Lecture Six

Formation Evaluation

Petroleum & Mining Engineering Collage

Reservoir Engineering Department / Third Year

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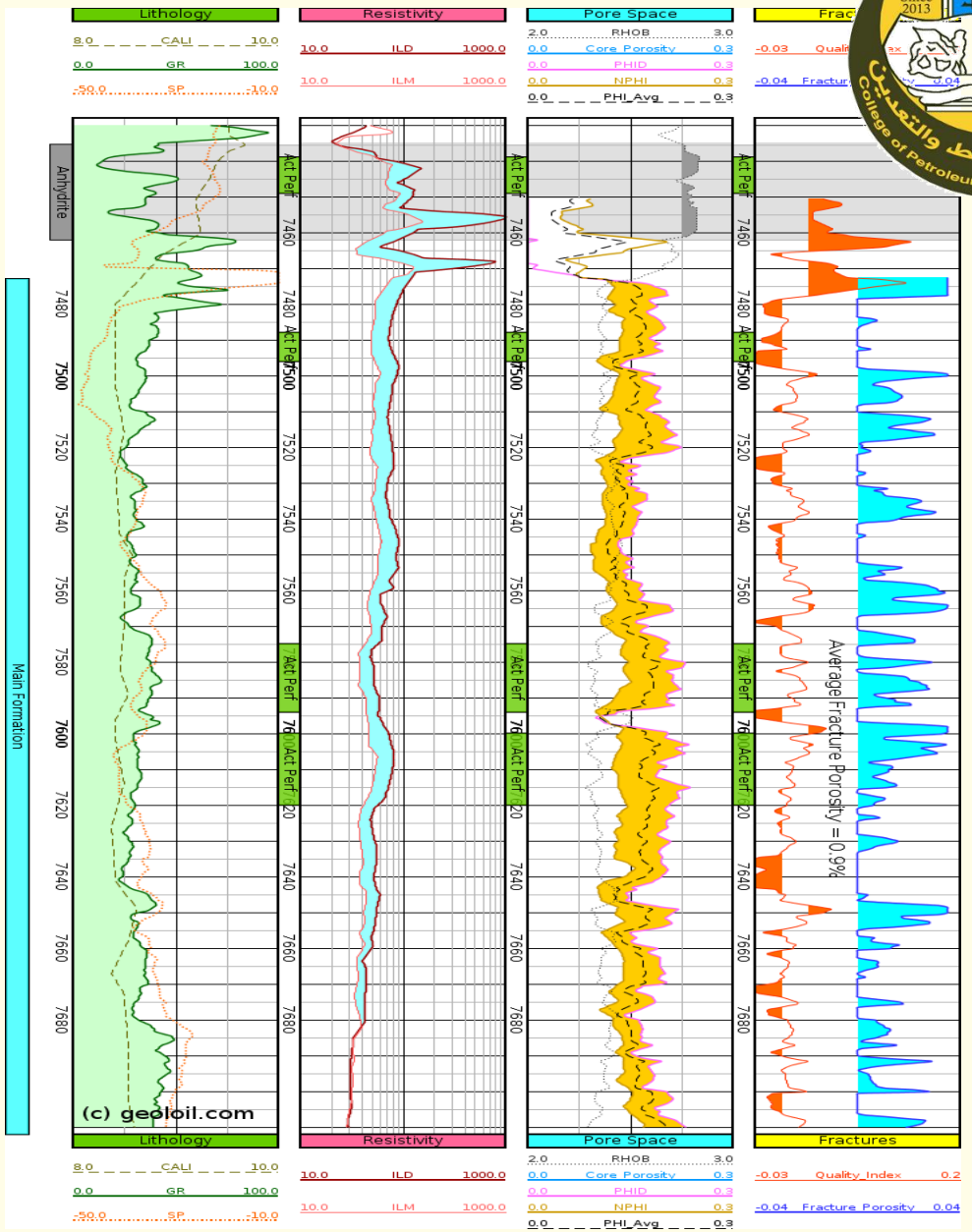
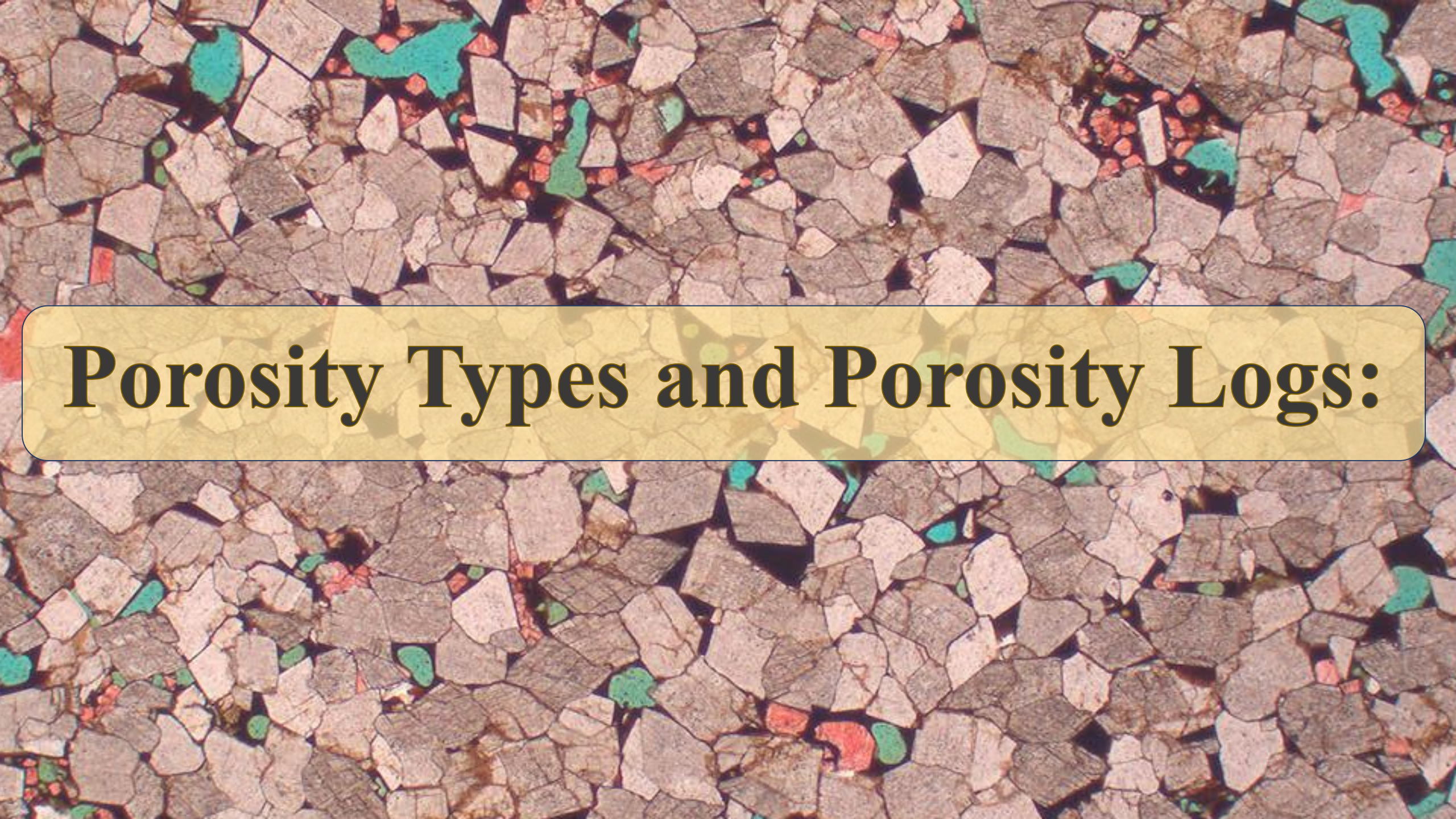
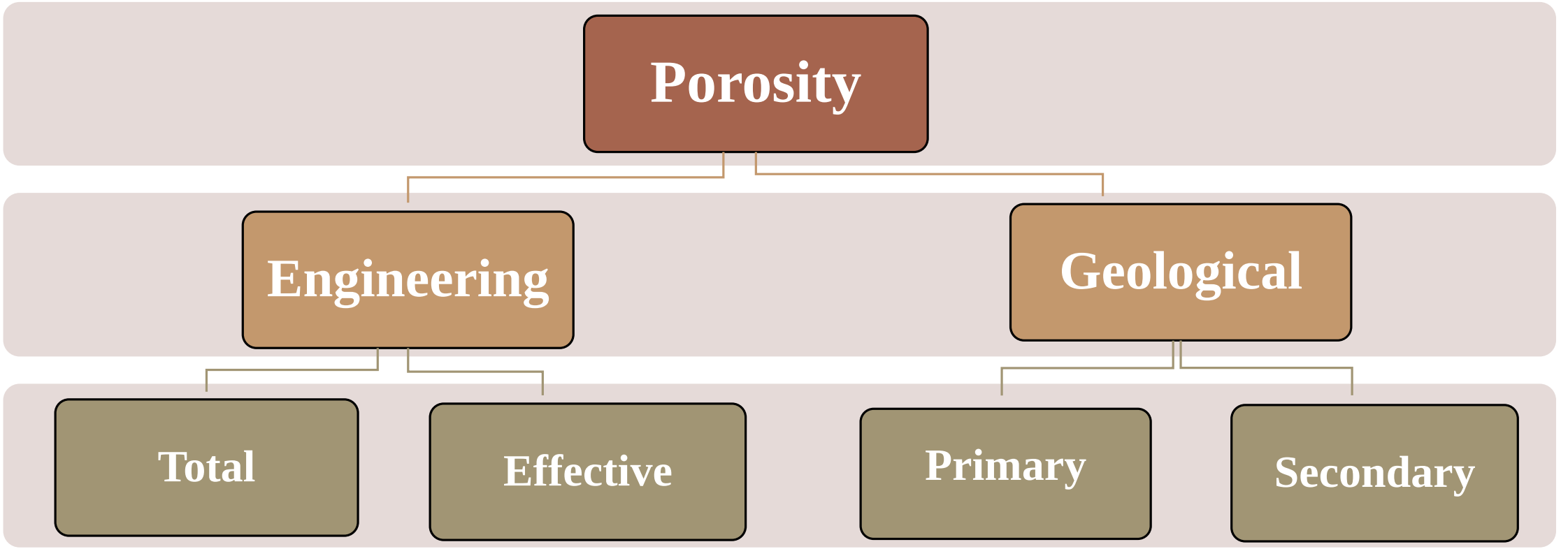




