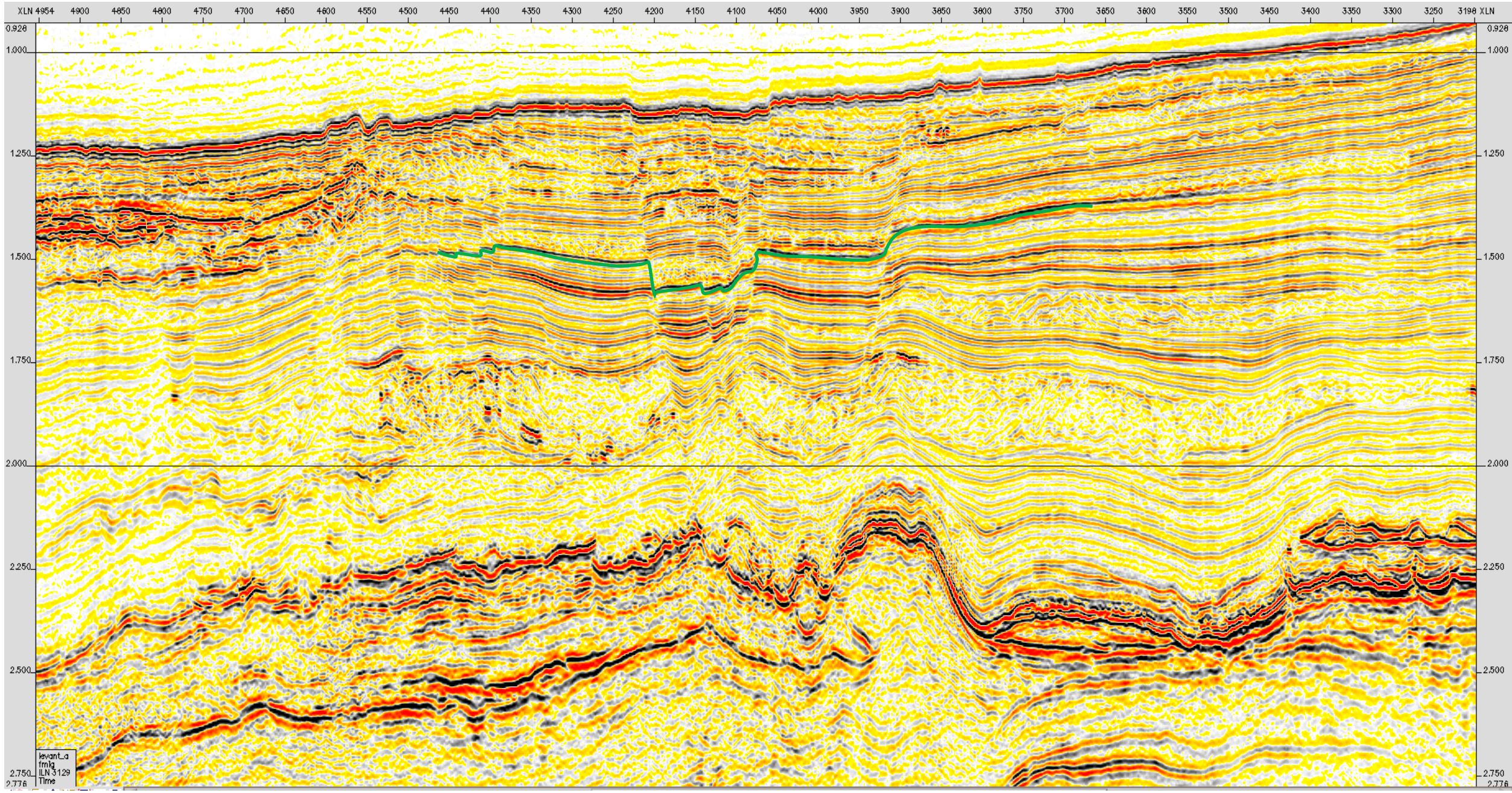
Fundamentals of Earth Sciences (ESO 213A)

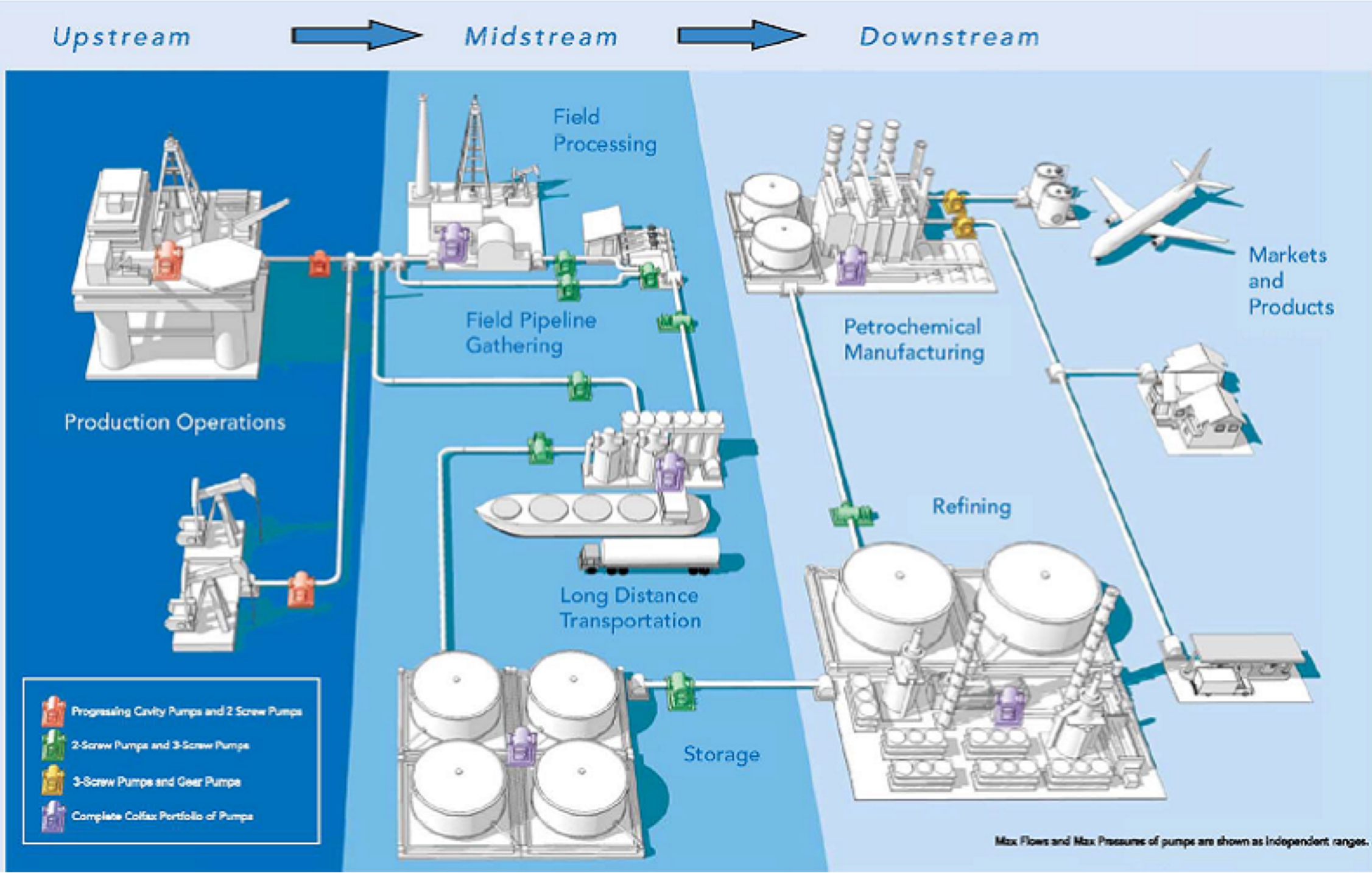
Dibakar Ghosal
Department of Earth Sciences

