Lecture Five

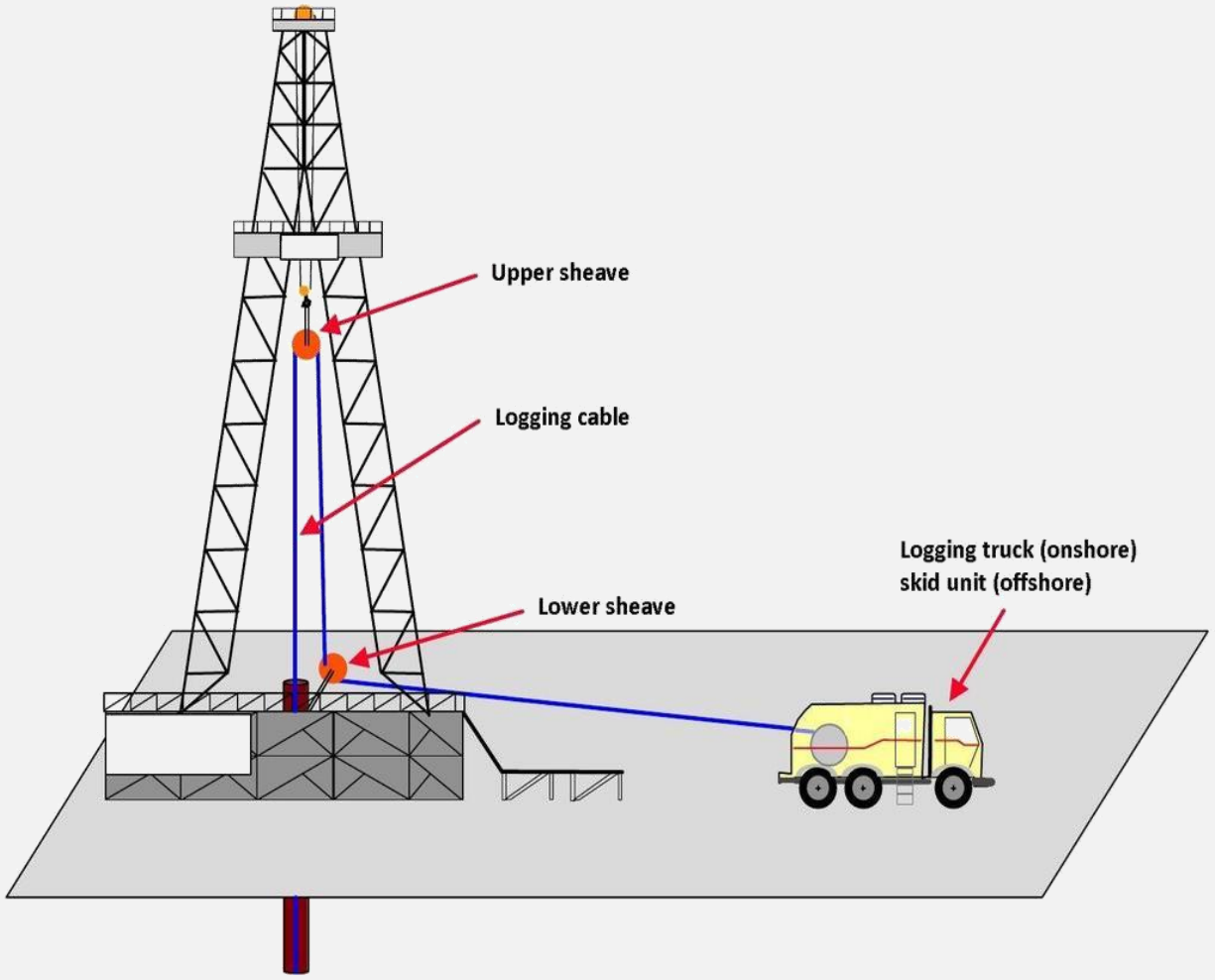
Well Logging in Formation Evaluation

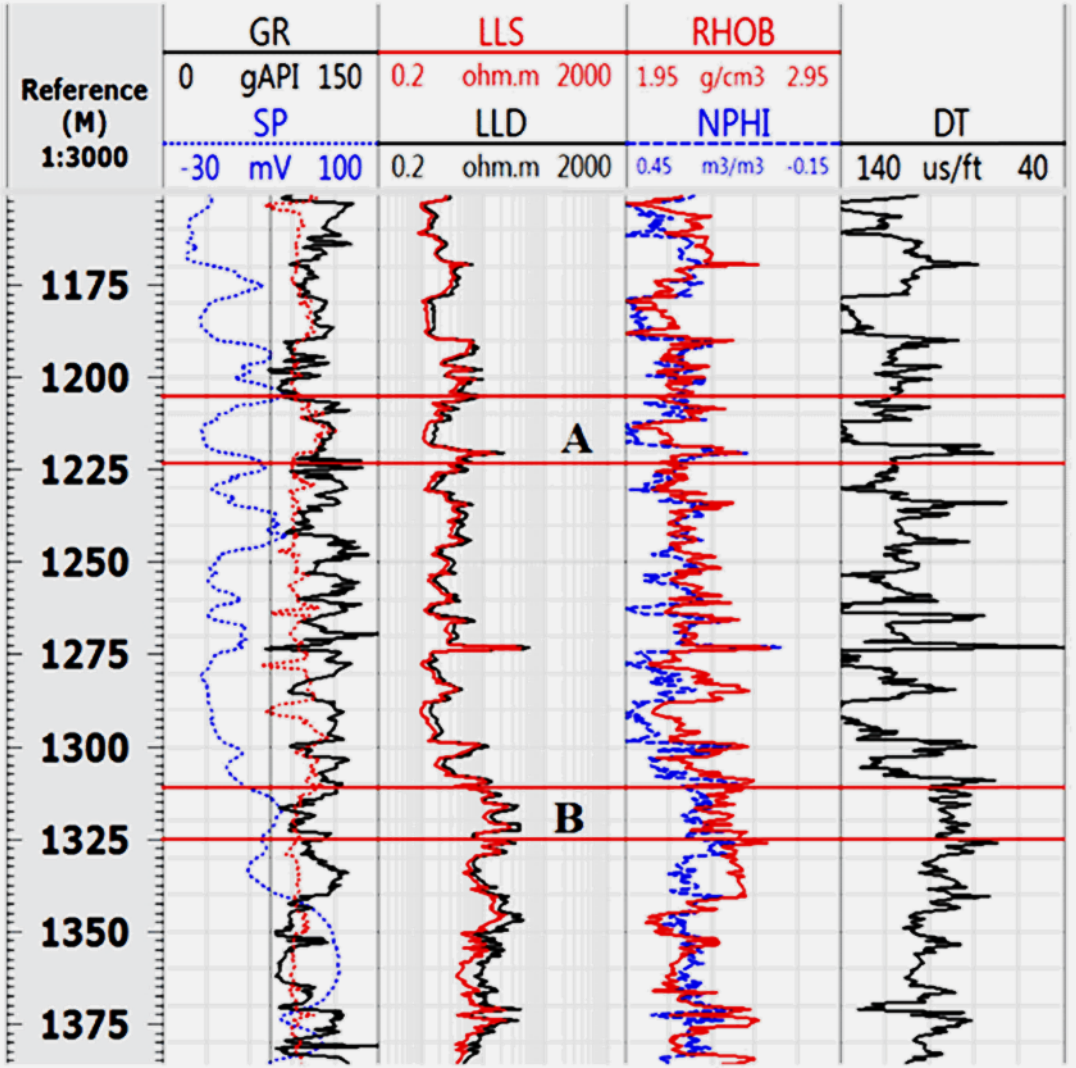
Petroleum & Mining Engineering Collage

Reservoir Engineering Department / Third Year

Dr. Maha Muneeb Al-Dabagh

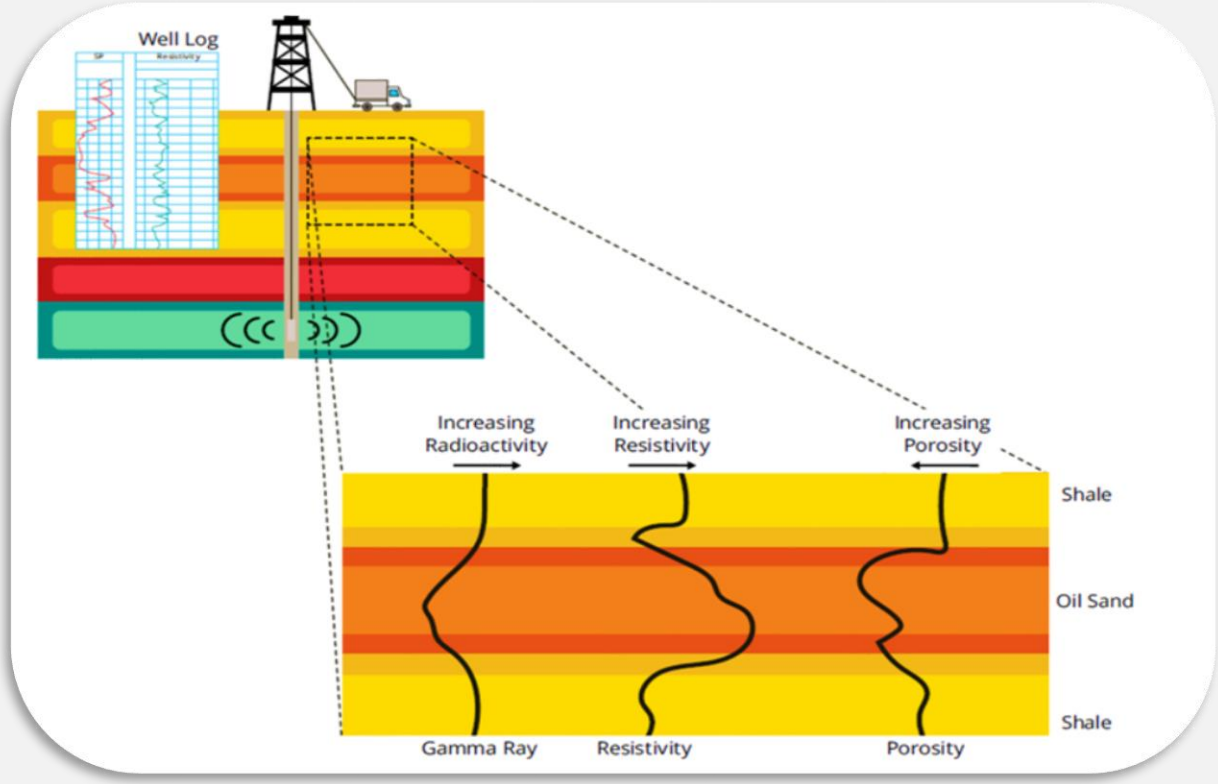
Well logs: *are continuous recordings of well depth versus different physical, chemical and electrical properties of the rocks and it's fluid contents through drilled borehole.*





Logging tools: *wide range of instruments that are lowered down a borehole to record the various properties of rock.*

Log: *is paper or digital continuous recording to physical property of the rock on one axis and depth on the other axis*



The Purpose of Log Measurements:

01.

Determining lithology, depth of formation and rock boundaries.

02.

Rock properties , rock composition and reservoir properties (porosity, saturation, permeability).

03.

Location of fluid contacts (e.g. gas/oil, gas/water and oil/water contacts).

04.

Estimate of the type and volume of hydrocarbon per cubic meter.

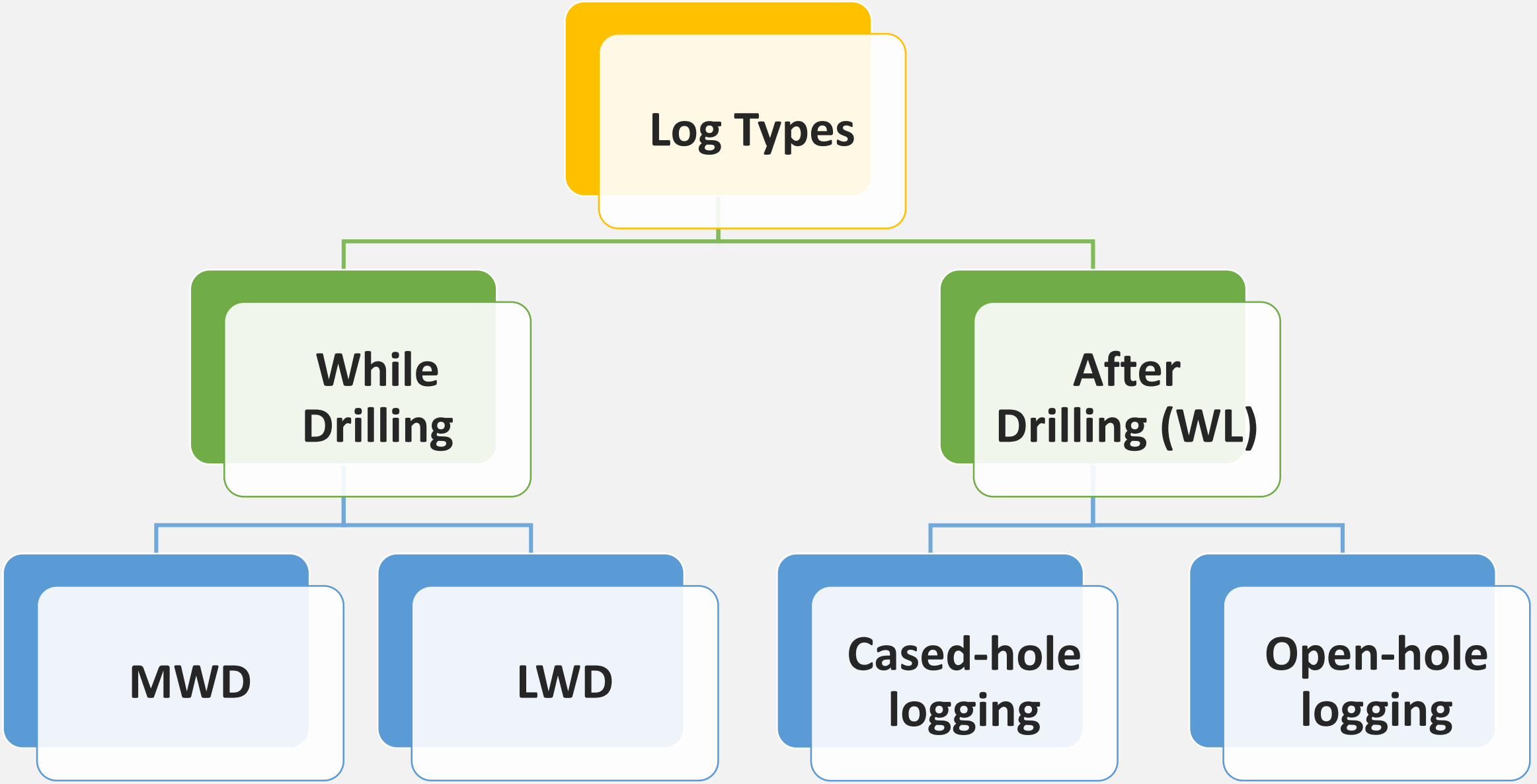
05.

