Subsurface Geology of oil and Gas Fields

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Subsurface Geology of oil and Gas Fields

What? Why? How?

Subsurface geology of oil and gas fields is the key specialized course for the students majored in petroleum engineering and exploration of mineral resources program.

Introduction

I. Content

II. Characteristics

III. Exercises: (Applied Problem)

I. Contents

1.Well Data (Foundation)

Drilling Geology
Evaluation Oil, Gas and Water Formation

2.Geology Structure of oil and gas field (Key)

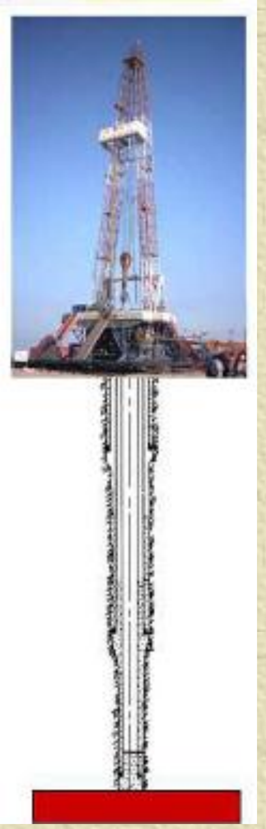
Stratigraphic Classification and Stratigraphic Correlation
Subsurface Structure Research

3.Hydrocarbon Reservoir Research (Purpose)

Formation Pressure and Formation Temperature
Reserves Calculation

Subsurface Geology of oil and Gas Fields

Petroleum Engineering programs are characterized as: highly unknown, complex in technology, long in running period, great in investment and more integrative.



II. Characteristics

Practice

Inference

Integration

III.Exercises: (Applied Problems)

1. Well Completion map
2. Oil and water formation identification
3. Well Correlation
4. Geologic Cross Section from Well Data
5. Pressure calculation and analysis
6. Reserve calculation

Chapter 1 Drilling Geology

- **Generalized drilling geology**

The whole work the geologists do during the drilling.

Before drilling ---- Well Design

During drilling ---- Geological logging and

Formation Testing

Finishing drilling----Well Completion

- **Narrowed drilling geology**

Geological logging

Chapter 1 Drilling Geology

Drilling operations are carried out during all stages of field development.

Section 1 Well Geologic Design

Section 2 Geological Logging

Section 3 Formation Testing

Section 4 Well Completion

Chapter 1 Drilling Geology

Section 1 Well Geologic Design

I. Well Type
II. Well Geologic Design
III. Directional Drilling

I. Well type

1. Stratigraphic well

parametric borehole, reference well

(formation, thickness, lithology, etc provide parameter)

Yanqi basin

2. Exploration well (Wildcat well)

objective----find hydrocarbon reservoir

3.Appraisal well (Evaluation well)

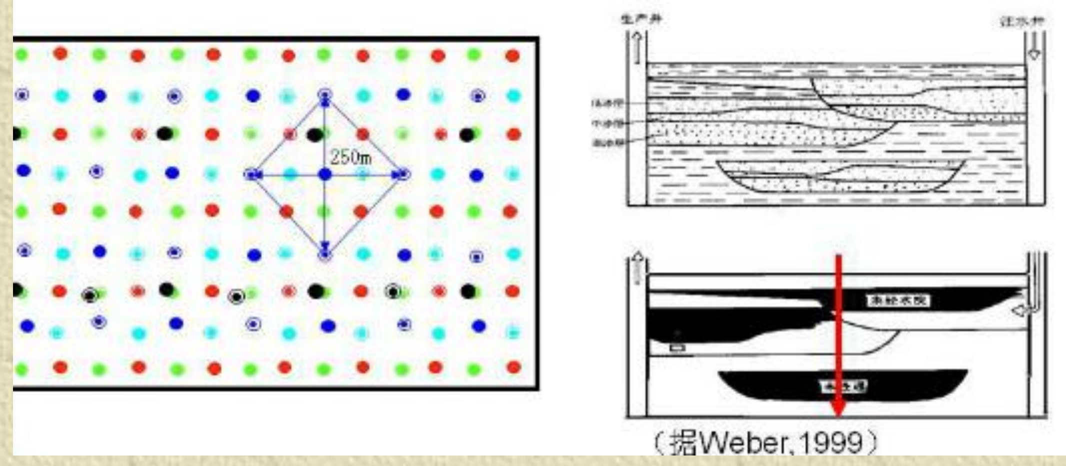
objective----commercial oil and gas flow

4.Development well (Producing well, Water injector, Gas injector,

Development plan and well pattern

5.Adjustment well

Adjustment development plan



II. Well Geologic Design

1. Basic data

well number, well type,

well site----well site coordinate, longitude and latitude, ground elevation, geographic location

target zone, designed well depth

2. Regional geology

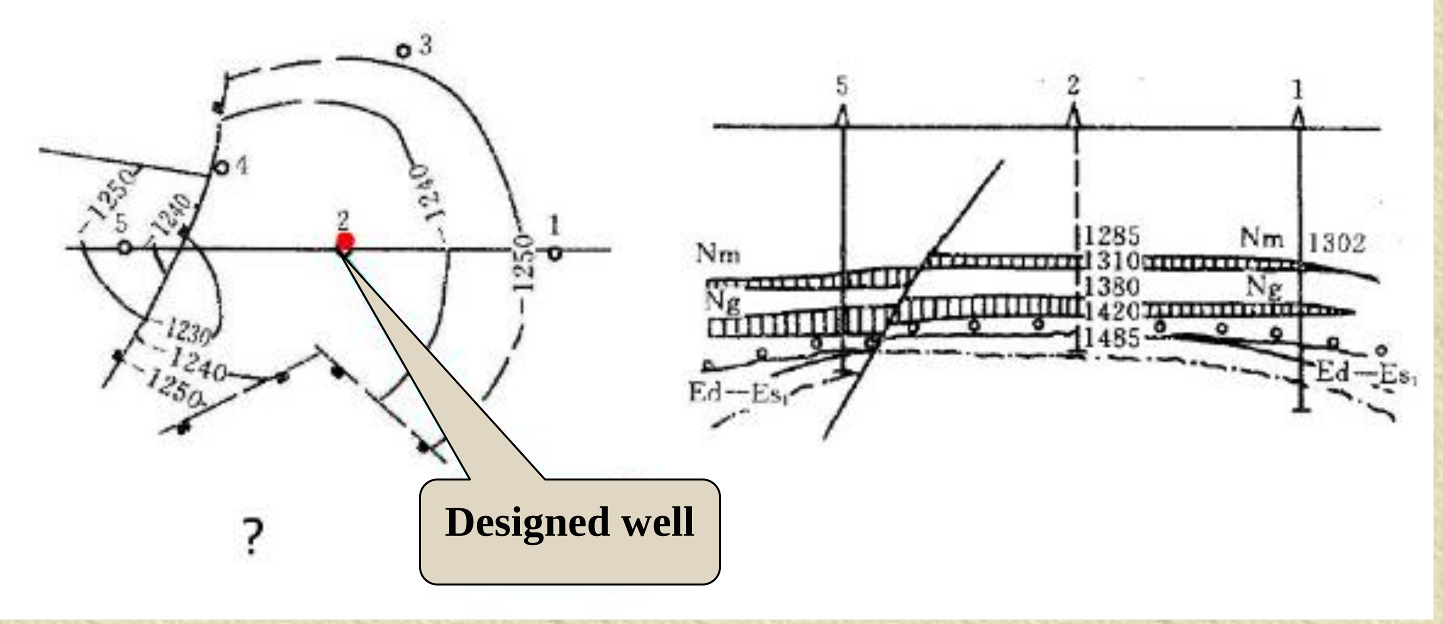
Formation

Tectonic setting

3. Drilling objective

4. Strata profile

predict the location of oil, gas and water bed



5.Formation Pressure Prediction and Drilling Fluid

Before drilling----

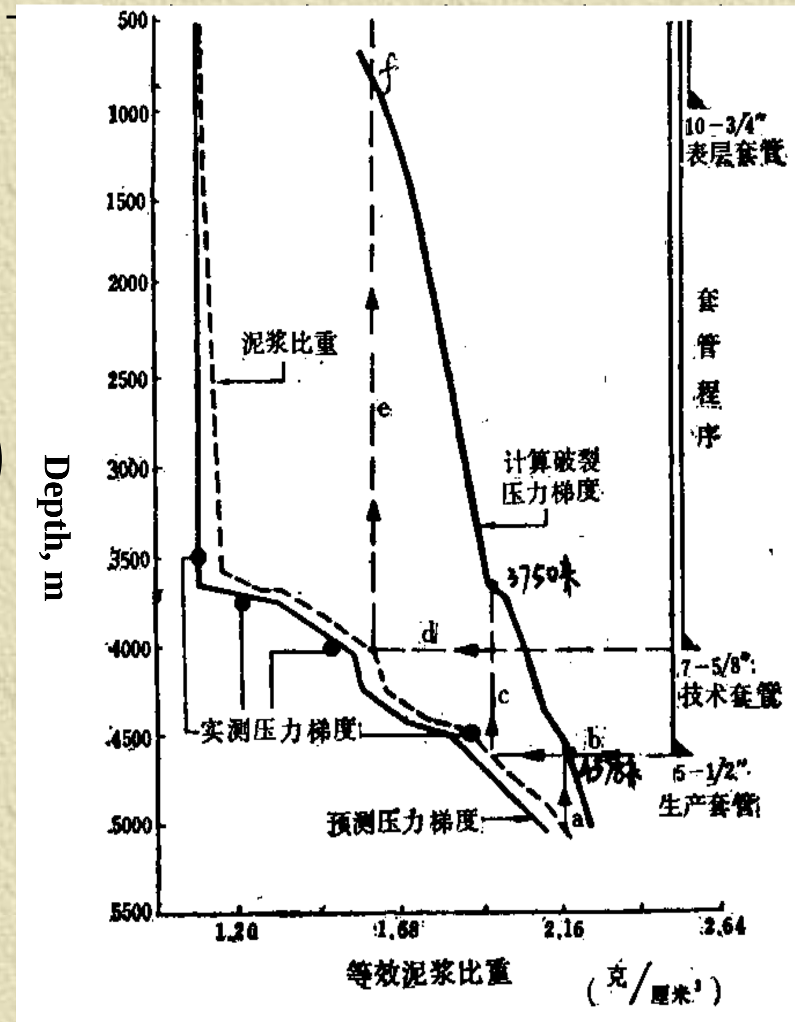
Seismic
Adjacent well

During drilling

Well logging
Drilling parameter
Geological logging

Drilling fluid property

Drilling fluid type, property



6.Required data

Geological logging (coring, cutting)

Required sample

Geophysical logging

7. Midway Test

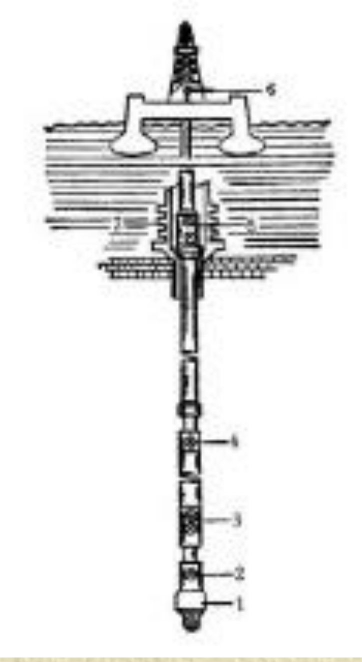
Formation: hydrocarbon reservoir

the formation with oil and gas shows;

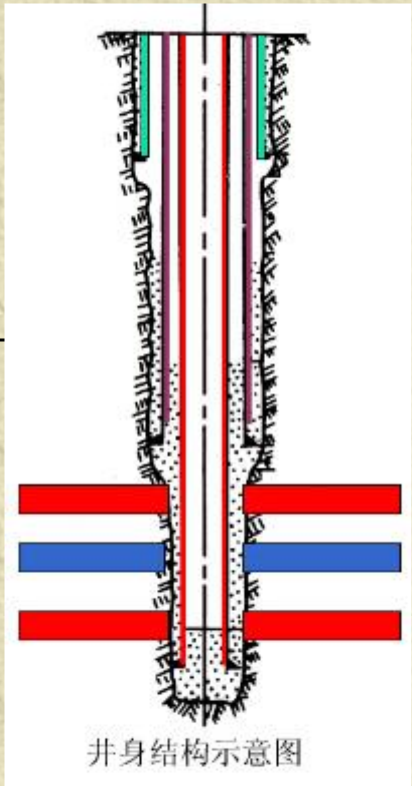
Method: wireline test

DST(drilling stem testing)