Geophysics: Borehole and Logging

Previous Class: Seismic

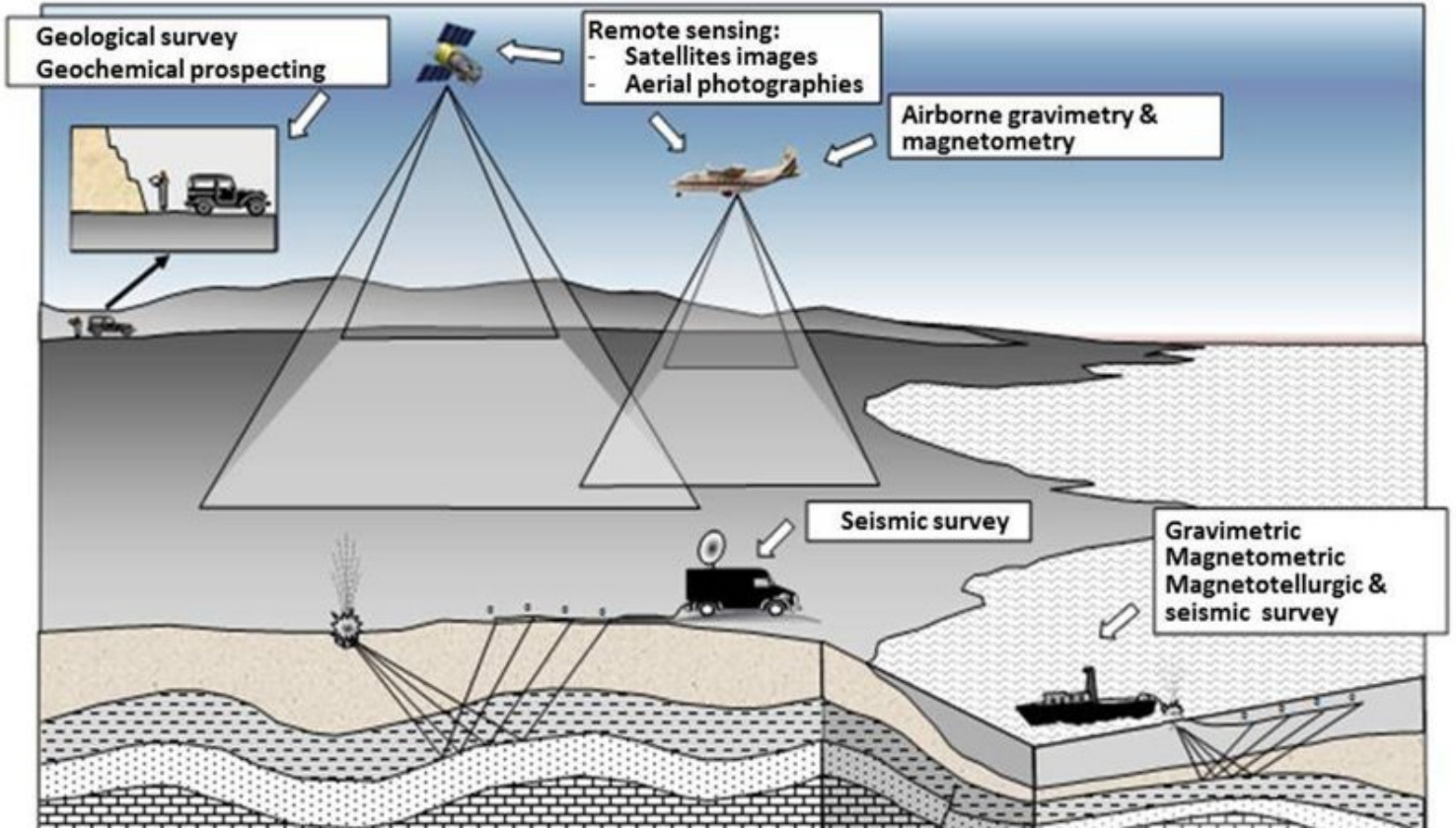
Seismic Image from Reflection data



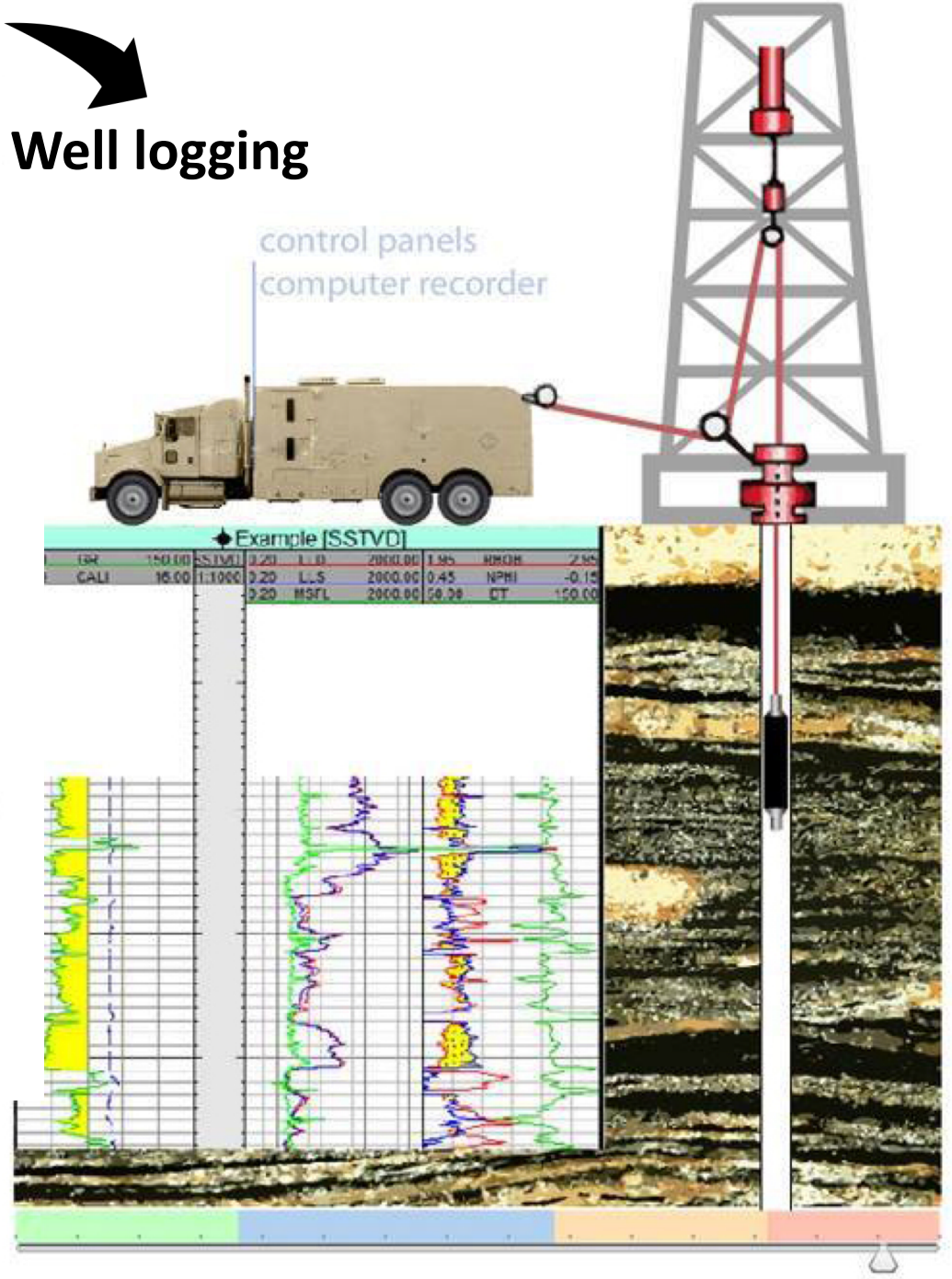

Upstream
Midstream
Downstream
Field Processing
Field Pipeline Gathering
Production Operations
Long Distance Transportation
Storage
Petrochemical Manufacturing
Refining
Markets and Products
Progressing Cavity Pumps and 2 Screw Pumps
2-Screw Pumps and 3-Screw Pumps
3-Screw Pumps and Gear Pumps
Complete Colfax Portfolio of Pumps
Max Flows and Max Pressures of pumps are shown as independent ranges.

GEOPHYSICS

Geophysical prospecting for oil



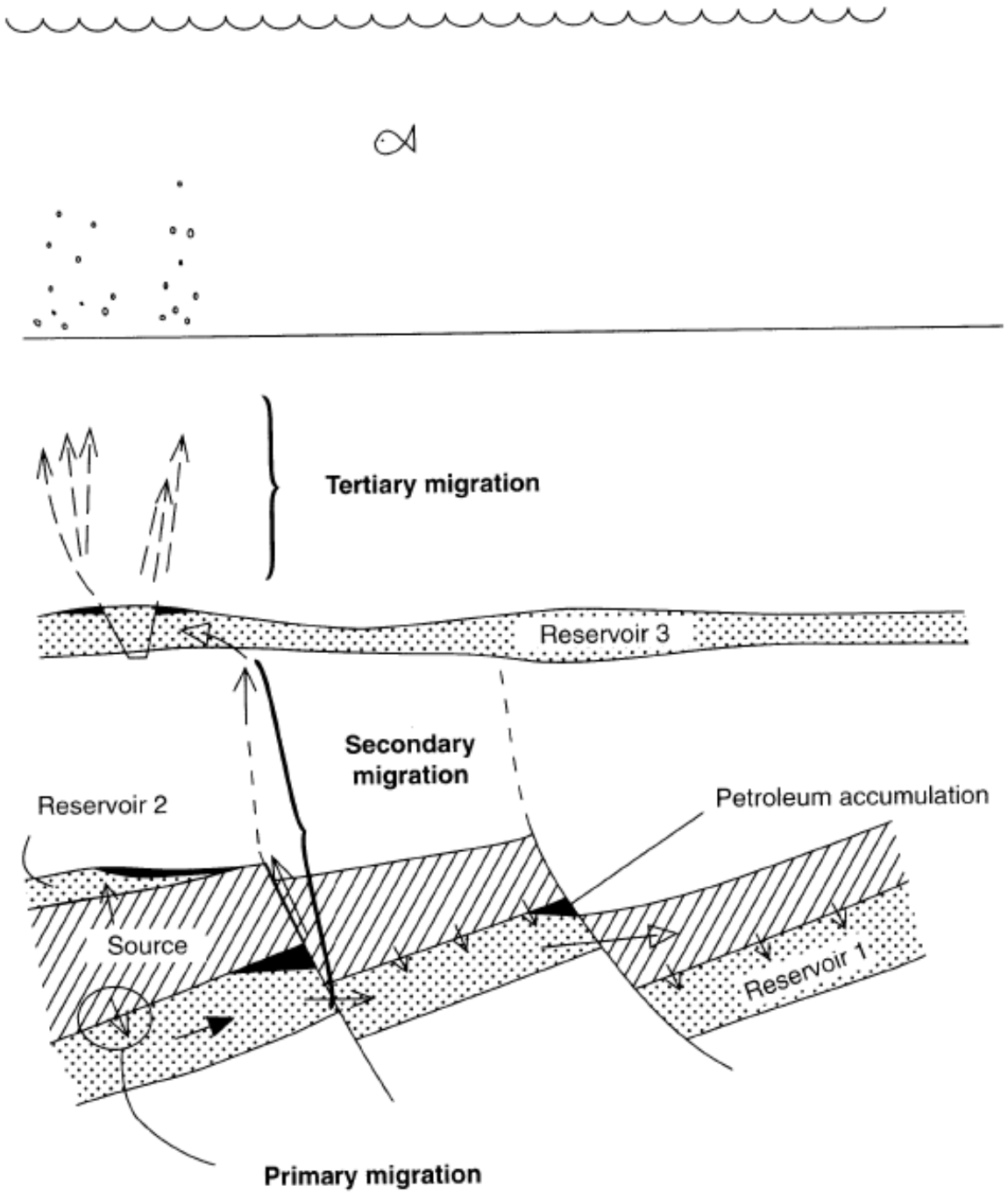
Well logging



Migration

- Hydrocarbons form in source rocks such as organic rich shales that undergo a degree of baking known at ‘thermal maturation’

- After formation, they will ‘migrate’ according to the laws of buoyancy through porous rocks like sandstone

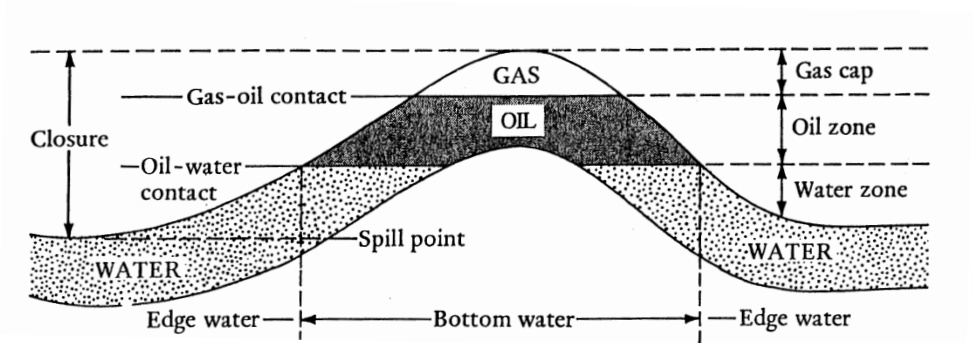


Traps

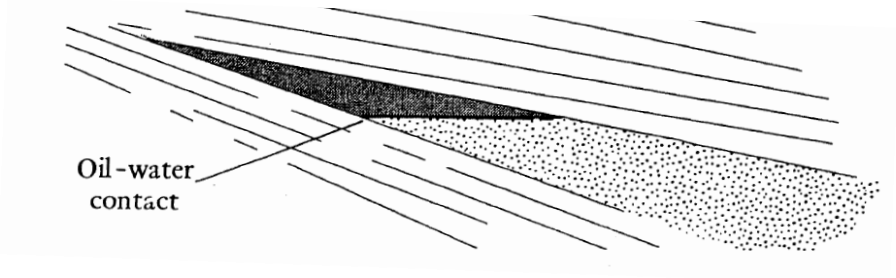
- An accumulation of hydrocarbons is called a trap
- This is because hydrocarbons migrate until trapped by a sealing membrane