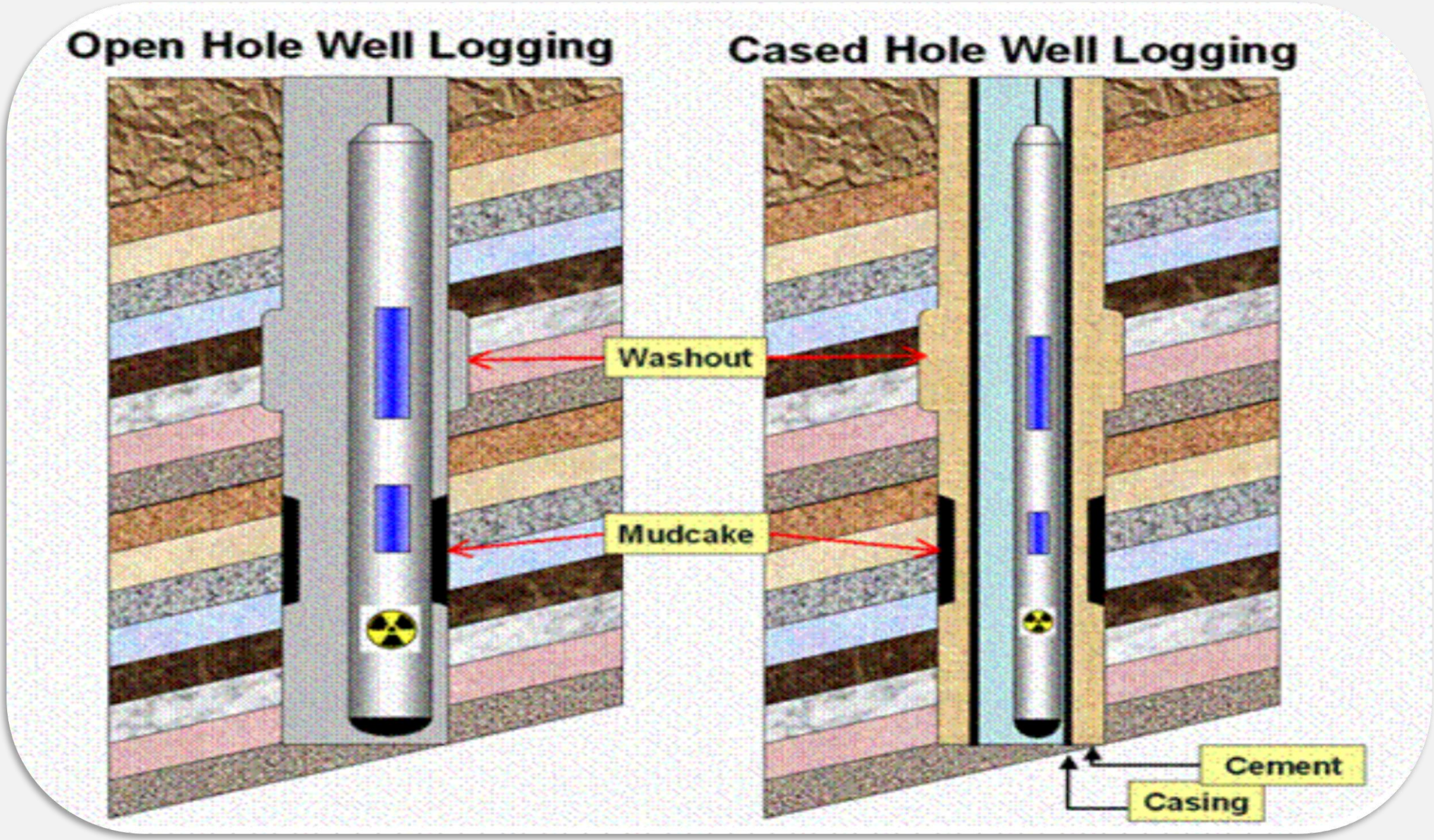
Identification of geological environments.

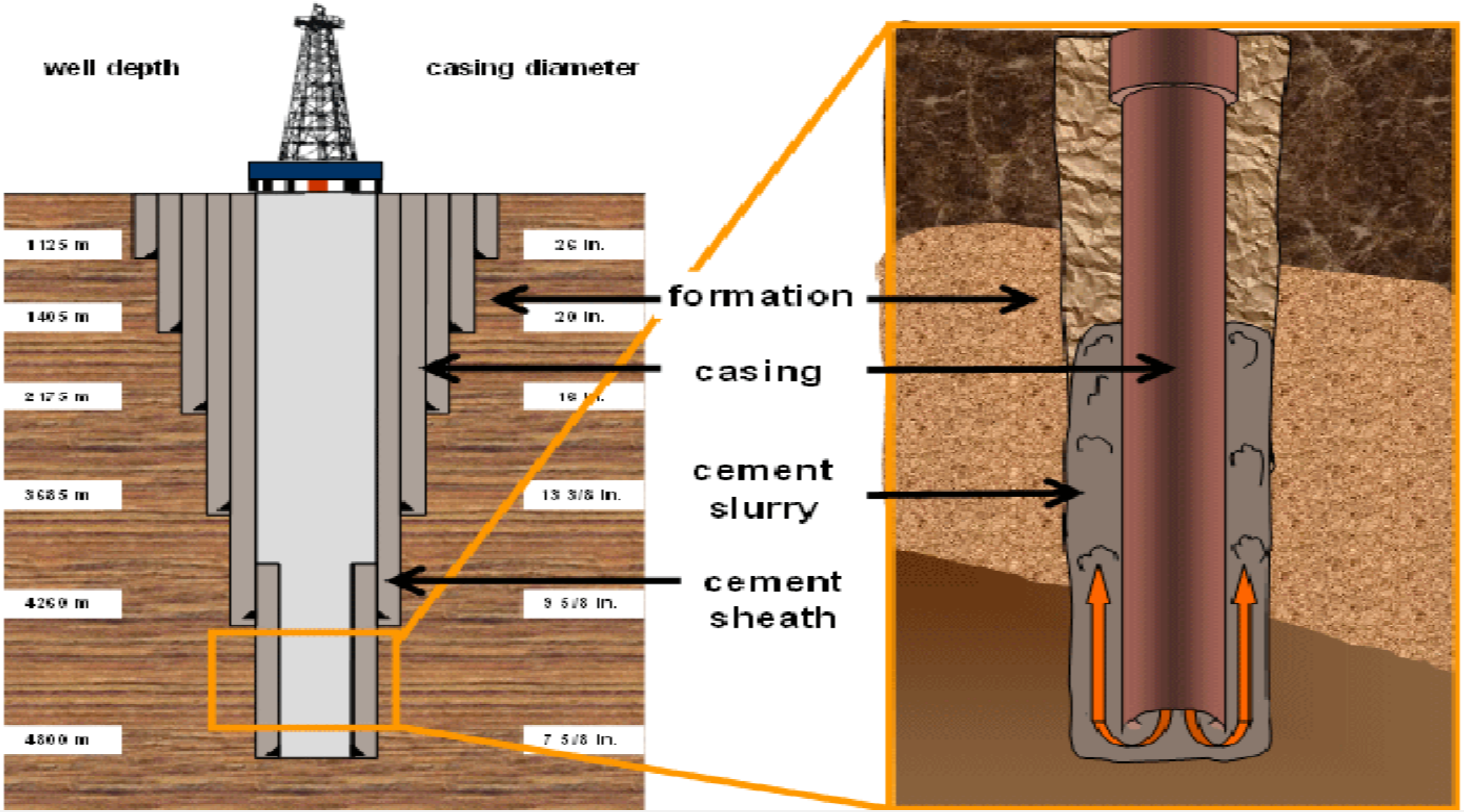
06.

Identification of reservoir pressure and Porosity/pore-size distribution.

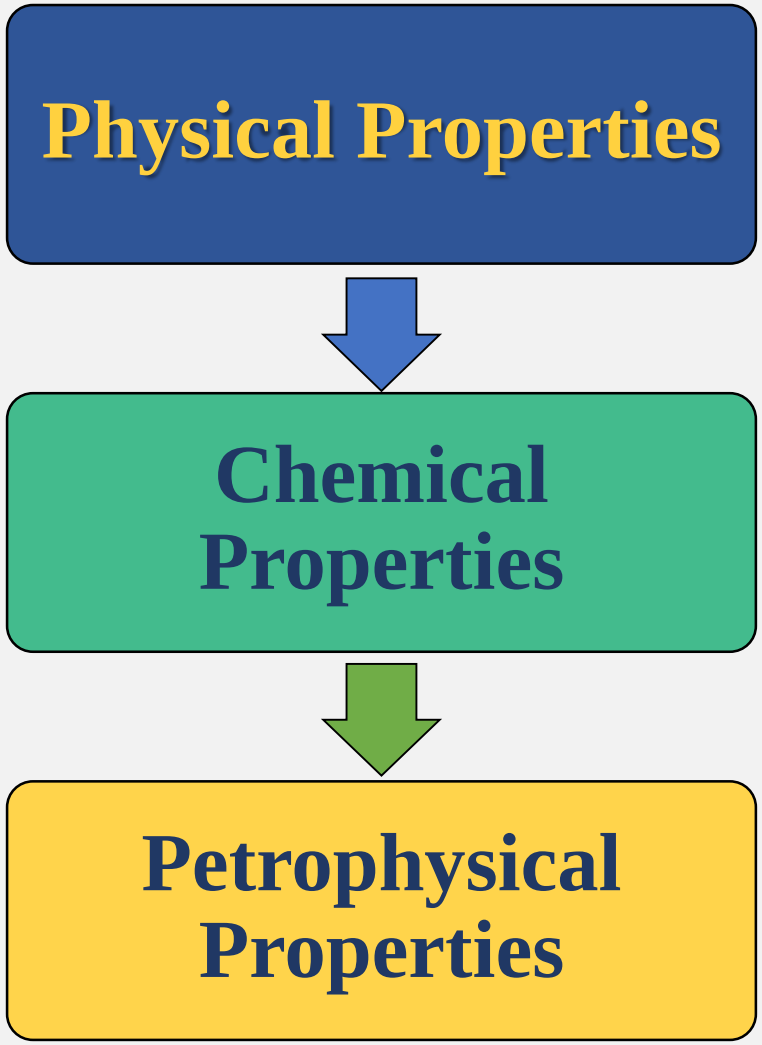
Basic Log Types:




Open Hole Well Logging
Cased Hole Well Logging
Washout
Mudcake
Cement
Casing


well depth
casing diameter
1125 m
1405 m
2175 m
3685 m
4260 m
4800 m
26 in.
20 in.
18 in.
13 3/8 in.
9 5/8 in.
7 5/8 in.
formation
casing
cement slurry
cement sheath

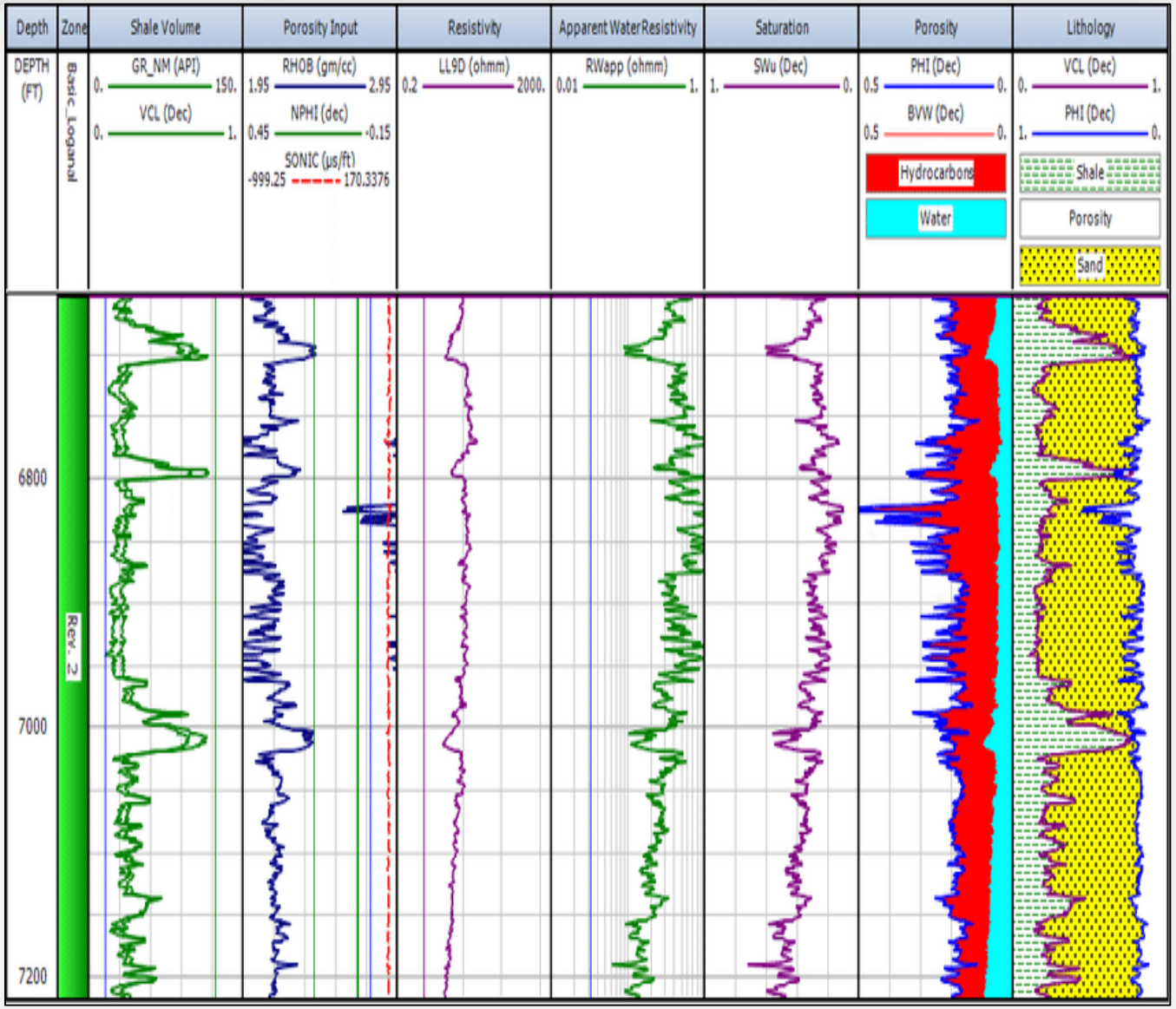
Rock Properties:



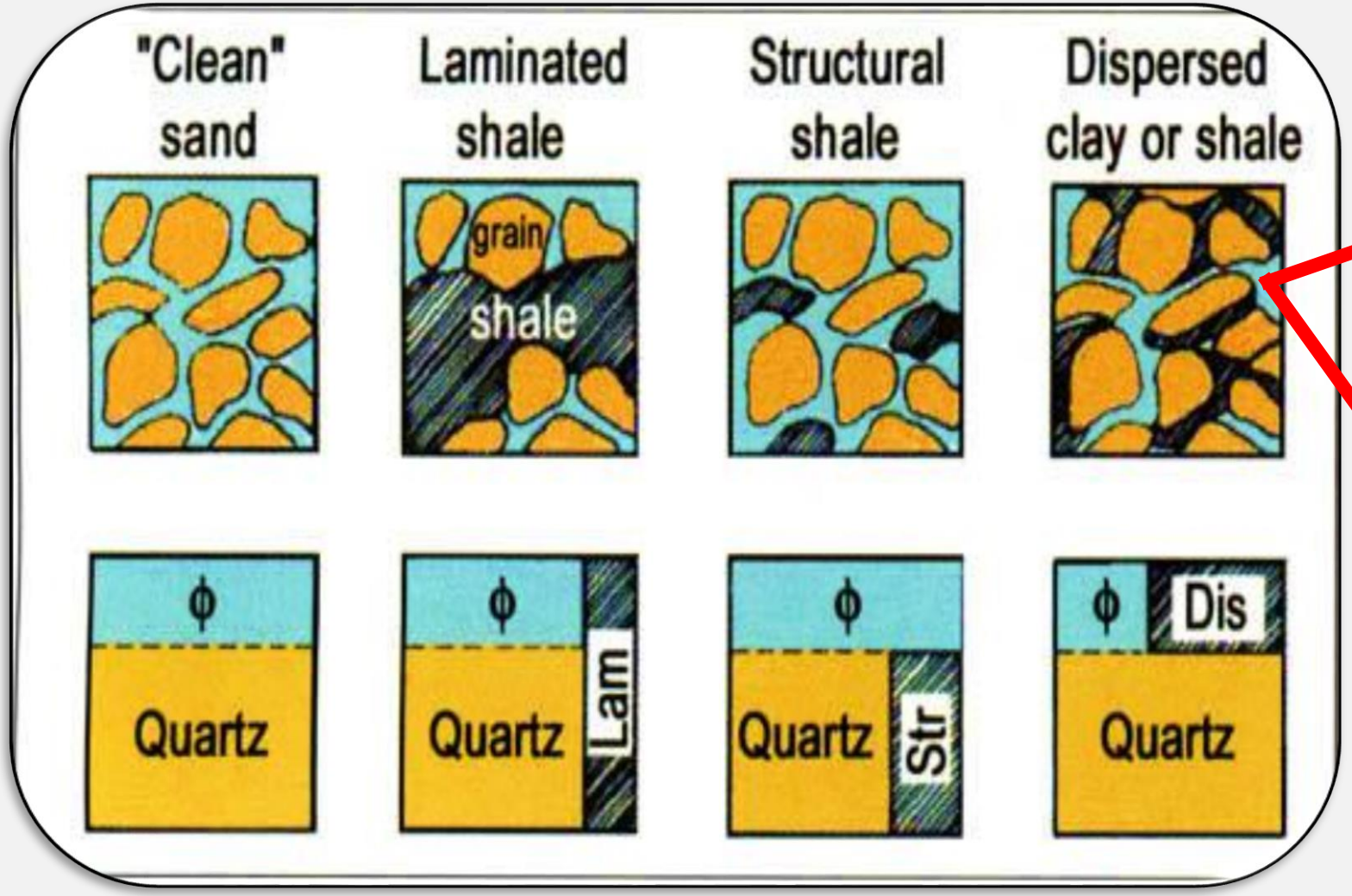
Factors Affecting the Petrophysical Properties:

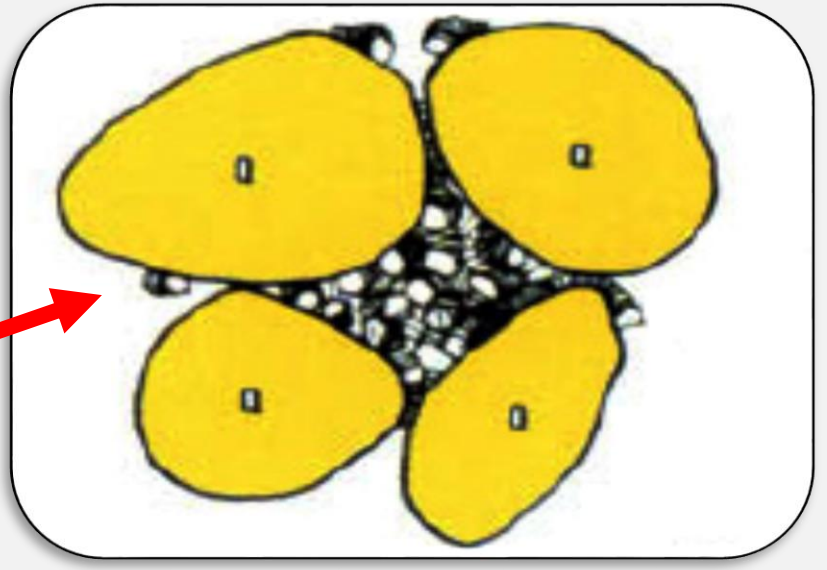
- **The lithology**
- **Claystones and shales**

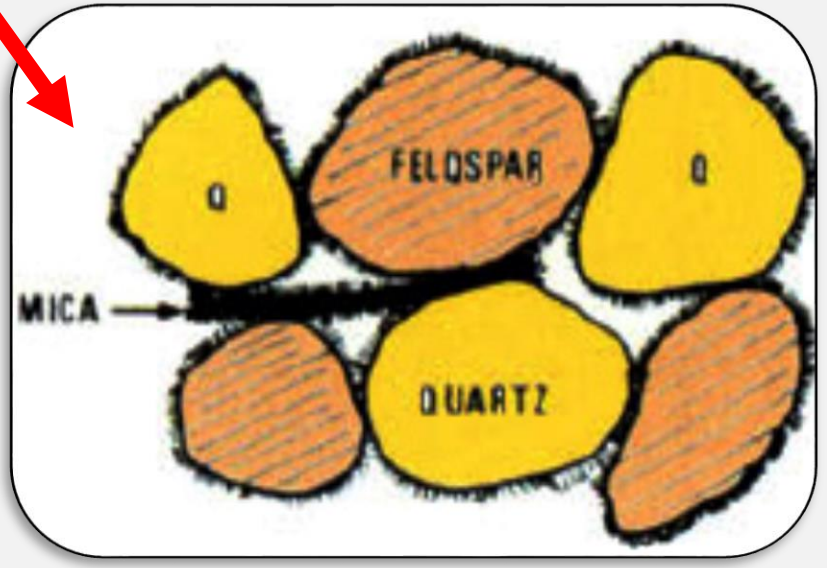
The amount of **clay water** varies according to the **clay type**, being ***higher*** for ***finer*** clays, such as ***Montmorillonite***, and ***lower*** for ***coarser*** clays, such as ***Kaolinite***



Clay Distribution



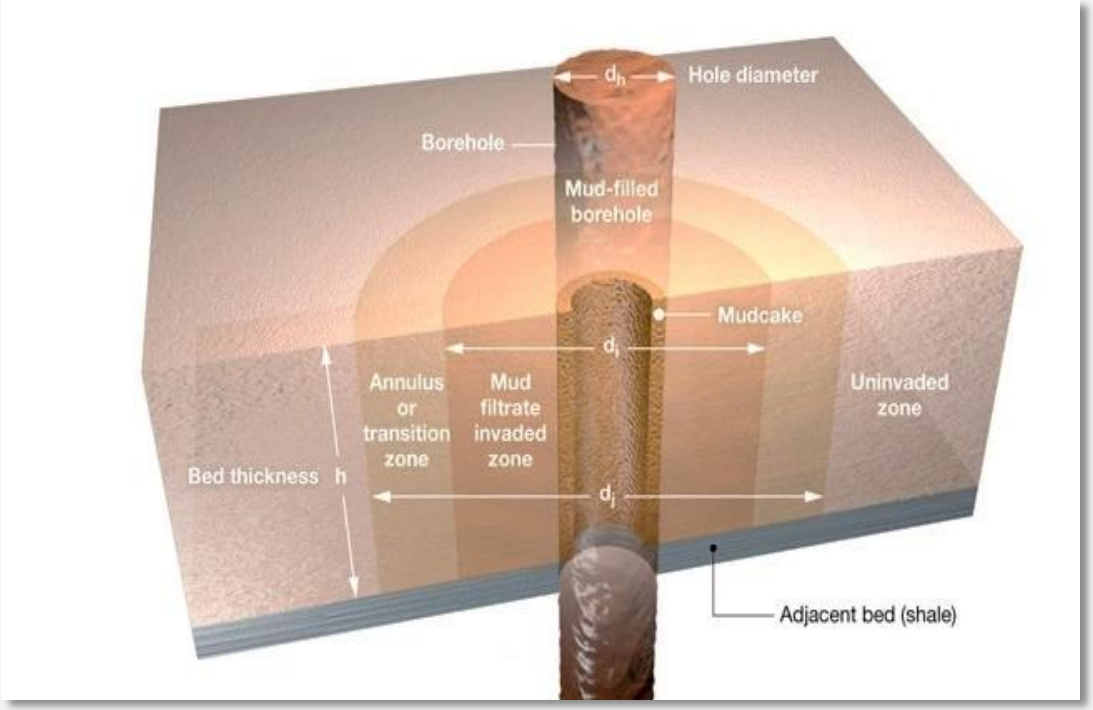


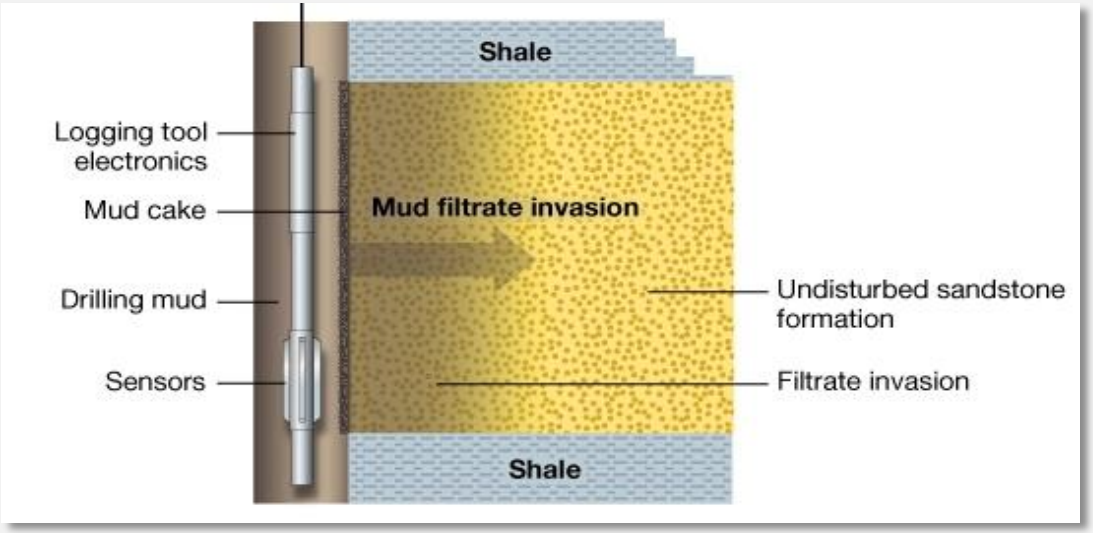


Borehole Environment

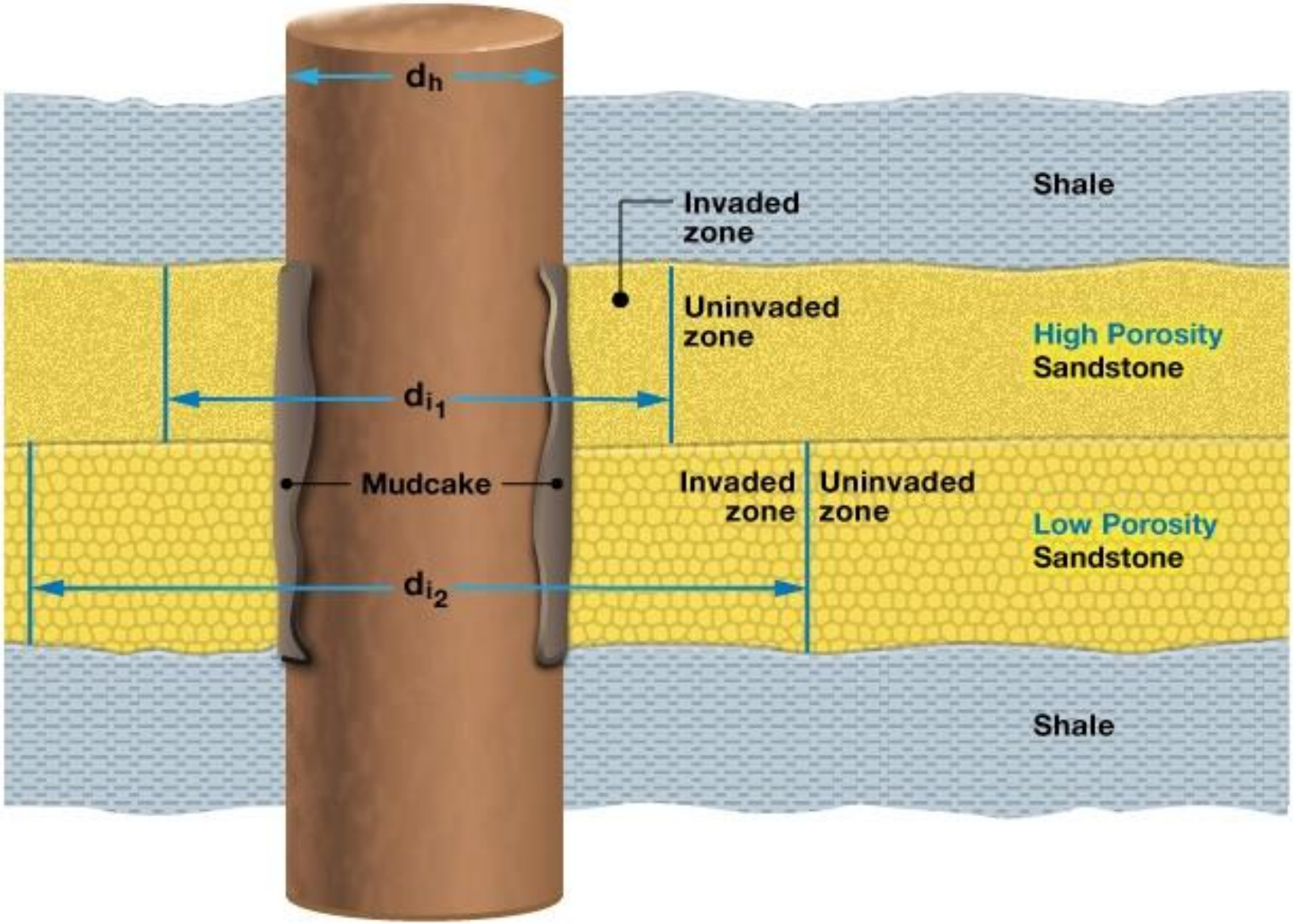
- Wireline log measurements respond to ***rock properties*** and the ***properties of the fluids in the pore space***.

