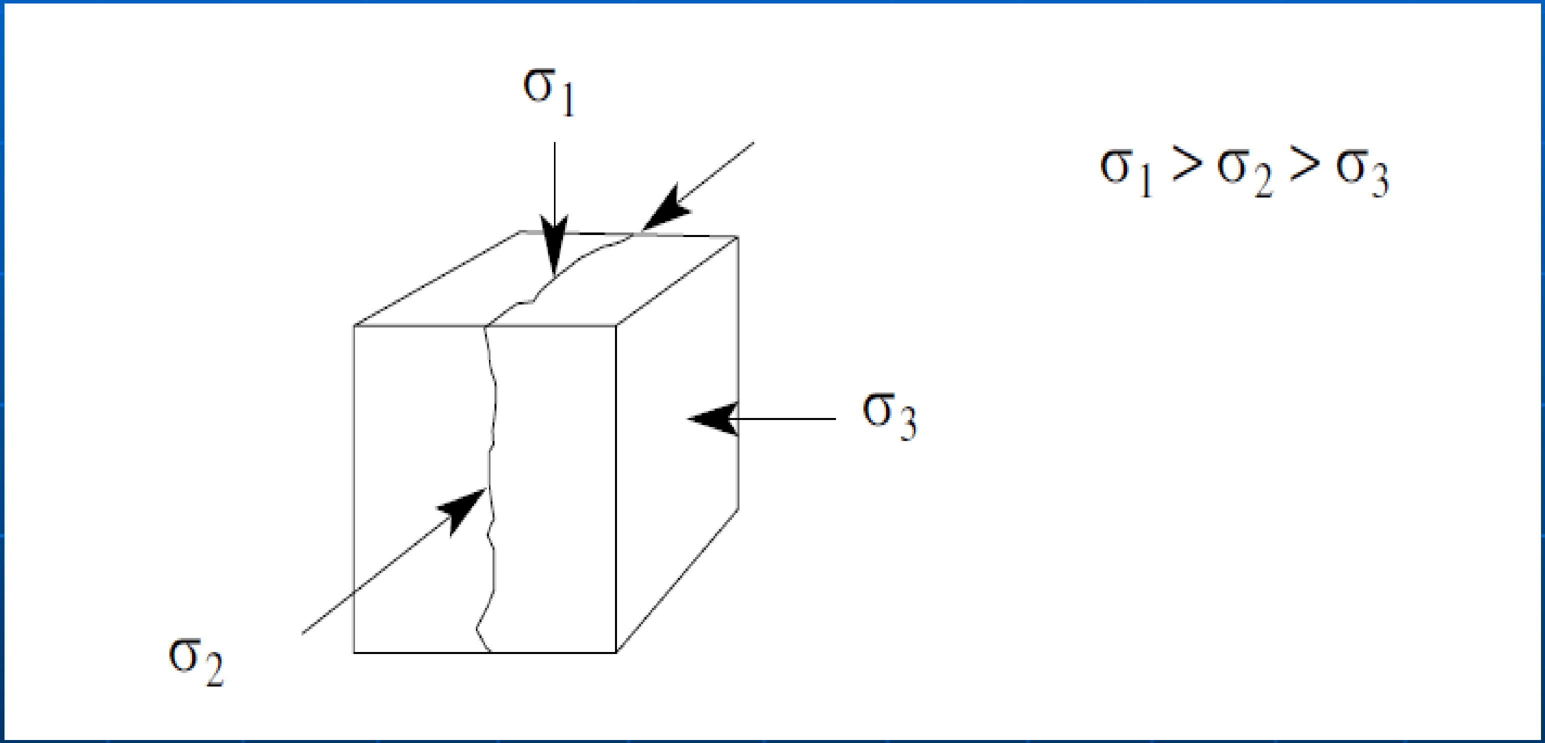


Source: Hydraulic fracturing manual, Heriot-Watt University

Formation stress

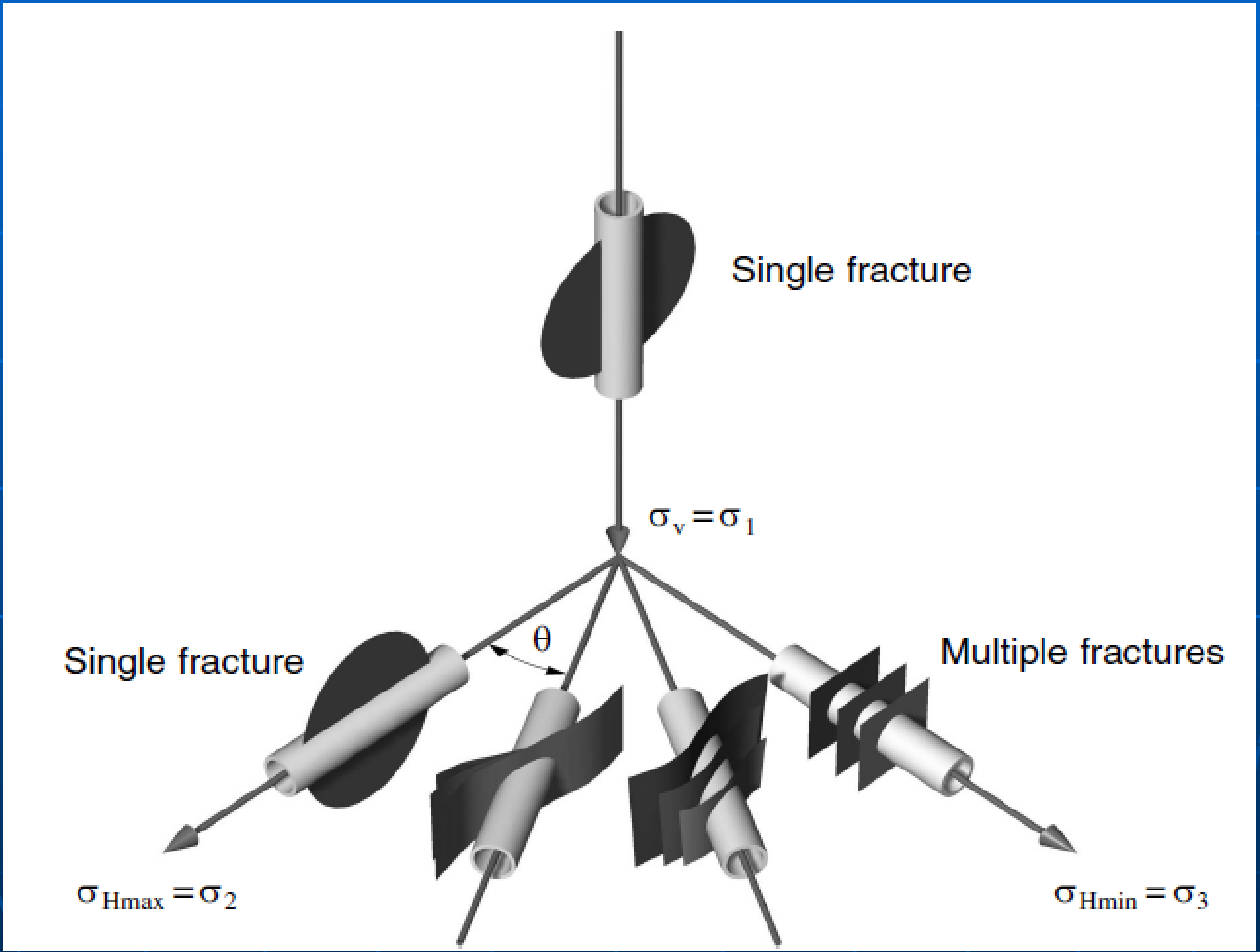
- Three principal stress components
  - Vertical: usually the largest
    can be measured or 1 psi/ft gradient
  - Two horizontal: can be obtained by
    calculations
- Poisson’s ratio
  - normal value is $v = 0.25$
- The fracture propagates in the direction of least resistance