Porosity Types and Porosity Logs:

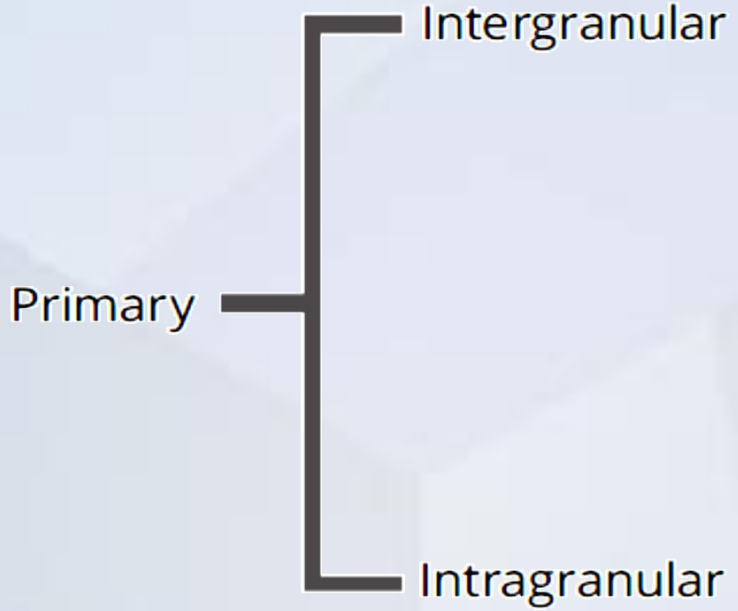
Porosity Classification

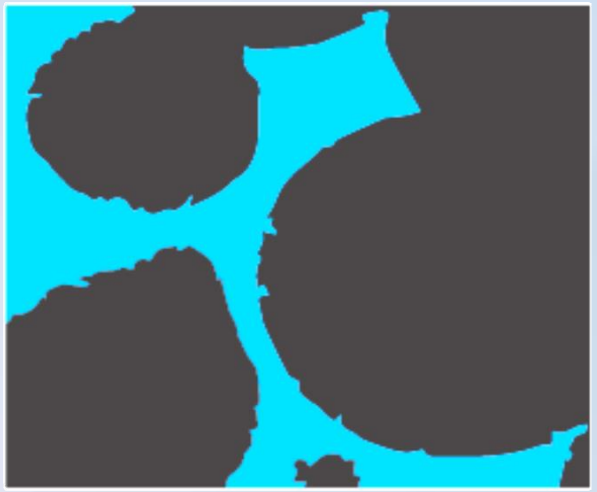


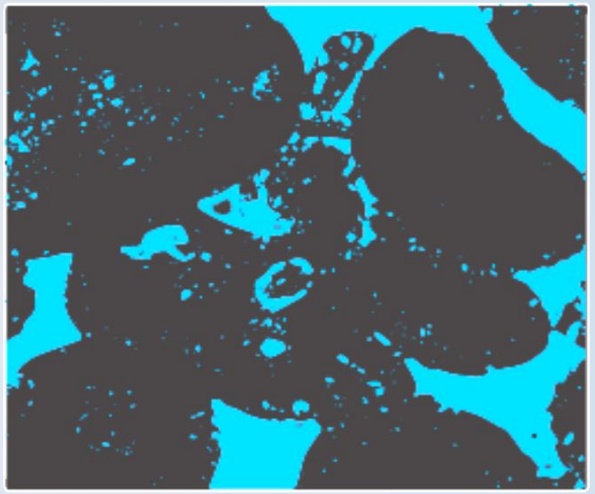
Porosity types

1- Geological Classification:

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





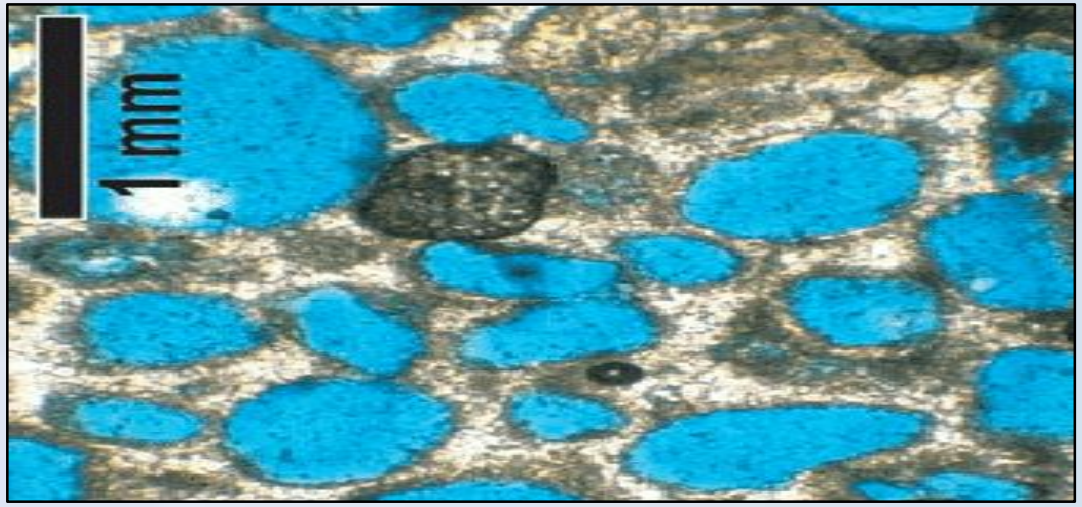


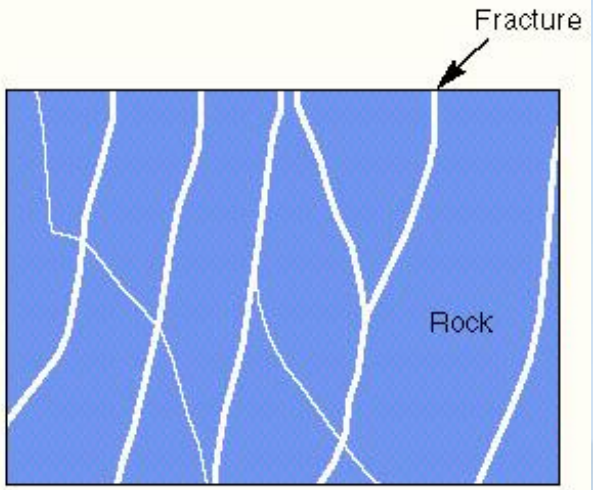
B-*Secondary Porosity*: developed by some geologic process after the deposition of the rock.

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

Intercrystalline Porosity:
Produced by spaces between carbonate crystals.

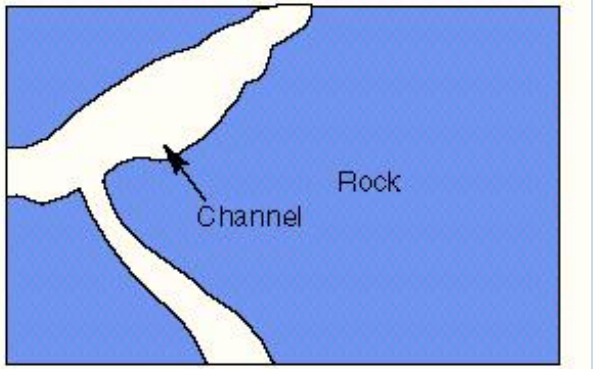
Moldic Porosity:
Pores created by the dissolution of grains or fossil remains.





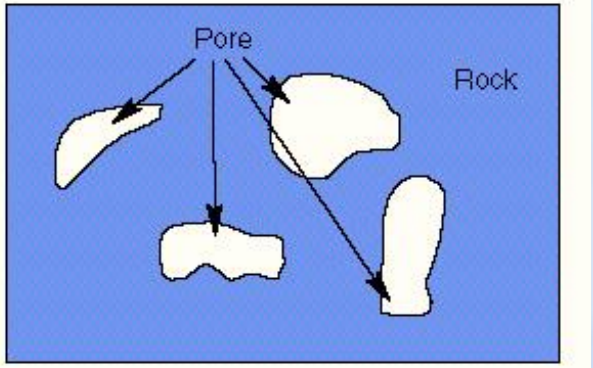
Fracture (Fissure) Porosity:

Pore spacing created by the cracking of the rock fabric.