- The nature of the fluids in the pore space immediately surrounding the borehole depends upon the ***amount and type of mud filtrate that invades the formation.***





Invaded and uninvaded reservoir zones



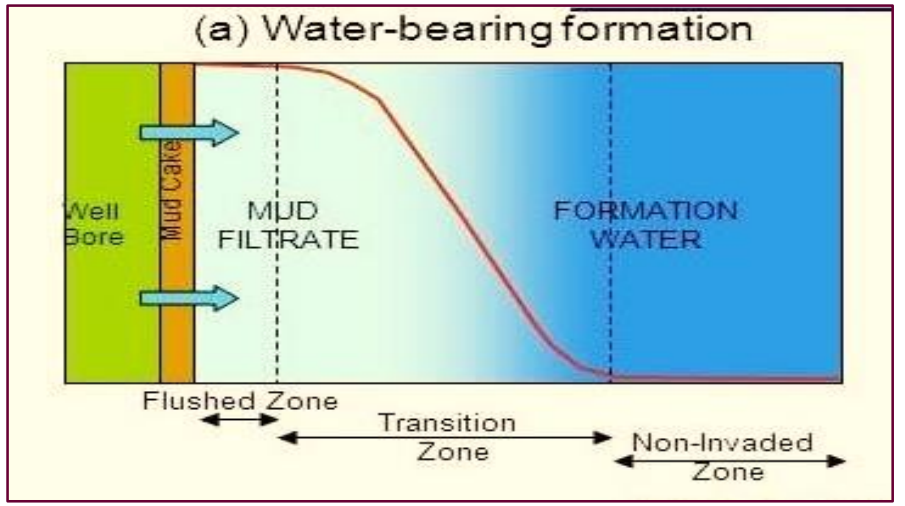
Fluid Drilling Mud

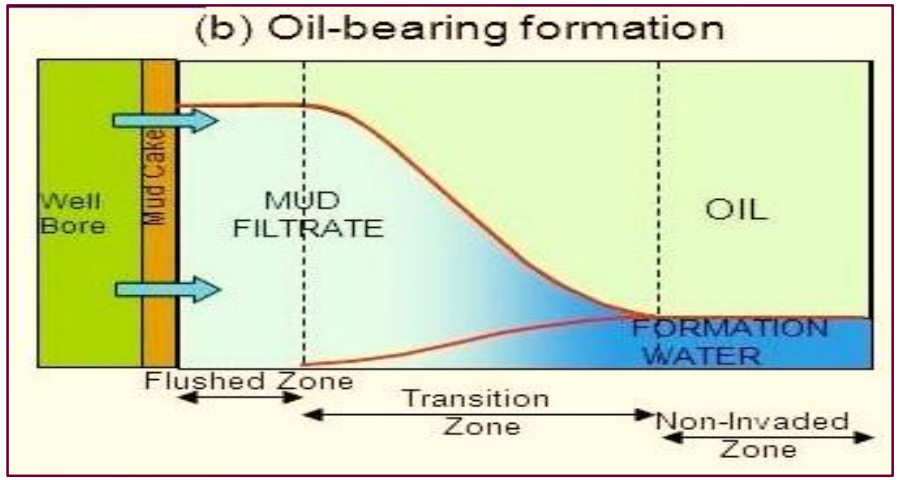
There are two main types of fluid drilling: ***Water-Based mud (WBM) and Oil-Based mud (OBM)***.

1- Invasion with Water – Based Drilling Muds

- In *Water-Bearing Formations,* the mud filtrate ***replaces all*** of the formation water close to the borehole and this decrease with depth of invasion.

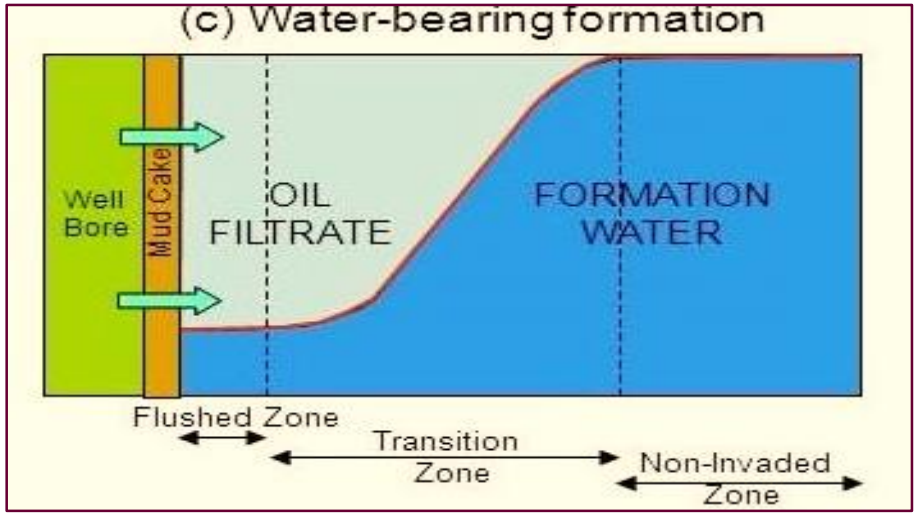
In *Oil-Bearing Formations,* the mud filtrate ***replaces all*** the formation water and ***most of the oil*** close to the borehole wall, again decreasing with distance into the formation



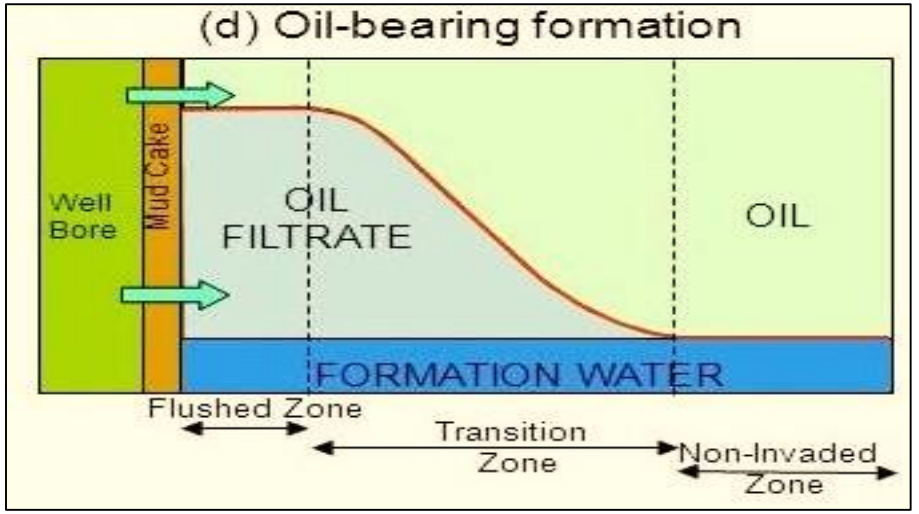


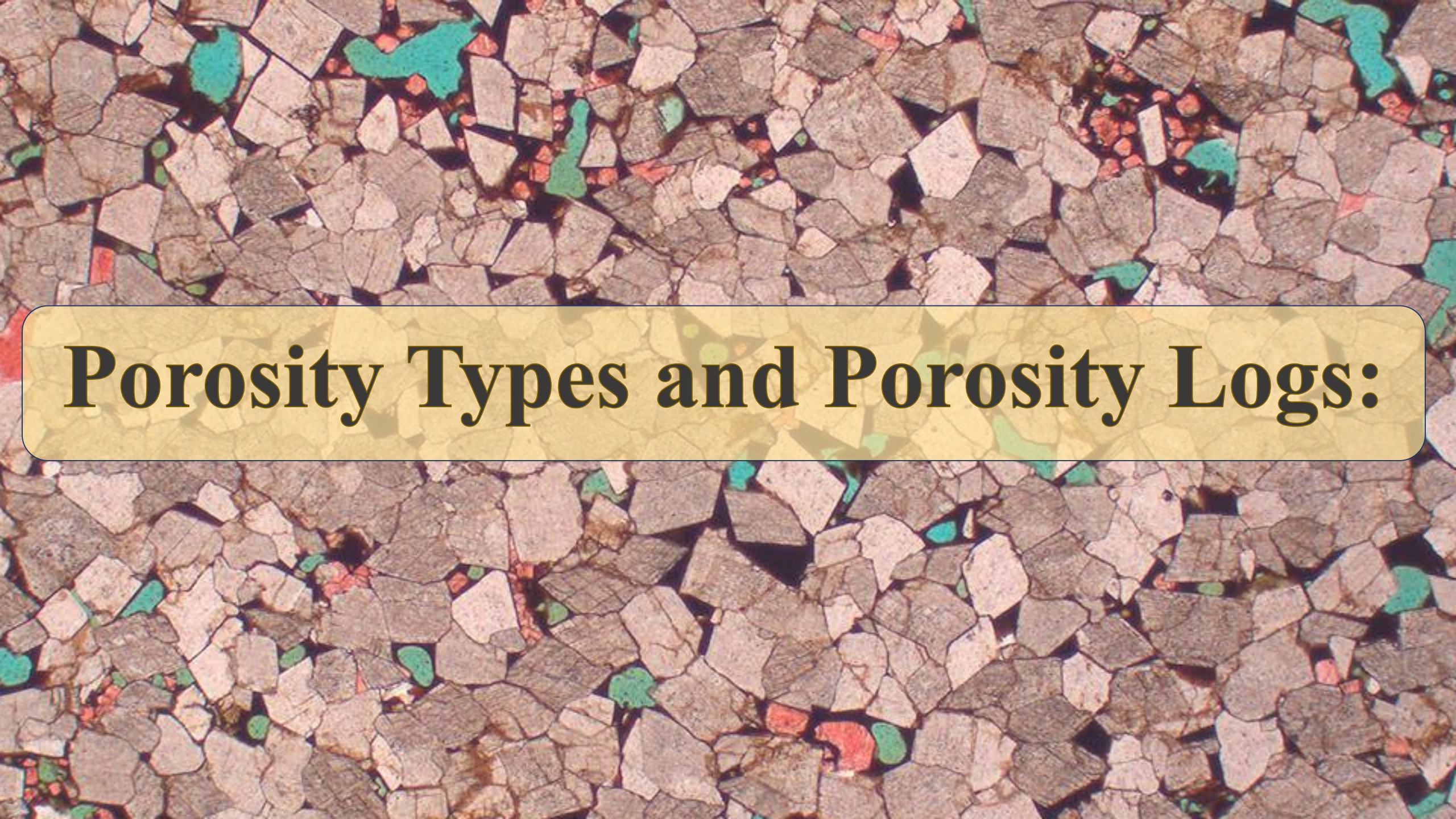
2- Invasion with Oil – Based Drilling Muds

- In *Water-Bearing Formations,* the oil-based mud filtrate ***does not replace*** all the formation water even close to the borehole wall.



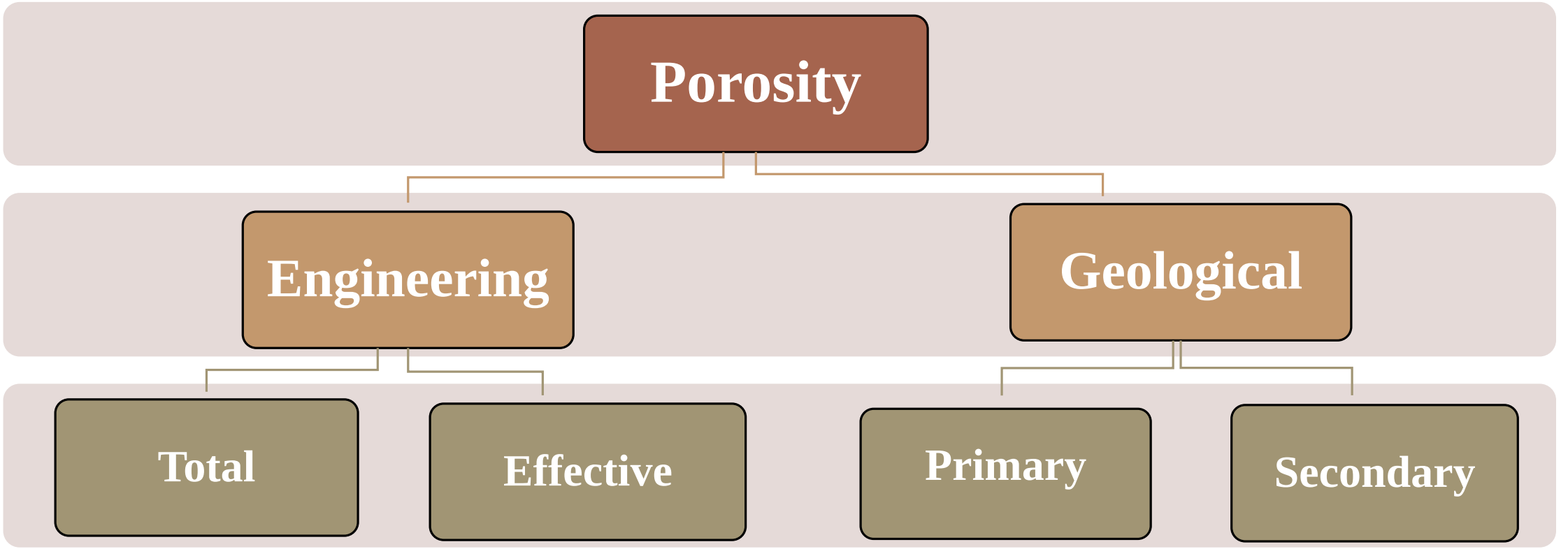
- In *Oil-Bearing Formations,* the oil-based mud filtrate ***only replaces*** the oil in the formation, leaving the formation water in place.





