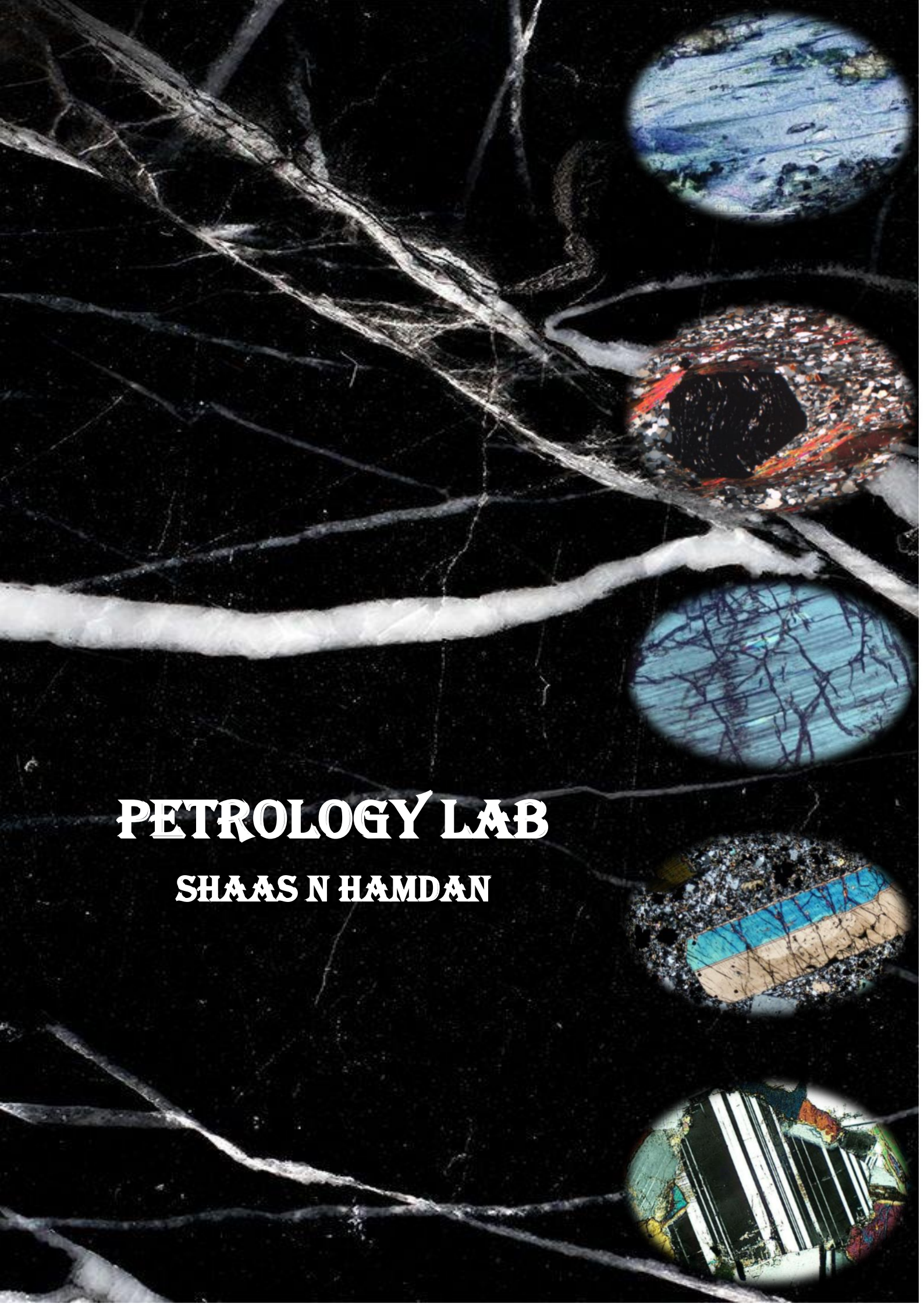
PETROLOGY LAB
SHAAS N HAMDAN

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Sources

ALEX STRECKEISEN SITE

DR. N. YASEEN, LECTURES

DR. N. YASEEN, SLIDES

K. HEFFERAN, J. O'BRIEN, EARTH MATERIALS, 1ST ED

IGNEOUS ROCK CLASSIFICATION (REVIEW)

INTRODUCTION FROM EARTH MATERIALS

Classification	Disruption	Composition
Ultramafic	Dark & greenish	Olivine + pyroxene ± amphibole
Mafic	Dark	Pyroxene ± amphibole ± olivine ± biotite
Intermediate	Grayish to salt, pepper	Plagioclase, amphibole ± biotite ± quartz
Felsic	Light, red	K-feldspar, quartz ± biotite ± muscovite

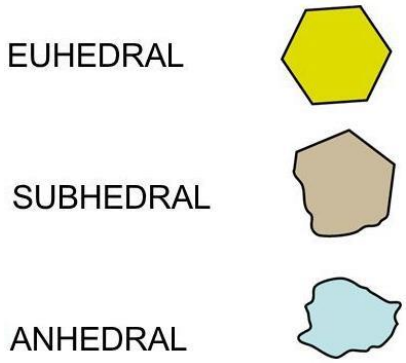
	Plutonic/Granitic	Volcanic / Basaltic
Occurrence	Intrusive	Extrusive
Produced by	Magma	Lava, volcanic debris
Solidifies	within Earth	at surface
Cools	slowly	rapidly
Producing	large crystals (phaneritic)	small crystal (Aphanitic), noncrystalline
Ultramafic	Peridotite	Comatiite
Mafic	Gabbro	Basalt
Intermediate	Diorite	Andesite
Felsic	Granodiorite, Granite	Dacite, Rhyolite

Texture	very dark (ultramafic)	Dark-colored (mafic)	gray (intermediate) to salt & pepper
SiO_2	**< 45%VolSiO_2 (ultrabasic)**	**45% - 52%VolSiO_2 (basic)**	**50 – 65%vol SiO_2**
Plutonic	**Peridotite, or Pyroxenite**	**Gabbro, in lower crust of ocean basin**	**Diorit**
Volcanic	**Comatite (rare)**	**Basalt, common volcanic, encompassing upper kilometers of ocean crust**	**Andesite, common around Pacific Ring of Fire**
Minerals	**Rich in Pyroxene, olivine, ± amphibole ± plagioclase**	**Rich in plagioclase, pyroxene, olivine**	**Rich in hornblende, pyroxene, & plagioclase**

Texture	Light-colored (felsic) rocks	Light-colored (felsic) rocks
SiO_2	**≈ 65%vol**	**> 65%vol (silicic or acidic)**
Plutonic	**Granodiorite, between granite & diorite**	**Granite, occur in continental crust**
Volcanic	**Dacite, occurs around the Pacific rim**	**Rhyolit, erupts in thick, continental crust**
Minerals	**Plagioclase, alkali feldspar, quartz, & small amounts of hornblende & biotite**	**quartz, alkali feldspar, & small amounts of plagioclase & biotit**