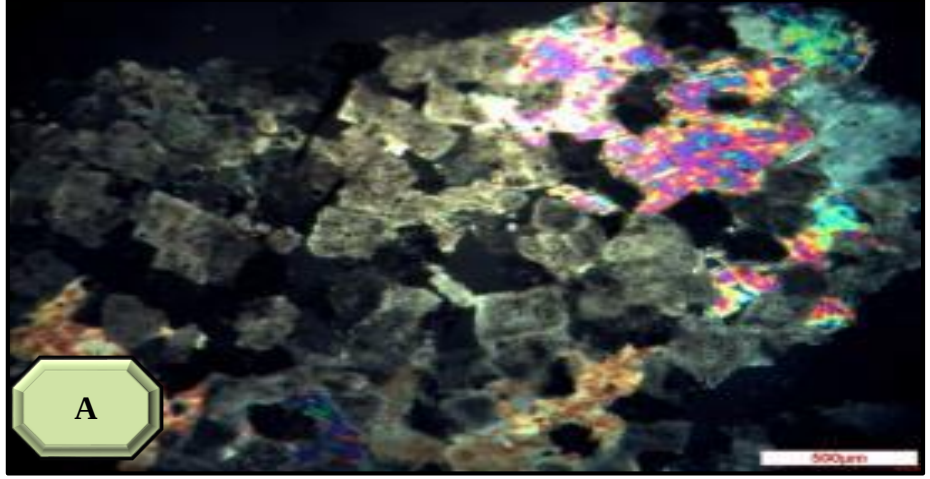
Channel Porosity:

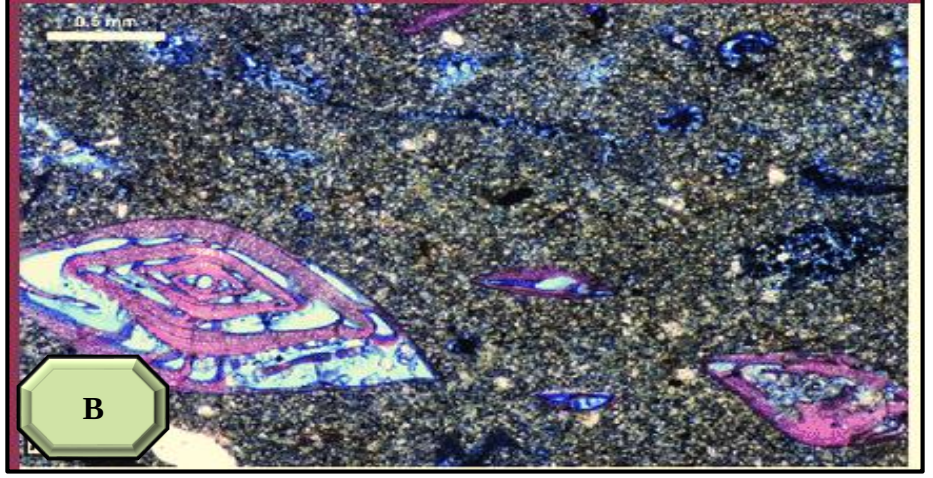
Similar to fracture porosity but larger.

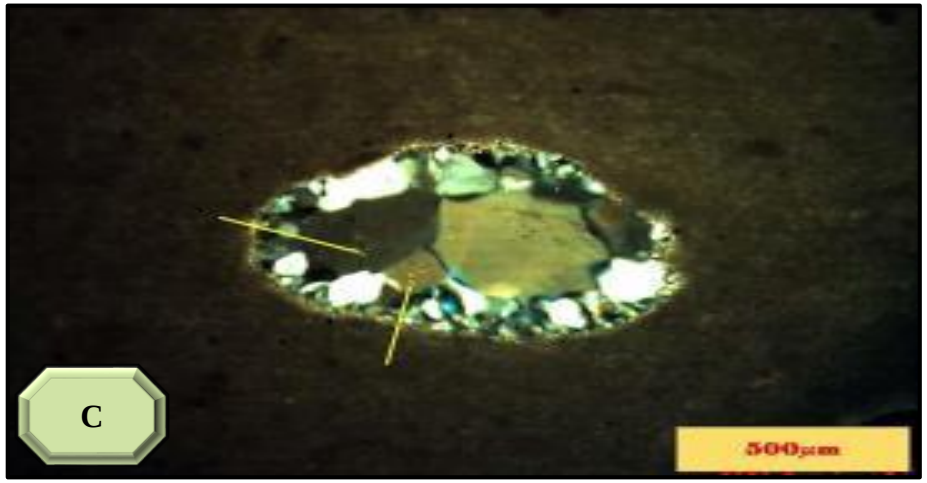


Vuggy Porosity:

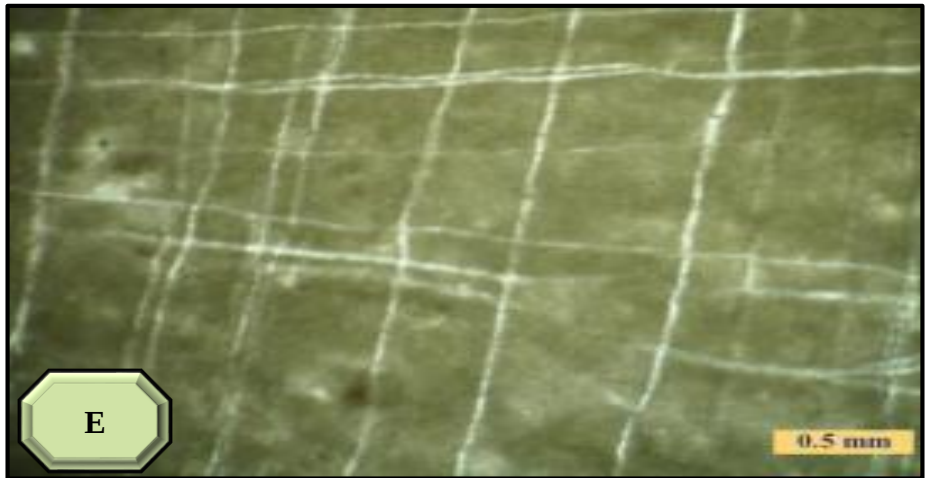
Created by the dissolution of fragments, but unconnected.