Purpose: P, Q, K



8. well structure



9. technical and quality requirement

major geological problem

preparatory project

10. geographical and environmental data

meteorological data

terrain feature

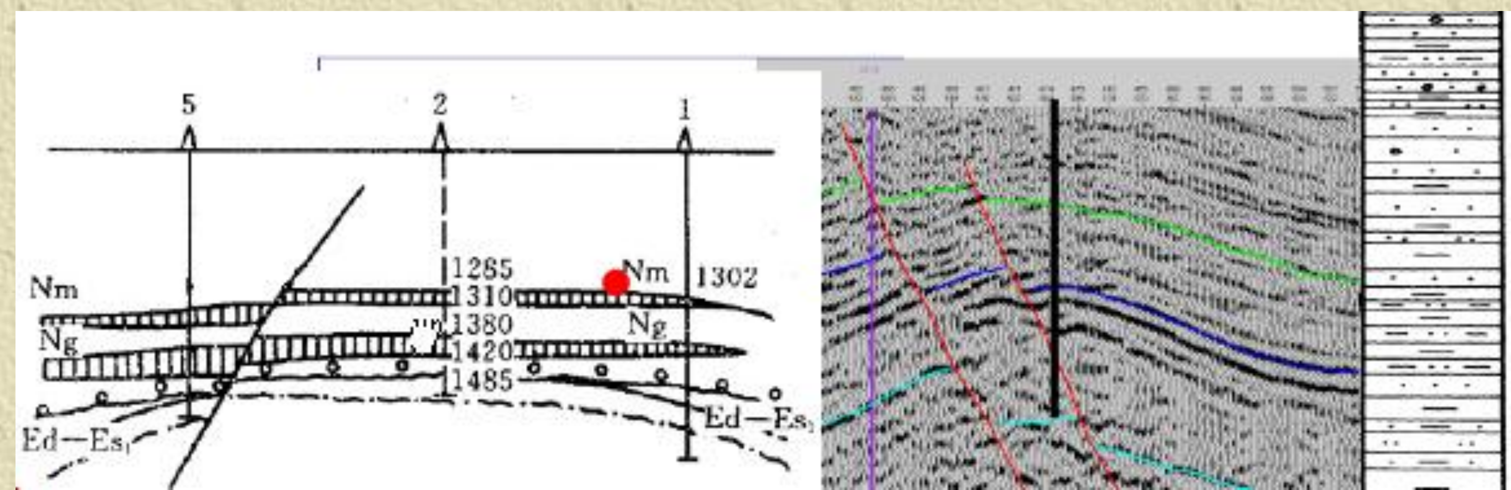
11.Accompanying table and figure

①Accompanying table:

Hierarchical table;
Seismic reflection depth table

② Accompanying figure:

Regional tectonic map, geographical location map
Local tectonic well location map;
Geologic profile, seismic time section
Formation columnar section



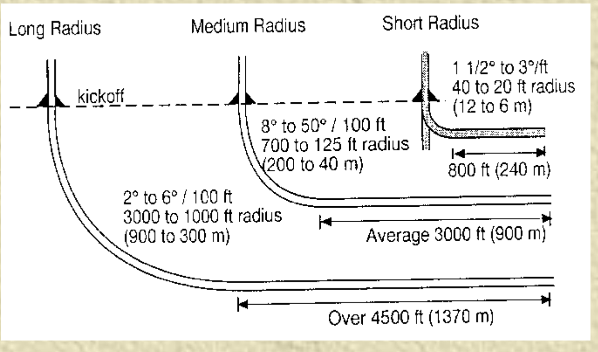
III. Directional Drilling

deviated well----the deflecting well with displacement and orientation

multiple well----wells group drilled in the offshore platform

relief well----wells design for engineering purposes

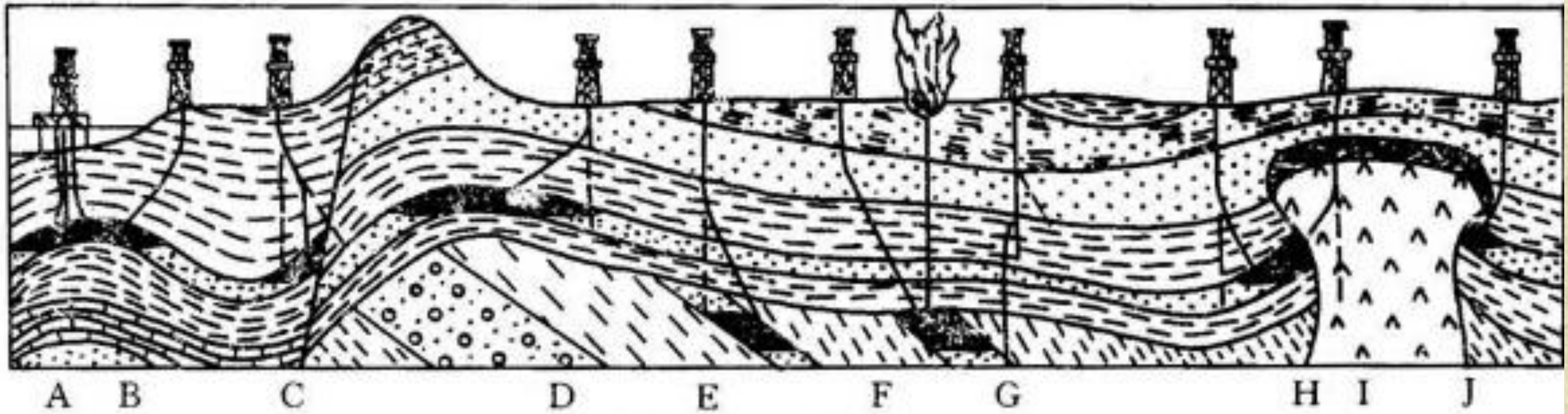
horizontal well----well with maximum angle approach or reach 90°.



Advantages of deviated and multiple well

1. It is conductive to find more oil fields, increase reserves and production;
2. Meet the requirement of underground location;
3. Reduce occupation area, moving and installation time, and before drilling engineering cost;
4. Control drilling accidents

A-multiple well；
B-coast drilling；
C-fault control；
D- shady location；
E-stratigraphic reservoir；
F-relief well；
G-sidetrack drilling；
H、I、J-salt drilling.



LeRoy, 1977

Chapter 1 Drilling Geology

Section1 Well Design

I. Well Type

II. Well Design

III. Directional Drilling

Chapter1 Drilling Geology

Section 1 Well Design

Section 2 Geological Logging

Section 3 Formation Testing

Section 4 Well Completion

Section 2
Geological Logging

Objective:

Getting information

Evaluating oil and gas reservoir

Method

cuttings logging
core logging
drilling-time logging
mud logging

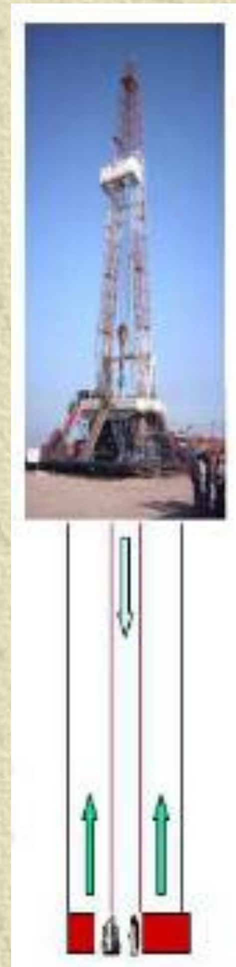
I. Cuttings logging

Cutting?

Cutting logging: sample interval, delay time, continues collection and observation cuttings

Feature?

Convenience ,
Economy,
Accurate and reliable,
In time,
Information system



I. Cuttings logging

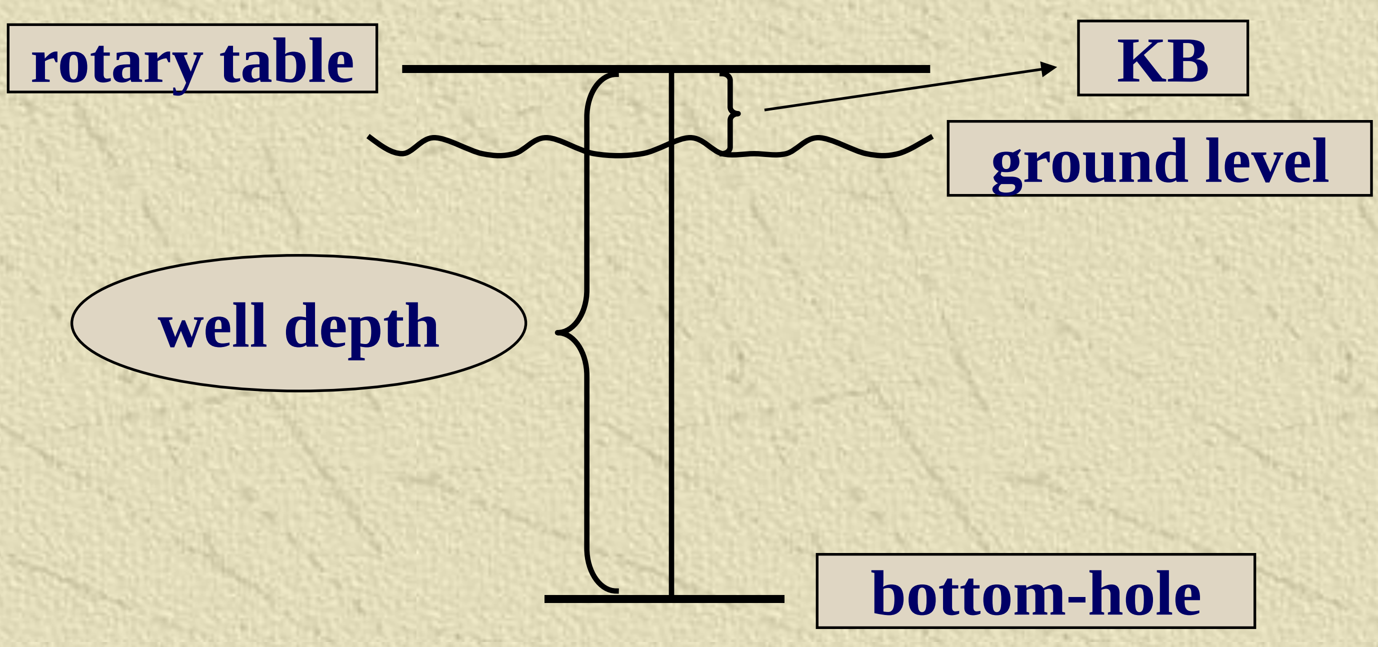
1. Well depth calculation;

