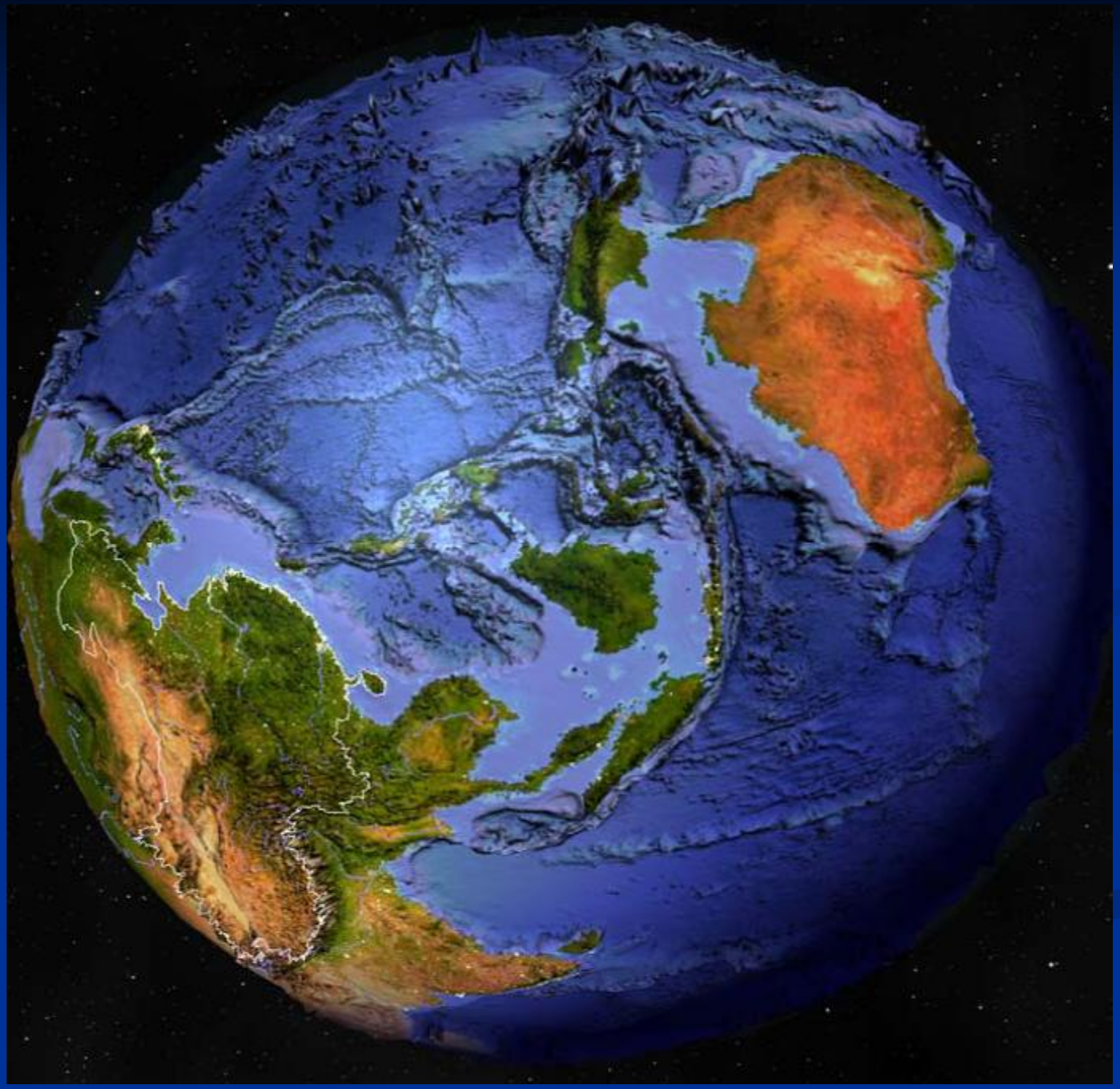
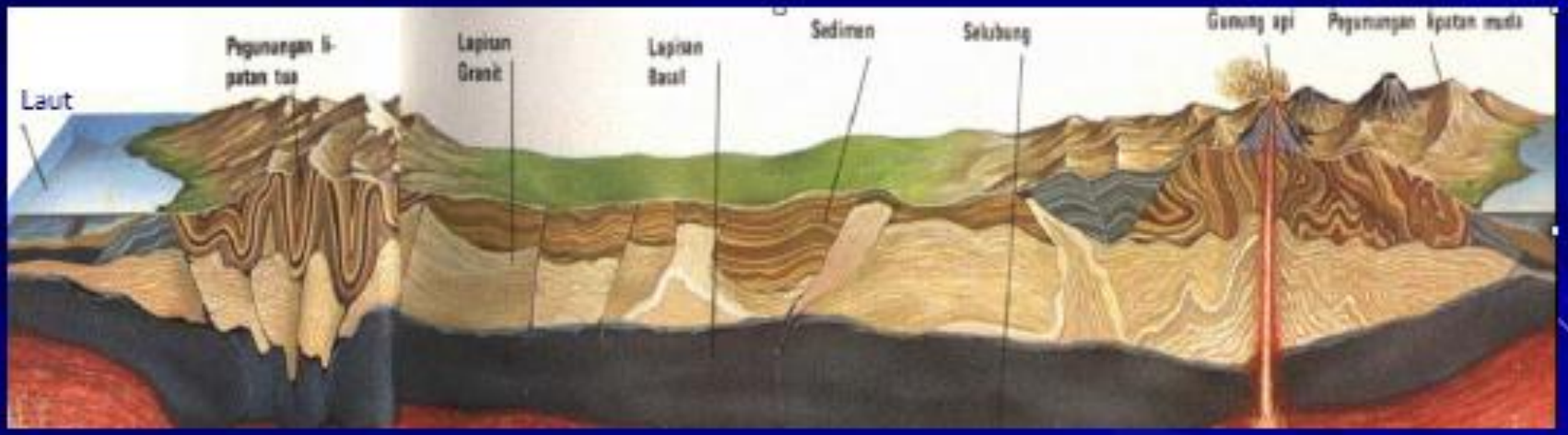
PENGANTAR SEDIMENTOLOGI & STRATIGRAFI



GAMBARAN PENAMPANG KERAK BUMI



New Venture 2001

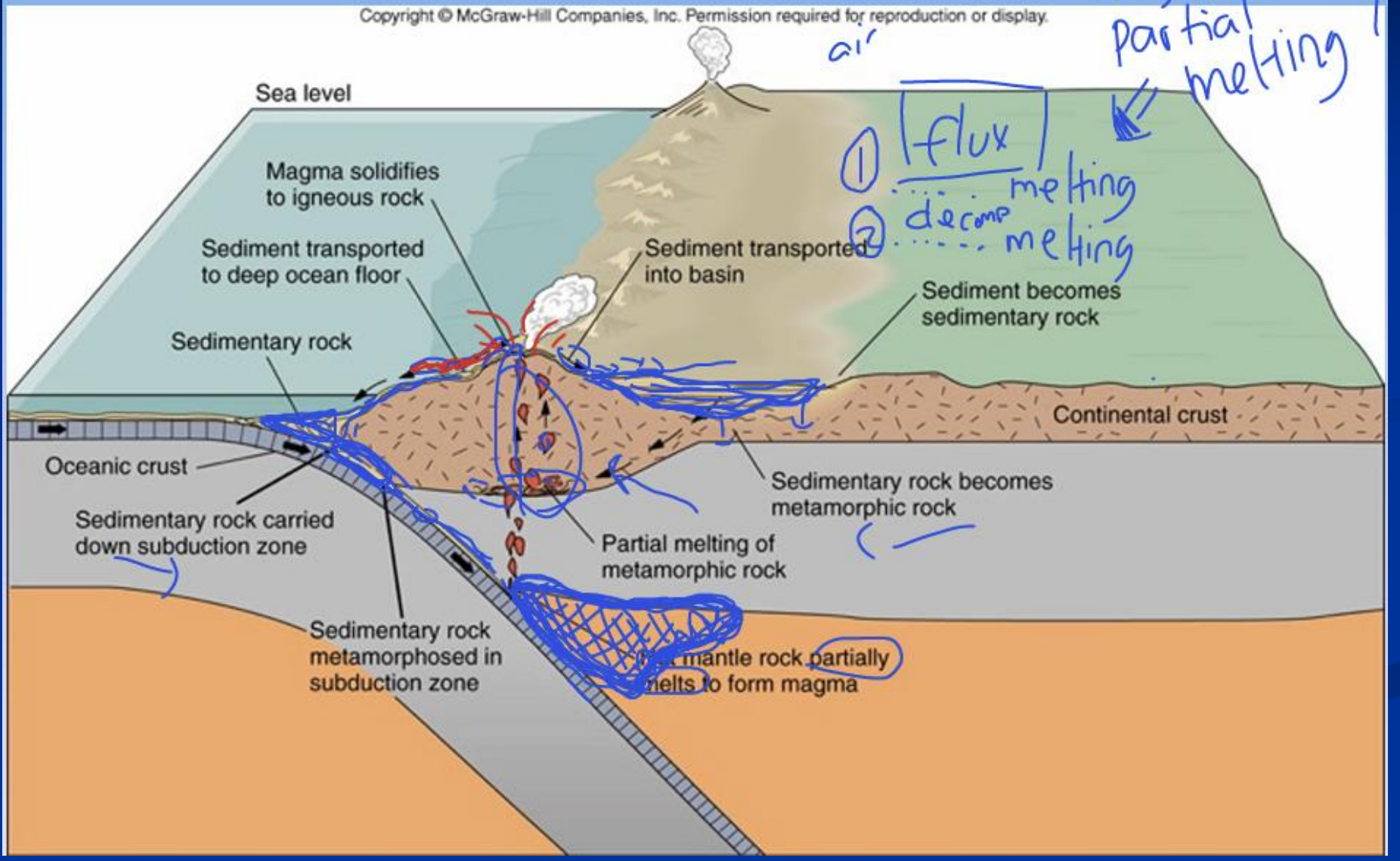
Sedimentary Petrography

is the description and classification of sedimentary rocks. The word petrography suggests the study is done using the petrographic microscope.

Sedimentary Petrology

merupakan ilmu tentang komposisi dan pembentukan batuan sedimen

Plate Tectonics and the Rock Cycle

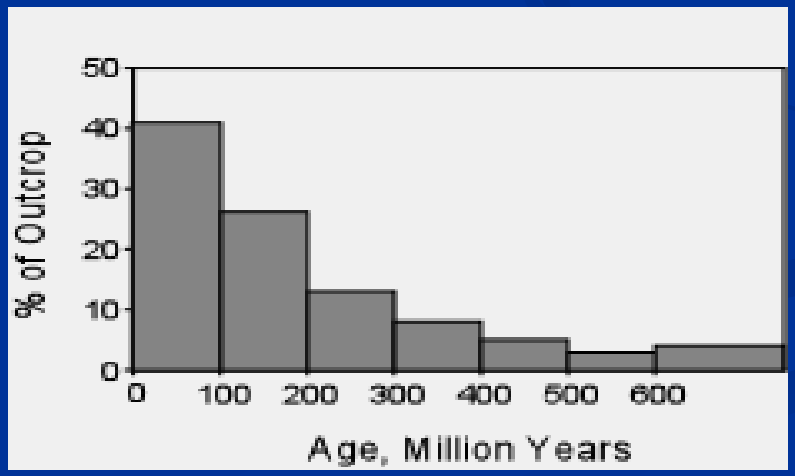


Keterdapatan batuan sedimen

- Ketebalan rata-rata 1.800 m di daratan; beberapa tempat mencapai 20.000 m
  (pantai Lousiana & Teluk Texas), di beberapa tempat lainnya tidak ada sedimen.
  - menempati wilayah sekitar 66 % di daratan/kontinen

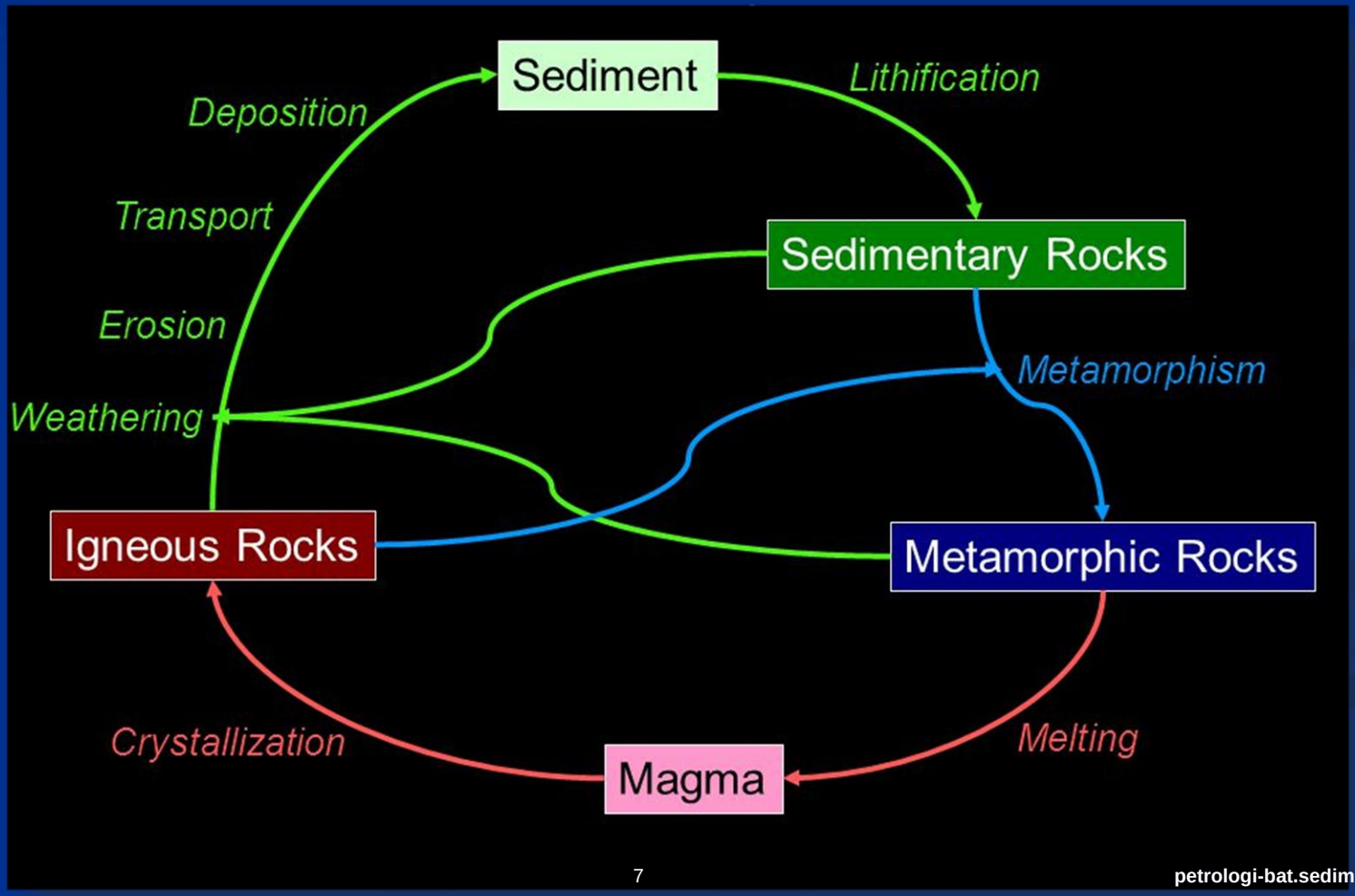
- Singkapan batuan sedimen berumur tua lebih sedikit dibandingkan dengan
  singkapan sedimen berumur lebih muda.

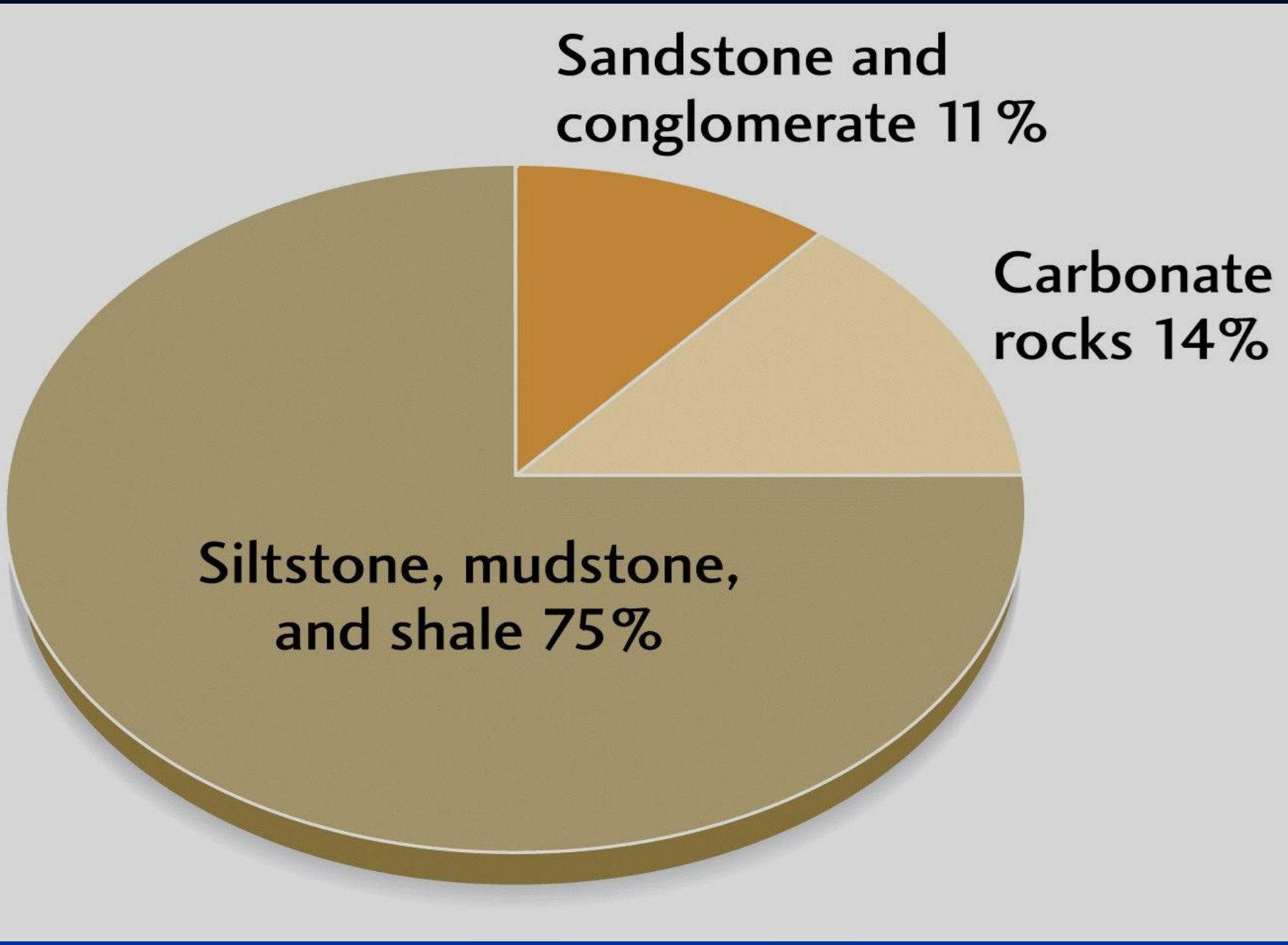
- Data : > 40 % batuan sedimen yang tersingkap, berumur lebih muda dari Kapur.