Texture	Rock	Color	Notes
Vesicular	**Pumice**	**Light-colored**	Lightweight rock rich in gas holes (vesicles)
	Scoria	**Dark-Colored**	Lightweight rock rich in gas holes (vesicles)
Glassy	**Obsidian**	**Black to Reddish**	Glassy luster & Conchoidal fracture
Pyroclastic	**Volcanic tuff**	**————**	Fine grain ash to sand size volcanic fragments
	Volcanic Breccia	**————**	Coarse grain gravel & larger size volcanic fragments

Igneous rock Textures & Structures



- Shapes of individual crystals
  1. **Euhedral**: A crystal completely bounded by its own faces
  2. **Subhedral**: some crystal bounded by its own faces & in surfaces developed through mutual interference of adjacent crystals
  3. **Anhedral**: A crystal not bounded by its own crystal faces

- Rock textures defined by single crystal shape
  1. **Hypidiomorphic**: euhedral & subhedral crystal
  2. **Idiomorphic**: all crystals are euhedral (absent in natural samples)
  3. **Allotriomorphic**: entirely anhedral crystals

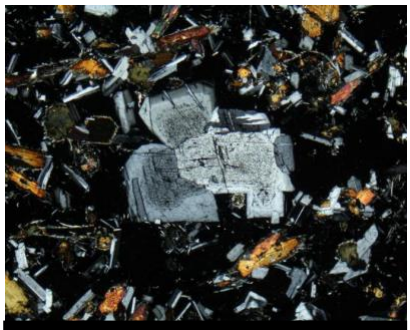
- Degree of crystallinity
  1. **Holohyaline (Vitreous)**: completely glassy without crystals
  2. **Holocrystalline**: rocks composed entirely of crystals
  3. **Hypocrystalline**: rocks composed of crystal & glass
     - Glass is color less under PPL, & Blake Under XPL

- **Phenocrysts:** Large crystals stands on a finer-grained groundmass

- Rock textures defined by grain size

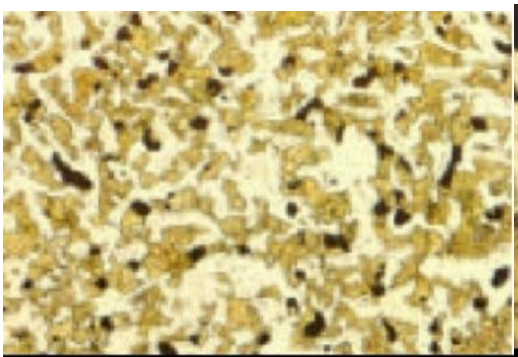
Equicrystalline		Porphyritic
Aphanitic	**Phaneritic**	
Microcrystalline Cryptocrystalline	Fine grained < 1mm Medium grained 1-5 mm Coarse grained 5-10 mm Pegmatitic > 10 mm	Porphyritic hyaline Porphyritic aphanitic Porphyritic phaneritic

  - **Aphanitic** crystals are too small (You can't see it with naked eye)
  - **Phaneritic** individual constituents visible to naked eye
  - **Microcrystalline** crystals may distinguished with aid of microscope
  - **Cryptocrystalline** mineral aggregate shown to be crystalline using scanning electron microscope or x-ray techniques but individual crystals not visible under the microscope.
  - **Groundmass** fine grained matrix (Any material you fail to know because it's too small)



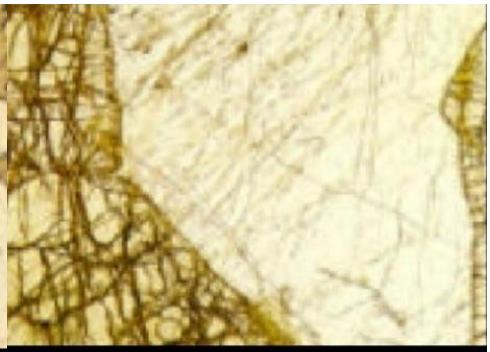
PLAGIOCLASE IN AN ANDESITE WITH HYPOCRYSTALLINE GROUNDMASS

PLAGIOCLASE IN AN ANDESITE WITH HYPOCRYSTALLINE GROUNDMASS

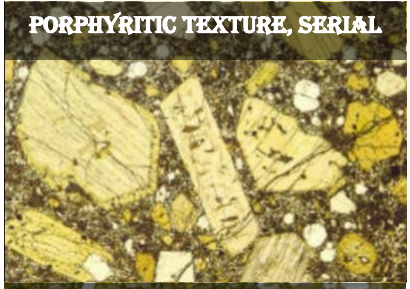


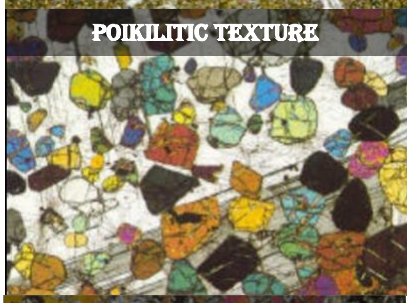
FINE GRAINED (<1MM)

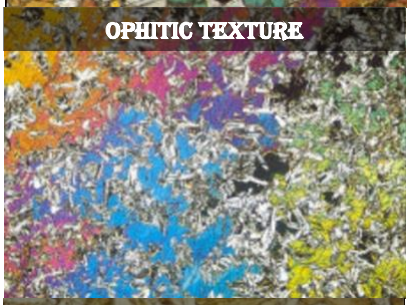
MEDIUM GRAINED (1-5MM)

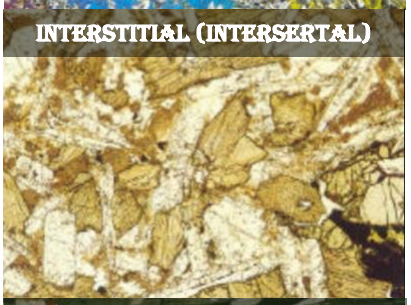


COURSE GRAINED (>5MM)









The most common textures in igneous rocks

- **Equigranular textures**

Texture	Crystal
Allotriomorphic or xenomorphic texture	Most crystals anhedral
Hypidiomorphic texture	Most crystals subhedral
Panidiomorphic or idiomorphic texture	most crystals euhedral

- **Inequigranular textures**

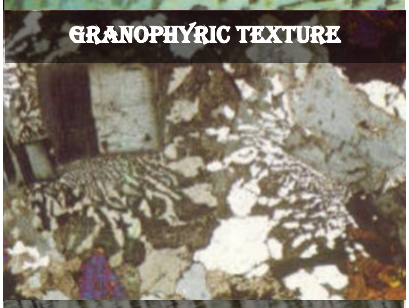
Texture	Crystal
Porphyritic	Large crystal (phenocryst) in finer grain or glassy matrix (non-uniform grain size distribution) بلورات كبيرة محاطة بارضية ناعمة
Serial	As several grain sizes are present, & the grain size is increasing in a certain direction. عندما يزداد حجم الحبيبات في اتجاه ما
Glomero-porphyritic (Microphyritic)	Phenocrysts occur in separated clusters (phenocrysts are forming aggregates) هو مثل Porphyritic ولكن تتشكل ال phenocrysts بمجموعات منفصلة
Poikilitic	a late crystals completely encloses grains of other minerals (Smaller crystals enclosed in larger crystals) هي معدن داخل معدن
Ophitic	Enclosure of plagioclase laths by larger augite in basalts & gabbros بلورات بلاجيوكليز صغيرة محاطة في داخل بلورة اوغايت كبيرة the term ***sub-ophitic*** is used when the enclosure is partial
Interstitial or Intergranular	The later formed crystals fill in the spaces after the crystallized of early grains euhedral & subhedral بلورات تعبي الفراغات بين Cpx fills gaps between plagioclase, found In basalts
Graunular or granitic	The grain-size is more or less uniform with euhedral, subhedral, & anhedral grains