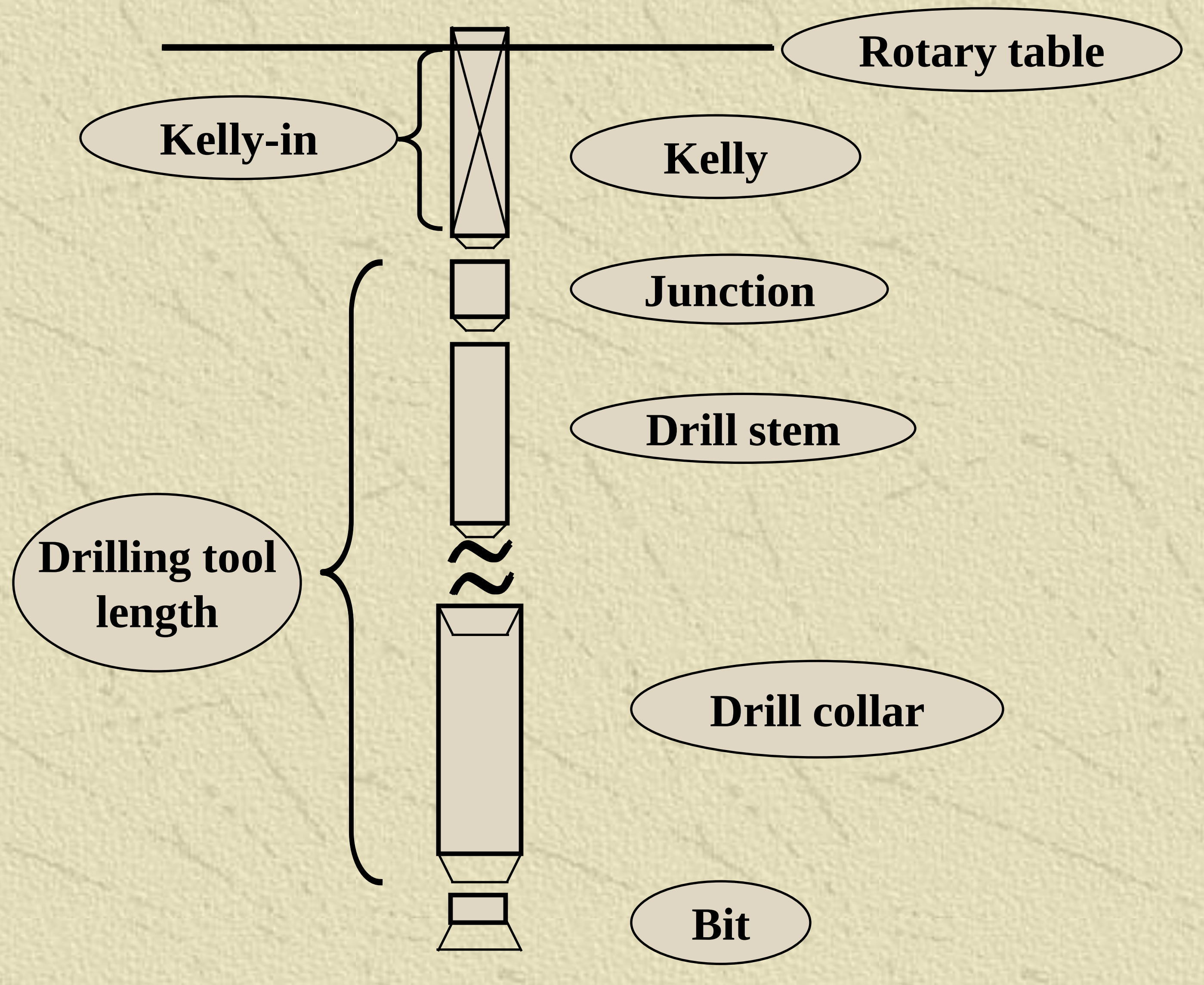
2. Delay time calculation;

3. Cutting identification and oil-bearing cutting inspection

1. Well depth calculation

Well depth: the length between bottom-hole to rotary table





Well depth =drilling tool length + bit +kelly-in

2. Delay time

delay time： The time which cuttings return from bottom hole to surface

- marker, index bed
- theoretical calculation
- actual measurement

3.Cutting identification and oil-bearing cutting inspection

(1)Identification of true/spurious cutting

In the drilling stage, the upper layer usually peel off due to the long barefoot interval, the changes of mud property and the frequent activity of drilling tool in the well, then mixed into the cutting in the hole bottom.

True cutting: fresh section, small pellet, 2-5mm

the pellet shape is related to lithology

Spurious cutting: fuzzy color, big pellet, round-sub-rounded, obvious abrasion

Cutting description

---far to color, near to lithology
---lamination, name, description

(2)lamination/ layering

A. **The occurrence depth of a new component corresponding to the top interface of the new lithology;**
B. **The depth of amount decrease corresponding to the bottom interface of this lithology;**
C. **The alternating increase and decrease percentage of two kind of cuttings indicate lithology interbed.**

1. **Well depth calculation;**
2. **Delay time calculation;**
3. **Cutting identification and oil-bearing cutting inspection**

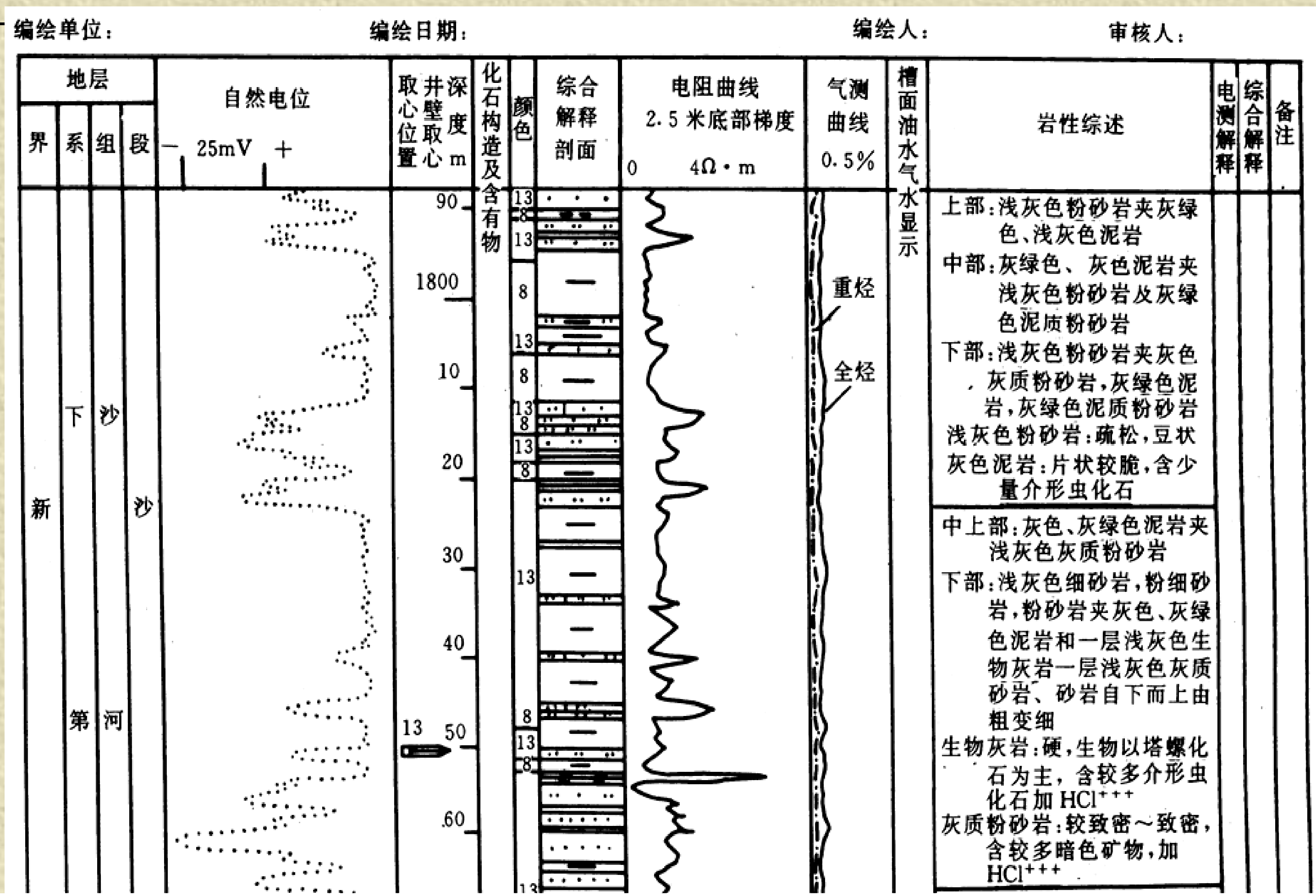
Comprehensive cutting logging ⇒

1. **For stratigraphic correlation;**
2. **Provide geological evidence for well log interpretation**
3. **Provide data for drilling engineering**

Cutting logging schematic + well logging curve

Cutting logging comprehensive chart

Scale 1:500



Cutting logging comprehensive chart

Section2 Geological Logging

Objective:

Getting information
Evaluating oil and gas reservoir

Method

cuttings logging
core logging
drilling-time logging
mud logging

II. Core logging

Put the coring tool into the bottom hole, drill some core using coring bit. Such a procedure is called coring.

The work that the geologist engaged in, including core arrangement, observation, description and mapping is called core logging

II. Core logging

Important first hand information

Hydrocarbon source rock: TOC, A, HC, Ro

Reservoir : ϕ, K, So

1. Coring type and principle
2. Data collection
3. Core description and hydrocarbon-bearing layer identification
4. Comprehensive core logging chart
5. Sidewall coring

1.Coring type and principle

Coring type:
- WBM (water-base mud) coring;
- OBM (oil-base mud) coring;
- SCD: sealing core drilling

◆ Exploration phase---- in order to understand the lithology, common diameter coring；

◆ Preparation phase---- in order to achieve necessary data, OBM or SCD；

◆ Development phase---- in order to understand the development effect, large diameter coring

Principle—different well type have different coring purpose and different coring amount

Parametric borehole coring: stratum、 structure 、source-reservoir-cap assemblage
Wildcat well coring： lithology, physical property, oil-gas possibility of oil-bearing layer
Appraisal well coring： lithology, physical property, oil-gas possibility of reservoir
Development well coring： internal reservoir characteristics, development effect

2.Data Collection

A. Data achievement during coring

- **Measuring kelly in, calculation drilling depth**
- **Recording Drilling time and cutting**
- **Observing oil and gas show from mud ditch**

B. Measure "headspace and bottom space"

"Bottom space"

---the bottom length of core barrel without core

"Headspace"

---the top length of core barrel without core

C. Core recovery calculation and coring logging

Coring measuring

Recovery of Core Extraction Calculation

Recovery of core/ core extraction ⇨

Reliability
Drilling technology

Recovery core extraction=length of Core/coring footage

Coring Numbering ---- mixed number

Top

5
3 ——
12

Bottom

3.Core description and hydrocarbon reservoir observation

(1)Core description:

lithology, color,

sedimentary structure,

cementing matter,

dips、fracture

(2)Hydrocarbon reservoir observation

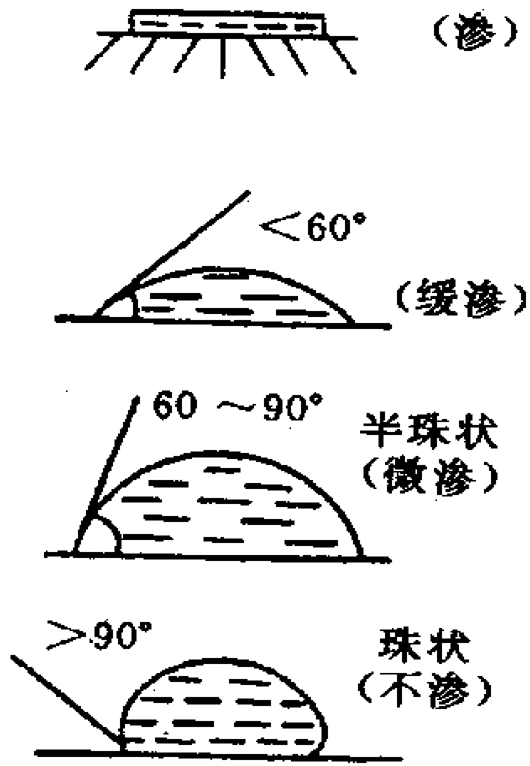
A. Gas showing experiment

B. Oil showing experiment

- Drop water experiment
- Leakage test (sealed, high temperature, 30min)
- Fluorescence test
- Oil-acid reaction
- Acetone experiment
- Visual inspection

