Chapter 6 Reserves Calculation

Section 1 Reserves Classification

Section 2 Volumetric Method

Section 3 Material Balance Method

Section 4 Pressure Decline Method

Section 1 Reserves Classification

		Oil and gas resources						
		verified reserves				Unverified reserves		
		Recovered	First developed reserves	Second Explored reserves	Third Probable reserves	Inferred reserves	Potential reserves	Prospective reserves
Economic benefits high and technical permit		Tabulated reserves				C		
Economic benefits low	High production cost	Untabulated reserves A				B		
	Low economic benefits							

high ← Economic benefits → low

high ← Geological data reliability → low

Section 1 Classification

1. Reserves
2. Untabulated reserves
3. Resources
4. Developed reserves
5. Explored reserves
6. Probable reserves
7. Inferred reserves
8. Potential reserves
9. Prospective reserves

Section 1 Classification

1. Reserves

Reserves in place: the verified reserves that can be obtained in the current technical and economic conditions

Section 1 Reserves Classification

		Oil and gas resources						
		verified reserves				Unverified reserves		
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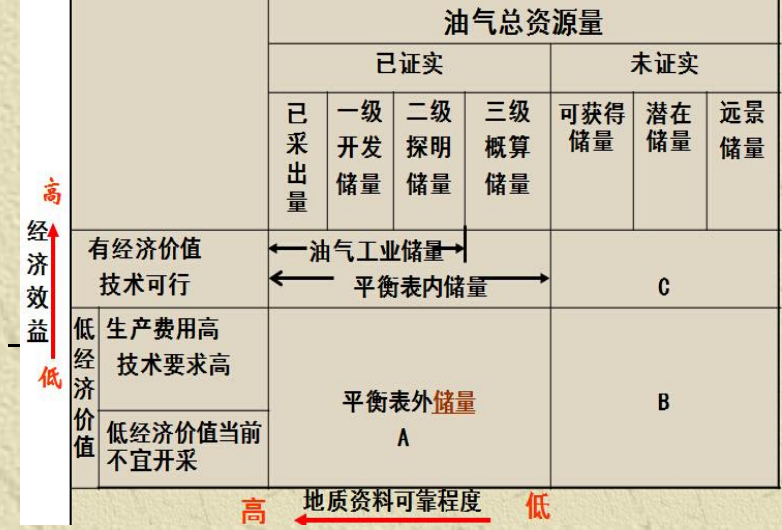
Section 1 Classification

2. Untabulated reserves

The verified reserves that could not be obtained in the current technical and economic conditions.

With the development of economy and technology, The untabulated reserves could be converted to reserves

Section 1 Classification



3. Resources

Unverified reserves and verified reserves which are not yet recoverable under current economic and technologic condition. (A+B+C in the sheet)

Total Reserves=
Resources + reserves (balance sheet)

Section 1 Classification

The oil resources of the whole world is about 311.3 billion tons

Saudi Arabia----51.26 billion tons, the first

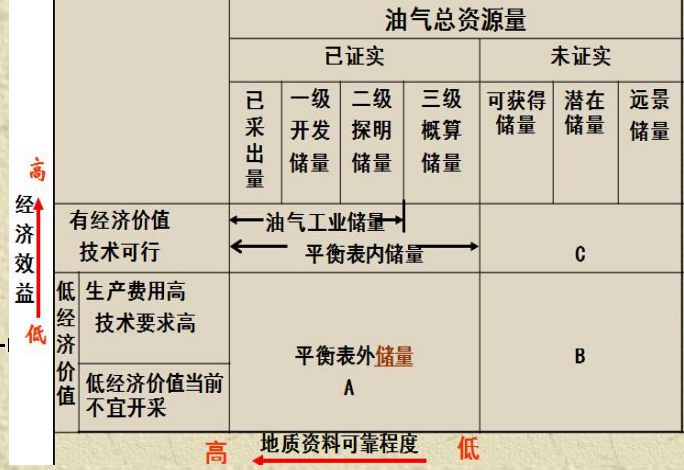
China----11.49 billion tons, the ninth

The gas resources of the whole world is about 327.7 trillion steres

Russia----107.2 trillion steres, the first

(The 14th oil conference communique)

Section 1 Classification



4. The first level reserves:

reserves calculated in development stage

developed reserves

Requirements:

Clear reservoir type, accurate drive type, oil layer distribution, oil-bearing area, oil-gas-water distribution, reliable effective oil layer thickness, practical reservoir parameters, such as pressure, temperature, gas-oil ratio and compressibility factor.

