Subsurface Geology of Oil and Gas Fields

Introduction

Chapter 1 Drilling Geology

Chapter 2 Evaluation Oil, Gas and Water Formation

Chapter 3 Stratigraphic Classification and Stratigraphic Correlation

Chapter 4 Subsurface Structure Research

Chapter 5 Formation Pressure and Formation Temperature

Chapter 6 Reserves Calculation

Hydrocarbon Reservoir

Two main issues which need to be resolved; firstly how much oil does the reservoir contain, and secondly how much can be recovered.

Chapter 5 Formation Pressure and
Formation Temperature

Chapter 6 Reserves Calculation

Chapter 5 Formation Pressure and Formation Temperature

Section 1 Initial Pressure and the Distribution in the Reservoir

Section 2 Abnormal Formation Pressure

Section 3 Formation Temperature

Chapter 5 Formation Pressure and Formation Temperature

Section 1 Initial Pressure and the Distribution in the Reservoir

I. Pressure Concept

1. fluidstatic pressure

2. overburden pressure

3. formation pressure

Section 1 Initial Pressure and the Distribution in the Reservoir

I. Pressure Concept

1. P_H(fluidstatic pressure) is caused by vertical column height

$$P_H=\rho \bullet H/10$$

ρ---fluid density, g/cm^3

H---height of liquid column, m

} → P_H--kg/cm^2

SI----International System of Units

Pressure unit---- Pascal, Pa

$1kg/cm^2 = 9.8*10^4Pa \approx 0.1MPa$

Section 1 Initial Pressure and the Distribution in the Reservoir

I. Pressure Concept

1. P_H(fluidstatic pressure)

fluidstatic pressure gradient:

the pressure on unit liquid column height

$$G_H = P/H = \rho \cdot H/10H = 0.1\rho$$

units: MPa/m

For example

Salinity ↗, density ↗ ➡ P_H ↗, G_H ↗

Solution gas ↗ ➡ PH ↘ , G_H ↘

Section 1 Initial Pressure and the Distribution in the Reservoir

I. Pressure Concept

1. P_H (fluidstatic pressure)

hydrostatic pressure

hydrostatic pressure gradient:

hydrostatic pressure on the unit liquid column height

formation water density:

$1 g/cm^3$ → $0.01 MPa/m$ **hydrostatic pressure gradient**

pressure gradient:

The unit is MPa/m or kPa/m, it is the metric unit
or SI (system of international unit);
psi/ft (English unit ）1psi =6.8965kPa=0.068atm

The pressure gradient is related to density. **If ground water is studied, then the Gw is called hydrostatic pressure gradient.**

The value is from 0.01MPa/m (fresh water) to 0.0115MPa/m (salt saturated brine).

Notice that the density of water, oil and gas are so significantly different. They will show quite different gradients on a pressure-depth plot.

This feature is very useful to define the interface between fluids.

Section 1 Initial Pressure and the Distribution in the Reservoir

I. Pressure Concept

2. Overburden pressure

The pressure caused by the total weight of overburden rock framework and liquid in pores.

$$P_o = H[(1-\bar{\Phi})\bar{\rho}_{ma} + \bar{\Phi}\bar{\rho}_f]/10$$

P_o: overburden pressure;

H: overburden vertical height

$\bar{\Phi}$: average porosity

$\bar{\rho}_{ma}$: matrix average density

$\bar{\rho}_f$: fluid average density

Section 1 Initial Pressure and the Distribution in the Reservoir

$$P_o = \sigma + P_f$$

P_o ---- overburden pressure

P_f ---- fluid pressure

σ ---- the stress between the rock grains

At a given depth, the OBP remains constant. With the production of the reservoir fluid, the less fluid pressure is, the more the grain stress is. Vice versa.

$$P_o = H[(1-\bar{\Phi})\bar{\rho}_{ma} + \bar{\Phi}\bar{\rho}_f]/10$$

$$P_o = \sigma + P_f$$

$$Po = \overline{\rho}_b \cdot H/10$$

$$G_0 = P_0/H = \overline{\rho}_b/10$$

$\overline{\rho}_b = 2.31 g/cm^3$ ➡ $G_0 = 0.0231 MPa/m$

$$P_o = \sigma + P_f$$

Section 1 Initial Pressure and the Distribution in the Reservoir

I. Pressure Concept

3. Formation pressure--P_f

Pressure on rock pore fluid (oil, gas, water) is also called pore fluid pressure or pore pressure

Pi--initial reservoir pressure/ initial formation pressure

P_b--bottom-hole pressure

Producing pressure drawdown

I. Pressure Concept

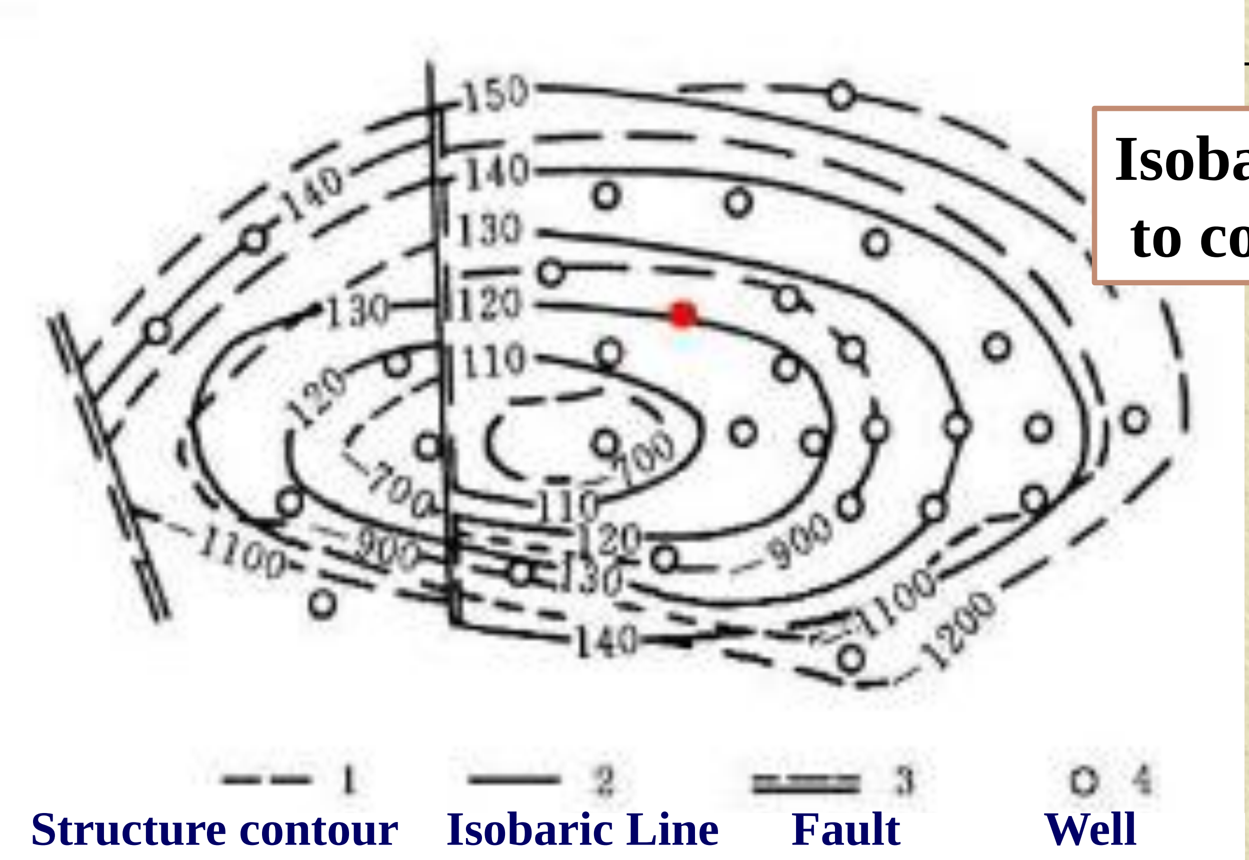
3. Formation Pressure

Pi--initial reservoir pressure,

initial formation pressure

The original state of pressure when the formation is undrilled

Initial pressure (formation pressure) isobaric map



Isobar is parallel to contour line

Initial pressure isobaric map

Initial pressure isobaric map of an oil field

Application of isobaric map

（1）To predict new well Pi

Thus can be used to confirm casing program and drilling fluid density of a new well

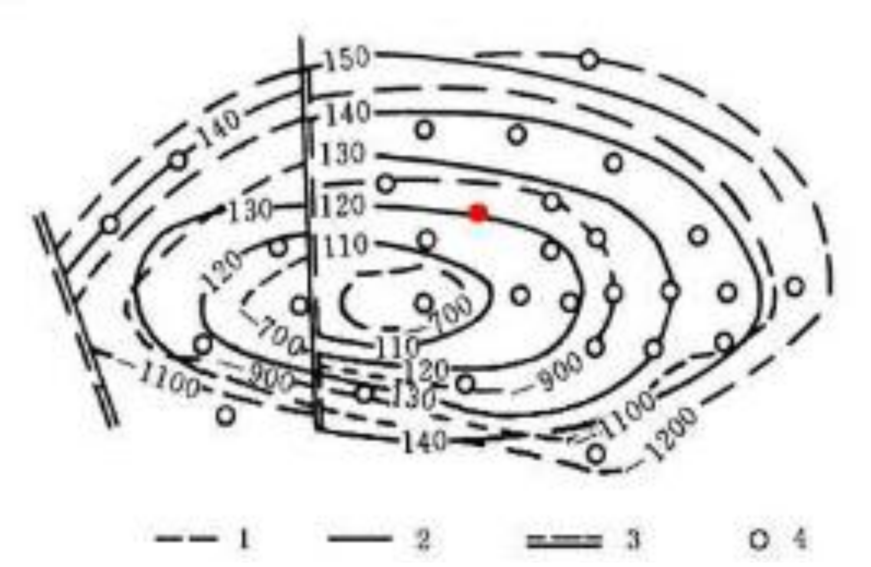
（2）To calculate average reservoir Pi

（Natural reservoir energy）

（3）Judge hydrodynamic system

Understand reservoir characteristic

In the unified pressure system,
the distribution of isobaric continuous,
if not, there may be a fault or
lithological pinch-out



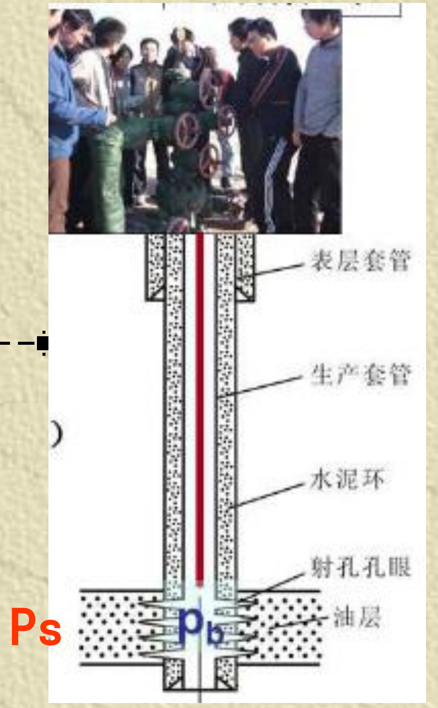
Initial pressure isobaric map of an oil field

（4）Calculate elastic energy

Difference value between initial oil layer and reservoir bubble point

I. Pressure Concept

3. Formation pressure



Current reservoir pressure----

reservoir pressure after a period of development

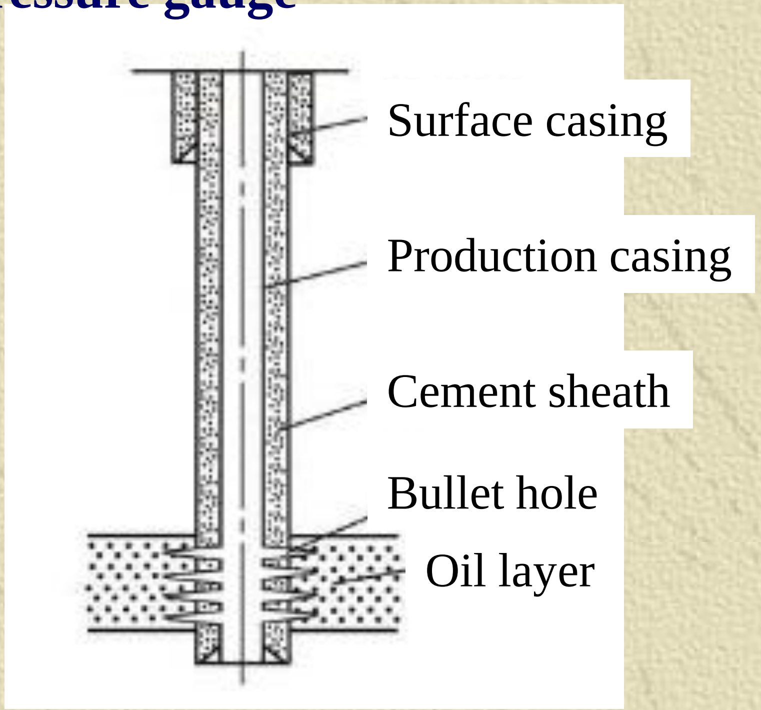
Reservoir static pressure—Ps: **After a period of production, close the well and measure the bottom hole pressure when it is stable, this pressure is also called moveable formation pressure which stands for the current pressure.**

Flowing bottom hole pressure—P_b: **the bottom hole pressure measured when it is producing.**

Reservoir static pressure

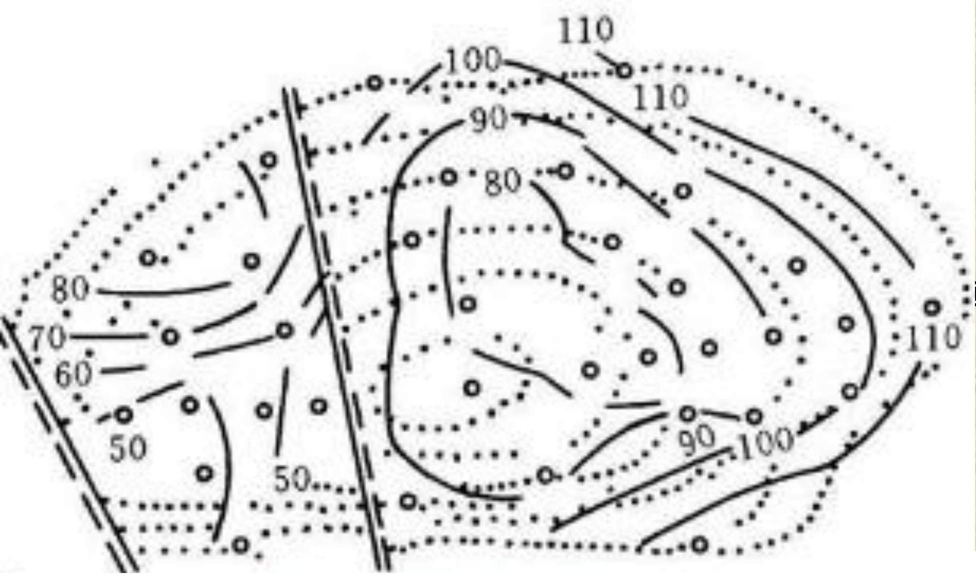
actual measurement

Close well after a period of time and then measure the pressure by using deep well pressure gauge



pressure build-up curve

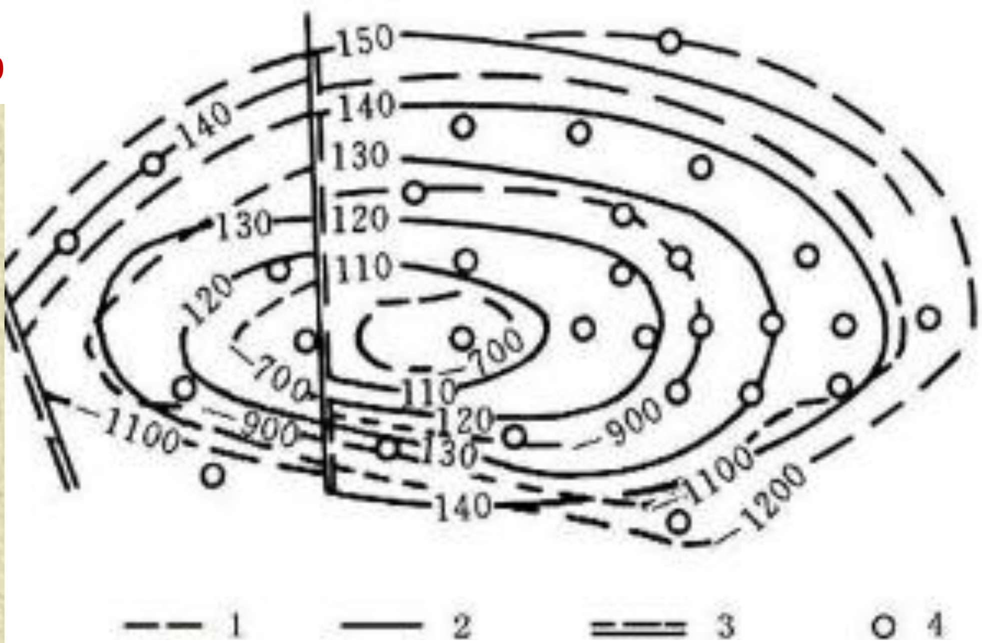
pressure drawdown curve



Reservoir static pressure isobaric map

pressure drop

Isobaric and structure contour lines intersect



Structure contour **Isobaric Line** **Fault** **Well**

Initial pressure isobaric map

Application of Reservoir static pressure isobaric map

（1） Reflect subsurface fluid dynamic

Low pressure area --injection supplement is not insufficient;

High pressure area--Water breakthrough

（2） Reflect production performance

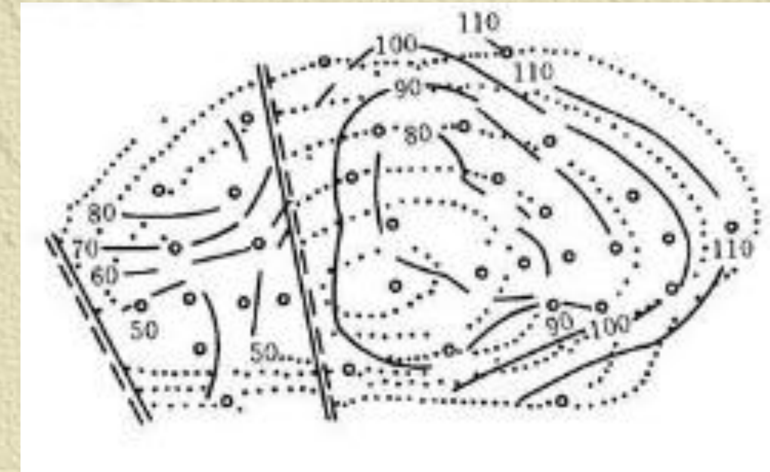
comparing reservoir static pressure isobaric maps which are measured at different production stages

（3） Define formation parameters

Reservoir geological feature ----fault

Pressure distribution➡

flow coefficient Kh/u；



I. Pressure Concept

3. Formation pressure

P_b---bottom-hole pressure

liquid column height in the borehole while production

I. Pressure Concept

3. Formation pressure

Drawdown pressure:

$$\triangle P = P_i - P_b$$

pressure difference between Pi and bottom-hole pressure

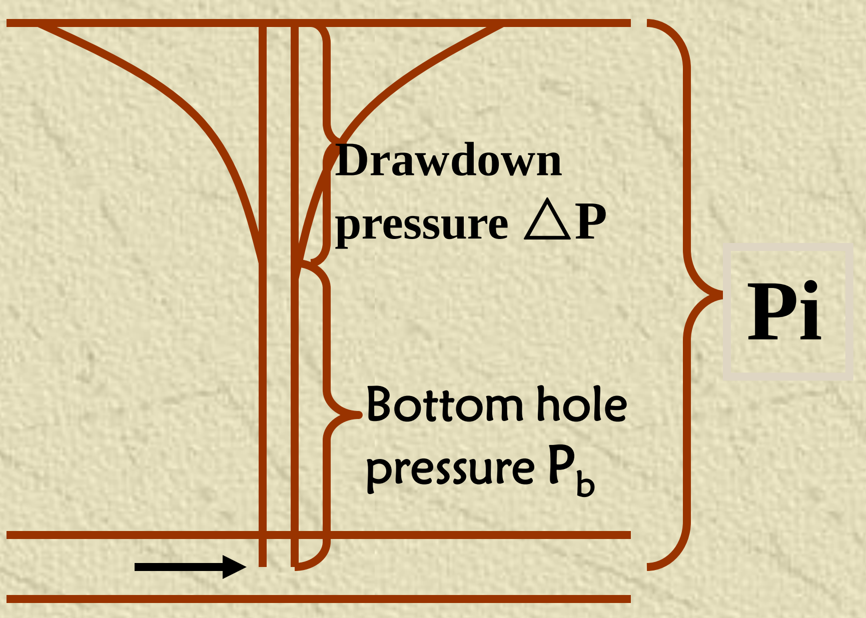
Oil and gas will be expulsed to bottom hole at the effect of drawdown pressure

I. Pressure Concept

3. Formation pressure

Dropdown curve

pressure cone of depression



Chapter 5. Formation Pressure and Formation Temperature

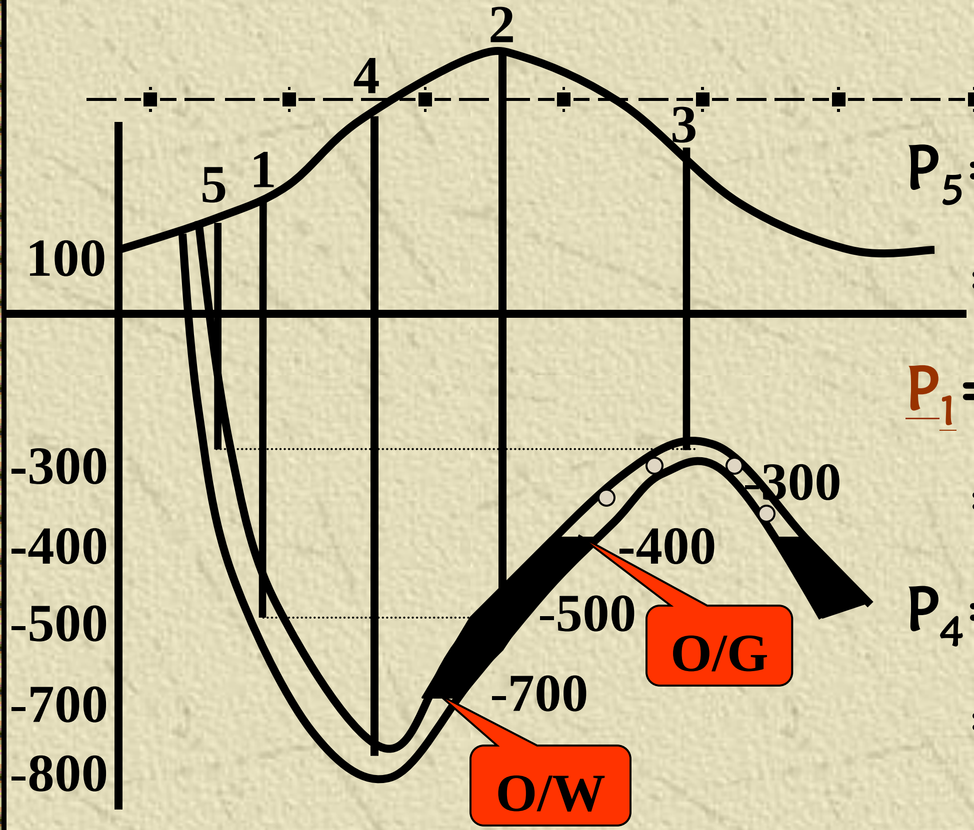
Section 1 Initial Pressure and the Distribution in the Reservoir

I Pressure Concept

II Initial pressure distribution in the reservoir

III Prediction O/W with Pi

II. Initial pressure distribution in the reservoir



$P_5 = \rho \cdot H/10 = 1.1 \times (300+100)/10$

$= 44 kg/cm^2 = 4.4 MPa$

$P_1 = \rho \cdot H/10 = 1.1 \times (500+100)/10$

$= 66 kg/cm^2 = 6.6 MPa$

$P_4 = \rho \cdot H/10 = 1.1 \times (800+100)/10$

$= 99 kg/cm^2 = 9.9 MPa$

Water supply area elevation :100m, O/W:-700m; O/G: -400m

Contributing region: 100m, O/W:-700m, O/G:-400m

Specific gravity of water, oil and gas: 1.1, 0.85, 0.78

II. Initial pressure distribution in the reservoir

$P_2 = P_{O/W} - P_{2\text{liquid column}} = [1.1 \times (700+100) - 0.85 \times 200]/10$

$= 88 - 17 = 71 kg/cm^2 = 7.1 MPa$

$P_3 = P_{wellhead} * e^{1.293*10^{-4} \rho H}$

$= 6.14 MPa$

$P_{O/G} = P_{O/W} - P_{oil} = 6.25 MPa$

Conclusions:

1. P_i will increase with the depth increasing

2. Fluid properties influence P_i greatly

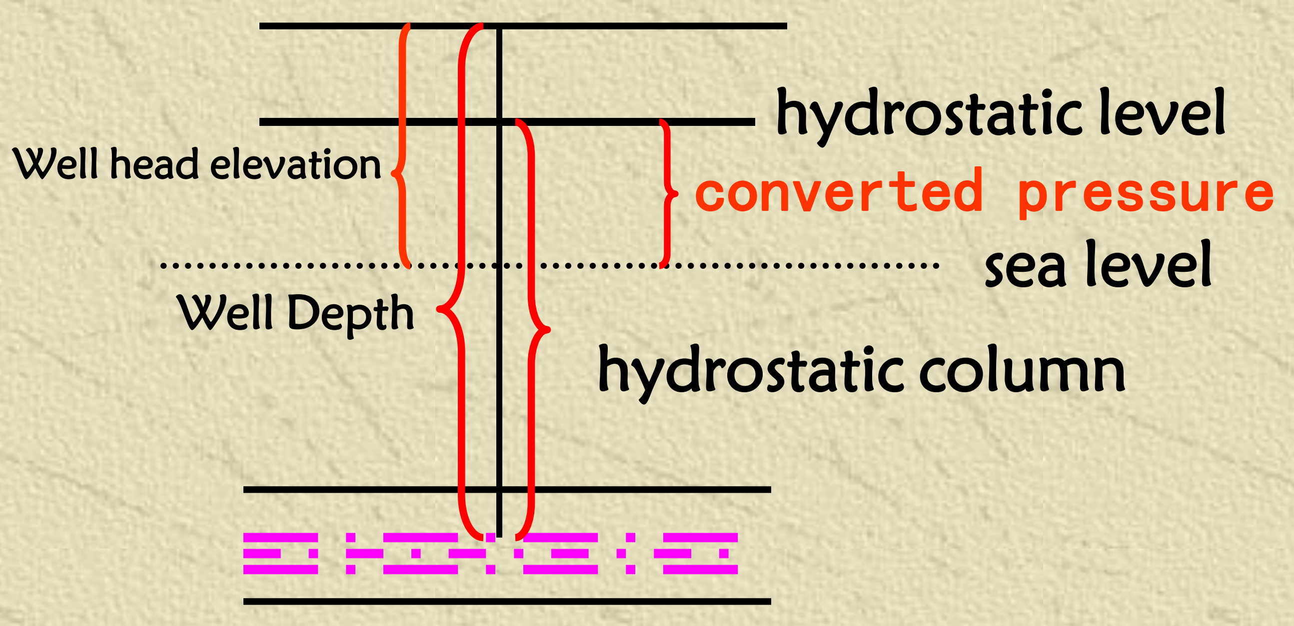
3. The height of gas column does not much affect P_i

II. Initial pressure distribution in the reservoir

reduced pressure, converted pressure:

hydrostatic level below or above the datum level

$$\pm l = h + H - L$$



II. Initial pressure distribution in the reservoir

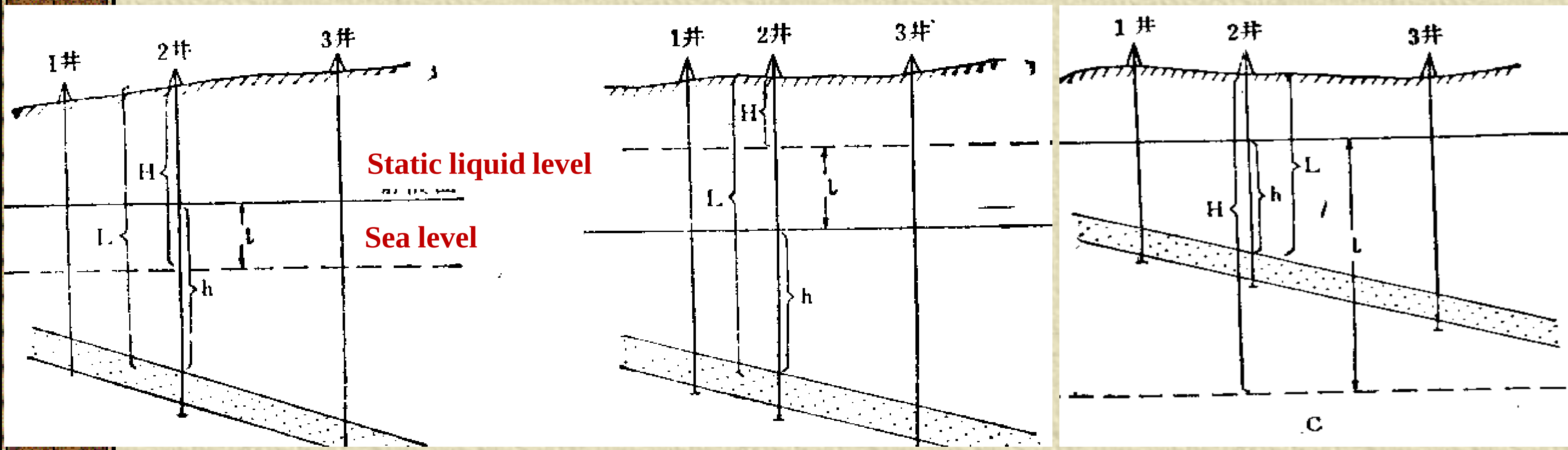
reduced pressure ——

hydrostatic level below or above the datum level

hydrostatic level above the datum level,

reduced pressure positive

hydrostatic level below the datum level, negative



II. Initial pressure distribution in the reservoir

reduced pressure：

hydrostatic level below or above the datum level

hydrostatic level above the datum level,

reduced pressure positive

hydrostatic level below the datum level, negative

For the hydrocarbon reservoir

without drainage area,

before development

reduced pressure equal

II. Initial pressure distribution in the reservoir

After development, reduced pressure change

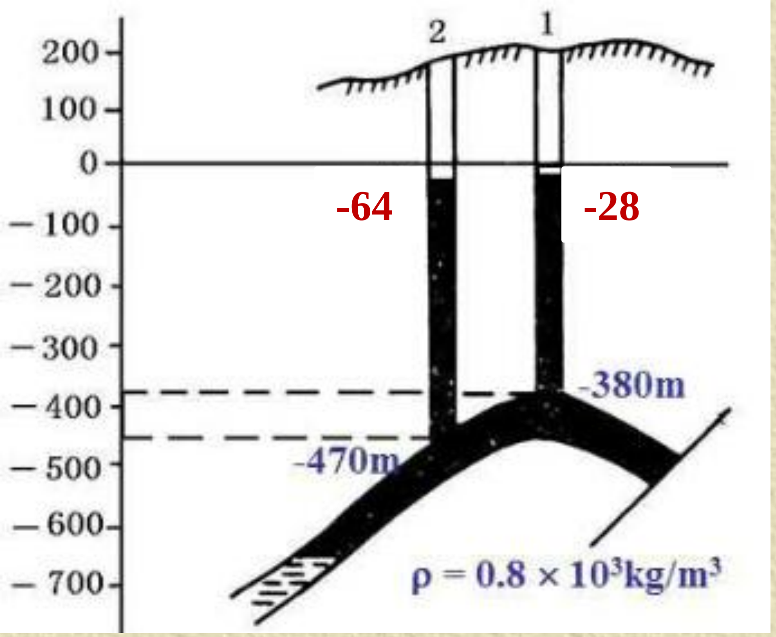
Well 2:

Current reservoir pressure

3.25MPa

Hydrostatic level elevation

-64m



Well 1:

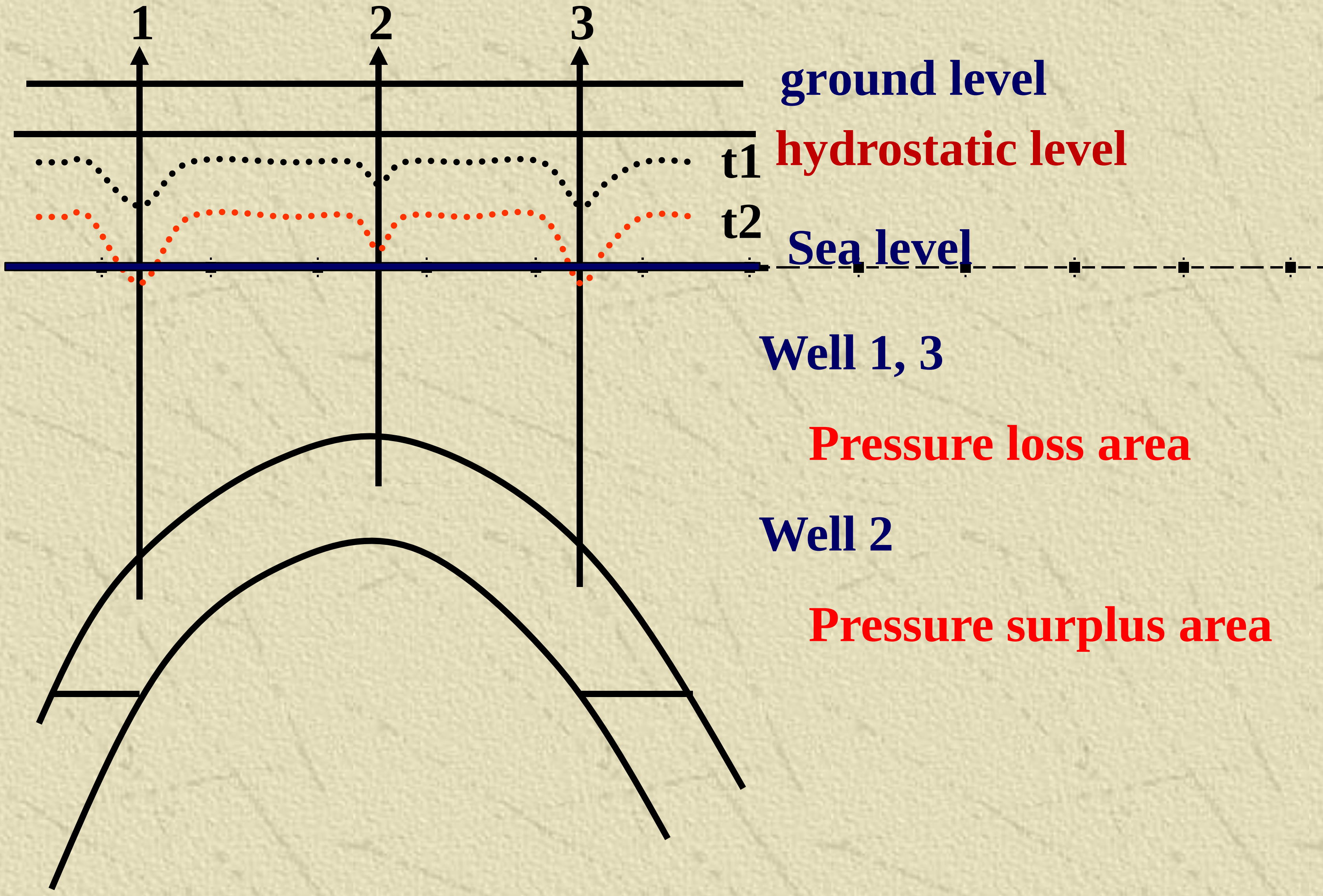
Current reservoir pressure

2.82MPa

Hydrostatic level elevation

-28m

Fluid flow from high reduced pressure to low reduced pressure, eliminate the influence of reservoir depth to pressure

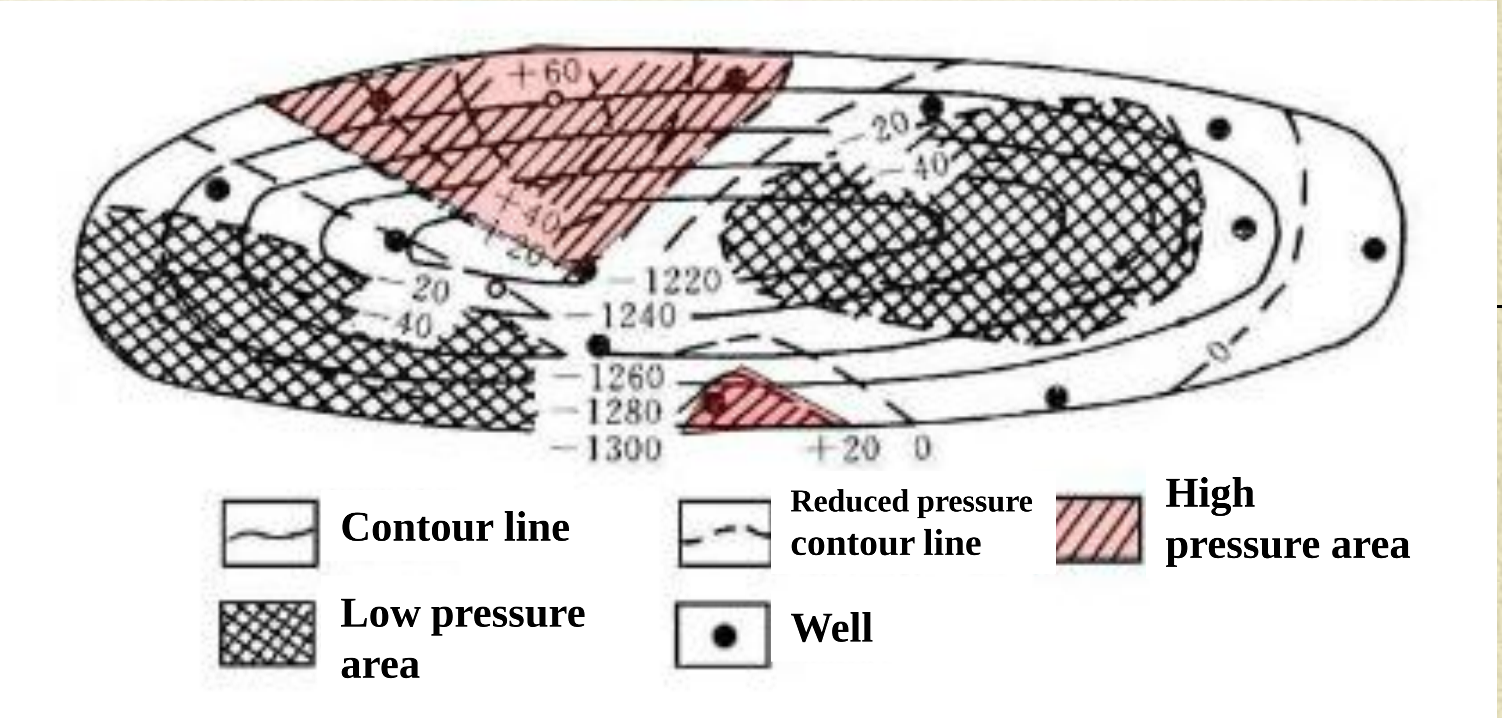


Well 1, 3

Pressure loss area

Well 2

Pressure surplus area

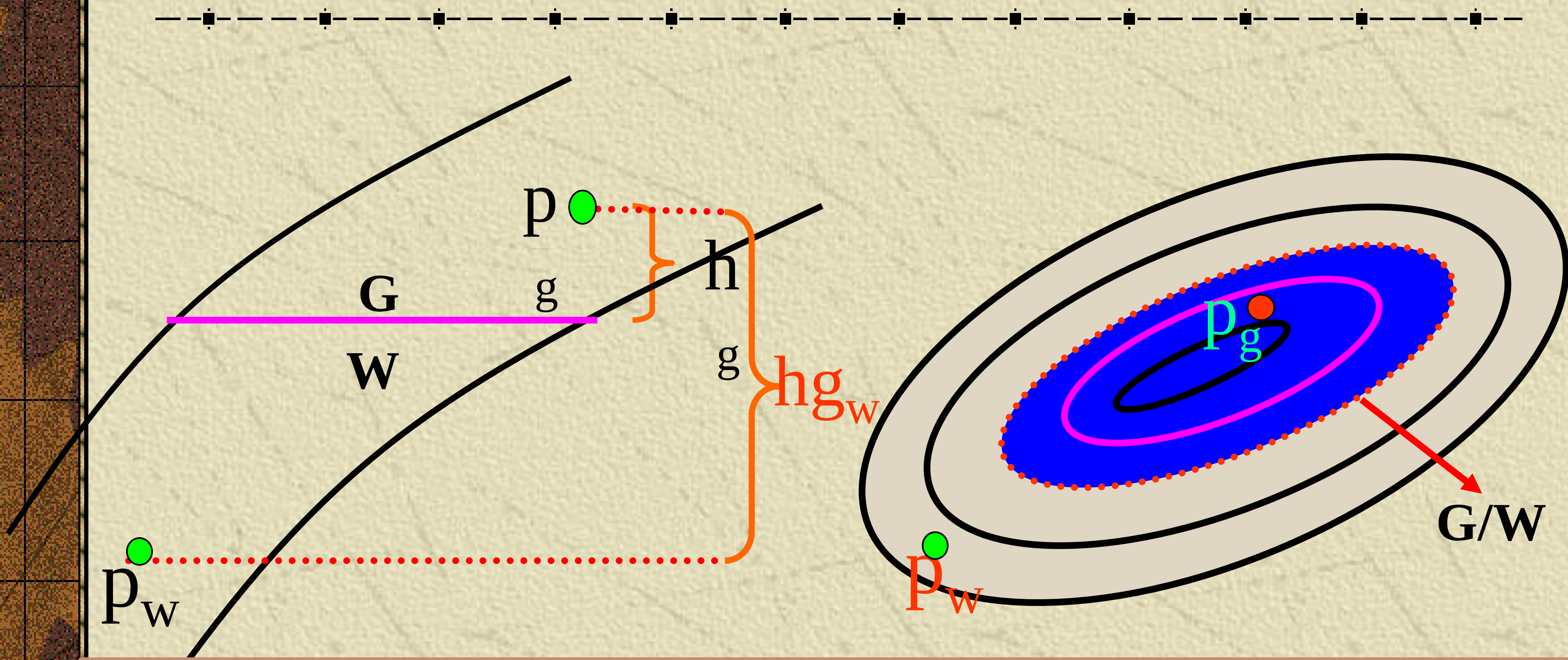


Reduced pressure contour map

- ▲ **Identify hydrodynamic system (before production)**
- ▲ **Uniform production and waterfront advance**