Drop water experiment

watering layer



oil-bearing formation

图 1－12　滴水级别的划分

（据《钻井地质录井手册》，1993）

Visual inspection

saturated oil: oil bearing area> 95%

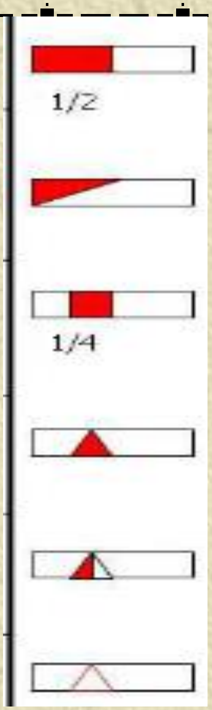
oil bearing: oil bearing area 70-95%

oil stained: oil bearing area 40-70%

oil spotted: oil bearing area 5-40%

oil trace: oil bearing area <5%

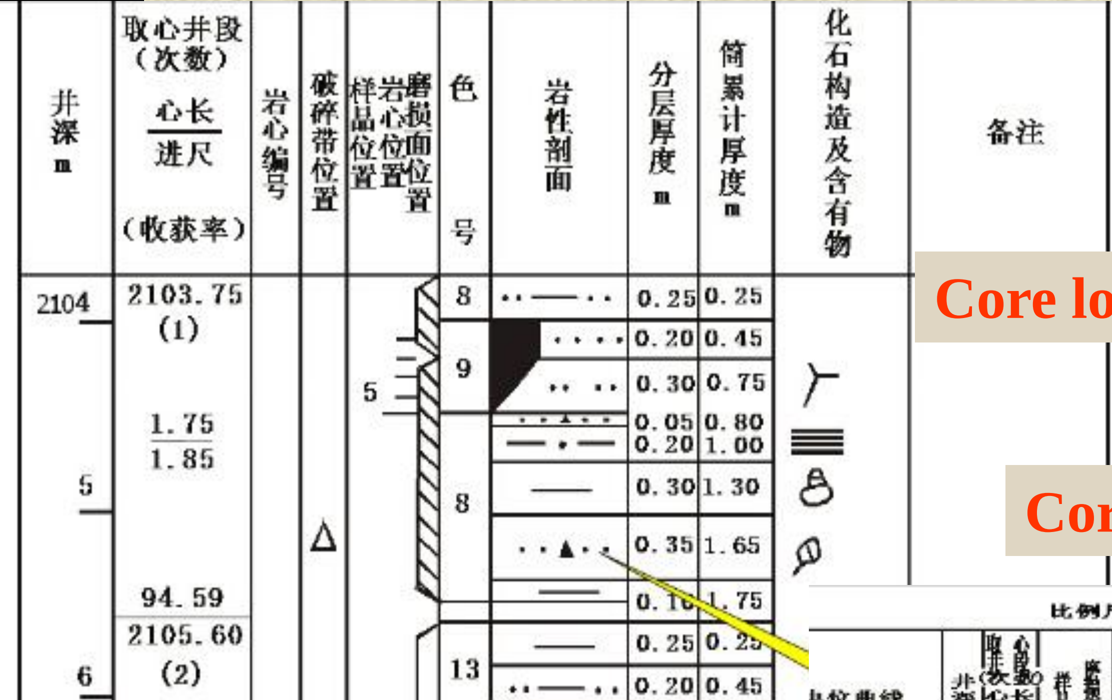
fluorescent show



4. Core logging comprehensive chart

Core logging comprehensive chart

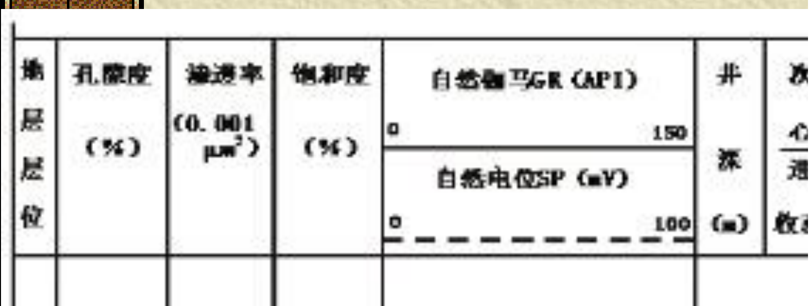
- Cored interval
- Lithology
- Hydrocarbon-bearing
- Electric property
- Physical property

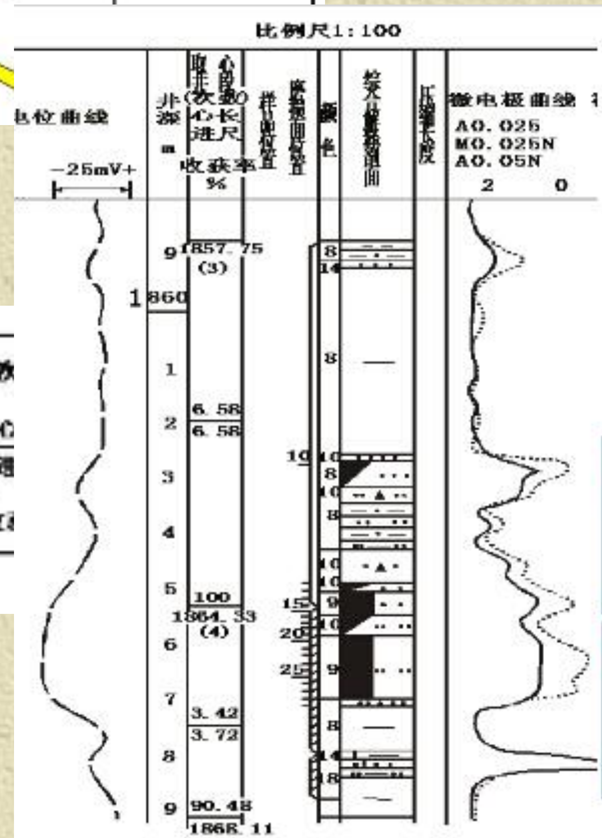


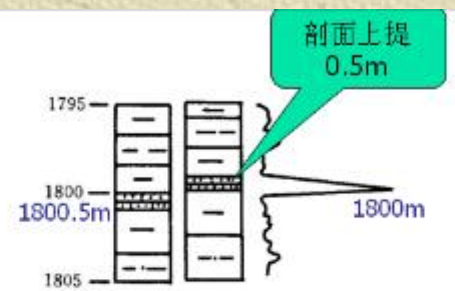
Core logging schematic

Core logging comprehensive chart

Scale 1:50 or 1:100







岩心归位

(1)以测井深度为准，将岩心的钻井深度校正到测井深度；

(2)对于取心率不到100%的取心，恢复岩心的原来位置。

5.Sidewall coring

The sidewall sampling tool can be used to obtain small plugs (2cm diameter, 5cm length, often less) directly from the borehole wall. The tool is run on wireline after the hole has been drilled. Some 20 to 30 individual bullets are fired from each gun at different depths. The hollow bullet will penetrate the formation and a rock sample will be trapped inside the steel cylinder. By pulling the tool upwards, wires connected to the gun pull the bullet and sample from the borehole wall.

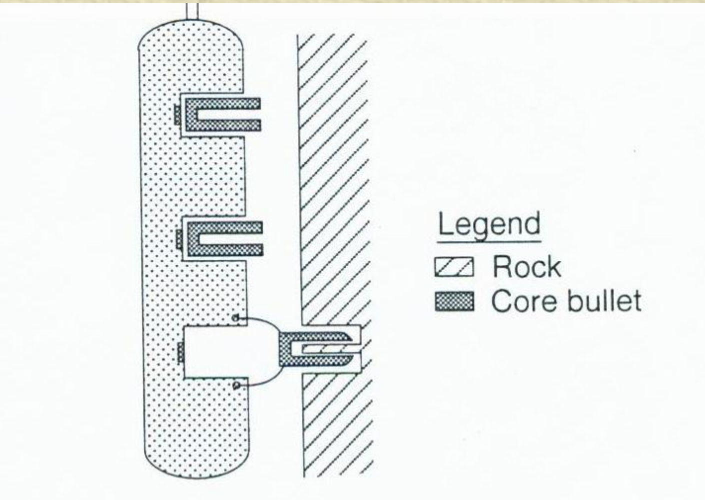


Figure 5.35 Sidewall sampling gun

The sidewall sampling tool are useful to obtain direct indications of hydrocarbons (under UV light) and to differentiate between oil and gas. The technique is applied extensively to sample microfossils and pollen for stratigraphic analysis (age dating, correlation, depositional environment). Qualitative inspection of porosity is possible, but very often the sampling process results in a severe crushing of the sample thus obscuring the true porosity and permeability.

Section2 Geological Logging

Objective:

Getting information

Evaluating oil and gas reservoir

Method

Cuttings logging

Core logging

Mud logging

Drilling-time logging

III. Mud logging

The mud circulation system is essentially a closed system. The mud is circulated over and over again throughout the drilling of the well. Of course, from time to time a few additions of water, clay, or other chemicals may have to be added to make up for losses or to adjust the mud’s properties as new and different formations are encountered.

1. Basic functions during drilling
2. Mud property
3. Oil and gas show observation
4. Geology factor of influence mud property

1. Functions

- To bring drilled cuttings from bottom hole to surface;
- To control subsurface pressure and to prevent blowout;
- To protect sidewall (consolidate the side of the drilled hole) wall building
- To cool bit and lubricate drill string;
- To provide subsurface information;

2.Mud property

- Specific gravity
- Viscosity
- Shear force
- Water loss / wall building property
- Sand content/sand cut
- ph value
- Salt content/ salinity

3. Oil and Gas Shows Observation

Oil and gas show

A.oil bloom、bubble: <30%

B.inrush of oil and gas: oil bloom and bubble 30-50%，

C.kicking: oil bloom and bubble >50%

D.well blowout

E.lost circulation, mud loss

Observation mud ditch

A. The time of oil bloom and bubble in the mud ditch;

B. The percentage of oil bloom and bubble in the mud ditch;

C. Hydrocarbon occurrence in the mud ditch

4.Geology factors of influence mud property

⑴ High pressure zone

⑵ Saltwater influx

⑶ Sand contamination

⑷ Argillichorizon/ horizon/clayey formation

⑸ Lost-circulation zone/leakage formation

Section 2 Geological Logging

Objective:

Getting information

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Method

cuttings logging

core logging

mud logging

drilling-time logging

IV. Drilling-time logging

Pure drilling time required per meter, min/m
Penetration rate reciprocal

Drilling-time logging: It is a logging method that geologist conducted by using the drill time recorder to record the needed time for each footage, and draw the drilling time-depth plot, and then used this plot to study the formation property and stratigraphic correlation

1. Influence factor
2. Application of drilling-time curve

1.Influence factor

(1) Rock drillability

(2) Buried depth

(3) Pore fluid pressure

(4) Bit type

(5) Mud property and drilling parameter

2.Application

(1) drilling-time curve

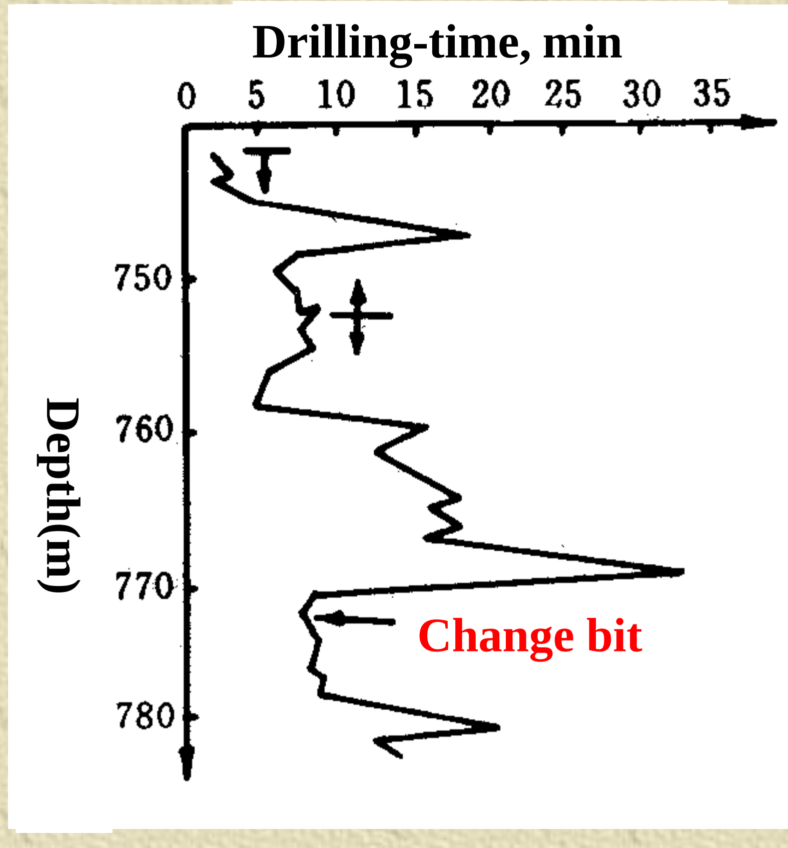
vertical coordinata----depth

abscissa----drilling-time

vertical scale 1:500

Measuring interval: 1m

Target zone measuring interval:0.5-0.25m



drilling-time curve

2.Application of drilling curve

A.Lithology identification, strata profile interpretation

sand ⟶ shale ⟶ carbonate

oil-bearing sandstone	the fastest
sandstone	fast
mudstone, limestone	slow
basalt, granite	the slowest