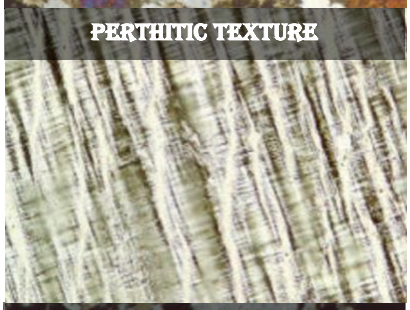
- **Directive textures** as magma flow in form of convection currents, & some crystals (E.g feldspar) may well align themselves in flow direction
  - Flow structures aren't found in extrusive rocks, & can be found in plutonic only where flow take the form of convection currents

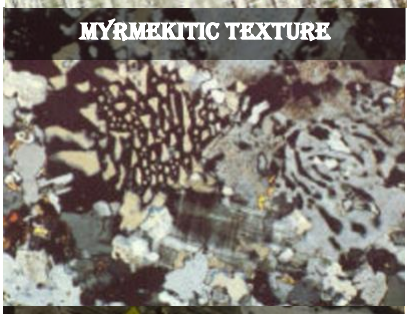
Texture	Crystal
Trachytic texture	parallel to subparallel arrangement of feldspar laths, found in volcanic rocks ترتيب متوازي للبلورات (بلورات الفلدسبار)
Trachytoid	Parallel arrangement of minerals (not feldspar) in mafic rock
Hyalopilitic	The arrangement of microlites in glassy rocks, هي ارضية ناعمة يظهر عليها ترتيب متوازي للمعادن بداخلها

- **Intergrowth textures** when a crystal of one mineral completely embedded within a crystal of another mineral. The crystals concerned are anhedral but one or both may be skeletal, dendritic or radiate.

Texture	Crystal
Micrographic	Graphic intergrowth of quartz–K-feldspar (under microscope)
Granophyric	Graphic intergrowth of quartz & alkali feldspar, in granite
Myrmekite	Graphic intergrowths of plagioclase & quartz







- **Exsolution (intergrowth):** Result from separation of homogenous alkali feldspar into K- & Na-feldspar, include Perthite, microperthite, mesoperthite, cryptoperthite, & Antiperthitic
    - Similar exsolution textures can be found in gabbros & basalts between orthopyroxenes & clinopyroxenes

Texture	Crystal
Perthitic	Parallel streaks & blebs of albite within a host of orthoclase or microcline, found in granite
Antiperthitic	Parallel streaks & blebs of orthoclase or microcline within a host of albite. Found in syenites & in some granites
Pyroxene exsolution	blebs of Opx in a host of Cpx, In slowly cooled Mafic rocks (gabbro, norite, Basalt)

Texture	Crystal
Corona texture	early formed mineral surrounded by fine-grained reaction product, represent a reaction between the mineral & melt
Vesicular	Open cavities in volcanic rocks
Amygdaloidal	When the vesicles are filled with secondary minerals
Resorption texture	The refusion or dissolution of a mineral back into the melt. commonly have rounded corners
Sperulitic	Devitrification of glass gives rise to large radial aggregates of crystals (silica & alkali feldspar) in the case of glass

- colour index of a rock & relative proportions of dark- to light-minerals

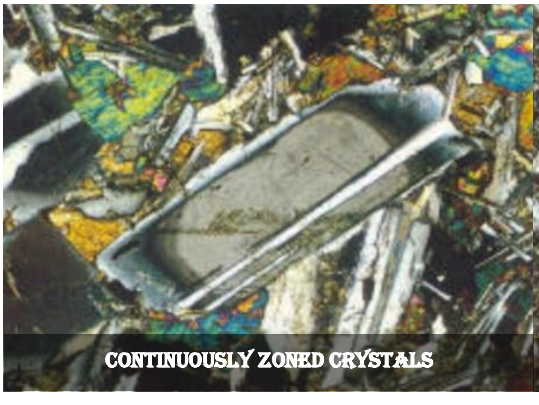
	Proportion of dark & light minerals	Eg
Melanocratic	>66%Dark-colored minerals	Mela-gappro
Mesocratic	66-33% Dark-colored minerals	Mela-gappro
Leucocratic	>33%Dark-colored minerals	Leuco-gapro

- **Essential** minerals necessary to the naming of rock but present in minor quantities (Eg. a crinanite contain a small amount of analcite)
- **Accessory** minerals are present in rocks in small amount (<1%), & ignored when naming the rock (such as opaque mineral in UM rocks)

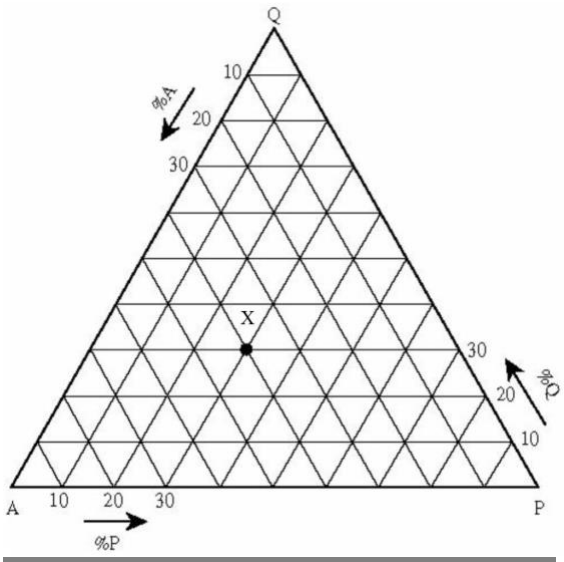
Zoning occur as mineral changes its composition in response to changes magma chemistry, led to change in the optical properties

- Many minerals zoned during growth due to solid-solution series, & equilibrium crystallisation is exceedingly rare

Texture	Crystal
Normal zoning	As crystal zoned from the high T endmember towards the low Eg. plagioclase zoned from Ca-rich to Na-rich compositions
Reverse zoning	As crystal zoned from the low T endmember towards the high Eg. plagioclase zoned from Na-rich to Ca-rich compositions
Oscillatory zoning	As the composition of the crystal switches from the high T to the lower endmember a number of times during growth