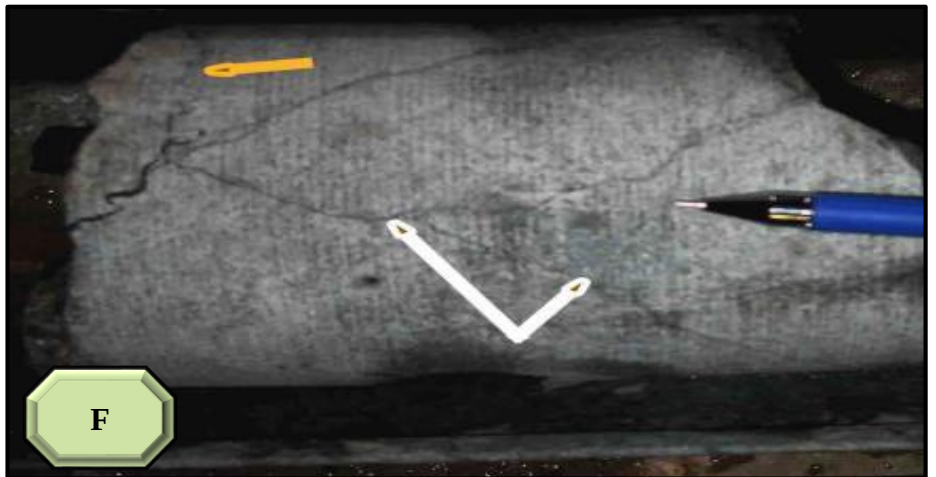

A

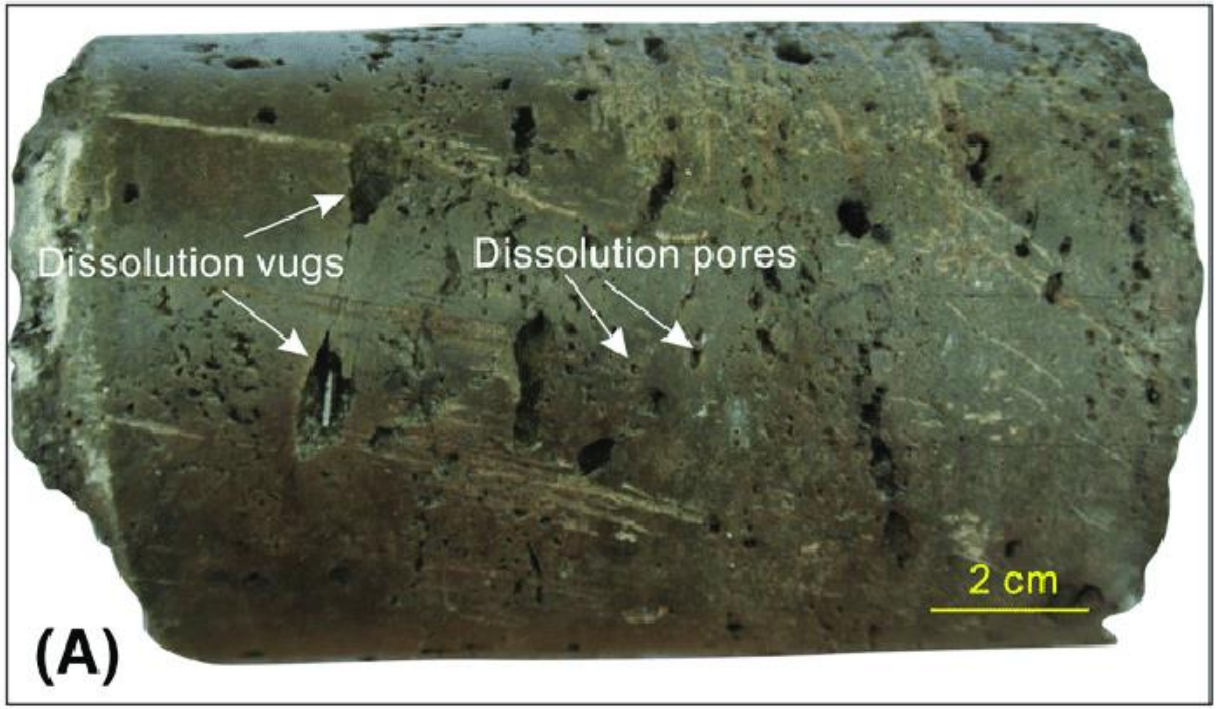

B

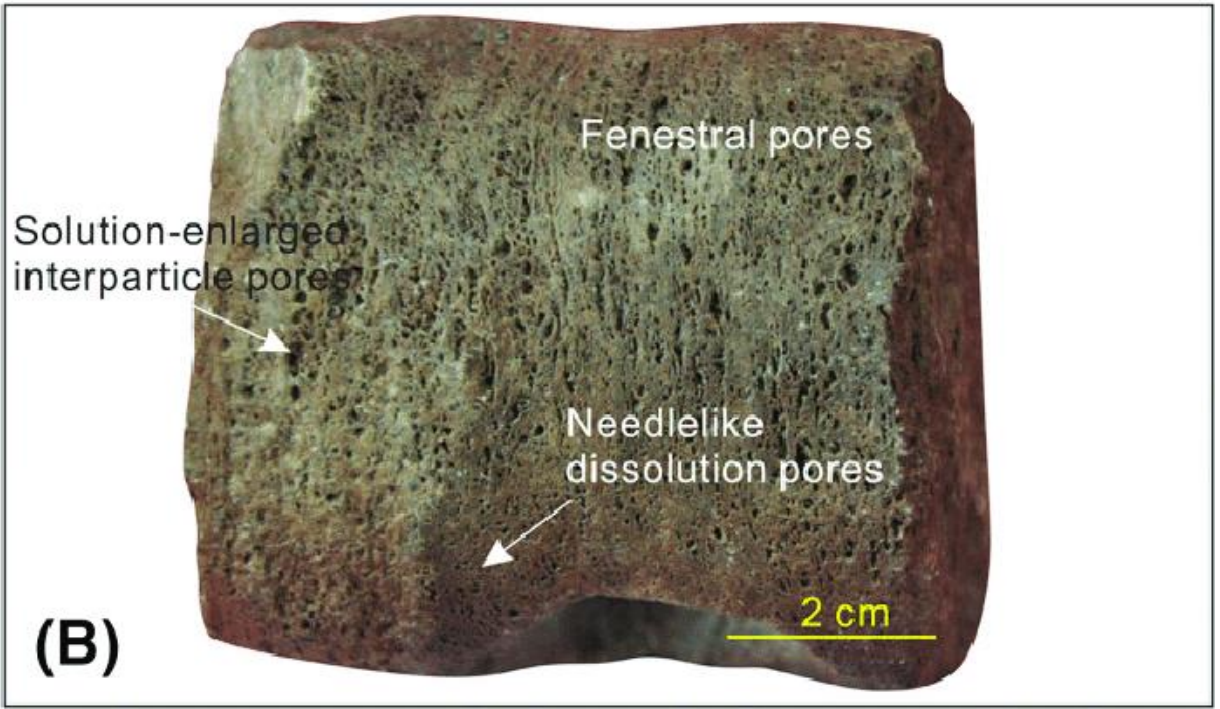

C
500µm

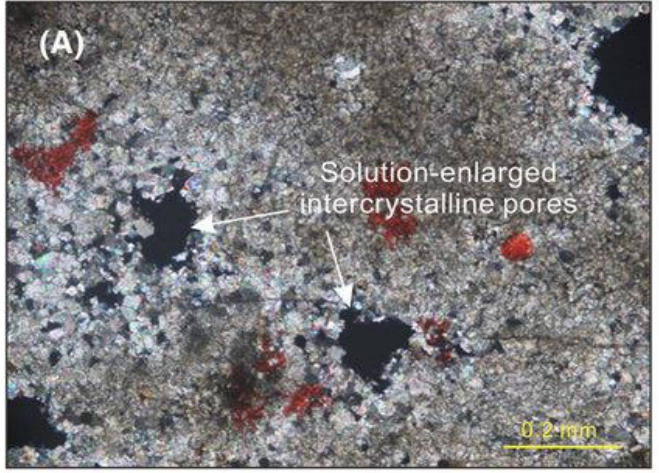

D

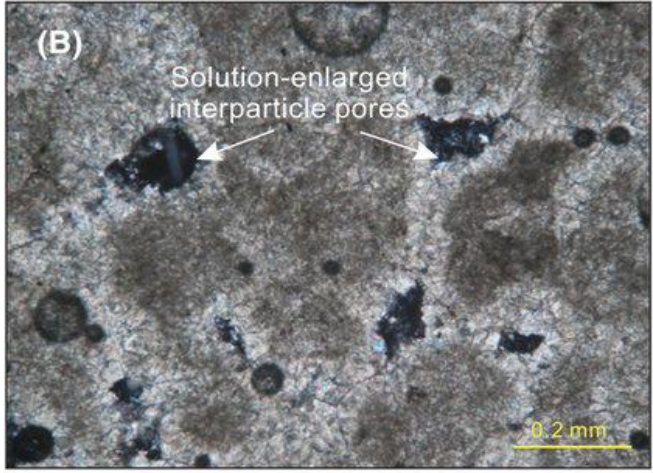

E
0.5 mm

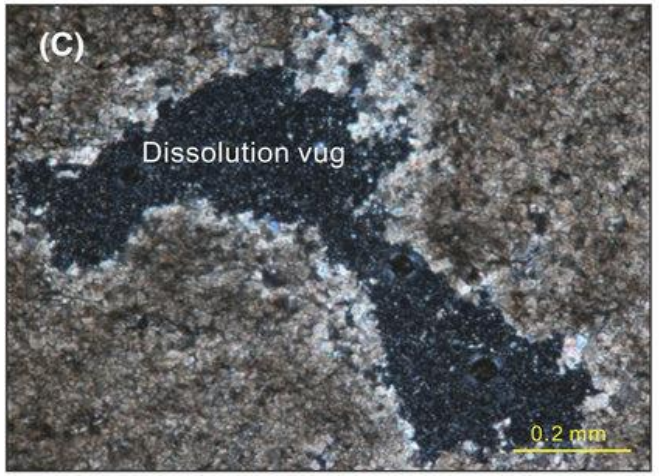

F

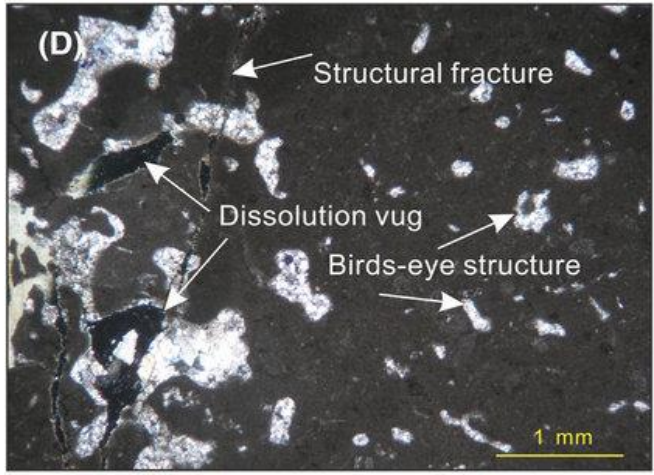

Dissolution vugs
Dissolution pores
2 cm
(A)

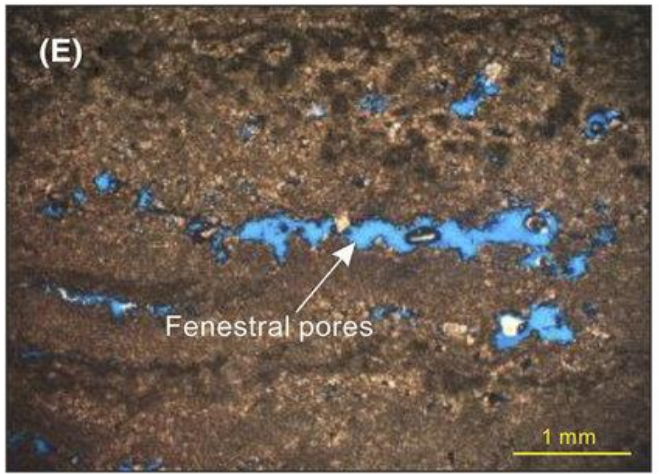

Fenestral pores
Solution-enlarged interparticle pores
Needlelike dissolution pores
2 cm
(B)