B. fracture/cavern identification

fracture/cavern --- drilling rate accelerate

Section 2 Geological Logging

Objective:

Getting information

Evaluating oil and gas reservoir

Method

- **cuttings logging**
- **core logging**
- **drilling-time logging**
- **mud logging**

Chapter1 Drilling Geology

Section 1 Well Geologic Design

Section 2 Geological Logging

Section 3 Formation Testing

Section 4 Well Completion

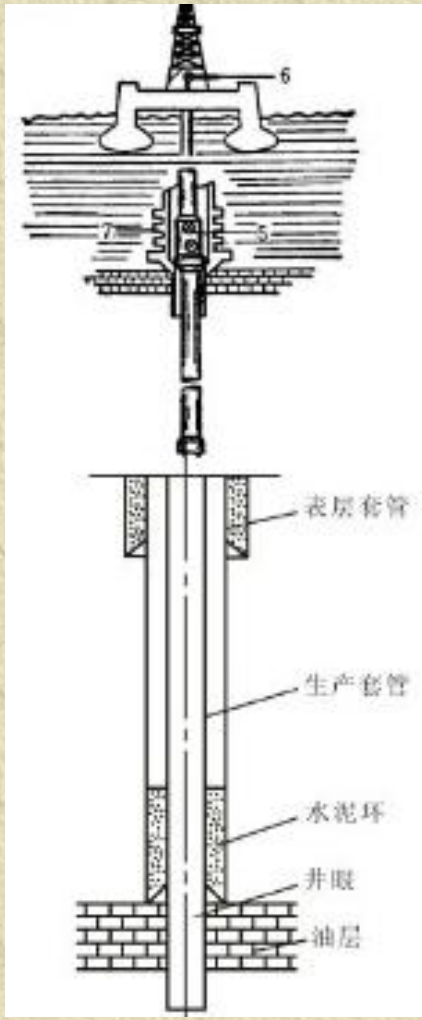
Section 3 Formation Testing

I. Advantages of formation testing

II. Testing Tool

III. Testing Process

IV. Interpretation and Application

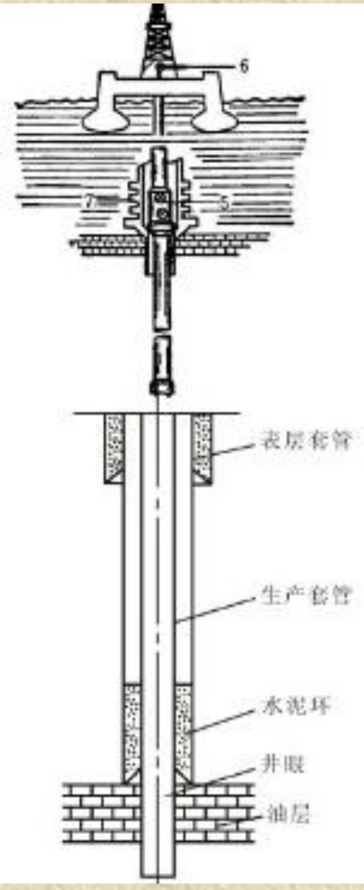


I. Advantages of formation testing

1. Saving steel and cement, reducing drilling cost;
2. Short time, achieve data quickly;
3. Timely oil reservoir evaluation, and it is the effect method to find oil reservoir in new exploration area

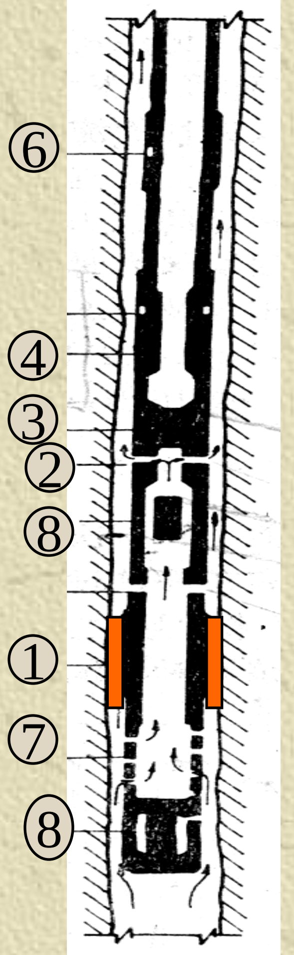
Conditions：

1. Dense lithology;
2. Smooth sidewall;
3. Formation is not easy to collapse;
4. Good casing programme;



II. Testing tool

1. packer
2. by-pass valve, equalizing valve
3. testing valve
4. double shut in pressure valve
5. sampler
6. reversing valve
7. sieve tube, perforated anchor pipe
8. pressure record



III. Testing process

1. trip-in

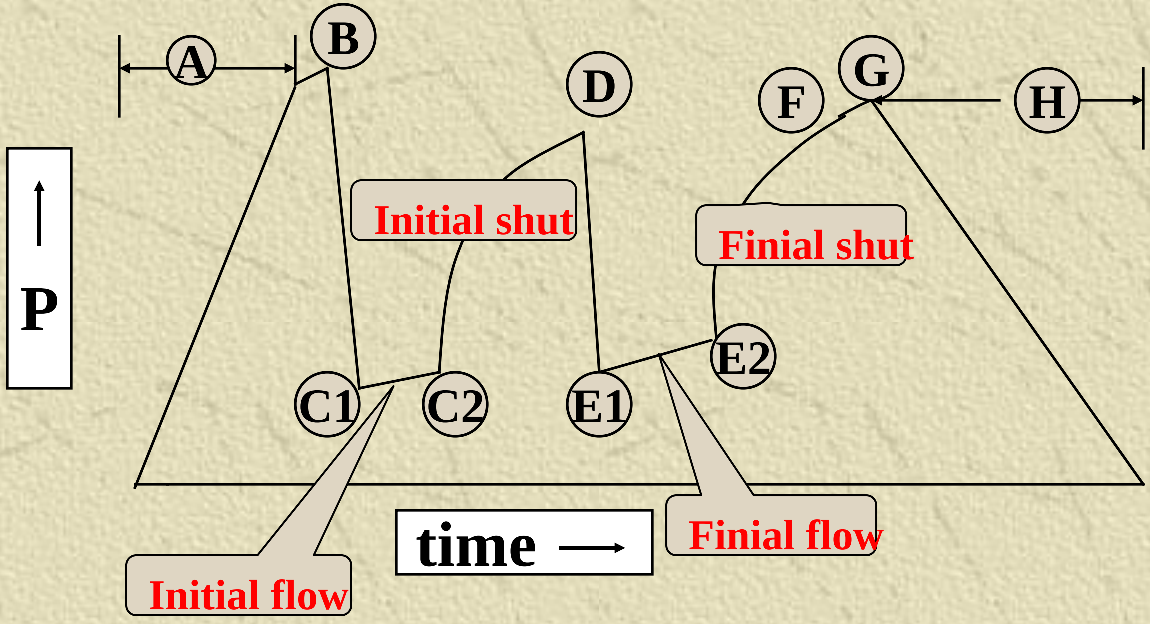
2. formation testing

3. shut-in pressure measured

4. reverse circulation and trip-out

IV. Interpretation and Application

（1） pressure card



- **B** Initial Hydrostatic Pressure
- **C1** Initial Flow Pressure (IFP1)
- **C2** Initial Flow Pressure (IFP2)
- **D** Initial Shut in Pressure
- **E1** Finial Flow Pressure (FFP21)
- **E2** Finial Flow Pressure (FFP21)
- **F** Finial Shut in Pressure
- **G** Finial Hydrostatic Pressure

（I）Pressure card explain and application

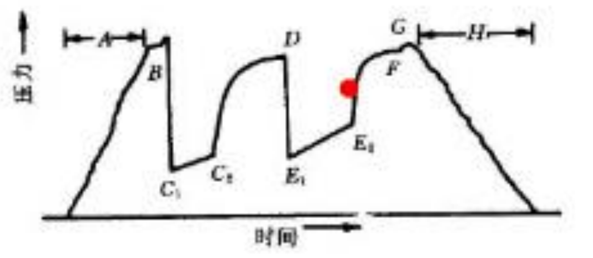
Pressure build-up and pressure drop curve

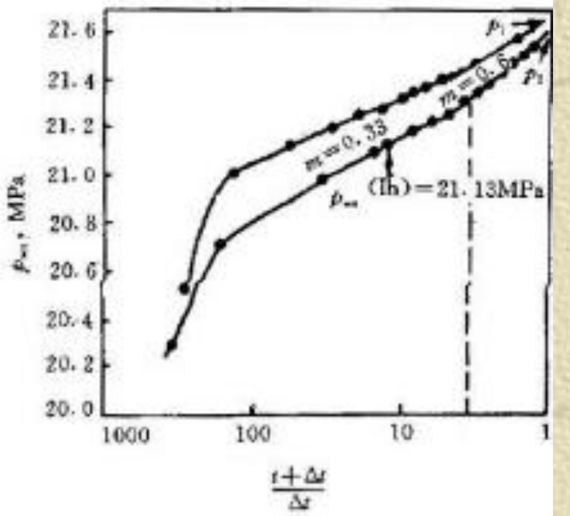
Pressure build-up fundamental formula

Horner：

$$Pws = Pi - m\log\frac{t+\Delta t}{\Delta t}$$

Pws----build-up pressure of bottom hole， MPa；
Pi ---- Initial pressure， MPa
m---- Slop of straightway in the pressure curve
t---- Production time after open the valve， h
△t----Pressure build-up time after close the valve， h

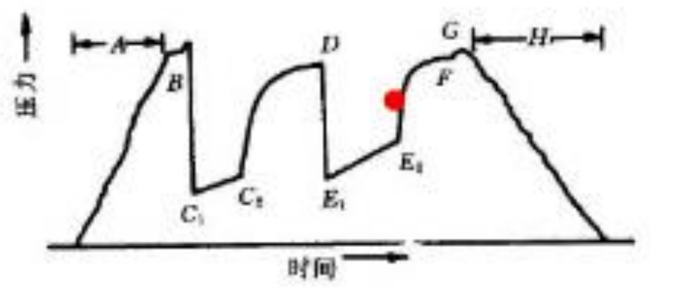


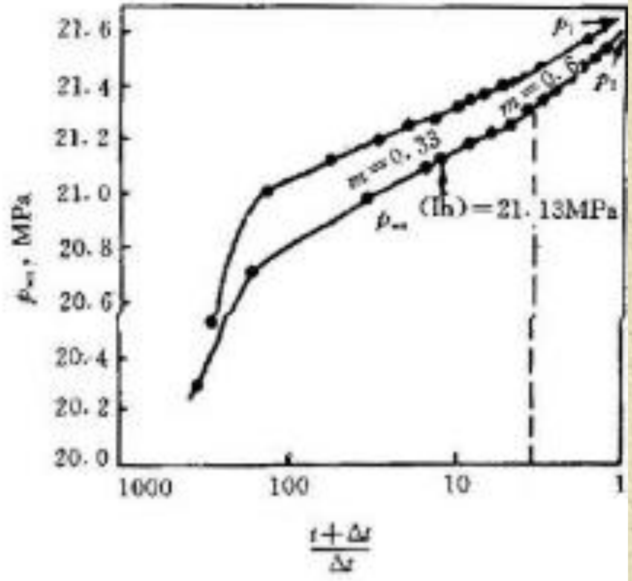


Horner

（I）Pressure card explain and application

$$m = \frac{2.12 * 10^{-3} Q_o \mu_o B_o}{K h \rho_o}$$





m----slope of straight line section of pressure curve
K---- formation effective permeability, μm^2
h --- formation effective thickness ,m；
△t---build-up time after closing test valve ,h
Φ--- formation effective porosity， decimal
μo---formation oil viscosity， mPa.s
Qo---reduced oil production in flow regime， t/d
Bo---formation oil volume factor
ρo---density of stock tank oil ,t/m^3