2 Types

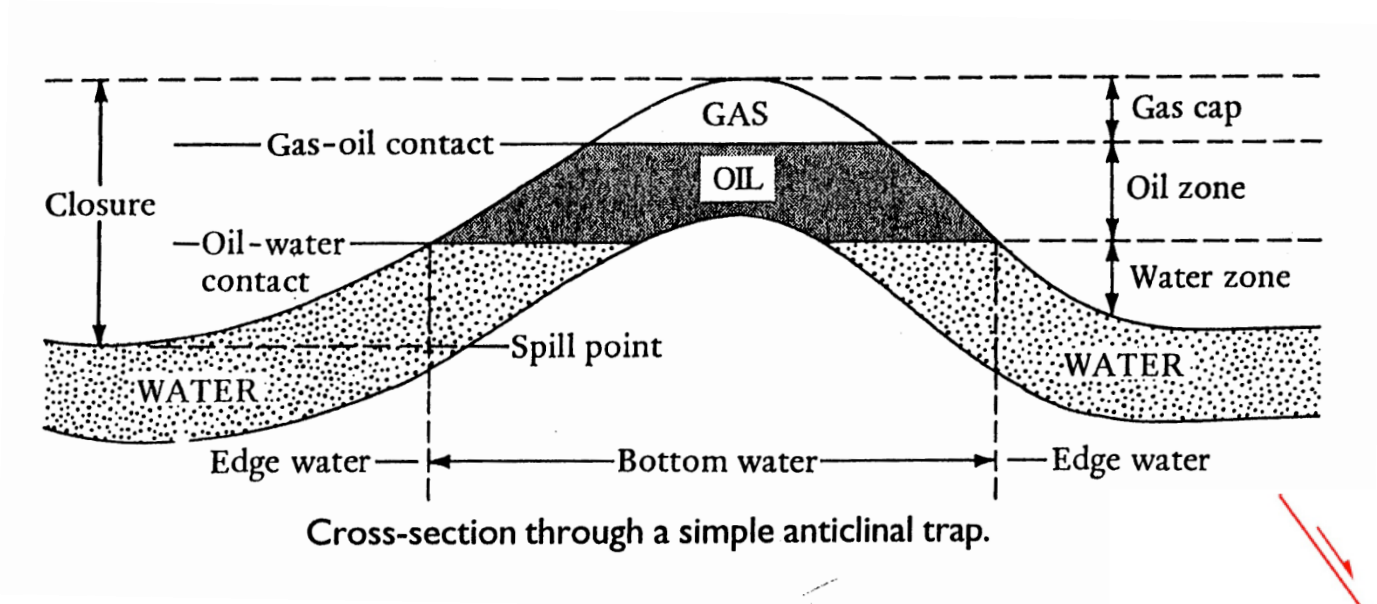
Structural



Stratigraphic

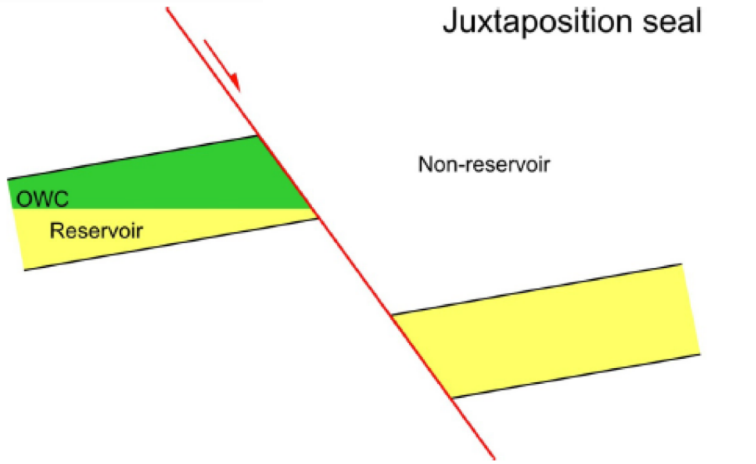


Structural Traps I



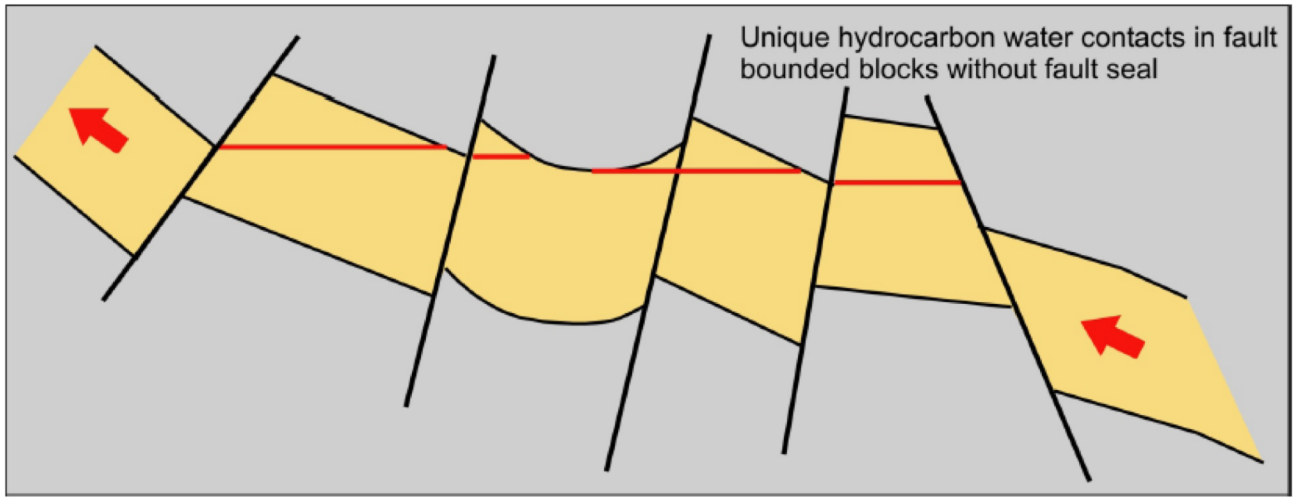
Cross-section through a simple anticlinal trap.

By folding, e.g. an anticline. (in 3D, an anticline forms a four-way closure).



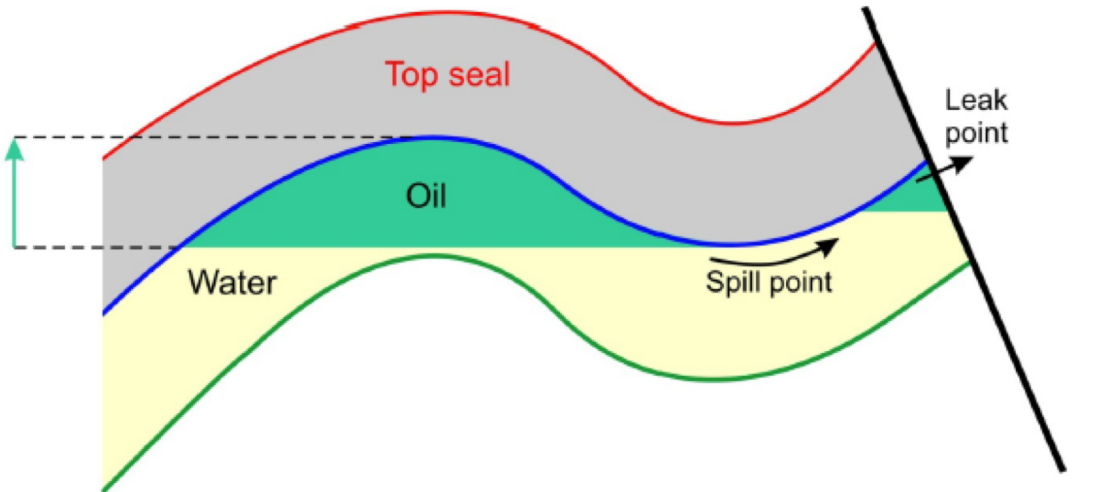
By faulting, e.g. fault acts as a seal or barrier to the fluid flow

Structural Traps II



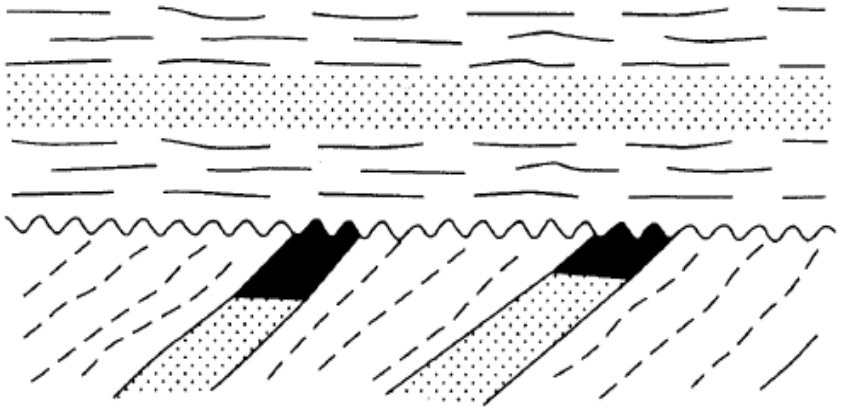
Traps can occur in high occurrence in an area due to many faults/folding acting as traps.

Traps can overflow and leak out

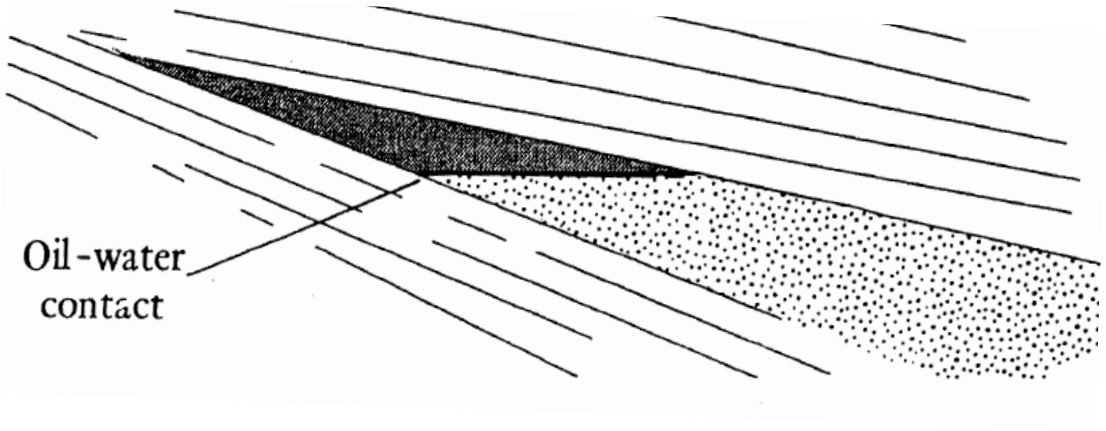


Stratigraphic Traps I

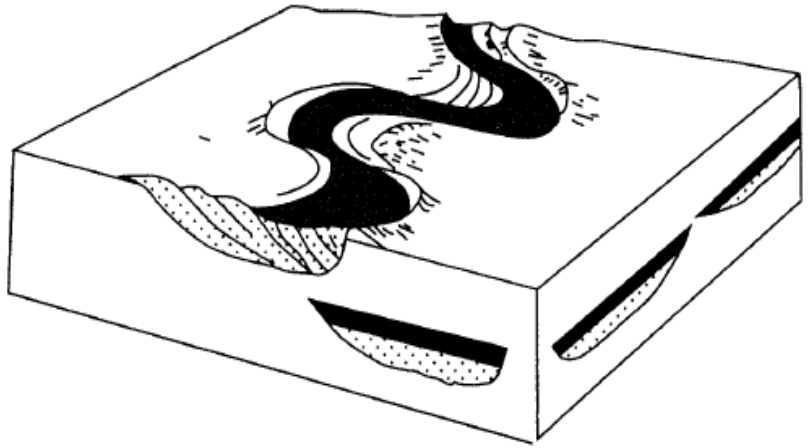
Unconformity



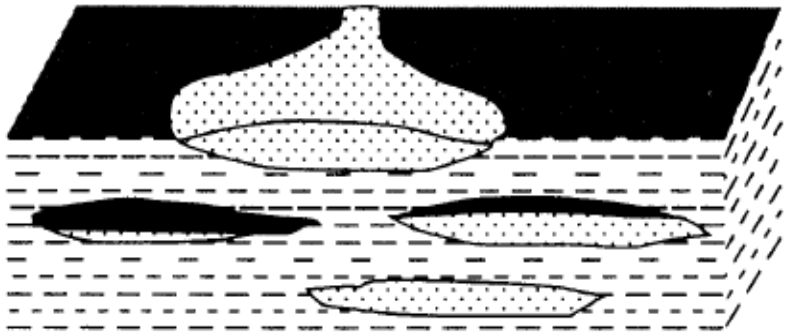
Stratigraphic ‘pinch-out’