Igneous rocks classification

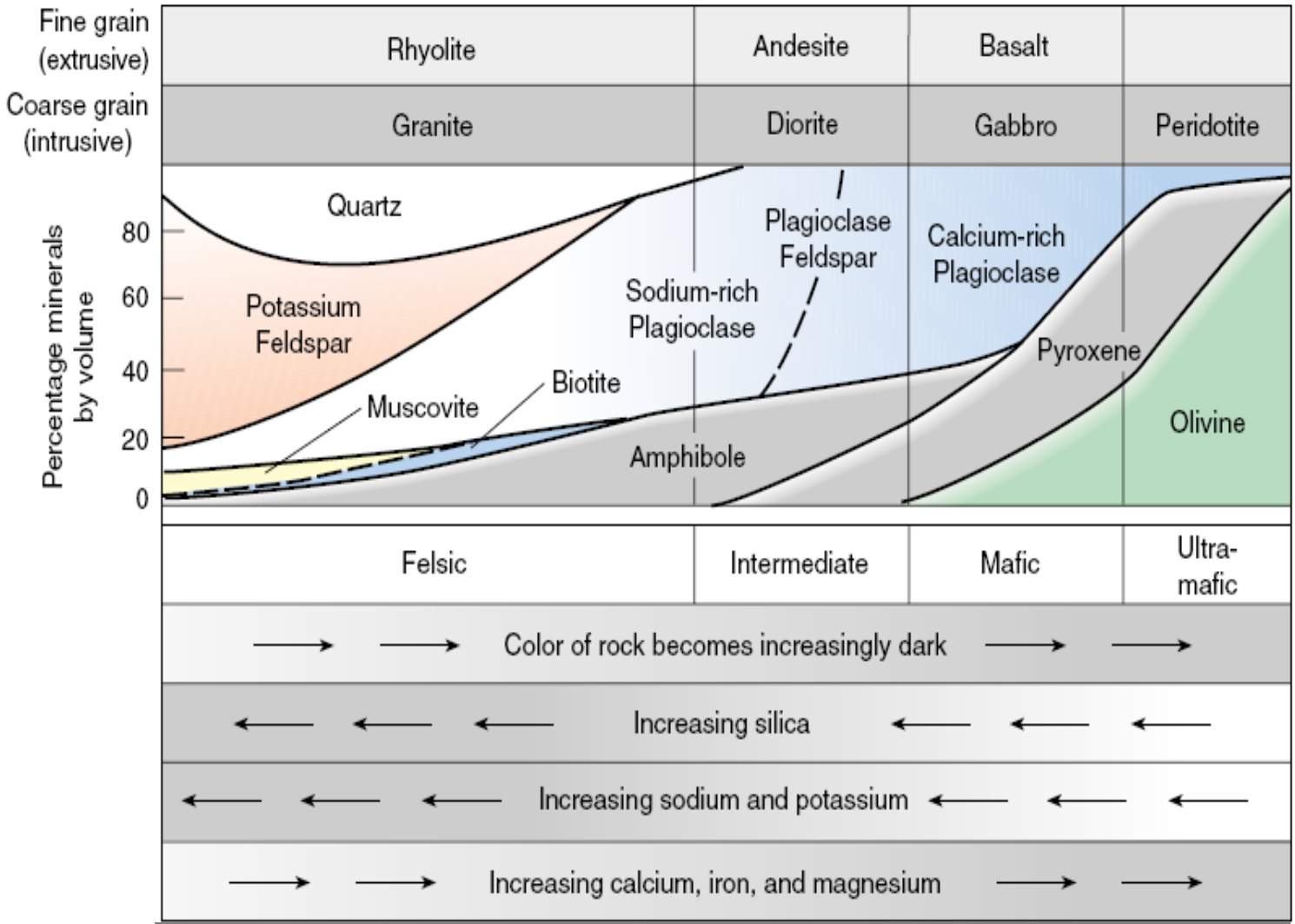


COMPOSITION OF DOT X
Q = 30%, A = 40 %, P = 30 %
THIS MINERALOGICAL COMPOSITION IS EQUIVALENT TO GRANITE

Igneous rocks classified based on: mineralogy, locality, & texture

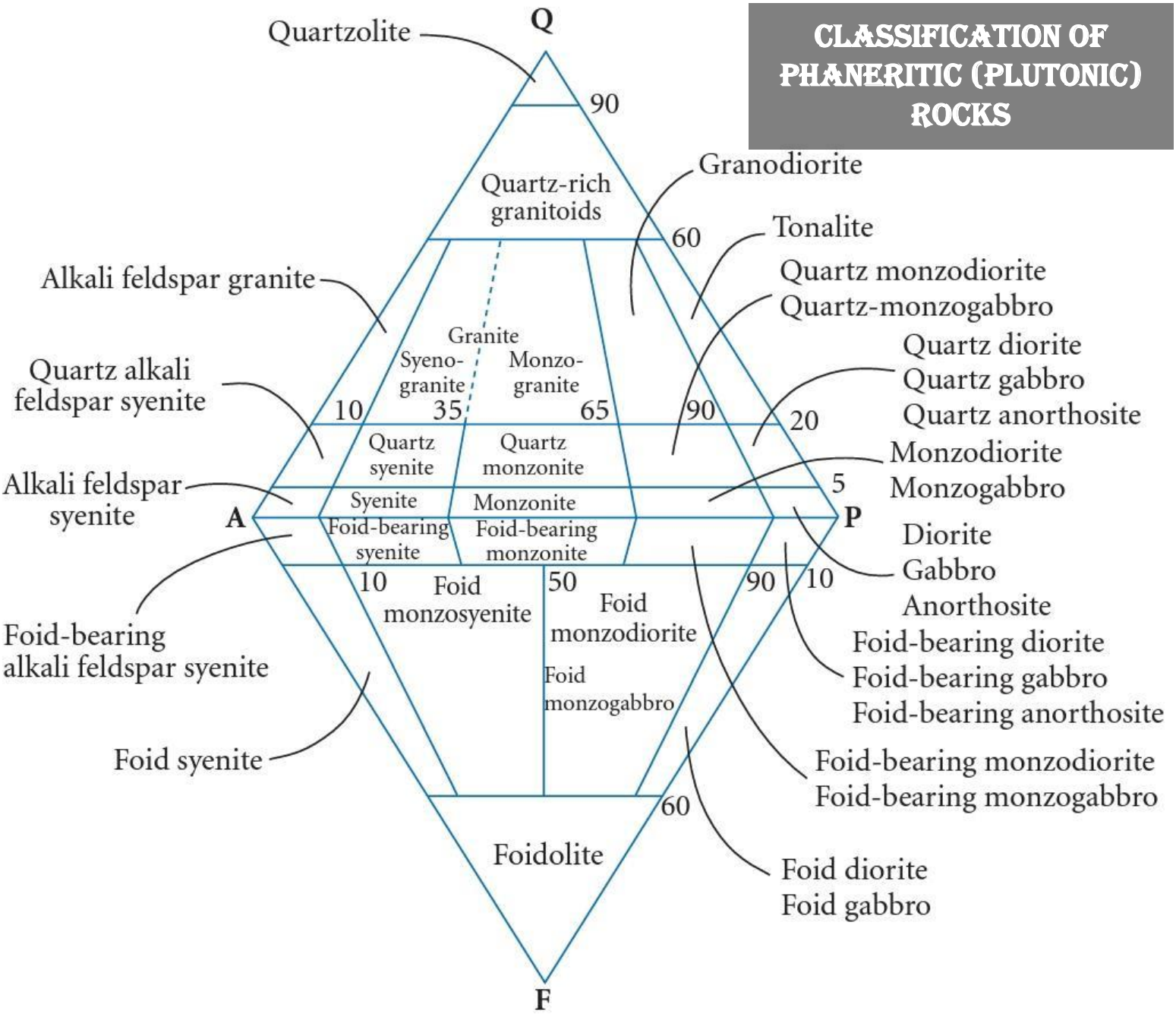
the IUGS system for classification of igneous rocks is based on the percentages of 5 minerals *Quartz (Q)*, *Plagioclase (P)*, *Alkali feldspar (A)*, *Ferromagnesian Minerals*, & *Feldspathoids (F)*