III. Prediction O/W with Initial pressure

1. Predict G/W according to Pw and Pg



Pg----Gas well initial pressure, MPa

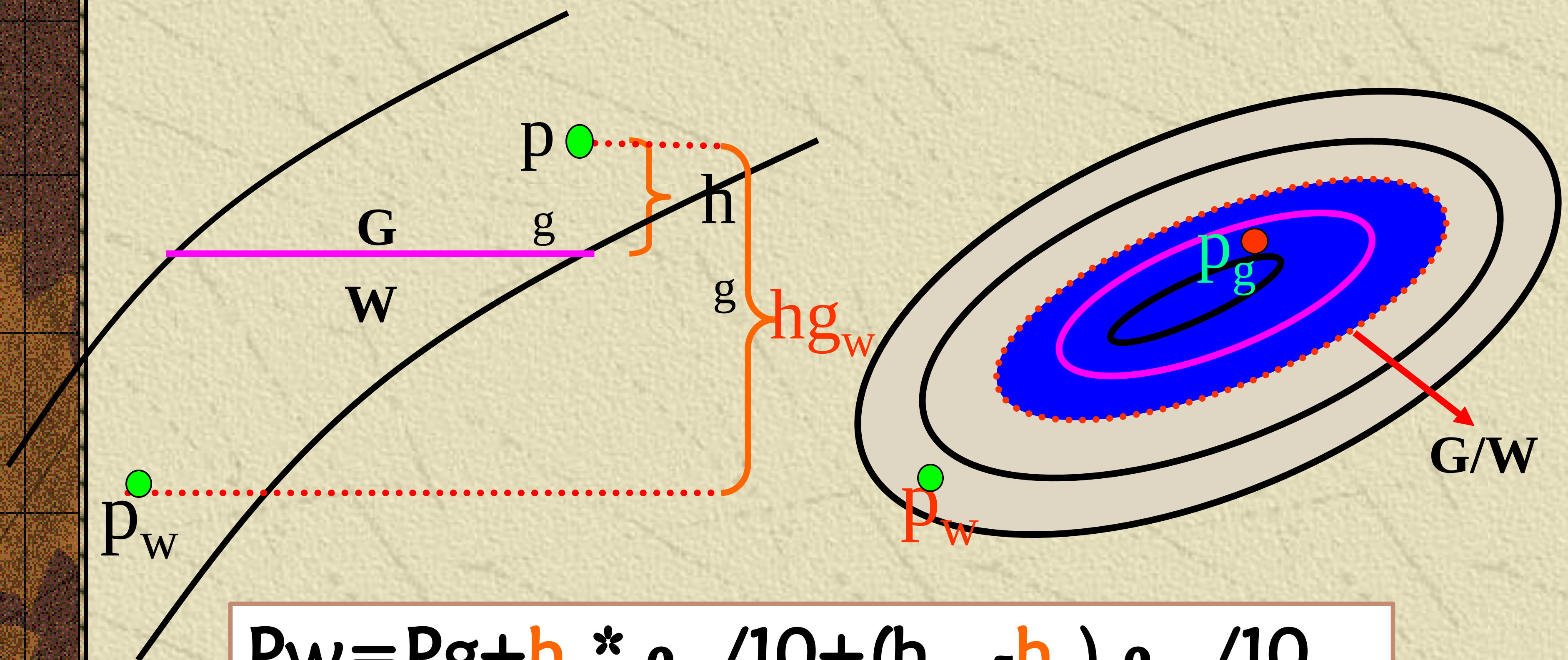
Pw----Water well initial pressure, MPa

hg-----Vertical distance between G/W and gas well, m

hgw----Vertical distance between gas well and water well, m

III. Prediction O/W with Initial pressure

1. Predict G/W according to Pw and Pg



$$Pw = Pg + h_g * \rho_g/10 + (h_{gw} - h_g)\rho_w/10$$

$$h_g = [h_{gw}\rho_w - 10(P_w - P_g)]/(\rho_w - \rho_g)$$

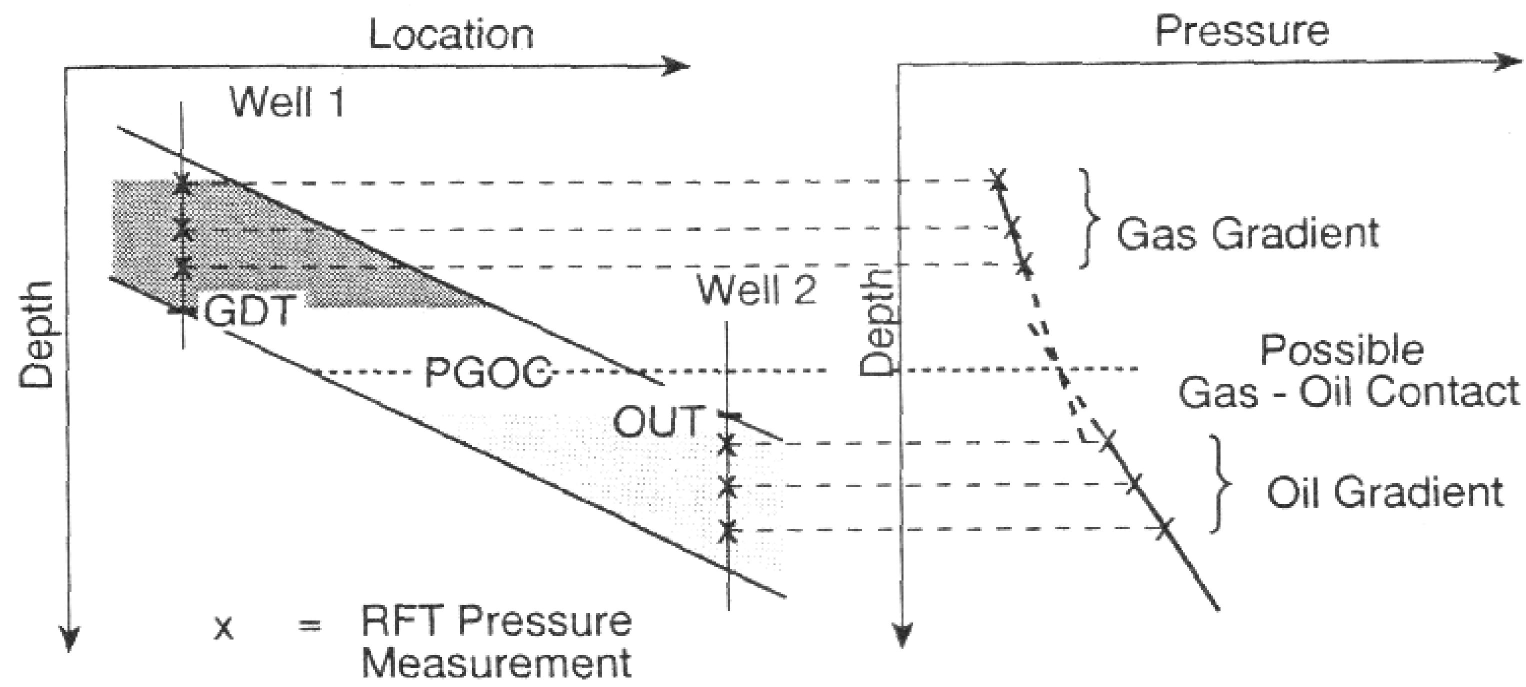
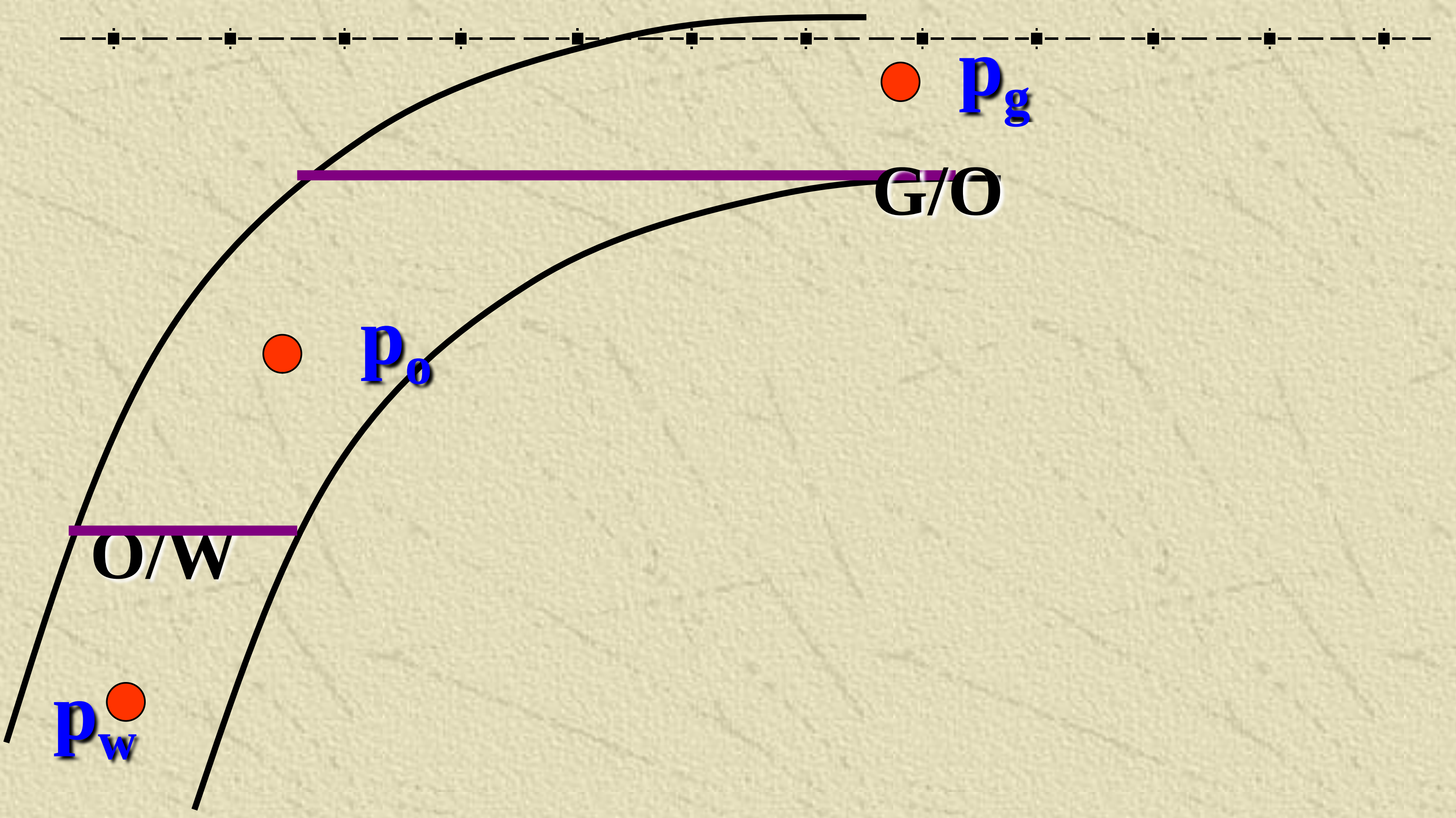


Figure 5.26 The gradient intercept technique

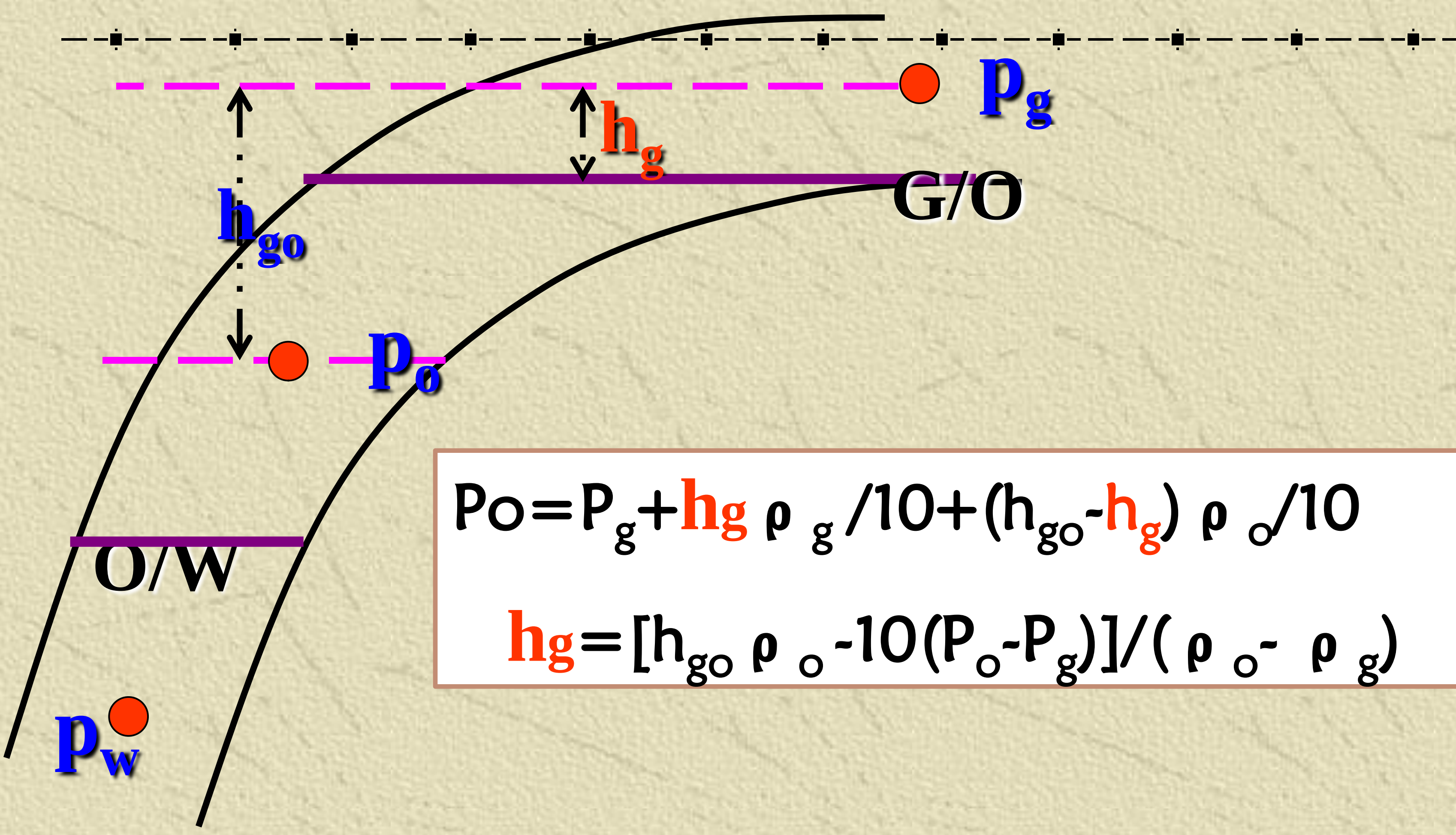
This feature is very useful to define the interface between fluids. The intercept between the gas and oil gradients indicates the gas-oil contact (GOC).

The intercept between the oil and water gradients indicates the oil water contact (OWC).

2. Prediction O/G, O/W interface with Pi



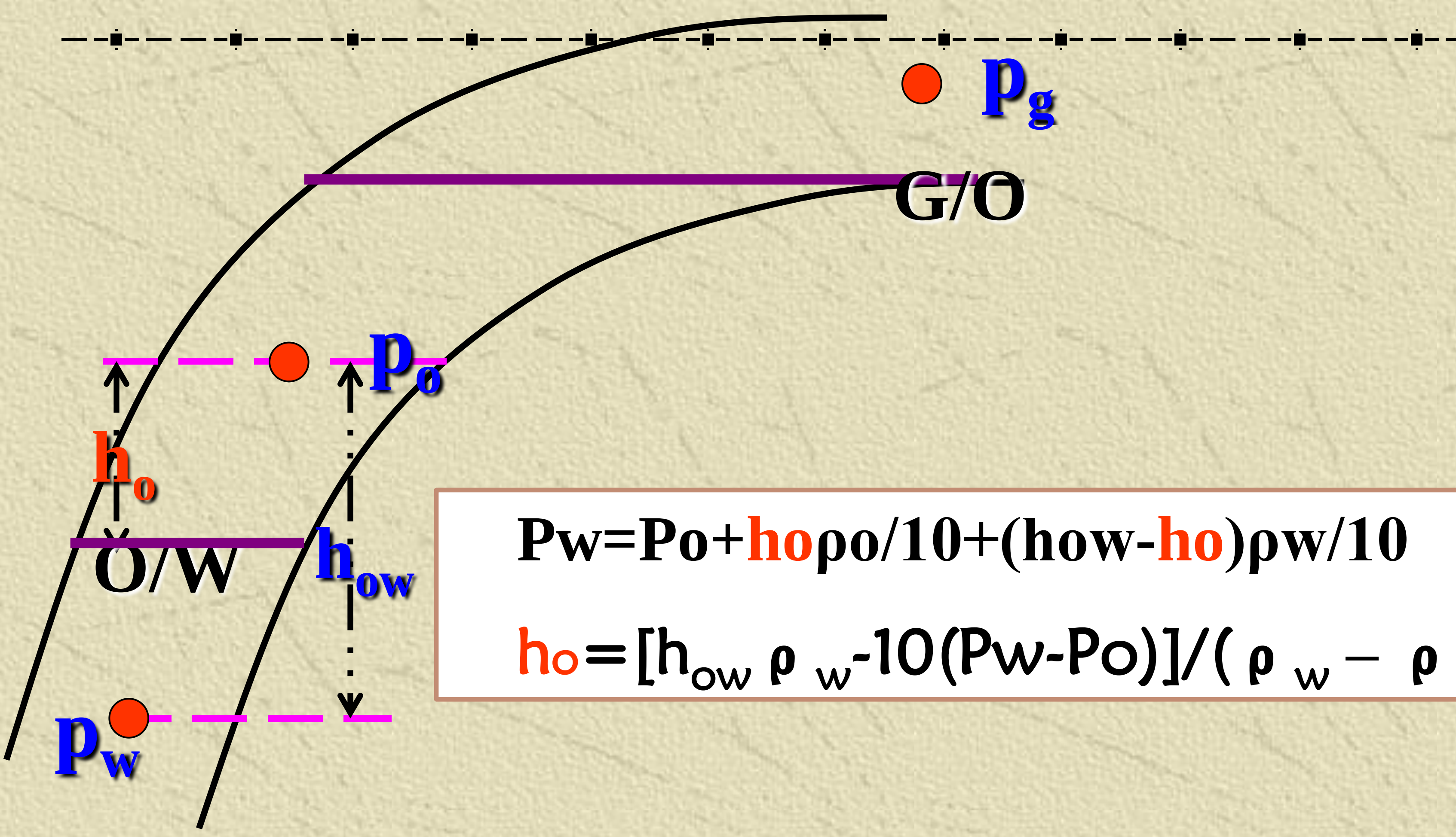
2. Prediction O/G, O/W interface with Pi



$$Po = P_g + h_g \rho_g/10 + (h_{go} - h_g)\rho_o/10$$

$$h_g = [h_{go}\rho_o - 10(P_o - P_g)]/(\rho_o - \rho_g)$$

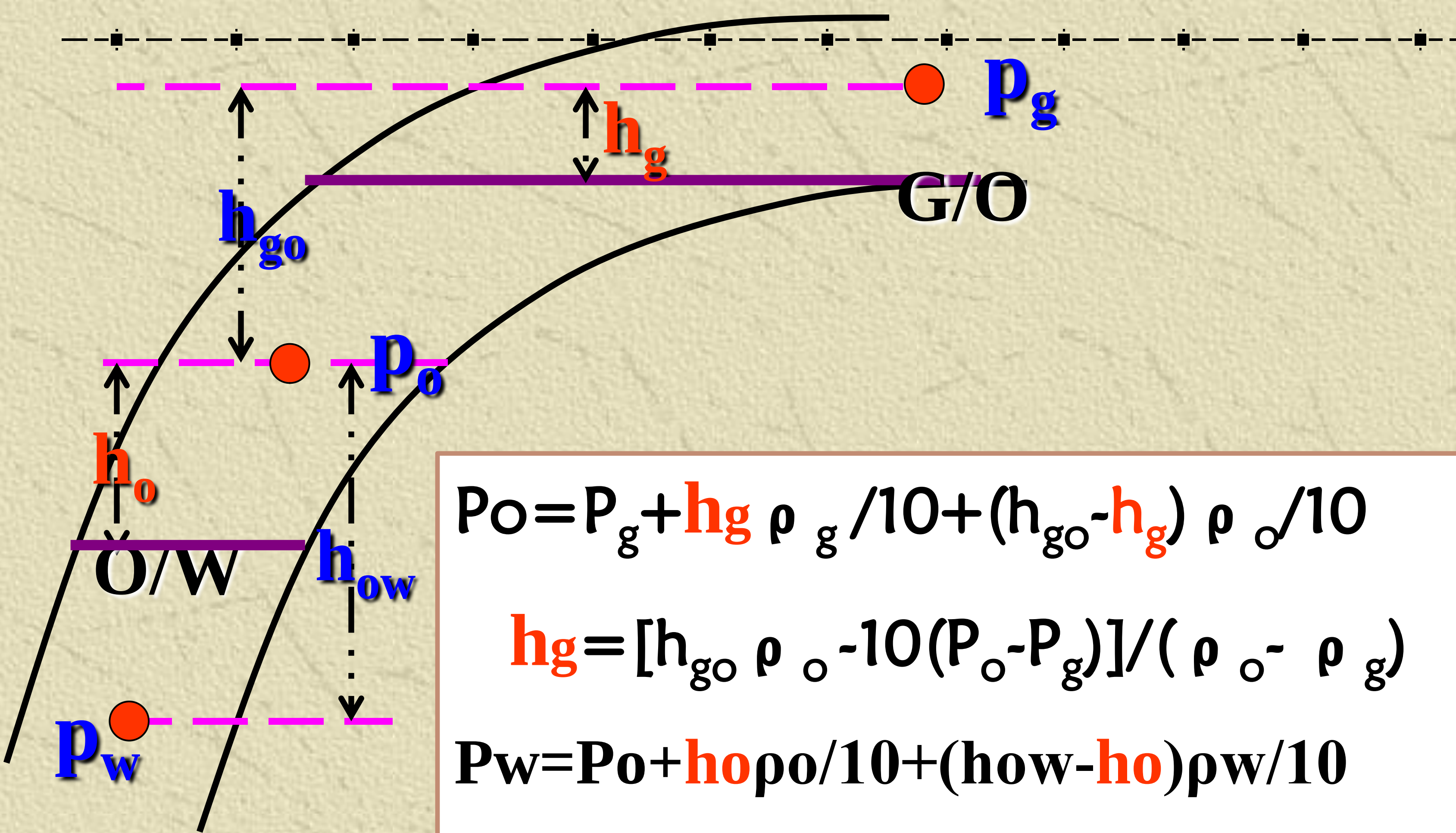
2. Prediction O/G, O/W interface with Pi



$$P_w = P_o + h_o \rho_o / 10 + (h_{ow} - h_o) \rho_w / 10$$

$$h_o = [h_{ow} \rho_w - 10(P_w - P_o)] / (\rho_w - \rho_o)$$

2. Prediction O/G, O/W interface with Pi



$$Po = P_g + h_g \rho_g/10 + (h_{go} - h_g)\rho_o/10$$

$$h_g = [h_{go}\rho_o - 10(P_o - P_g)]/(\rho_o - \rho_g)$$

$$Pw = Po + ho\rho o/10 + (how - ho)\rho w/10$$

$$h_o = [h_{ow}\rho_w - 10(Pw - Po)]/(\rho_w - \rho_o)$$

Chapter 5 Formation Pressure and Formation Temperature

Section 1 Initial Pressure and the distribution in the reservoir

Section 2 Abnormal formation pressure

Section 3 Formation Temperature

2003. 12. 23

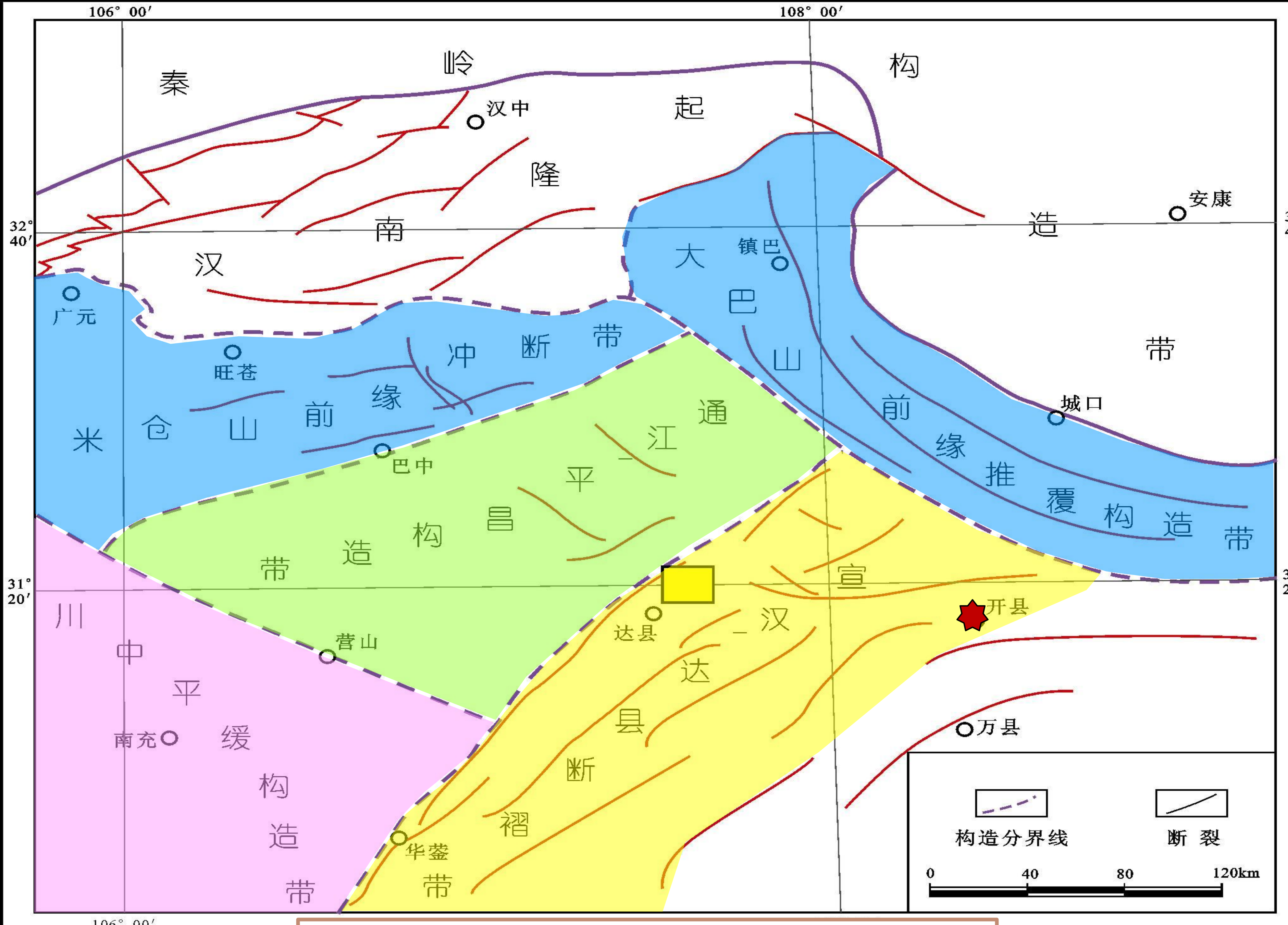
Death 243 people

H2S Poisoning 2142 people

Evacuation resettlement：65000 people

Direct economic losses

64.3231million￥



ChuanDongbei Area

Oil well blowouts are wasteful, not only of time and money spent for control, but of pressure in the formation, which is needed to move the oil from the underground reservoir and raise it the surface. Many men have been killed or injured by blowout.

1901.1.10. Lucas at Spindletop, near Beaumont, Texas

Section 2 Abnormal Formation Pressure

I. Abnormal pressure Concept

II. Compaction Model Test

III. Geological Condition

IV. Overpressure Prediction

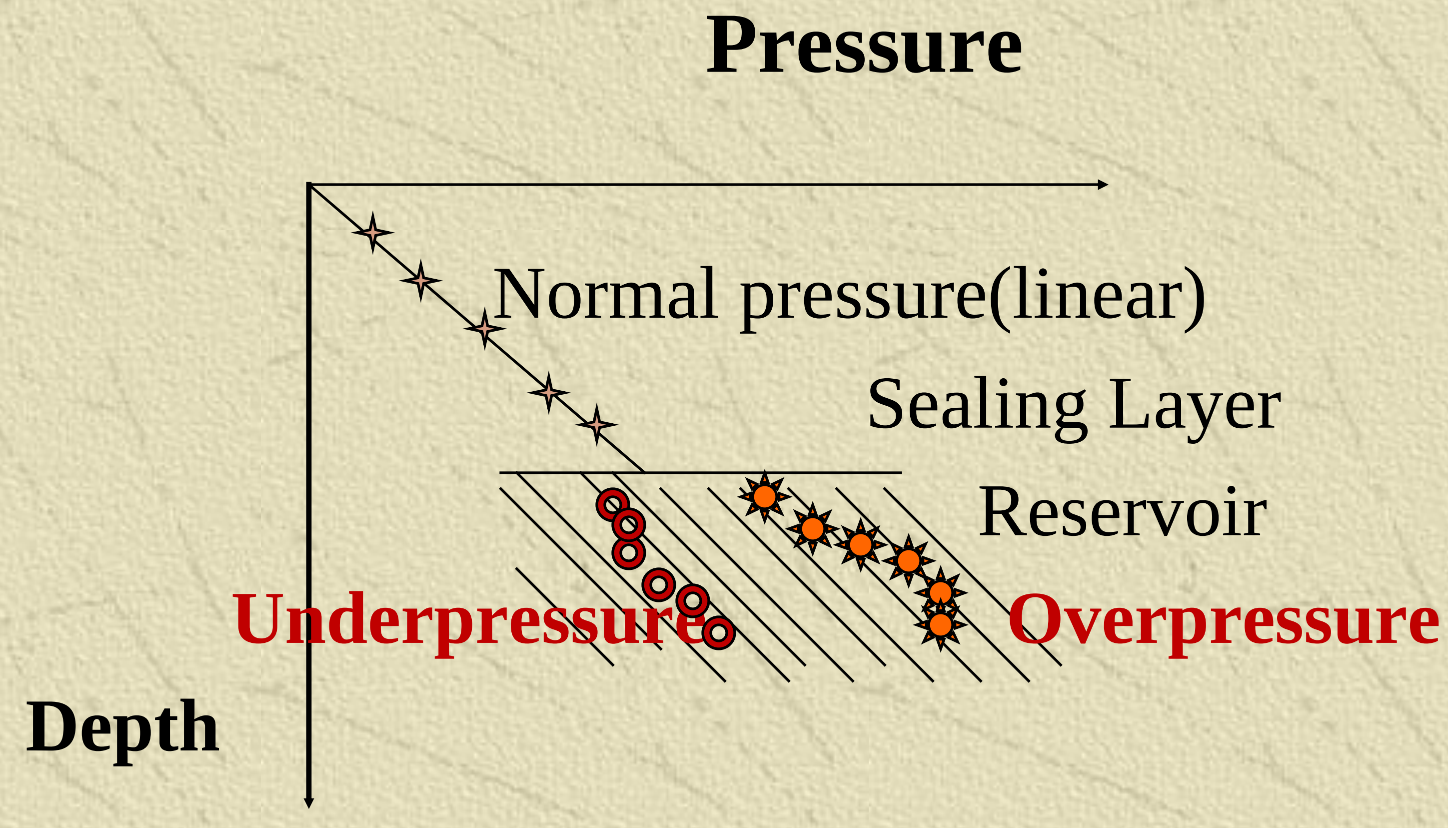
V. Signification

Section 2 Abnormal Formation Pressure

I. Abnormal pressure Concept

Abnormal pore fluid pressure

- **Abnormally High Pore Fluid Pressure** — **overpressure**
- **Subnormal formation pressure** — **underpressure**


Pressure
Normal pressure(linear)
Sealing Layer
Reservoir
Underpressure
Overpressure
Depth

Normal pressure regimes follow a hydrostatic fluid gradient from surface, and are approximately linear. Formation pressures that are obviously lower or higher than the hydrostatic pressures at the same burial depth are called abnormal pressures.