Pressure card application

- Calculation of flow coefficient
- Calculation of impervious boundary distance
- Inferred initial reservoir pressure
- Calculation of skin factor
- Analysis of formation plugging or damage
- Identification of total compressibility

Pressure card

Oil, gas and water productivity

Fluid sample under formation condition

（II）Oil, gas and water productivity

1. Oil and water productivity

artesian flowing well ： controlled by choke(flow nipple) and separator, to calculate oil and water productivity

nonflowing artesian： calculate productivity by height of level in drill pipe

$$Q = \frac{H}{t} Vu * 1440$$

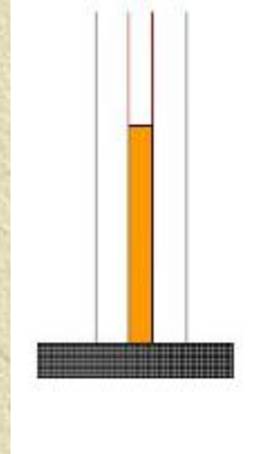
where：

Q----liquid yield， m^3/d（surface）

H----height of level， m

Vu---volume of drill pipe per unit length， m^3/m

t---flowing time， min



？ stabilization time： 24 hours

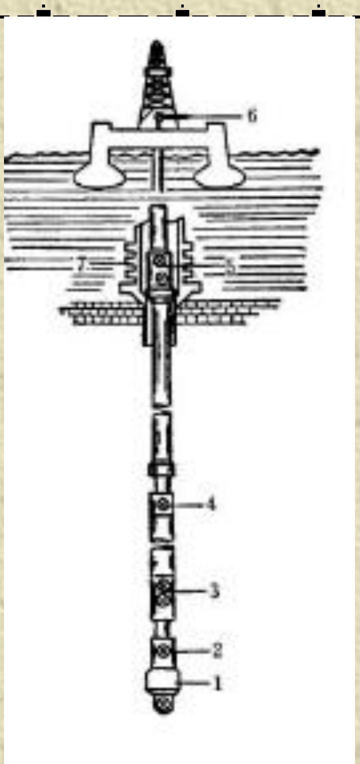
2. Gas production

orifice flowmeter

Calculate gas production by measure drawdown in front and back of orifice

packing ring flowmeter

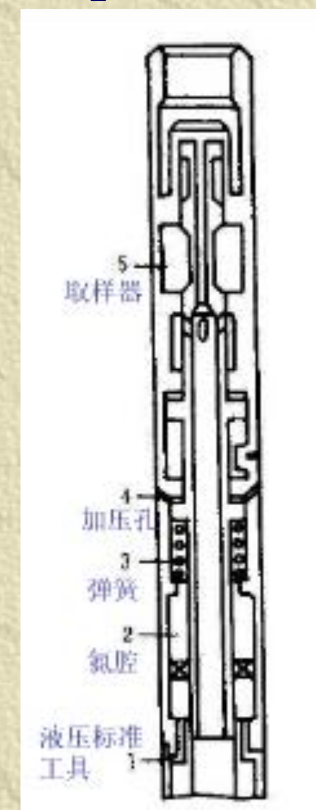
(when gas production in test zone is small, tens or thousands of cubic meter)



（III）Fluid sample under formation condition

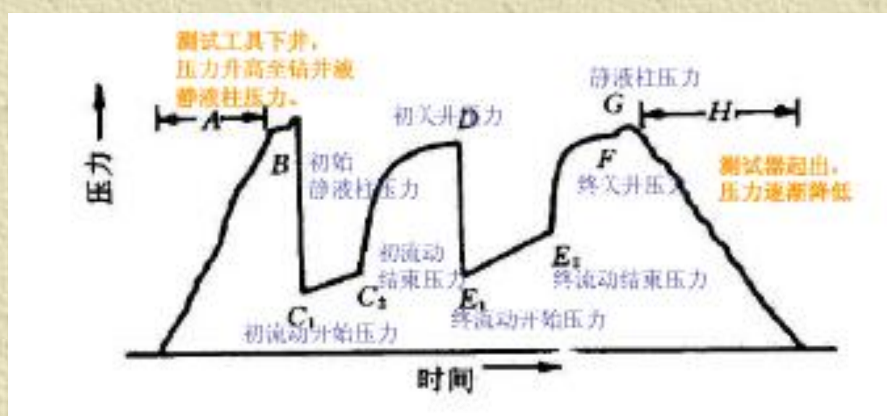
Obtain fluid sample under formation condition by sampler taker

sampling before final flow ends



→ **PVT analysis**

（pressure-volume-temperature)



Chapter1 Drilling Geology

Section 1 Well Design

Section 2 Geological Logging

Section 3 Formation Testing

Section 4 Well Completion

Section 4 Well Completion

- Well logging
- Sidewall coring
- Well cementing
- Well completion

→

Well cementing
Well completion

I. Well Cementing

The borehole needs to be stabilised and the drilling progress safeguarded. This is done by lining the well with casing which is cemented in place.

Casing and Cement

I.Well Cementing

1. Well cementing objectives
2. Casing program
3. Casing and cementing

I.Well Cementing

1. Well cementing objectives

- **To bond the casing to the formation and thereby support the borehole wall**
- **To prevent the casing from buckling in critical sections**
- **To separate the different zones behind the casing and thereby prevent fluid movement between permeable formations**
- **To seal off trouble horizons such as lost circulation zones**

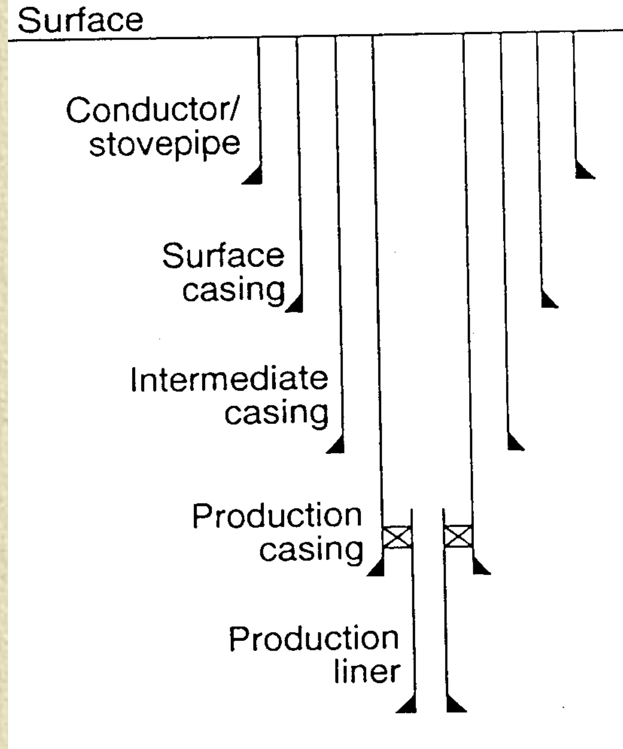
I. Well Cementing

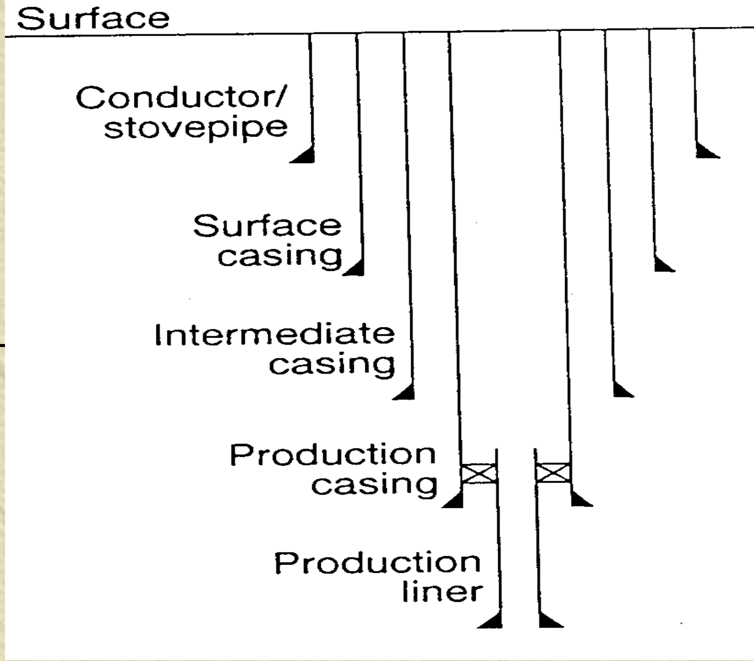
2.Casing program →

- Casing string
- Casing diameter
- Casing setting depth

Casing Scheme---- The borehole needs to be stabilised and the drilling progress safeguarded. This is done by lining the well with steel pipe (casing) which is cemented in place. In this manner the well is drilled like a telescope.

(1) surface casing
(2) intermediate casing
(3) production casing





Casing Scheme

Casing scheme includes surface casing, intermediate casing, production casing. Except for these, sometimes it also includes conductor and production liner.

Casing joints are available in different grades, depending on the expected loads to which the string will be exposed during running, and the lifetime of the well.