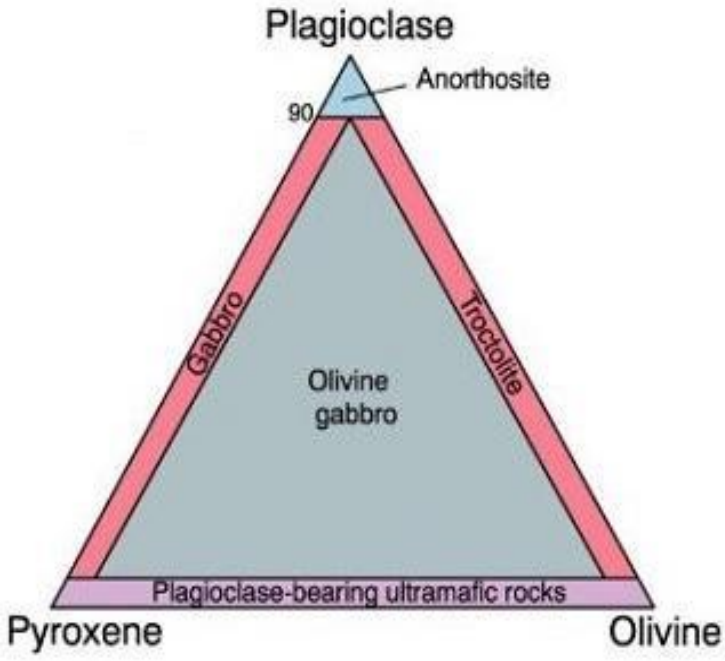
The mode of a rock : actual mineral composition, expressed in %vol, & calculated from the chemical composition of the rock



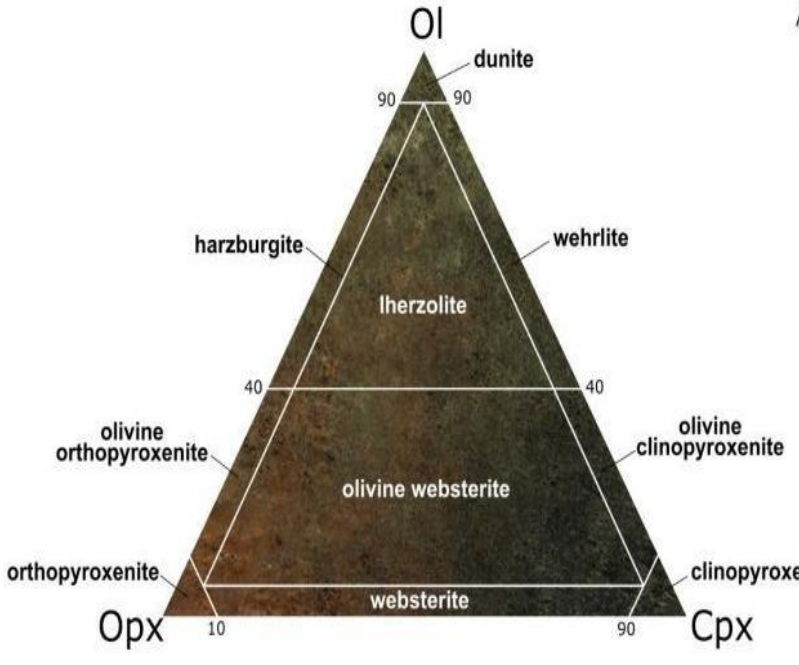
A MINERAL'S ABUNDANCE IN A ROCK IS PROPORTIONAL TO THE THICKNESS OF ITS COLORED BAND BENEATH THE ROCK NAME. IF A ROCK HAS A FINE GRAIN TEXTURE, ITS NAME IS FOUND IN THE TOP ROW OF ROCK NAMES; IF IT HAS A COARSE GRAIN TEXTURE, ITS NAME IS IN THE SECOND ROCK