Abnormal pressure regimes include overpressured and underpressured fluid pressures, and represent a discontinuity in the normal pressure gradient.

Overpressure, sometimes called geopressure, is a pressure state where formation pressure is obviously higher than the hydrostatic pressure at the same burial depth. By contrast, **underpressure** or subnormal pressure is a pressure state that the fluid pressure is significantly lower than the hydrostatic pressure.

Section 2 Abnormal Formation Pressure

Formation Pressure Coefficient

Formation Pressure Coefficient =

measured pressure/hydrostatic pressure (same depth)

Formation Pressure Coefficient =1 Normal pressure

Formation Pressure Coefficient >1 overpressure

Formation Pressure Coefficient <1 underpressure

Gp=0.01MPa/m, normal formation pressure

Gp>0.01MPa/m, overpressure

Gp<0.01MPa/m, underpressure

The former Soviet union Classification scheme

Pressure Coefficient	Pressure classification
<0.8	Anomaly underpressure
0.8-1.0	underpressure
1.0-1.05	Normal pressure
1.05-1.3	Slight high pressure
1.3-2.0	overpressure
>2.0	Strong overpressure

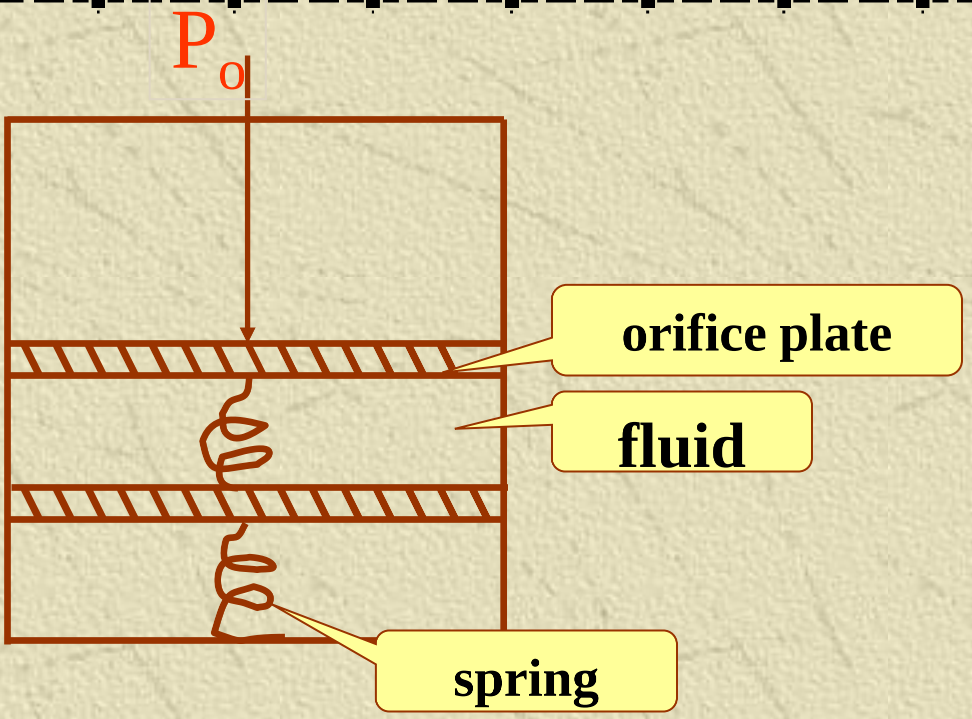
Exxon Oil Company Classification scheme

Pressure Coefficient	Pressure classification
<1.0	underpressure
1.0-1.27	Normal pressure
1.27-1.5	Transitional zone
1.5-1.73	overpressure
1.73-1.92	Strong overpressure

Pressure classification China

Pressure Coefficient	Pressure classification
<0.96	Anomaly underpressure
0.96-1.06	Normal pressure
1.06-1.27	Weak overpressure
1.27-1.73	overpressure
>1.73	Strong overpressure

II.Compaction test

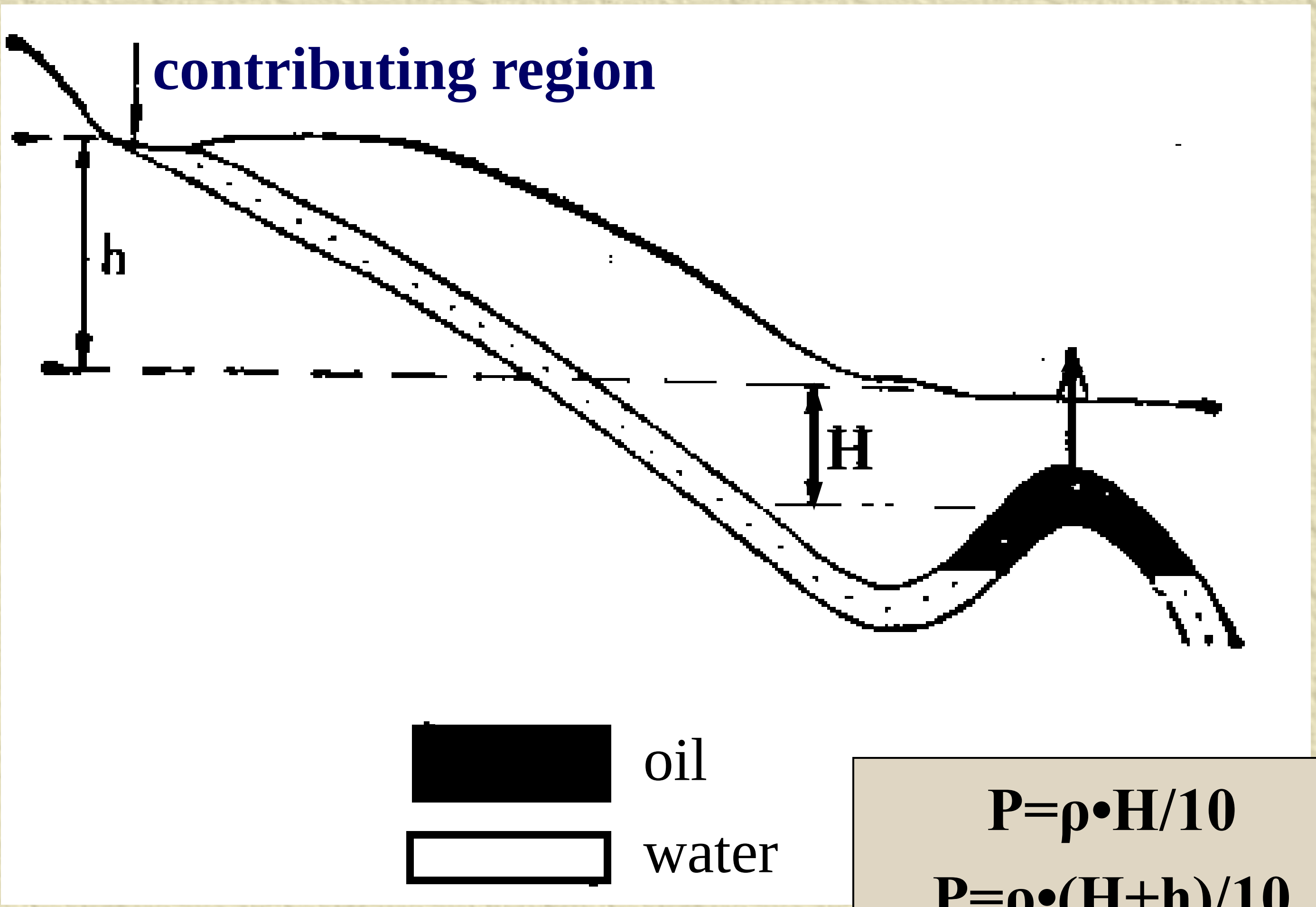


III. Geological setting of Overpressure

1. The elevation of contributing region is significantly higher than that of oil and gas well
2. Specific gravity
3. Tectonic movement
4. Rapid subsidence
5. Geotemperature
6. Osmotic pressure
7. Alteration of clay mineralog

III. Geological setting of Overpressure

1. The elevation of contributing region is significantly higher than that of oil and gas well



$P=\rho \bullet H/10$

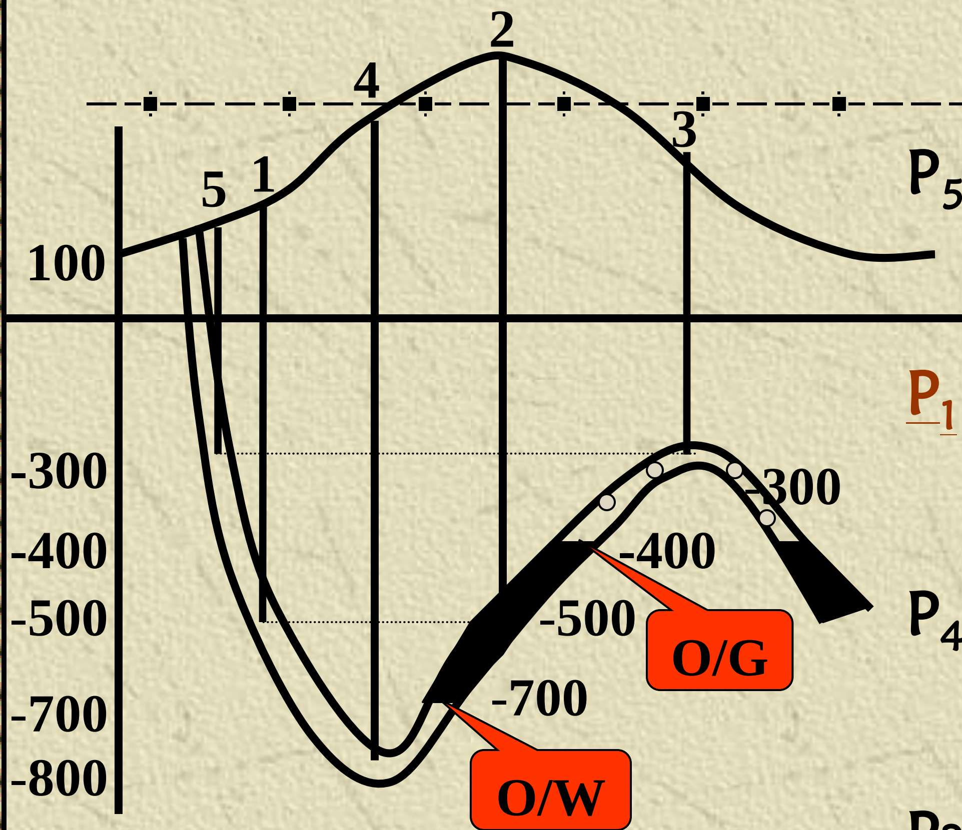
$P=\rho \bullet (H+h)/10$

III. Geological setting of Overpressure

2. Differences in specific gravity between oil, gas and water

Oil, gas and water well with same central reservoir elevation

$$P_{\text{gas well}} > P_{\text{oil well}} > P_{\text{water well}}$$



$P_5 = \rho \cdot H/10 = 1.1 \times (300+100)/10$

$= 44 kg/cm^2 = 4.4 MPa$

$P_1 = \rho \cdot H/10 = 1.1 \times (500+100)/10$

$= 66 kg/cm^2 = 6.6 MPa$

$P_4 = \rho \cdot H/10 = 1.1 \times (800+100)/10$

$= 99 kg/cm^2 = 9.9 MPa$

$P_2 = 7.1 MPa$, $P_3 = 6.14 MPa$

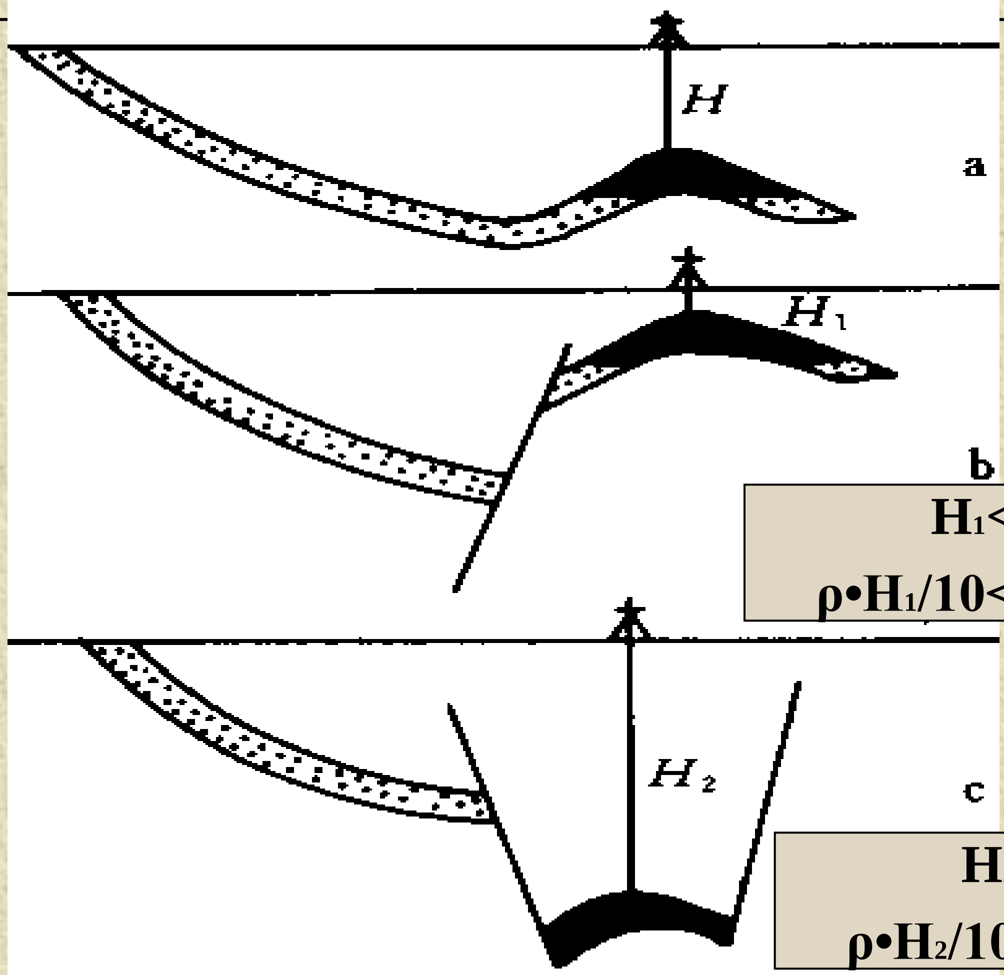
Oil, gas and water well with same central reservoir elevation

$P_{gas\ well} > P_{oil\ well} > P_{water\ well}$

0.78

III. Geological setting of Overpressure

3. Tectonic movement



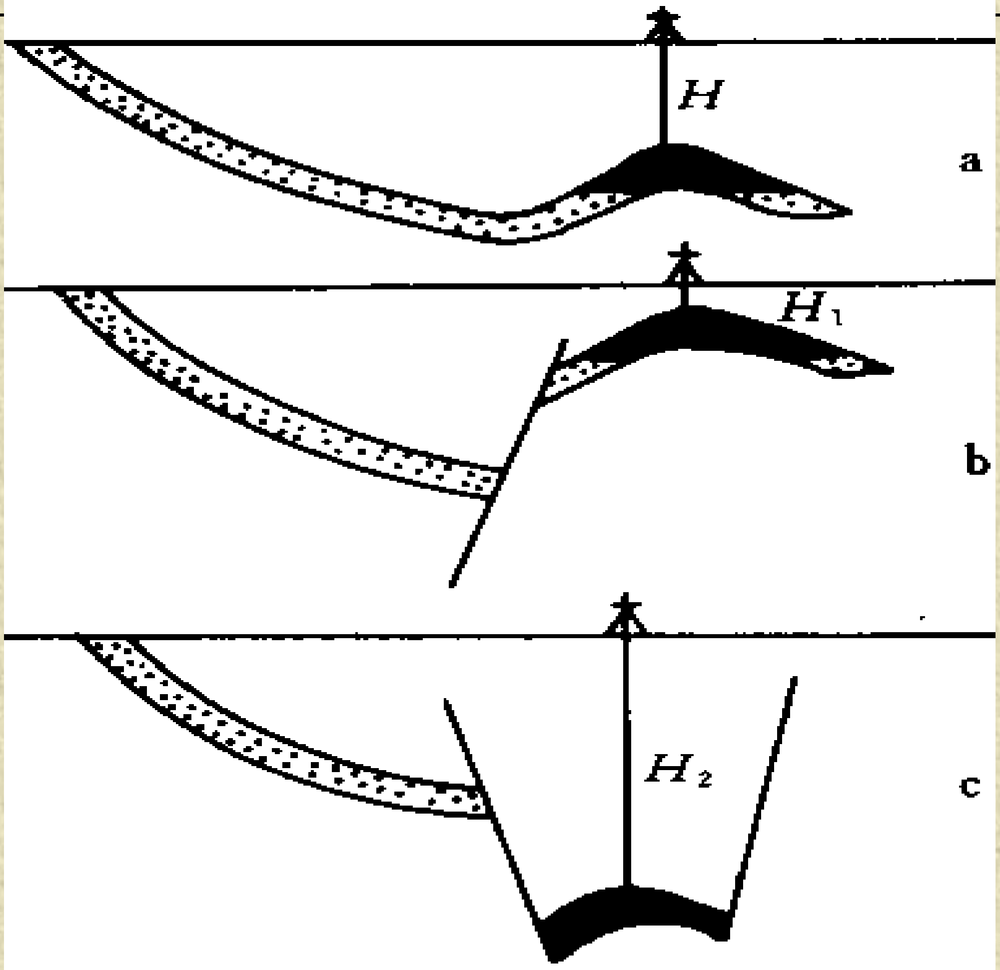
$H_1 < H$

$\rho \cdot H_1/10 < \rho \cdot H/10$

$H_2 > H$

$\rho \cdot H_2/10 > \rho \cdot H/10$

Abnormal pressure caused by rifting



uplift

burial of rock

graben

Abnormal pressure caused by rifting

III. Geological setting of Overpressure

4.Rapid subsidence

Rapid burial of sediments

Conditions for uneven compaction：

（1）Huge sediment total thickness；

（2）The existence of the thick layer of argillaceous rock；

（3）The formation of interbed sandstone；

（4）Rapid subsidence and filling；

III. Geological setting of Overpressure

5. Geotemperature

Thermal effects

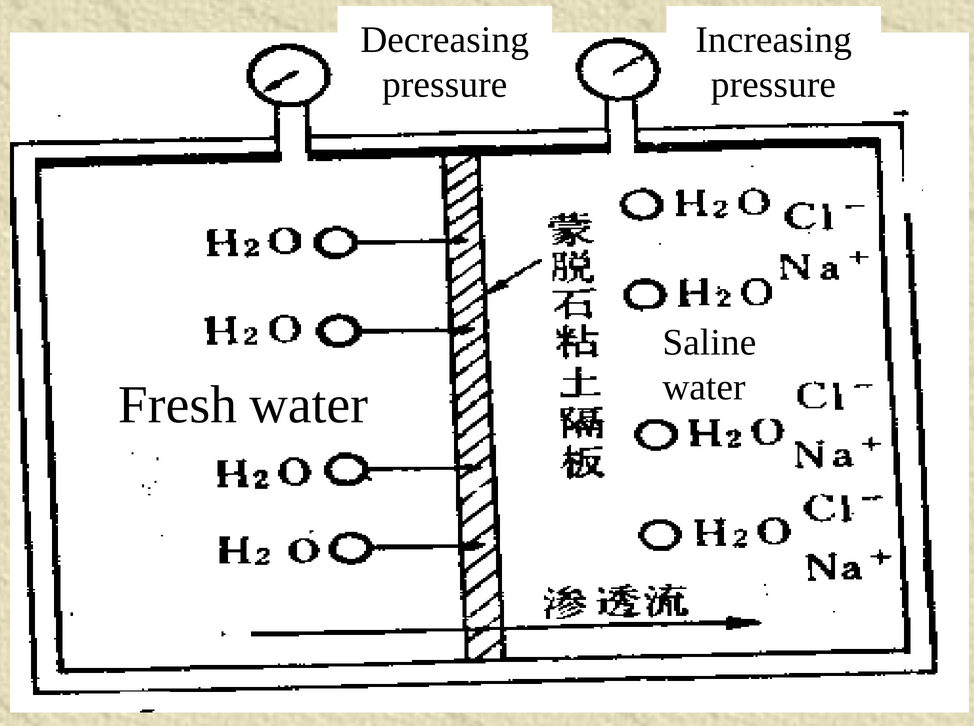
(1) Abnormal overpressure occur accompanied by abnormal high pressure;

(2) The rising temperature leads to changing phases of pore liquid

Kerogen ---- thermal cracking ➡ hydrocarbon

III. Geological setting of Overpressure

6.osmotic pressure



III. Geological setting of Overpressure

7. Alteration of clay mineralogy

Montmorillonite

dehydration （**interlayer water，absorbed water**）→

illite

III. Geological setting of Overpressure

Gypsum dehydration effect

anhydrite into gypsum

$CaSO4 \cdot 2H_2O \longrightarrow CaSO_4$

secondary cementation

oil and gas generation and accumulation

"The Generation and migration of petroleum from abnormal pressured fluid compartment" .

