Predicating formation pressures

Formation pressure can be the major factor affecting drilling operations. If pressure is not properly evaluated, it can lead to drilling problems such as lost circulation, blowouts, stuck pipe, holes instability, and excessive costs. Unfortunately, formation pressures can be very difficult to quantify precisely where unusual, or abnormal, pressures exist.

The complete well planning process, with few exceptions, is predicated on a knowledge of formation pressures. As shown in Fig.1, the pressure is the foundation for many segments of the well plan. If proper attention is not given to formation pressure predictions, the other technical portions of the well plan may be inadequate.

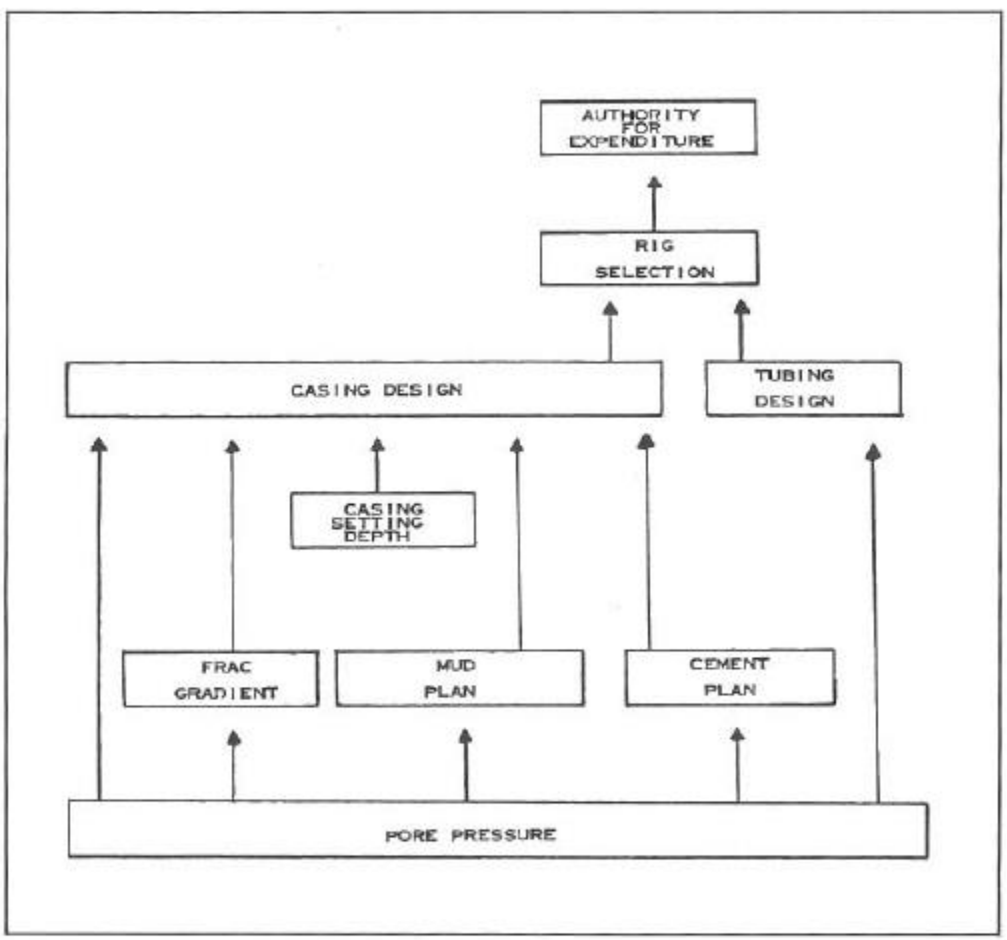


Fig. 1: Schematic illustrating the impact of pore pressures on the major segments of a well plan

Pressure Prediction Methods

Several methods of pressure prediction are available to the engineer. These methods can be grouped logically as follows:

1. Areal analysis from seismic data
2. Offset well correlation
   - log analysis
   - drilling parameter evaluation
   - production or test data
3. real-time evaluation
   - qualitative
   - quantitative

The real-time analysis involves monitoring drilling and logging parameters while the prospect well is drilled.

Knowledge of formation pressures is vital to the safe planning of a well. Accurate values of formation pressure are used to design safe mud weights to overcome fracturing the formation and prevent well kicks.

All wellbores pressures (formation pressure, fracture pressure, fluid density and overburden pressure) are measured in terms of hydrostatic pressure.

Formation pressure : formation of a well contain pressure which may vary in magnitude depending on depth location and proximity to other structures.