CLASSIFICATION OF PHANERITIC (PLUTONIC) ROCKS



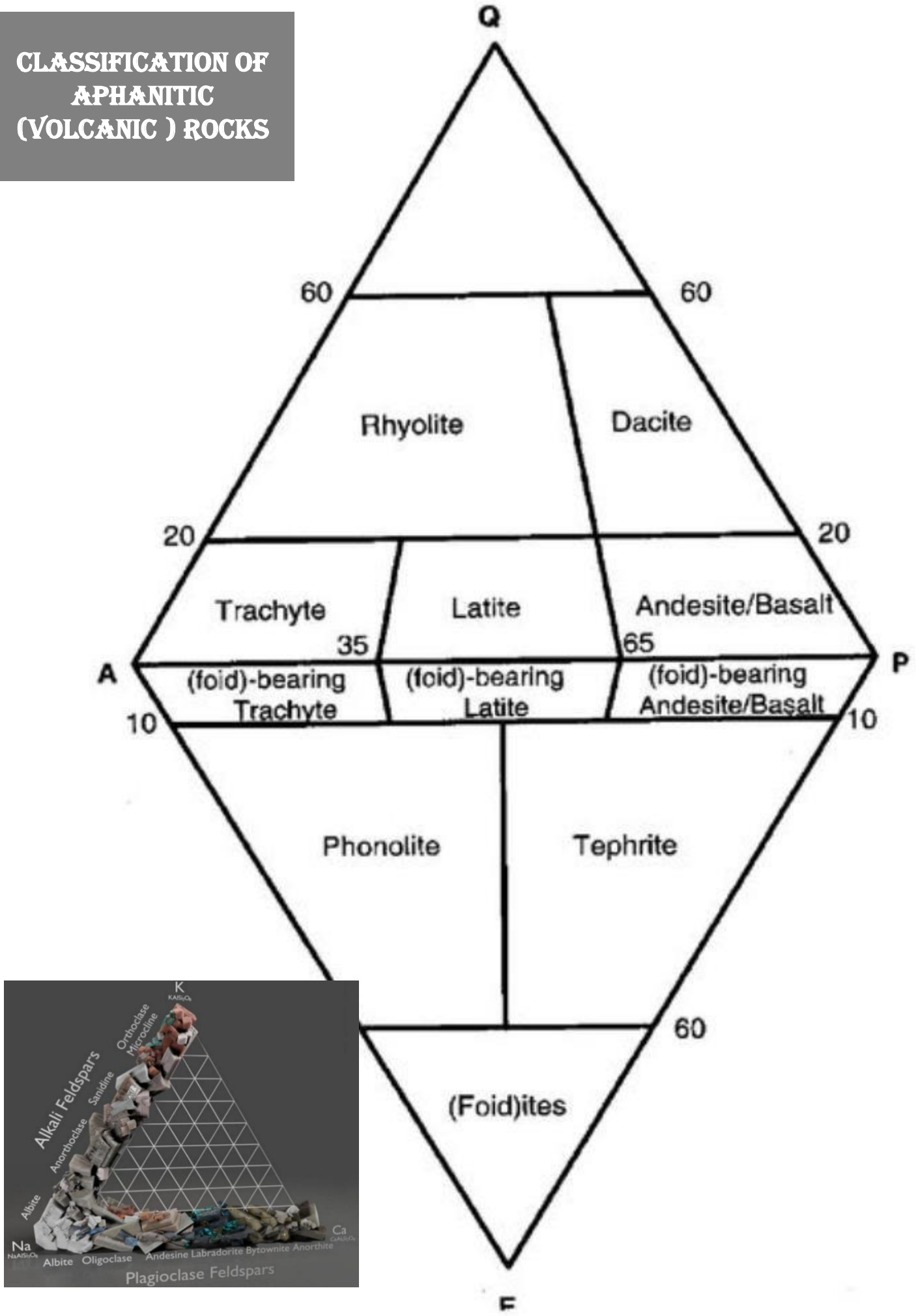


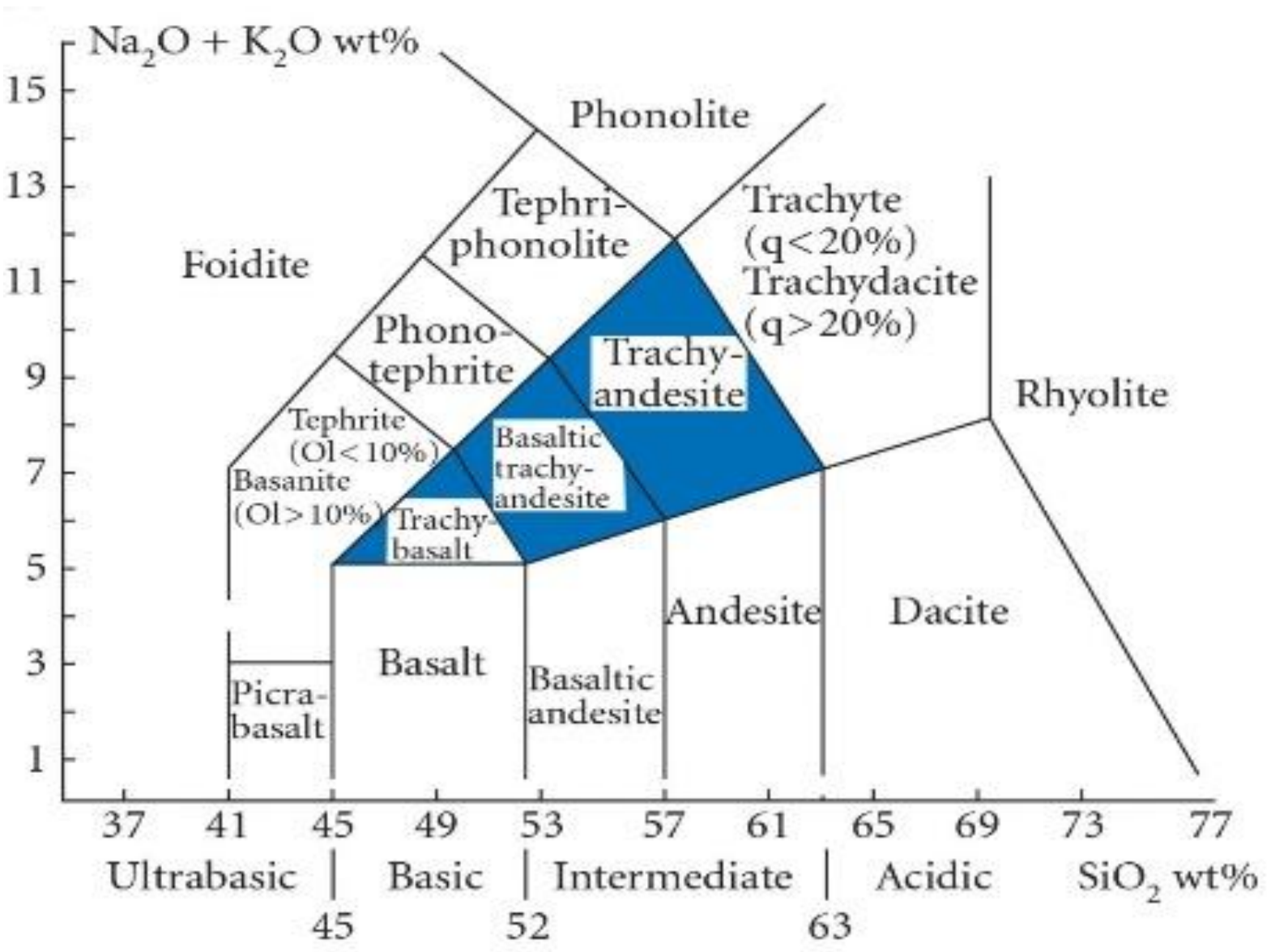
CLASSIFICATION OF GABBROIC ROCKS



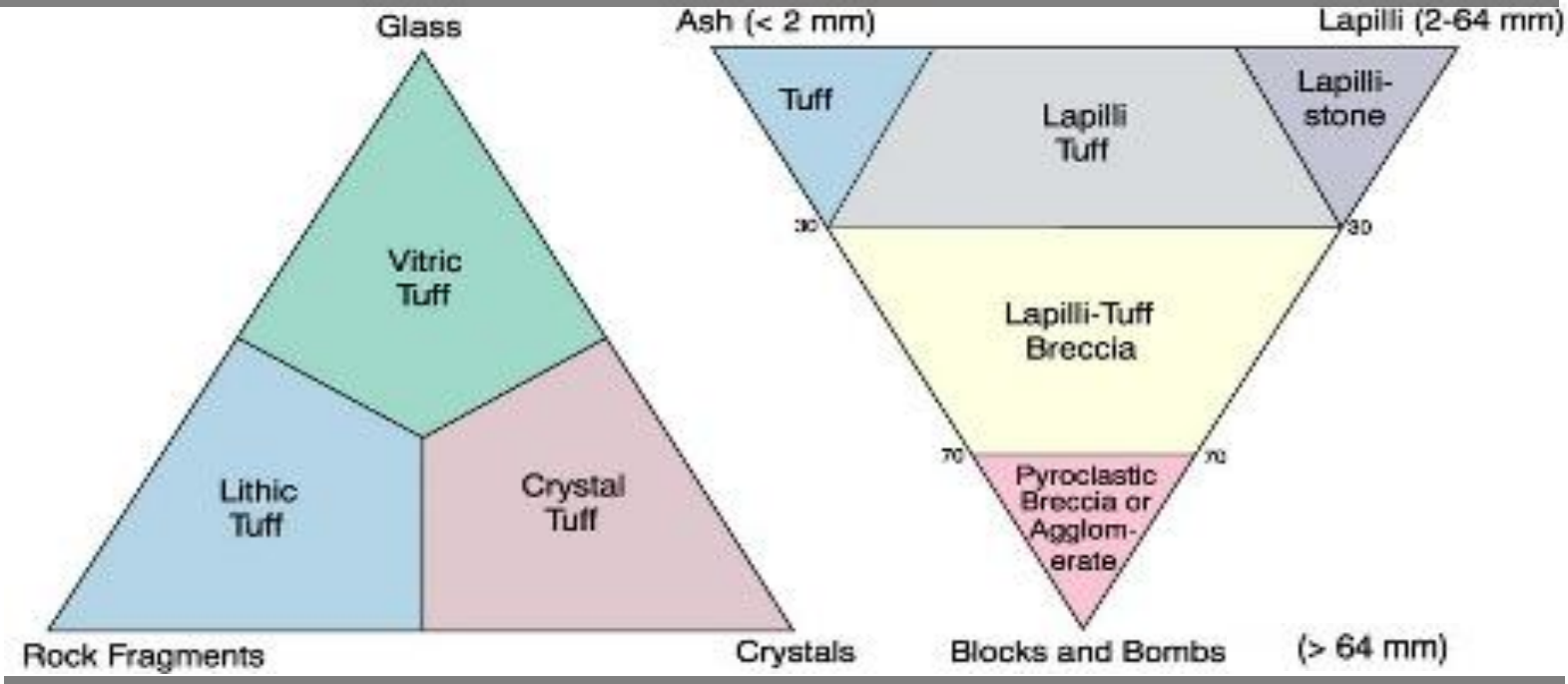
CLASSIFICATION OF MAFIC ROCKS

CLASSIFICATION OF APHANITIC (VOLCANIC) ROCKS



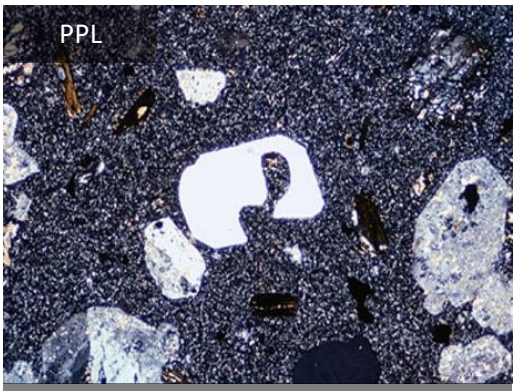


A CHEMICAL CLASSIFICATION OF VOLCANICS BASED ON TOTAL ALKALIS VS. SILICA

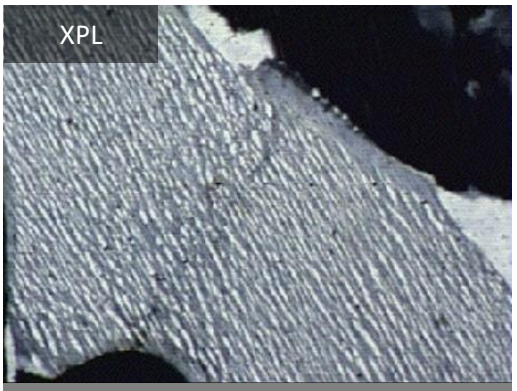


CLASSIFICATION OF THE PYROCLASTIC ROCKS
LEFT: BASED ON TYPE OF MATERIAL, RIGHT: BASED ON THE SIZE OF THE MATERIAL

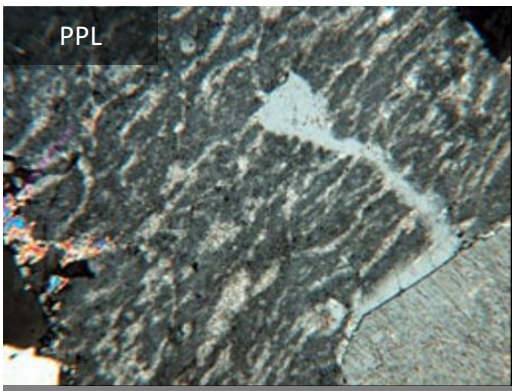
Felsic rocks: Plutonic Granite & volcanic equivalents Rhyolite