The parameters have been verified by practical data

the calculation of first level reserves matches with recovered reserves for 90%

Section 1 Classification

5. The second level reserves: reserves calculate at the end of detailed prospecting stage

explored reserves

The accuracy of second level reserves equals 80% of first level reserves

Section 1 Classification

6. The third level reserves: commecial oil and gas flow found in a petroleum bearing trap which contains more than 3 wells

Reserves calculated in the pre-prospects stage

Commecial oil and gas flow:
the lowest oil and gas quantity of a well under current economic and technological conditions

probable reserves

The accuracy of third level reserves equals 50% of first level reserves
It is the basis for further detailed prospecting

Section 1 Classification

The first level reserves
The second level reserves
The third level reserves

} Verified

Available reserves
Potential reserves
Prospective reserves

} Unverified

Section 1 Classification

7. Available reserves

(inferred reserves)

Commercial oil and gas flow have been found at least 1-3 wells in a known oil provience, calculate the reserves by using reseasonable geological inference.

Section 1 Classification

8. Potential reserves

It is calculated in favorable structures where no wells has been drilled or where has good oil and gas show though no commecial oil and gas show has been found by wells.

Section 1 Classification

9. Prospective reserves

It is quantively estimated in unknown oil provience by comparing with adjacent region where is characteristied by corresponding geological conditions.

Chapter 6 Reserves Calculation

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Section 2 Volumetric Method

Calculated oil and gas reserves by calculating the space for oil and gas.

- Calculation of oil reserves
- Calculation of gas reserves
- Calculation of gas reserves in condensate gas reservoir

Volumetric Method
is used in different exploration stages

Section 2 Volumetric Method

Formula used in oil reserves calculation

Formula $Q=F\bullet h\bullet \Phi\bullet S_{oi}r_o/B_{oi}$

Q----initial oil reserves in place in standard ground conditions, t

F----oil-bearing area, m^2

h----net pay thickness, effective pay thickness, m

Φ----effective porosity, active porosity

Soi----initial oil saturation

r_o----average density

B_{oi}----volume factor

1、confirmation of oil-bearing area

confirmation of oil-water interface

① Use core data, logging data and oil testing data

core—oil saturation and color； logging—SP, Rt

② Use capillary pressure data；

③ Use pressure data。

① Use core data, logging data and oil testing data

Firstly， based on oil test data and combine with analysis of core data，

→Design the standard of well logging in judging oil/water layer;

→Divid oil layer, water layer and oil-water layer

A）Calculate the elevations of the lowest oil reservoir bottom boundary and the highest oil-water reservoir boundary or the highest water reservoir boundary in a certain oil system