Batuan sedimen

Batuan sedimen terdiri dari material hasil rombakan / pelapukan batuan sebelumnya




Sandstone and conglomerate 11%
Carbonate rocks 14%
Siltstone, mudstone, and shale 75%

Definisi Batuan

- Batuan merupakan aggregat padat yang terdiri dari mineral atau mineraloid. Kebanyakan batuan terdiri atas beberapa jenis mineral (mineral, gelas, ubahan mineral organik, dan kombinasi dari komponen-komponen tersebut) *(Ernest G. Ehlers & Harvey Blatt, 1980).*

- Batuan juga didefinisikan sebagai kumpulan mineral alamiah yang terkristalkan oleh 'proses pembentukan batuan) *(Huckenholz, 1982).*

Batuan Sedimen

Dua kategori utama batuan sedimen:

1. Batuan klastika (~ detrital)
2. Kimia (biogenic, inorganic)

Some generalities :

1. Shale 65%, sandstone 15-20%, limestone 10-15%, others <5%
2. Cover ~75% of land area on continents (including continental shelf)
3. Average ~2 km thick on continents
4. < 5% crustal volume
5. Oceanic sediments: average thickness ~0.5 km

Kenapa batuan sedimen ?

- Minyak bumi, gas bumi, dan endapan batubara, serta endapan mineral terdapat pada batuan sedimen
- Merupakan bahan penting untuk material bangunan

- Batuan sedimen meliputi 75% dari presentasi batuan di permukaan bumi

How do sedimentary rocks form ?

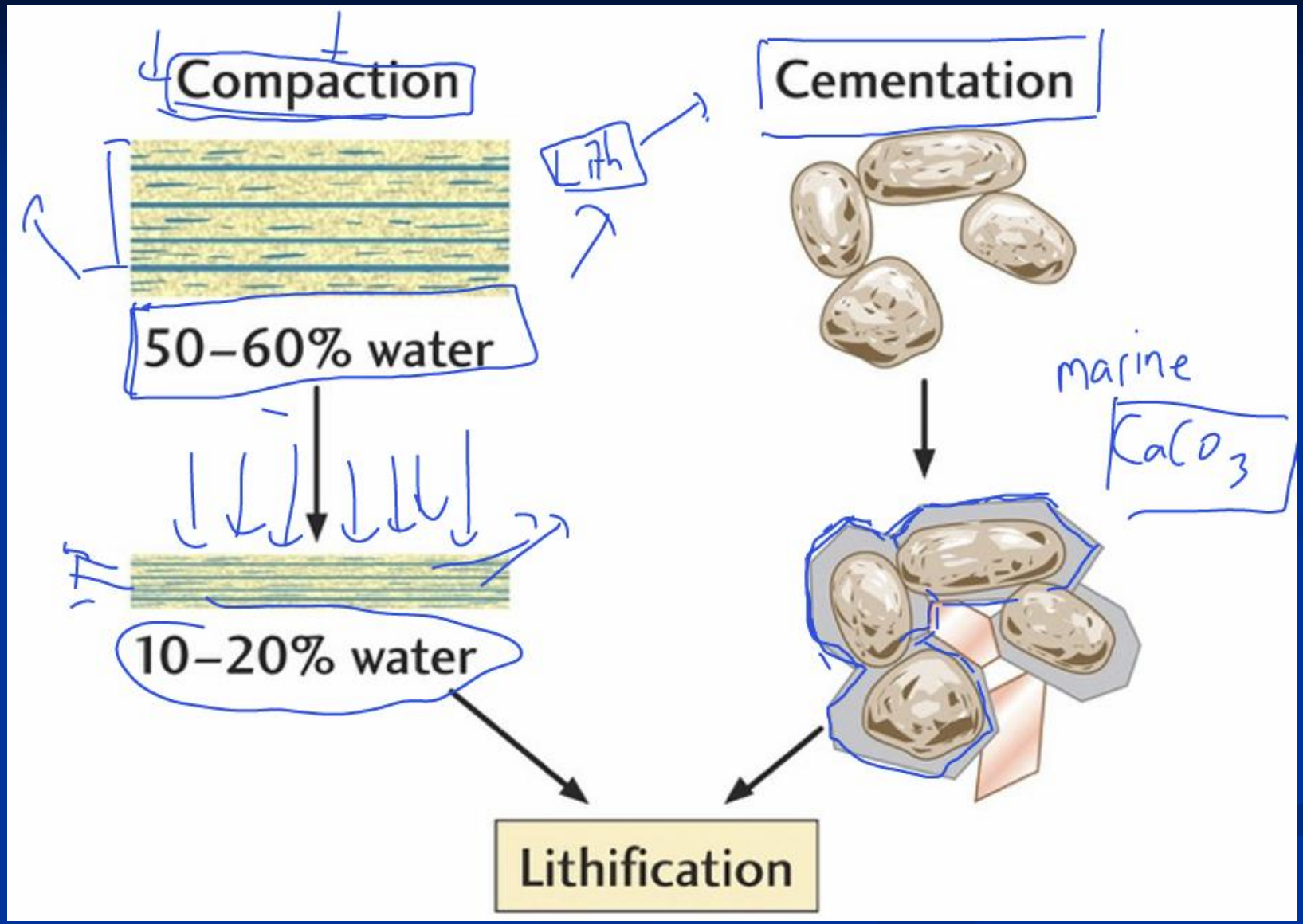
- Erosion
- Transportation
- Pengendapan (deposition)
  - Rivers, Lakes, Deltas, Fan, etc
- Presipitasi/precipitation
- Marine/ groundwater processes
  - Sea, Lakes, Cave systems, etc

Sedimentary rocks are the end product of a series of processes:

- **W**eathering
- **E**rosion
- **T**ransportation: (via water, air, ice, gravity) as solid particles or in solution
- **D**eposition: (wide variety of depositional environments)
- **L**ithification: process of turning loose sediment into solid rock by compaction and cementation during burial
- **D**iagenesis: physical, chemical and biological changes due to burial and modest heating (up to ~150°C)

Constituents of sedimentary rocks

- Clastic rocks: Clay minerals > Quartz > Feldspar (K-fsp > plag) + a few % super-stable heavy minerals (zircon, tourmaline, rutile)


Compaction
Cementation
50–60% water
marine
$CaCO_3$
10–20% water
Lithification

Three types of Sedimentary Rocks

- Clastic
- Biochemical
- Chemical


Batubara Bituminus.JPG


Batubara Lignite.JPG


Batupasir .JPG


Batupasir Limonitic.JPG


Batupasir Mika.JPG


Batupasir Milt-seed.JPG


Breksi .JPG


Breksi gamping.JPG


Bt Lempung Boulder .JPG


Chert.JPG


flinnt.JPG


Gritstone Felspatic.JPG


Gritstone Kuarsa.JPG


Jet rough.JPG


Jet.JPG


Konglomerat .JPG


Konglomerat Kuarsa.JPG


Konglomerat


Marl Hijau.JPG


Mudstone Lumpur.JPG


Ortokuarsite Grey.JPG

Batuan sedimen klastik / silisiklastik

Sedimen hasil rombakan --→ di endapkan --→ diagenesis

Batupasir, konglomerat, serpih dll

2. Batuan sedimen non klastik (kimiawi)

Material yang larut -→ presipitasi, evaporasi -→ batuan sedimen kimiawi

Batugamping kristalin, rijang, halit

3. Batuan sedimen organik

Akumulasi organik

Batubara, batugamping,dolomit

TYPES OF SEDIMENTARY ROCKS

Clastic rocks

- Sandstones
- Conglomerates
- Breccia
- Shale/mudstones

Chemical & Organic rocks

Evaporitic rocks

These rocks are formed due to evaporation of saline water (sea water)
eg. Gypsum, Halit (rock salt)

Carbonate rocks

Form basically from $CaCO_3$ – both by chemical leaching and by organic source (biochemical)
eg. Limestone; dolomite

Organic rocks

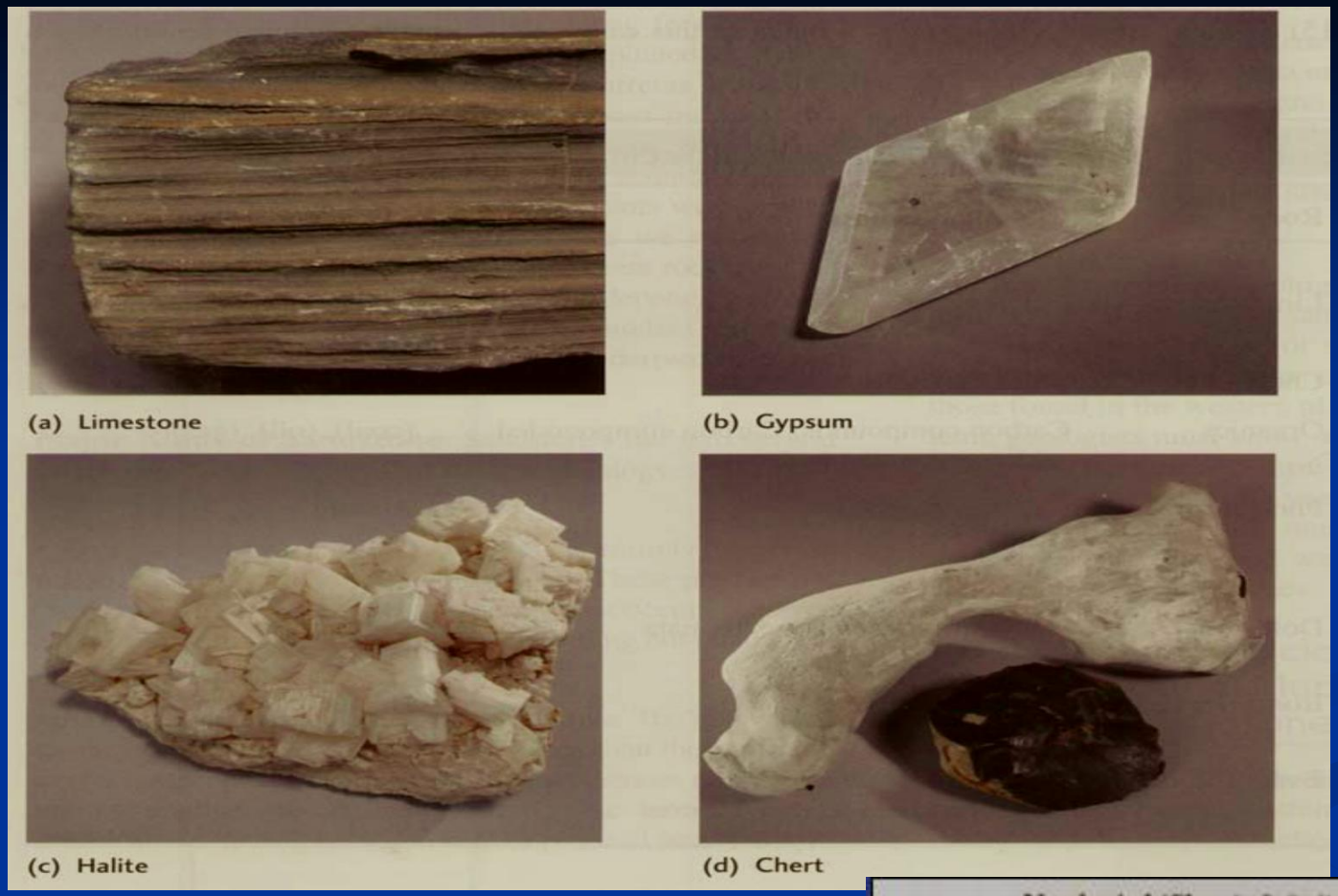
Form due to decomposition of organic remains under temperature and pressure eg. Coal/Lignite etc.


Batupasir


Batupasir


Breksi


Konglomerat



(a) Limestone

(b) Gypsum

(c) Halite

(d) Chert

Batuan sedimen kimiawi

Nondetrital (Chemical) Sedimentary Rocks

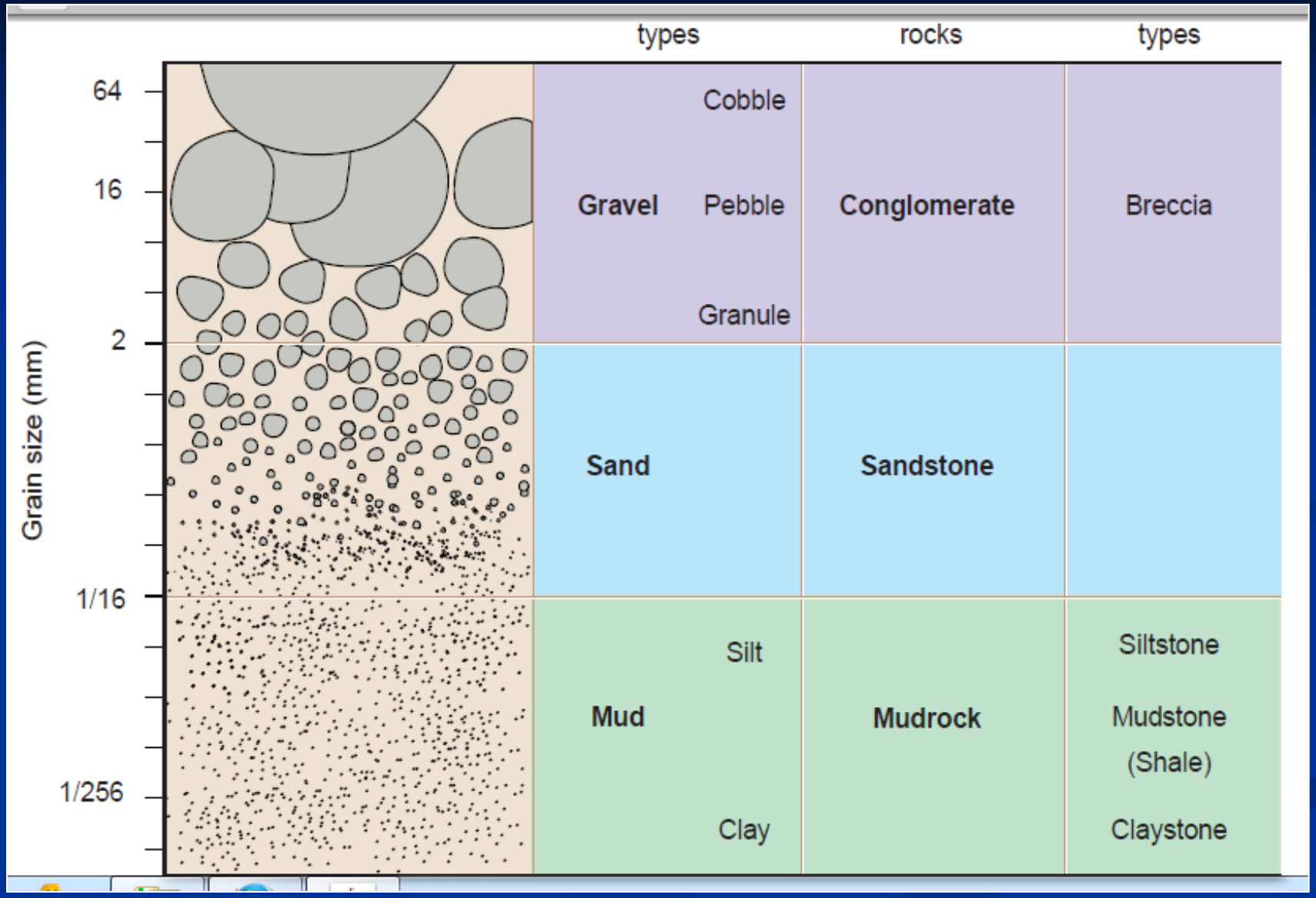
Composition	Rock Name
megascopic fossils	Fossiliferous Limestone
microcrystalline calcite	Micrite Limestone
sand-sized calcite spheres	Oolitic Limestone
dolomite	Dolostone
halite	Rock Salt
gypsum	Rock Gypsum
microcrystalline quartz	Chert