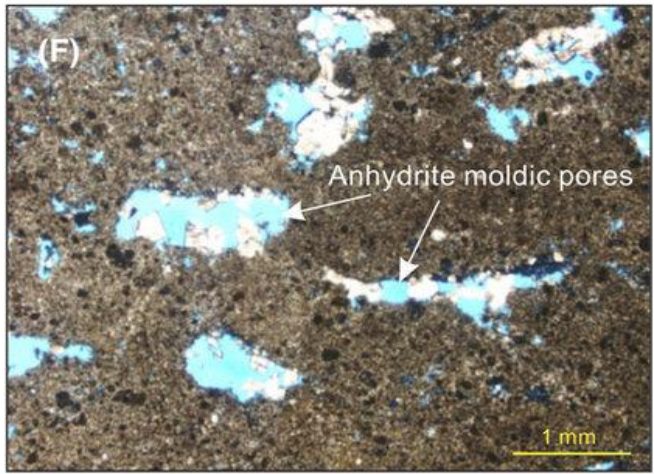

(A)
Solution-enlarged intercrystalline pores
0.2 mm

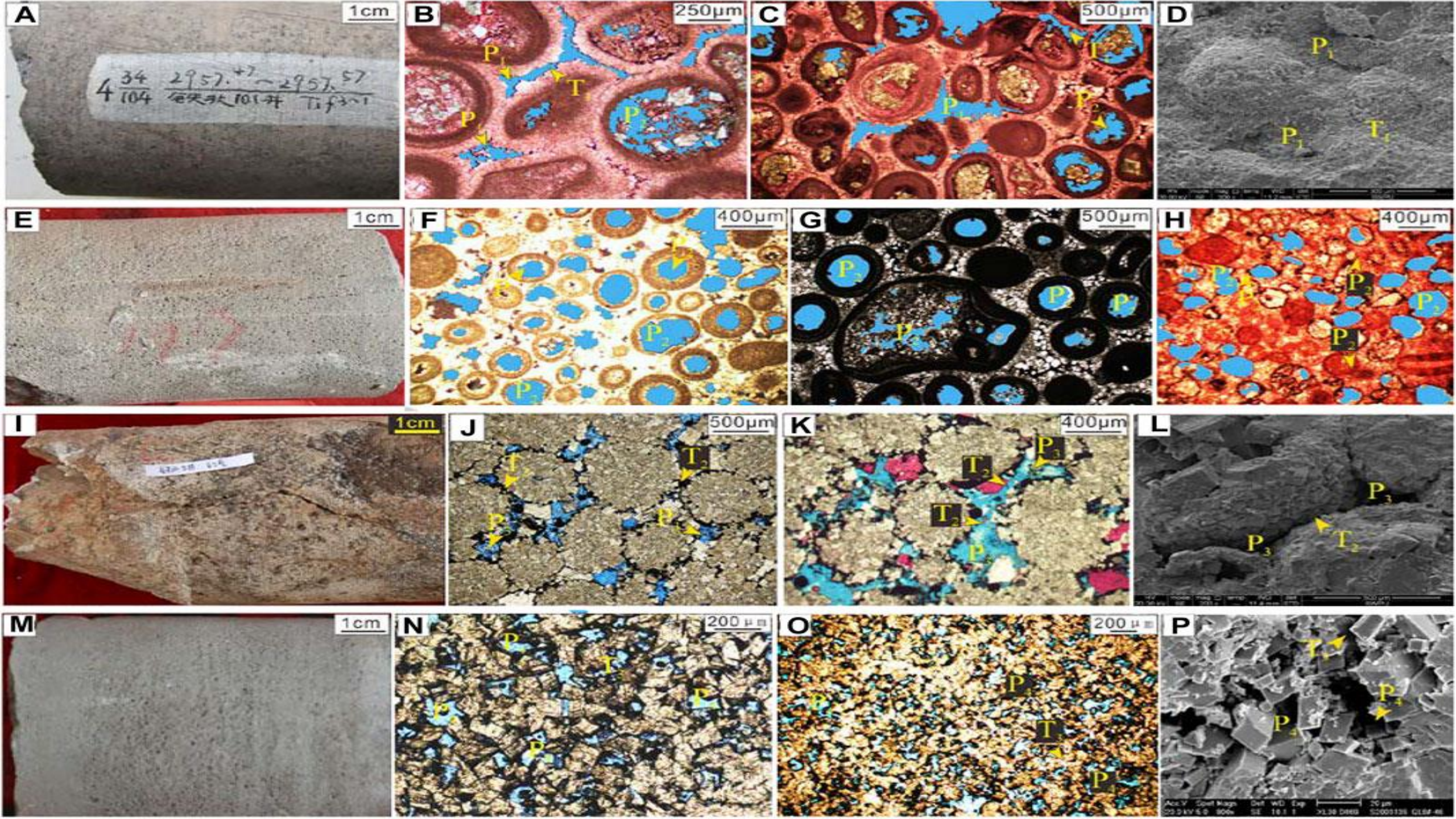

(B)
Solution-enlarged interparticle pores
0.2 mm

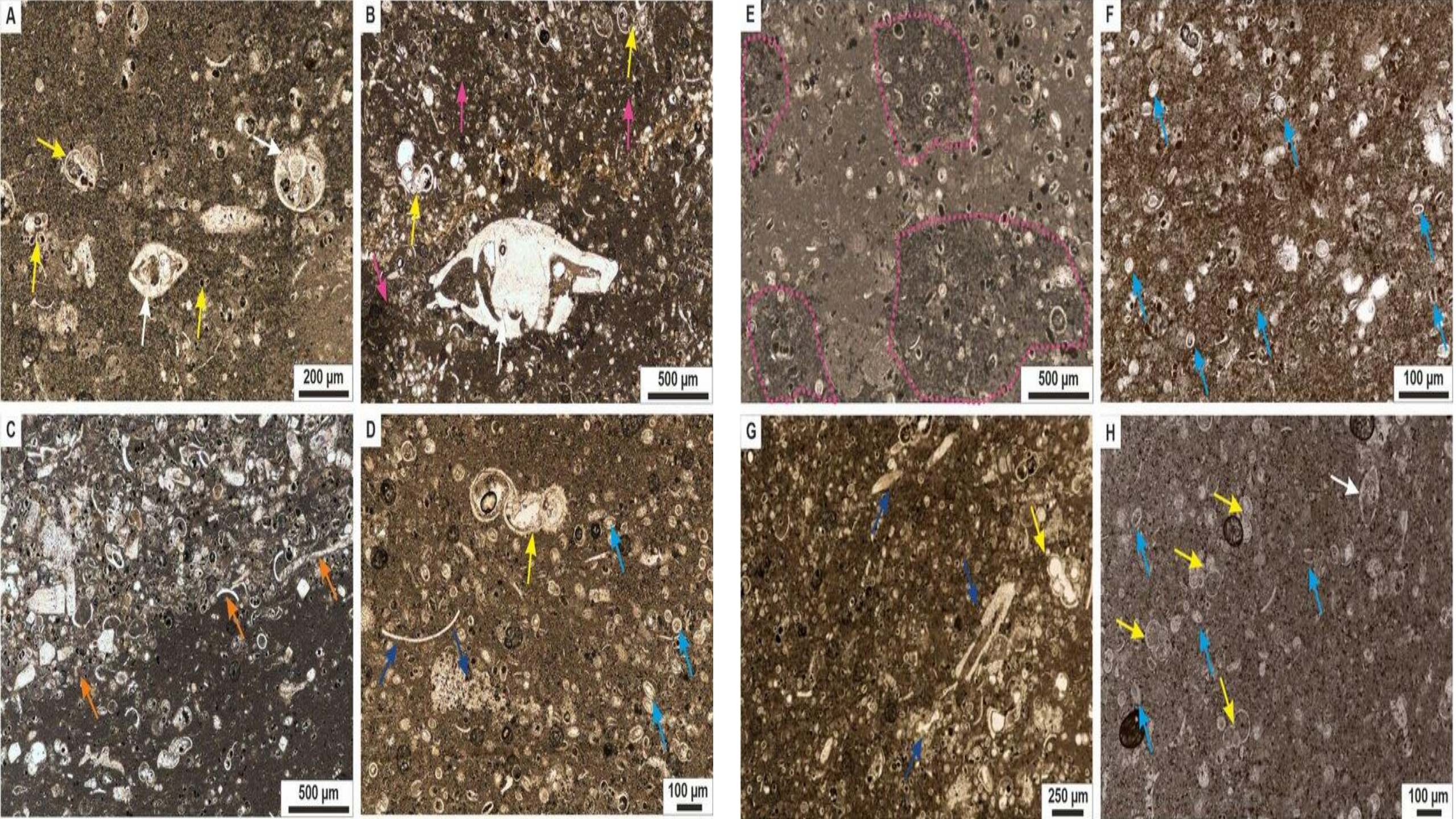

(C)
Dissolution vug
0.2 mm

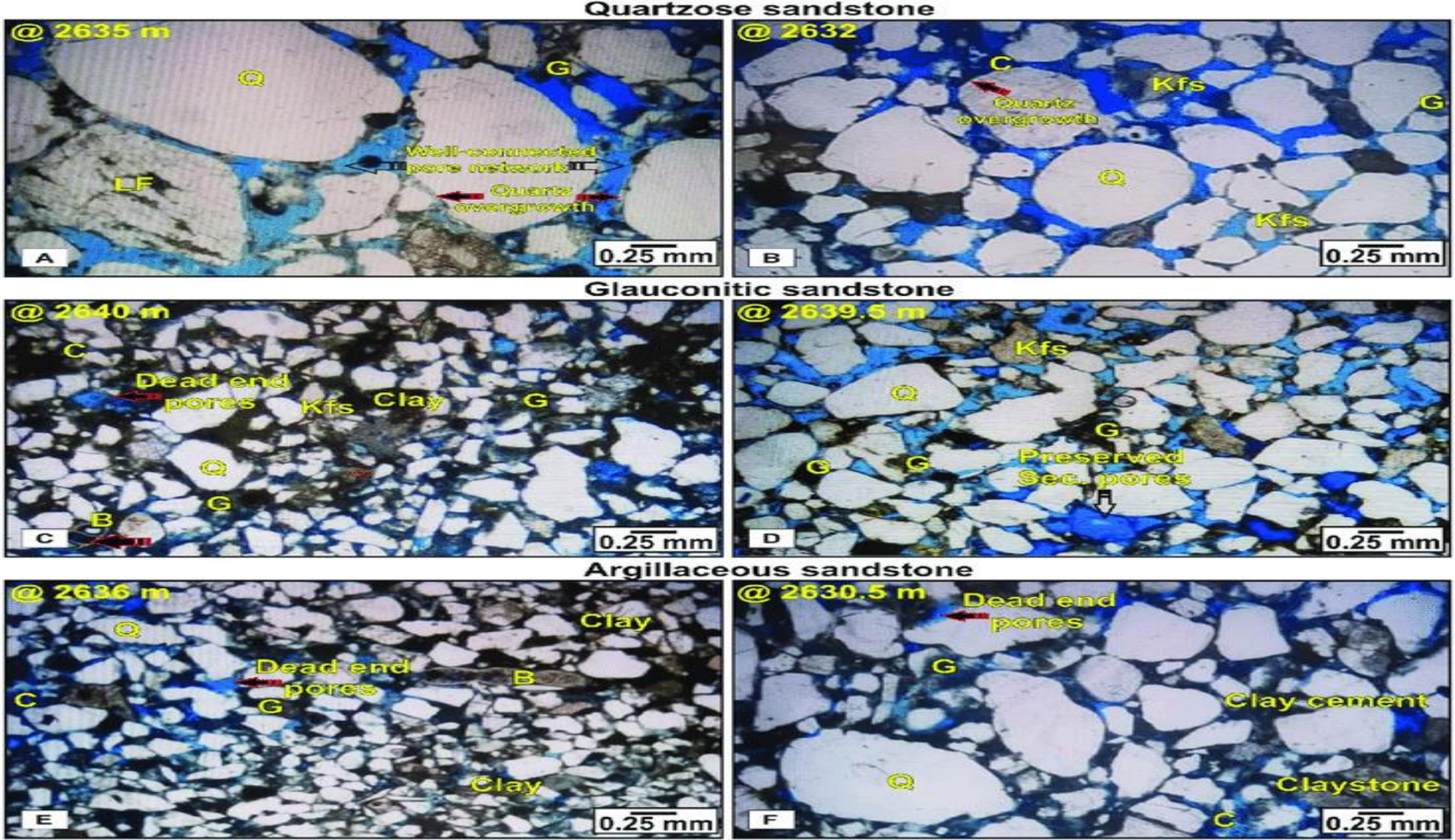

(D)
Structural fracture
Dissolution vug
Birds-eye structure
1 mm


(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

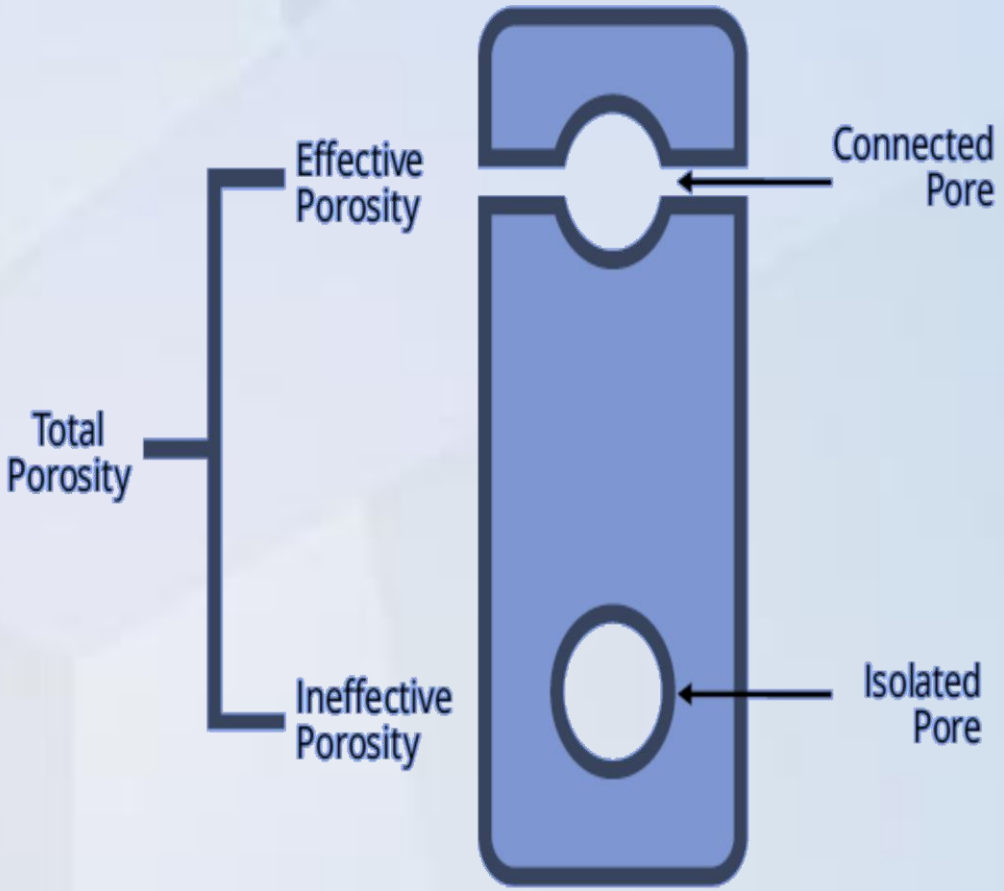