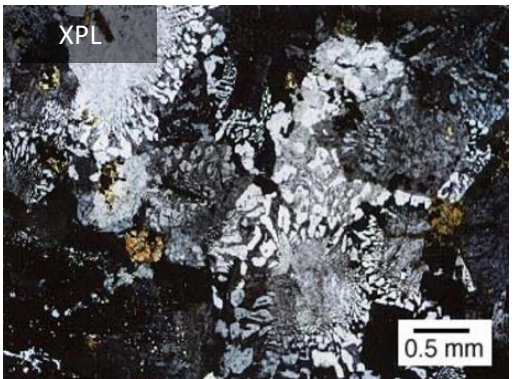
RHYOLITE
CONTAINS PHENOCRYSTS OF QUARTZ, K-FELDSPAR (SANIDINE), PLAGIOCLASE, & BIOTITEIN



PERTHITETEXTURE IN MICROCLINE



PERTHITETEXTURE IN MICROCLINE



MICROGRAPHIC TEXTURE (QUARTZ + K-FELDSPAR)

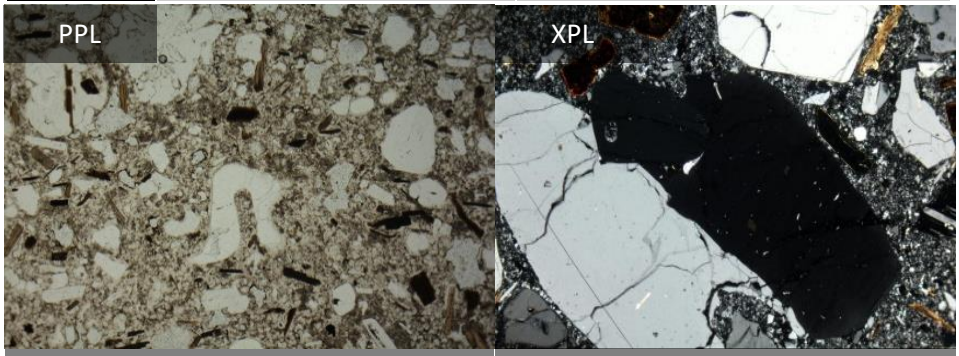
Mineralogy:

- ***Felsic minerals:*** 20%quarzt, 40-50%alkali-feldspar , & some plagioclase
- ***mafic minerals:*** Biotit ± hornblend
- ***Accessory minerals:*** muscovite, Magnetite, illmenite, zircon, & apatite
- ***Alteration product:*** chloritization, sericitization

Textural

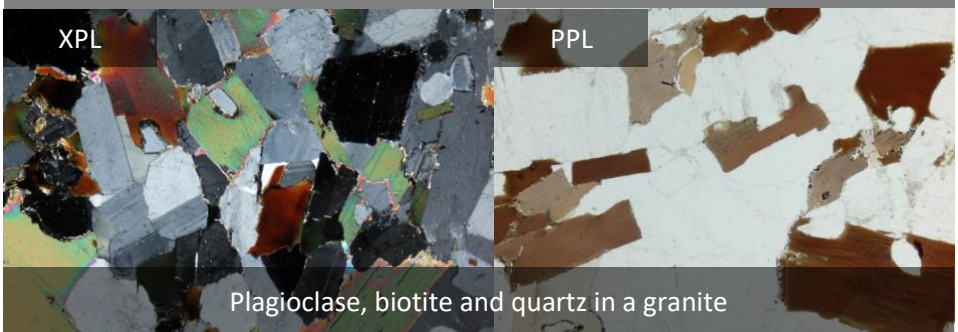
- Perthitic, antiperthitic, micrographic, myrmekitic, poikilitic & others