Porosity Types and Porosity Logs:

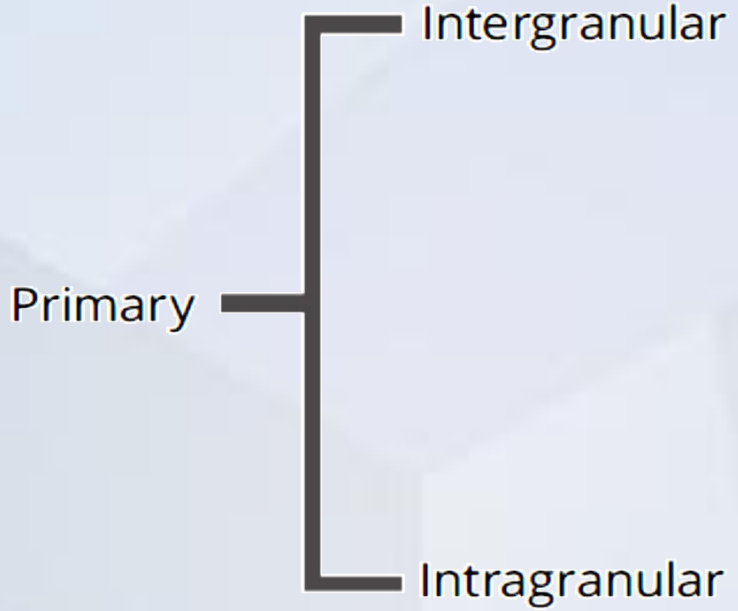
Porosity Classification

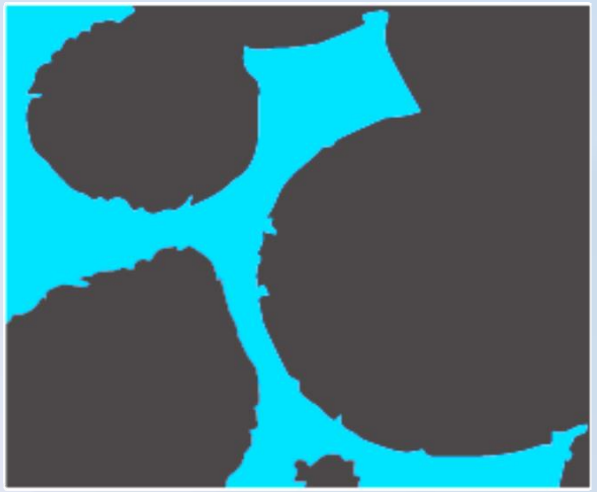


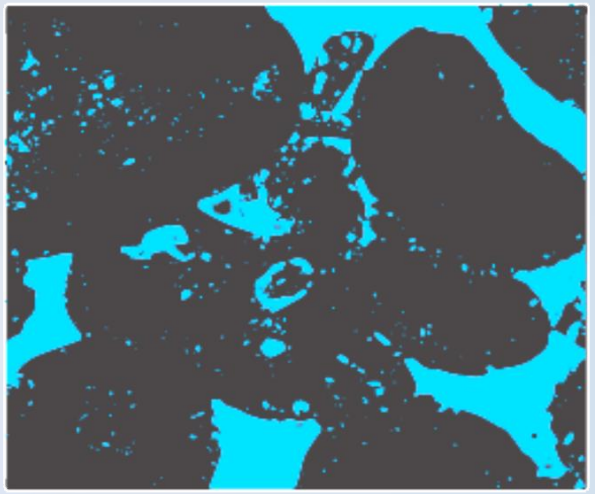
Porosity types

1- Geological Classification:

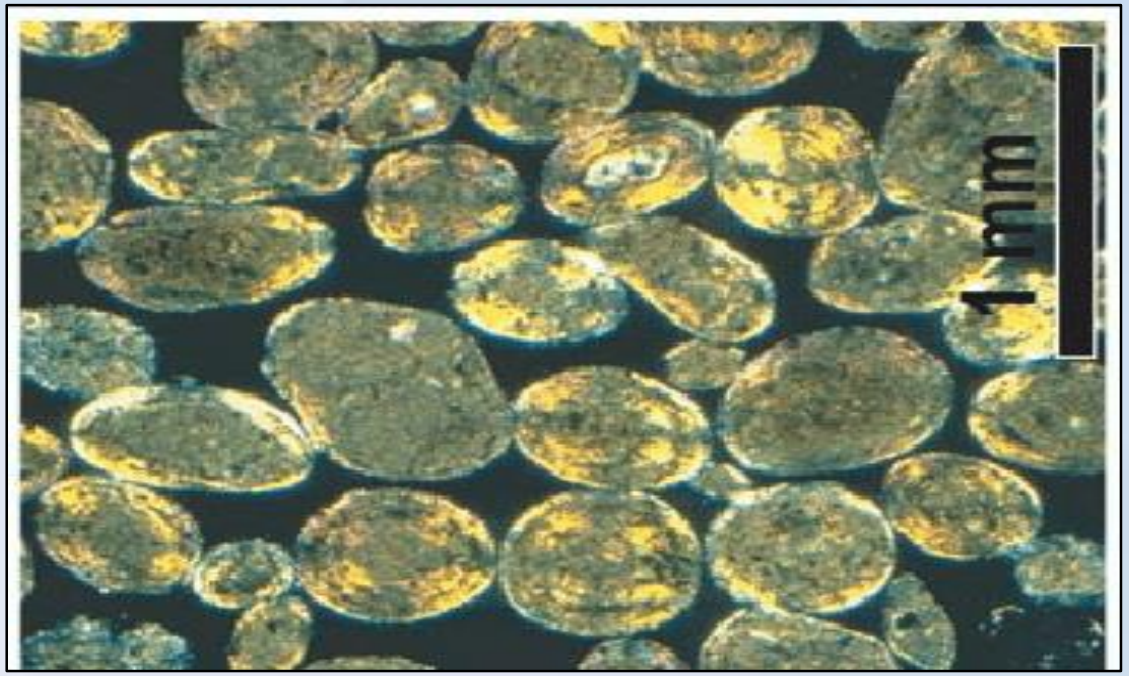
A- *Primary Porosity*: developed during deposition of the sediment, same as ***Intergranular (Interparticles)*** **porosity, *Intragranular* porosity.**



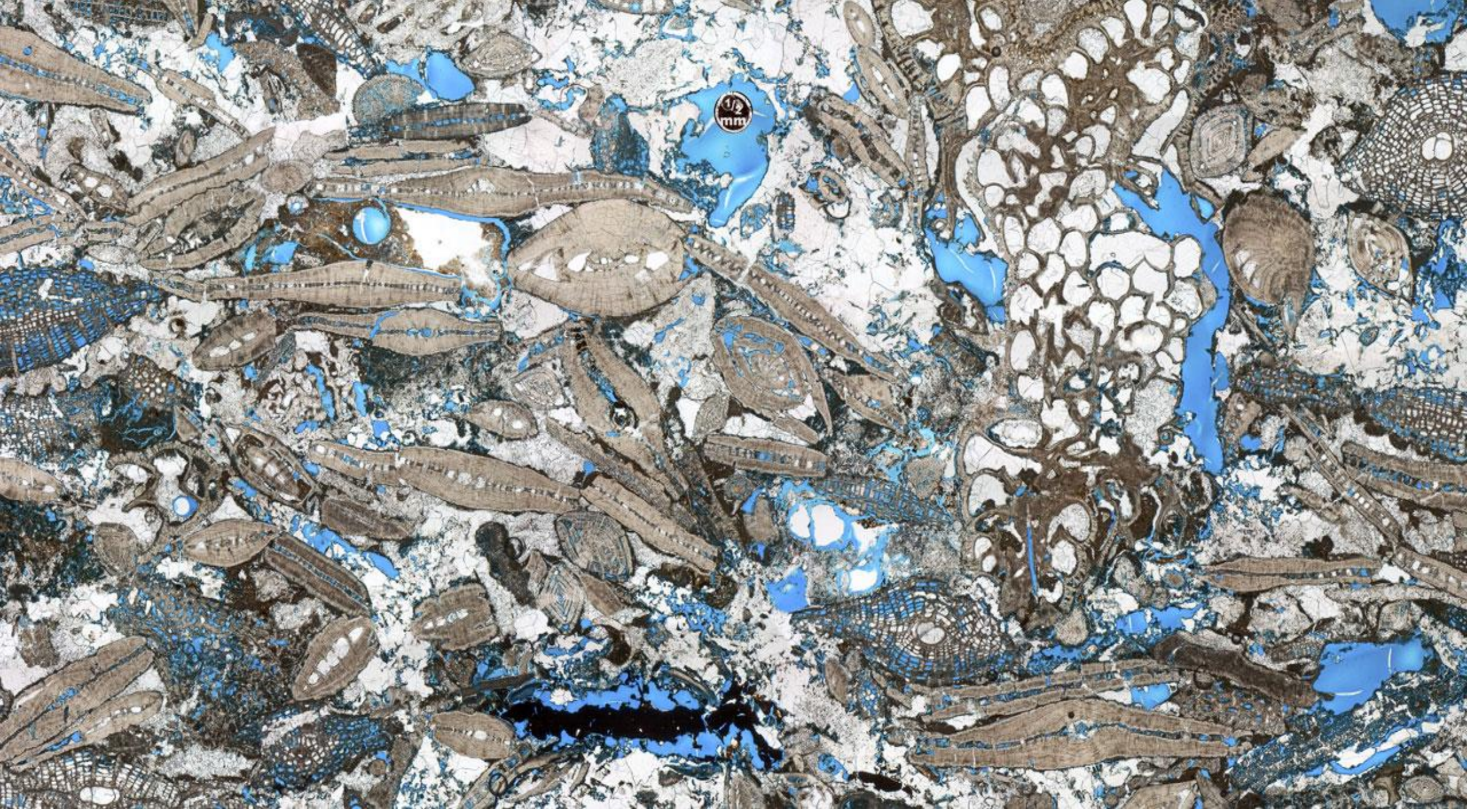




Interparticle Porosity (Carbonate):
Each grain is separated, giving a similar pore space arrangement as sandstone.



Intragranular Porosity:
The porosity due to voids within the rock grains.

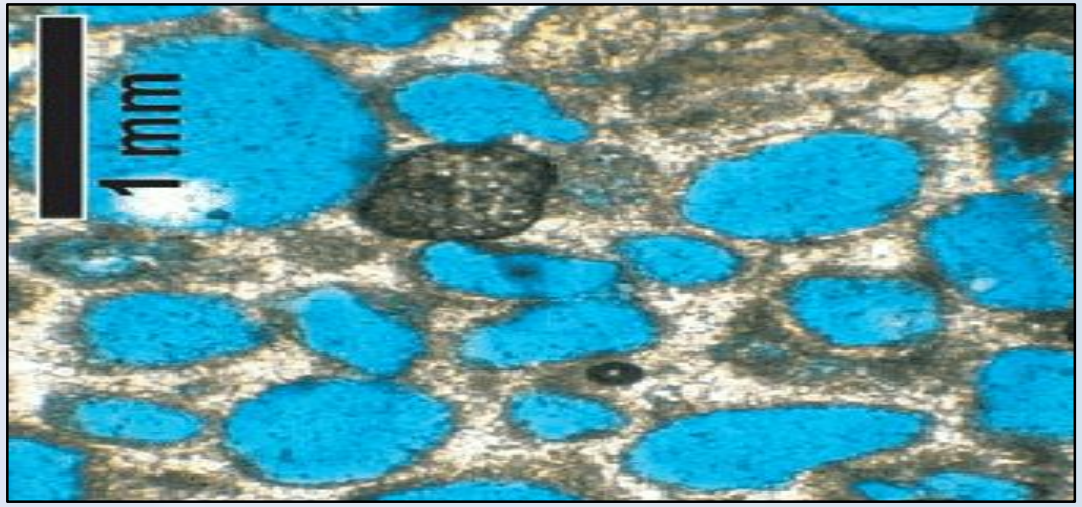

1/2
mm

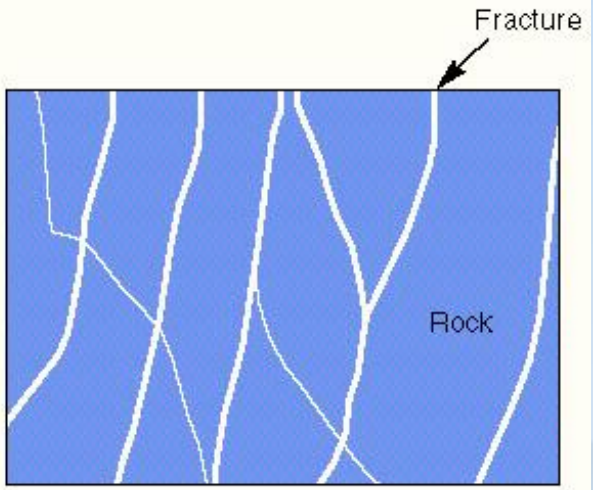
B-*Secondary Porosity*: developed by some geologic process after the deposition of the rock.

Secondary porosity is more diverse in morphology and more complex in genesis than primary porosity.

Intercrystalline Porosity:
Produced by spaces between carbonate crystals.

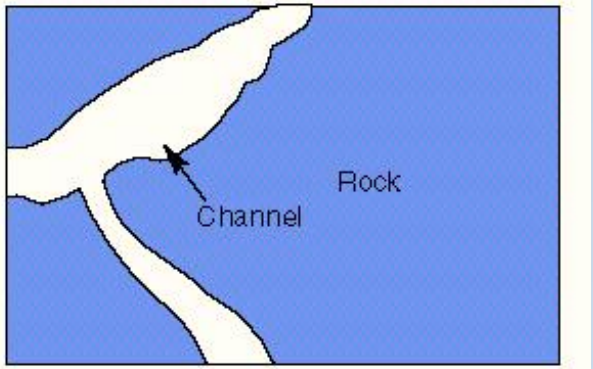
Moldic Porosity:
Pores created by the dissolution of grains or fossil remains.





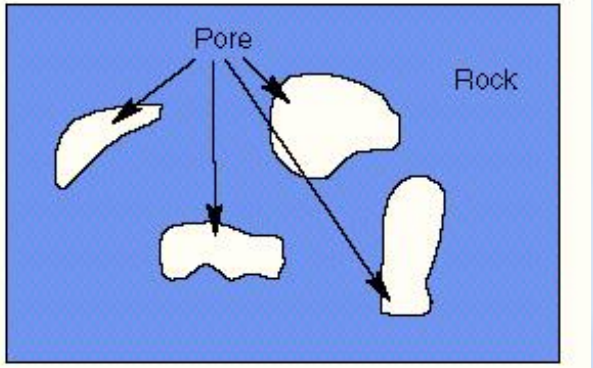
Fracture (Fissure) Porosity:

Pore spacing created by the cracking of the rock fabric.