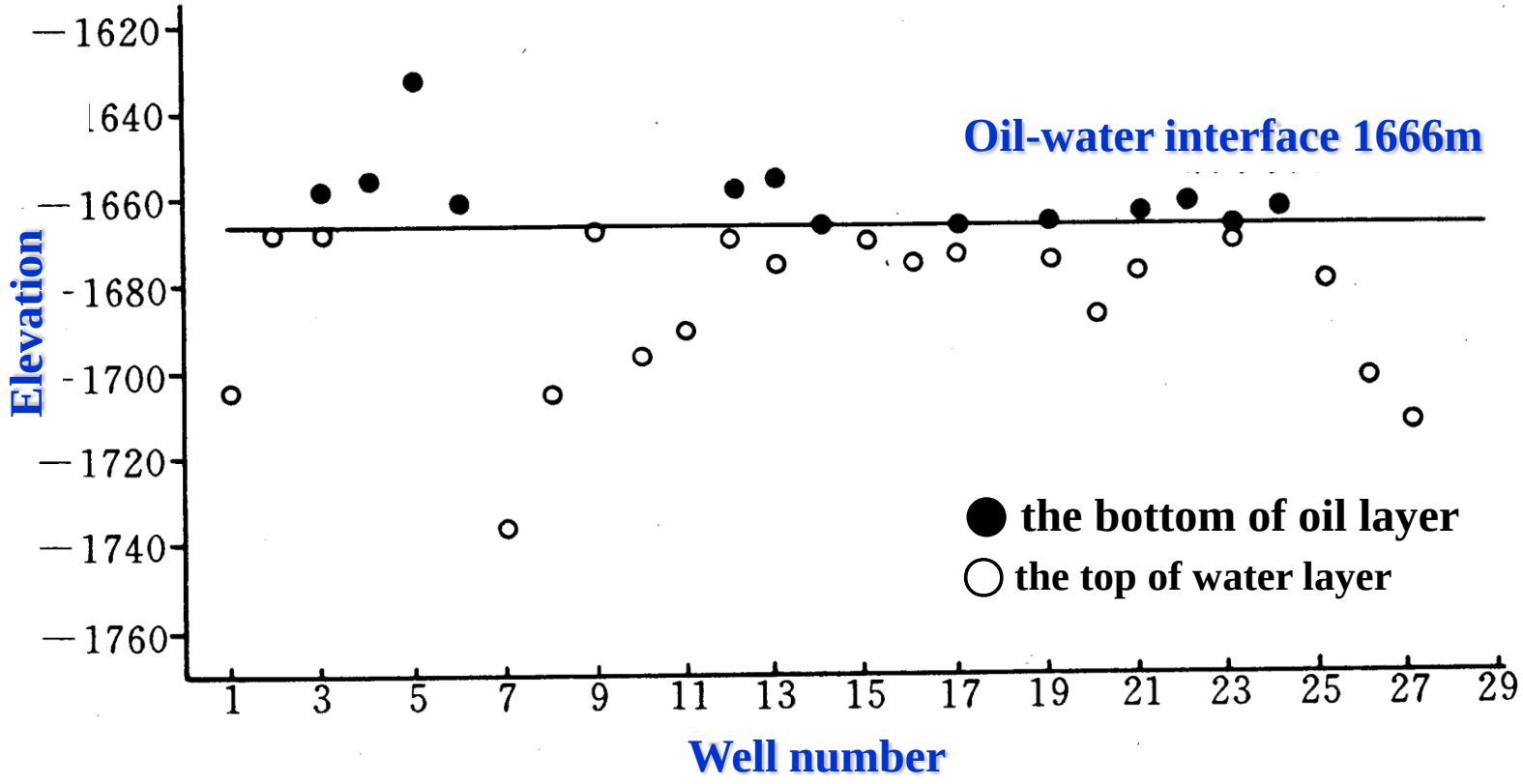
B) Indicate the location of oil layer bottom and water layer top of each wells in the map

C）Divide oil-water interface between oil layer bottom and water layer top. When data is little and the distance between oil layer bottom and water layer top, the oil-water interface should be set near the oil layer in order to prevent the enlargement of area。

A） Calculate the elevations of the lowest oil reservoir bottom boundary and the highest water reservoir boundary

B) Indicate the location of oil layer bottom and water layer top of each wells in the map

C） Divide oil-water interface between oil layer bottom and water layer top.