In-situ stress field



Source: Shell Hydraulic fracturing manual

Fracture geometry

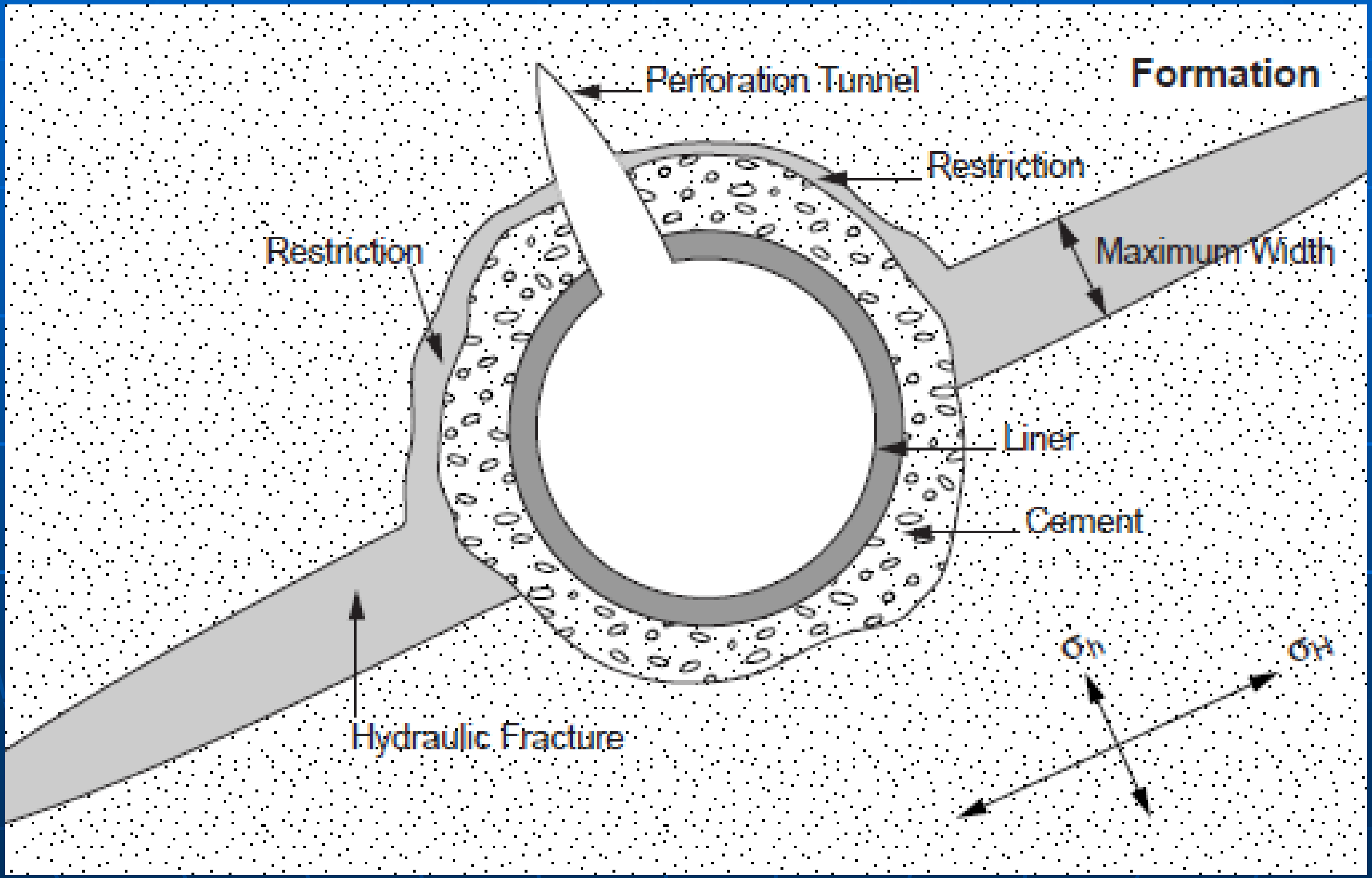


Source: Shell Hydraulic fracturing manual

Fracture propagation

- Net pressure
  - Treatment's pressure must overcome the different forces in the formation
- Affecting factors:
  - Fluid friction
  - Fluid leakoff
  - Elastic fracture opening
  - Breaking rock at fracture tip
- Perforation orientation is important factor