TEKSTUR BATUAN SEDIMEN

- Ukuran butir : skala Wentworth
- Bentuk butiran /fragmen : menyudut, membulat, menyudut tanggung, membulat tanggung.
- Kemas / fabric : long, point, concavo – convex contact
- Sortasi : baik, buruk, sedang/menengah
- Porositas : baik, sedang, buruk atau dinyatakan dalam persen
- Permeabilitas : baik, buruk, sedang

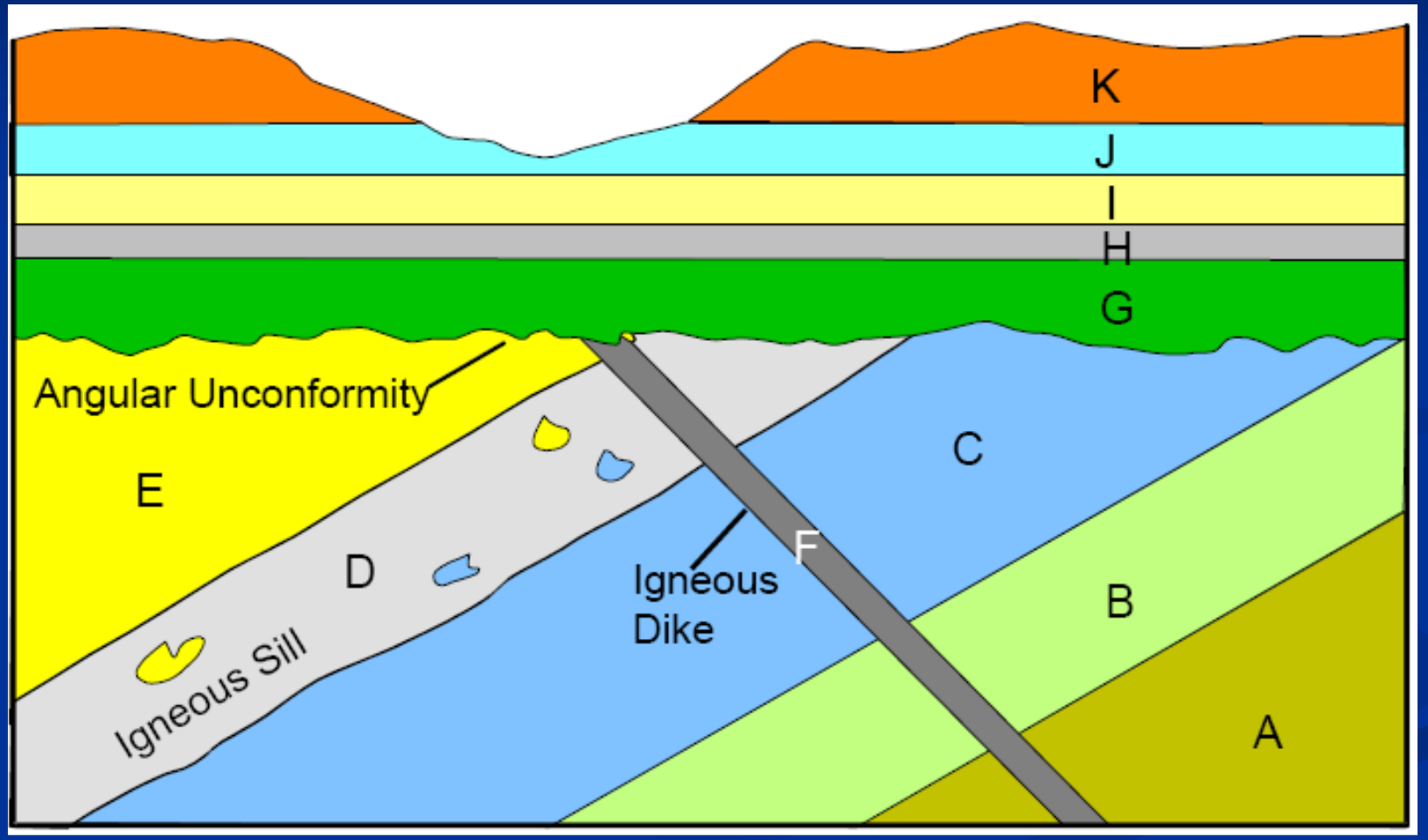
KLASIFIKASI WENTWORTH

mm	phi	Name	
256	−8	Boulders	Gravel Conglomerate
128	−7		
64	−6	Cobbles	
32	−5		
16	−4		
8	−3	Pebbles	
4	−2		
2	−1	Granules	
1	0	Very coarse sand	Sand Sandstone
0.5	1	Coarse sand	
0.25	2	Medium sand	
0.125	3	Fine sand	
0.063	4	Very fine sand	
0.031	5	Coarse silt	Mud Mudrock
0.0156	6	Medium silt	
0.0078	7	Fine silt	
0.0039	8	Very fine silt	
		Clay	

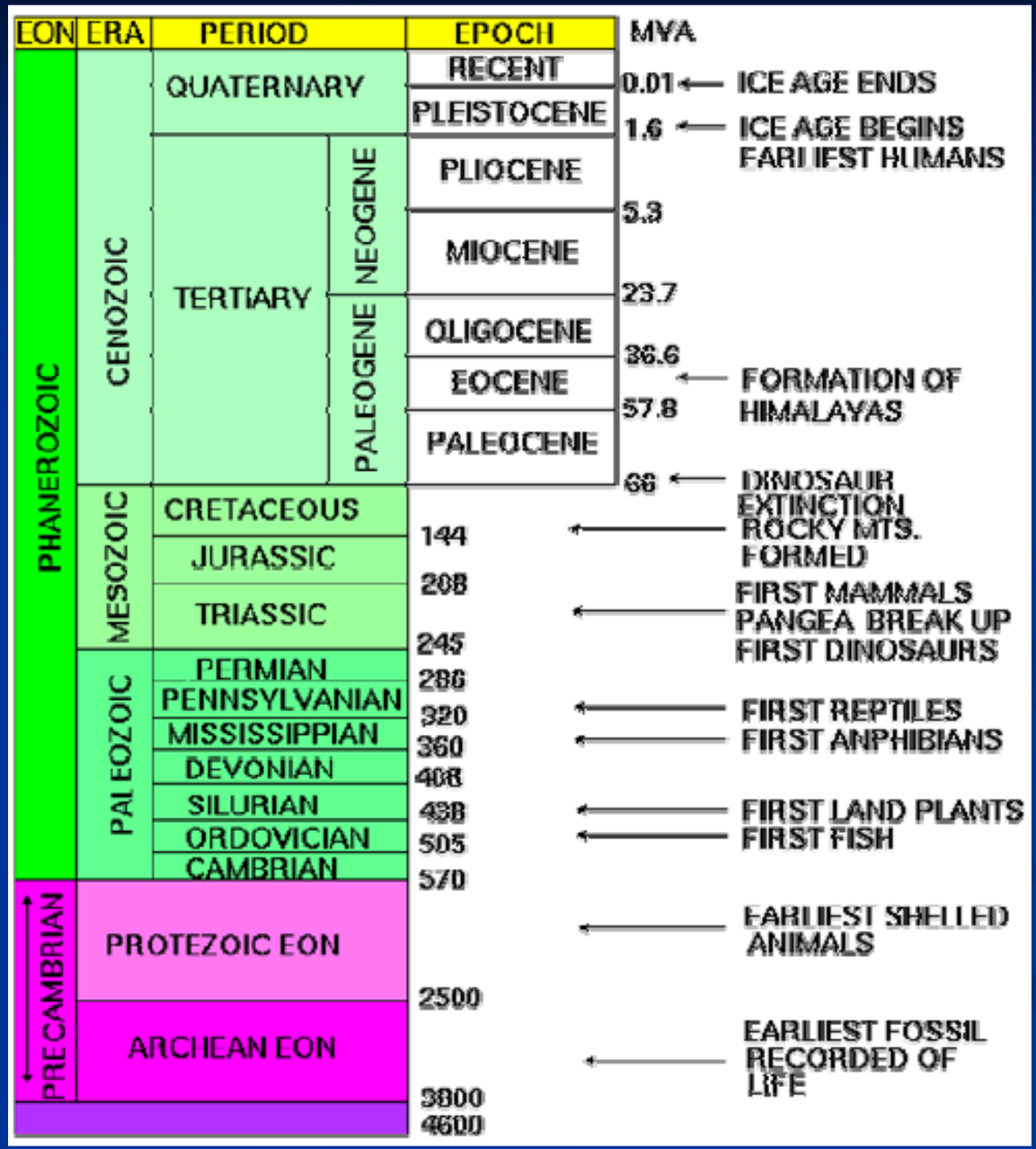

types
rocks
types
64
16
2
1/16
1/256
Grain size (mm)
Cobble
Gravel
Pebble
Granule
Conglomerate
Breccia
Sand
Sandstone
Silt
Mud
Mudrock
Siltstone
Mudstone
(Shale)
Clay
Claystone

Diameter (mm)	Nama butiran	Nama batuan
> 256	Bongkah	
64 - 256	Berangkal	Konglomerat (membulat)
4 – 64	Kerakal	Breksi (menyudut)
2 – 4	Kerikil	
1/64 – 2mm	Pasir	Batupasir
1/256	Lanau	Batulanau
< 1/256	Lempung	Batulempung

Cross-Cutting Relationship



Geologic Time Chart

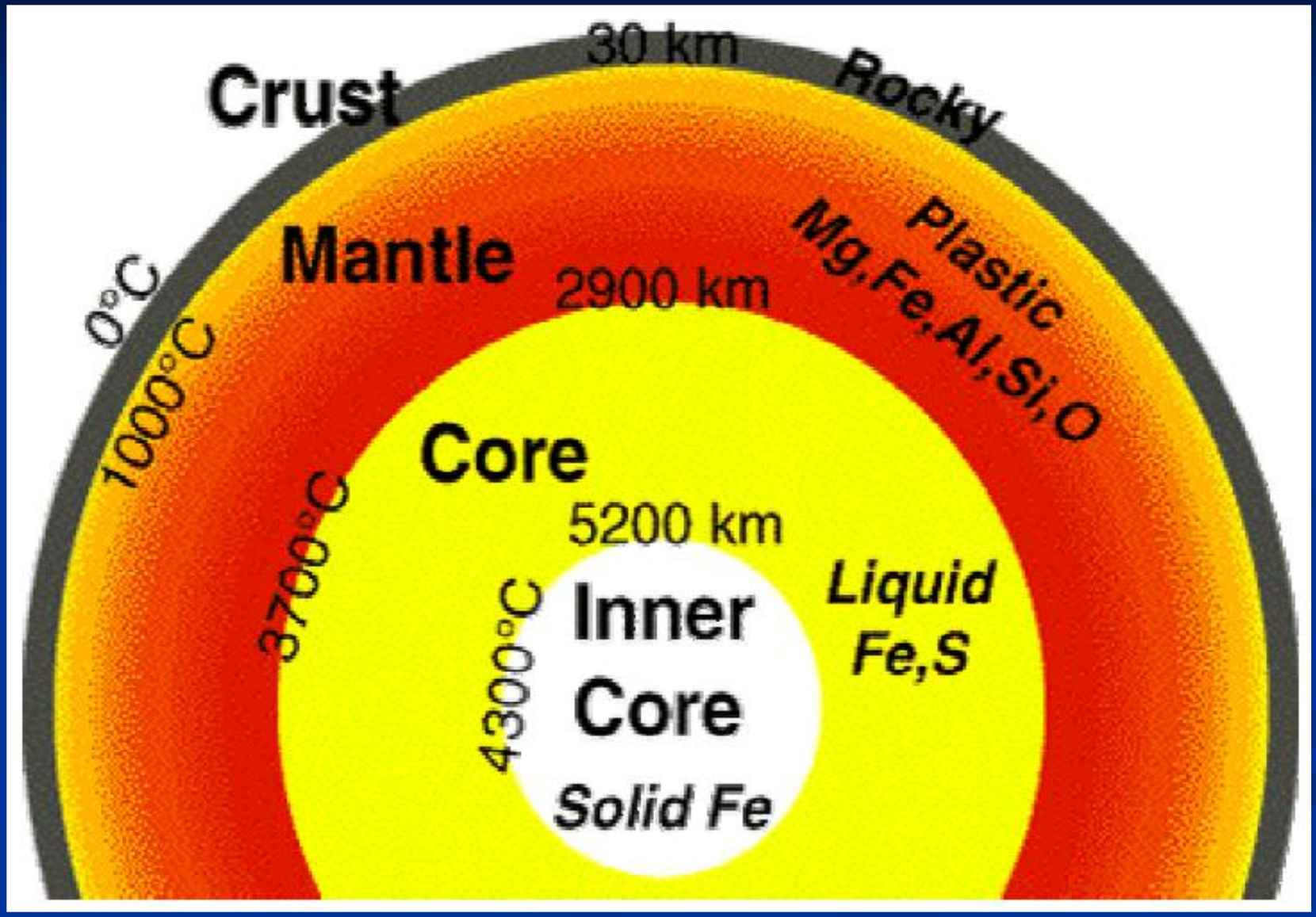


Berdasarkan Genesa & Komposisi:

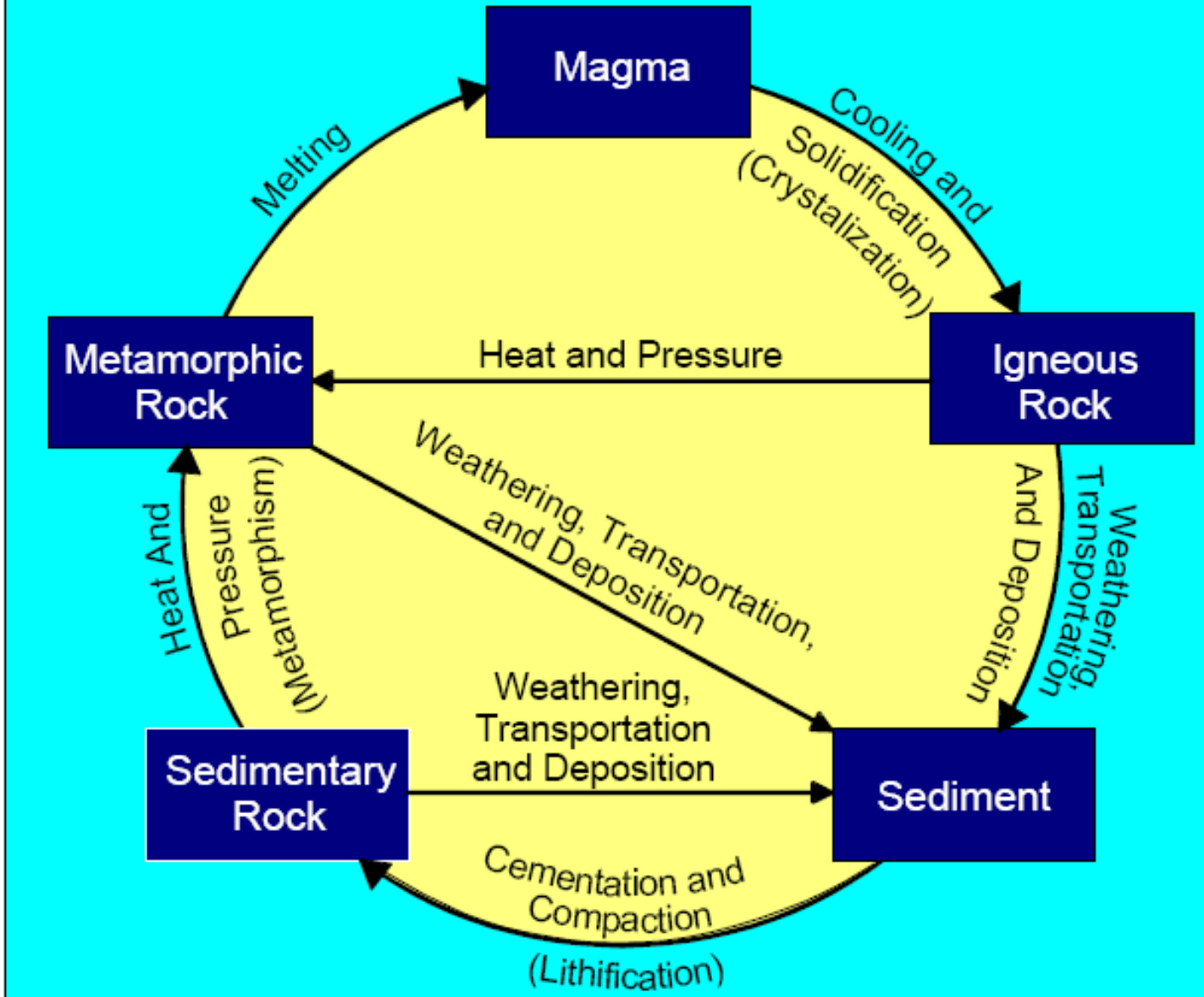
1. Batuan Beku
2. Batuan Sedimen
3. Batuan Piroklastik
4. Batuan Metamorf

Distribusi Batuan di Bumi

- Batuan Beku → di kerak bumi bagian luar (outer crust).
- Batuan Sedimen → di permukaan.
- Batuan Metamorf → di inti dalam (inner core), mantel (mantle), kerak bumi bagian dalam (inner crust).