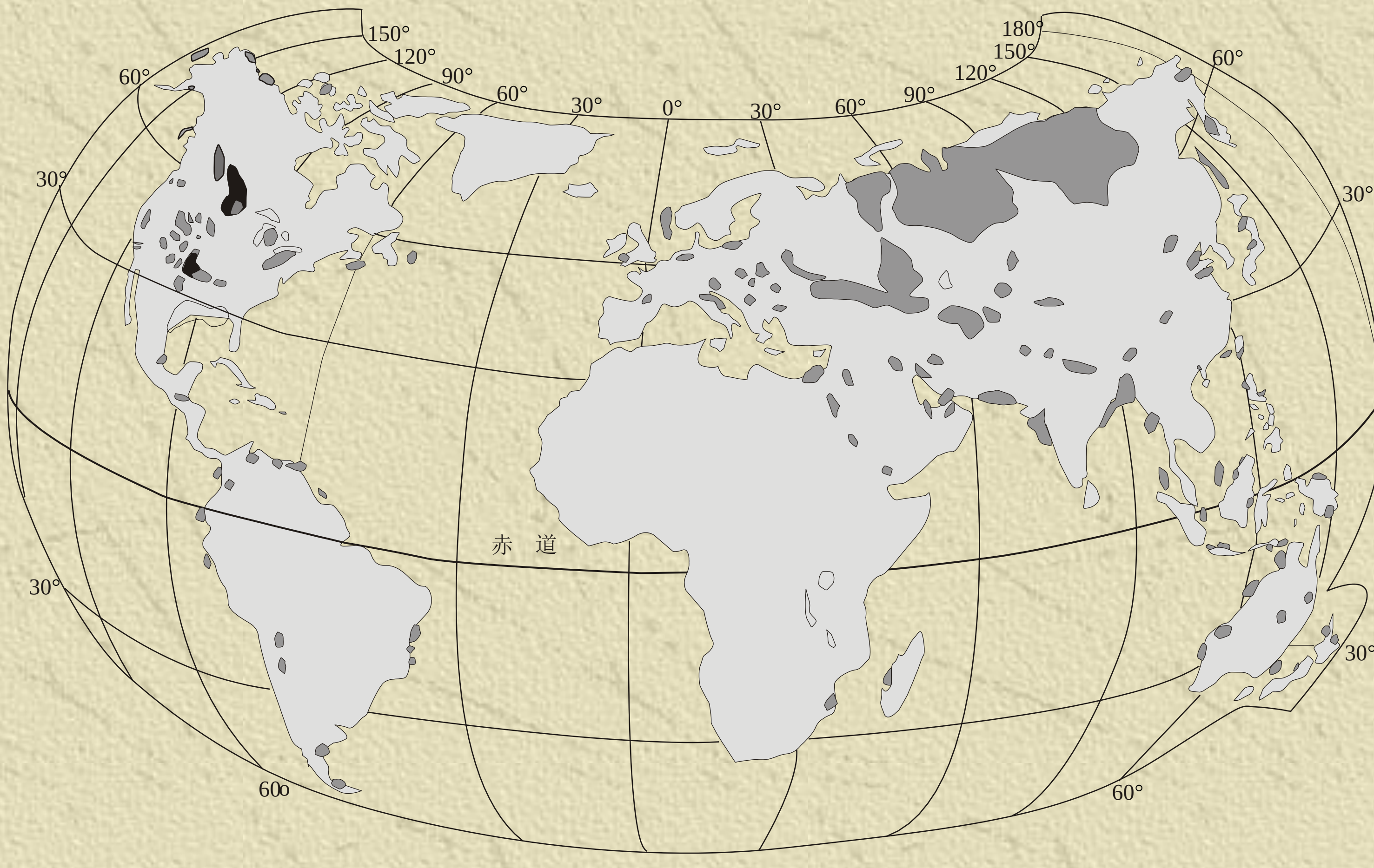
A.A.P.G. 1990. Vol.74, No.1. 1-12

Pressure Research

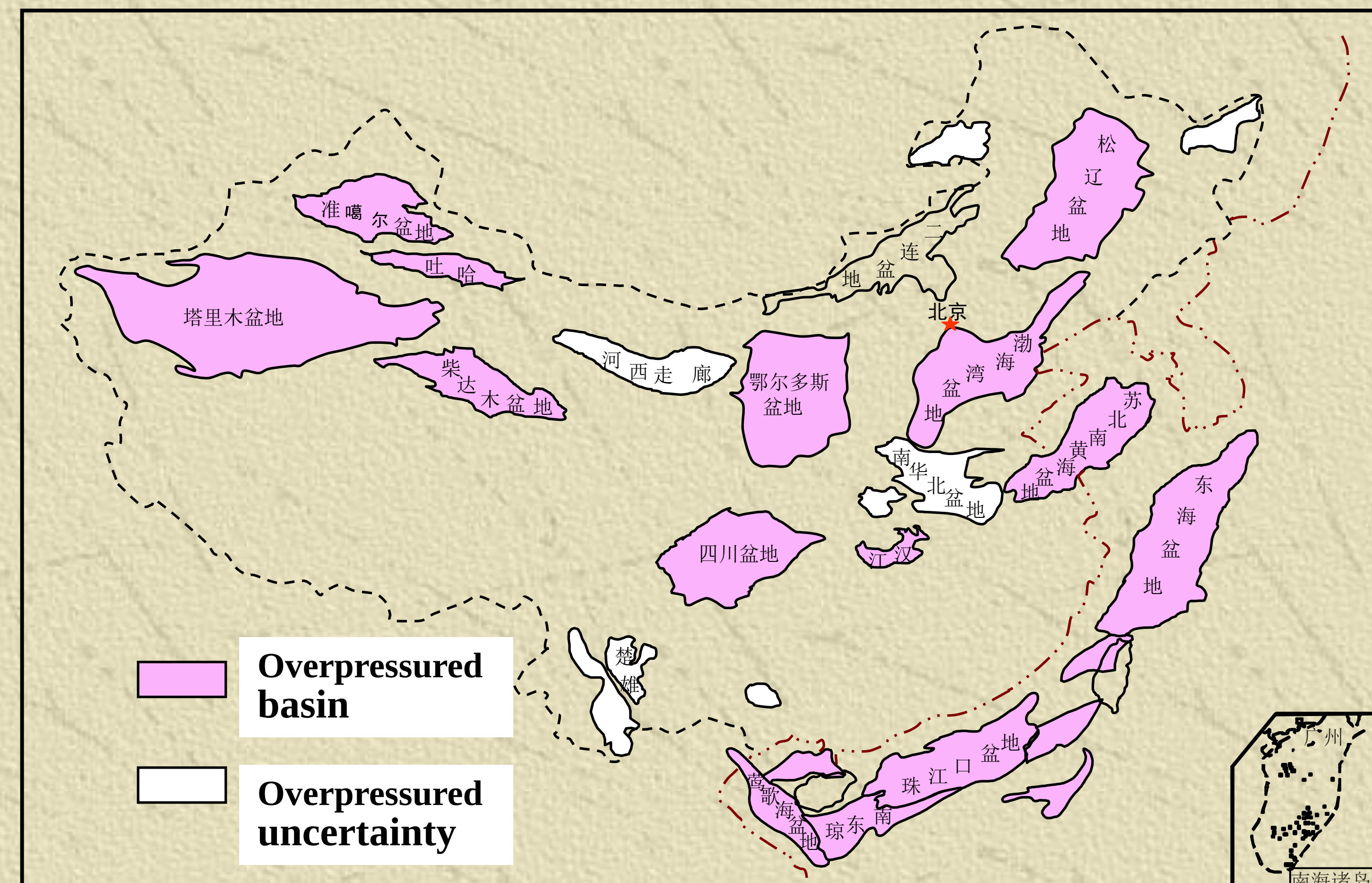
Comparing with the underpressure basins, overpressure basins are much more developed in the world.

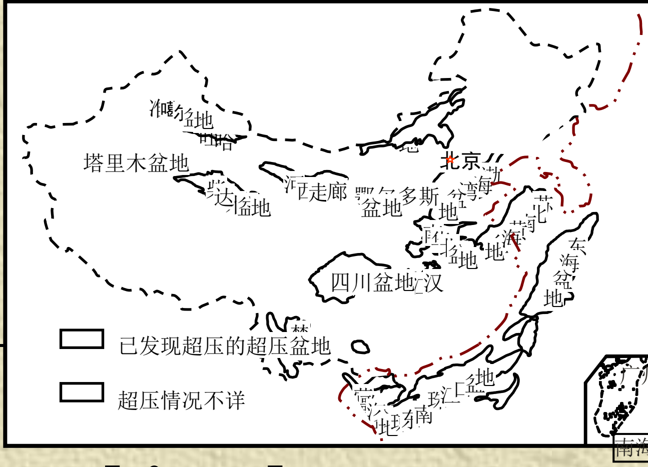
Overpressure which has been found in about 180 sedimentary basins plays an important role in petroleum geology and petroleum engineering. Much of the world’s oil and gas is considered to have been generated from overpressured ***source rocks***. It influences the safeguarding drilling. Drilling through abnormal pressure regime requires special care.

Major abnormally pressured areas in the world



Overpressured basins in China

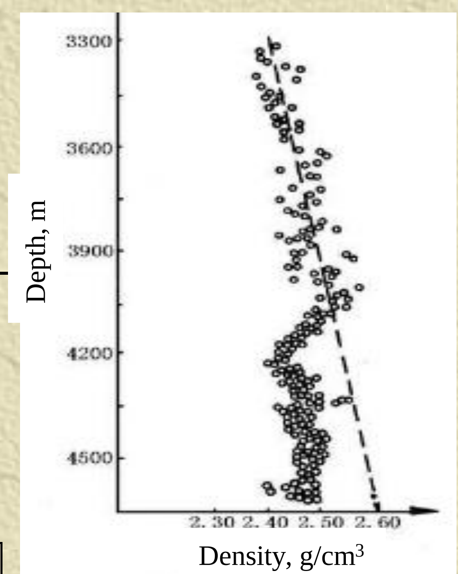




Overpressure has been found in almost all important petroleum basins in China, including the Songliao basin and the Bohai Bay basin in eastern China, the Junggar and Qaidam basins in western China, the Sichuan basin in central China, as well as offshore basins such as the Yinggehai, Qiongdongnan and Beibuwan basins.

IV.Overpressure Prediction

1. Character

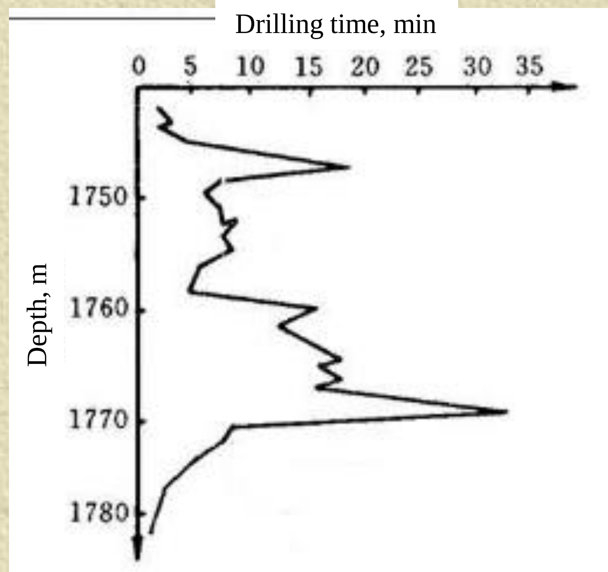


Relationship between cutting density and depth

Physical features Φ increasing, ρ decreasing

Drilling Drillability enhanced, drilling time decreasing, well kicking and blowout

Well logging Resistivity decreasing
△t increasing



2. Overpressure prediction

(1) Drilling data

(2) Well logging

2. Overpressure prediction

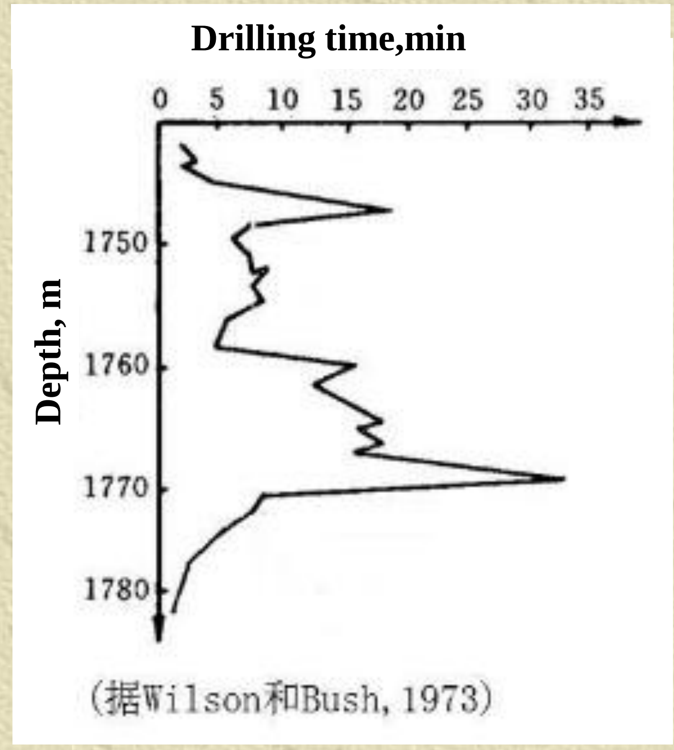
(1) drilling data

- drilling speed, penetration rate
- d exponent
- retuened mud temperature

2. Overpressure prediction

(1) Drilling parameter

drilling speed



2. Overpressure prediction

(1) Drilling parameter----d exponent)

$$d = \frac{\lg 0.0547 V / N}{\lg 0.672 P / D}$$

V----penetration rate, m/h;

D----bit diameter, mm

P----drilling weight, ton

N----revolution speed, r/min

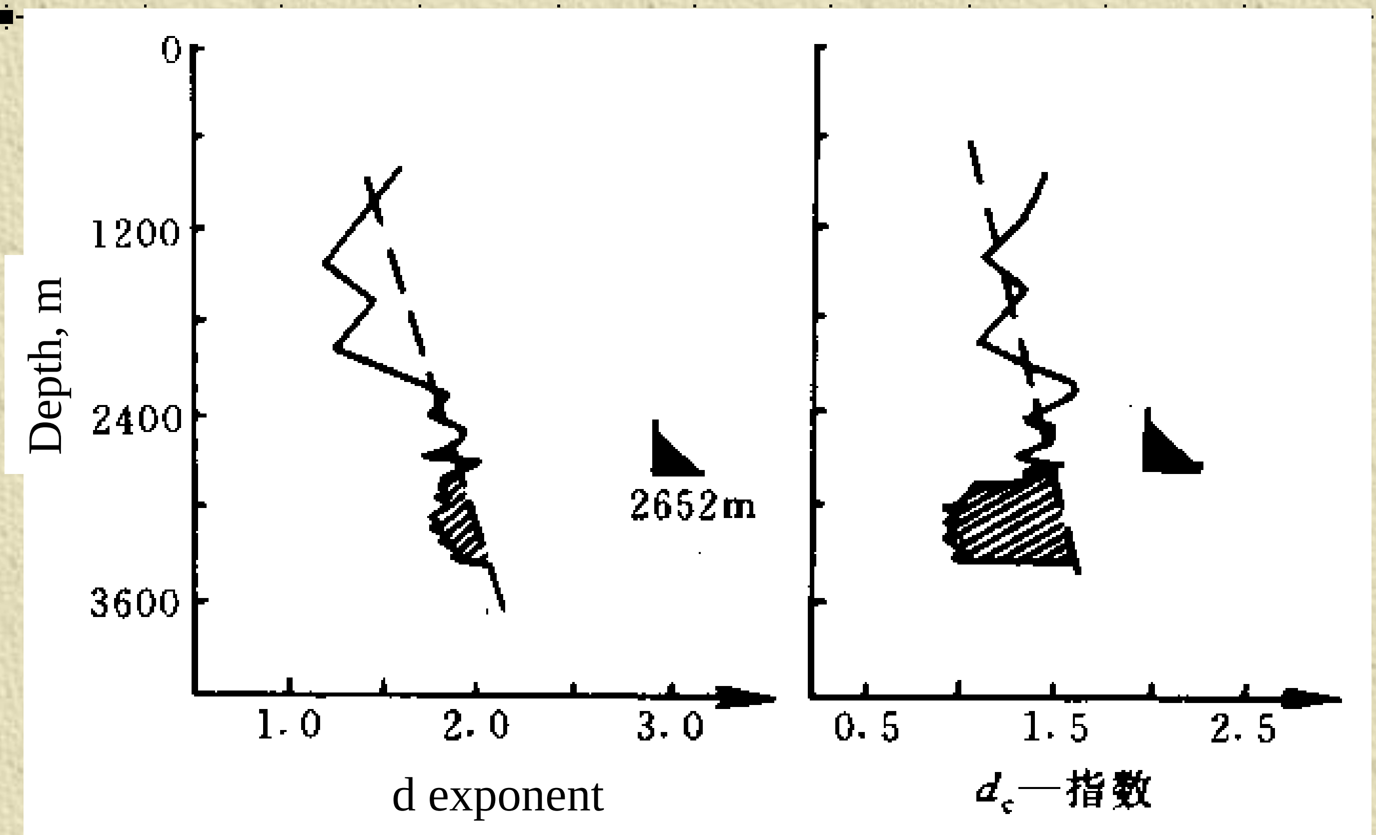
d exponent

$$dc = d \bullet \frac{r_w}{r_m}$$

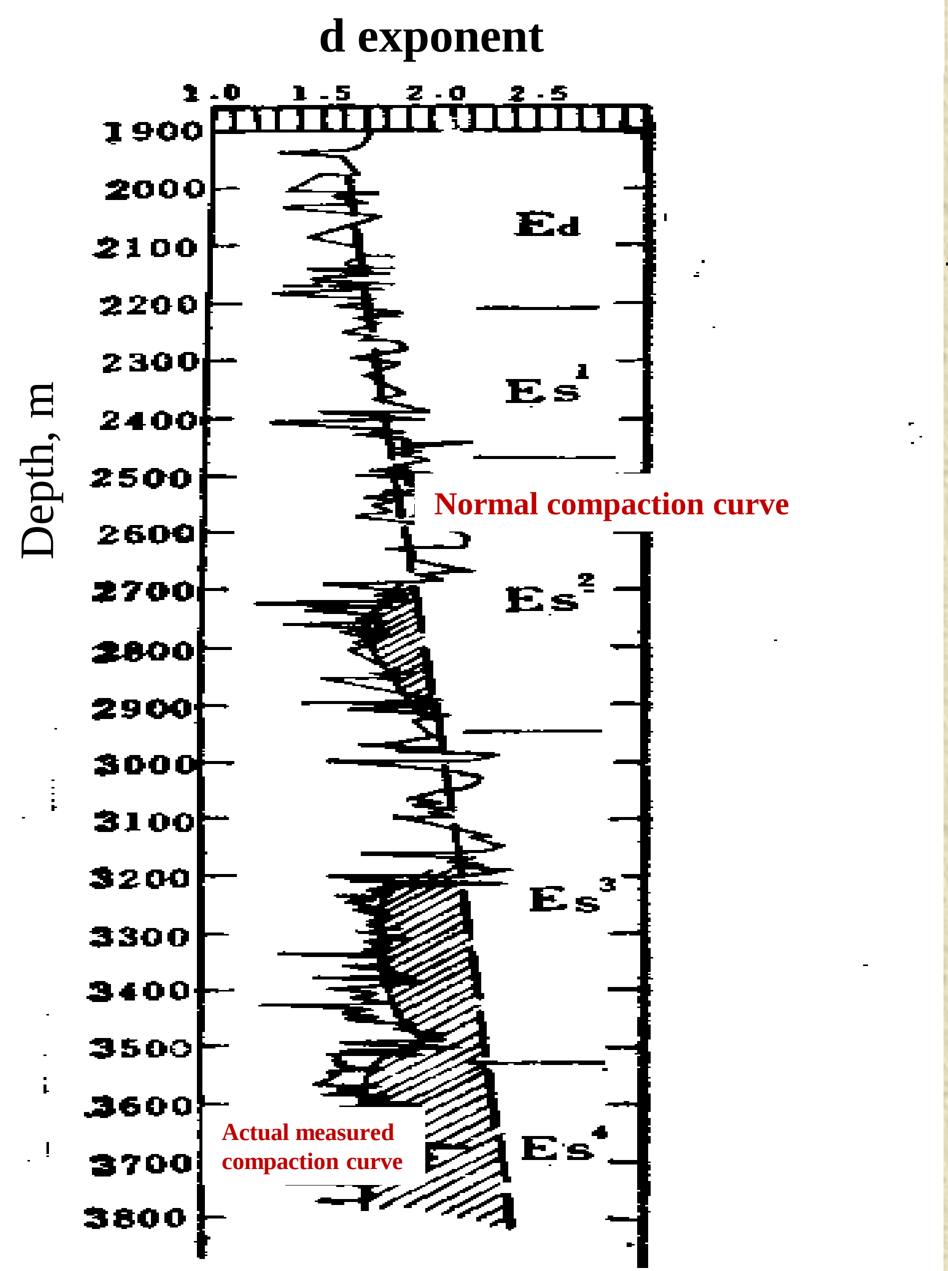
r_w **Mud weight under normal pressure**

r_m **Actual mud weight**

d exponent



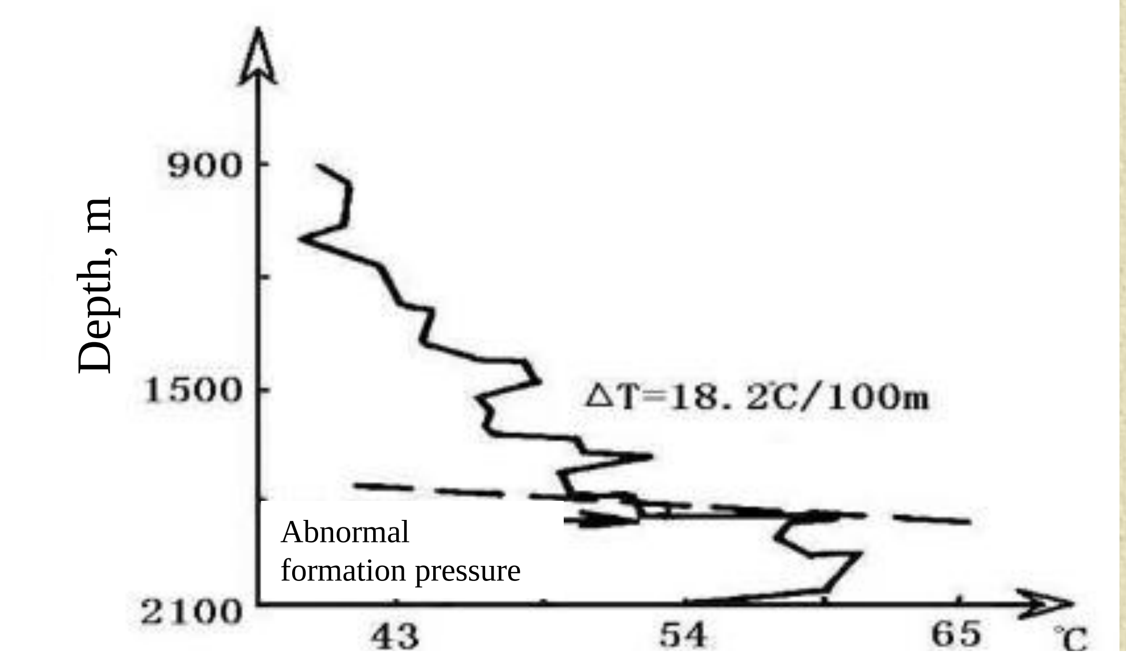
d exponent curve and dc exponent curve



Huabei oil field Kai24 well de curve

2. Overpressure prediction

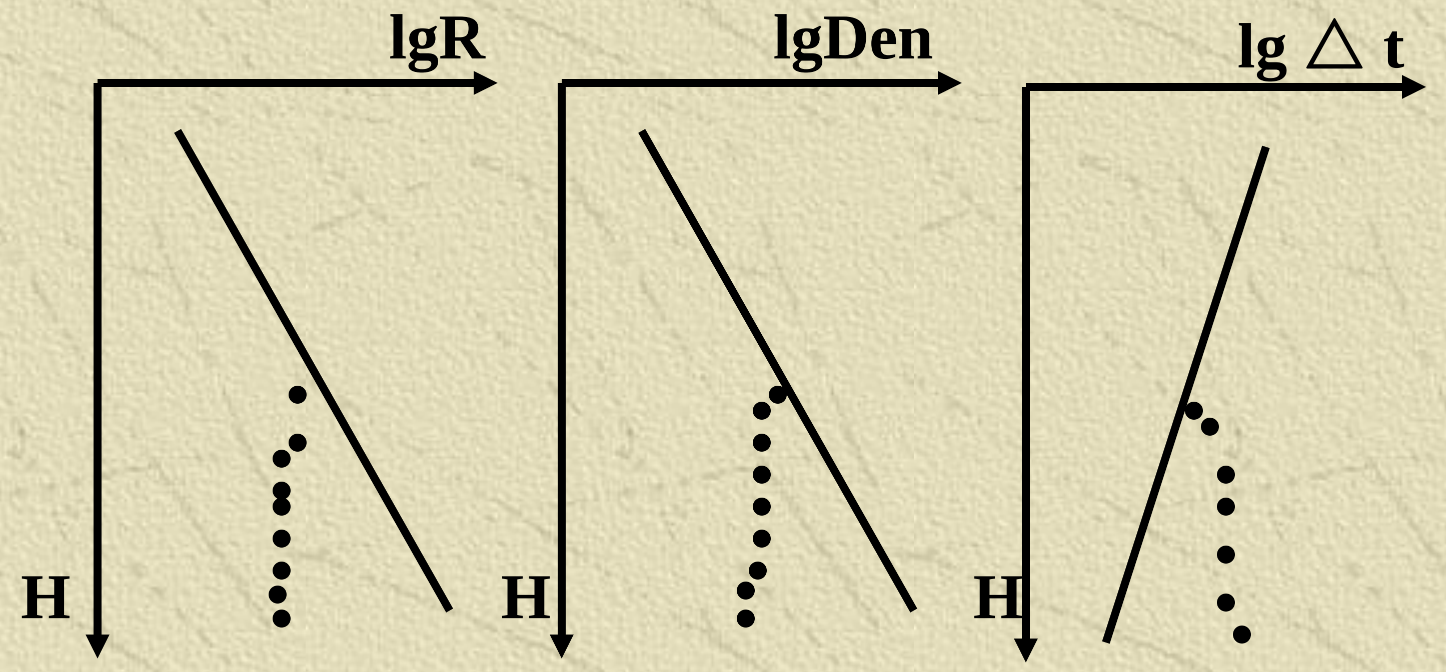
The temperature of returned drilling fluid----abnormal high temperature（abnormal overpressure often associated with abnormal high temperature）