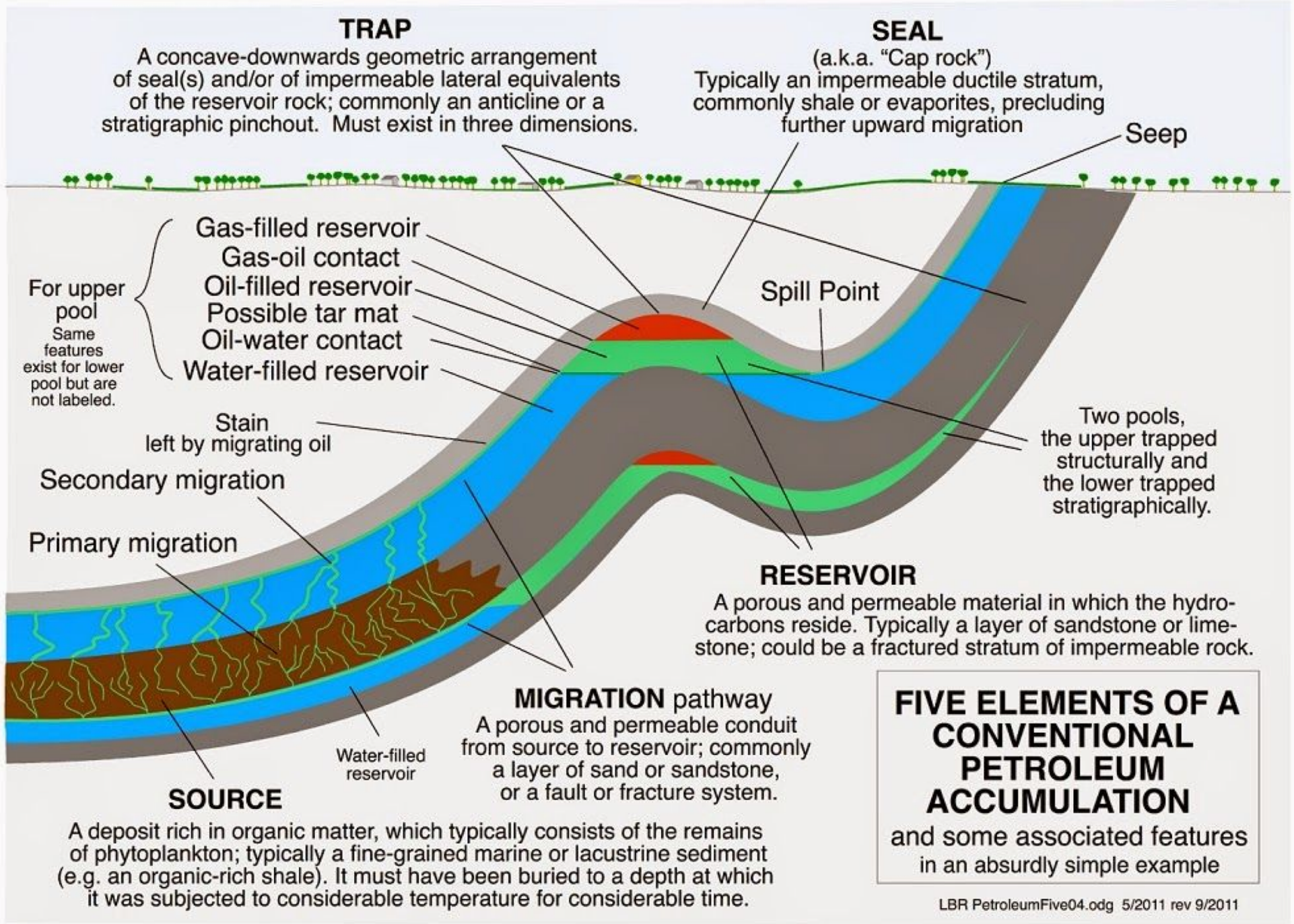


Channels

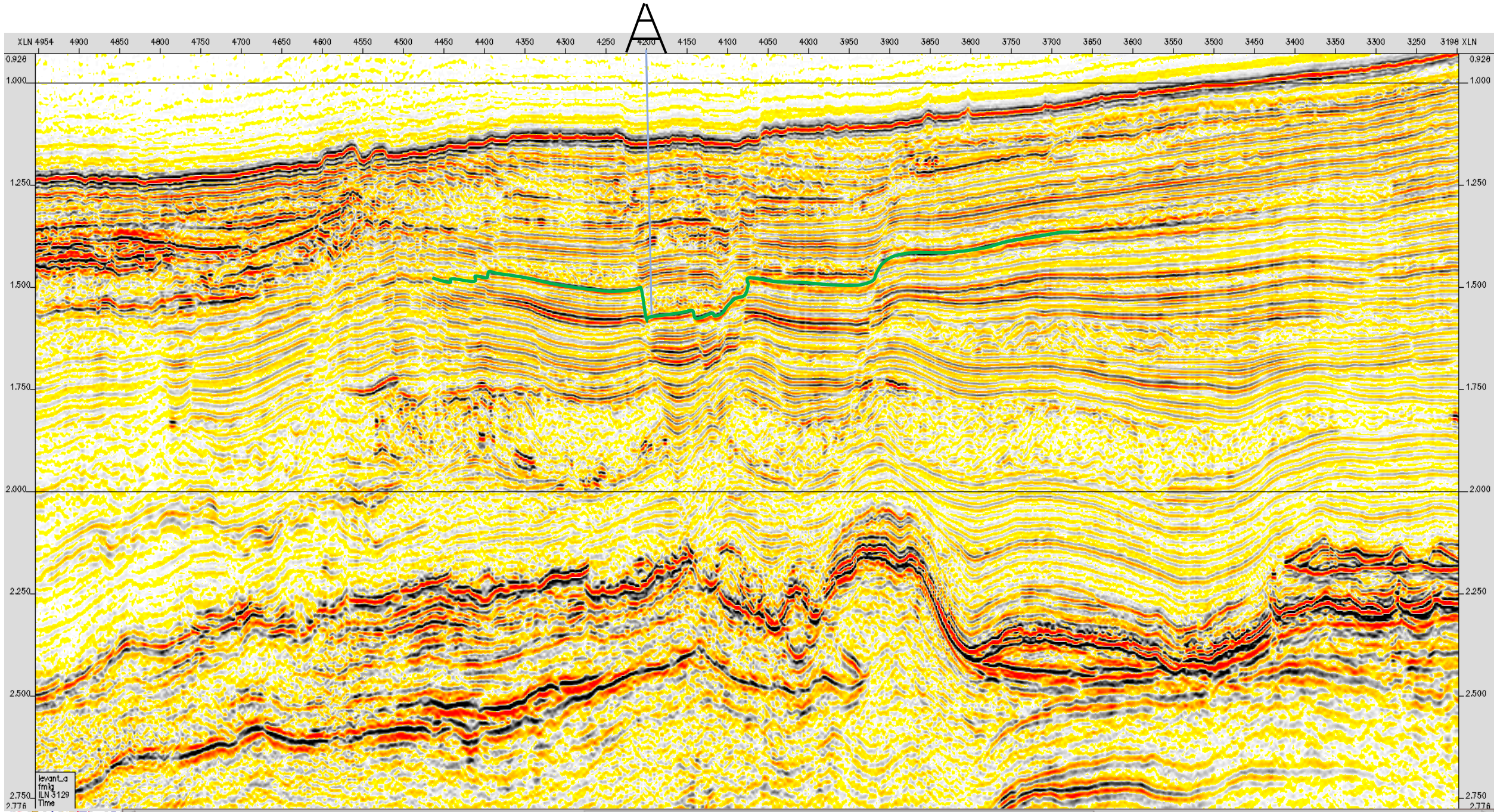


Lenses




TRAP
A concave-downwards geometric arrangement of seal(s) and/or of impermeable lateral equivalents of the reservoir rock; commonly an anticline or a stratigraphic pinchout. Must exist in three dimensions.
SEAL
(a.k.a. "Cap rock")
Typically an impermeable ductile stratum, commonly shale or evaporites, precluding further upward migration
Seep
Gas-filled reservoir
Gas-oil contact
Oil-filled reservoir
Possible tar mat
Oil-water contact
Water-filled reservoir
For upper pool
Same features exist for lower pool but are not labeled.
Spill Point
Stain
left by migrating oil
Secondary migration
Primary migration
Two pools, the upper trapped structurally and the lower trapped stratigraphically.
RESERVOIR
A porous and permeable material in which the hydrocarbons reside. Typically a layer of sandstone or limestone; could be a fractured stratum of impermeable rock.
MIGRATION pathway
A porous and permeable conduit from source to reservoir; commonly a layer of sand or sandstone, or a fault or fracture system.
Water-filled reservoir
SOURCE
A deposit rich in organic matter, which typically consists of the remains of phytoplankton; typically a fine-grained marine or lacustrine sediment (e.g. an organic-rich shale). It must have been buried to a depth at which it was subjected to considerable temperature for considerable time.
FIVE ELEMENTS OF A CONVENTIONAL PETROLEUM ACCUMULATION
and some associated features
in an absurdly simple example
LBR PetroleumFive04.odg 5/2011 rev 9/2011

Seismic Image from Reflection data (Where do you want to drill?)



Drilling Technology Basics

Drilling is an art that has progressed a great deal since the first wells were drilled about 150 years ago. At that time, the main product was kerosene to be burned in lamps. Gasoline didn't come in until the automobile was on its way around 1900. Drillers didn't trouble themselves with environmental concerns, and the process was dirty and wasteful.

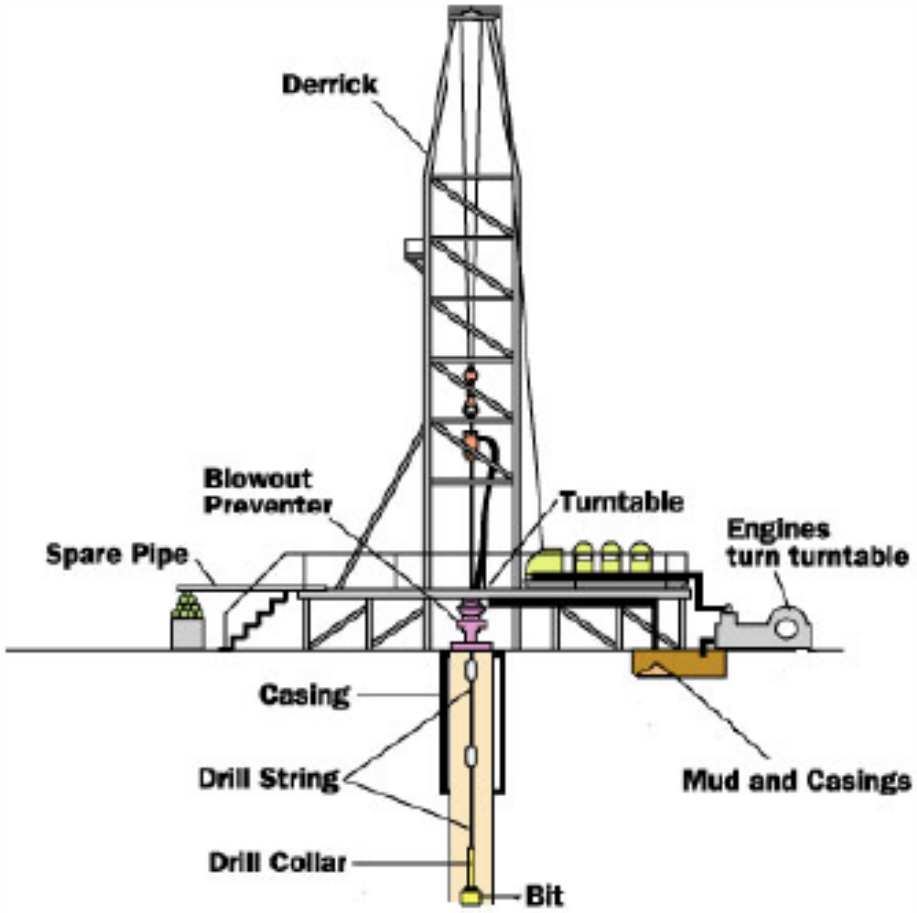
BOP Stack: Wells now all have a blow-out-prevention stack (BOP stack) at the ground level which can cut and seal the pipe and/or any casing strings quickly if pressure in the hole indicates that a highly overpressured zone has been encountered.

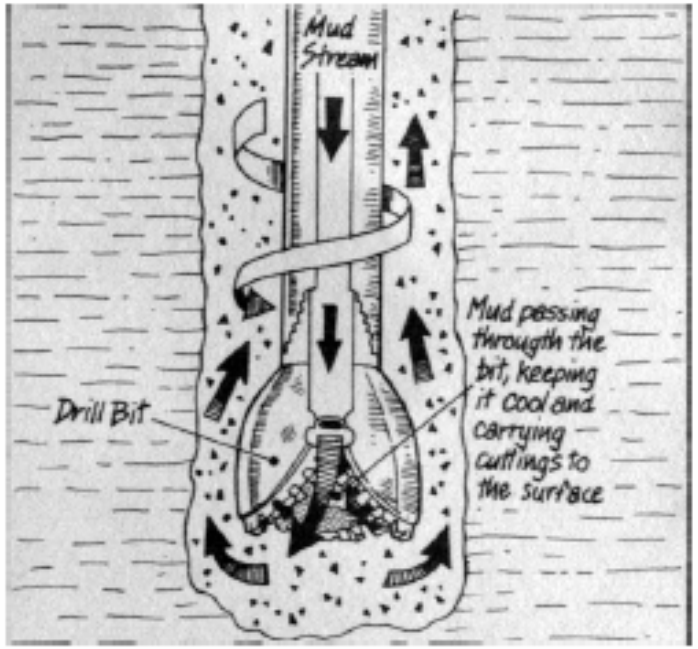
Drill pipe is HEAVY. The *Joides Resolution* string weighs about 600 tons. The drillers must be sure that the pipe is always in tension. The only part of the pipe in compression is at the bit itself. Heavy weighted pipes (drill collar) just above the bit keep the bottom section in tension.