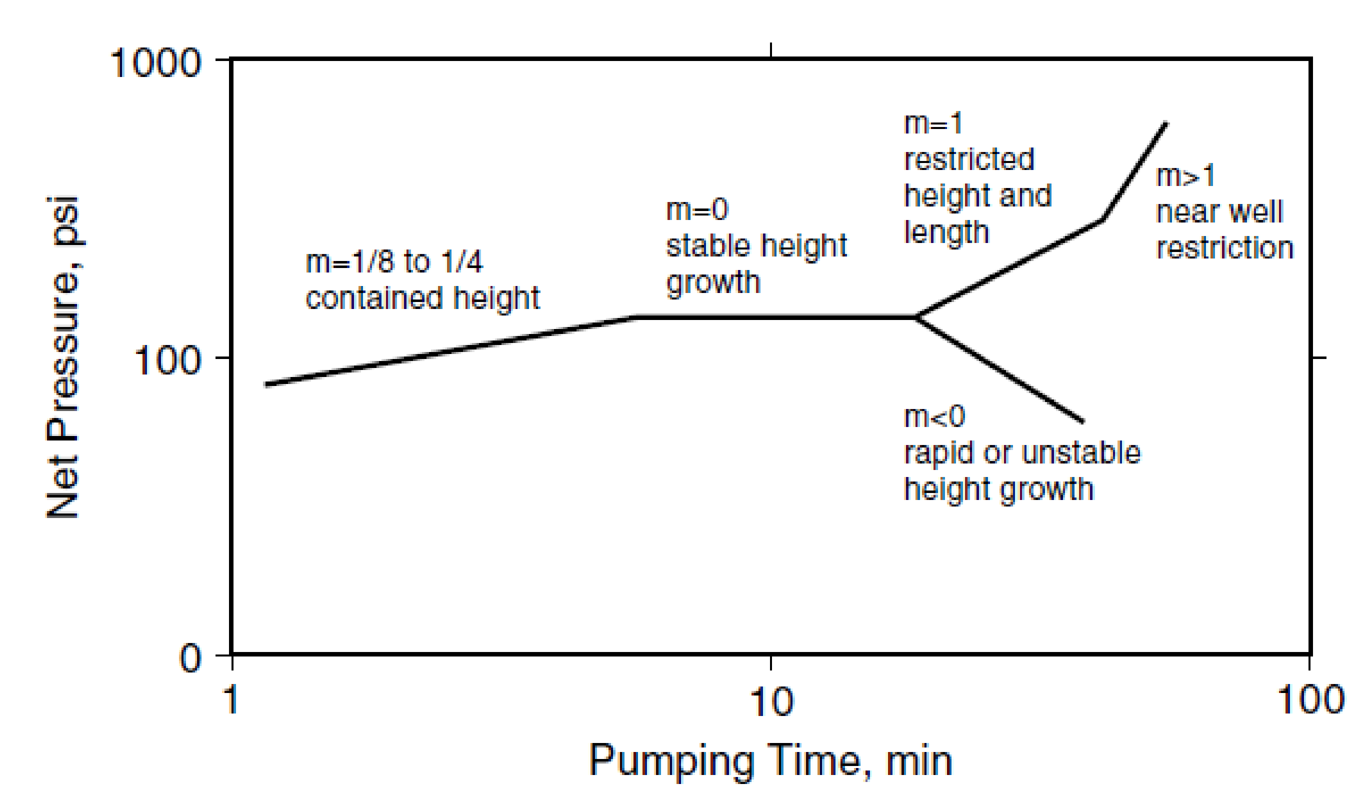
Perforation orientation



Source: Hydraulic fracturing manual,
Heriot-Watt University

Fracture growth analysis

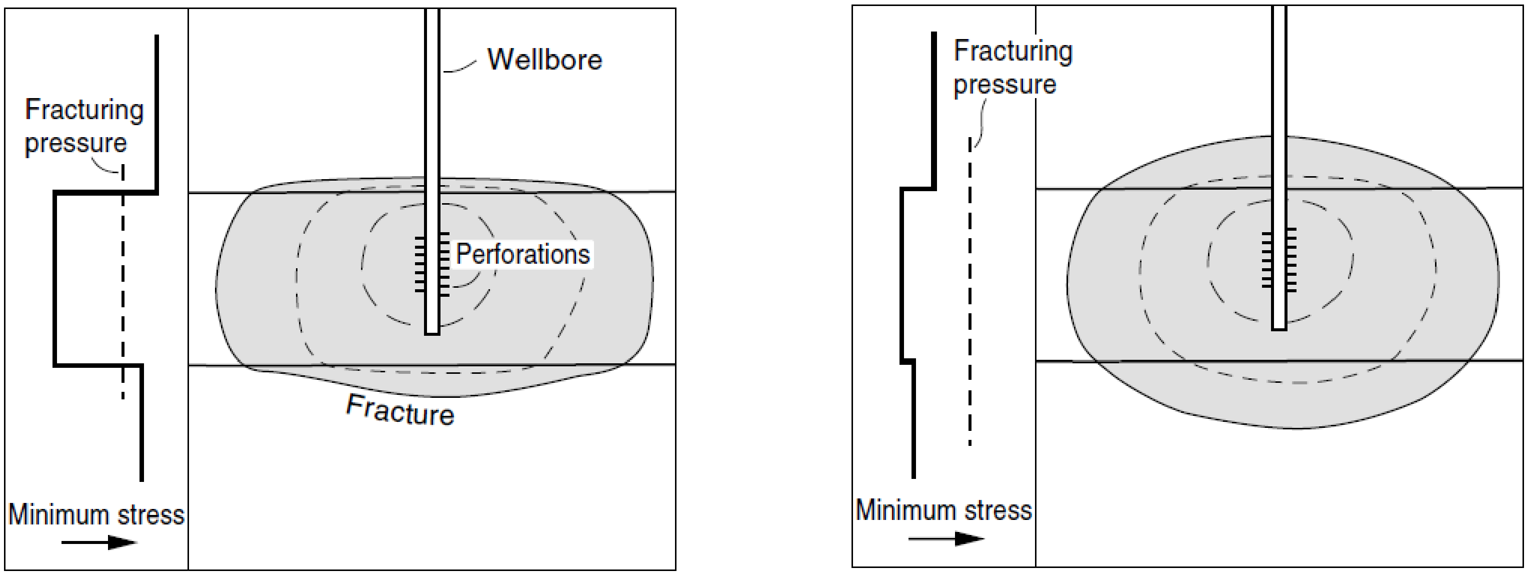
- Nolte and Smith plot



Fracture containment

- Lithological contrast
- Mainly vertical containment
- Main influencing factors
  - Young’s modulus
  - Poisson’s ratio
  - High leak-off