Crust
30 km
Rocky
Mantle
2900 km
Plastic
Mg,Fe,Al,Si,O
0°C
1000°C
3700°C
Core
5200 km
4300°C
Inner
Core
Solid Fe
Liquid
Fe,S

The Rock Cycle



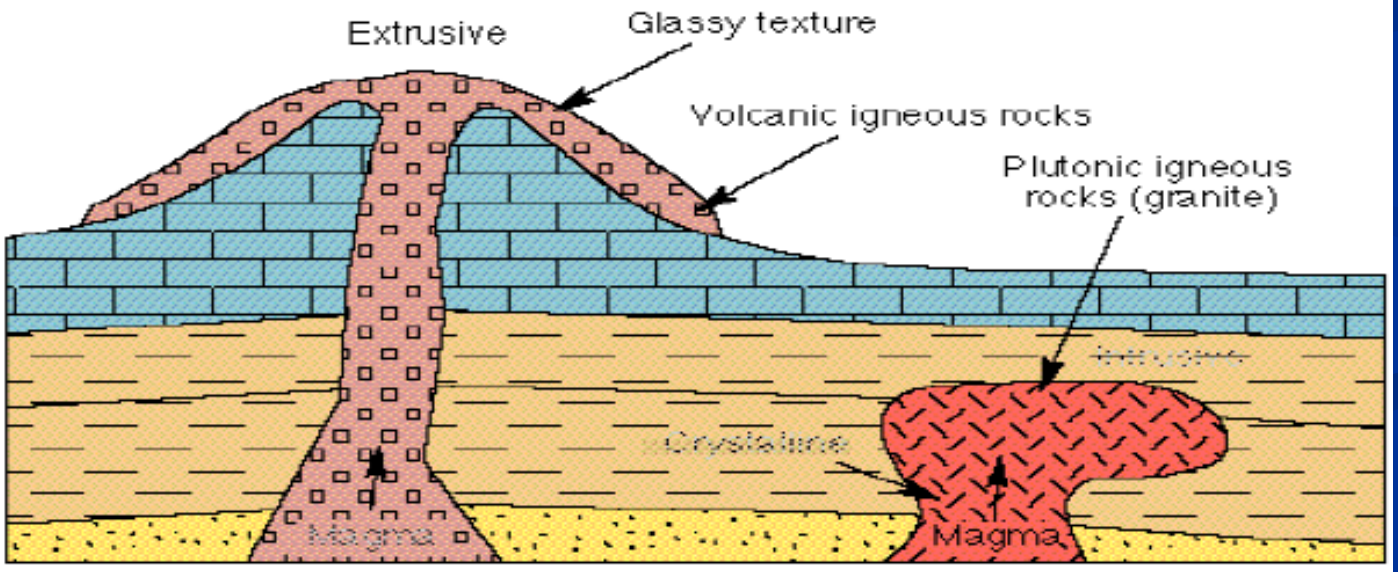
Igneous Rocks

Comprise 95% of the Earth's crust.

Originated from the solidification of molten material from deep inside the Earth.

There are two types:

- **Volcanic - glassy in texture due to fast cooling.**
- **Plutonic - slow-cooling, crystalline rocks.**



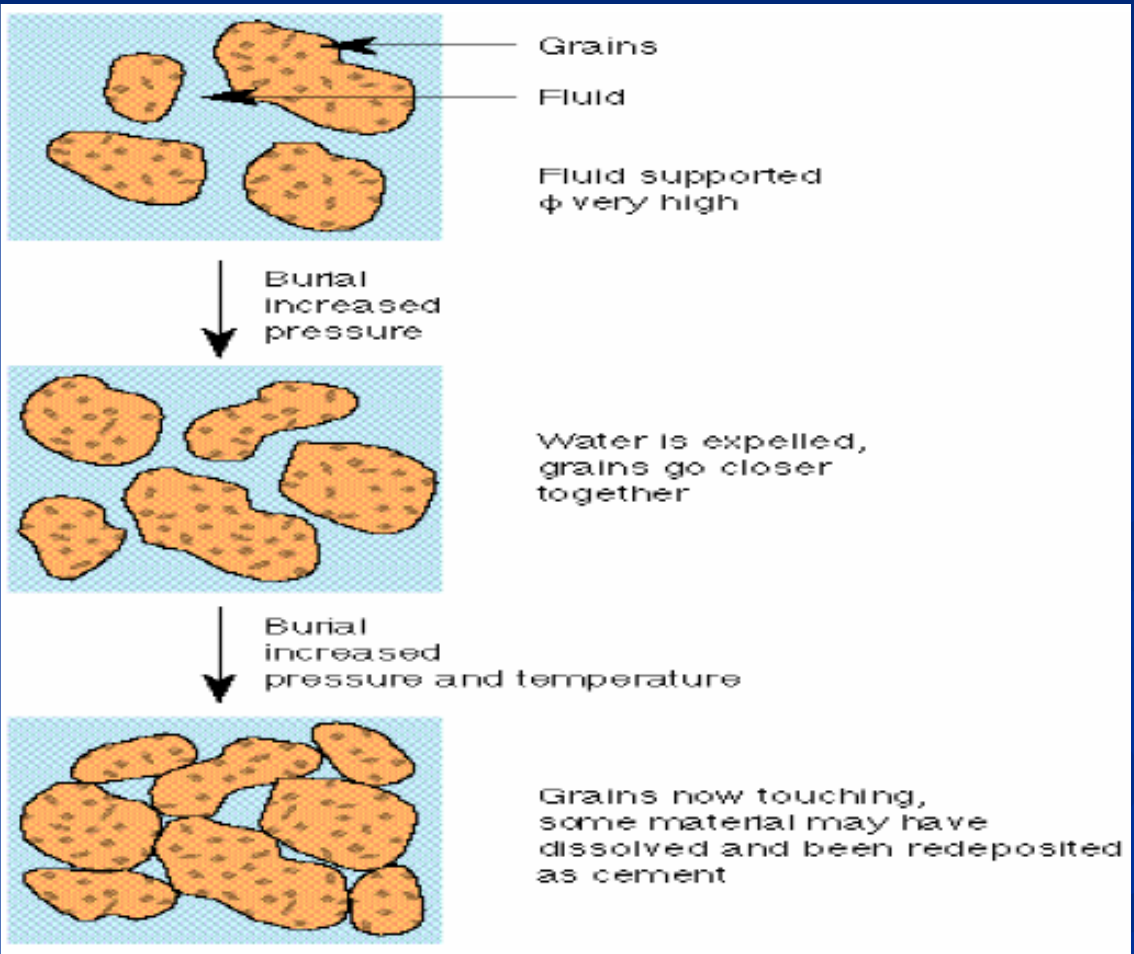
Sedimentary Rocks

- These are the most important for the oil industry as it contains most of the source rocks and cap rocks and a majority of the reservoirs.
- Sedimentary rocks come from the debris of older rocks and are split into two categories
- Clastic and Non-clastic.
  - Clastic rocks - formed from the materials of older rocks by the actions of erosion, transportation and deposition.
  - Non-clastic rocks - from chemical or biological origin and then deposition.

Batuan Sedimen

- Batuan sedimen adalah batuan yang berasal dari rombakan batuan yang telah mengalami siklus sedimentasi (pelapukan-erosi-transportasi-sedimentasi-diagenesa).

Sedimentation



Sedimentation

- Sedimentary muds become sedimentary rocks.
  - Calcareous muds become limestone.
  - Sands become sandstone.
- Grains in the matrix and the fluids reacting to create new minerals changing the matrix and porosity. Fluids can also change creating a new set of minerals.
- This whole process is called *Diagenesis*.

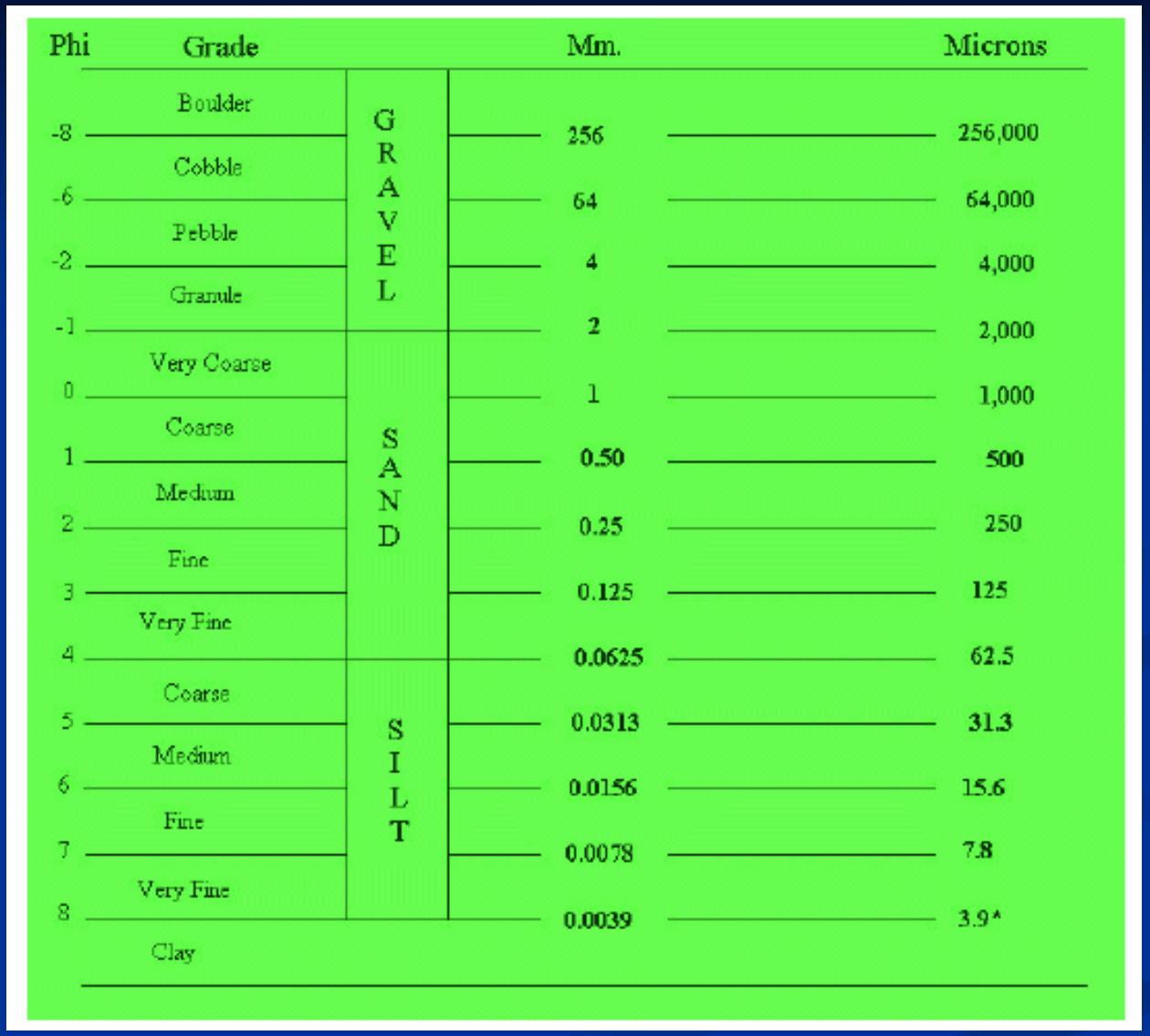
Sedimentary Rock Classifications

Clastics

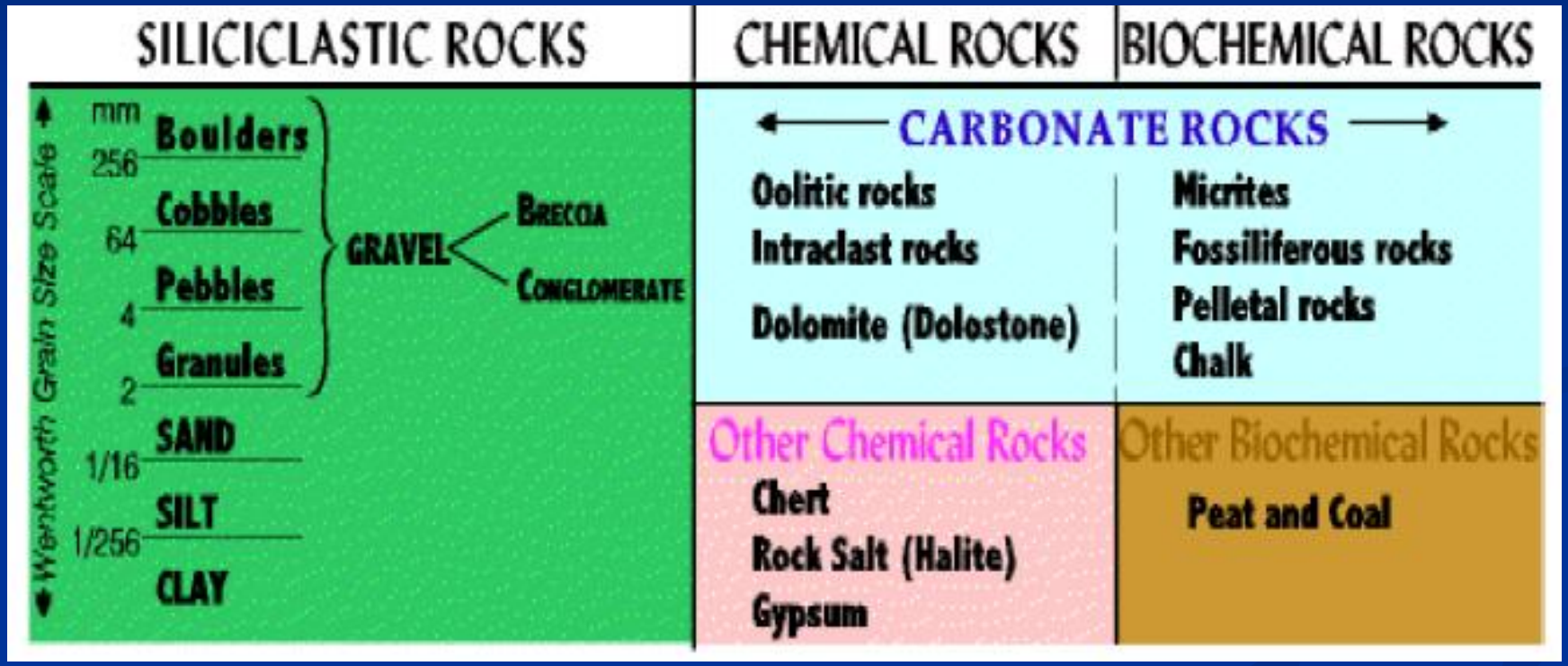
Rock type	Particle diameter	
• Conglomerate Pebbles	2 - 64mm	
• Sandstone	Sand	.06 - 2mm
• Siltstone	Silt	.004 - .06mm or 4 to 65 microns
• Shale	Clay	< .004mm or 4 microns

Non-Clastics

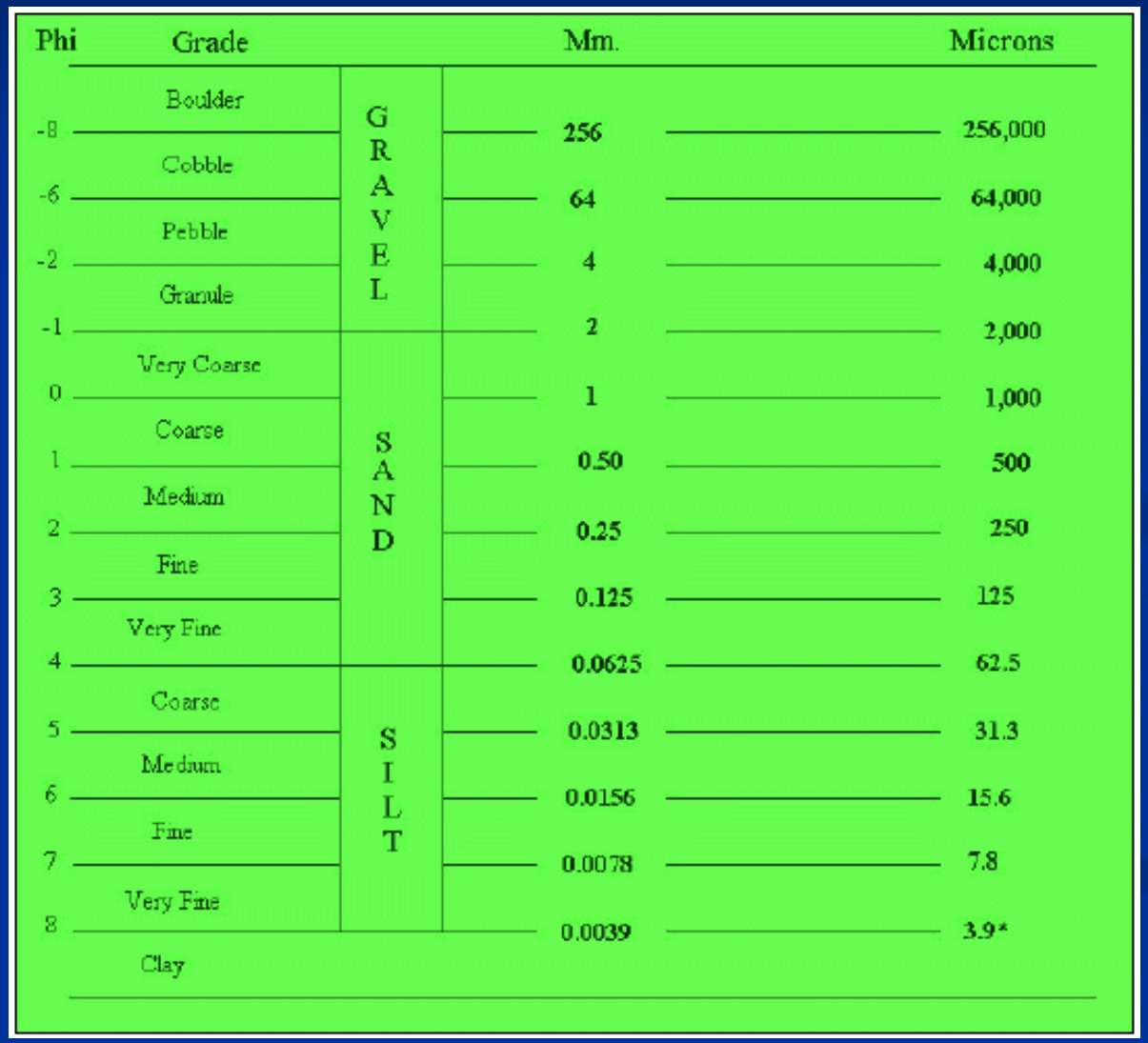
Rock type	Composition
• Limestone	$CaCO_3$
• Dolomite	$CaMg(CO_3)_2$
• Salt	NaCl
• Anhydrite	$CaSO_4$
• Gypsum	$CaSO_4.2H_2O$
• Coal	Carbon