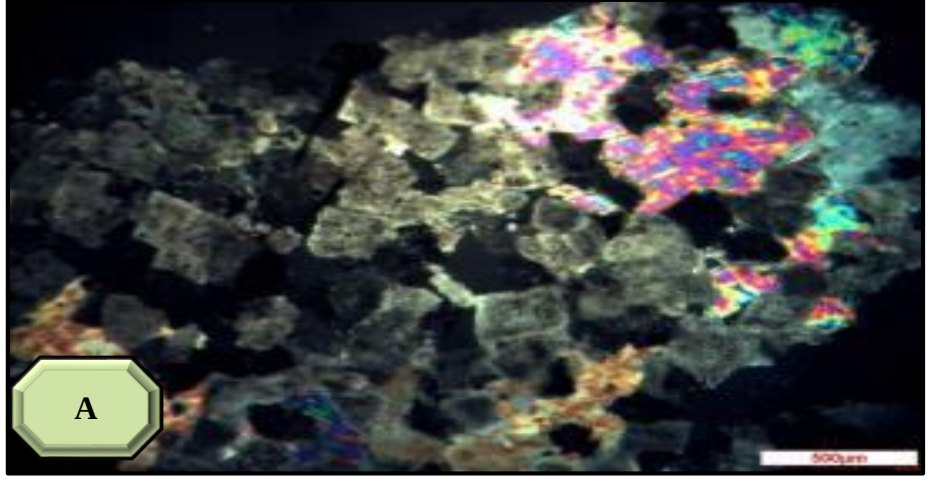
Channel Porosity:

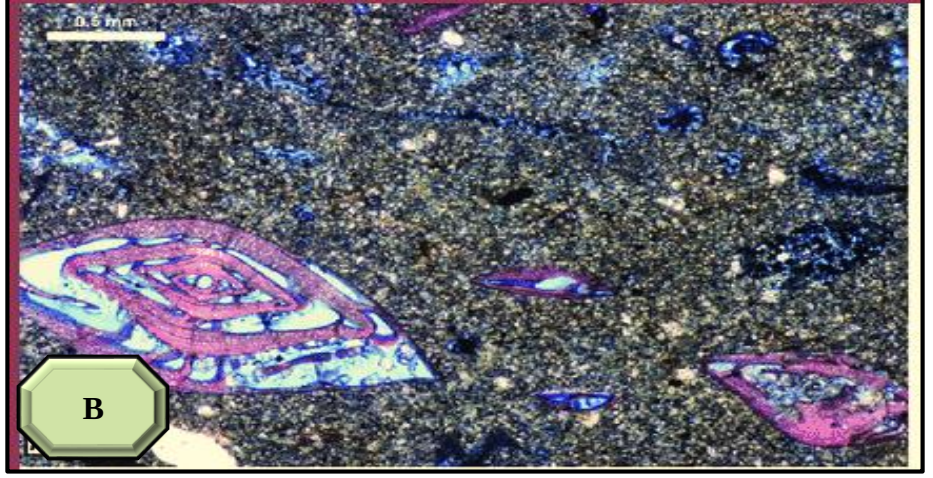
Similar to fracture porosity but larger.

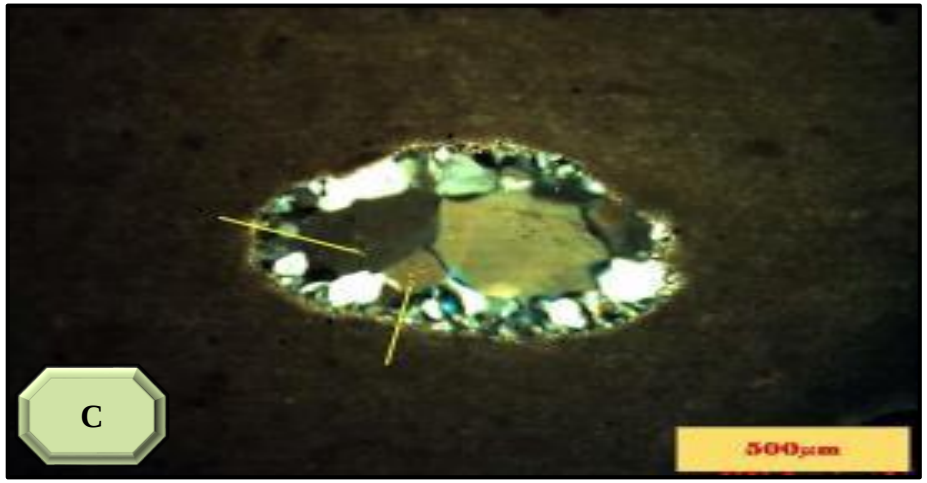


Vuggy Porosity:

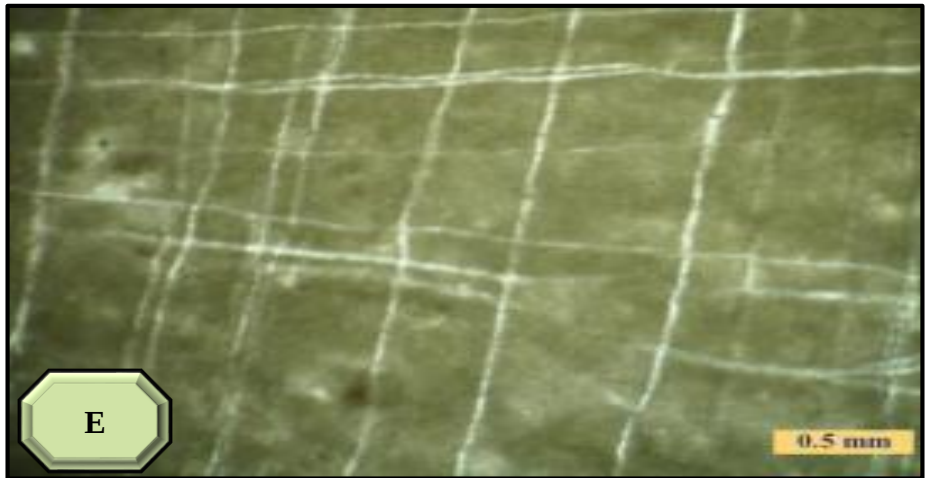
Created by the dissolution of fragments, but unconnected.

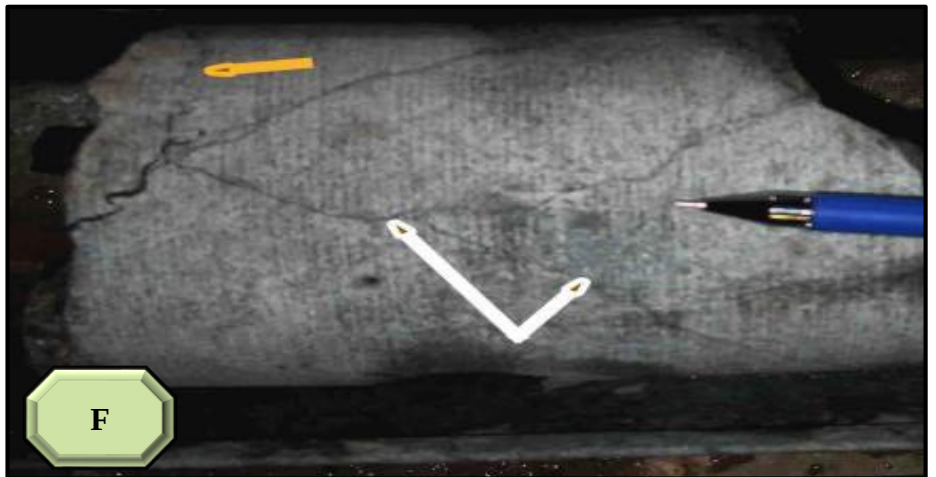

A

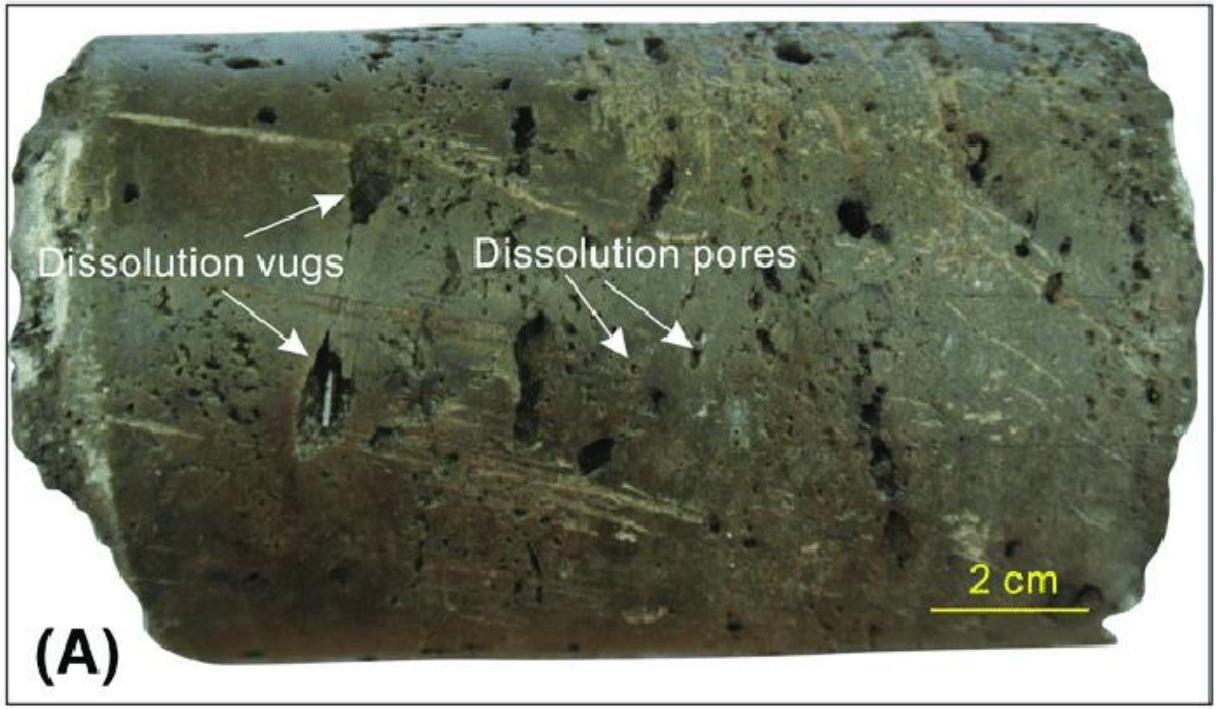

B

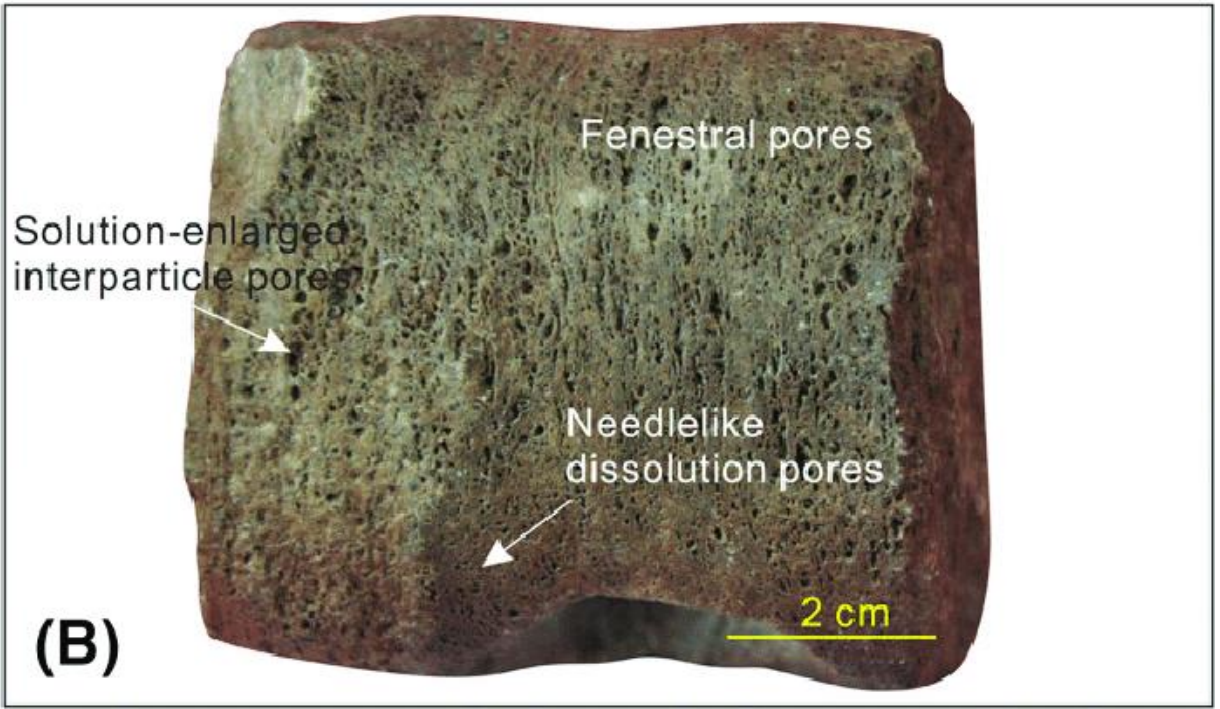

C
500µm

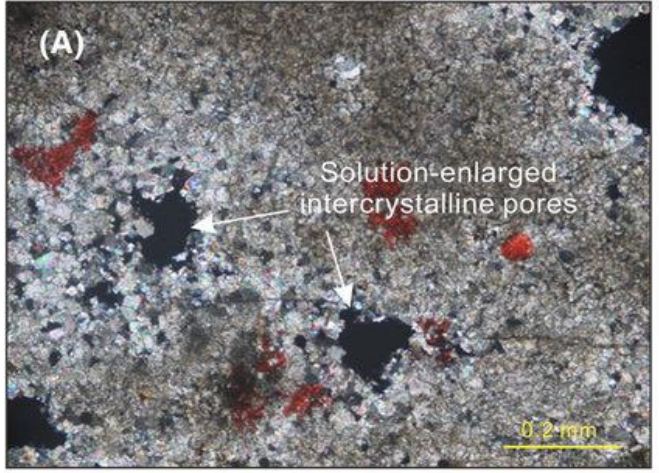

D

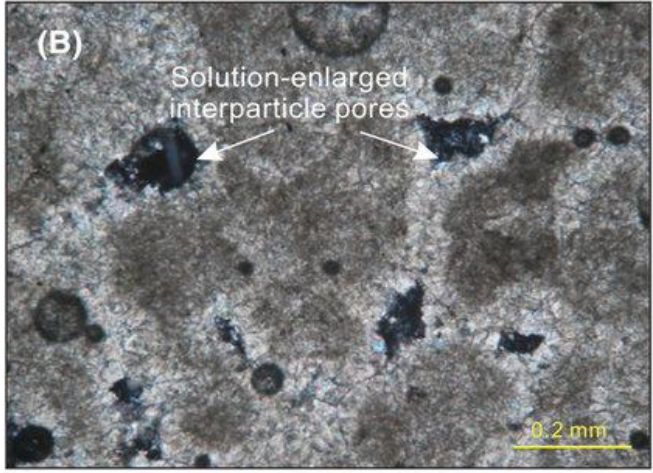

E
0.5 mm

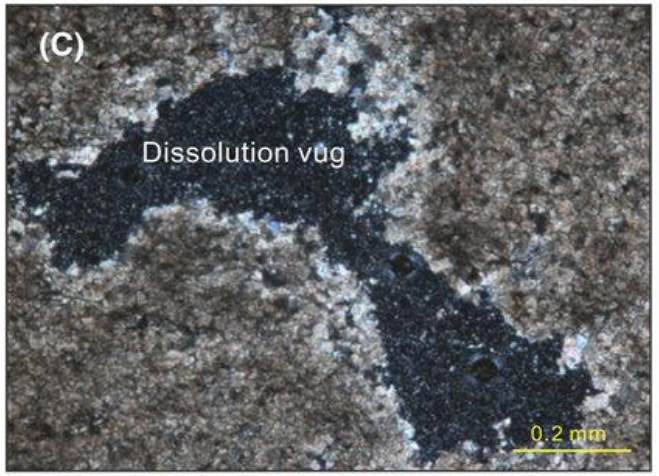

F

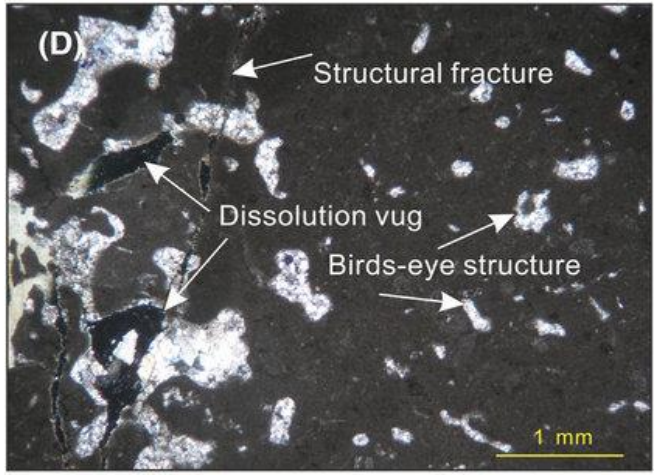

Dissolution vugs
Dissolution pores
2 cm
(A)