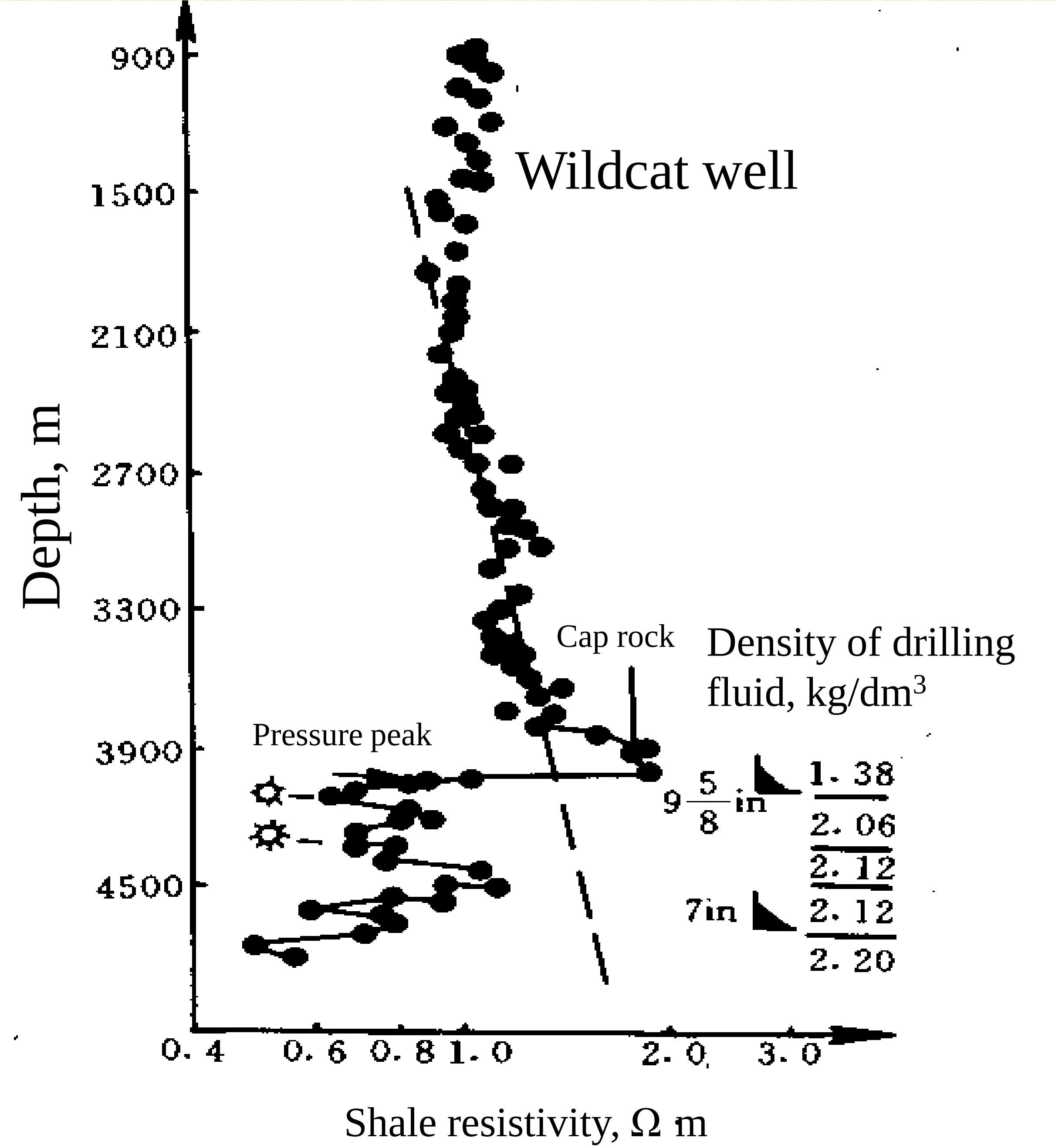


Relationship between returned drilling fluid and depth

2.Overpressure prediction

log parameters





Wildcat well
Depth, m
900
1500
2100
2700
3300
3900
4500
Cap rock
Density of drilling fluid, kg/dm3
Pressure peak
9 5/8 in
1.38
2.06
2.12
7in
2.12
2.20
0.4
0.6
0.8
1.0
2.0
3.0
Shale resistivity, Ω m

3.Pressure calculation

① empirical curve

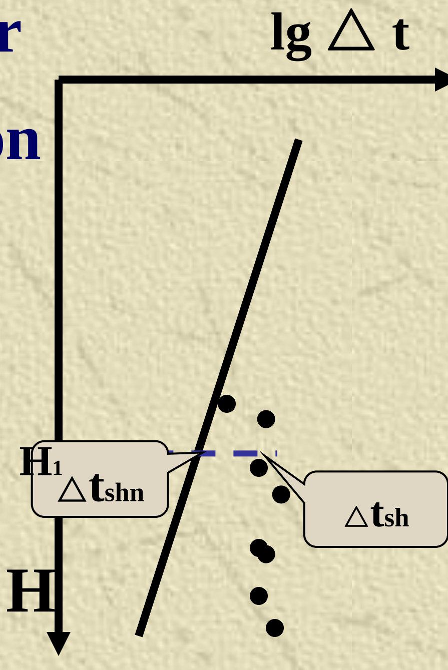
acoustic logging
resistivity method

② equivalent depth

3. Pressure calculation

① Experience curve: Interval transit time

Propose chart between well logging parameter and pressure gradient, then pressure prediction



A.Calculation pressure gradient, G=P/H

B.Calculation interval transit time deviation:

$\triangle t_{sh} - \triangle t_{shn}$

($\triangle t_{sh}$----Actual $\triangle t_{sh}$;

$\triangle t_{shn}$---- Normal tendency △t at the same depth

C. Pressure Gradient ~ $\triangle t_{sh} - \triangle t_{shn}$ chart

D. Regression, plotting chart ➡ pressure prediction

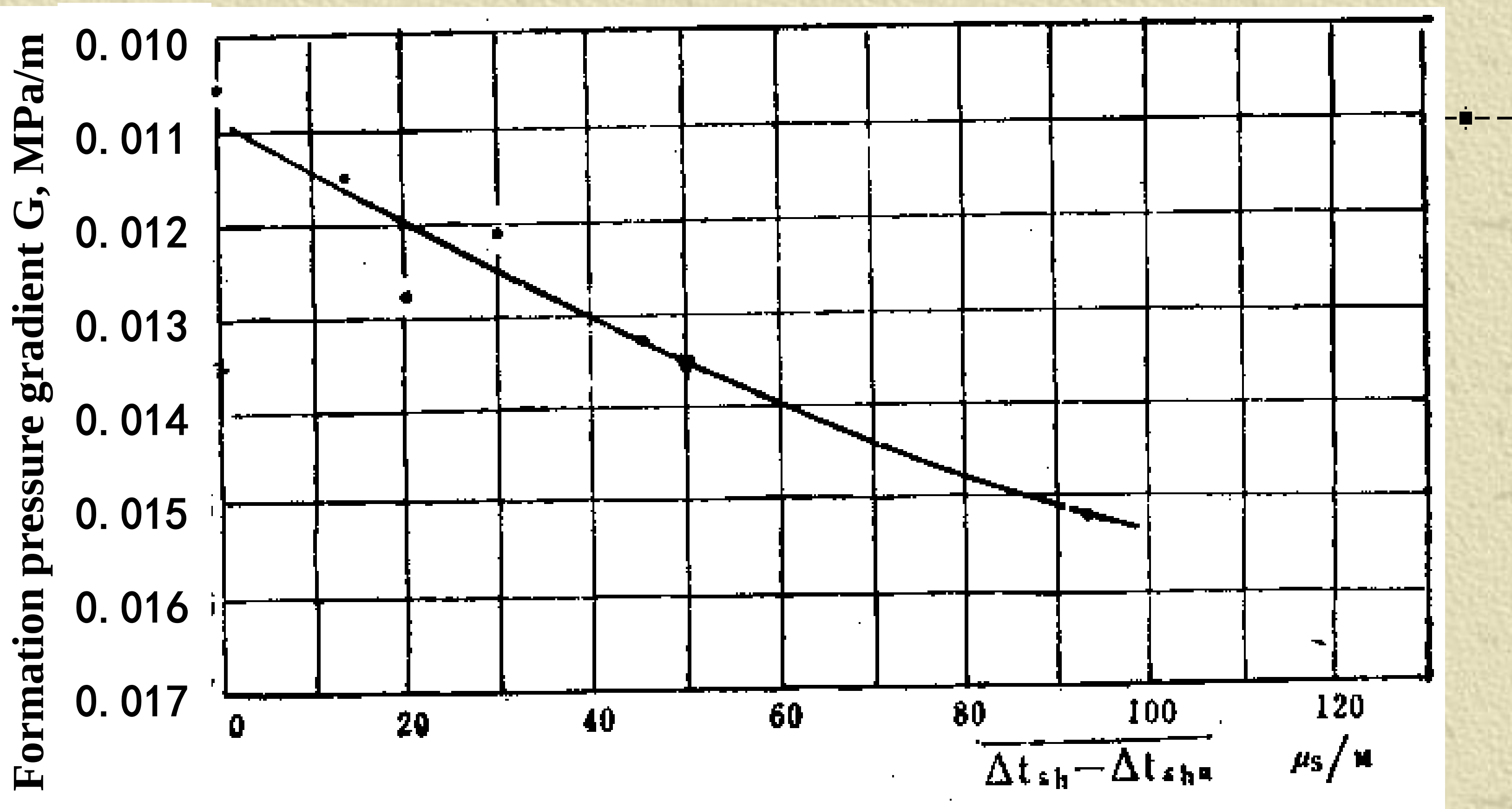


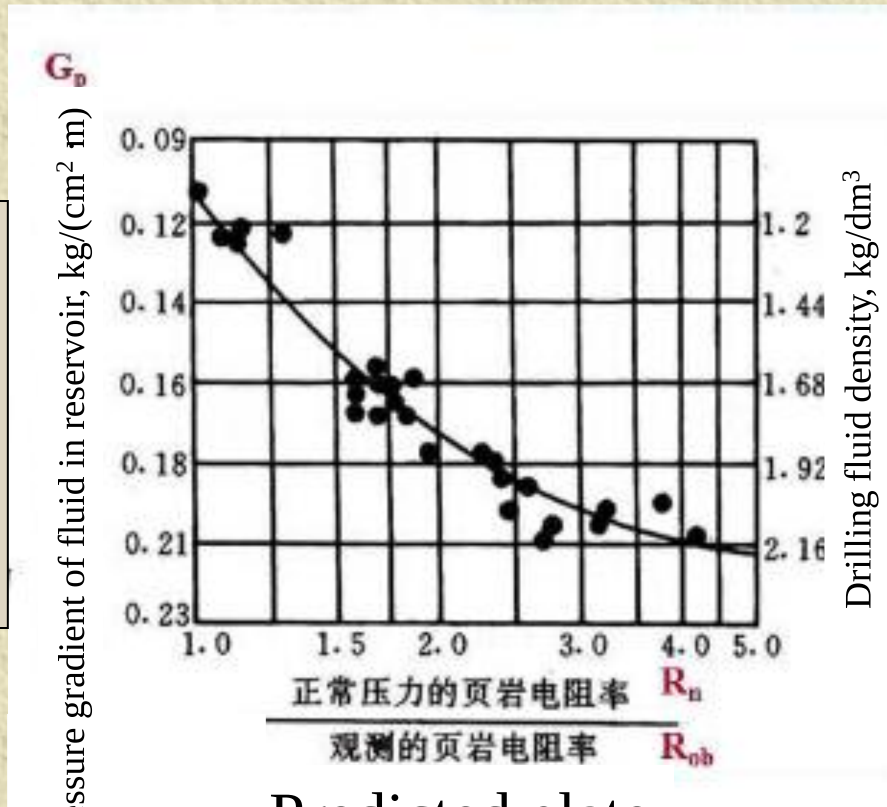
Plate for calculating formation pressure by $\triangle t_{sh}$- $\triangle t_{shn}$

Resistivity method: R_{shn}/R_{shob}

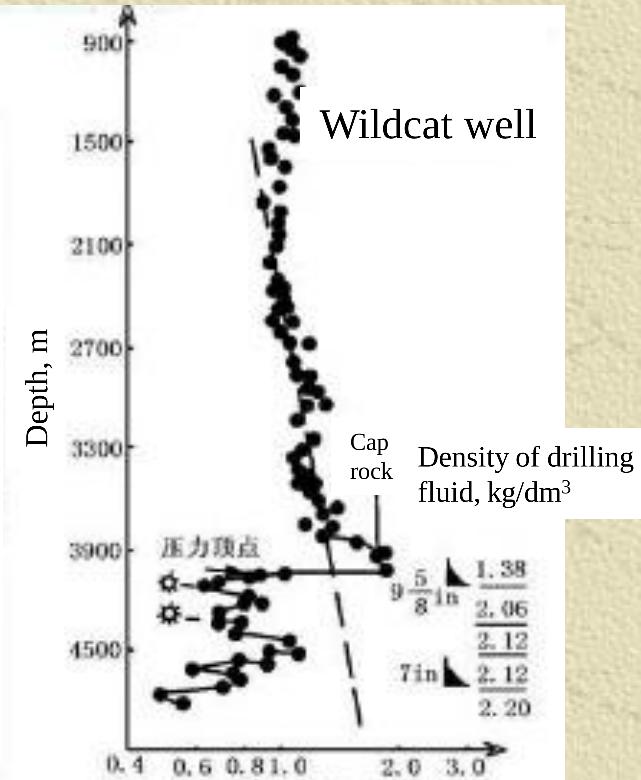
R_{shob}: **Actually measured shale resistivity**

R_{shn}: **Normally compacted shale resistivity at same depth**

A. Make plate
(known data)
B. Get $_{shn}/R_{shob}$
C. Get Gp
D. Calculate pressure



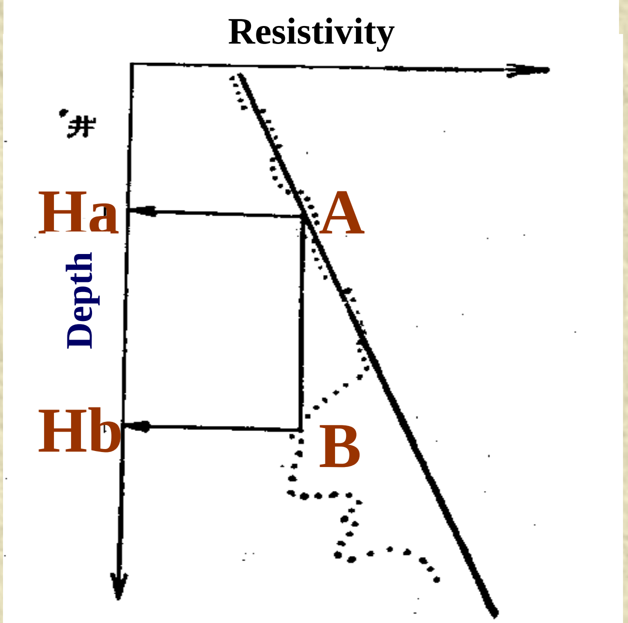
Predicted plate



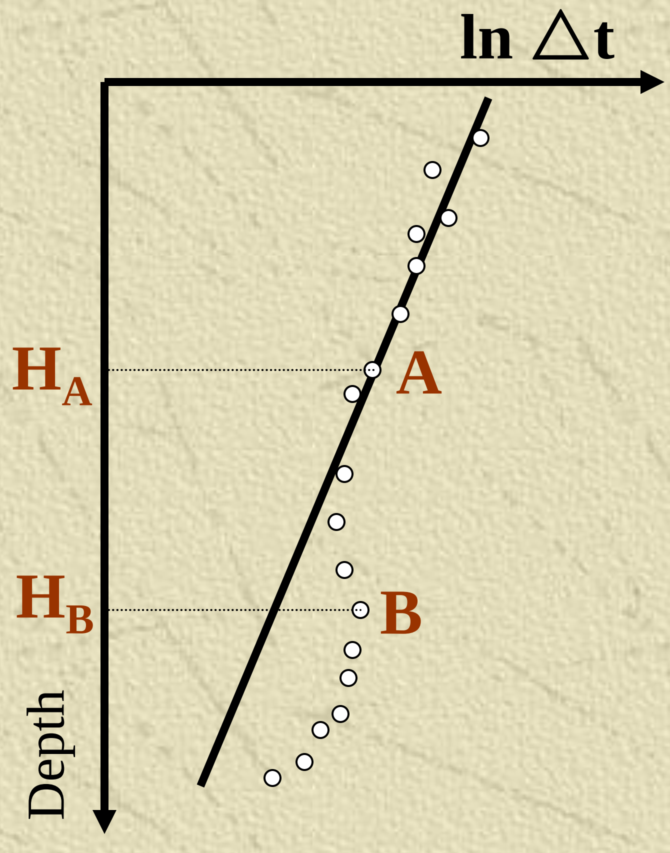
Shale resistivity, Ω m

② Equivalent depth method

Equivalent depth: The depth in normal at which the logging parameters are the same as that of the overpressure zone without consideration of formation temperature.



Sketch map of predicted overpressure
formation by using equivalent depth



A,B have the same △t,

B locates in uncompacted belt

A locates in normal compacted curve

H_A is the equivalent depth of H_B

$$\left.\begin{array}{l} P_{OA} = \sigma_A + P_A \\ P_{OB} = \sigma_B + P_B \end{array}\right\} \quad \boxed{\sigma_A = \sigma_B}$$

$$\boxed{P_B = P_A + (P_{OB} - P_{OA})}$$

$$P_B = P_A + (P_{OB} - P_{OA})$$

Expressed by pressure gradient

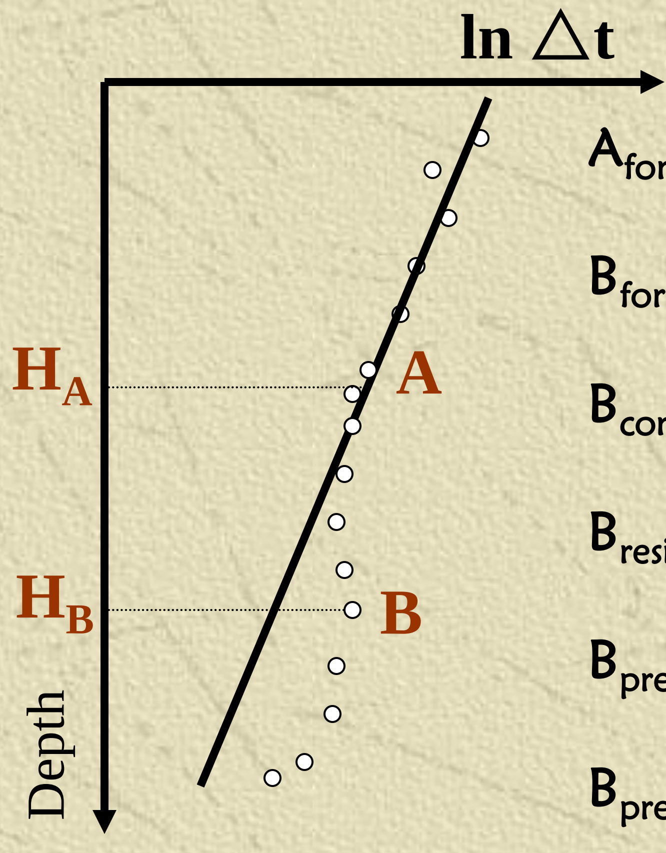
$$P_B = G_H * H_A + G_O (H_B - H_A)$$

G_H----Hydrostatic pressure gradient, 0.01MPa/m

G_o----Overburden pressure gradient, 0.0231MPa/m

Example: H_A=1500m, H_B=2500m,

G_H=0.01MPa/m, G_o=0.0231MPa/m



$A_{\text{formation pressure}}$ = P_A=0.01*1500=15MPa

$B_{\text{formation pressure}}$ = P_B=P_A+0.0231(2500-1500) =38.1MPa

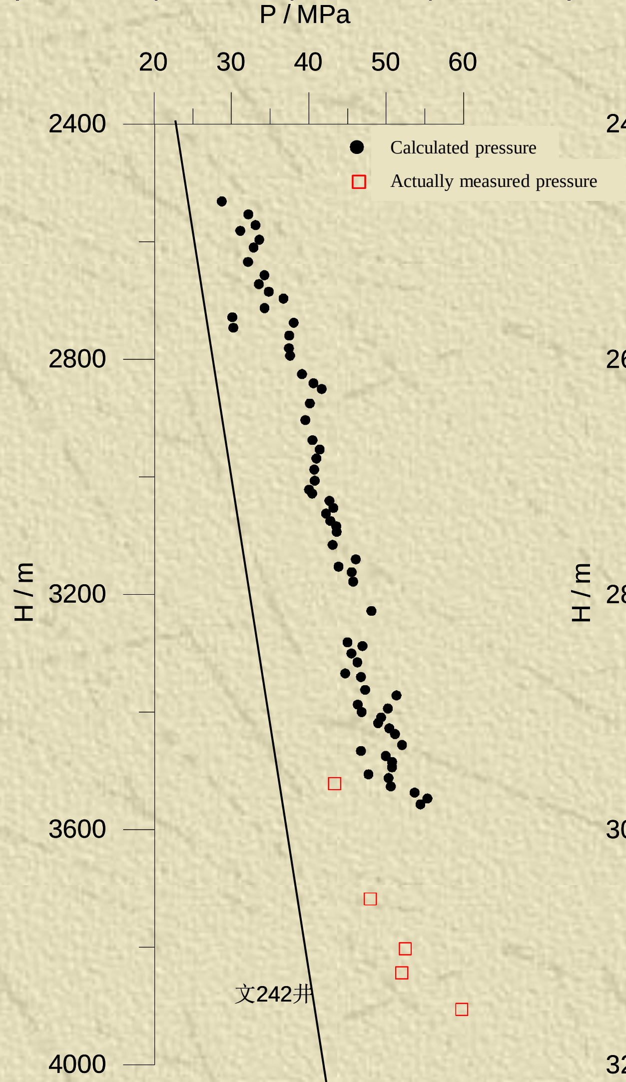
$B_{\text{corresponding hydrostatic pressure}}$ = 0.01*2500=25MPa

$B_{\text{residual pressure}}$ = △P_B=38.1-25=13.1MPa

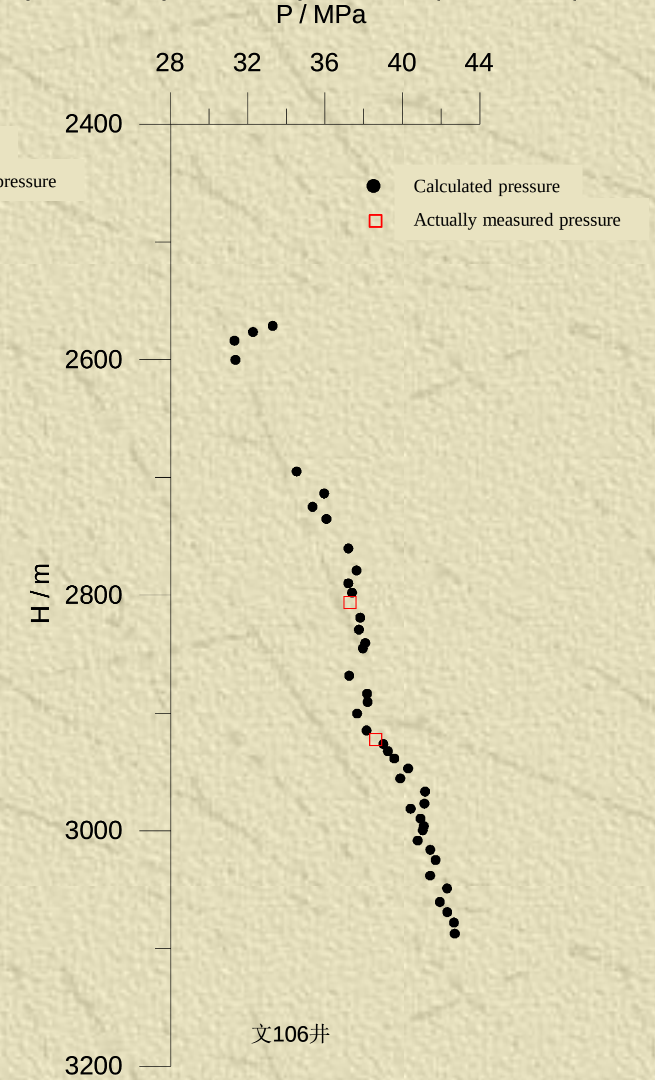
$B_{\text{pressure coefficient}}$ = 38.1/25=1.524

$B_{\text{pressure gradient}}$ = 38.1/2500=0.01524MPa/m

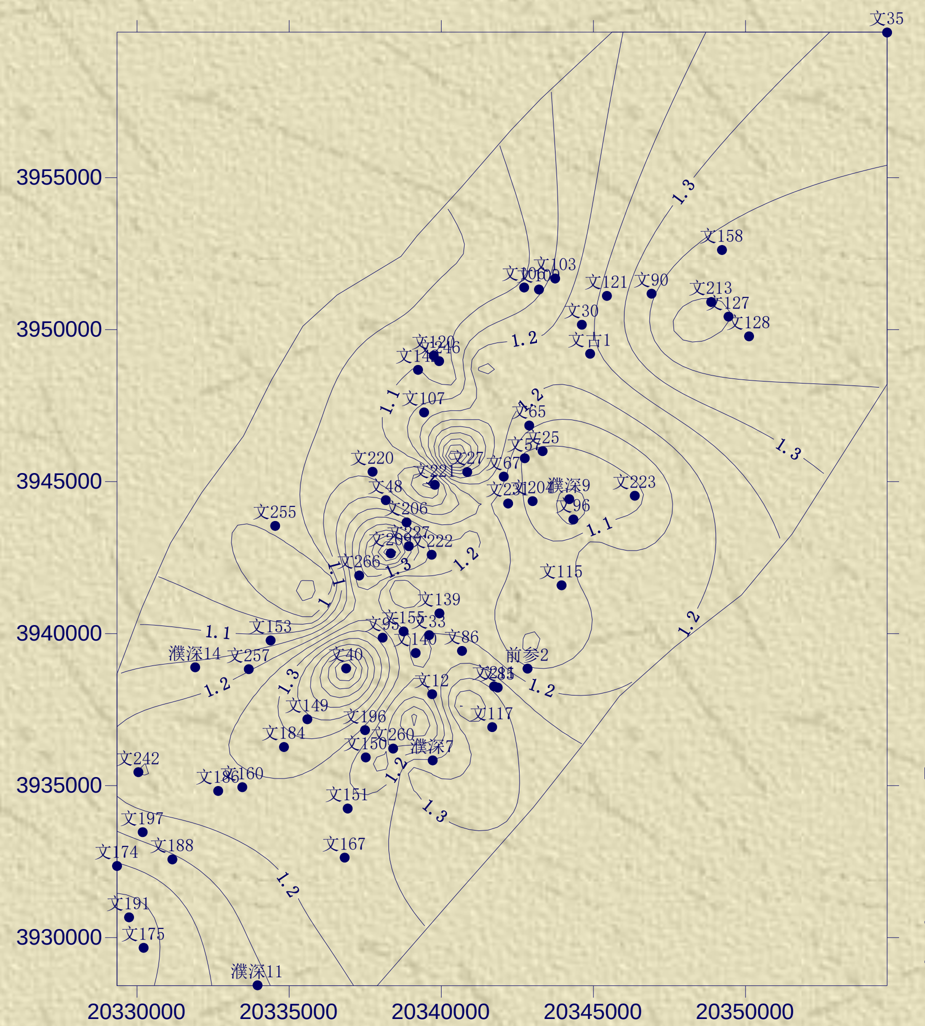
If point B needs balanced drilling,
how much specific gravity should be prepared?