Fracture containment



a Large stress contrast

b Small stress contrast

Source: Shell Hydraulic fracturing manual

Data gathering

- Minifrac (<50 m^3)
- Microfrac (<5 m^3)
- Leak-off test
  - Cost effective
  - Less accurate

Fracture gradient determination

- Planning of a drilling program
- Calculation of MAASP
- Calculation of kick tolerances
- Estimation of pressures required for hydraulic fracturing

Fracture gradient determination

- Eaton's method
  - $$F = \left(\frac{S-P}{D}\right) * \left(\frac{v}{1-v}\right) + \frac{P}{D}$$
  - Where: *v* is Poisson's ratio
    F is fracturing gradient [psi/ft]
    P is pore pressure [psi]
    D is depth [ft]
    S is overburden stress [psi]

Results

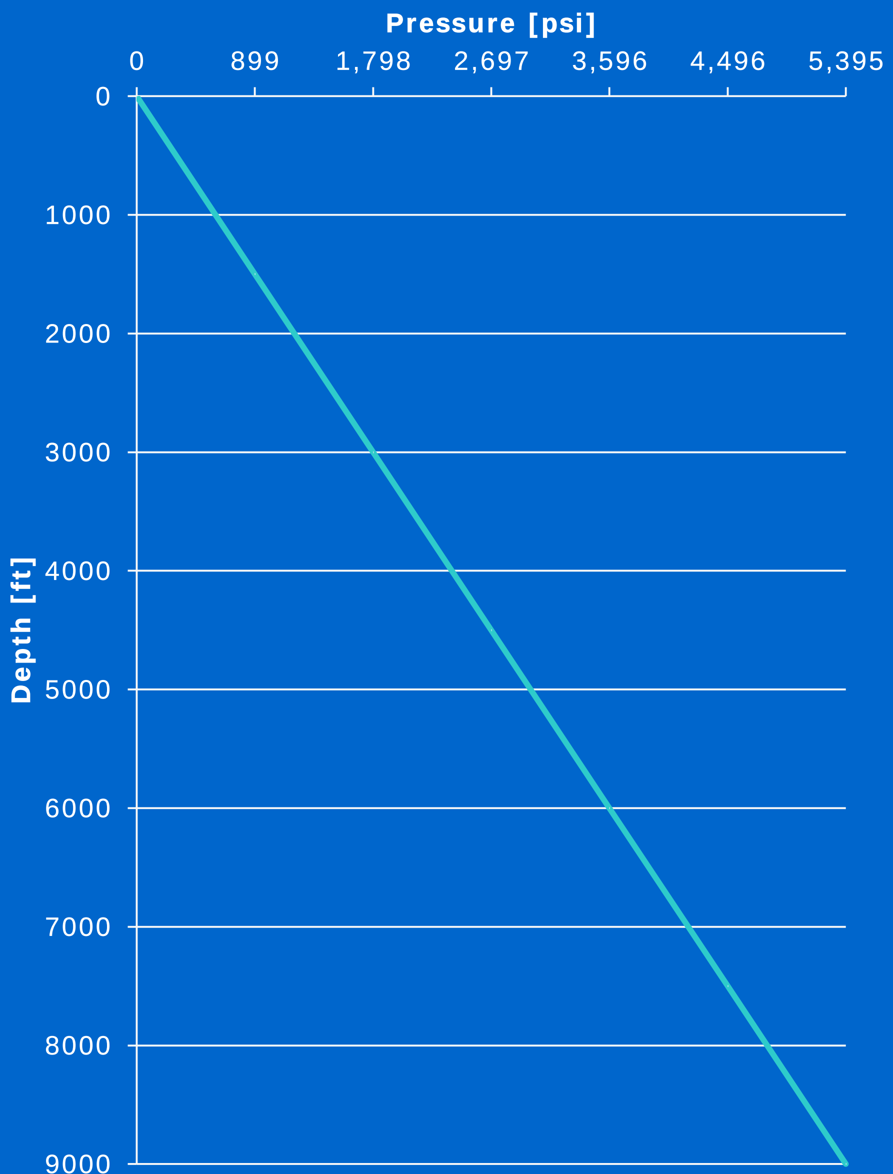
- 200 wells analysed
- Two methods used
- Calculation with standard and modified Poisson's ratio
- Assumption of 0,442 psi/ft formation gradient