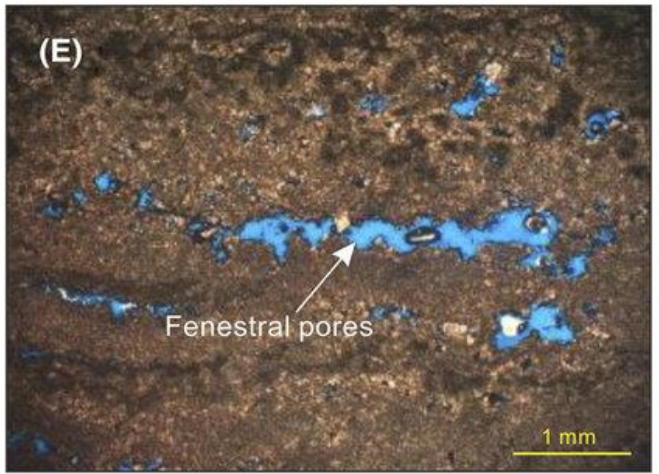

Fenestral pores
Solution-enlarged interparticle pores
Needlelike dissolution pores
2 cm
(B)

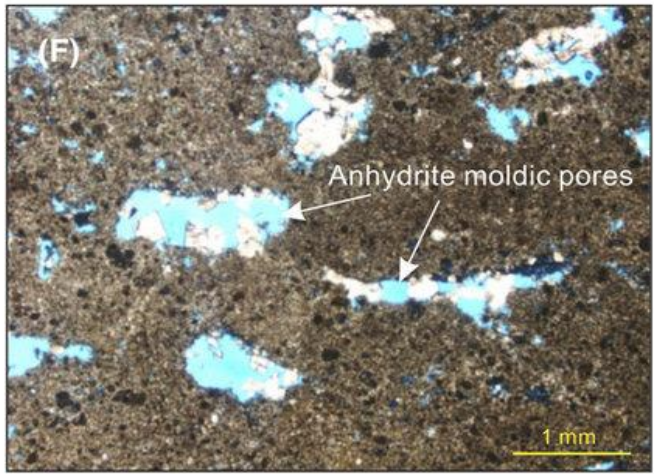

(A)
Solution-enlarged intercrystalline pores
0.2 mm

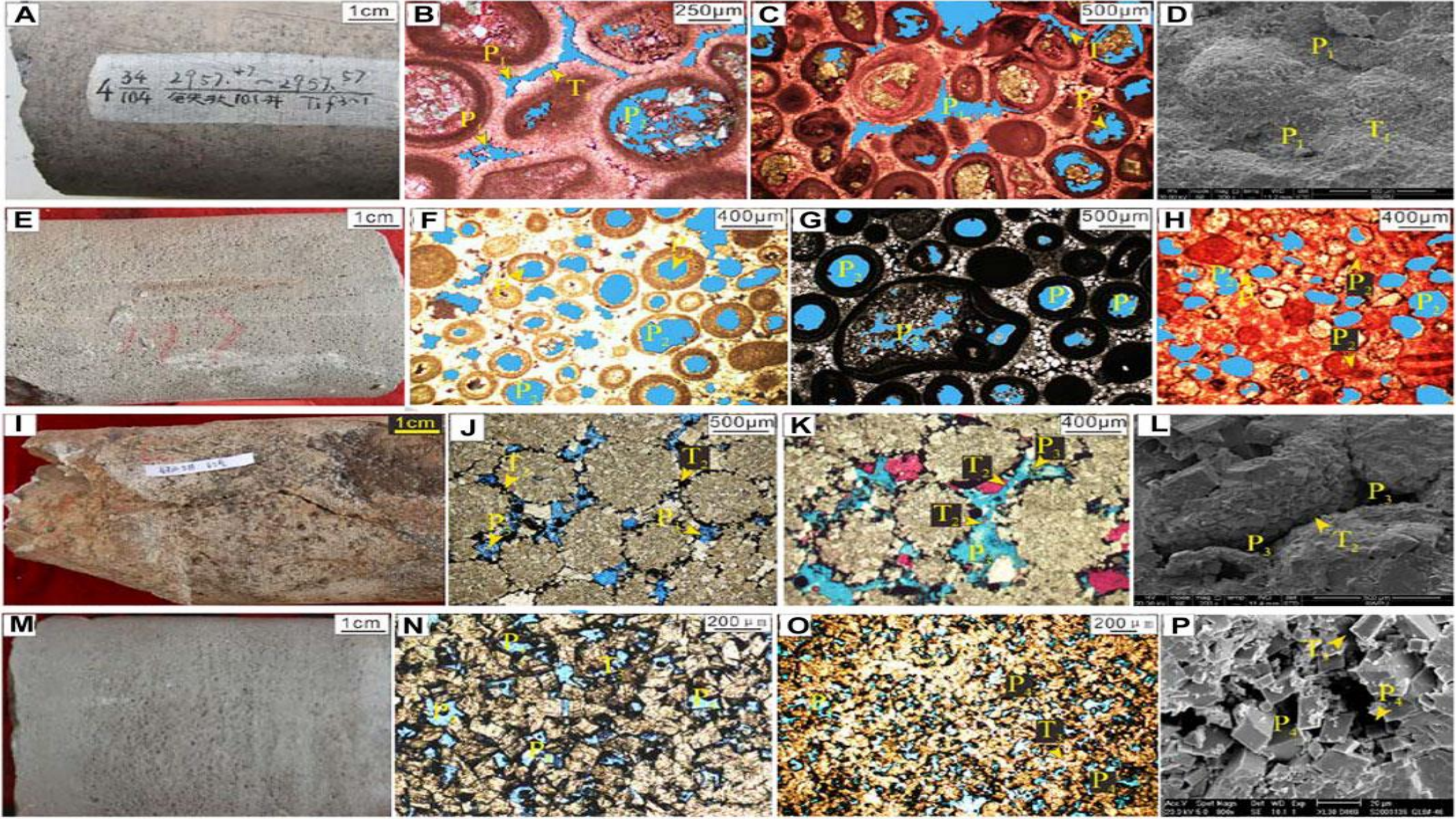

(B)
Solution-enlarged interparticle pores
0.2 mm

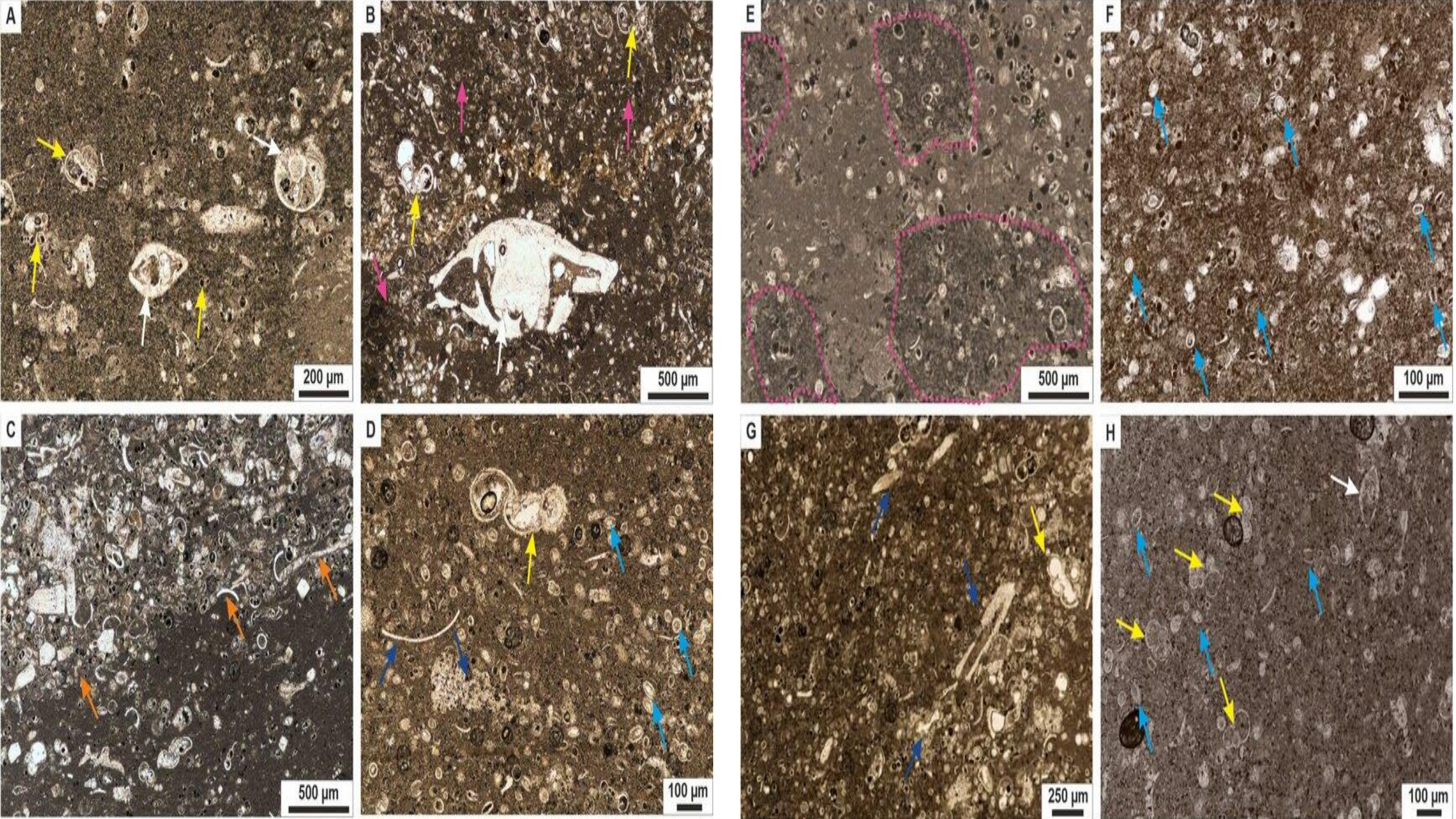

(C)
Dissolution vug
0.2 mm

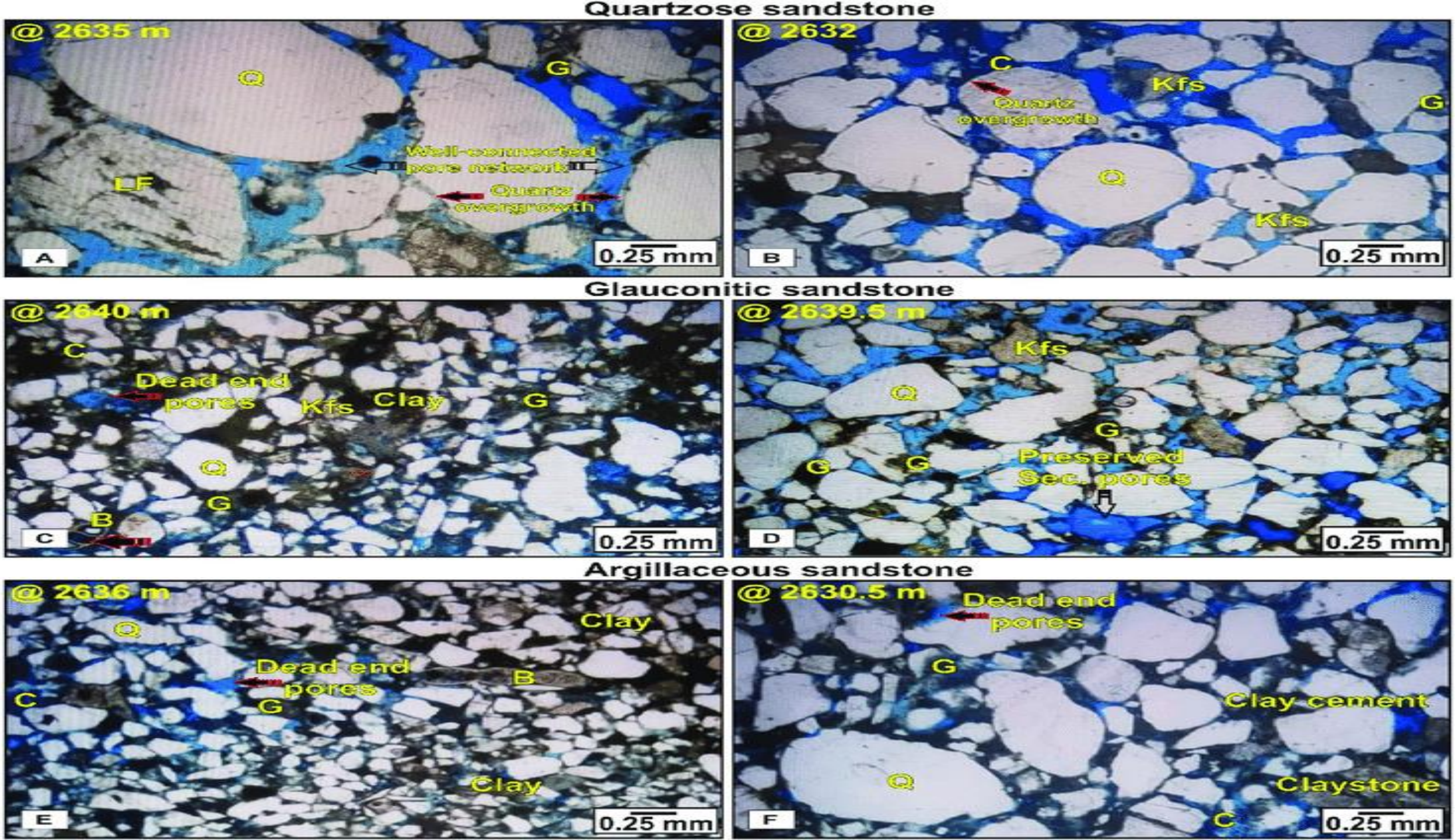

(D)
Structural fracture
Dissolution vug
Birds-eye structure
1 mm


(E)
Fenestral pores
1 mm


(F)
Anhydrite moldic pores
1 mm


A
1cm
B
250μm
C
500μm
D
E
1cm
F
400μm
G
500μm
H
400μm
I
1cm
J
500μm
K
400μm
L
M
1cm
N
200 μm
O
200 μm
P