Map showing the determination of oil-water interface

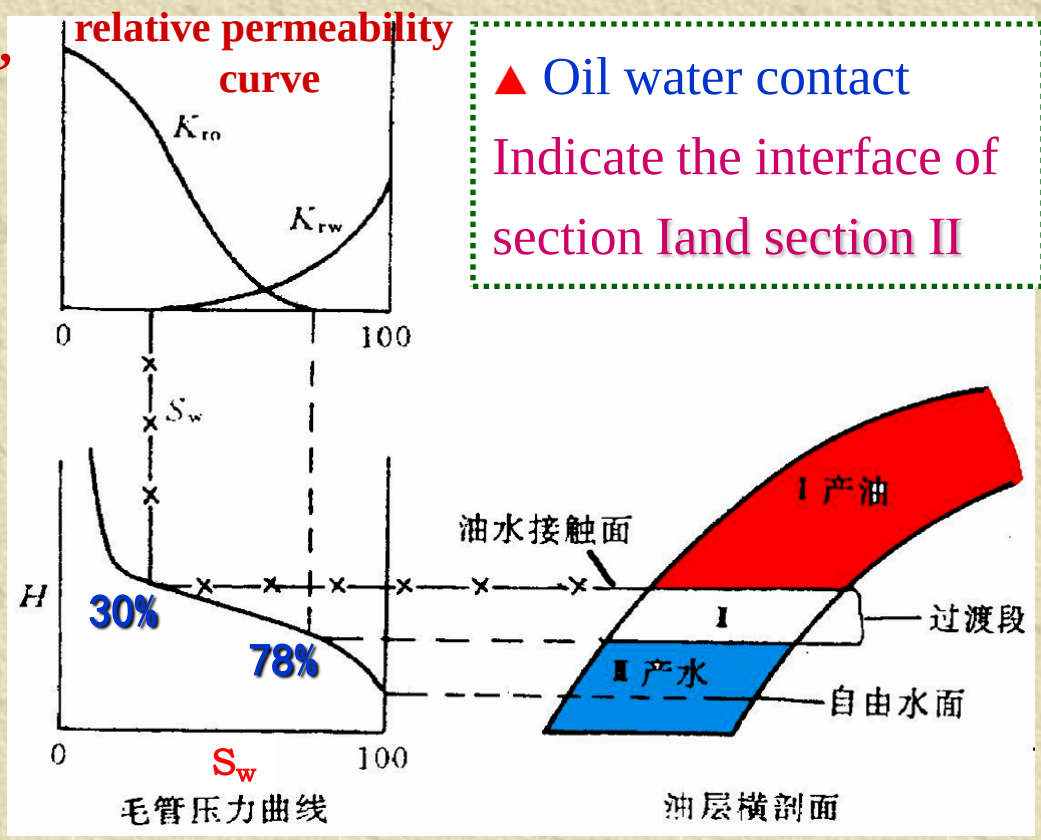
② Using capillary pressure curve to identify O/W contact

Using capillary pressure curve and relative permeability curve, based on the yield characteristic of wells, the vertical distribution of oil and water can be divided into 3 sections:

I pure oil section

II Oil water transition section

III pure water section



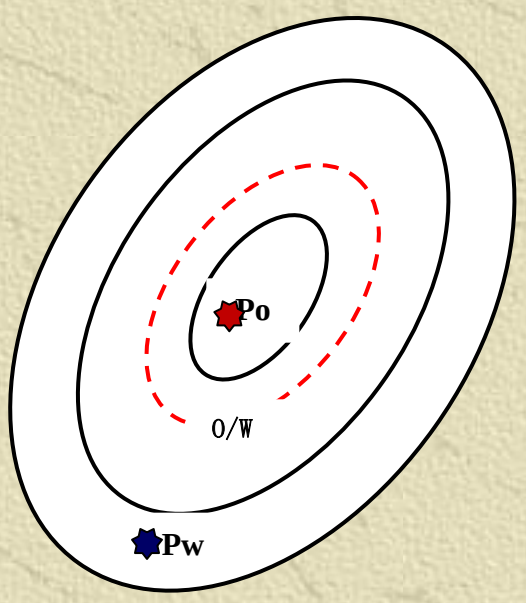
▲ Oil water contact Indicate the interface of section Iand section II