Phi
Grade
Mm.
Microns
Boulder
Cobble
Pebble
Granule
Very Coarse
Coarse
Medium
Fine
Very Fine
Coarse
Medium
Fine
Very Fine
Clay
GRAVEL
SAND
SILT
-8
-6
-2
-1
0
1
2
3
4
5
6
7
8
256
64
4
2
1
0.50
0.25
0.125
0.0625
0.0313
0.0156
0.0078
0.0039
256,000
64,000
4,000
2,000
1,000
500
250
125
62.5
31.3
15.6
7.8
3.9*

Sedimentary Rock Classifications

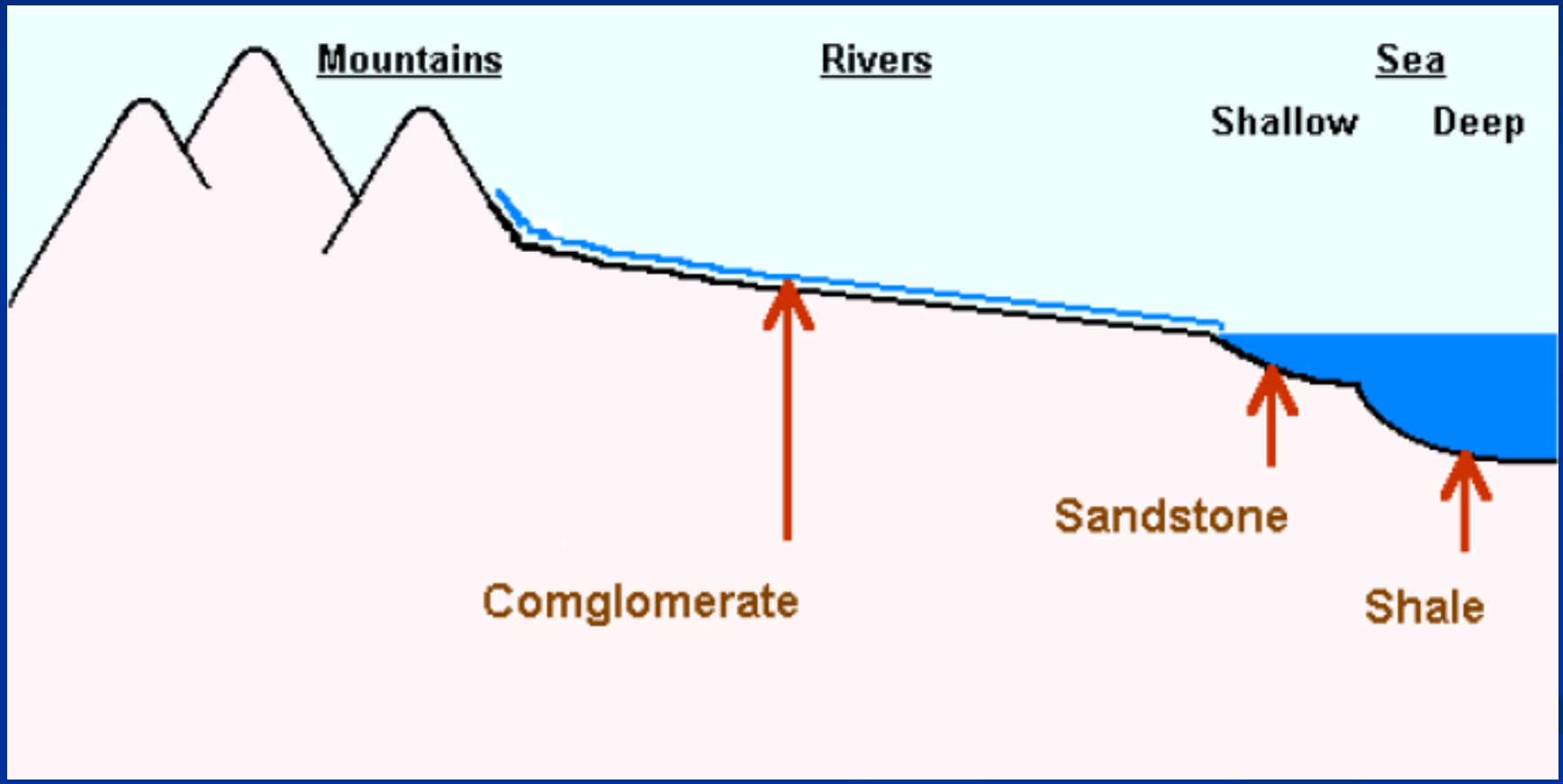


Wentworth Grain Size Scale



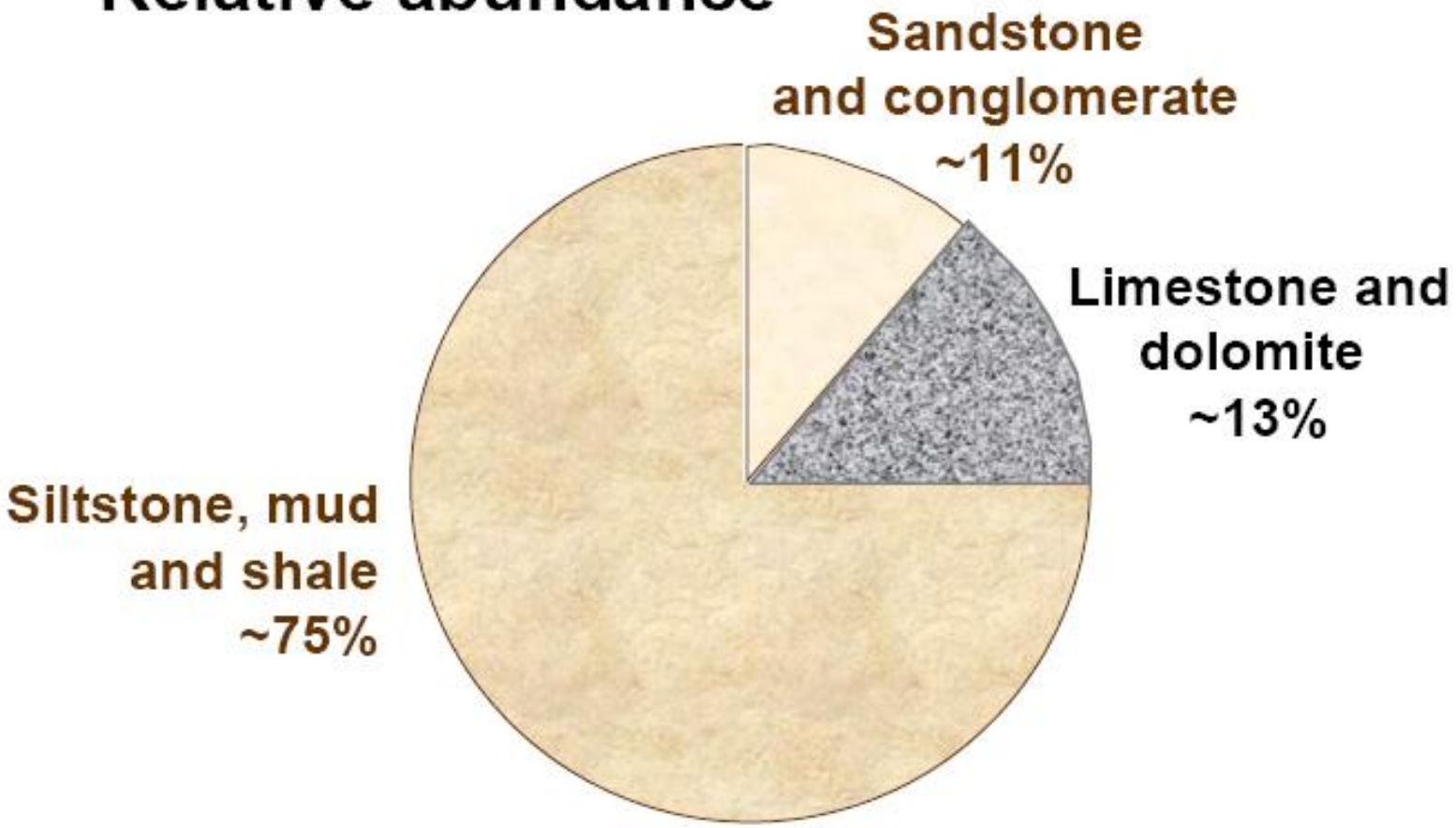
Phi	Grade		Mm.	Microns
-8	Boulder	GRAVEL	256	256,000
-6	Cobble		64	64,000
-2	Pebble		4	4,000
-1	Granule		2	2,000
0	Very Coarse	SAND	1	1,000
1	Coarse		0.50	500
2	Medium		0.25	250
3	Fine		0.125	125
4	Very Fine		0.0625	62.5
5	Coarse	SILT	0.0313	31.3
6	Medium		0.0156	15.6
7	Fine		0.0078	7.8
8	Very Fine		0.0039	3.9*
	Clay			

Fraksinasi Besar Butir



Sedimentary Rock Types

- Relative abundance



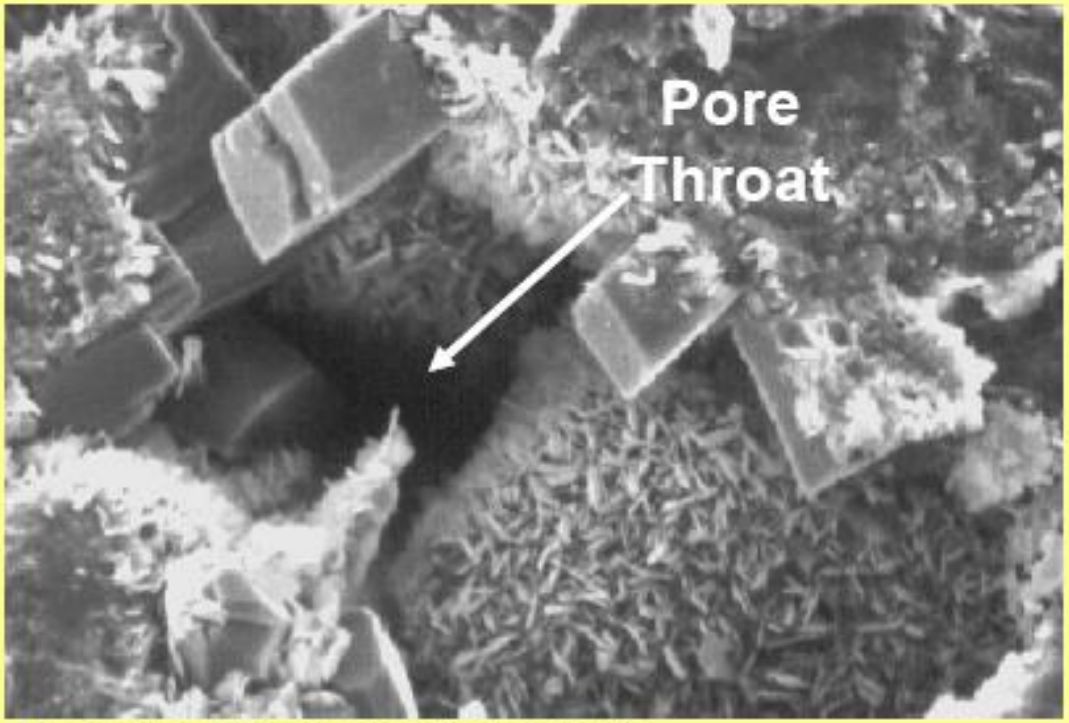
Clastic Sedimentary Rocks

SINGKAPAN BATUAN SEDIMEN

Clastic Reservoirs

- Consolidated and unconsolidate sands
- Porosity
  - Determined mainly by the packing and mixing of grains.
- Permeability
  - Determined mainly by grain size and packing, connectivity and shale content.
- Fractures may be present.

Porosity in Sandstone



Scanning Electron Micrograph
Norphlet Formation, Offshore Alabama, USA

Pores Provide the Volume to Contain Hydrocarbon Fluids

Pore Throats Restrict Fluid Flow

Carbonate Reservoirs

- Carbonates (limestone and dolomite) normally have a very irregular structure.
- Porosity:
  - Determined by the type of shells, etc. and by depositional and post-depositional events (fracturing, leaching, etc.).
- Permeability:
  - Determined by deposition and post-deposition events, fractures.
- Fractures can be very important in carbonate reservoirs.

Carbonate Types

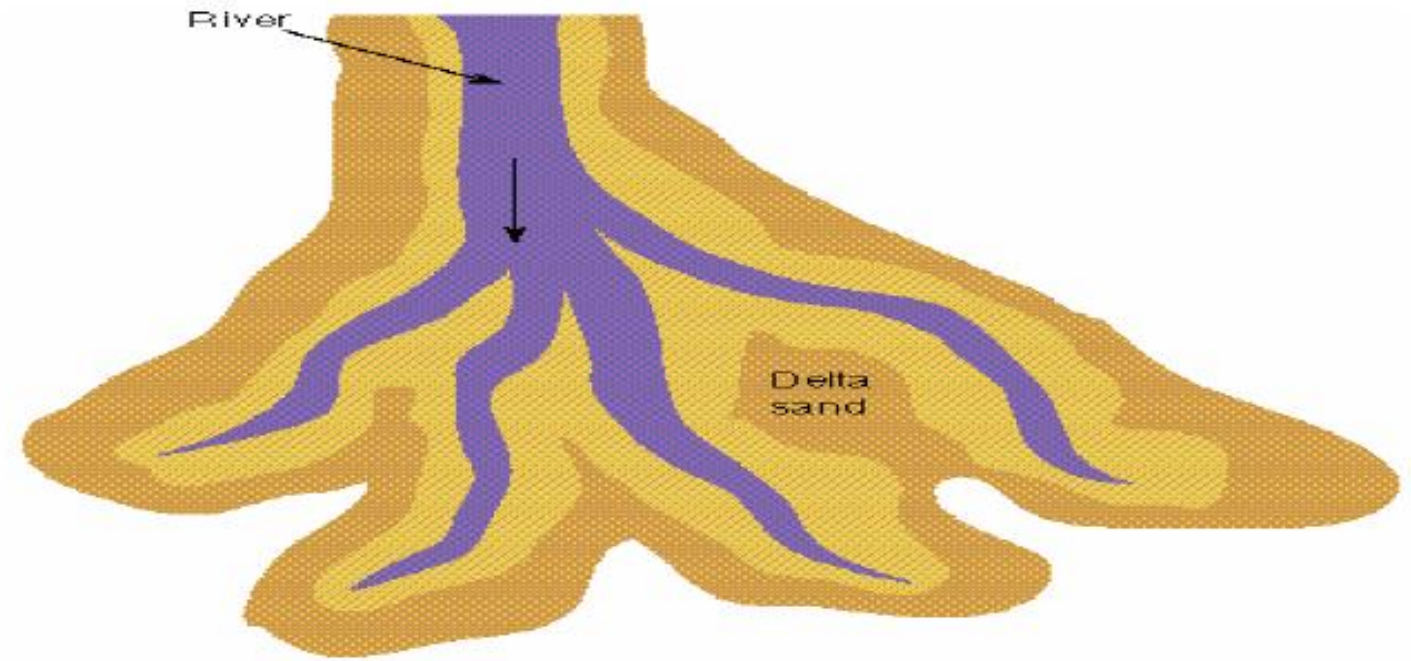
- Chalk is a special form of limestone ($CaCO_3$) and is formed from the skeletons of small creatures (cocoliths).
- Dolomite ($CaMg(CO_3)_2$) is formed by the replacement of some of the calcium by a lesser volume of magnesium in limestone by magnesium. Magnesium is smaller than calcium, hence the matrix becomes smaller and more porosity is created.
- Evaporites such as Salt ($NaCl$) and Anhydrite ($CaSO_4$) can also form in these environments.