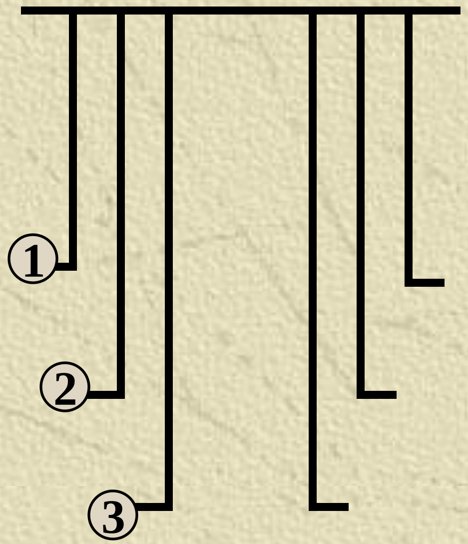
I.Well cementing

2. Casing program

(1)surface pipe / surface casing

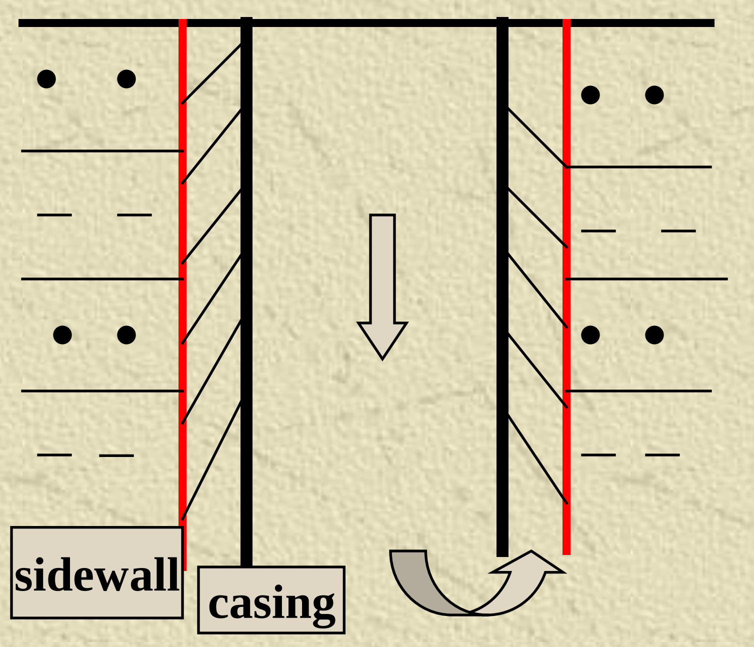
(2) technical pipe
intermediate casing

(3)reservoir pipe / production casing



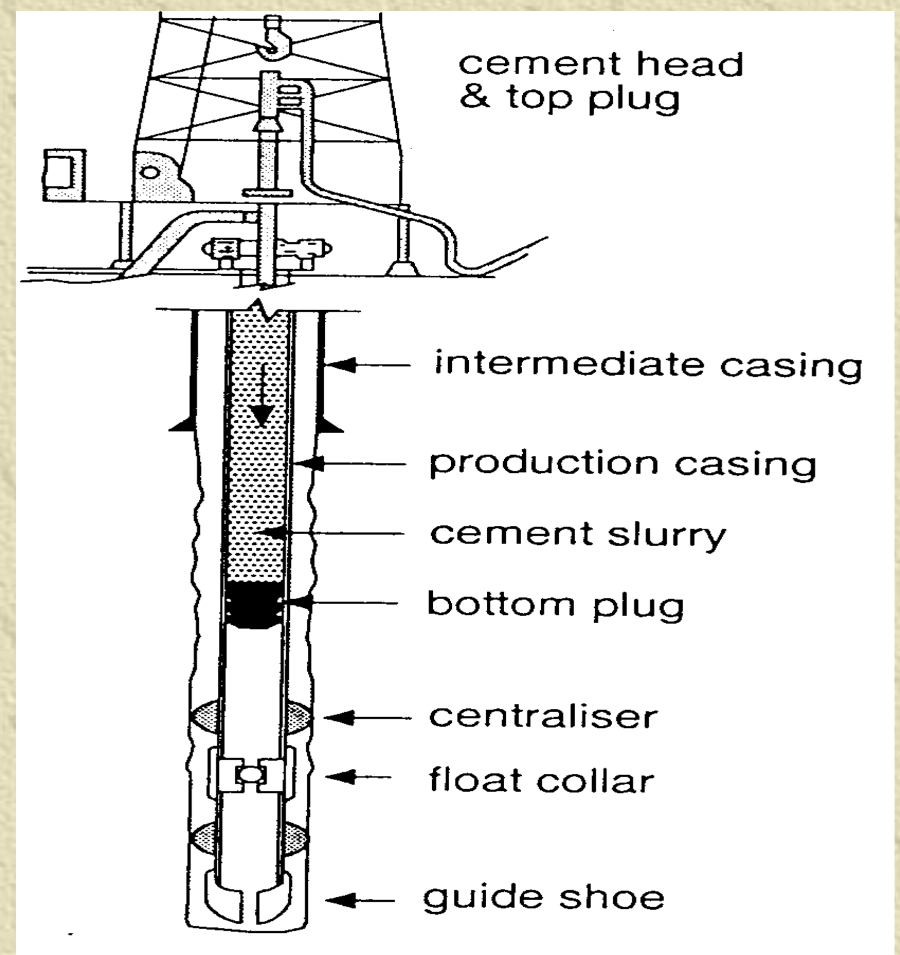
well cementing

It's the job to set casing and fill cement in annular space between borehole wall and casing.



Well Cementing

Principle of Casing Cementation



Running casing is the process by which 40 feet sections of steel pipe are screwed together on the rig floor and lowered into the hole. The bottom two joints will contain a guide shoe, a protective cap which facilitates the downward entry of the casing string through the borehole. Inside the guide shoe is an one way valve which will open when cement / mud is pumped down the casing and is displaced upwards on the outside of the string. The valve is necessary because at the end of the cementing process the column of cement slurry filling the annulus will be heavier than the mud inside the casing and 'U tubing' would occur without it. To have a second barrier in the string, a float collar is inserted in the joint above the guide shoe. The float collar also catches the bottom plug and top plug between which the cement slurry is placed. The slurry of cement is pumped down between the two rubber seals(plugs). Their function is to prevent contamination of the cement with drilling fluid which would cause a bad cement bond between borehole wall and casing. Once the bottom plug bumps into the float collar it ruptures and the cement slurry is pushed down through the guide shoe and upwards outside the casing. Thus the annulus between casing and borehole wall is filled with cement. The success of a cement job depends partly on the velocities of the cement slurry in the annulus. The cement has to be placed evenly around each casing joint. This becomes more difficult with increasing deviation angle since the casing joints will tend to lie on the lower side of the borehole preventing cement slurry entering between casing and borehole wall. To avoid this happening steel springs or centralizers are placed at intervals outside the string to centralize the casing in the borehole.

After the cement is run, a waiting time is allotted to allow the slurry to harden. This period of time is referred to as waiting on cement or simply WOC.

After the cement hardens, tests maybe run to ensure a good cement job, for cement is very important.

1.Cement supports the casing, so the cement should completely surround the casing; this is where centralizers on the casing help. If the casing is centered in the hole, a cement sheath should completely envelop the casing.

2. Cement seals off formations to prevent fluids from one formation migrating up or down the hole and polluting the fluids in another formation.

3. Cement protects the casing from the corrosive effects that formation fluids may have on it.

After the cement hardens and tests indicate that the job is good, the rig crew attaches or nipples up the blowout preventer stack to the top of the casing. The BOP stack is pressure-tested, and drilling is resumed.

Sometimes primary cementations are not successful, for instance if the cement volume has been wrongly calculated, if cement is lost into the formation or if the cement has been contaminated with drilling fluids.

In this case a remedial or secondary cementation is required. This may necessitate the perforation of the casing a given depth and the pumping of cement through the perforations.

I.Well Cementing

1. Well cementing objectives
2. Casing program
3. Casing and cementing

II. Well completion

Well completion objectives:

- **good for borehole stability;**
- **sufficiently expose hydrocarbon reservoir;**
- **good for oil and gas flowing to ground;**
- **good for oil and gas wells normal production ;**
- **good for stimulation measurement,**

fracturing, acidifying etc.

simple process, quick well completion, low cost

initial completion
later completion

1. Initial completion

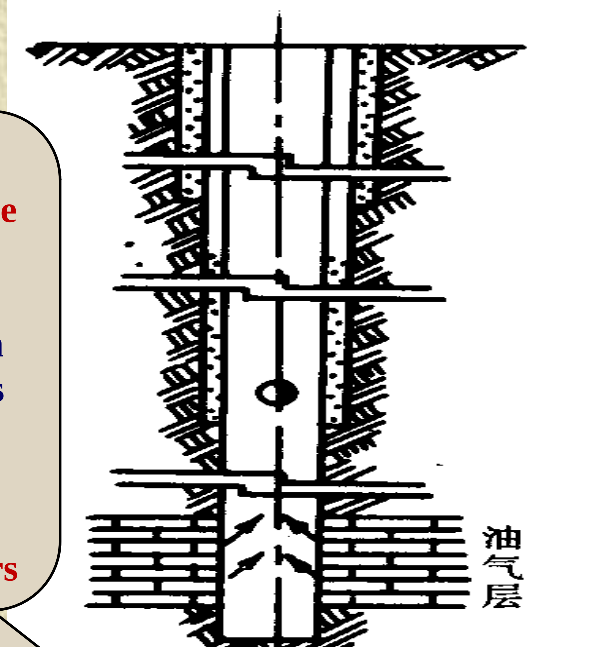
Initial completion----

production casing before broaching reservoirs

barefoot completion/ open hole completion

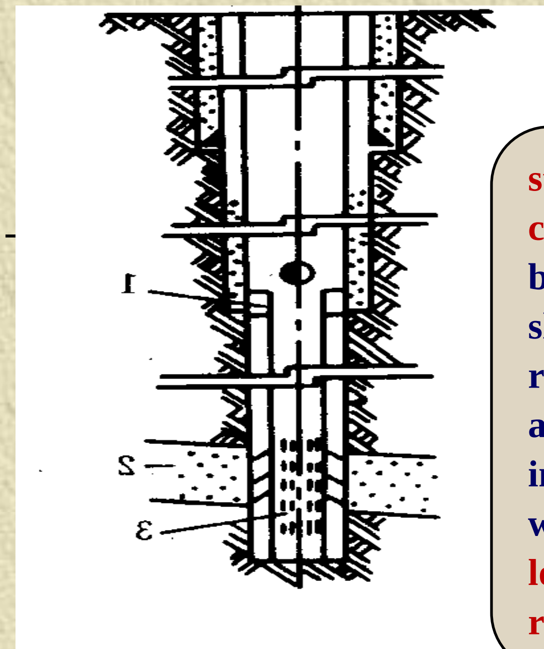
liner perforation completion

Apply to single reservoir with stable lithology and no interbedded reservoirs; wells in multiple reservoirs with uniform character. Widely used in Fractured carbonate reservoirs



open hole completion

After broaching to the top of reservoir, trip in production casing for completion. Then use small bits to broach reservoir. After completion, reservoir connect to wellbore



strong sand control, prevent borehole wall sloughing, large reservoir, (not applicable in interbedded water), adopts in loose sandstone reservoirs.

liner completion

After broach the reservoirs, trip in liner(slotted casing) for completion

Initial completion----

production casing before broaching reservoirs

Advantage: good for protecting and liberating oil and gas reservoirs.

In compacted carbonate reservoirs without the interaction of interbedded water, it is always adopted.

Disadvantage: interfere in barefoot interval if reservoirs have different pressure; easy to collapse in weak formation.

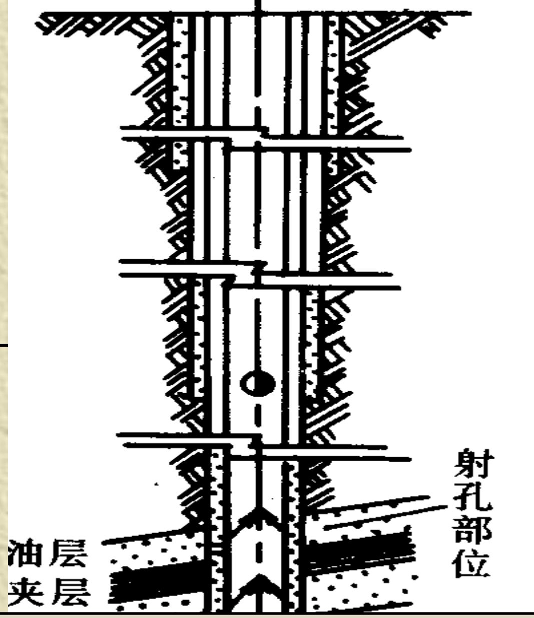
2.Later completion

Broaching reservoirs before production casing

perforation completion

liner completion

perforated pipe completion



perforation completion

After broaching oil and gas reservoirs, trip in production casing to the bottom of contributing zone. Trip in bullet gun to perforate in oil and gas reservoirs, penetrate the casing and cement mantle to enter formation, To make channels for oil and gas flowing into well

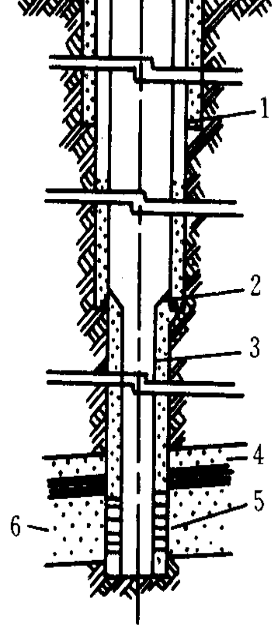
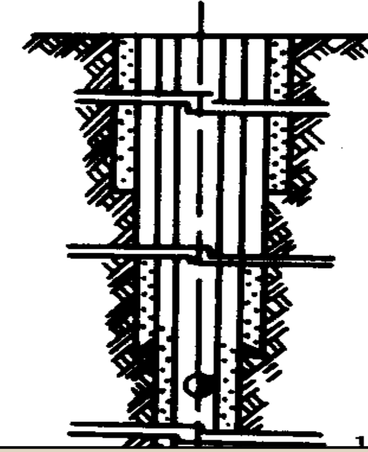


图 1－36　尾管射孔完成

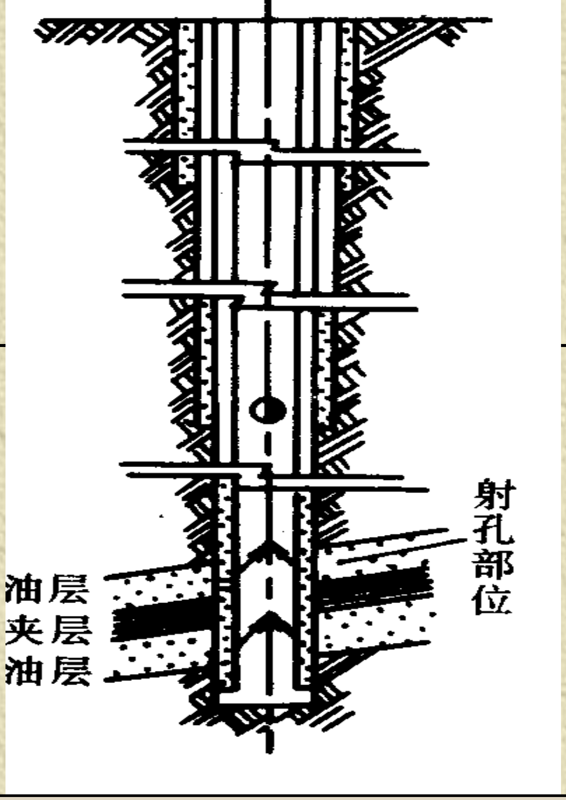
liner completion

Broaching to top of reservoirs, trip in production casing, broach reservoir. Trip in tail pipe, and connect wellbore and reservoir by perforation.



perforated pipe completio

The casing facing reservoirs is perforatec and cement basket is fixed outside the casing in top of reservoirs. cement milk in annular space won't flow down t block reservoirs. After production casing completion, broaching cement plug can connec reservoir and wellbore.



perforation completion

After broach reservoirs, trip in production casing to bottom of the pay zone. Trip in specific bullet gun to perforated reservoirs. Broach casing and cement mantle to enter the formation, to make channels for oil flowing into wells.