oil water vertical distribution diagram

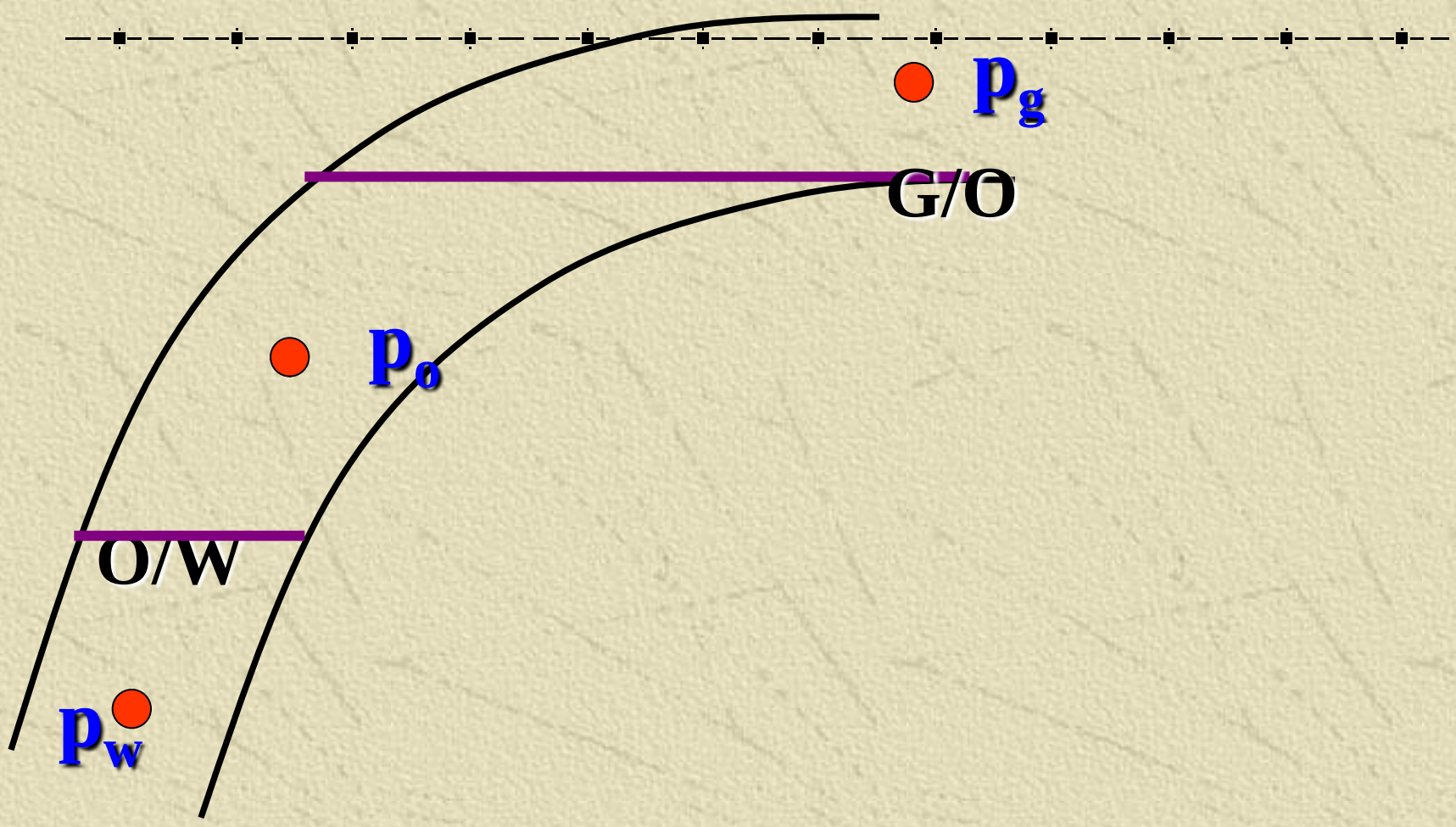
Using capillary pressure curve and relative permeability curve, based on the yield characteristic of wells, the vertical distribution of oil and water can be divided into 3 sections :

	water saturation	Relative permeability	yield characteristic
I	S_w＜30%	Water Relative permeability=0	pure oil
II	S_w30%～78%	Oil and water Relative permeability＞0	oil water transition
III	S_w＞78%	Water Relative permeability=0	pure water