Pressure gradient: is the rate of increase in pressure per unit vertical depth i.e, psi per foot (psi/ft). note: psi = lb/in^2

ppg is also gradients

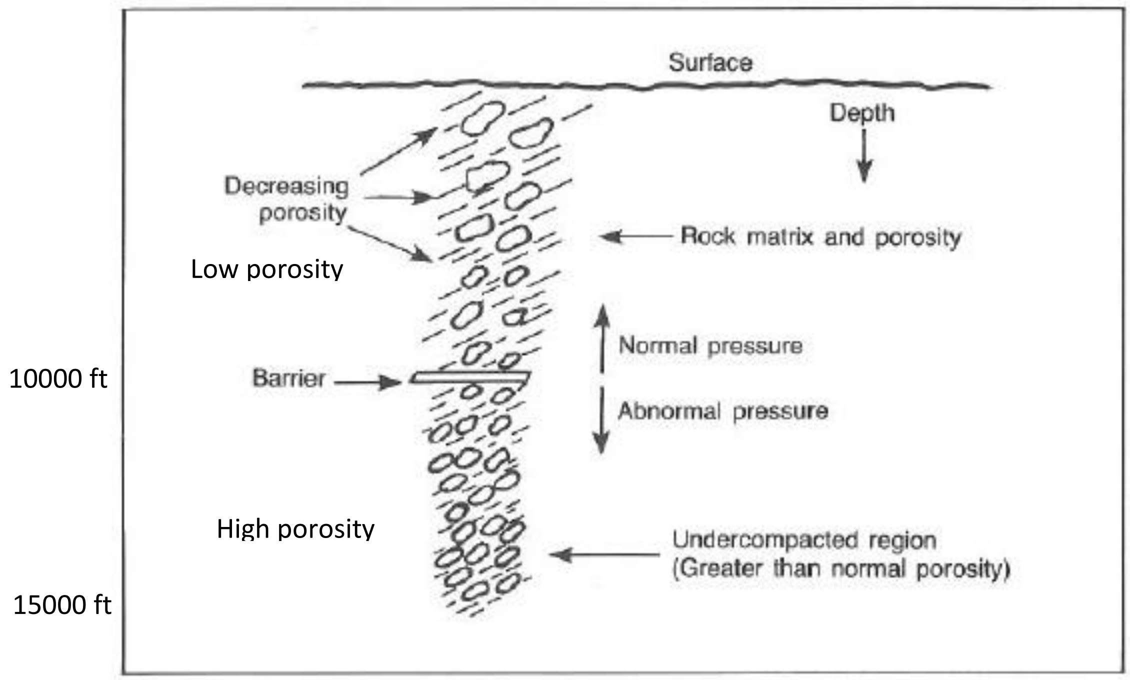
HG = HP/D ------------ (psi/ft)

HG: Hydrostatic pressure gradient

HP: Hydrostatic pressure.

Example : A well is to be drilled to 15,000 ft. The entrance into abnormal pressures at 10,000 ft is caused by under compaction. Calculate the expected formation pressure at 15,000 ft. Assume that the formation fluid and overburden stress gradients are 0.465 psi/ft and 1.0 psi/ft, respectively.

To solve this example, we have to know:



Formation pressure at 15000 ft means under barrier (abnormal pressure), can be calculated using eq. below:

$P=0.465psi/ft.D_B+1.0psi/ft(D_I-D_B)$

D_B= depth of the barrier, i.e, low permeability section, ft.

P=formation pressure at D_I, psi.

D_I=depth of interest below the barrier, ft

The normal formation fluid pressure gradient is 0.465 psi/ft.

The overburden pressure gradient is assumed to be 1.0 psi/ft.

P=0.465psi/ft(10000)+1psi/ft (5000)

=4650psi+5000psi

=9650psi

=12.4 lb/gal EMW

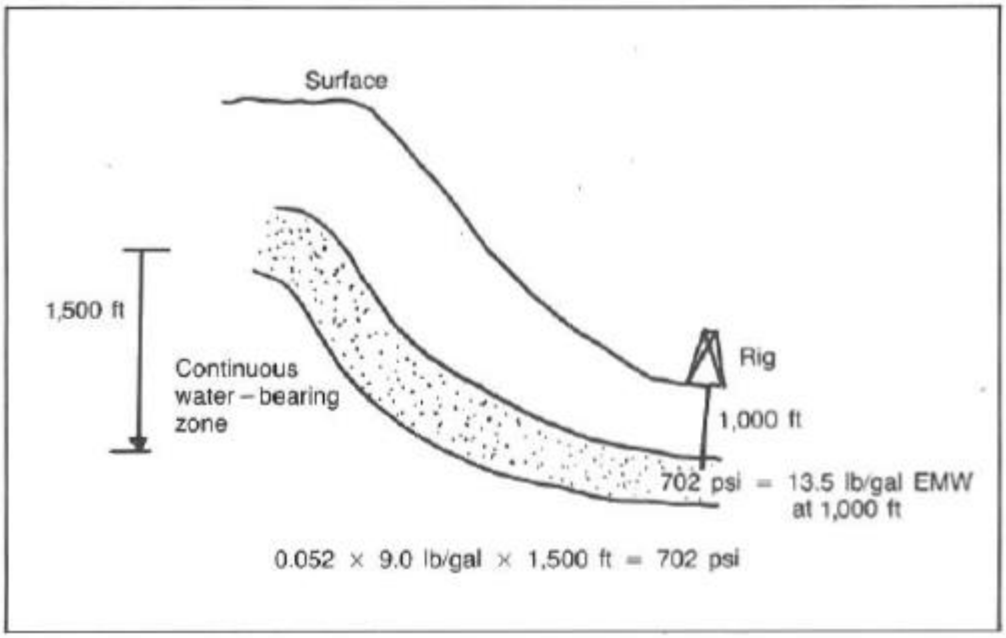
9650/(0.052*15000)=12.4 lb/gal.