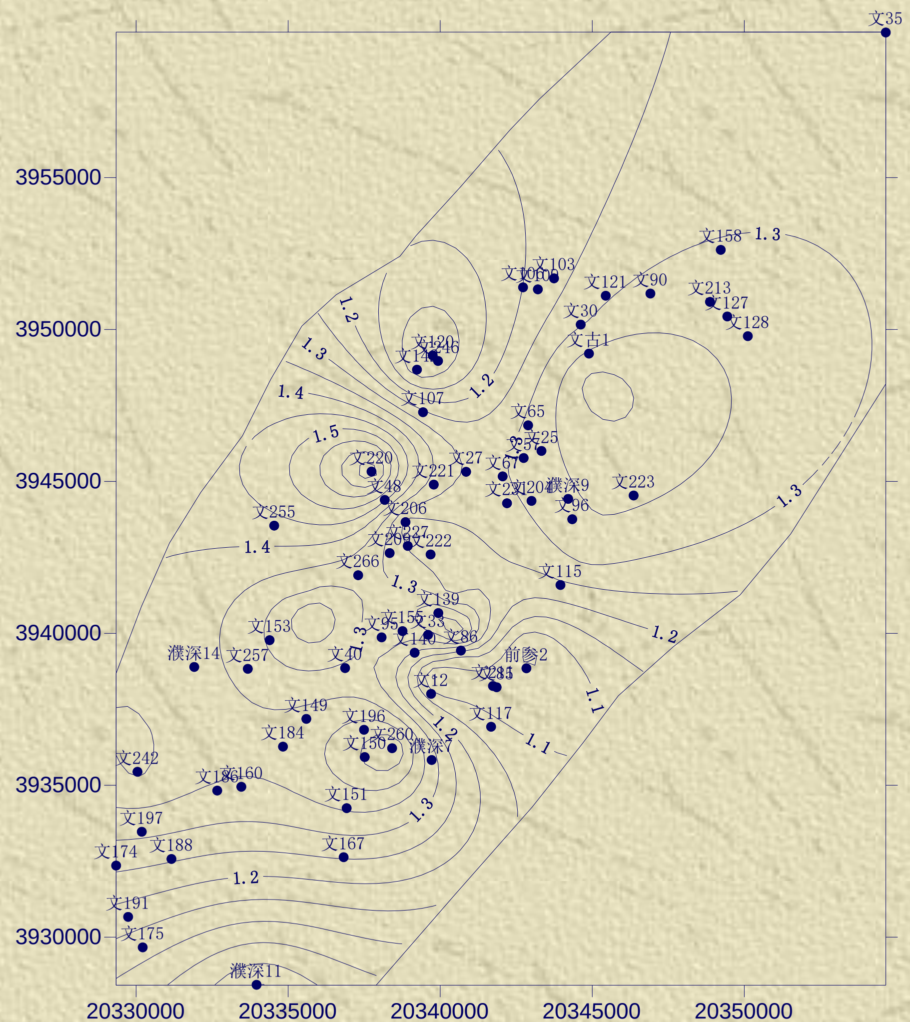
P / MPa
20
30
40
50
60
2400
2800
3200
3600
4000
H / m
Calculated pressure
Actually measured pressure
文242井



P / MPa
28
32
36
40
44
2400
2600
2800
3000
3200
H / m
Calculated pressure
Actually measured pressure
文106井



The pressure coefficient map of $E_2S_3^1$ formation



The pressure coefficient map of $E_2S_3^2$ formation

Section 2 Abnormal Formation Pressure

I. Abnormal Formation Pressure Concept

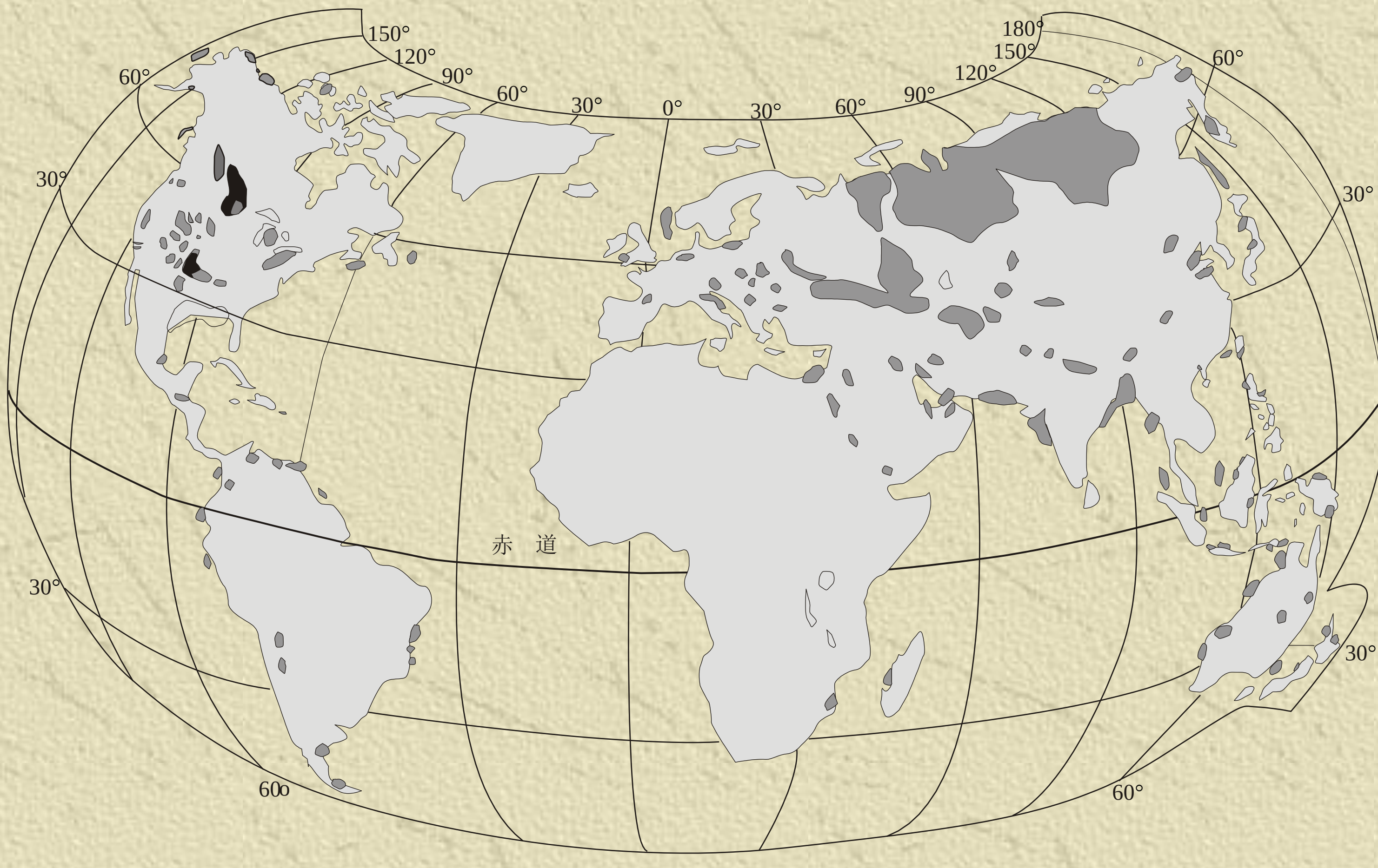
II. Compaction Model Test

III. Geological Condition

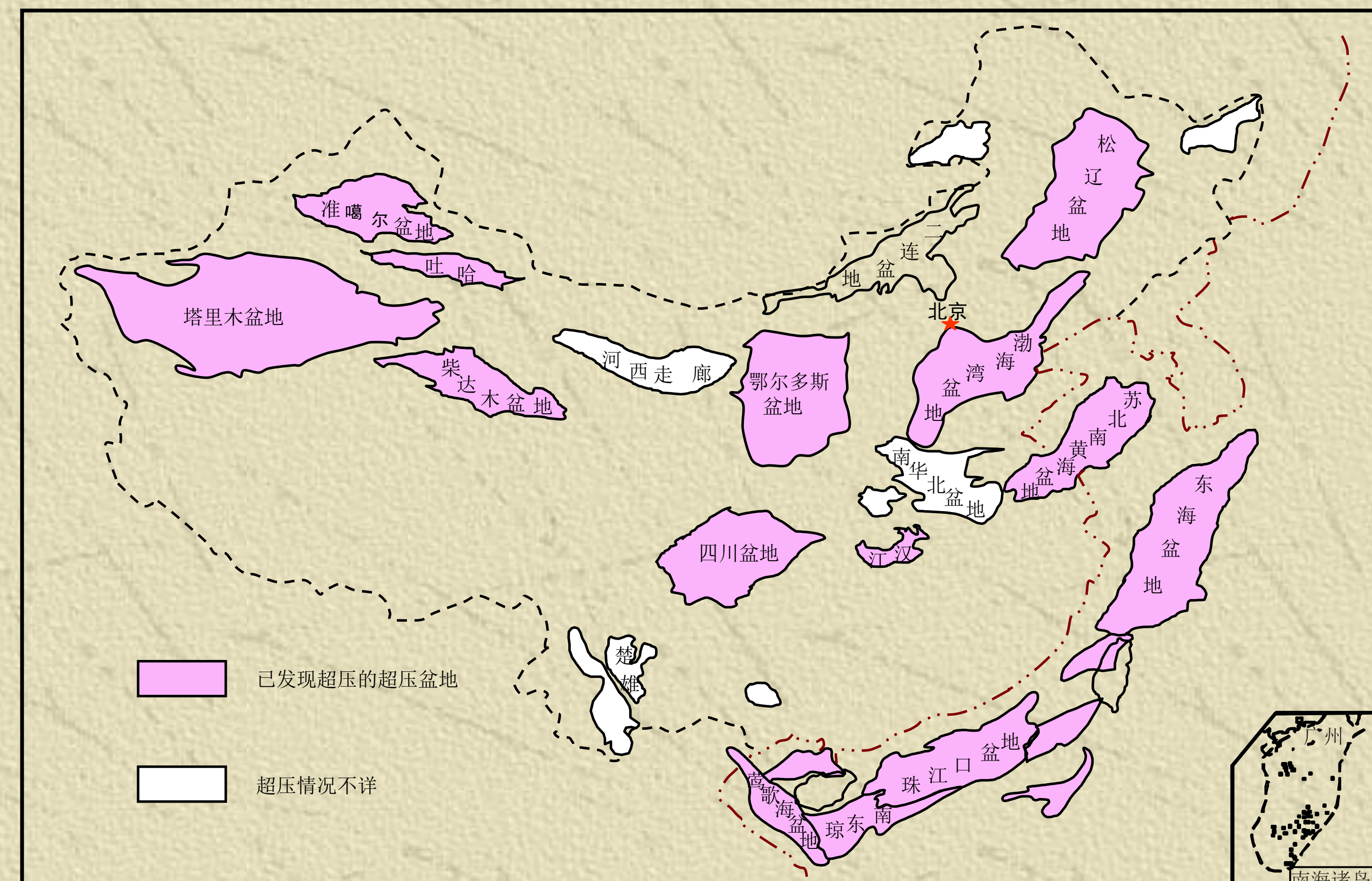
IV. Overpressure Prediction

V. Signification

Major abnormally pressured areas in the world



Overpressured basins in China



V. Significance

- Protect oil layer, safety production
- Design reasonable casing programm and completion method
- Study petroleum generation, migration and accumulation, direct petroleum exploration

V. Significance

1. Drilling engineering aspect

① Adjust mud weight

② Predict fracture pressure gradient

③ Design wellbore configuration

V. Significance

1. Drilling engineering aspect

① Adjust mud weight

Drilling through abnormal pressure regimes require special care.

Mud column pressure

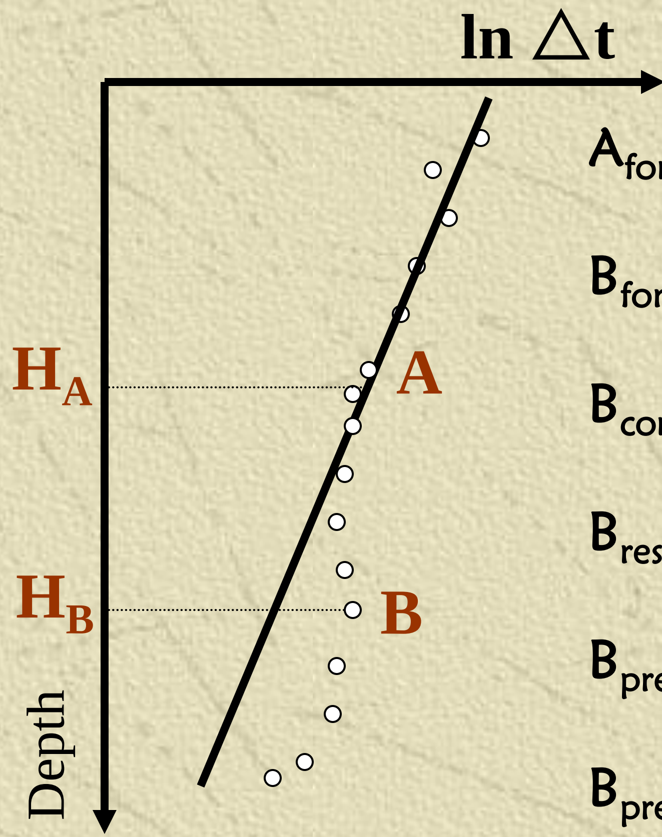
=formation pressure+safety factor(10% formation pressure)

=1.1 formation pressure

Drilling through abnormal pressure

When drilling into an overpressure formation, the mud weight must be increased. If this increased mud weight would cause large losses in shallower, normally pressured formations, it is necessary to isolate the normally pressured formation by casing before drilling into the overpressured formation. The prediction of overpressures is important in well design.

Example: H_A=1500m, H_B=2500m, G_H=0.01MPa/m, G_o=0.0231MPa/m



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$B_{\text{residual pressure}}$ = $\triangle P_B$=38.1-25=13.1MPa

$B_{\text{pressure coefficient}}$ = 38.1/25=1.524

$B_{\text{pressure gradient}}$ = 38.1/2500=0.01524MPa/m

If point B needs balanced drilling, how much specific gravity should be prepared?

P_{mud}=1.1P_B=41.91MPa

γ_{mud} = P_{mud}/2500=1.676

V. Significance

1. Drilling engineering aspect

② Fracture pressure gradient prediction

A. Eaton $FPG = \frac{P_f}{D} + (\frac{\mu}{1-\mu})(\frac{P_o}{D} - \frac{P_f}{D})$

D ----Well depth, m

μ---Poisson's ratio;

P_f/D----Formation pressure gradient, MPa,/m

P_o/D----Overburden pressure gradient, MPa,/m

V. Significance

1. Drilling engineering aspect

② Fracture pressure gradient prediction

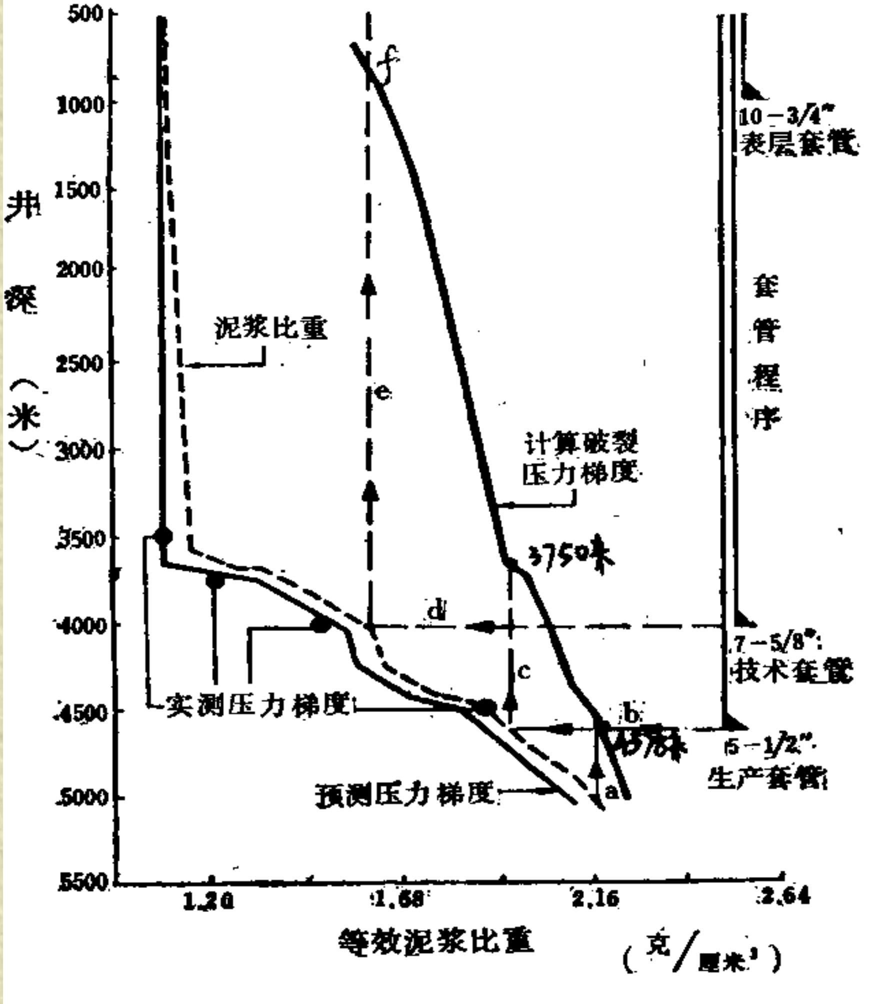
B. experience factor, empirical coefficient