Vienna
Bratislava
Eisenstadt
Gyor
Tatabanya
Budapest
Salgotarjan
Miskolc
Eger
Nyiregyhaza
Satu Mare
Debrecen
Oradea
Szombathely
Szekesfehervar
Veszprem
Zalaegerszeg
Szolnok
Kecskemet
Bekescsaba
Arad
Kaposvar
Szekszard
Pecs
Timisoara
Bér-1
Hatvan-É-1
Mogyoród-2
Valkó-1
Tó-D-6
Tó-D-7
Tó-D-4
Tó-D-5
Nkáta-3
Tbics-1
Csh-2
Ócsa-4
Ócsa-2
Bar-1
Ráckeve-1
Ráckeve-Ny-1
Tiszi-3
Tiszi-2
Hsz-197
Hsz-198
Hsz-196
Léta-1
Léta-2
Mpi-D-1
Mpi-K-1
Karcag-ÉK-2
Pü-K-1
Beru-1
Föl-23
Hen-1
Beru-6
Beru-4
Beru-2
Bem-D-1
Zsáka-1
Sas-Ny-2
Sas-Ny-10
Komádi-Ny-2
Mgyán-D-1
Nk-D-3
Nsz-ÉK-1
Szabadk-1
Pf-É-1
Psz-57
Kág-4
Mbh-K-2
Mbh-K-3
Tompu-1
Tompu-2
Mh-DK-1
Mh-DK-2
Páhi-2
Szk-148
Zsana-É-68
Zsana-É-72
Ü-73
Szmt-1
Algyő-Ny-2
Makó-Ny-1
Borota-2
Jh-D-1
Zomba-1
Kerb-1
Zab-1
Radi-1
Pöt-2
HE-92
Torm-1
Zal-É-1
Zal-2
Sző-K-1
Sika-1
Nr-M-1
Be-M-1
Be-24
Be-K-2
Őrtilos-1
Ber-2
Víz-S-1
Víz-S-2
Víz-D-1
Her-D-1
Phida-1
Potony-1
Barcs-Ny-1
Lakócsa-1
Zaláta-1
Zaláta-K-1
0 12.5 25 50 75 100
km
N
W
E
S
ESRI

Example

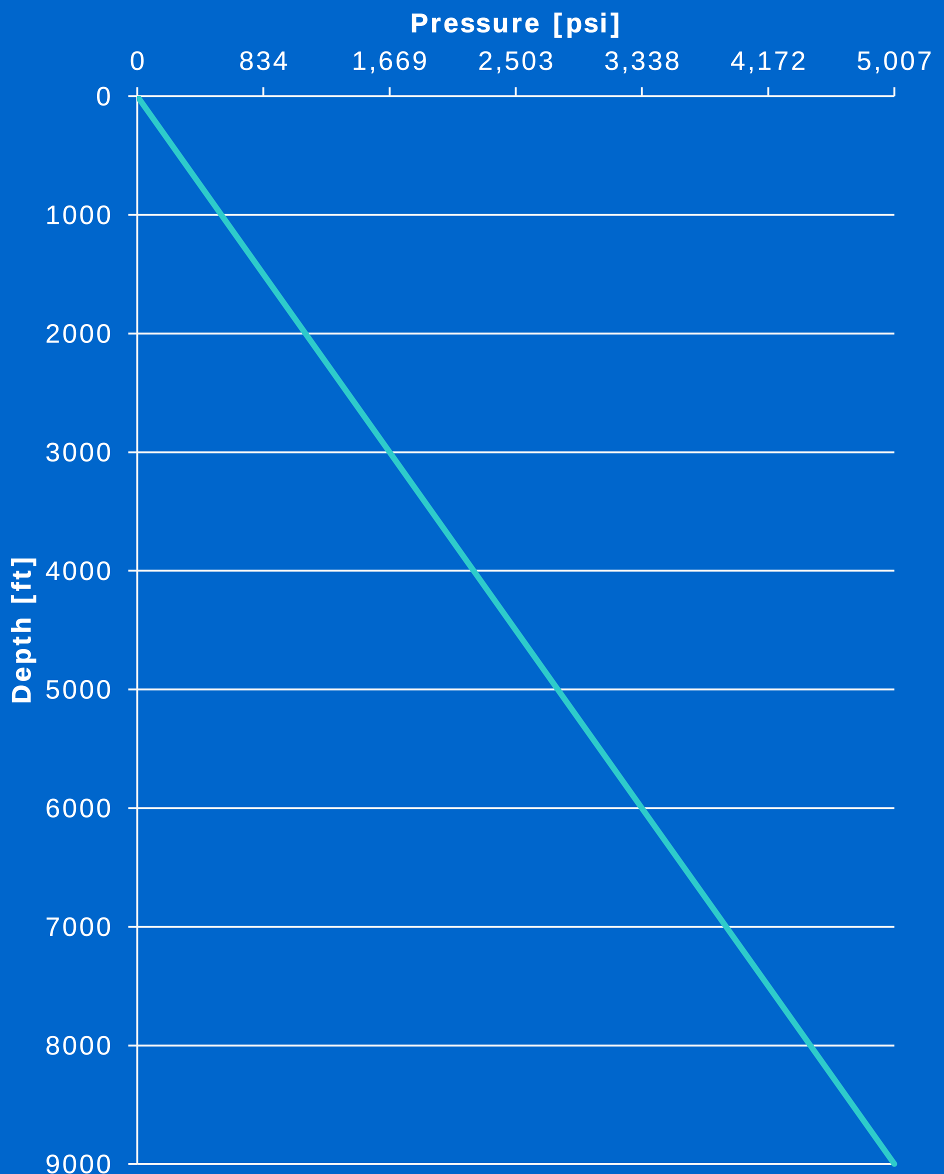
Legal Well Name	Pressure [psi]	TVD [ft]	Pore pressure [psi]	Hubbert Willis [psi]	Eaton / 0,25 Poisson [psi]	Eaton / different Poisson [psi]	Fracture pressure [psi]	Formation	Poisson ratio	Gradient [psi/ft]
Algyő-Nyugat-2	638	3352,2	1481,655	2105,16	2105,2	2209,073	2119,654	siltstone sand	0,28	0,659
Csanádapáca É-2	507,5	2889,7	1277,24	1814,72	1814,7	1732,029	1784,738	sandstone	0,22	0,599385