Clastic Sedimntary Environments

Environment	Agent Of Transportation Deposition	Sediments
Alluvial	Rivers	Sand, gravel, mud
Lake	Lake currents, waves	Sand, mud
Desert	Wind	Sand, dust
Glacial	Ice	Sand, gravel, mud
Delta	River + waves, tides	Sand, mud
Beach	Waves, tides	Sand, gravel
Shallow shelf	Waves, tides	Sand, mud
Deep sea	Ocean currents, settling	Sand, Mud

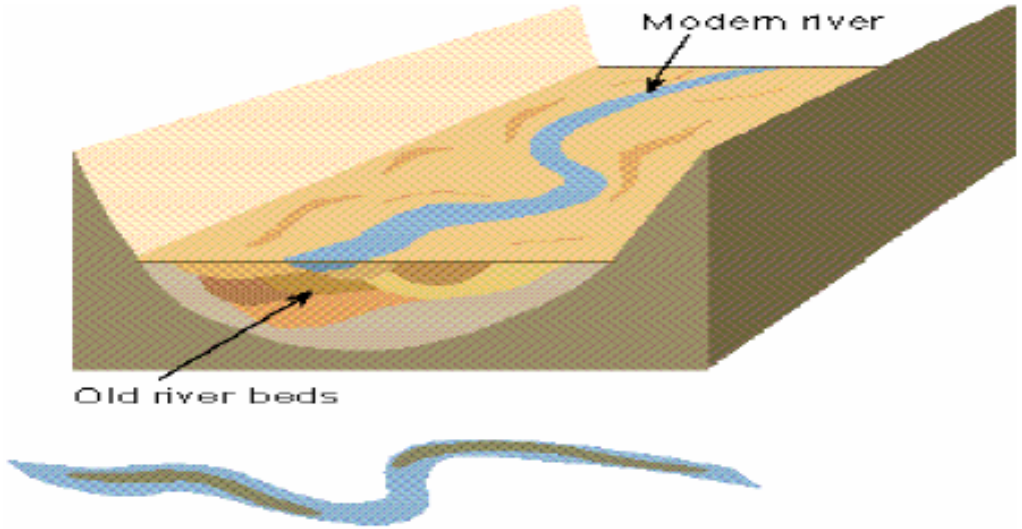
Depositional Environment - *Delta*

- Sediments are transported to the basins by rivers.
- A common depositional environment is the delta where the river empties into the sea.
- **A good example of this is the Mississippi (Miocene and Oligocene sands)**



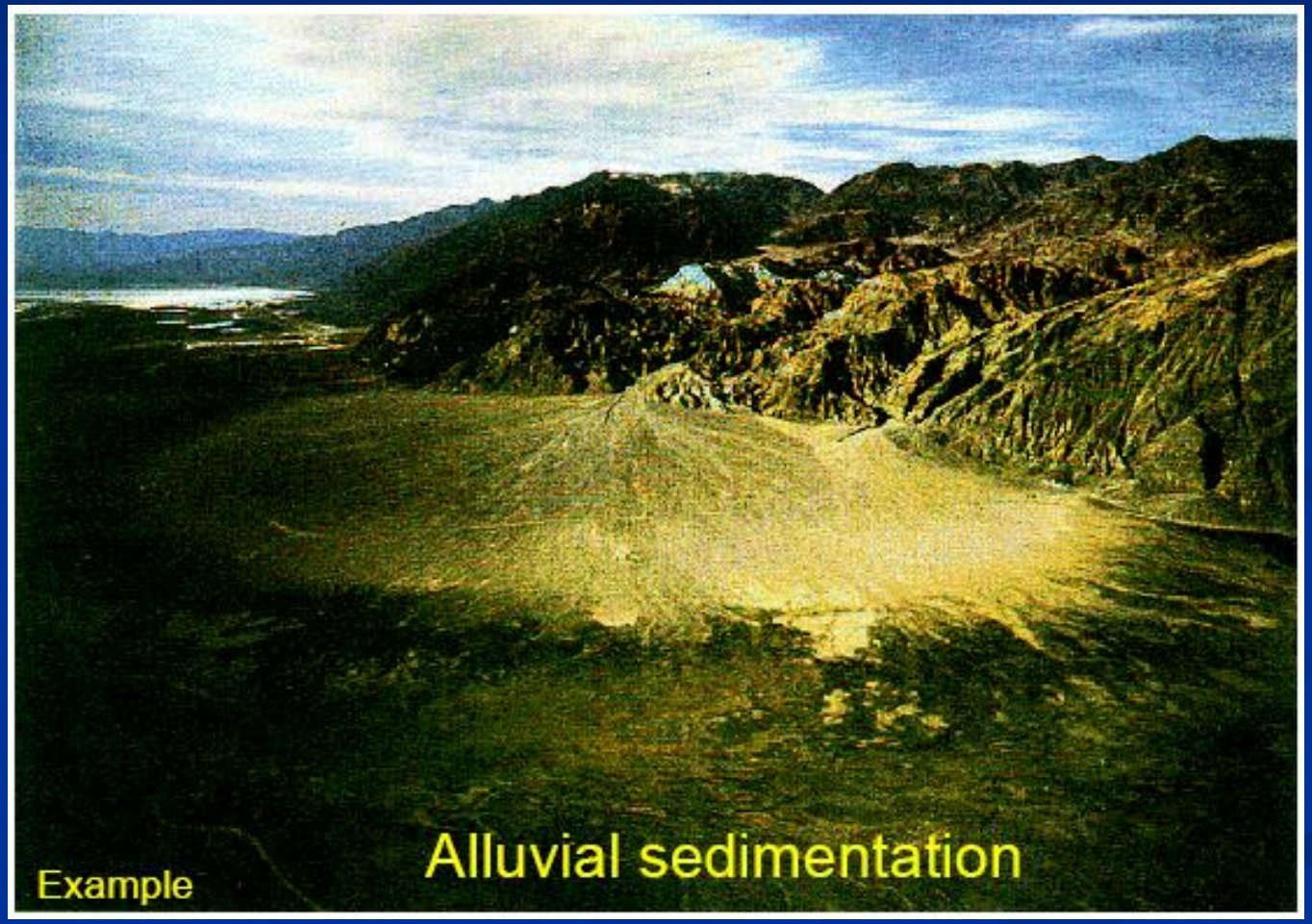

STS61A-42-0051 Mississippi River Delta, Louisiana, U.S.A.
October 1985
N
20 mi
NASA PHOTO

Depositional Environment – *Rivers (Fluvial)*

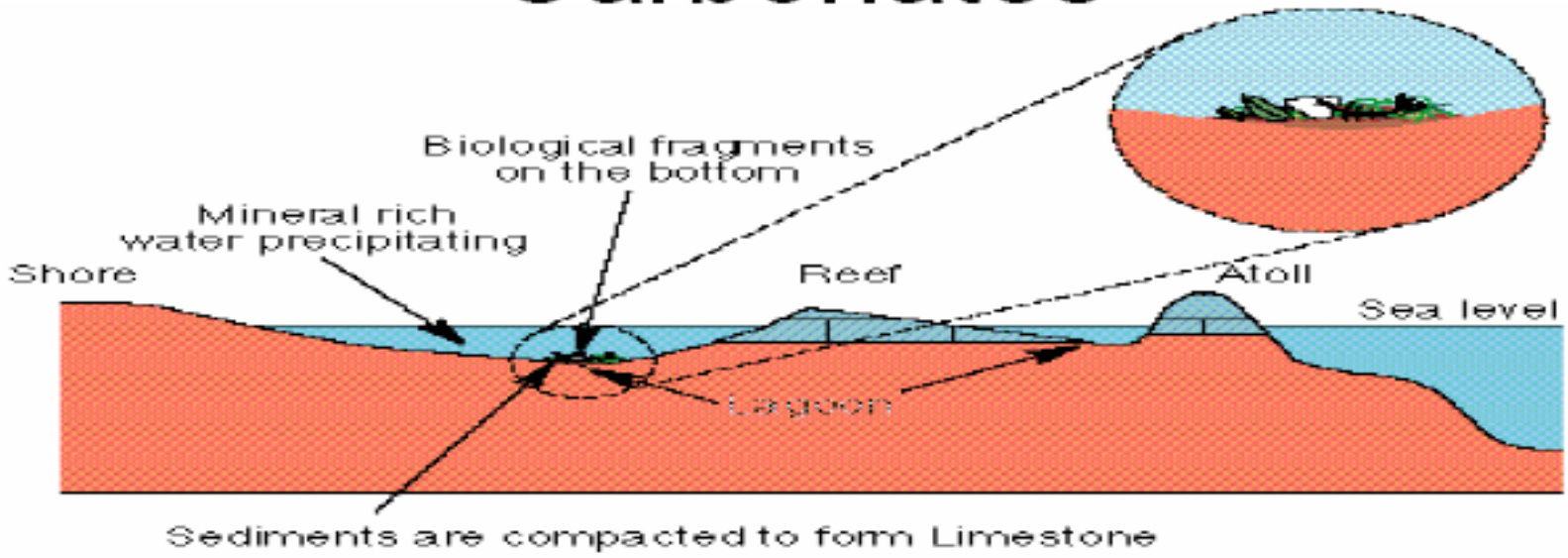


- Some types of deposition occur in rivers and sand bars.
- The river forms a channel where sands are deposited in layers. Rivers carry sediment down from the mountains which is then deposited in the river bed and on the flood plains at either side.
- Changes in the environment can cause these sands to be overlain with a shale, trapping the reservoir rock.

Fan Deposition



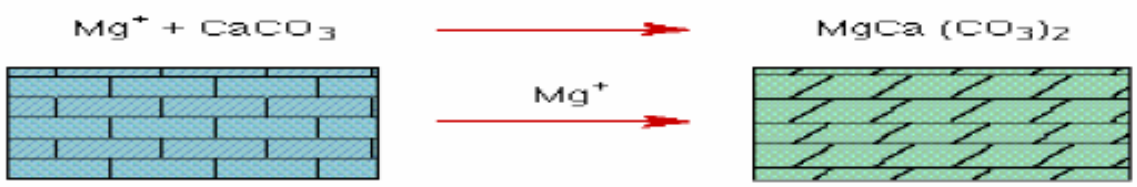
Depositional Environment Carbonates



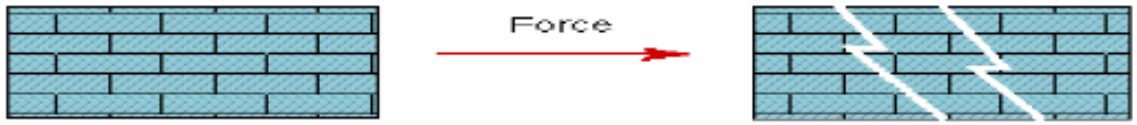
- Carbonates are formed in shallow seas containing features such as:
  - Reefs.
  - Lagoons.
  - Shore-bars.

Diagenesis

- The environment can also involve subsequent alterations of the rock such as:
  - Chemical changes.
  - Diagenesis is the chemical alteration of a rock after burial. An example is the replacement of some of the calcium atoms in limestone by magnesium to form dolomite.

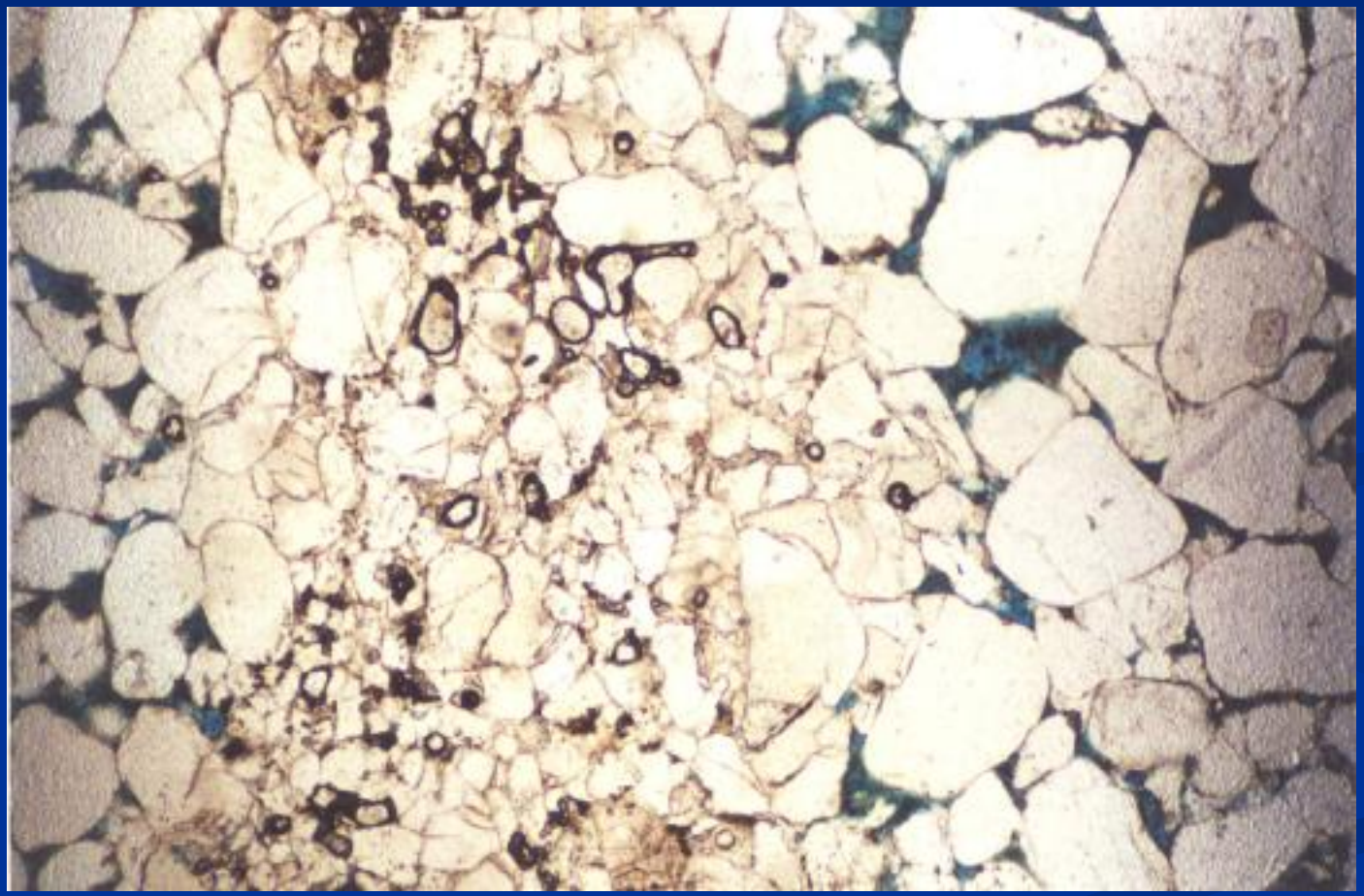


  - Mechanical changes - fracturing in a tectonically-active region.

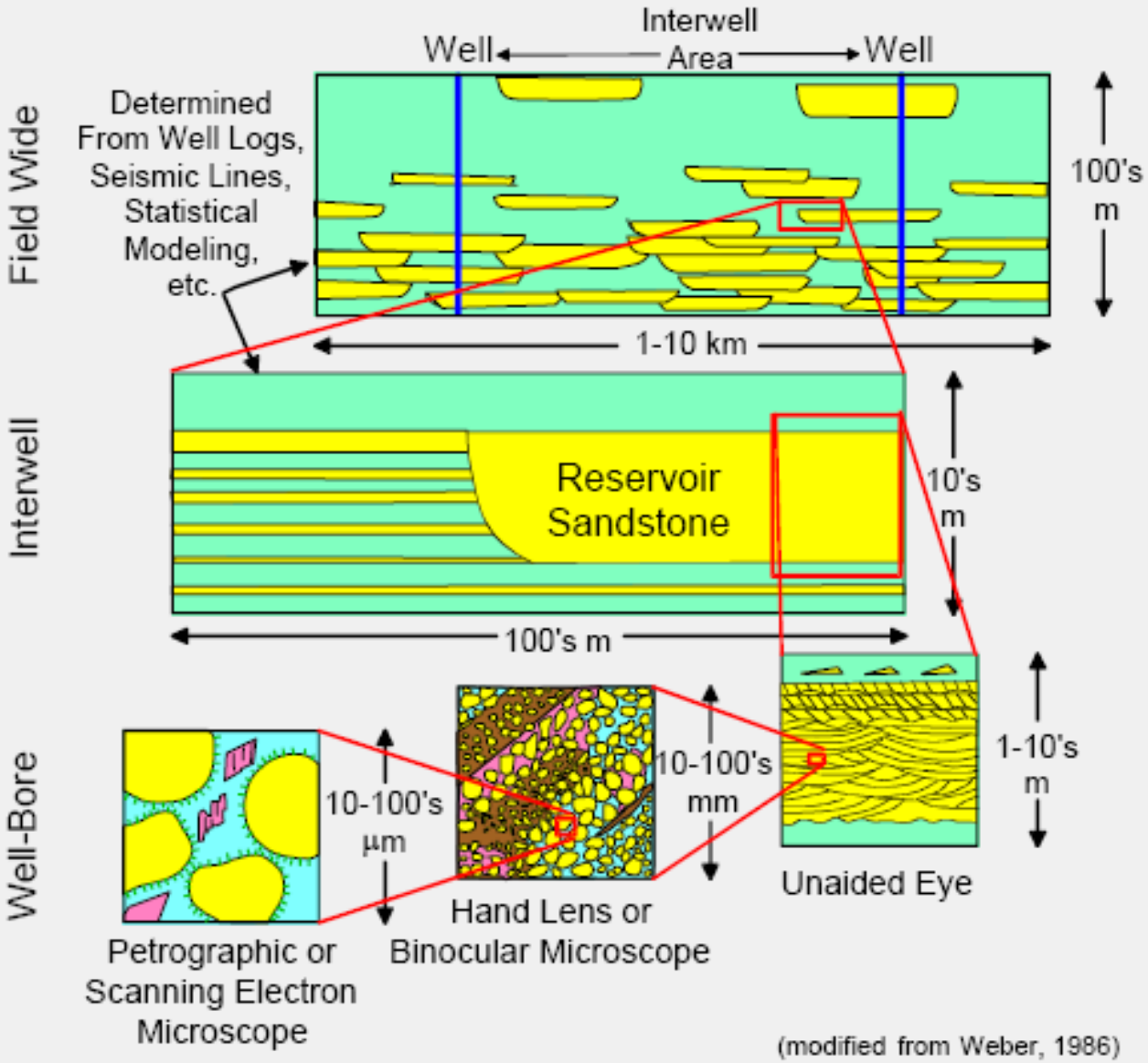


HETEROGENEITY

Geologic Reservoir Heterogeneity



Scales of Geological Reservoir Heterogeneity



RESOLUSI
PENGUKURAN & KORELASI

Evaluation Magnitude

Order in meter	Formation Evaluation Technique	Purpose
10^{6}	Satelite Imagery	
10^{5}	Basin Geological Studies	Gross structure
10^{4}	Seismic, Gravity, Magnetics	
10^{3}	Borehole gravimeter, Ultra Long-Spacing Log	Local structure
10^{2}	Drilstem test (DST)	Productivity
10^{1}	Wireling Formation Test (RFT/SFT)	and reserves
10^{0}	Full diameter cores	Local porosity
10^{-1}	Sidewal Cores, most conventional well logs, Measurement while drilling (MWD/LWD)	permeability, age and lithology
10^{-2}	Microfocused Log, coreplug analyses	
10^{-3}	Cuttings analyses (Mud logging)	Local HC content
10^{-4}	Core analyses	Rock properties
10^{-5}	X-Ray mineralogy	Rock and clay typing
10^{-6}	Scanning Electron Microscope (SEM)	Micropore structure