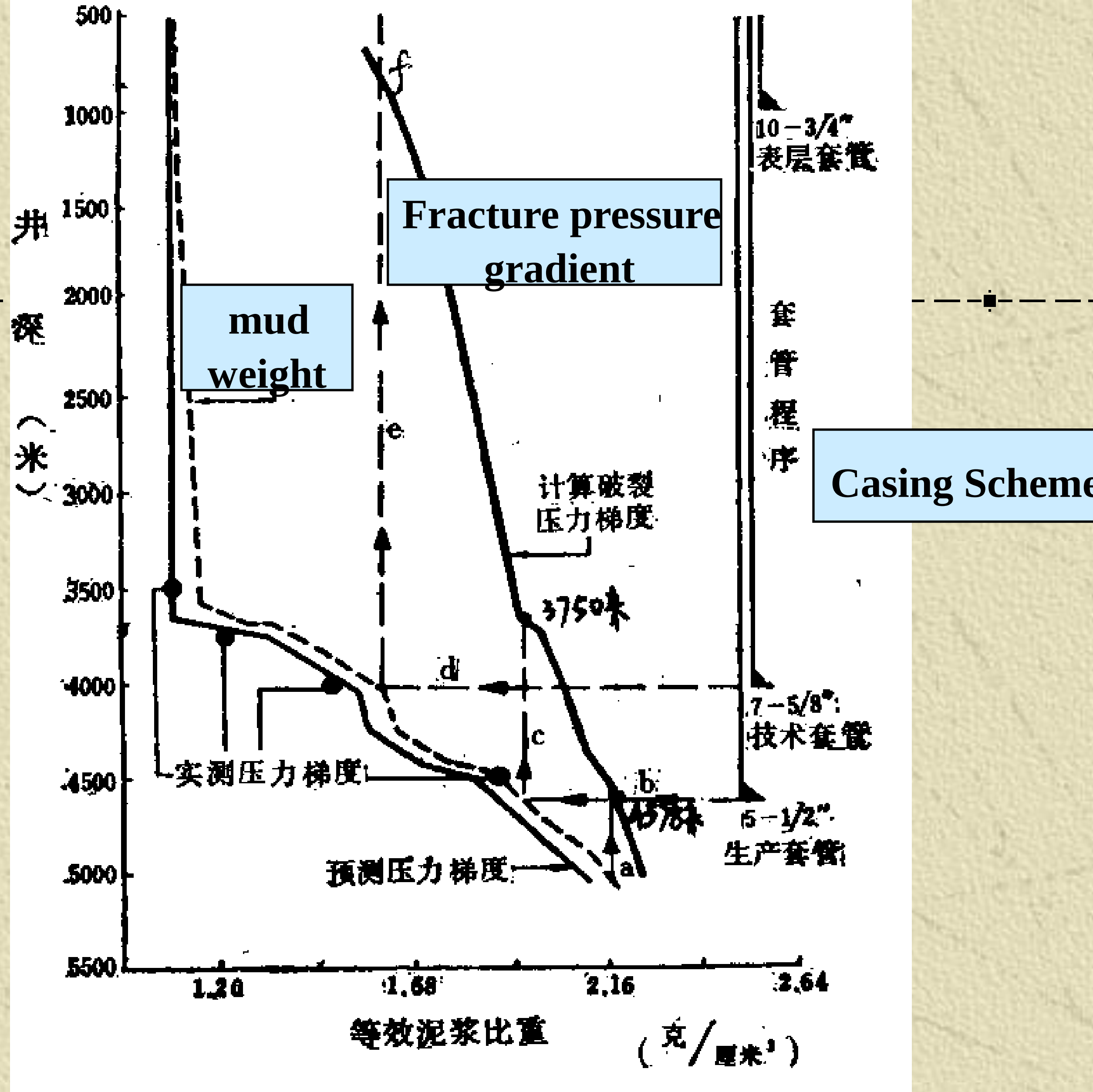
$$FPG = P_f/D + k(P_o/D - P_f/D)$$

V. Significance

1. Drilling engineering aspect

③Wellbore configuration design

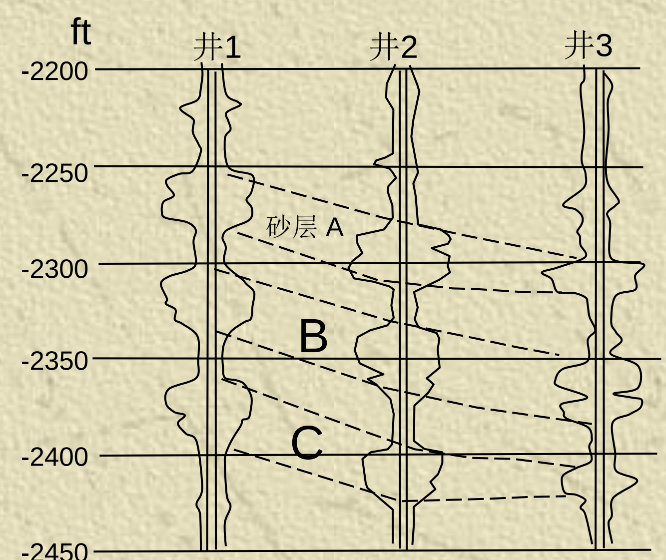




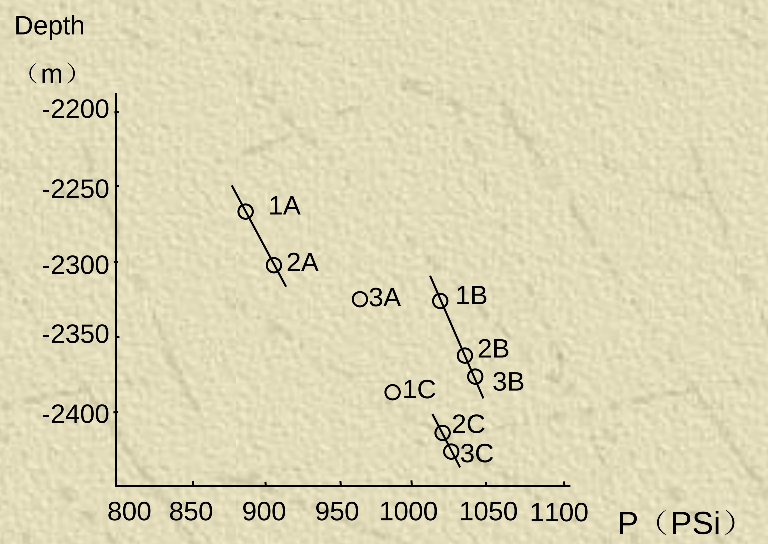
Well structure design

2. Geological Application

(1)hydrodynamic system



Well logging correlation



2. Geological Application

(2) Formation energy variation during production

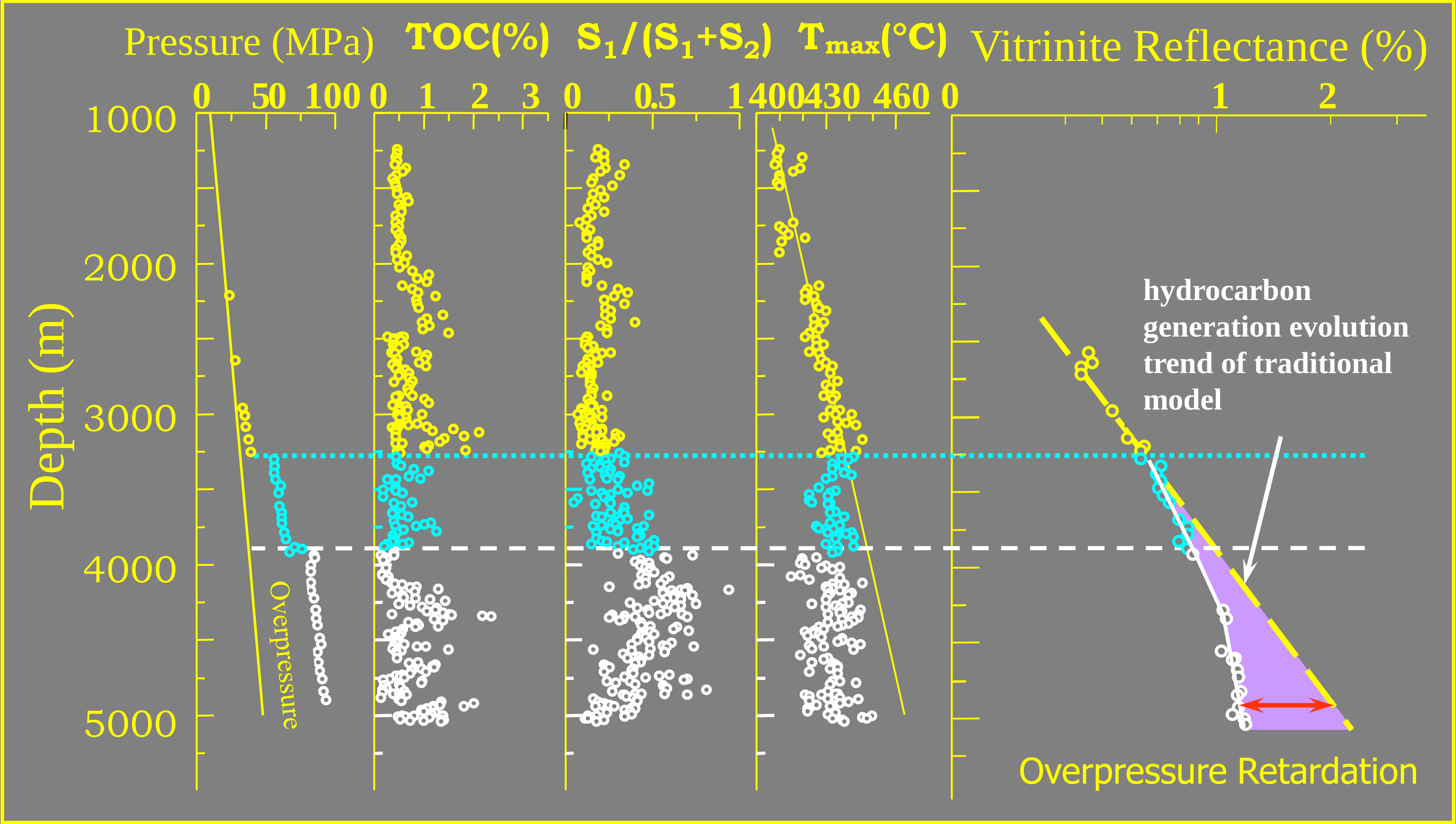
To prevent oil and gas two-phase flow underground

Formation pressure > Saturation pressure,
Bubble point pressure

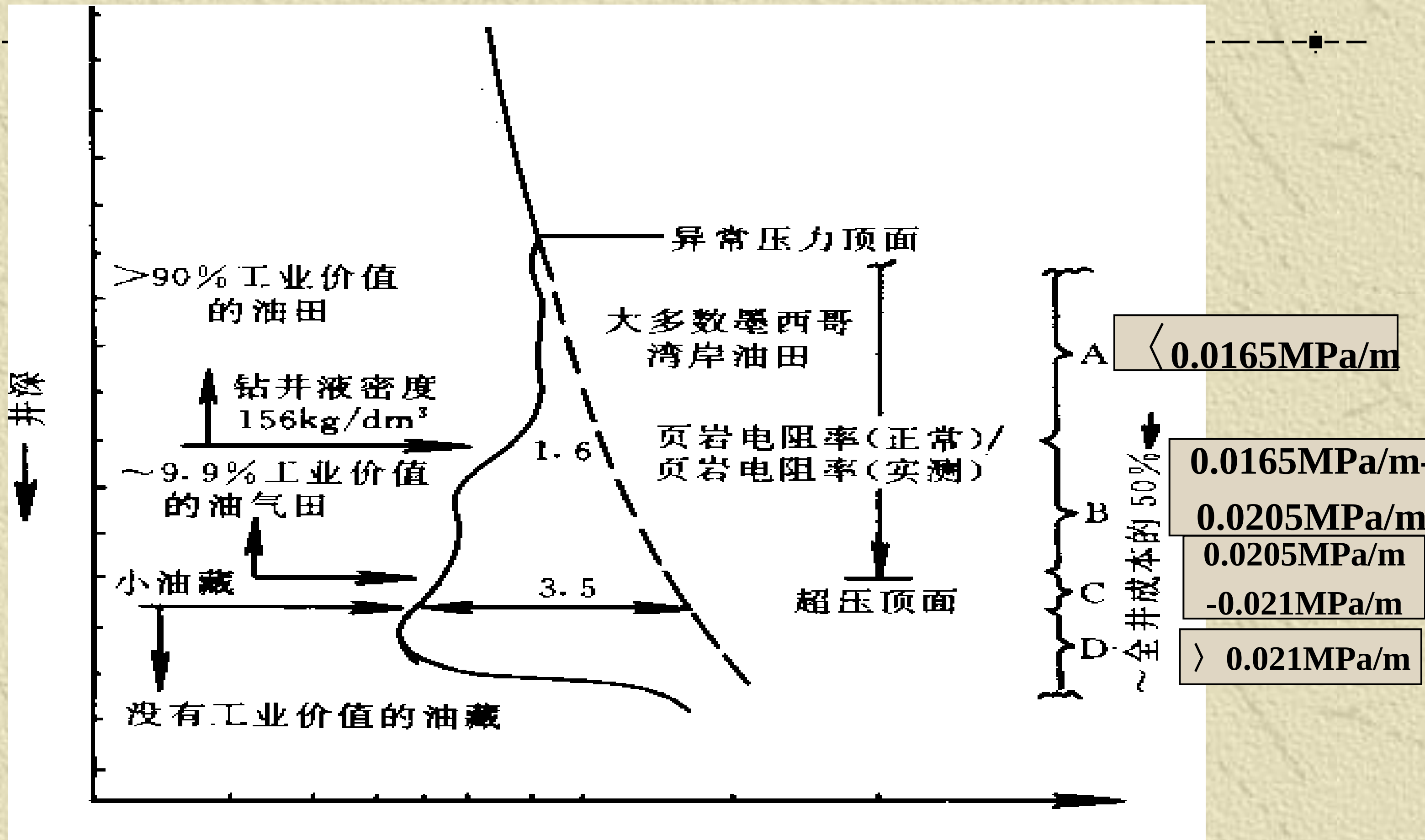
2. Geological Application

(3) Calculation natural gas reserves with abnormal pressure

Since 1990s, the significant breakthrough of hydrocarbon generation theory: break through time-temperature controlling model, reveal different inhibition of hydrocarbon generation caused by overpressure, prove liquid in overpressure formation can exist under petroleum dead line.



3. Overpressure and hydrocarbon distribution



墨西哥湾岸典型的页岩电阻率剖面

Chapter 5 Formation Pressure and Formation Temperature

Section 1 Initial Pressure and the distribution in the reservoir

Section 2 Abnormal formation pressure

Section 3 Formation Temperature

Section 3 Formation Temperature

Palaeogeotherm

The relationship between palaeogeotherm and hydrocarbon generation

Geotemperature field

the relationship between hydrocarbon distribution and Formation temperature

Section 3 Formation Temperature

- **I. Geothermal gradient and geothermal step**
- **II. Geothermal survey**
- **III. Influence factors controlling geothermal**

Section 3 Formation Temperature

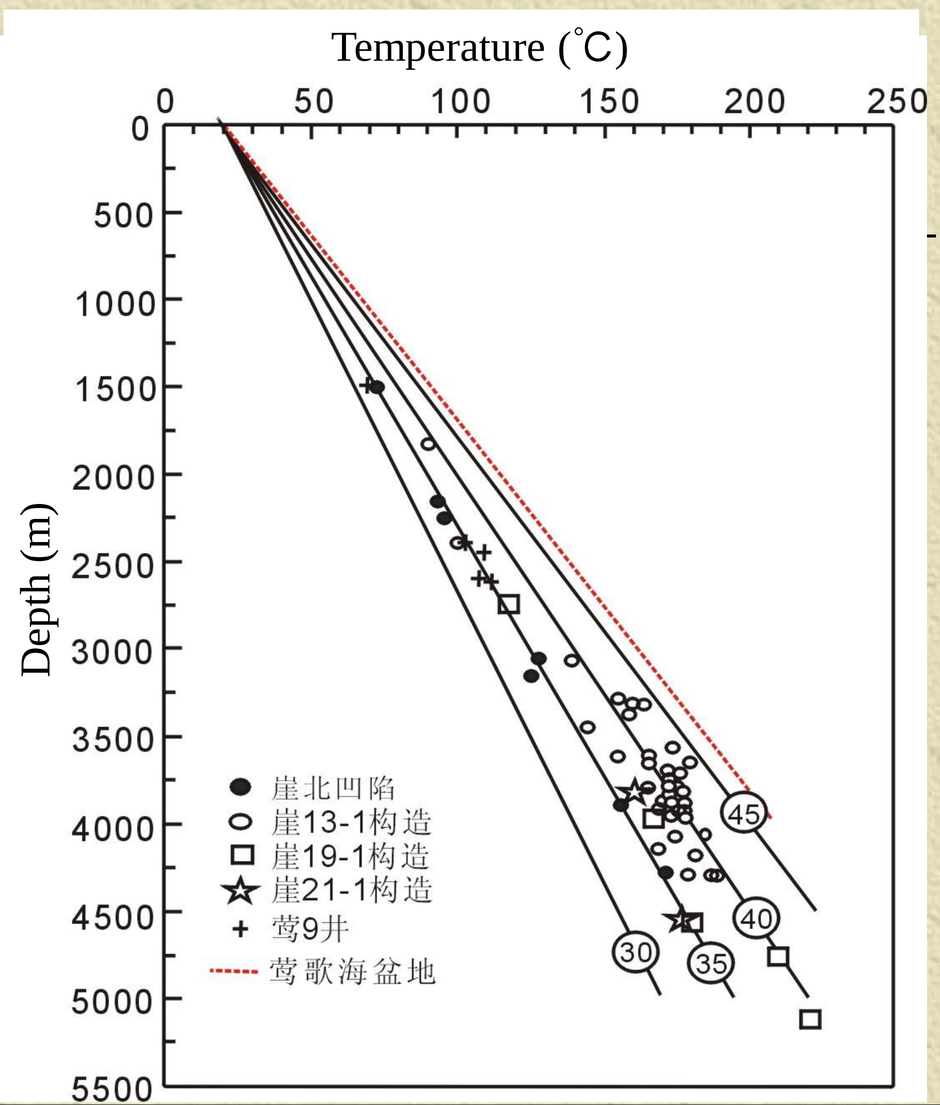
I. Geothermal gradient

G_T (geothermal gradient)

The temperature increased per 100m under constant temperature belt

$$G_T=100(T-t)/(H-h)$$

ºC/100m



Sichuan basin Longnvsi structure 100-6010m, geothermal gradient 2.6 ℃/100m, Xinjiang Karamay Oil Fields 2.0 ℃/100m（200-2000m）

Section 3 Formation Temperature

- I.Geothermal gradient

  geothermal step D_T

  The depth increased of per geothermal

$$D_T=(H-h)/(T-t)$$

$m/^oC$

Geothermal step of South Sichuan gas field is 41.5m/ ℃，

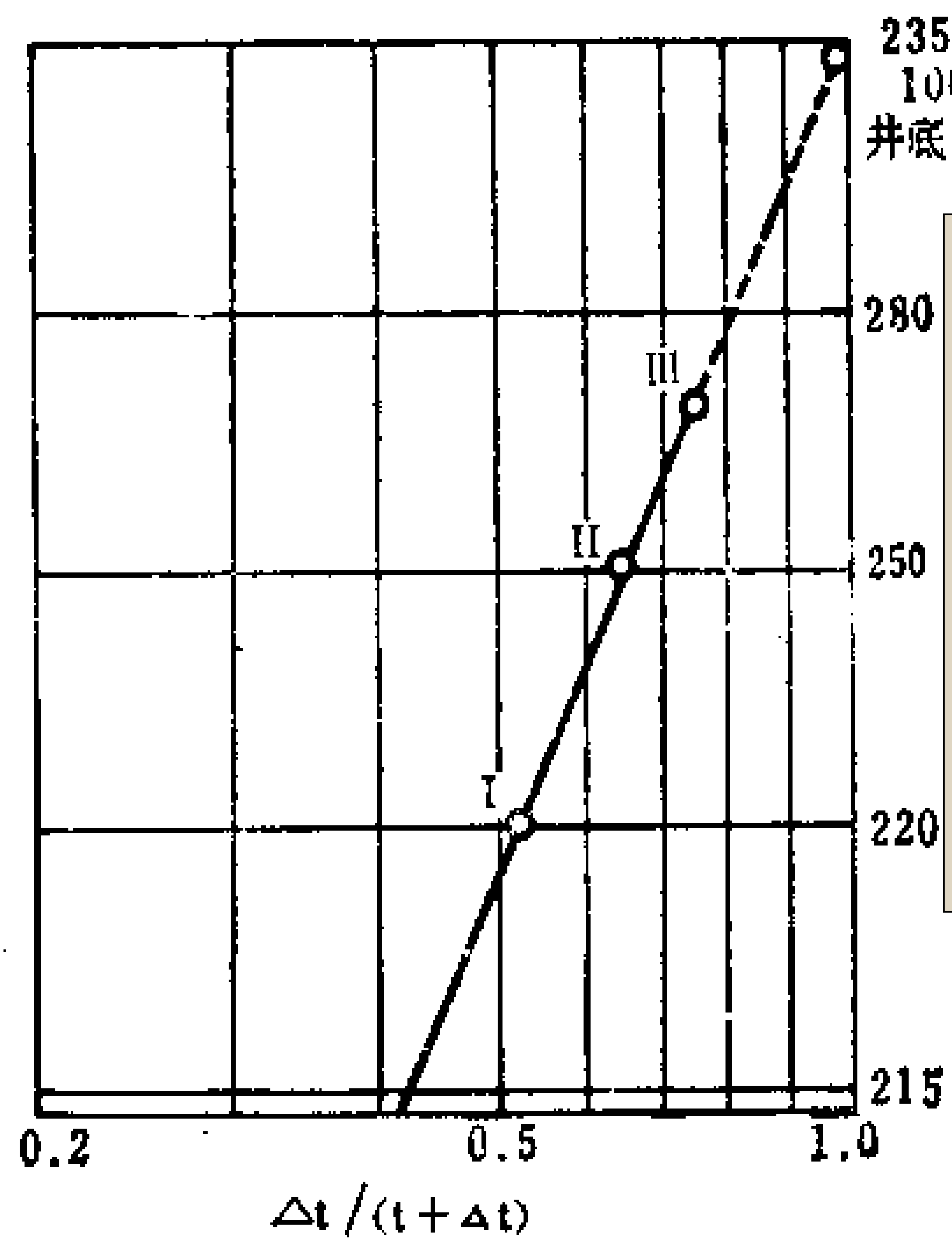
Geothermal step of Tertiary stratum in Laojunmiao oil field is 26m/ ℃.

Section 3 Formation Temperature

- **II. Formation Temperature measurement**

1. Actual measurement

2. Extrapolation



2. Extrapolation

Method:

Before measuring, circulation mud,

Record the circulation time----t,

After stopping circulation,

measuring the temperature with thermometer and get temperature----T

△t/（t+△t）--T

Section 3 Formation Temperature

III. The influencing factors of formation temperature distribution

1. The basement ups and downs

- **Basement uplift, geotemperature increasing, geotemperature gradient increasing**
- **Basement subsidence, geotemperature decrease, geotemperature gradient decrease**

Section 3 Formation Temperature

III. The influencing factors of ground temperature distribution

2. Rock thermal conductivity

heat conductivity

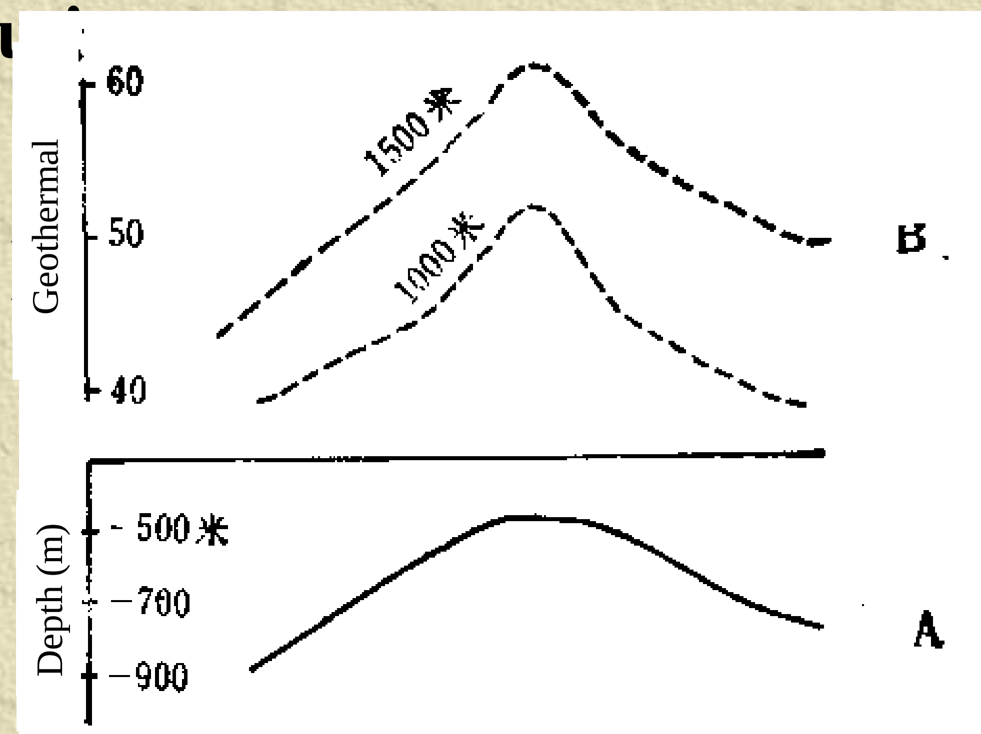
magmatic rock, clastic rock, carbonate rock

Section 3 Formation Temperature

III. The influencing factors of ground temperature distribu

3. Structure factor

Heat conductivity anisotropism

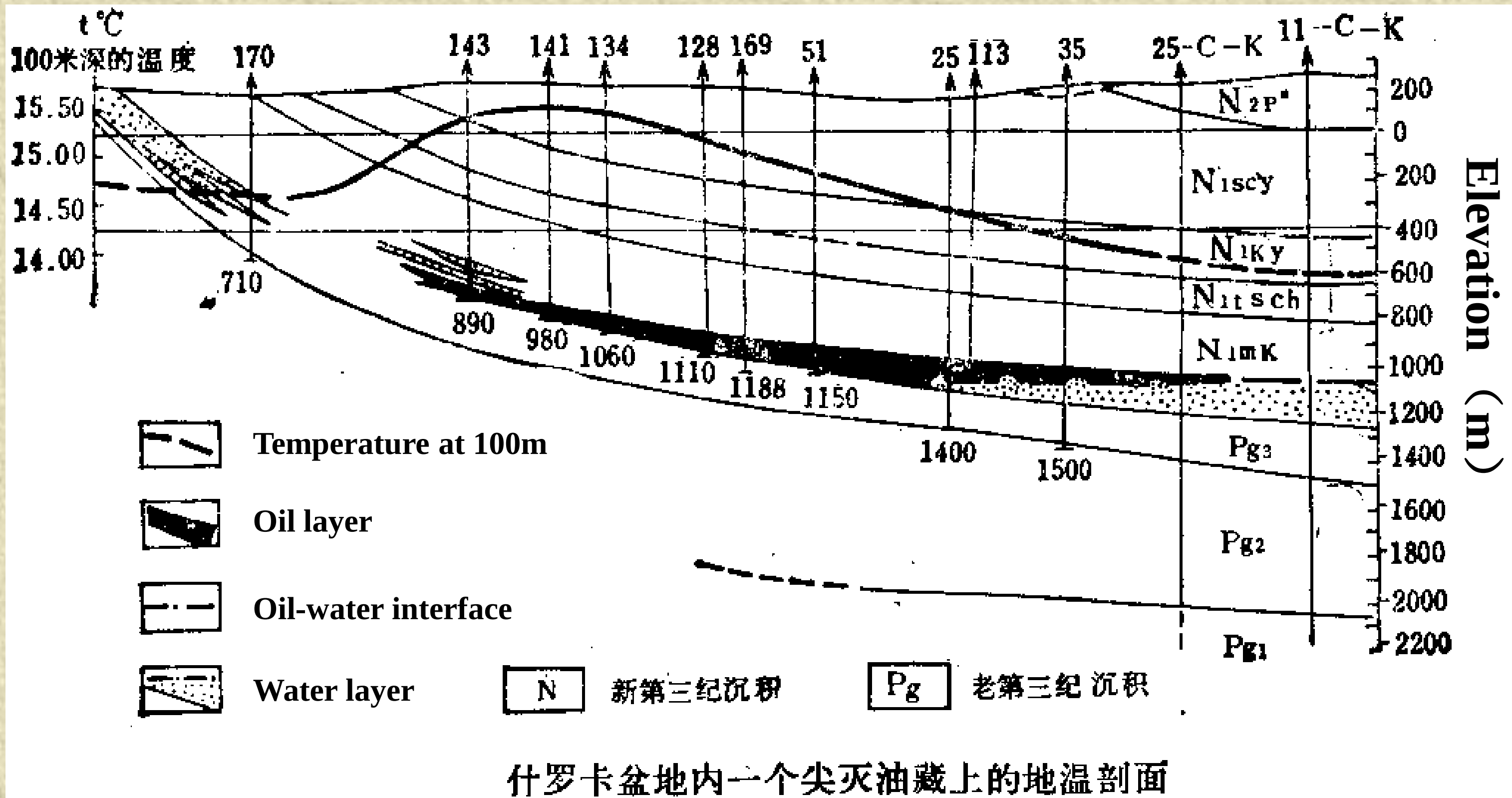


四川隆昌某气田构造剖面（A图）上，1000米和1500米深的地温变化（B图）

Section 3 Formation Temperature

III. The influencing factors of ground temperature distribution

4. Hydrocarbon distribution



Section 3 Formation Temperature

III. The influencing factors of ground temperature distribution

5. Overpressure distribution

Section 3 Formation Temperature

III. The influencing factors of ground temperature distribution

6.Groundwater circulation

Reservoir temperature and development dynamic

1. Reservoir temperature is the sensitivity which influences viscosity of crude oil. Increase reservoir temperature can enhance liquidity of crude oil;
2. During the production, if the formation pressure decreases and below saturation pressure, a large number of dissolved gas in oil will escape, expand and surge often leads to temperature reduction. Especially around the downhole, the temperature variation always lead to cement and wax precipitation, thus block the oil into well;
3. Thermal recovery technology --EOR