2- Engineering Classification:

1. Total Porosity:

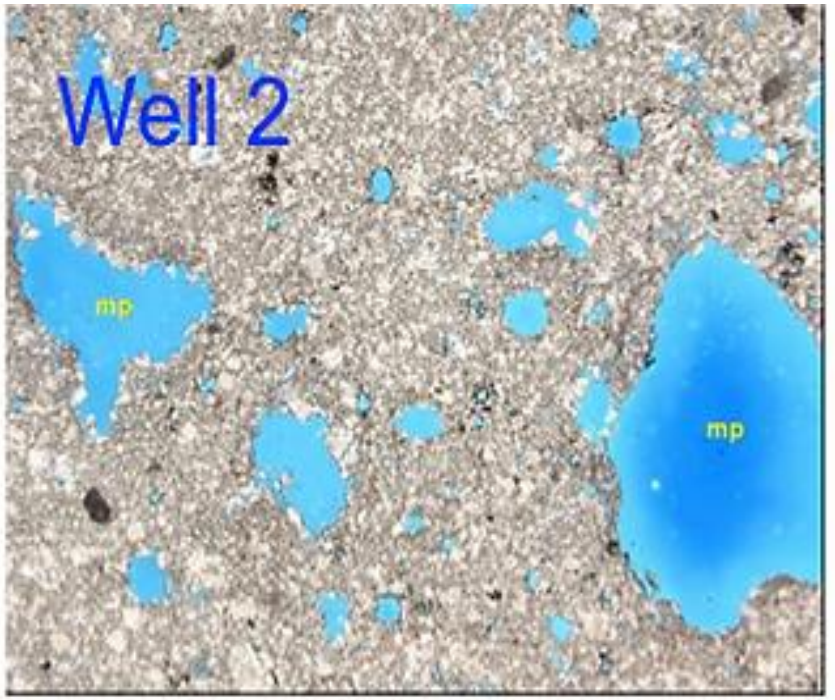
(ϕ_t) is the total pore volume of the rock divided by the bulk volume.

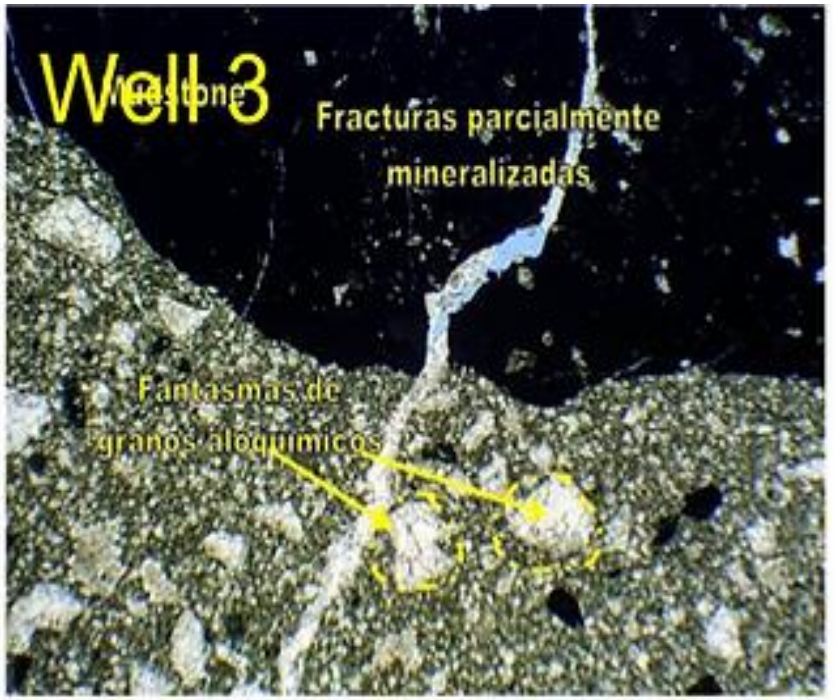
2. Effective porosity:

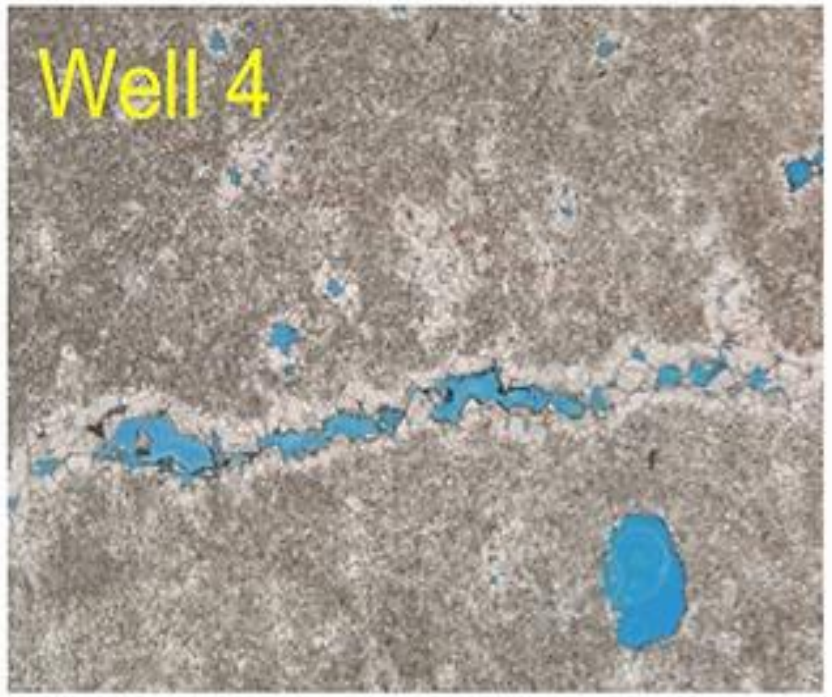
(ϕ_e) is the interconnected pore volume divided by the bulk volume. ***Ineffective porosity*** is the isolated pore volume divided by the bulk volume.