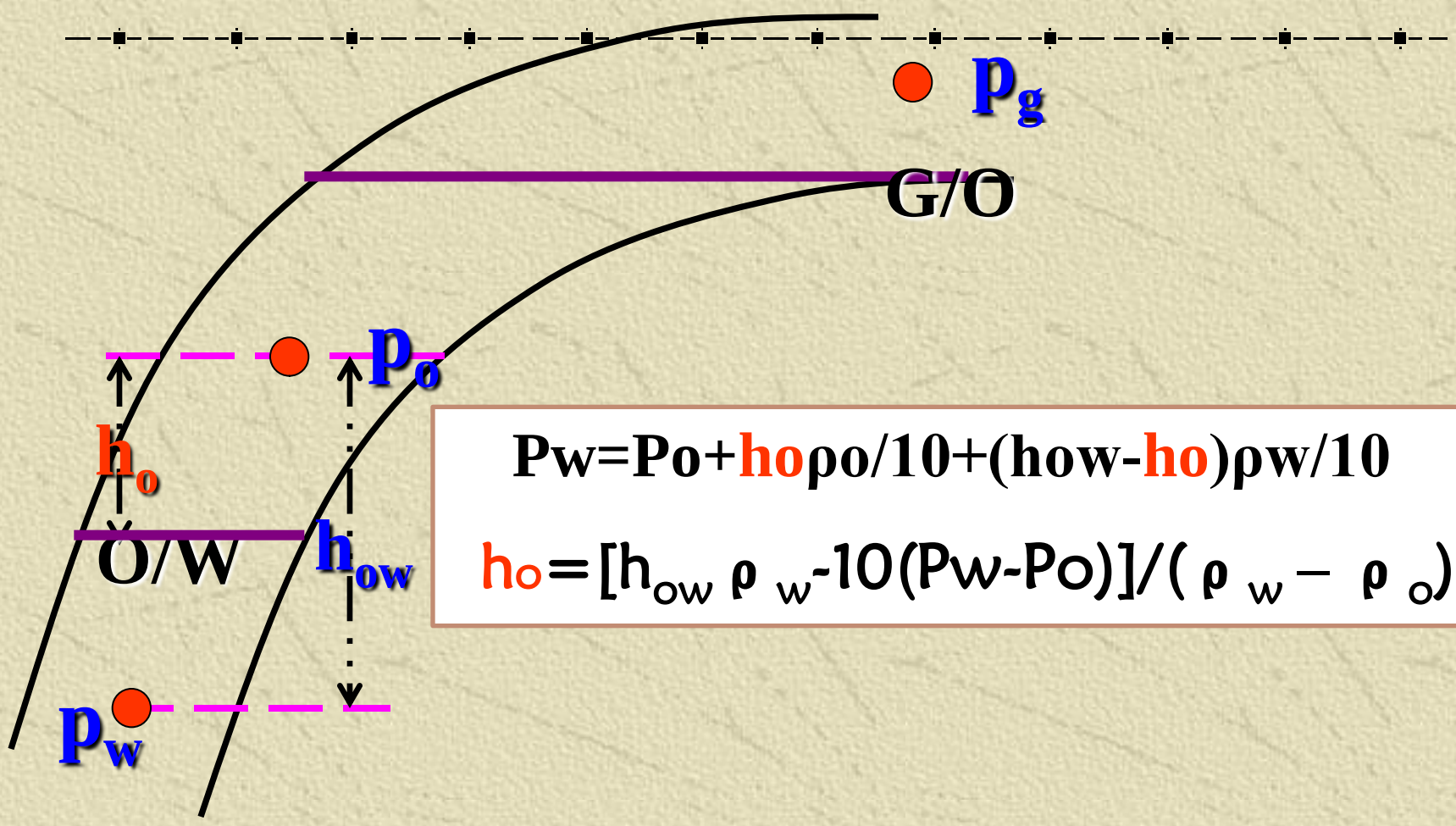
③ Using pressure data to identify O/W contact



Predict oil/water, oil/gas contact based on Pi



Predict oil/water, oil/gas contact based on Pi



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

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

Section 2 Volumetric Method

Reserves volume calculation

$$Q=F\bullet h\bullet \Phi\bullet S_{oi}r_o/B_{oi}$$

Q---- stock tank oil original in place,ton

F---- oil-bearing area, ㎡

Area of region with industrial oil and gas flow

h---- effective pay thickness, m

Φ---- effective porosity

Soi----initial oil saturation

r_o---- average density

B_{oi}----volume factor

Net pay thickness, Effective pay thickness

Definition： **The reservoir thickness which has industrial oil production under certain pressure difference.**