Perforation completion only selectively perforates in reservoirs. The rest of borehole wall are sealed by production casing.

Advantage: **block up reservoirs, prevent interference between reservoirs, good for separate well test, Separate production and separate flood. Remove influence of borehole wall sloughing to wells. Strong adaptiveness, widely adopted in completion.**

Disadvantage: **small reservoir exposure area, Large resistance when oil flow into wells. Bad sand control. Bad for production in loose reservoirs. Reservoirs suffer heavy damage by drill fluid and cement milk during drilling and completion**

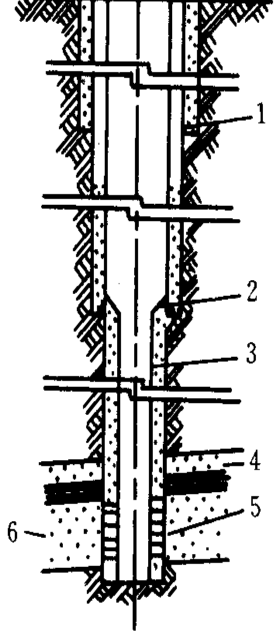


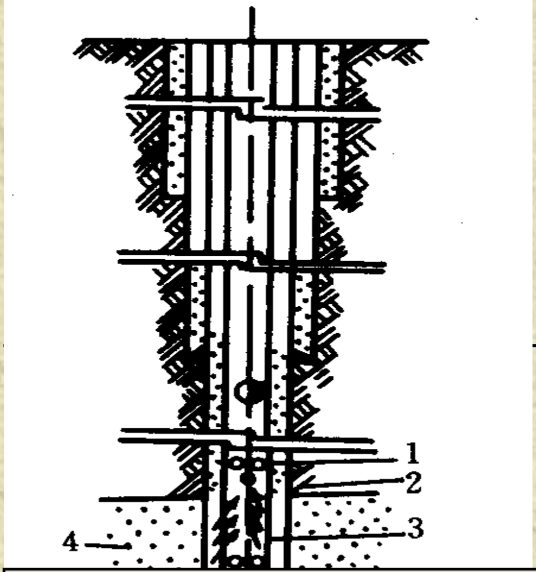
图 1－36　尾管射孔完成

liner completion

Broaching to top of reservoirs, trip in production casing, broach reservoir. Trip in tail pipe, and connect wellbore and reservoir by perforation.

Tail pipe: pipe which trip in wells but do not connect to well mouth. The upper part of tail pipe overlap with casing for 100-200m, the annular space outside the tail pipe is cemented. Perforate reservoirs to connect well mouth with reservoirs.

Advantage: save steel and cement, decrease drilling cost



perforated pipe completion

The casing facing reservoirs is perforated, and cement basket is fixed outside the casing in top of reservoirs. cement milk in annular space won’t flow down to block reservoirs. After production casing completion, broaching cement plug can connect reservoir and wellbore.

Advantage: sufficient exposure of hydrocarbon reservoirs, oil and gas flow fluently, good sand control.

disadvantage: hydrocarbon reservoirs hard to be blocked after appearing above water during production. Cement basket easy to be crushed, making cement milk intruding into reservoirs.

Section 4 Well Completion

- well logging
- sidewall coring
- well cementing
- well completion

⇨

well cementing
well completion

Chapter 1 Drilling Geology

Section 1 Well Design

Section 2 Geological Logging

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Section 4 Well Completion

1. **Summary main well type**
2. **The Objective of appraisal well**
3. **What is the difference purpose between evaluation well and appraisal?**
4. **Explain generalized drilling geology**
5. **Summaries the main contents of drilling geologic design for an exploration well.**
6. **Analysis advantages of deviated and multiple well**
7. **What are the purposes and main methods of geological logging?**
8. **Analysis the cutting logging features.**
9. **How to calculate the well depth during cutting logging?**
10. **Explain delay time. How to get delay time?**
11. **Coring type and principle**
12. **Explain mud circulation**
13. **Explain drilling fluid properties.**
14. **What are the basic functions of drilling fluid during drilling?**
15. **Explain the application of drilling –time curve**
16. **What are the advantages of formation Testing?**
17. **Explain the pressure card**
18. **Explain the Casing scheme**
19. **The purpose of well cementing**
20. **Well completion objective**

Exercise one:

Drawing a summary map for a drilled well

1. **Data Provided:**

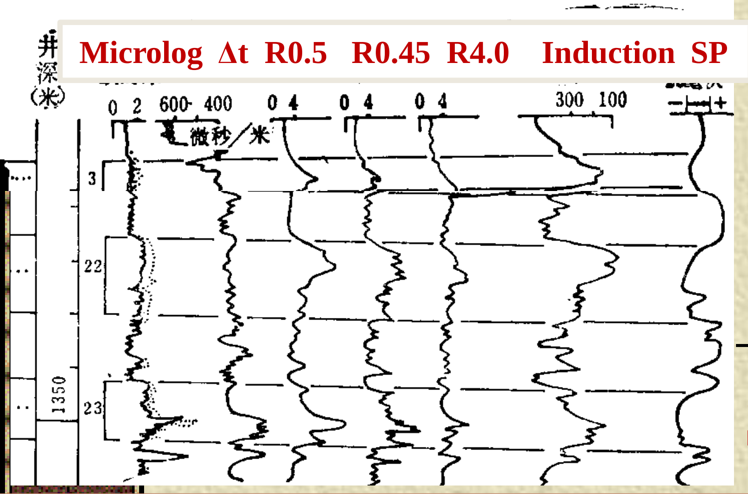
- Geological logging (cutting, drilling-time curve, sidewall coring)
- Geophysics logging (R, SP, GR, NGR)

2. **Requirements:**

- To laminate / to stratification
- To identify lithology
- To identify / recognize oil-bearing formation and water-bearing formation
- To summarize lithological association

Cutting percentage ---- lamination/ layering

A. The occurrence depth of a new component corresponding to the top interface of the new lithology;
B. The depth of amount decrease corresponding to the bottom interface of this lithology;
C. The alternating increase and decrease percentage of two kind of cuttings indicate lithology interbed.



Main well logging Methods

Spontaneous Potential (SP) Log

Usually the Spontaneous Potential (SP) line on the log shows a more or less **straight line opposite impermeable shales,** and will **show peaks to the left opposite permeable strata**.

The shapes and amplitudes of the peaks may be different according to the type of formation.

The variations of shapes and amplitudes are related to the lithology.

The main uses for the SP curve ----

- To detect permeable beds, that is sand vs. shale formations
- To locate the boundaries between beds
- To obtain good values for formation water resistivity
- To correlate **equivalent beds** from well to well.

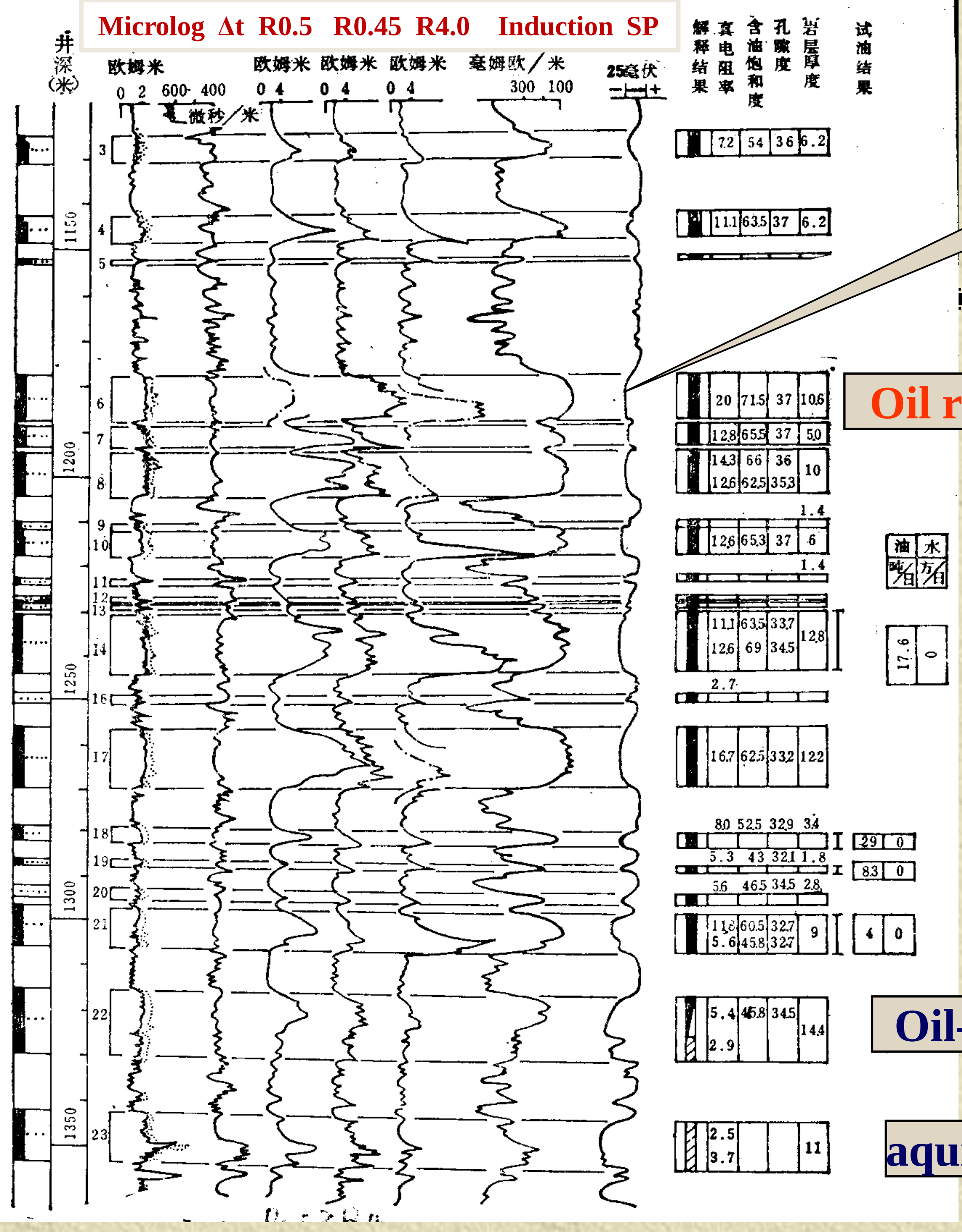
Main well logging Methods

Electric logs
Acoustic log
Radioactivity log
Other well logging

Spontaneous Potential (SP) Log

The SP deflection is measured with respect to the shale base line.
(reference line ----extreme positive side of the SP curve, a straight vertical line)
The maximum SP deflections toward the negative side on the log are opposite permeable formations.

The SP curve is important in geological correlation because the shapes of these curves in different wells for certain geologic horizons will be comparable.



negative anomaly

Oil reservoir

Oil-water reservoir

aquifer