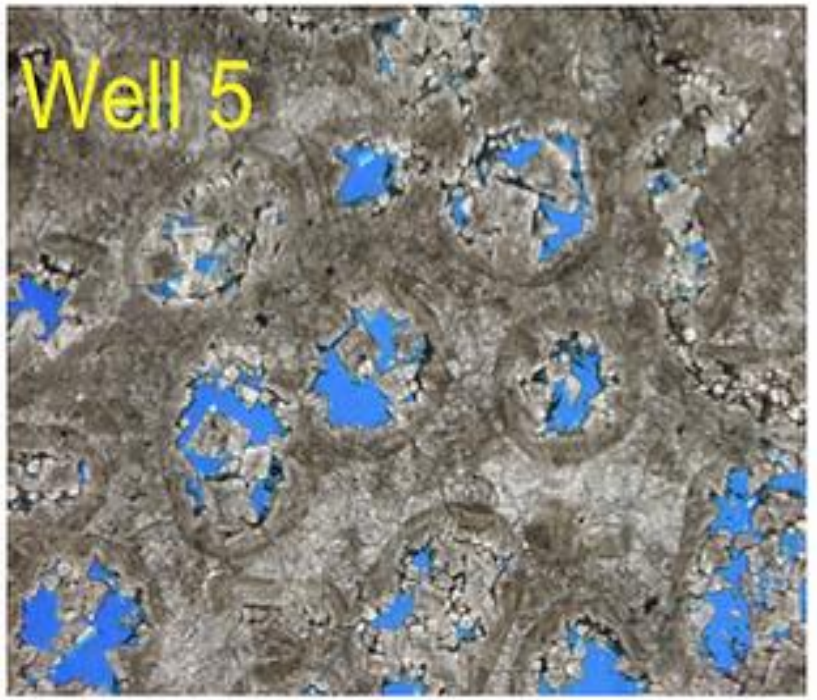


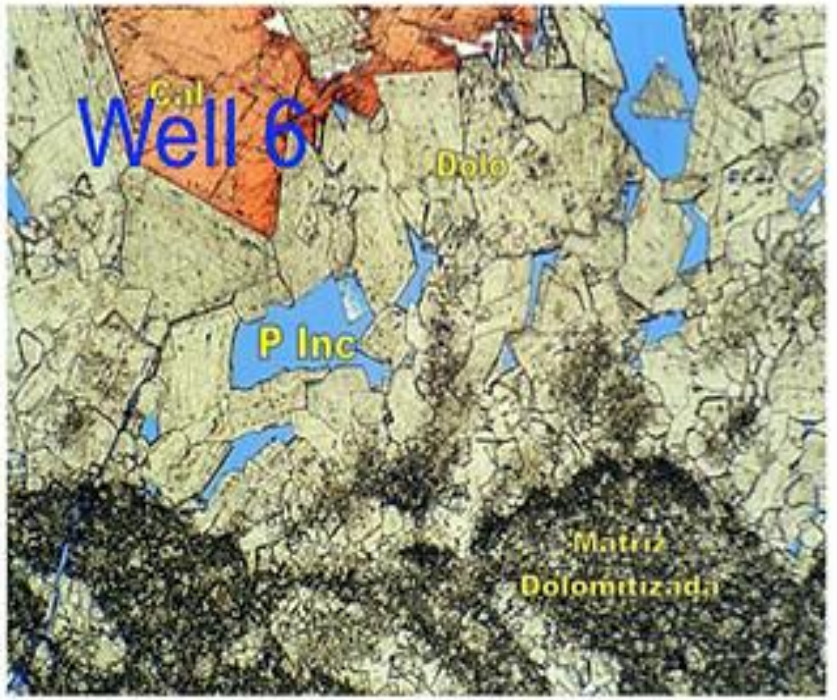

Well 1


Well 2
mp
mp


Well 3
Limestone
Fracturas parcialmente
mineralizadas
Fantasmas de
granos aloquímicos


Well 4


Well 5


Cal
Well 6
Dolo
P Inc
Matriz
Dolomitizada

Porosity Logs

The porosity of a formation can be estimated either from ***neutron, density, sonic*** logging.

The density, neutron logs are ***nuclear measurements*** whereas the sonic log uses ***acoustic measurements***.

Density Log (Gamma –Gamma Ray):

density log is porosity log that measures the bulk density of the formation. It measures in grams per cubic centimeter g/cm3 and is indicated by the Greek letter ***ρ*** (rho).

Formation bulk density (ρb) is a function of ***matrix density, porosity, and density of the fluid in the pores (saltwater mud, freshwater mud, or hydrocarbons).***