A
200 µm
B
500 µm
E
500 µm
F
100 µm
C
500 µm
D
100 µm
G
250 µm
H
100 µm


Quartzose sandstone
@ 2635 m
Q
G
Well-connected pore network
LF
Quartz overgrowth
A
0.25 mm
@ 2632
C
Quartz overgrowth
Kfs
G
Q
Kfs
B
0.25 mm
Glauconitic sandstone
@ 2640 m
C
Dead end pores
Kfs
Clay
G
Q
G
B
C
0.25 mm
@ 2639.5 m
Kfs
Q
G
G
G
Preserved Sec. pores
D
0.25 mm
Argillaceous sandstone
@ 2636 m
Q
Clay
Dead end pores
B
C
G
Clay
E
0.25 mm
@ 2630.5 m
Dead end pores
G
Clay cement
Q
Claystone
C
F
0.25 mm

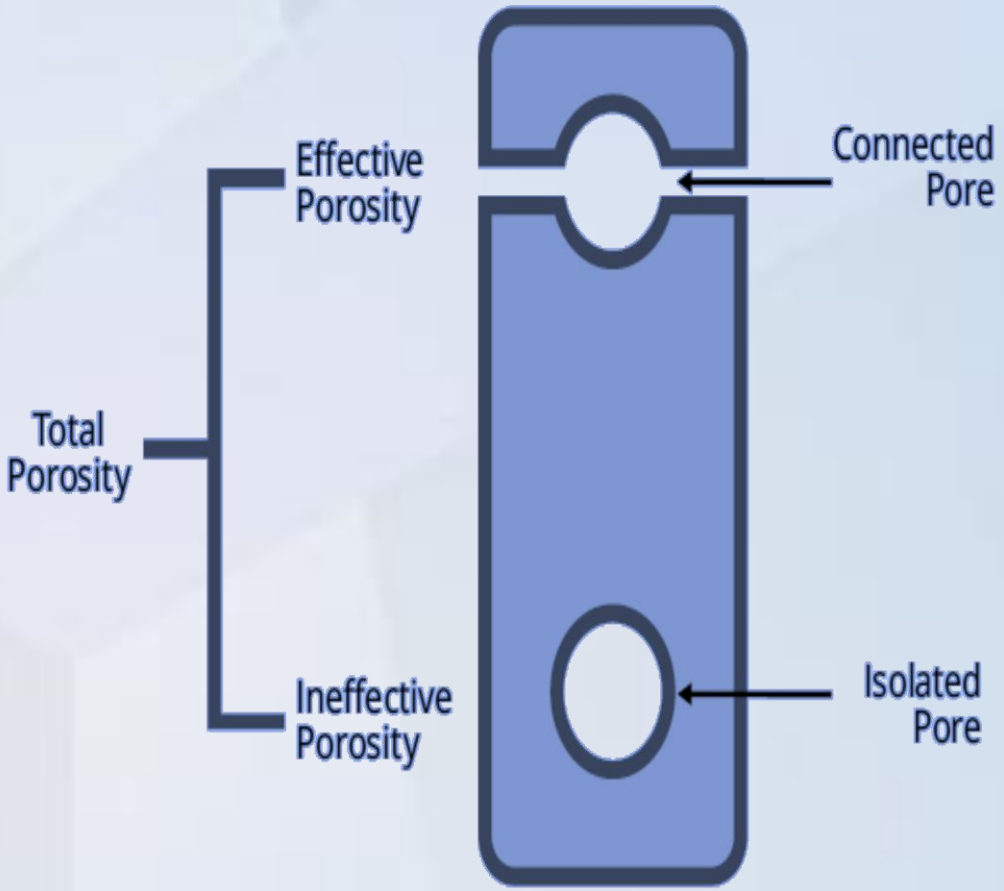
2- Engineering Classification:

1. Total Porosity:

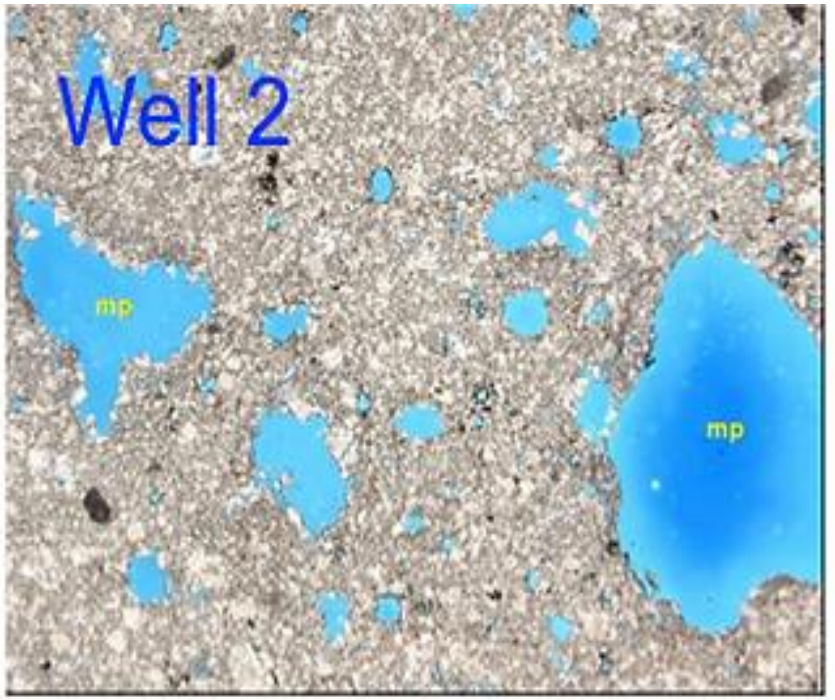
(ϕ_t) is the total pore volume of the rock divided by the bulk volume.

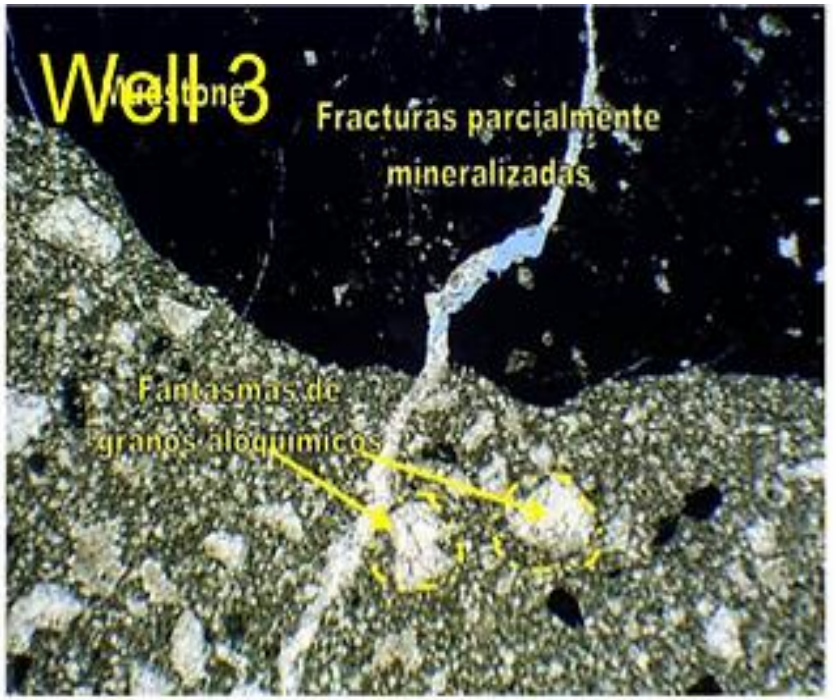
2. Effective porosity:

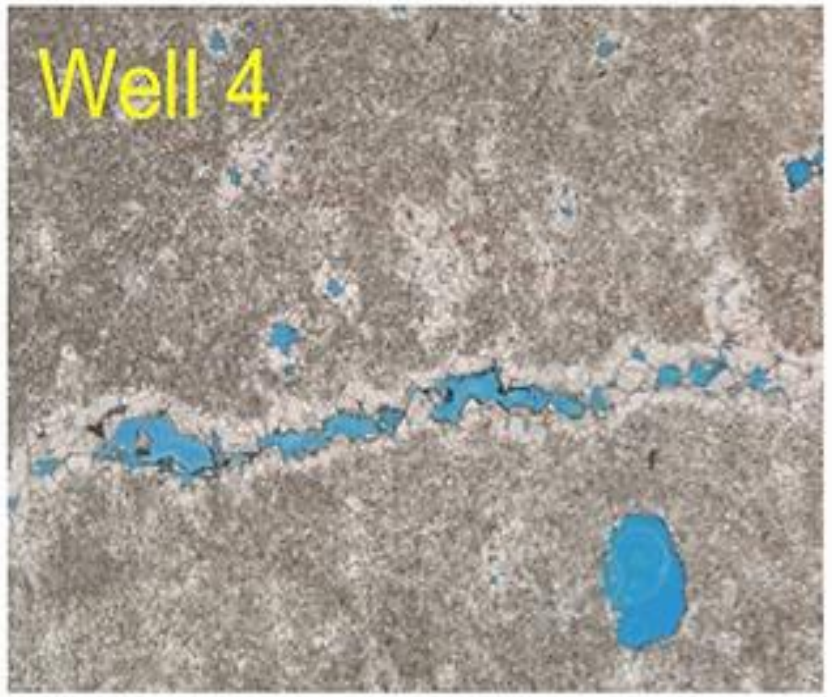
(ϕ_e) is the interconnected pore volume divided by the bulk volume. ***Ineffective porosity*** is the isolated pore volume divided by the bulk volume.

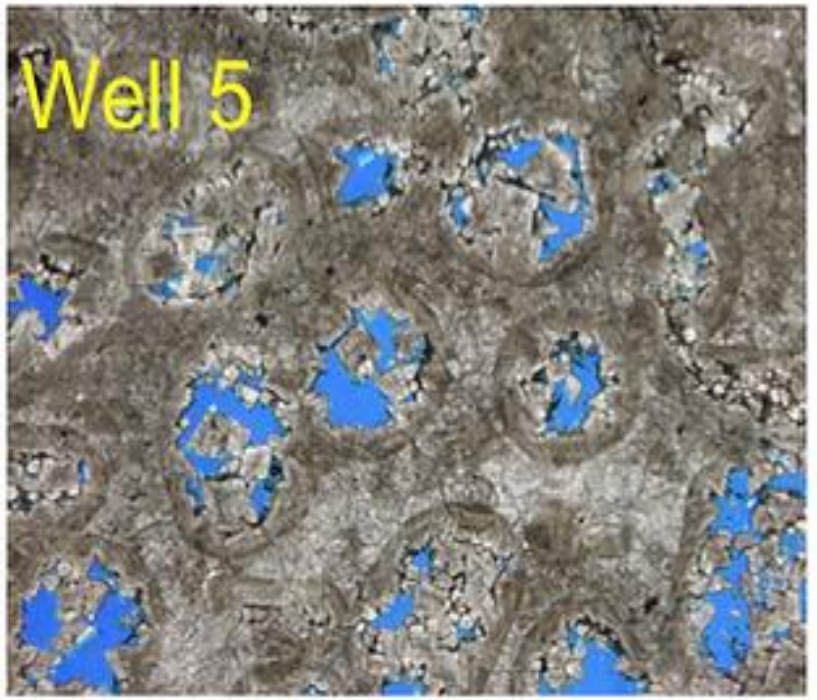



Well 1


Well 2
mp
mp


Well 3
Limestone
Fracturas parcialmente
mineralizadas
Fantasmas de
granos aloquímicos


Well 4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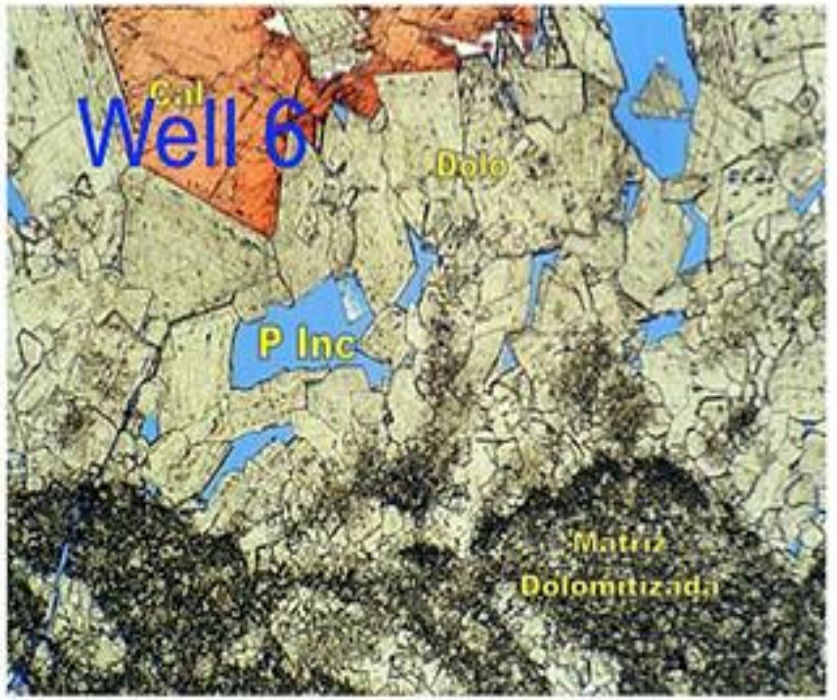
Cal
Well 6
Dolo
P Inc
Matriz
Dolomitizada