Fracture gradient of sandstones



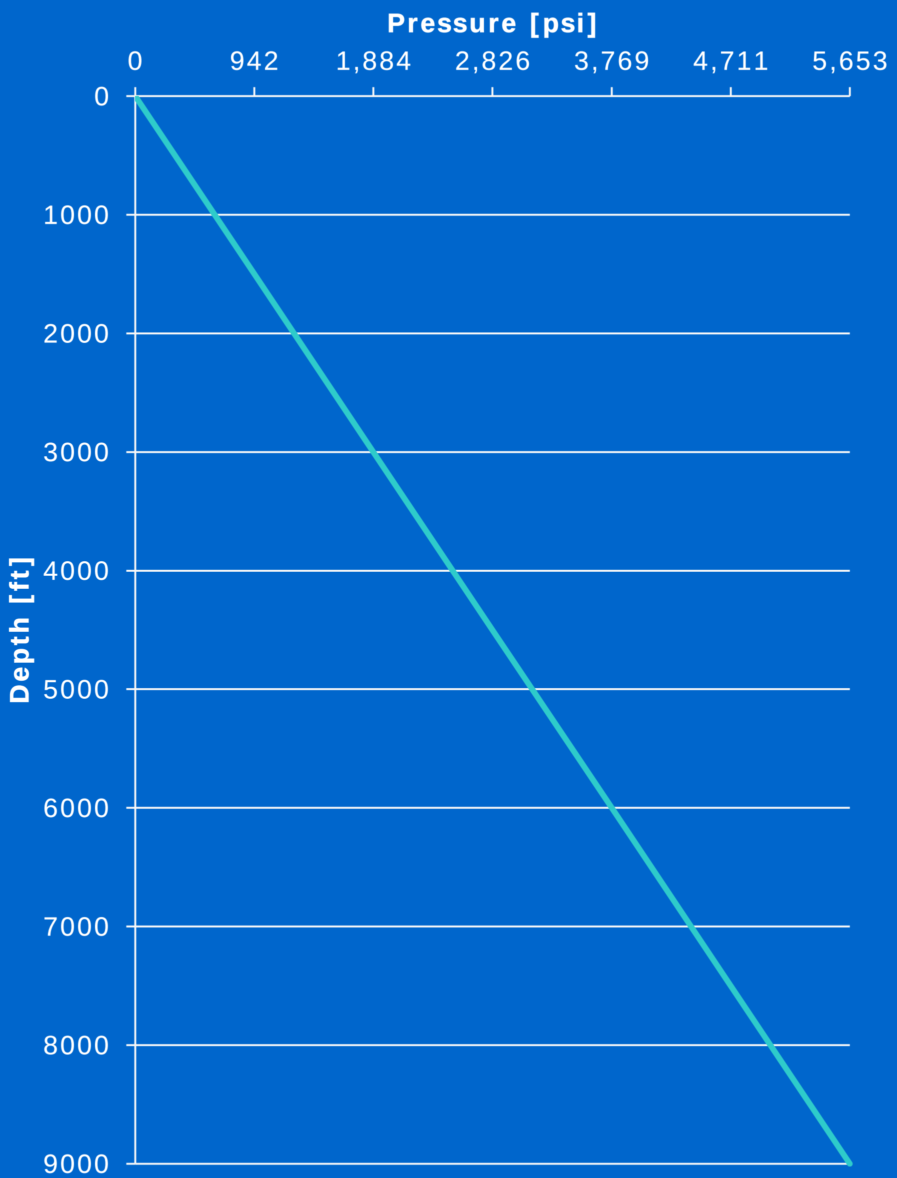
Gradient=0,5994 psi/ft

Fracture gradient of limestones



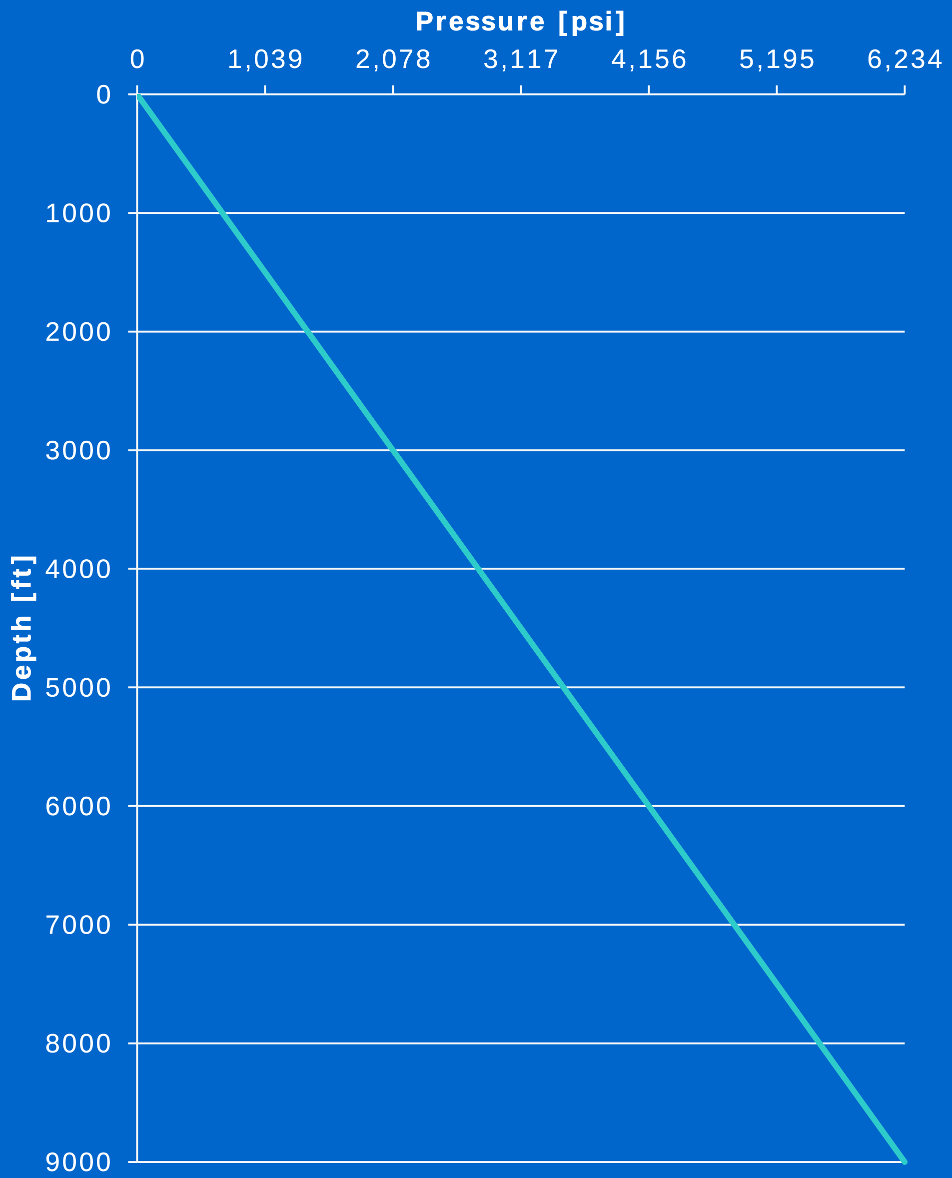
Gradient=0,5563 psi/ft

Fracture gradient of siltstones



Gradient=0,6281 psi/ft

Fracture gradients of clay marls



Gradient=0,6927 psi/ft

THANK YOU FOR YOUR KIND ATTENTION!

Any question?