Uses of Density logs

01 Calculate the Porosity

02 Detect gas-bearing zones

03 Determine hydrocarbon density

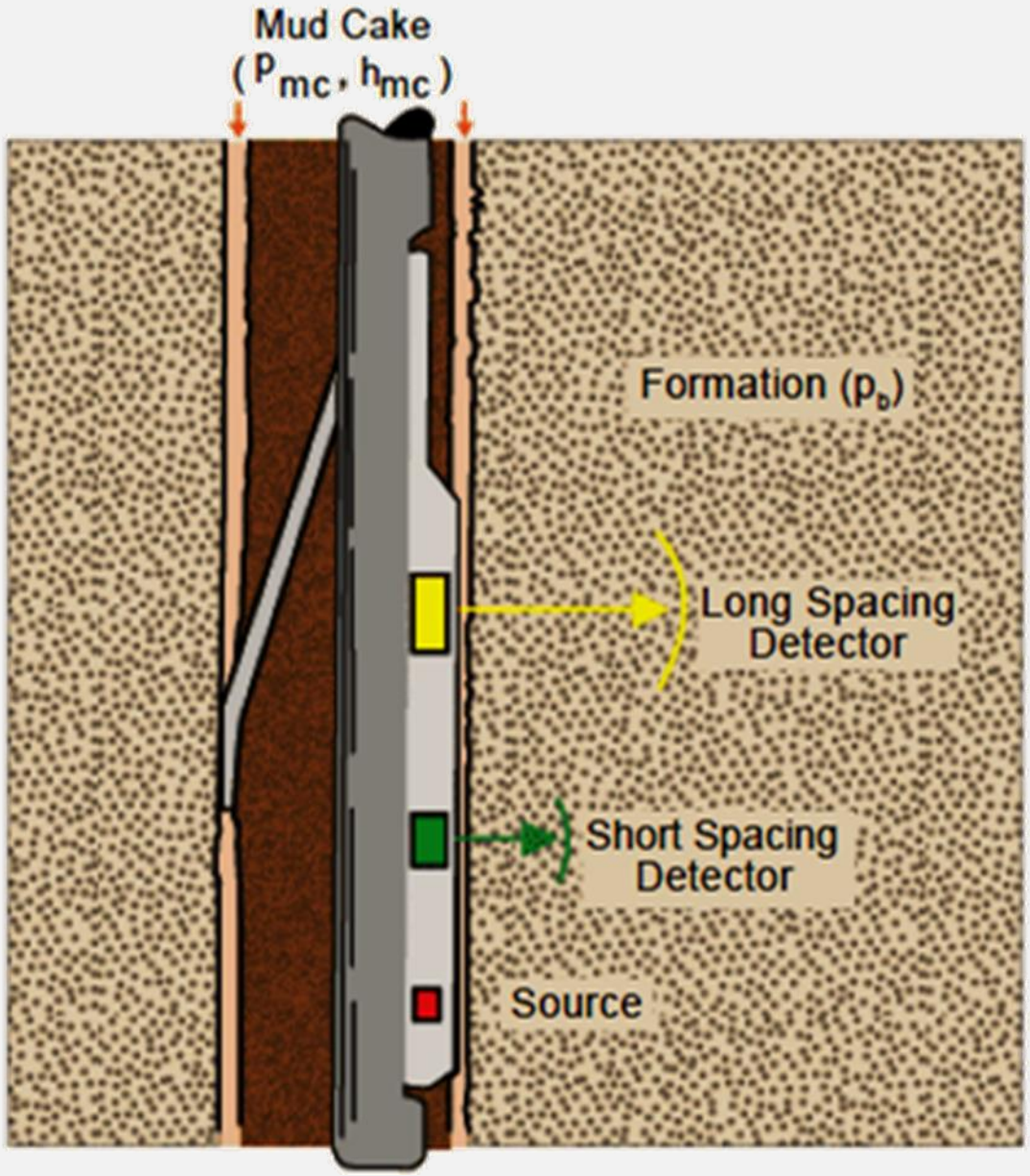
04 Evaluate shaly-sand reservoirs

05 Identify evaporite minerals

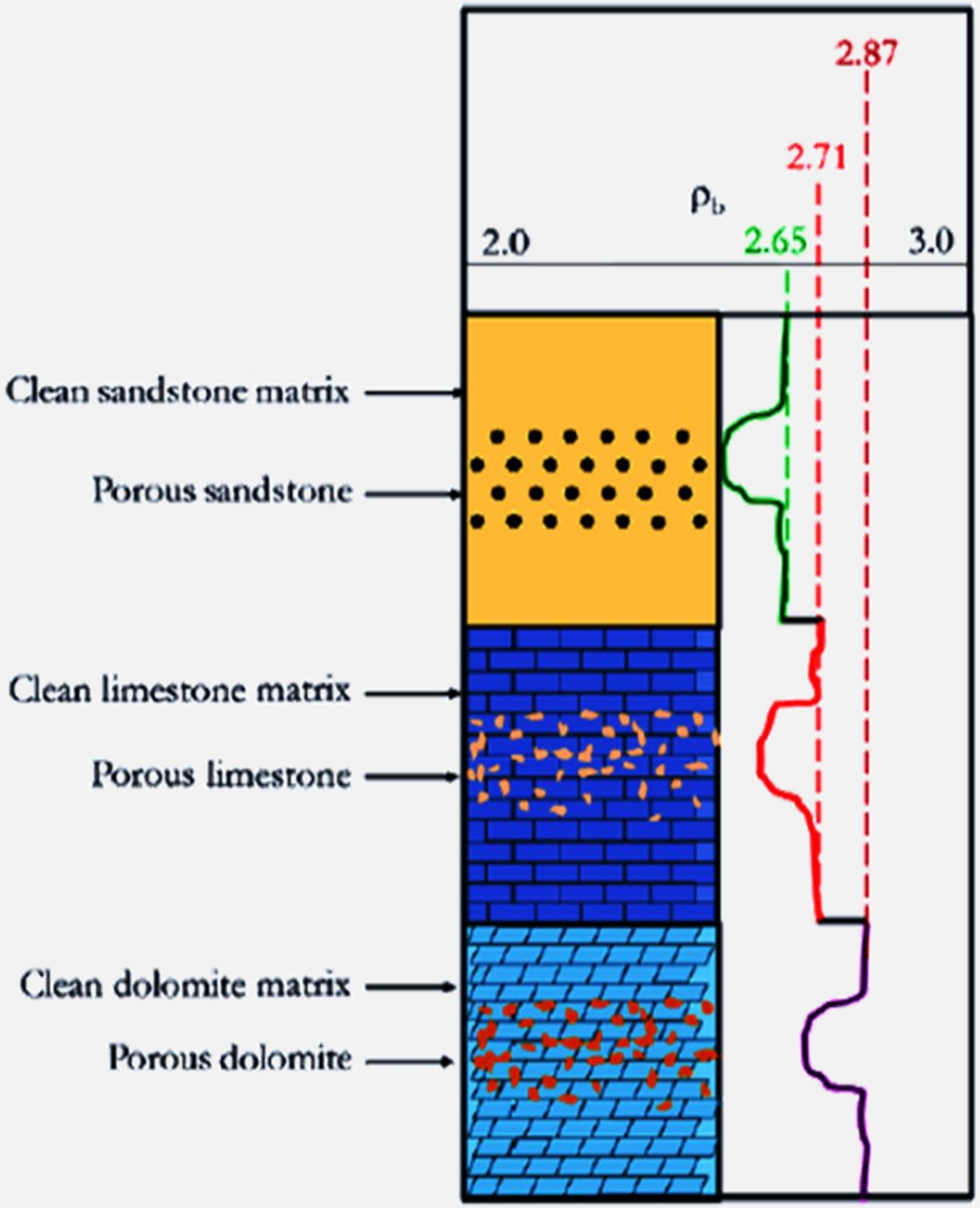
06 Assess source rock organic matter content

Physics of the Measurement:

- Medium - energy gamma rays are emitted from a chemical source (usually Cesium 137) into the formations.
- These gamma rays ***collide with the electrons*** in the formation. At each collision a gamma ray ***loses*** some of its energy to the electrons and continuous reduce energy.
- Two detectors in the tool count the number of returning gamma rays which are related to formation electron density.




Long
Short
Source



The bulk density decreases due to the effect of the pore spaces (porosity) in each lithology

Schlumberger adopted the nomenclature FDC, for Formation Density – Compensated log

Name	Symbol	Company
Formation Density Compensated	FDC	Schlumberger
Compensated Densilog	CDL	Western Atlas, Halliburton
Compensated Density	CDS	BPB

Calculation of Porosity from Density Log:

Formation bulk density (ρb) follows a linear bulk mixing law, hence:

$$\rho_b = \phi_D \rho_f + (1 - \phi_D)\rho_{ma}$$

So to Calculation the Porosity from Density Log use the following equation:

$$\emptyset_D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$

- Where:

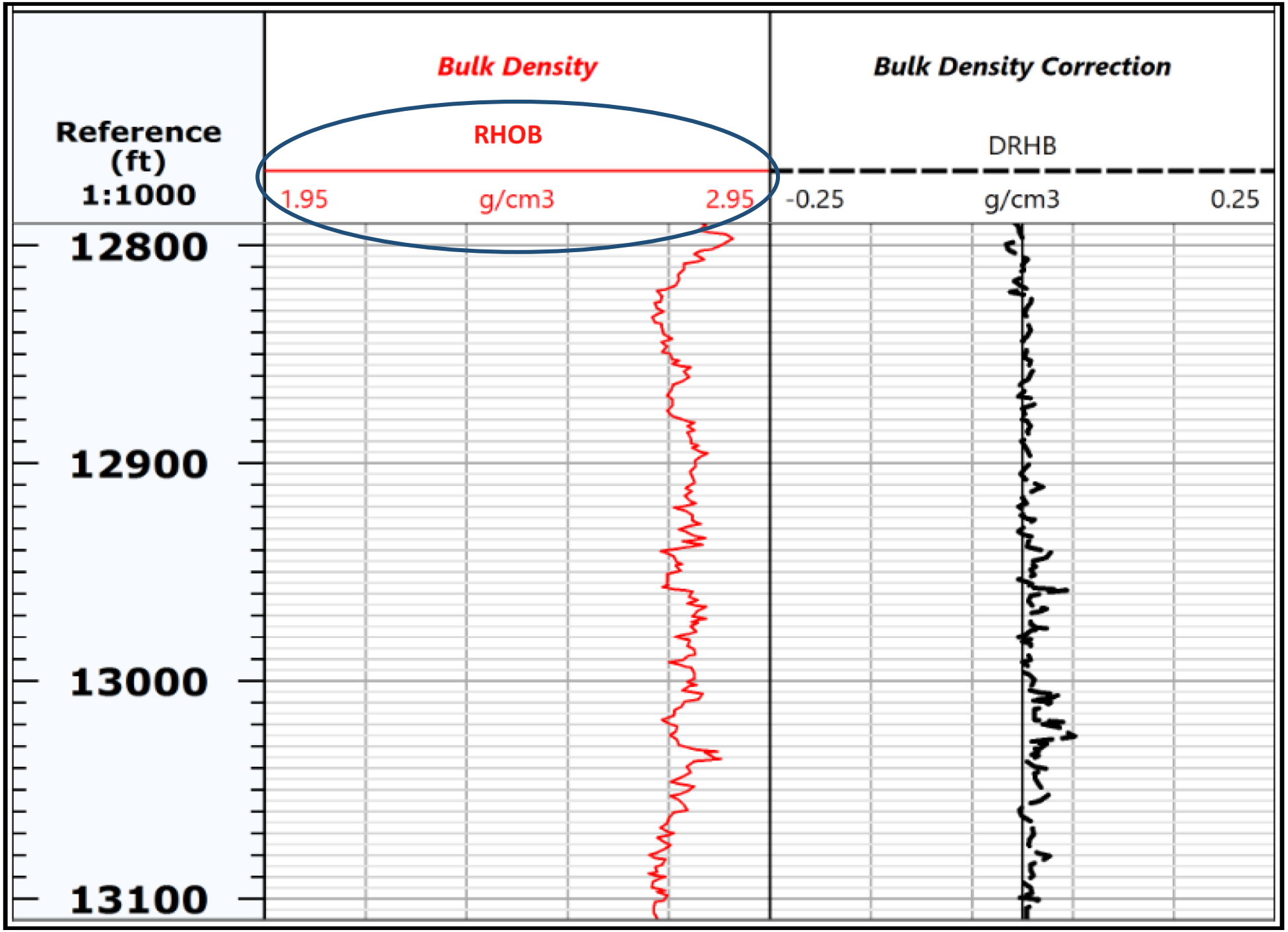
$\emptyset_D$ = Porosity from density log

ρ_{ma} = Matrix density,

ρ_b = Bulk density (reading of density log),

ρ_f = Fluid density.

Material	Density(gm/cc)	Fluid	Density (gm/cc)
Quartz	2.65	Fresh Water	1.00
Calcite	2.71	Salt Water	1.15
Dolomite	2.87	Oil	0.85
Anhydrite	2.96		


Reference
(ft)
1:1000
Bulk Density
RHOB
1.95
g/cm3
2.95
Bulk Density Correction
DRHB
-0.25
g/cm3
0.25
12800
12900
13000
13100

The unit for ρb is g/cc and density porosity is in porosity units (pu). When a sandstone matrix density is used for calculating density porosity, it is called the **sandstone porosity unit (SSPU or SPU)**; when a limestone matrix density is used for density porosity calculations, the porosity unit is the **limestone porosity unit (LPU).**

- Another approach for presenting the density porosity is using the varying lithology of the formation at different depths. Hence, density porosity at each depth is calculated with the correct matrix density when known. *So Density logging logs requires that matrix type be known in order for it to be used for porosity calculation*.

Shale Effect

- Shale densities ***tend to be lower at shallow depths***. For example, shallow uncompacted clays have densities around 2.0 g/cm^3, while at depth, this value commonly rises to 2.6 g/cm$^{3.}$

- ***The increase in shale density during compaction, essentially due to a decrease in porosity. Shale density is often indicative of age. In general, older shale are more dense from younger (recent) shale.***

So, to determine porosity in shaly formation (V_{sh}) must be use (Shale effect correct):

$$\emptyset_{Dc} = \left(\frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}\right) - V_{sh} * \left(\frac{\rho_{ma} - \rho_{sh}}{\rho_{ma} - \rho_f}\right)$$