Sumber : Bambang S Murti

(Batteman, 1988)

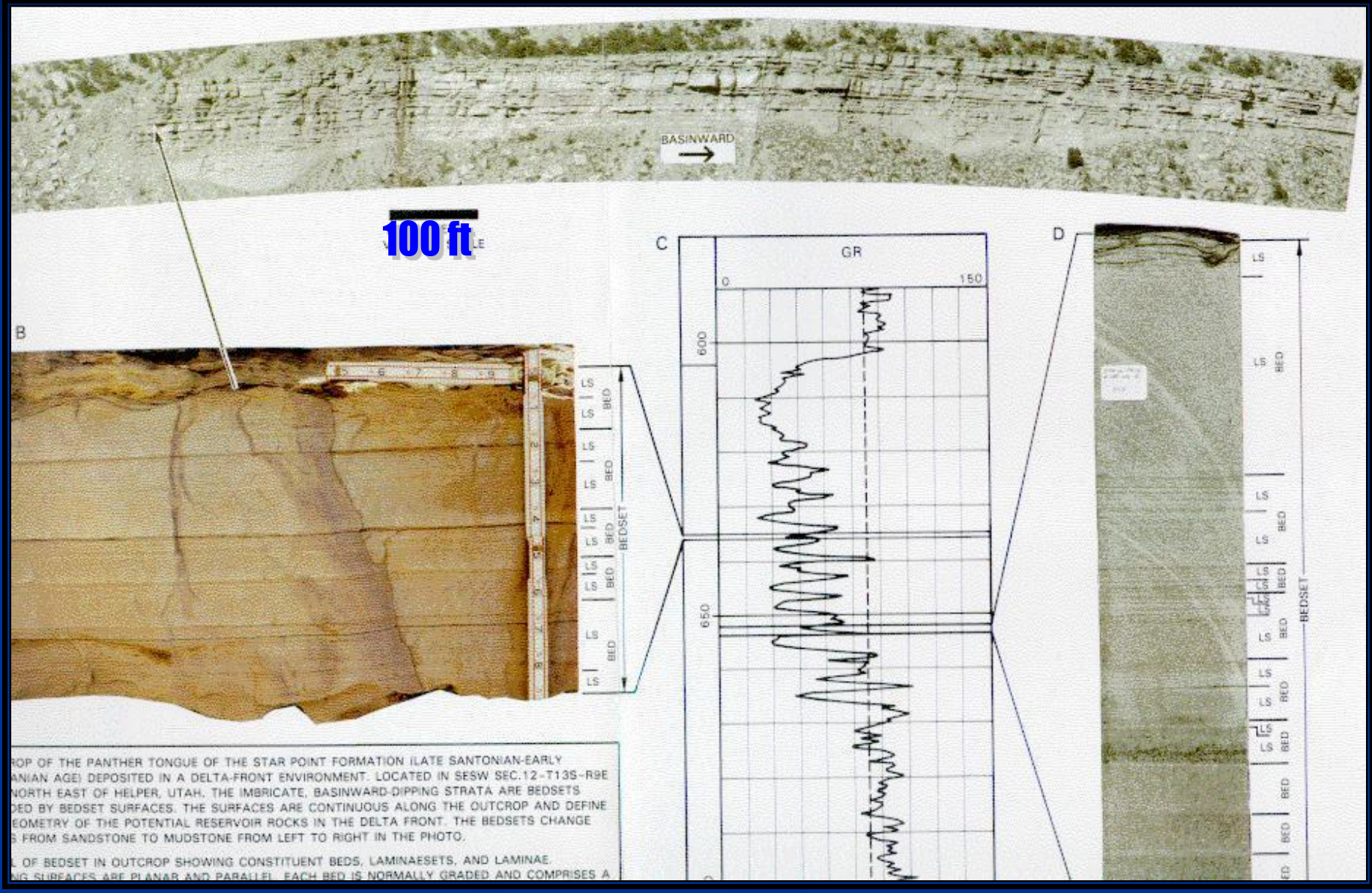
Resolusi Vertikal

- Seismic: 20 – 60 m
- Log-log lama (analog): 0.5 – 1 m
- Log-log baru (digital): 0.1 – 0.5 m
- Micro Devices: 0.2 cm (2 mm)
- Conventional Core: Resolusi Visual
- Petrografi: 0.1 mm

Sumber : Bambang S Murti

Sumber : Bambang S Murti

Observasion Scale

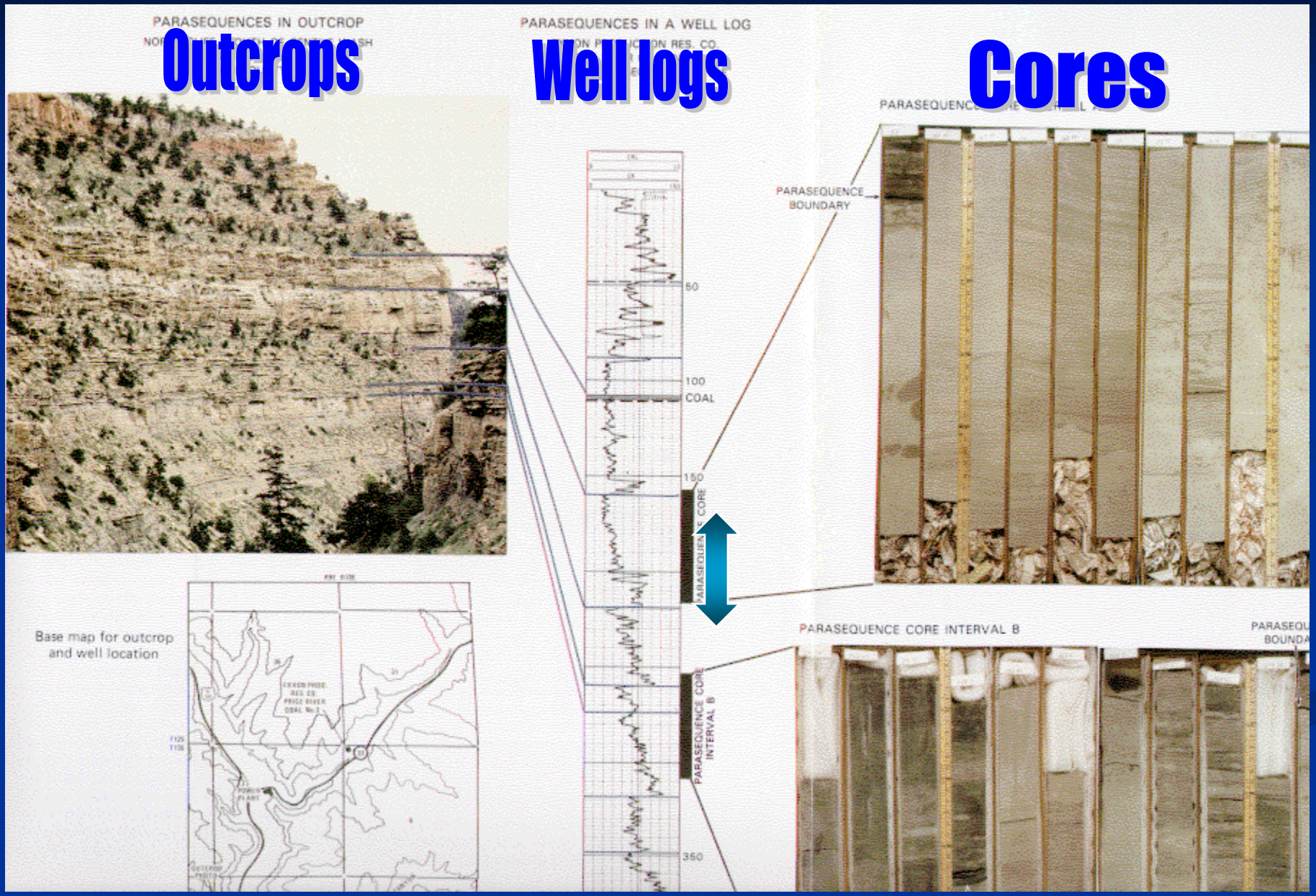


ROP OF THE PANTHER TONGUE OF THE STAR POINT FORMATION (LATE SANTONIAN-EARLY ANIAN AGE) DEPOSITED IN A DELTA-FRONT ENVIRONMENT. LOCATED IN SESW SEC.12-T13S-R9E NORTH EAST OF HELPER, UTAH. THE IMBRICATE, BASINWARD-DIPPING STRATA ARE BEDSETS DED BY BEDSET SURFACES. THE SURFACES ARE CONTINUOUS ALONG THE OUTCROP AND DEFINE EOMETRY OF THE POTENTIAL RESERVOIR ROCKS IN THE DELTA FRONT. THE BEDSETS CHANGE S FROM SANDSTONE TO MUDSTONE FROM LEFT TO RIGHT IN THE PHOTO.

L OF BEDSET IN OUTCROP SHOWING CONSTITUENT BEDS, LAMINASETS, AND LAMINAE. NG SURFACES ARE PLANAR AND PARALLEL. EACH BED IS NORMALLY GRADED AND COMPRISES A

Sequence

Sumber : Bambang S Murti



General Gamma Ray Response to Variations in Grain Size

Cylindrical GR->

Aggrading

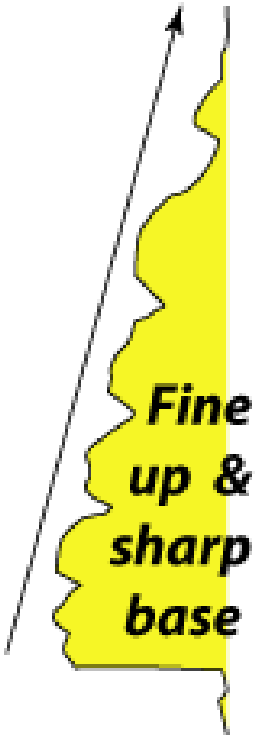
Eolian, braided fluvial, distributary channel-fill, submarine canyon-fill, carbonate shelf-margin, evaporite fill of basin.

Funnel GR->

Prograding

Crevasse splay, river mouth bar, delta front, shoreface, submarine fan lobe, change from clastic to carbonates.

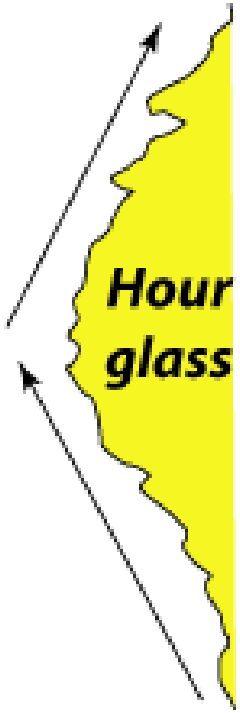
Bell GR->



Retrograding

Fluvial point bar, tidal point bar, deep-tidal channel-fill, tidal flat, trangressive shelf.

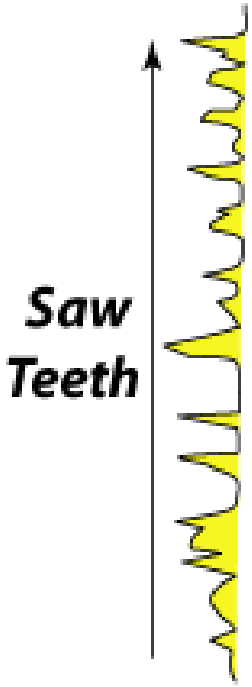
Symmetrical GR->



Prograding & Retrograding

Reworked offshore bar, regressive to transgressive shore face delta.

Serrated GR->



Aggrading

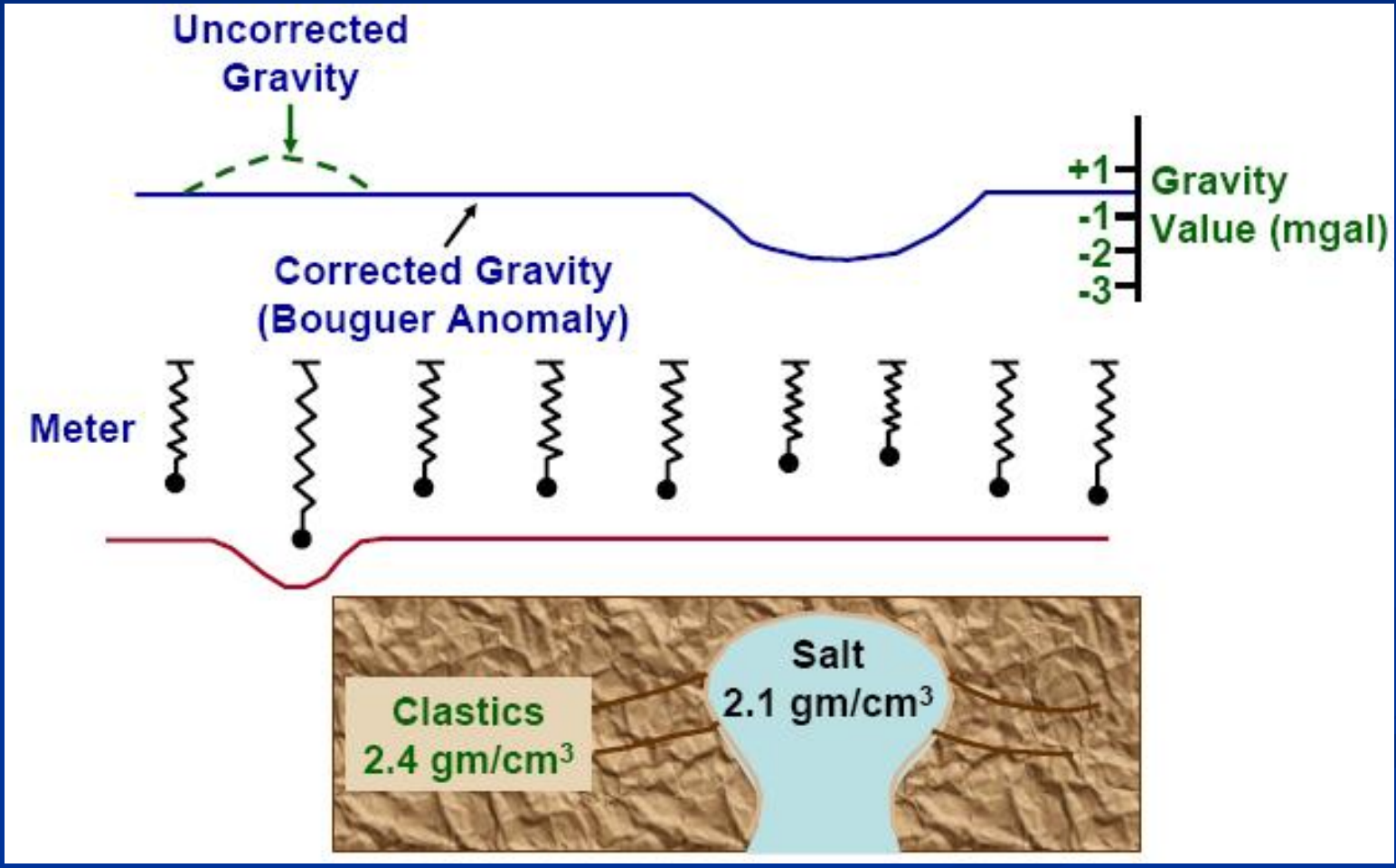
Fluvial floodplain, storm-dominated shelf, and distal deep-marine slope.

PETROLEUM EXPLORATION:
Geophysical Application to Petroleum Geology

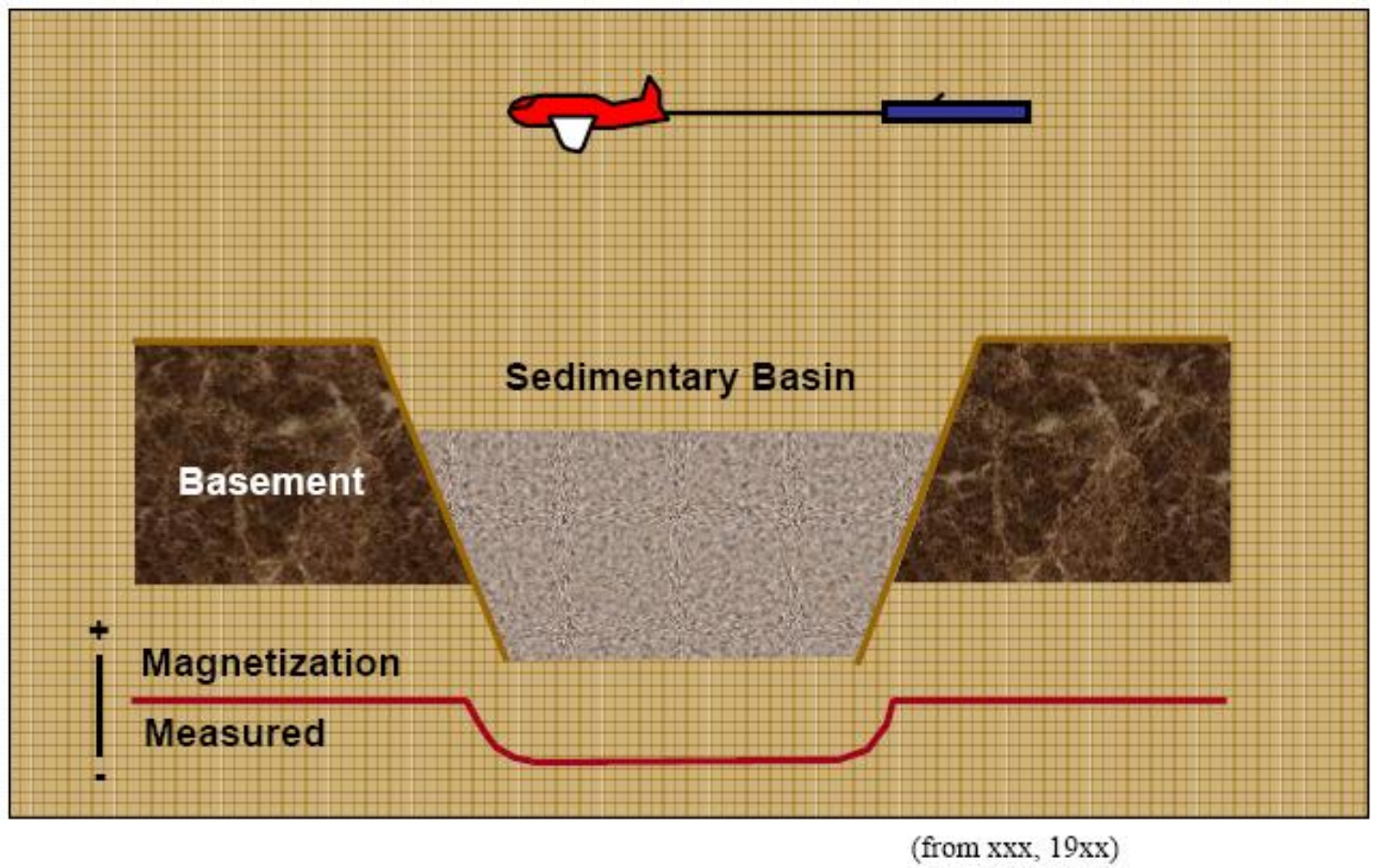
Petroleum Exploration – *Geophysical Methods*

- Gravity surveys
- Magnetic surveys
- Seismic surveys

Principles of Gravity Survey



Principles of Magnetic Survey



(from xxx, 19xx)

Seismic Survey

- The seismic tools commonly used in the oil and gas industry are 2-D and 3-D seismic data.