Example: (Hydrostatic Pressure) calculate the hydrostatic pressure for the following wells:

a. Mud weight = 9 ppg, hole depth = 10100 ft (measured depth), 9900 ft TVD (true vertical depth).
b. Mud gradient 0.468 psi/ft, hole depth= 10100ft MD (measured depth), 9900 ft TVD.

a. HP=0.052xρ_f(ppg)xD_{ft} = 0.052 x 9 x 9900=4632 psi
b. HP=fluid gradient (psi/ft)*depth (ft) =0.468psi/ft * 990=4633psi

Example: calculate EMW at 1000 ft.



EMW= 702/(0.052 x 1000)=13.5 ppg

Porosity and Permeability

Porosity: is the total pore (void) space in a rock.

Permeability: is the ease with which fluid can flow through the rock.

Overburden pressure:

The overburden pressure is defined as the pressure exerted by the total weight of overlying formation above the point of interest.

The total weight is the combined weight of both the formation solids (rock matrix) and formation fluids in the pore space.

The density of the combined weight is referred to as the bulk density (ρ_b).

$$\sigma_{ov} = 0.052\rho_b D$$

σ_{ov}= overburden pressure, (psi)

ρ_b= formation bulk density (ppg)
D=true vertical depth (ft)

Gradient (EMW) in ppg:

$$\sigma_{ovg} = \frac{0.433\rho_b}{0.052}$$

σ_{ovg}= overburden gradient, ppg
ρ_b= formation bulk density (gm/cc)
0.433= converts bulk density from gm/cc to psi/ft.

$$\sigma_{ovg} = 0.433[(1-\varphi)\rho_{ma} + (\varphi\rho_f)]$$

σ_{ovg}= overburden gradient, psi/ft
φ= porosity expressed as a fraction
ρ_f=formation fluid density, gm/cc
ρ_{ma}= matrix density, gm/cc

Using this equation when the calculations or the density unit is gm/cc. because this equation useful in petroleum productions.