The pipe is kept in rotation as much as possible with fluid pumped down through the pipe through the bit. The fluid keeps bits of rock (cuttings) from falling back down and clogging the pipe.

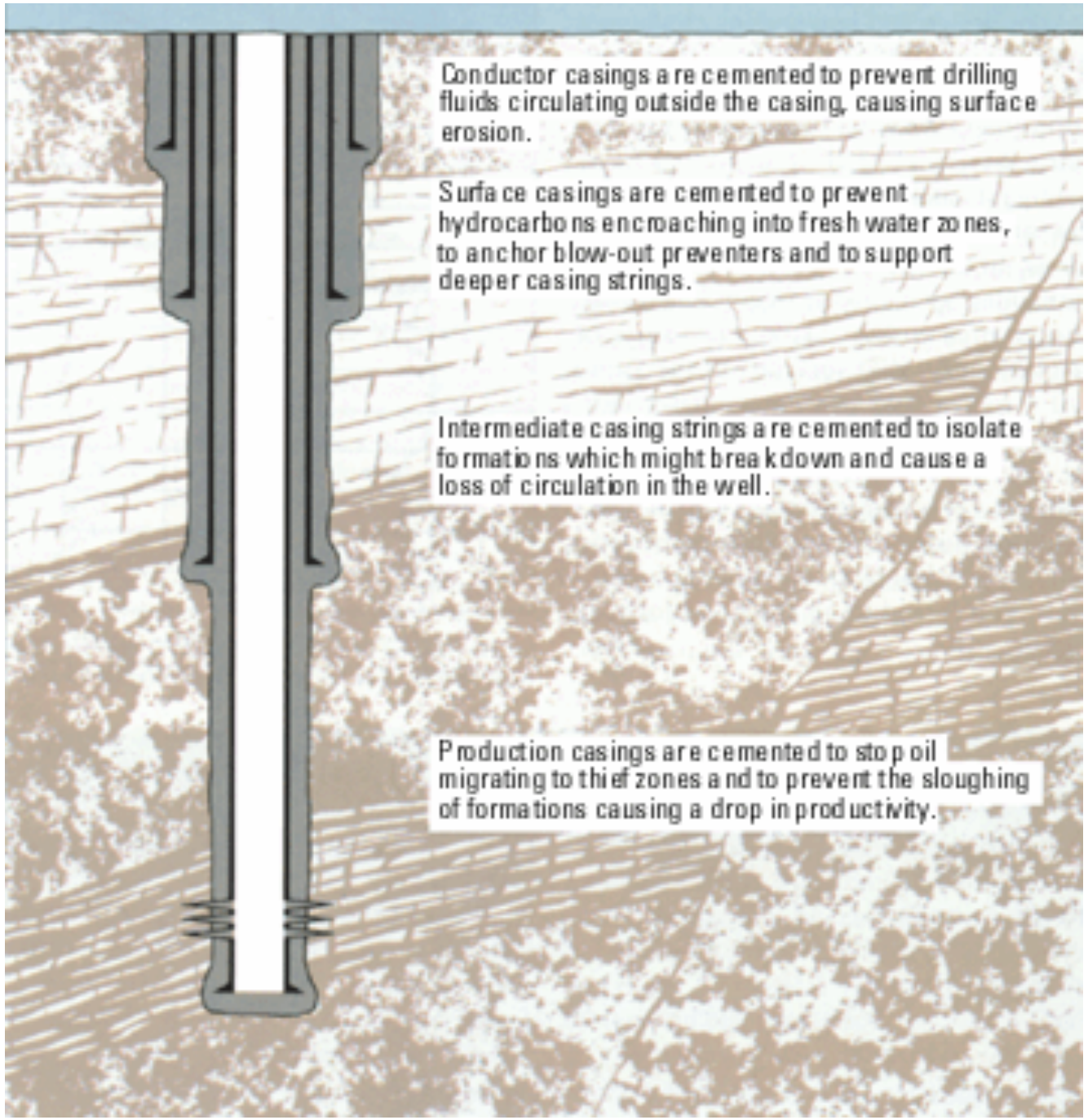
The pipe can only rotate in one direction. If it were to rotate backwards, all the screw joints between pipe stands would come apart.

The borehole





During drilling a liquid mixture containing clays and other natural materials, called **'Mud'** is pumped down the drill string forcing the rock cuttings up to the surface. These cuttings are analysed for indications of oil or gas.

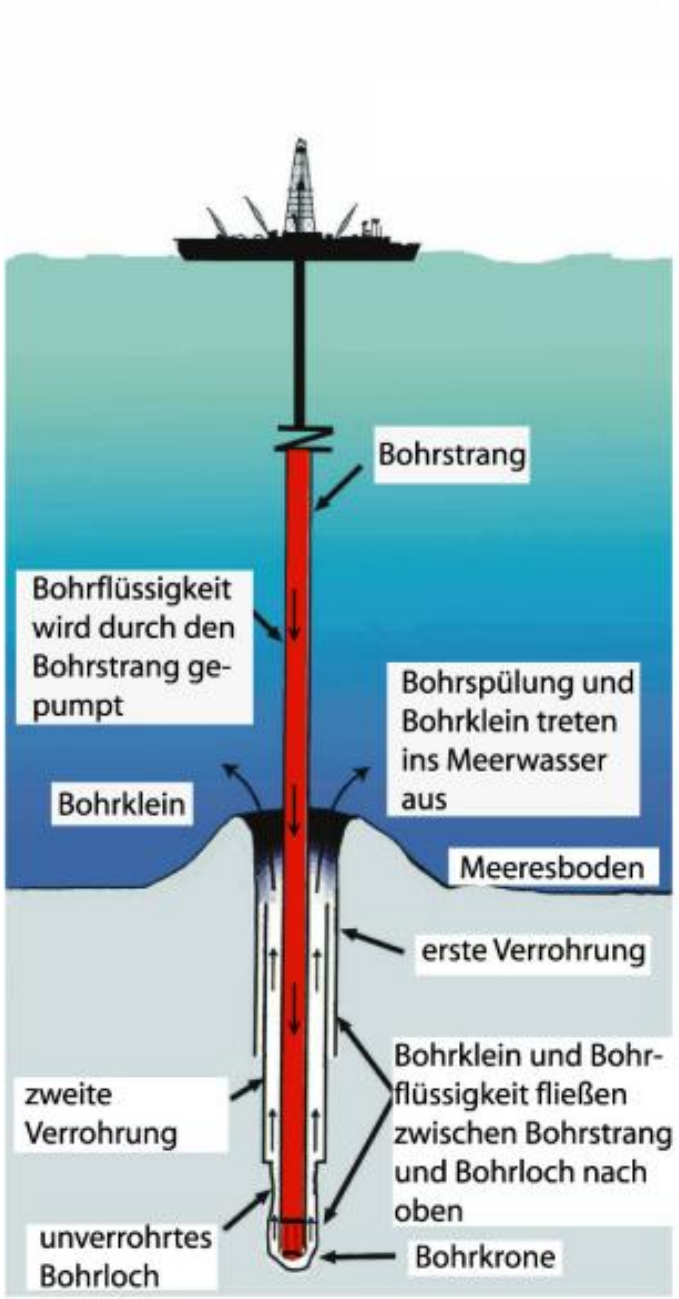


Drilling mud is used to bring heavy cuttings back to the surface. If water were used, these cuttings would tend to sink back down the hole because of the density difference.

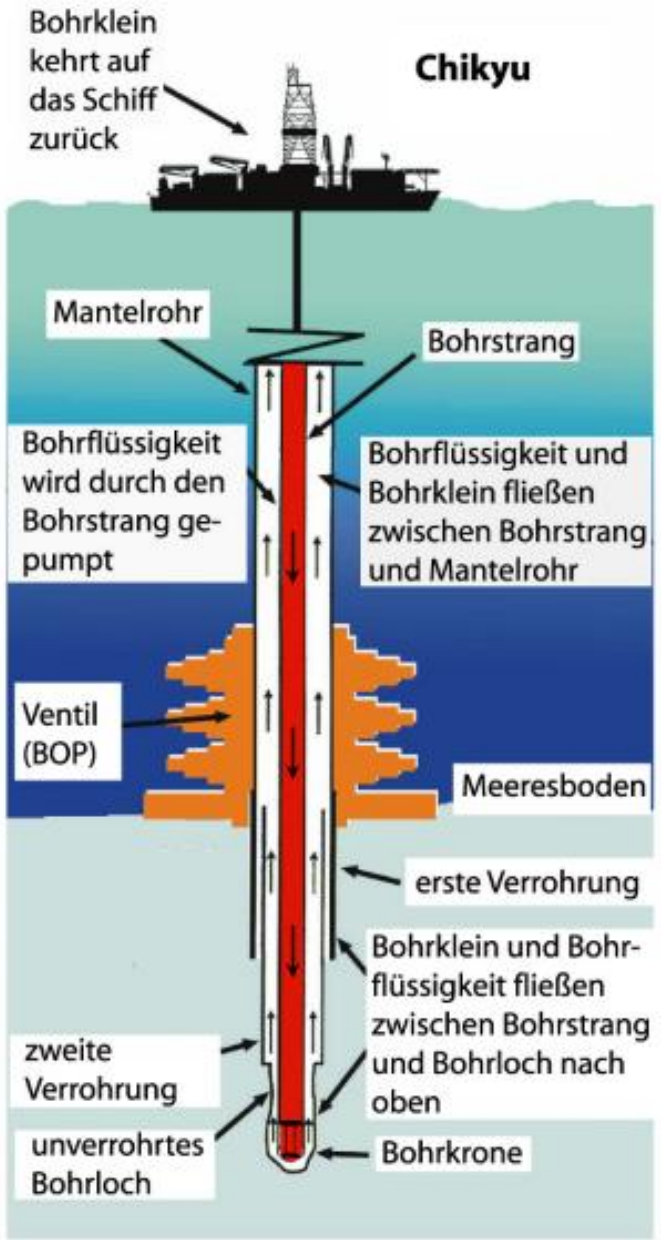
What can be measured in a borehole is limited by the characteristics of the hole. While drilling, holes are CASED with steel pipe to prevent the hole from collapsing in around the drill pipe.

As the hole is deepened, more casing – with smaller diameter is inserted in the hole. The diameter of the outermost casing might be 16”, and the smallest only 5”.

Bohren mit offenem Spülungskreislauf



Bohren mit geschlossenem Spülungskreislauf



Marine drilling allows deeper penetration because mud can be circulated up to the drill ship.