- Seismic data are used to:
  - Define and map structural folds and faults.
  - Identify stratigraphic variations and map sedimentary facies.
  - Infer the presence of hydrocarbon.
  - Establish gas/water contact.

Applications of Seismic Data

- Make a structural model of the reservoir
- Delineate and map reservoir-quality rocks
- Establish gas/water contacts

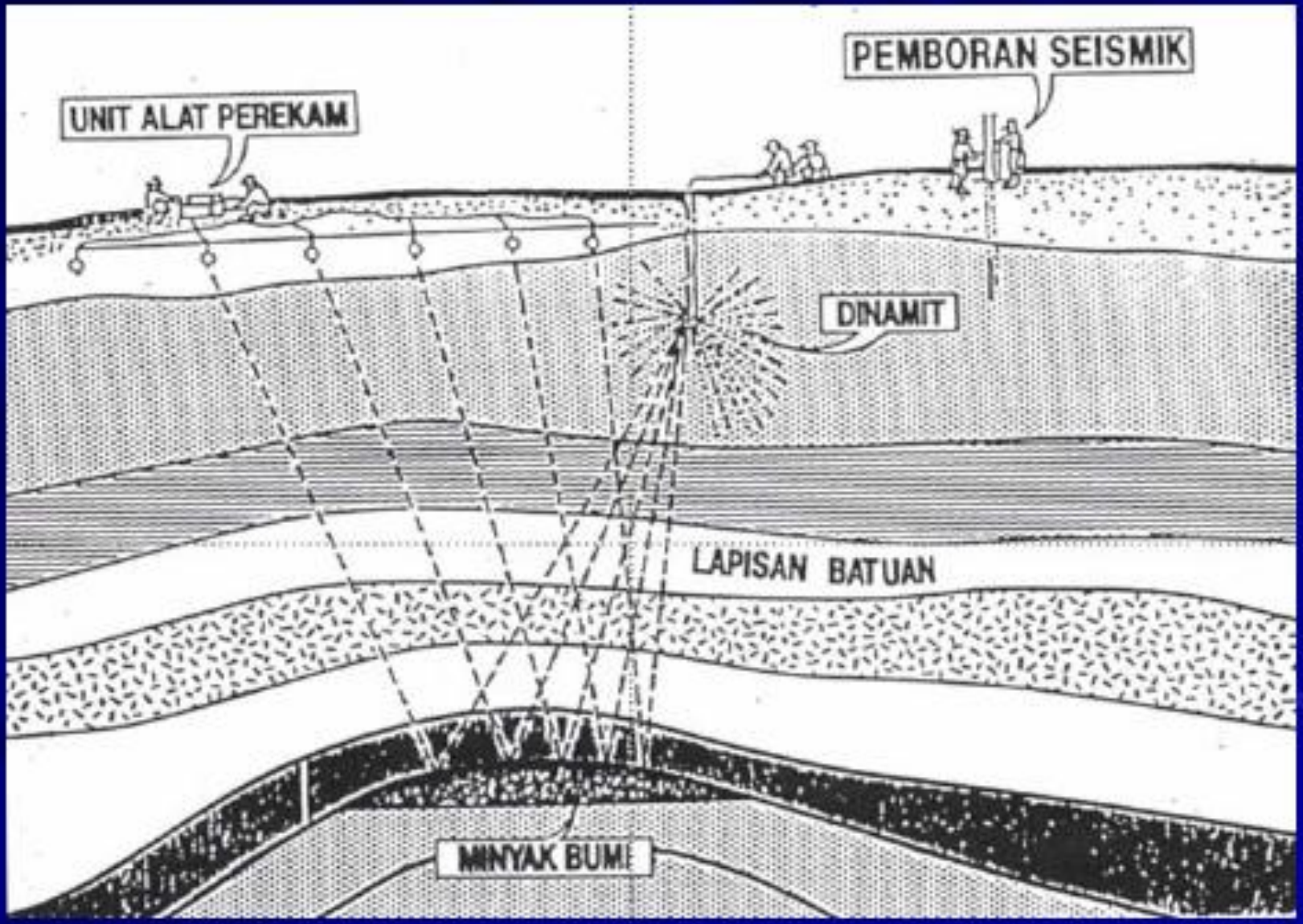
4-D Seismic Surveys

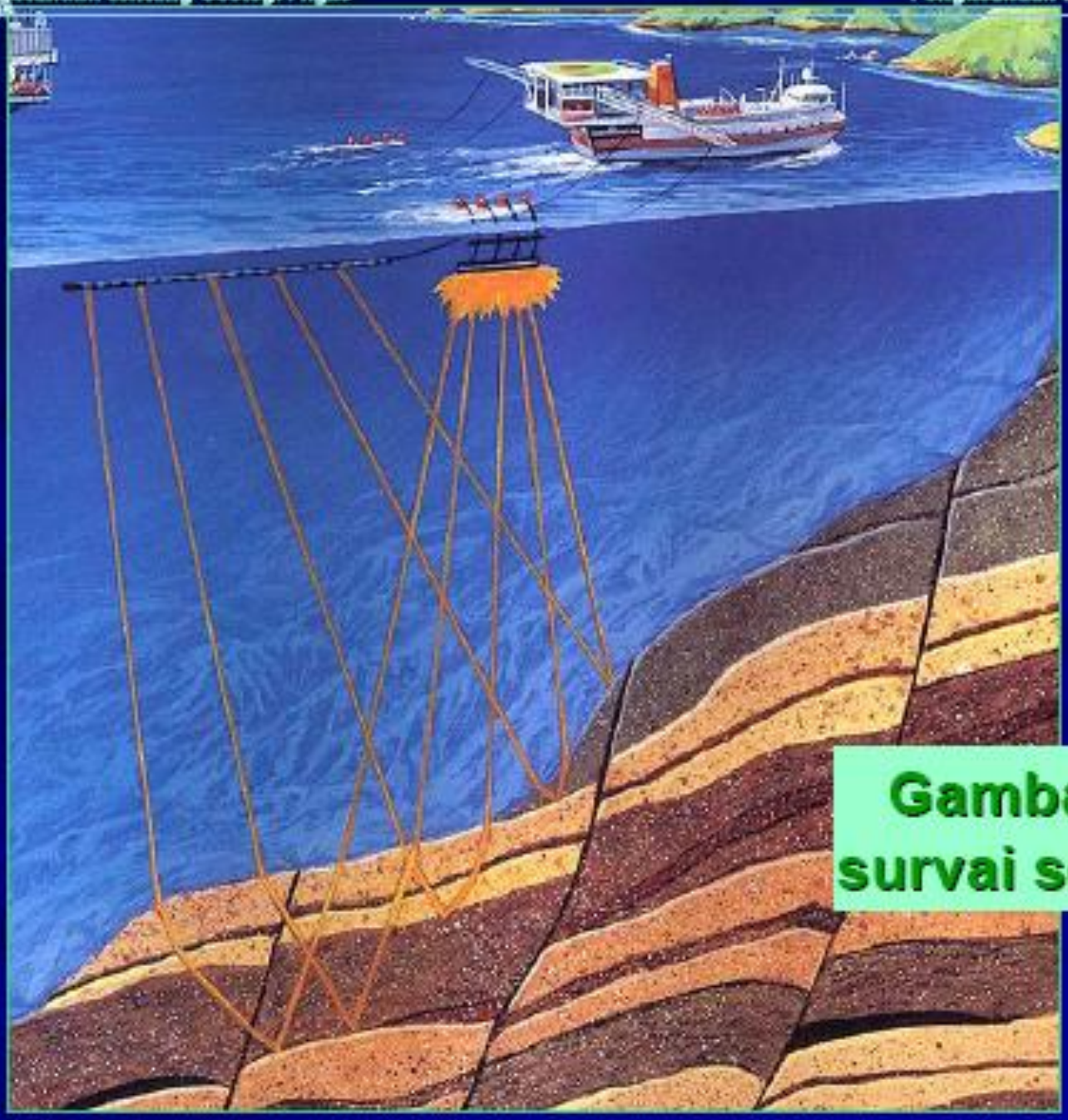
- The ‘4’ in 4-D seismic is time.
- A 4-D survey means that at least two 3-D seismic surveys have been made at different times over the same field.
- Reflection character (attributes) change through time.
- These changes result from migration of the water contact in the reservoir.

Importance to Schlumberger

- Source of revenue.
- Allows our Engineers to:
  - Better understand the limitations of a reservoir.
  - Design better treatments

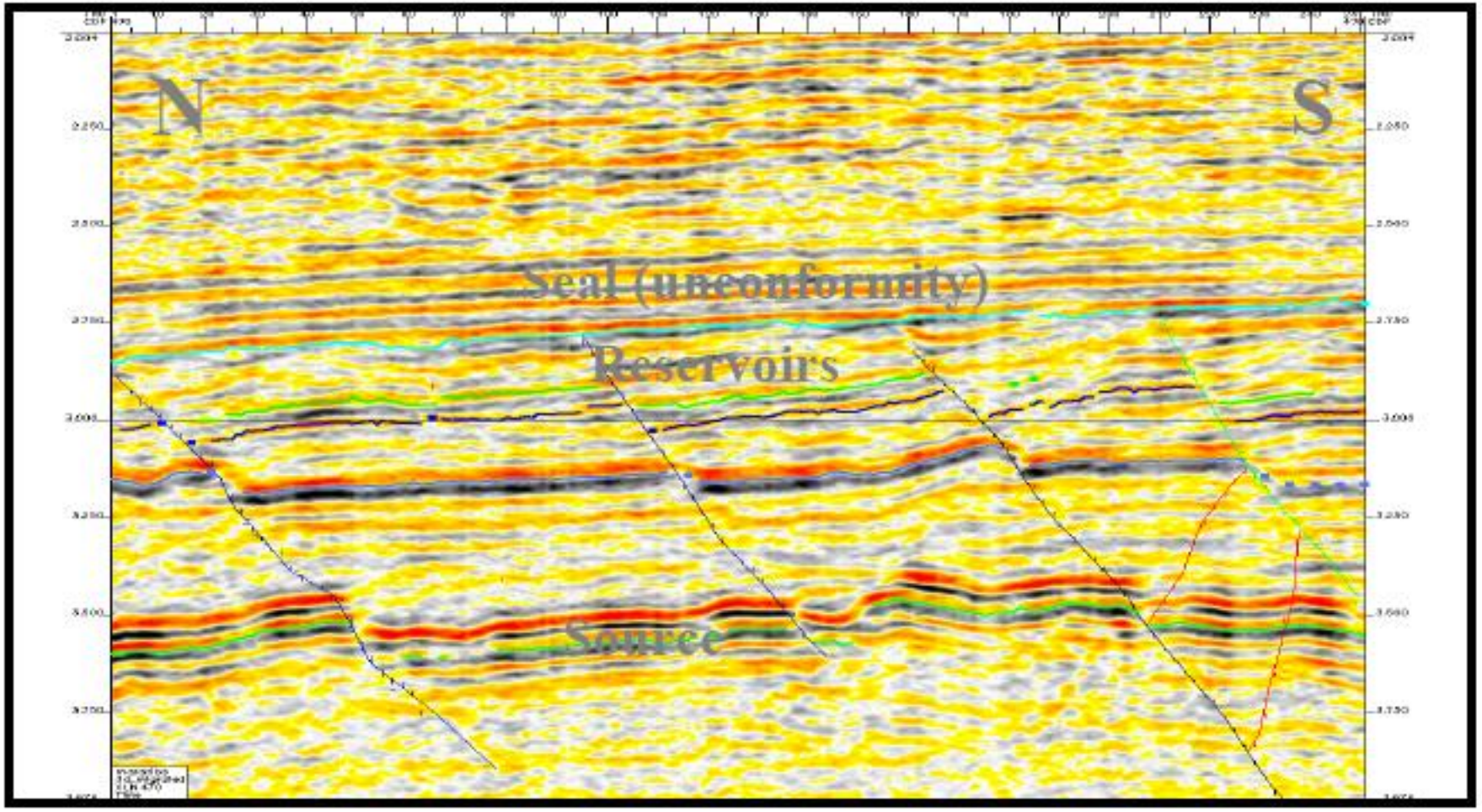
GAMBARAN KEGIATAN OPERASI SEISMIK

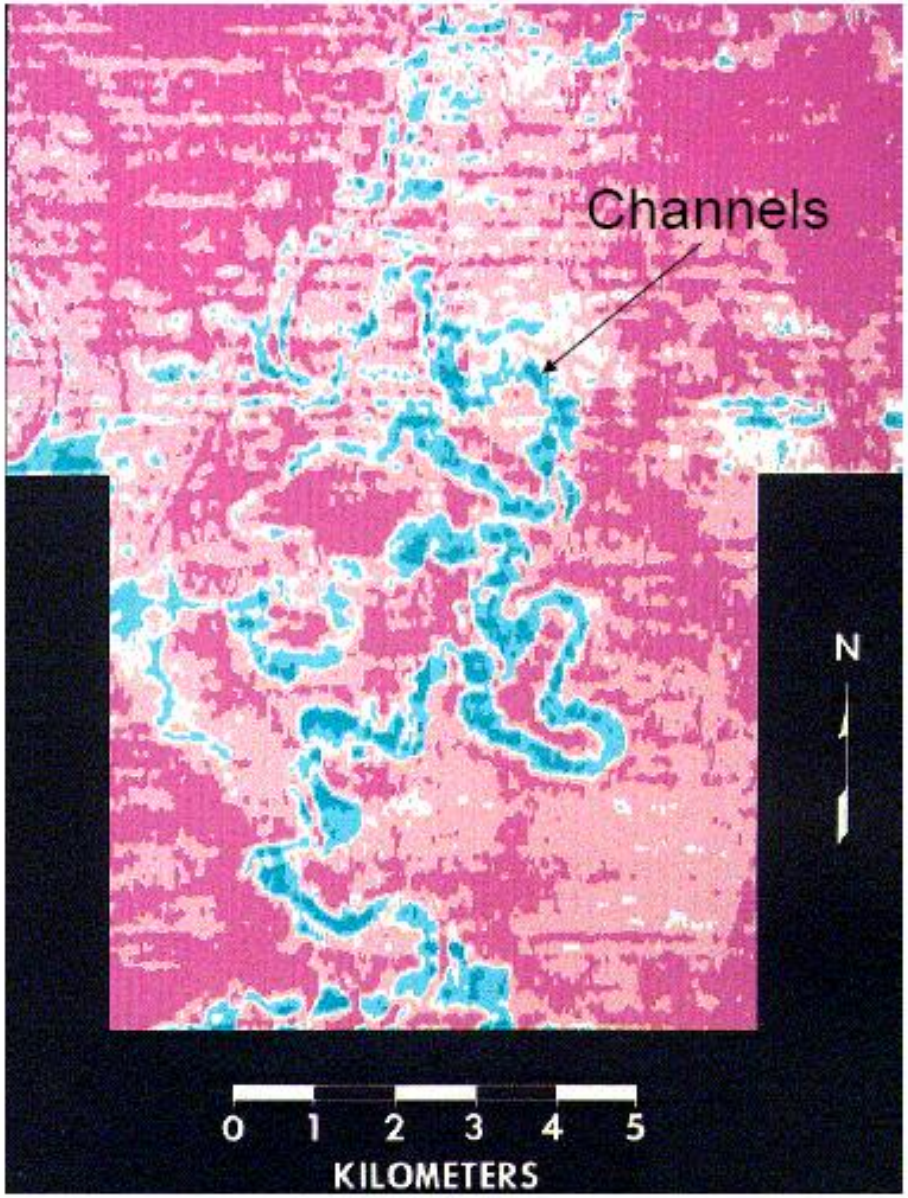




Gambaran kegiatan survai seismik di laut

Crossline 470 (East)





Seismic Amplitude Map of a Horizon

3-D Seismic data define reservoir-quality,channel-fill sand deposits

Modified from Brown, 1996