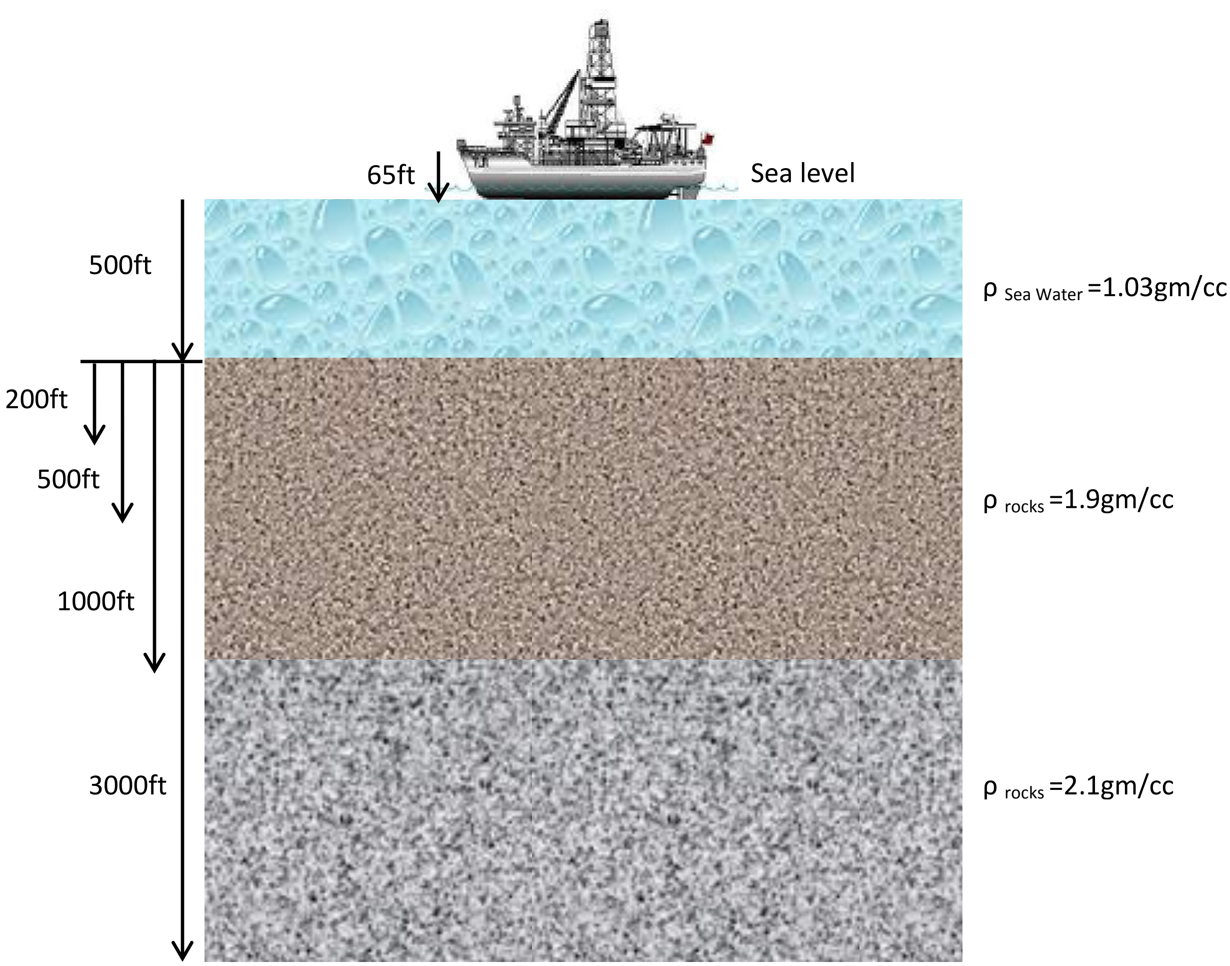
Example: calculate the overburden gradient for the following:
Formation type: sandstone=2.65gm/cc
Formation water:1.03 gm/cc
For porosity: 5%, 20%, 35%

For Sandstone
For φ=5%
$\sigma_{ovg} = 0.433[(1-0.05)2.65 + (0.05 * 1.03)]$
= 1.11 psi/ft
For φ=20%
$\sigma_{ovg} = 0.433[(1-0.2)2.65 + (0.2 * 1.03)]$
= 1.01 psi/ft
For φ=35%
$\sigma_{ovg} = 0.433[(1-0.35)2.65 + (0.35 * 1.03)]$
= 0.9 psi/ft

Example : Determine the overburden gradient at various depths for the following offshore well:
Water depth = 500 ft
RK/MSL = 65 ft
Rotary table, Kelly
Means, Sea, Level
specific gravity of sea water = 1.03 gm/cc
rock density =1.9 gm/cc from seabed to 1000 ft and 2.1 gm/cc from 1000-3000ft.
Calculate the overburden gradient of the formations:
at seabed, 200 ft, 500 ft, 1000 ft and at 3000ft below seabed.

Sol.:
To convert densities from gm/cc to psi/ft we have use factor 0.433

a. At seabed



HP of water =0.433 . ρ . h = 0.433 . 1.03 . 500 = 233psi

Overburden gradient at sea bed
OBG=(0.433 . $\rho_{sea\text{-}water}$. h)/total depth at seabed
= 223/(65+500)= 0.395psi/ft
= 0.395/0.052 = 7.6ppg

b. At 200ft below sea bed
Water pressure =223psi
Formation pressure=0.433 . ρ_{rocks} . h = 0.433 . 1.9 . 200 =164.54psi

OBG at 200ft = (223+164.54)/(65+500+200)=0.507psi/ft
= 0.507/0.052=9.74ppg

c. At 500ft below sea bed
Water pressure =223psi
Formation pressure=0.433 . ρ_{rocks} . h = 0.433 . 1.9 . 500 =411.4psi

OBG at 200ft = (223+411.4)/(65+500+500)=0.605psi/ft
= 0.605/0.052=11.6ppg

d. At 1000ft below sea bed
Water pressure =223psi
Formation pressure=0.433 . ρ_{rocks} . h = 0.433 . 1.9 . 1000 =822.7psi

OBG at 200ft = (223+822.7)/(65+500+1000)=0.668psi/ft
= 0.668/0.052=12.9ppg

e. At 3000ft below sea bed
Water pressure =223psi
Formation pressure at3000=0.433 . ρ_{rocks} . h = 0.433 . 1.9 . 1000 =822.7psi

Formation pressure from 1000 to 3000=0.433 . ρ_{rocks} . h = 0.433 . 2.1 . 2000
=1818.6psi
OBG at 3000ft = (223+822.7+1818.6)/(65+500+3000)=0.805psi/ft
= 0.805/0.052=15.5ppg