Logging

Logging office

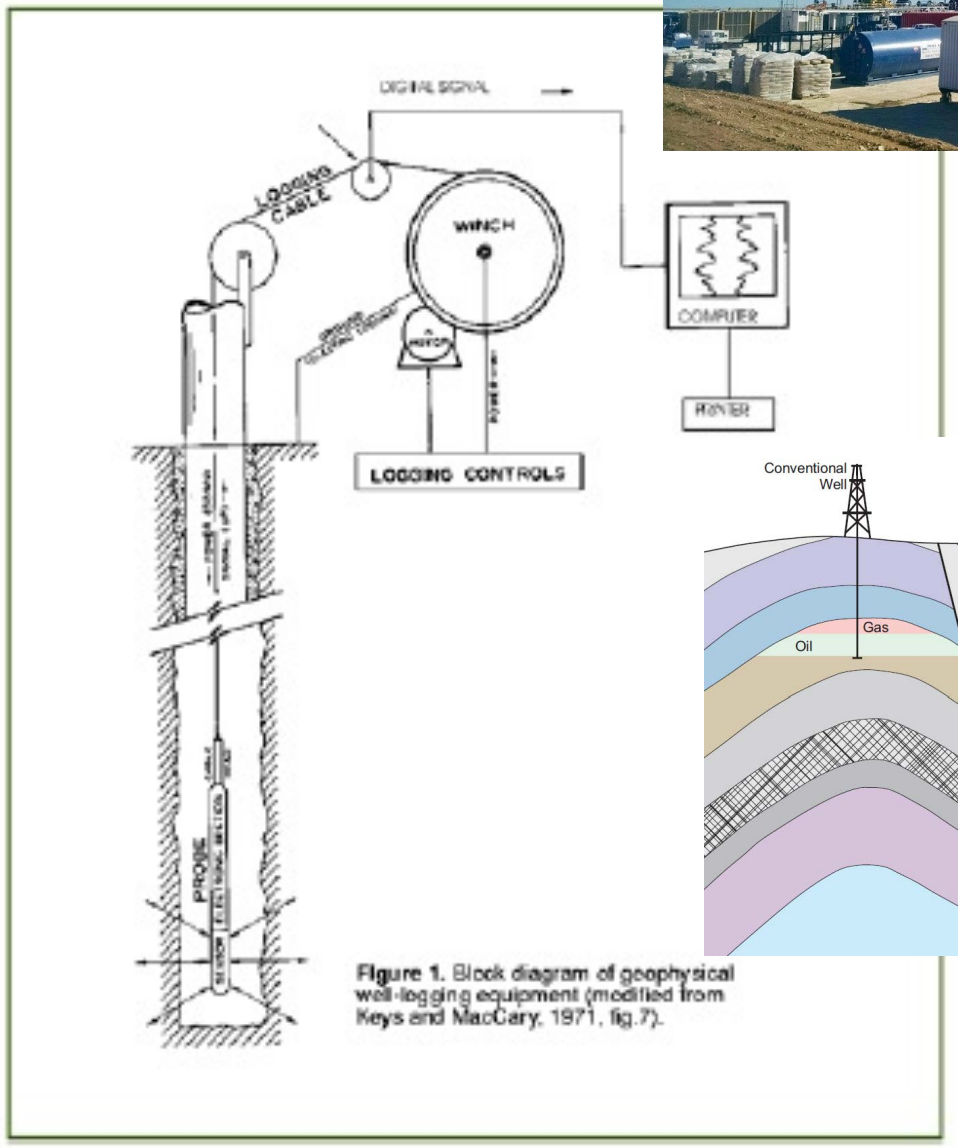
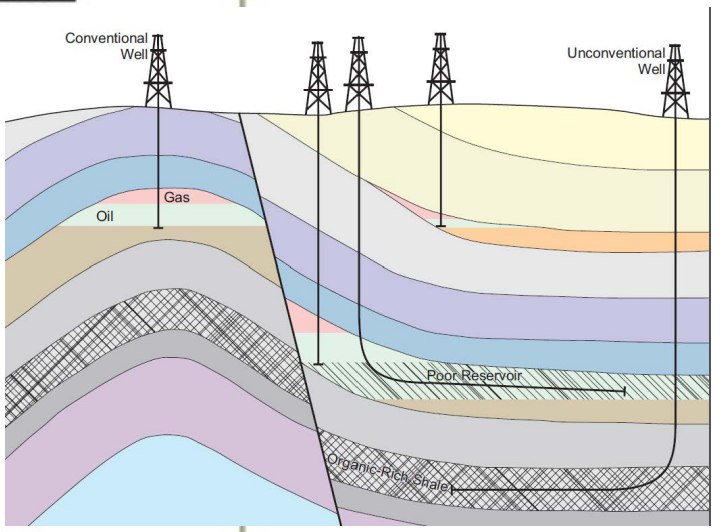
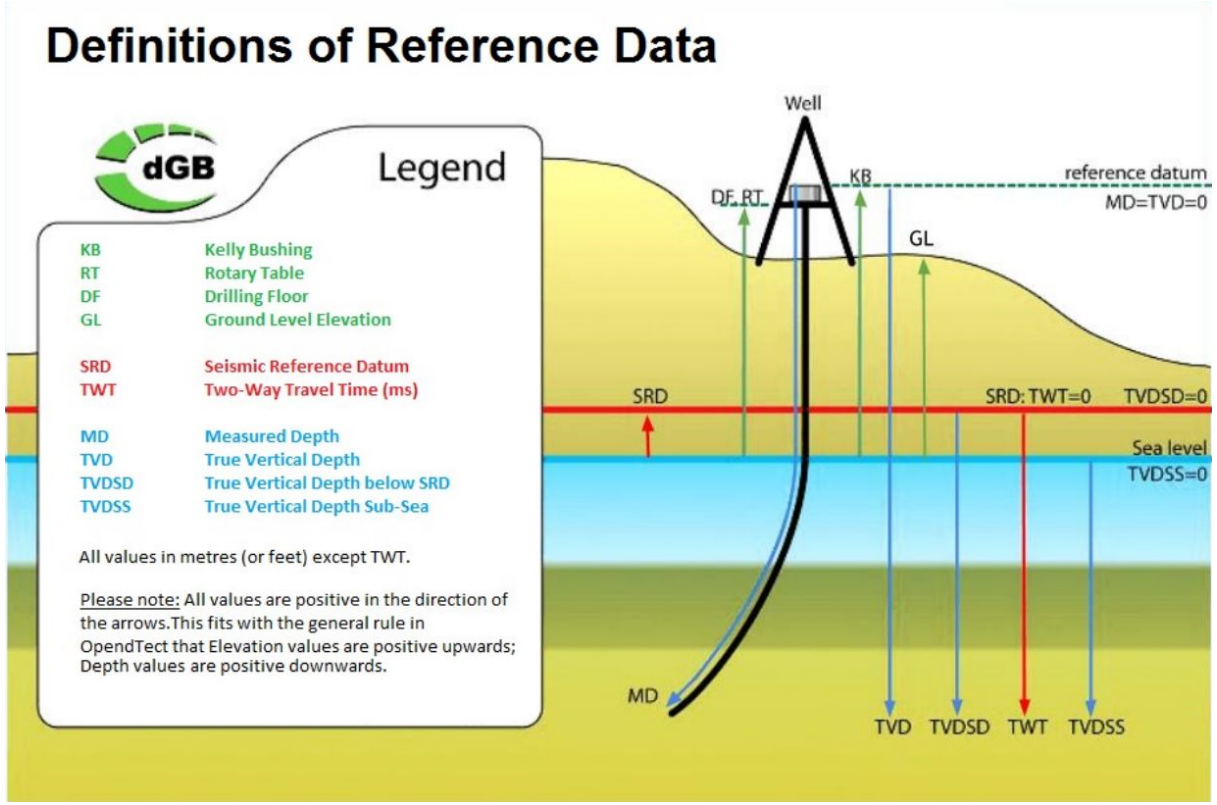


Figure 1. Block diagram of geophysical well-logging equipment (modified from Keys and MacCary, 1971, fig.7).



Header



Company:

Well:

Field:

Rig Name: Kedarnath Country: India

Composite Log (PEX-HRLA-HNGS-SP)

2703.5m - 1799.6m

1:200 & 1:500 MD

Oil and Natural Gas Corporation Ltd.

Rig Name: Kedarnath
Field:
Location:
Well:
Company:

Location:

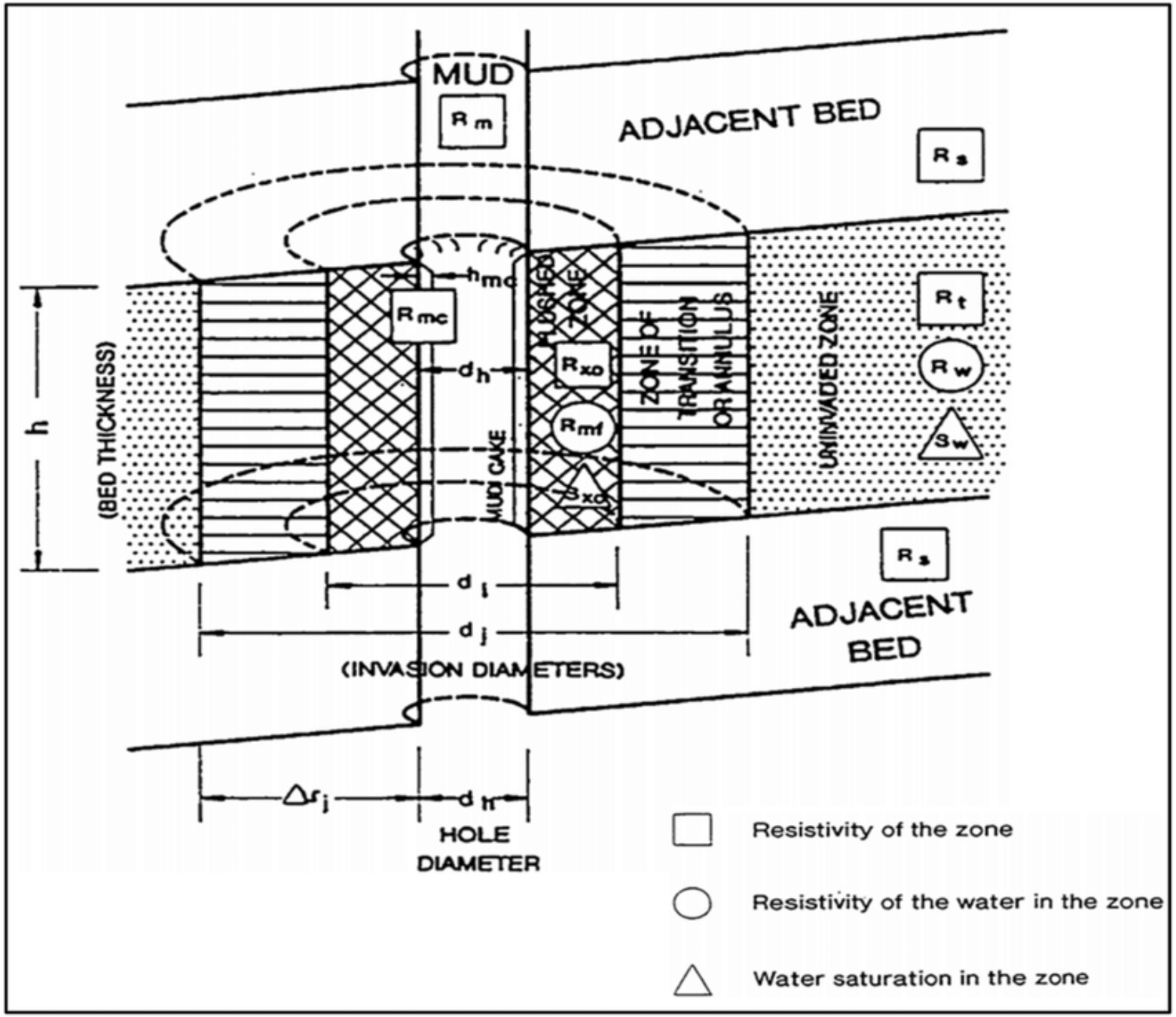
Western Offshore Basin		Elev.: K.B.	30.18 m
Arabian Sea			G.L. -23.99 m
			D.F. 30.18 m
Permanent Datum:	Mean Sea Level	Elev.:	0.00 m
Log Measured From:	Kelly Bushing	30.18 m	above Perm.Datum
Drilling Measured From:	Kelly Bushing		

State:	Max.Hole Deviation	Longitude:	Latitude:
Maharashtra	0 deg	71° 55' 53.922" E	20° 17' 40.663" N

Logging Date		24-Nov-2015				
Run Number		Run 1A				
Depth Driller		2710.00 m				
Schlumberger Depth		2708.50 m				
Bottom Log Interval		2703.50 m				
Top Log Interval		1799.60 m				
Casing Driller Size @ Depth		13.375 in	@	1800.00 m		
Casing Schlumberger		1799.6 m				
Bit Size		12.25 in				
Type Fluid In Hole		KCL Polymer				
MUD Density	Viscosity	11.9 lbm/gal		53 s		
MUD Fluid Loss	PH	3 cm3		9		
MUD Source of Sample		Active Tank				
RM @ Meas Temp		0.06 ohm.m	@	66 degF		
RMF @ Meas Temp		0.03 ohm.m	@	66 degF		
RMC @ Meas Temp		0.13 ohm.m	@	66 degF		
Source RMF	RMC	Pressed		Pressed		
RM @ BHT	RMF @ BHT	0.02 @ 250		0.01 @ 250		
Max Recorded Temperatures		250 degF				
Circulation Stopped	Time	25-Nov-2015		00:00:00		
Logger on Bottom	Time	24-Nov-2015		11:30:00		
Unit Number	Location:	OSU_FM-1812		INOF		
Recorded By		Udyan Mehra				
Witnessed By		Mr K. Maurya				

Most drill holes are not cored. Drillers depend on cuttings brought up with the drilling mud to tell what rock they are in, and on WELL LOGGING.