Conditions to be net pay thickness

(1)Should have mobile oil, Smos>0;

(2)Could be developed under current technology condition

Interbed deduction

interbed：

- **Thickness of bed which does not produce oil**

muddy interbed（low-resistance interbed）

calcareoous interbed (high-resistance interbed)

Top-bottom interbed layer

Chapter 6 Reserves Calculation

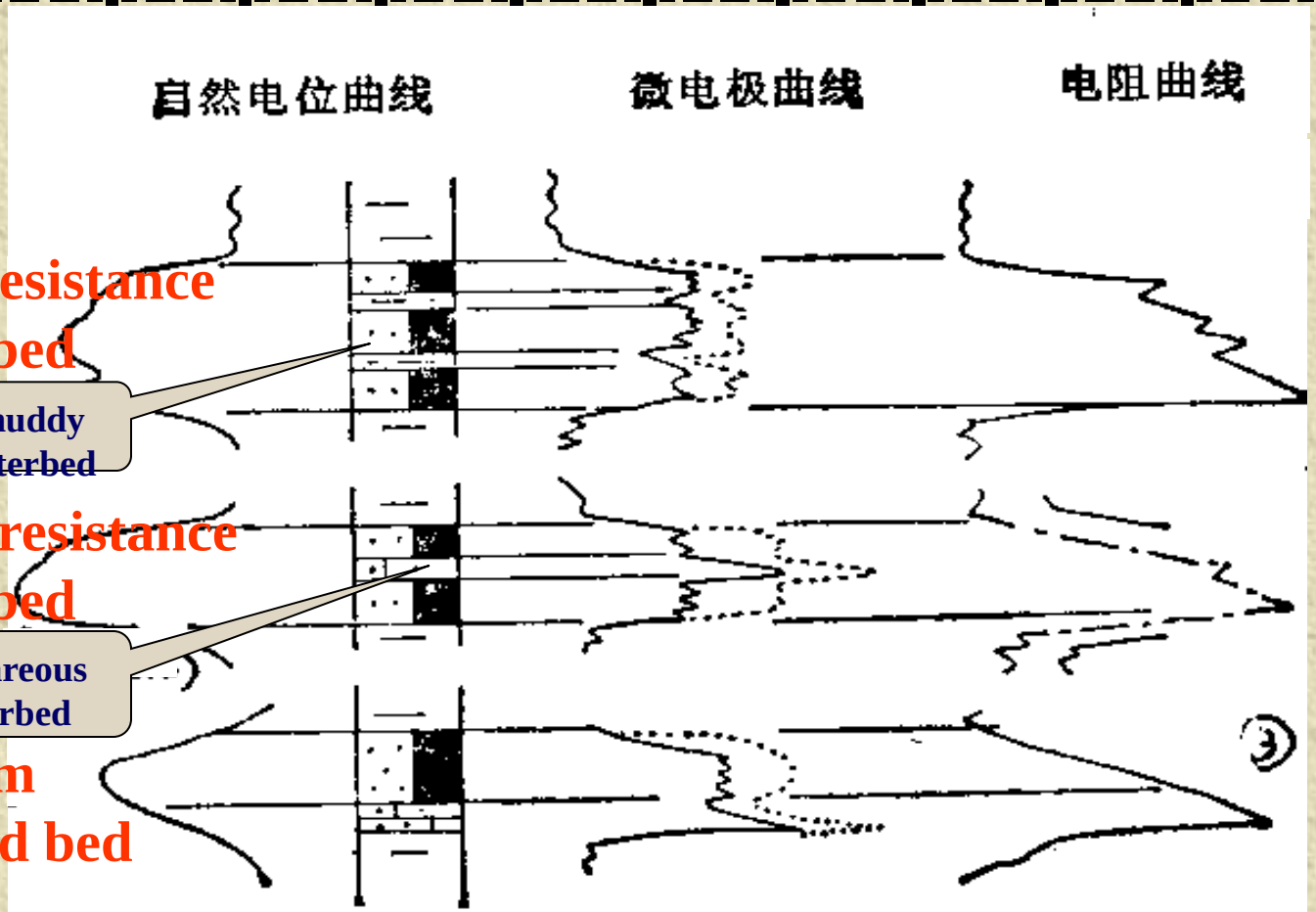


图 7—7 夹层扣除示意图

Section 2 Volumetric Method

Zero thickness:

minimal thickness for oil reserves calculation

A. Perforation accuracy

B. Logging interpretation reliability

C.The value and function of oil sheet in development

Identify the zero thickness of effective pay

Perforation accuracy: After using magnetic locating and tracking perforation technique, accuracy can reach 0.2m.

Logging interpretation accuracy:

Related to geological conditions.

Accuracy of normal area can reach

0.4～0.6m in reservoirs.

Accuracy of area with stable deposition can reach

0.2m oil sheet.

In China: zero thickness is 0.2～0.5m

Section 2 Volumetric Method

Calculation of oil reserves

Formula $Q=F\bullet h\bullet \Phi\bullet S_{oi}r_o/B_{oi}$

Q---- stock tank oil original in place,ton

F---- oil-bearing area, ㎡

h---- effective pay thickness, m

Φ---- effective porosity

ratio of oil –saturated connected porosity volume to rock volume under certain pressure difference

Soi----initial oil saturation

r_o---- average density

B_{oi}----volume factor

Identification of effective porosity

(1) **Based on core analysis data conducted in labs;**

measure gross rock volume, rock particle volume, porosity volume

(2) For well without coring, using logging data to calculate effective porosity.

Acoustic logging, neutron logging, density logging

Section 2 Volumetric Method

Calculation of oil reserves

Formula $Q=F\bullet h\bullet \Phi\bullet S_{oi}r_o/B_{oi}$

Q---- stock tank oil original in place,ton

F---- oil-bearing area, m^2

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ratio of oil –saturated connected porosity volume and rock volume under certain pressure difference

Soi----initial oil saturation

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Initial oil saturation

Usually, define the S_{wi} first,

then $S_{oi}=100\%-S_{wi}$

The methods to define the Soi

measuring directly by core data

(sealing core, oil-based mud core)

well logging interpretation

5. Volume factor

6、Average density

Section 2 Volumetric Method

Calculation of oil reserves

$$Q = F \cdot h \cdot \Phi \cdot S_{oi} \cdot r_o / B_{oi}$$

reservoir volume

Effective porosity volume

Oil volume

Oil weight

Surface oil weight

- **Reserves in place (N)** ——**Gross Oil and gas which are in original state in oil producing zone under the initial condition of formation.**

- **Recoverable reserves (Nr)** ——**reserves which could be recovered from geological reserves under current technology condition.**

Section 2 Volumetric Method

Nr----recoverable reserves

reserves which could be recovered from geological reserves under current technology condition

$$Nr=Q\cdot\eta$$

η ---- producible oil index

Restricted by reservoir condition, fluid properties and economic condition

Producible oil index, Recovery efficiency

reserves which could be recovered from geological reserves under current technology condition

primary recovery efficiency	Secondary recovery efficiency
Dissolved gas drive 10- 30%	Water injection drive 25- 60%
Elastic drive 2-5%	Gas injection drive, 30- 50%
Gas-cap drive 25- 50%	Miscible displacement 40-60%
Water drive 25-50%	Thermal drive, 20-50%
Gravity drive 30-70%	

Reserves evaluate ----

abundance evaluation of petroleum reserves

abundance evaluation of petroleum reserves----

Reserves in place of per unit area in an oil field.

Unit: 10^4 t/ km^2 or 10^4 m^3/ km^2

Petroleum 10^4 t/ km^2	
>300	High abundance
100-300	Medium abundance
50-100	Low abundance
<50	Special low abundance

abundance evaluation of petroleum reserve----

Reserves in place of per unit area in an oil field.

Unit: 10^4 ton/ km^2

Petroleum 10^4 t/ km^2	
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