The pressure at the cutting head is kept high to prevent blow-outs. Water penetrates the formations and can confuse the picture obtained from logging.



Logging

- Three general types of logs:
  - Electrical
    - e.g.
      - Spontaneous Potential
      - Resistivity
  - Nuclear
    - e.g.
      - Gamma Ray
      - Density
      - Neutron
  - Acoustic / Sonic
    - e.g.
      - Transit time

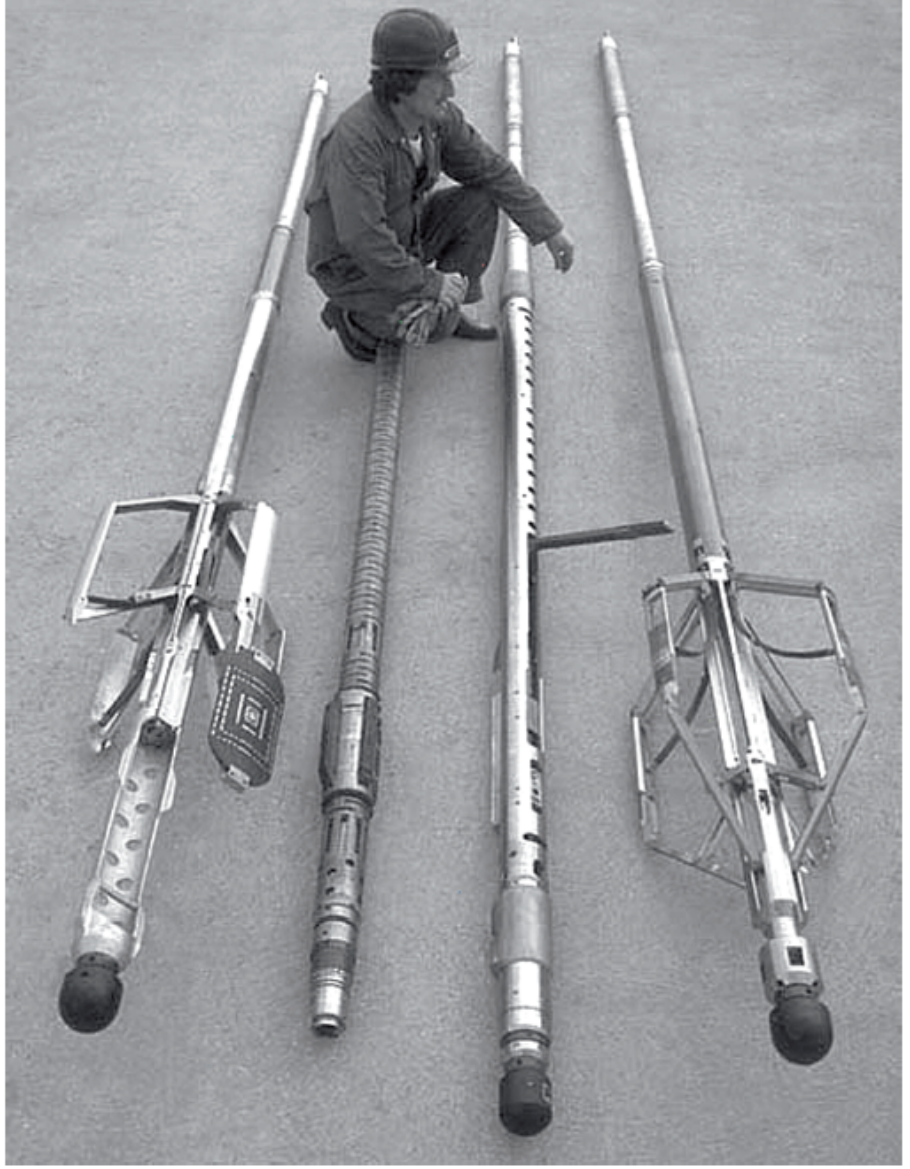


Fig. 1.2 Examples of four logging tools. The dipmeter, on the left, has sensors on four actuated arms, which are shown in their fully extended position. Attached to the bottom of one of its four arms is an additional electrode array embedded in a rubber "pad." It is followed by a sonic logging tool, characterized by a slotted housing, and then a density device with its hydraulically activated back-up arm fully extended. The tool on the extreme right is another version of a dipmeter with multiple electrodes on each pad. Courtesy of Schlumberger.

Down-hole logging methods

In all wireline methods, a string of probes is lowered down into the well. Different properties are measured by the probe and plotted as a function of depth. Logging is usually done as the probe is coming back up the well. Probes are stacked together in strings to obtain as much information in as little time as possible. A string might be 30 m long.

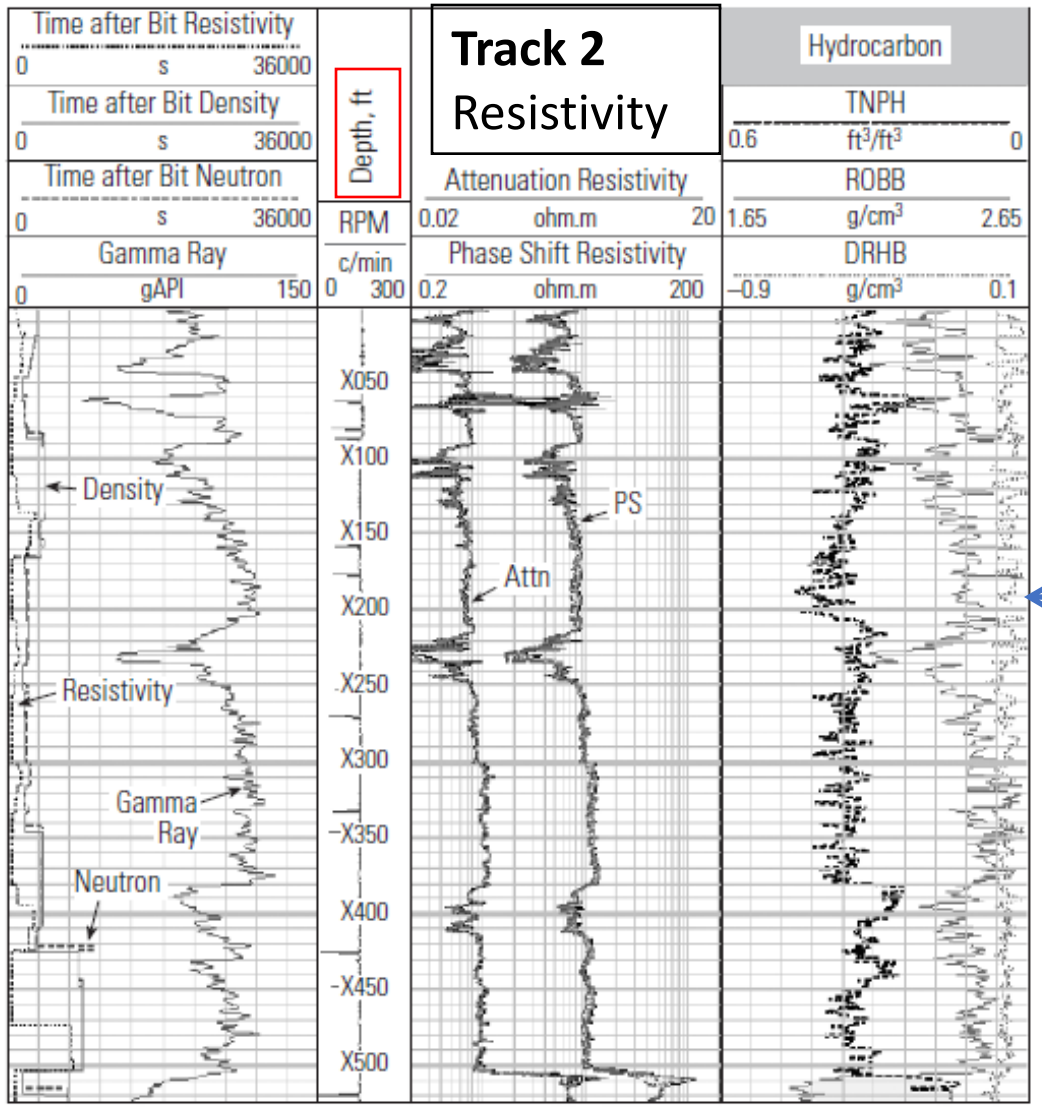
Geophysics in **well logging:** **COMMON TOOLS**

tool	method	uses
seismic (sonic) borehole televiewer	refraction reflection	very high resolution velocities vs. depth, porosity estimates, shear modulus, fracture porosity high resolution hole characteristics
spontaneous potential (SP)	measures natural voltages	permeability - good differentiation between shales (highly conductive) and other rocks
resistivity (laterolog)	electrical	formation resistivity, changes in lithology
induction	induced electrical	resistivity in dry holes or high resistivity formations
density	gamma ray scattering	apparent density of formations
porosity	neutron energy changes by hydrogen	porosity of formation
Natural gamma	natural radiation	mineralogy
caliper		hole diameter

Logging

- Rock properties that affect logging measurements:
  - Porosity
  - Lithology
  - Mineralogy
  - Permeability
  - Water Saturation
  - Resistivity

Tracks



Track 1

Bit size
Caliper
SGR
SP

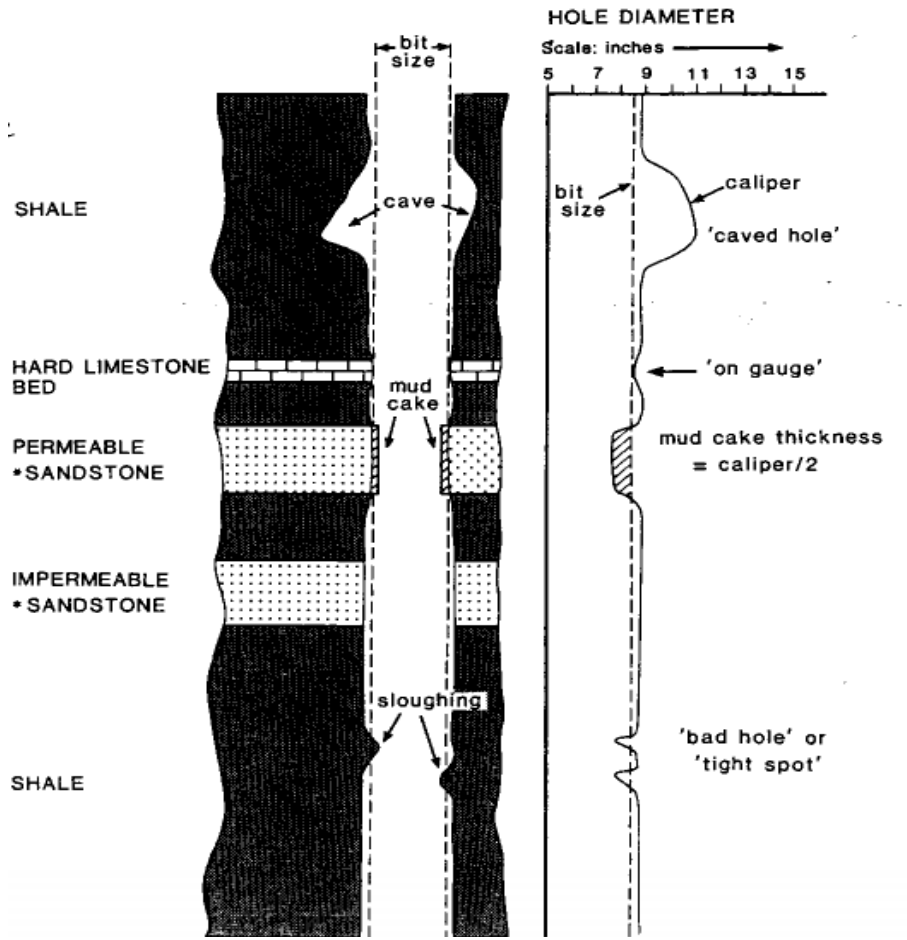
Track 3 (Porosity)

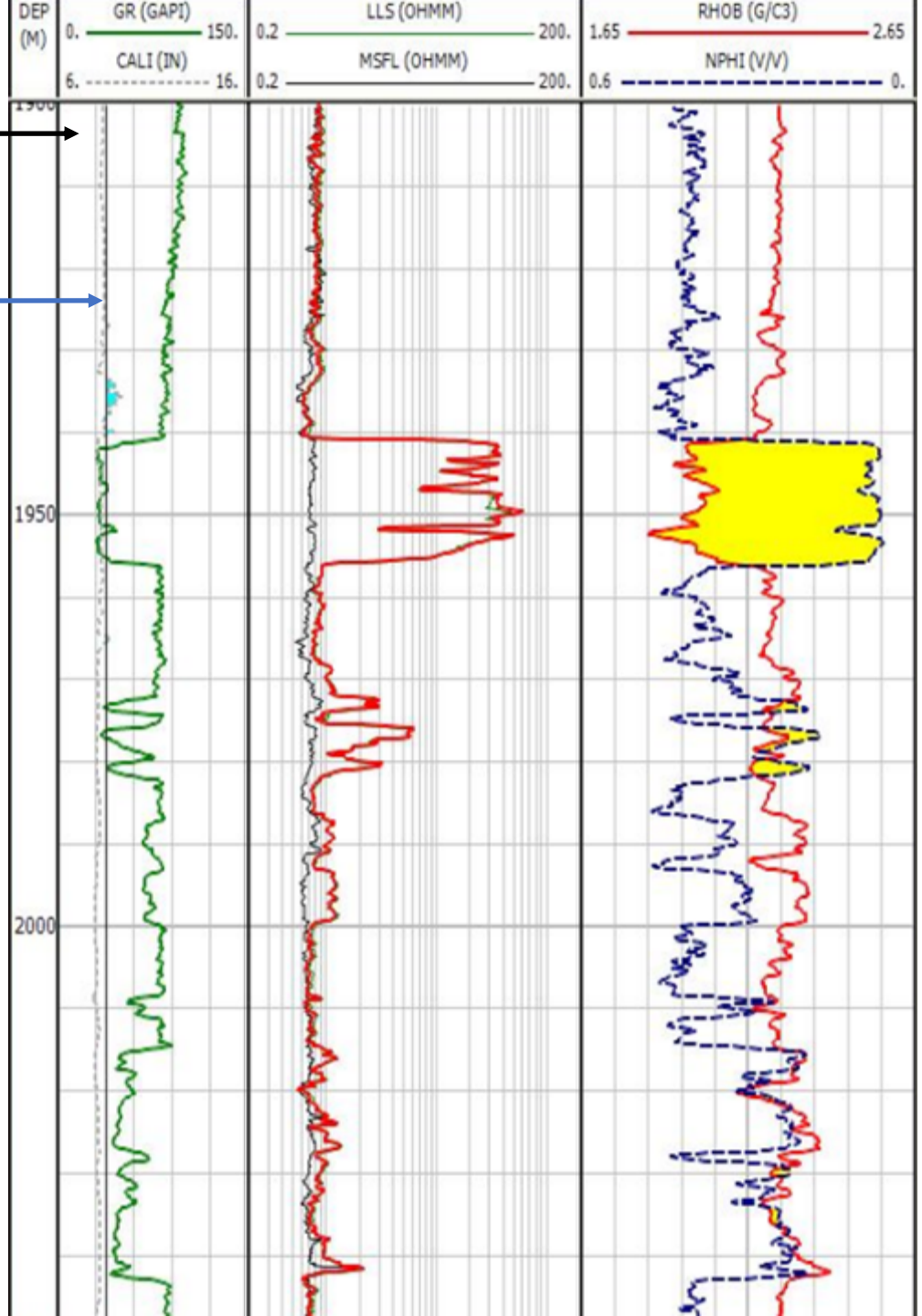
Sonic
Density
Neutron

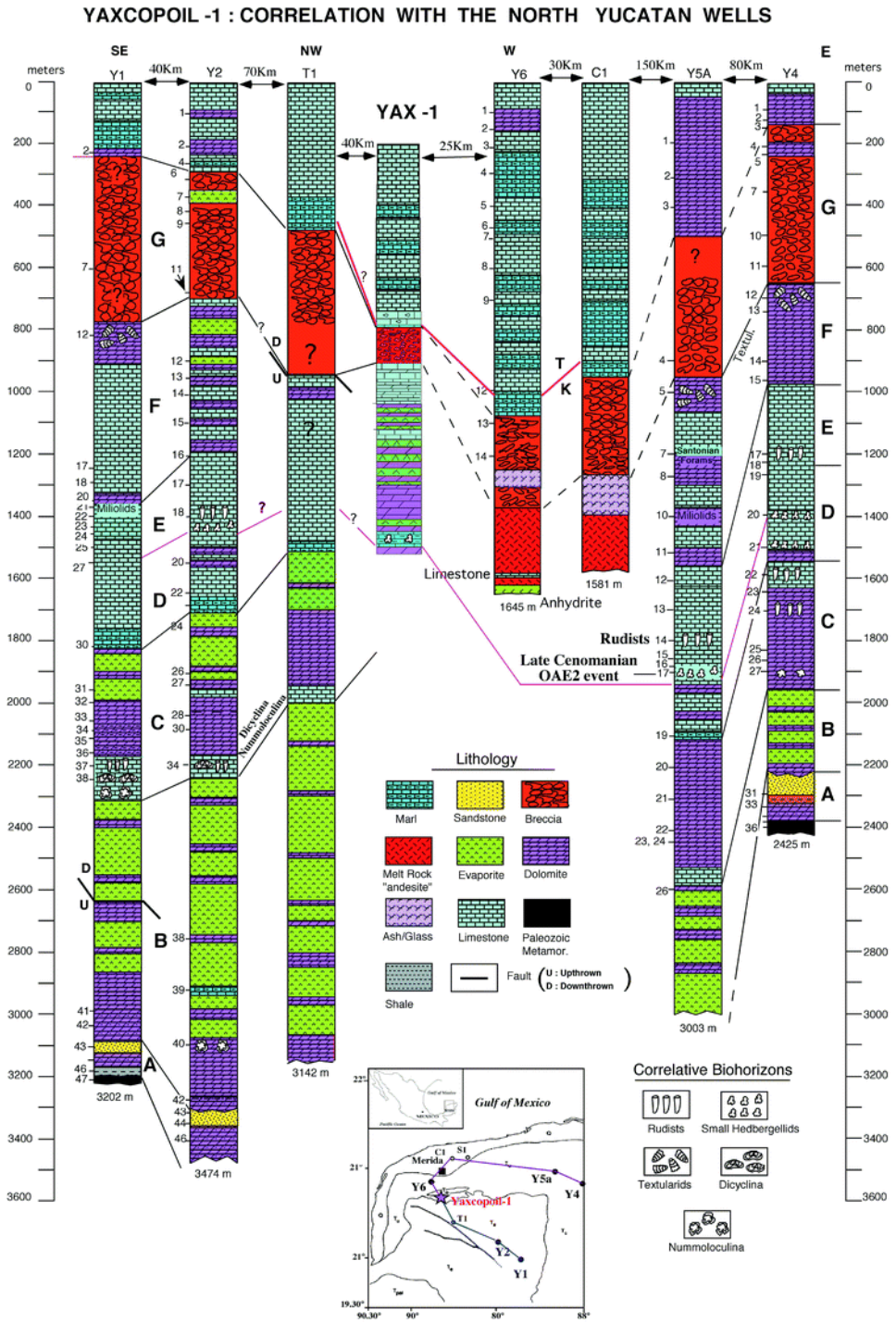
Fig. 2.17 An example of an LWD log in a horizontal well. In track 1 is the familiar GR along with three curves indicating the time delay between drilling and the three types of measurements made; the tool rotation rate appears in the depth track. Track 2 contains two types of resistivity measurements, each with multiple depths of investigation that overlay in this example. The third track contains the LWD versions of the neutron measurement (TNPH), the density measurement (ROBB), and the density correction (DRHB).

Basic Log examples

Calliper log







Logs from nearby drill holes can be correlated to identify variations in structures and lithologies. In the oil industry, they provide data on how quickly a reservoir is being depleted and how quickly water is encroaching on producing regions.

The logs to the left (red areas) show the location of the Cretaceous impact deposits in the Yucatan wells.

The logs on the next slide show an area of producing wells.

Basic Steps for Quick Look Evaluation

- ROCK
  - Reservoir
    - Hydrocarbon bearing
      - Gas bearing
      - Oil bearing
    - Water bearing
  - Non-Reservoir

Petrophysical Interpretation

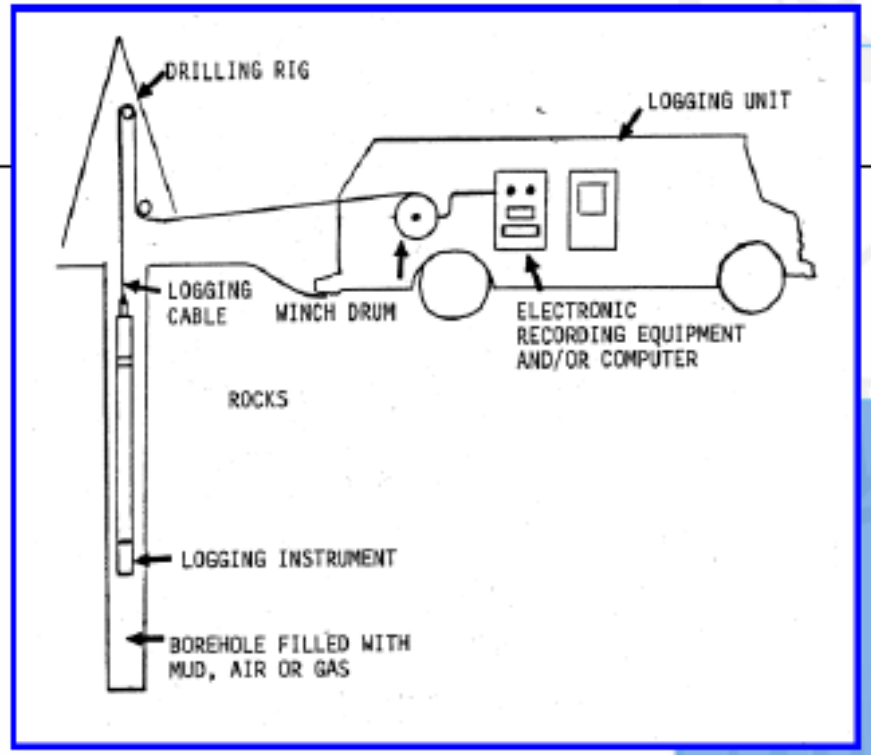
Qualitative assessment

Assessment of reservoir properties,
fluid type form log pattern.

Quantitative assessment

Numerical estimation of reservoir properties viz. % of oil, water etc.

Importance of Geophysical Well Logging



- Zone correlation
- Structure and Isopach mapping
- Defining physical rock characteristics:
  - Lithology
  - Porosity
  - Pore geometry
  - Permeability
- Identification of productive zones
- Determination of depth and thickness of zones
- Distinguish between oil, gas and water
- Estimation of hydrocarbon reserves
- Determination of facies relationships

Advantages of Logging

Provides objective and quantitative data for existing wells.
Requires only one or two people.
Test can be repeated.
Non-destructive.
Fast and economical.
Much cheaper than coring.

Disadvantages of Logging Methods

Equipment is expensive.
Will not define all important contacts.
Requires trained people for data collection and interpretation.

Entire Syllabus, but Lectures to stress upon for End Sem:

Lecture 2= Universe (Sl 9-11; sl 19)
Lecture 3=Earth&Moon (sl 22-35)
Lectures 5 =Plates (sl 2-4) and Polar wandering (sl 18-20; sl 26), Plates (sl 33 and 39)
Lecture 6 = Plates (sl 5-19; sl 22-35)
Lecture 8a =Magma and igneous (sl 3-23)
Lecture 8b=Volcanoes (sl 21, 25, 34-36)
Lectures 9= sedimentary (sl 7-39)
Lecture 10= metamorphic (sl 6-14; 24-25; 27-29)
Lecture 11-12= geologic time(sl 22, 28-33)
Lecture 13b-15= structures (all), earthquakes (all)
All after Midsem

Exam details:
Marks: 40 (15 objectives/MCQ+25 conceptual)
15 marks MCQ+conceptual from before midsem and rest of the marks from after midsem
No negative marks! Goodluck!