Rock	Texture	Mineralogy
Rhyolite	Porphyritic Allotriomorphic Holocrystaline	Phenocrysts of quartz & feldspar (sanidine) in a felsic groundmass & Biotite commonly found as accessory mineral
Granite	Phaneritic texture Graphic intergrowth Hypidiomorphic Holocrystaline May be Twining in Pl	Composed mainly of quartz & feldspar with minor amounts of mica, & amphiboles

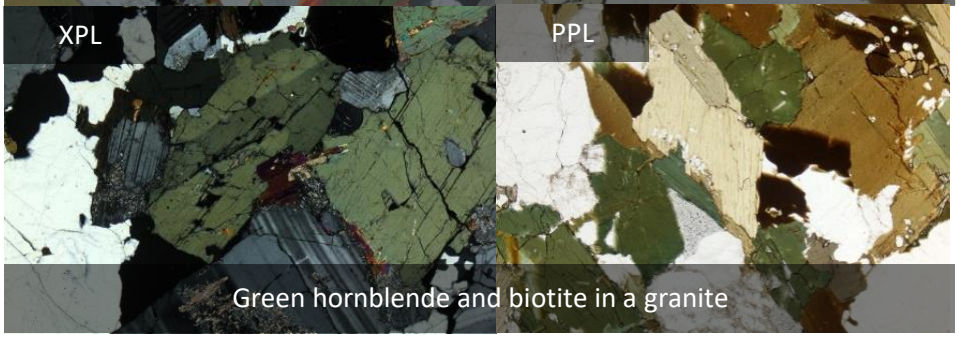


Quartz & plagioclase crystal in a Rhyolite with felsic groundmass
The Brown is biotite

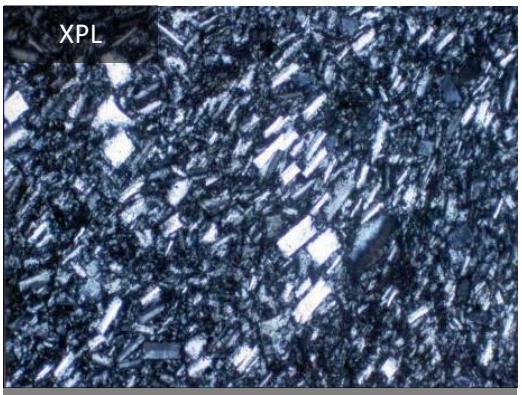
Quartz & plagioclase crystal in a Rhyolite with felsic groundmass
The Brown is biotite



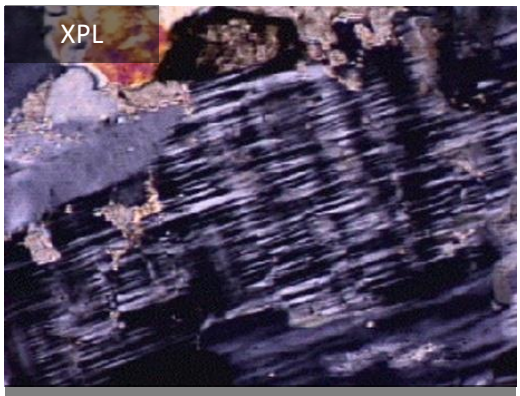
Plagioclase, biotite and quartz in a granite



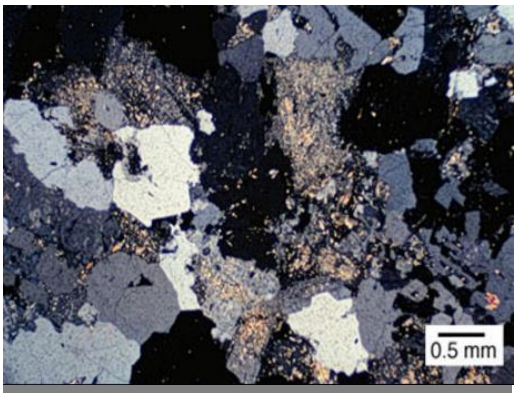
Green hornblende and biotite in a granite



TRACHYTIC TEXTURE



CROSS-HATCHED ('TARTAN) TWINNING IN MICROCLINE



SERICITIC ALTERATION

TRACHYTIC TEXTURE

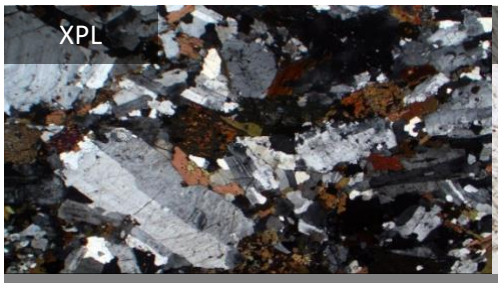
Felsic rocks: Plutonic Syenite & volcanic equivalents Trachyte

Mineralogy

These rocks same as granite & rhyolite but rich in alkali feldspar (usually orthoclase) rether than quartz (<5%), & Plagioclase feldspars may be present in small quantities (<10%), & may be contain feldspathoid rether than quartz

Textural features: similar to granite

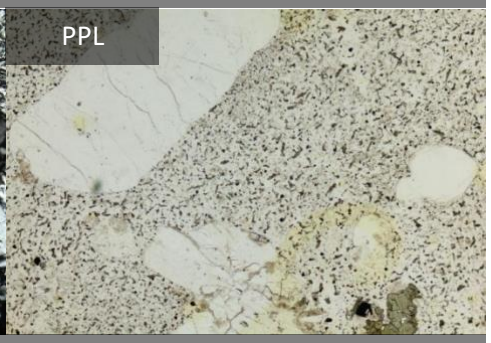
Rock	Mineralogy
Syenite	• Quartz <5%, plagioclase<10%, orthoclase (alkali feldspar) • Ferromagnesian: hornblende amphibole, rarely pyroxene • Biotite is rare, because most Al is used in producing feldspar • Accessory: Sphene, Zircon, & apatite
Trachyte	• Composed largely of alkali feldspar with minor amounts of dark-colored mineral(biotite,hornblende,pyroxene) • called latite if Na-plagioclase > the quantity of alkali feldspar



Orhoclase, small plagioclase crystals (with polysynthetic twinning) & biotite (brown) in syenite

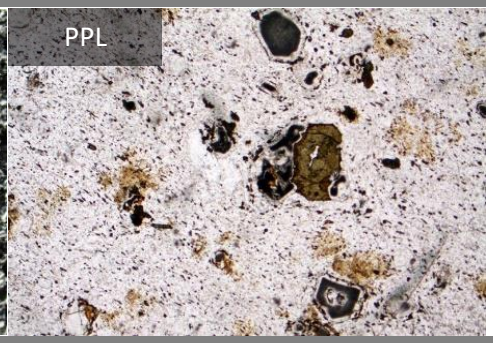
Orhoclase (with sericite alteration), apatite (colorless, high relief) & amphibole crystals in Syenite

Leucite crystal (with plagioclase inclusions) in a Trachyte



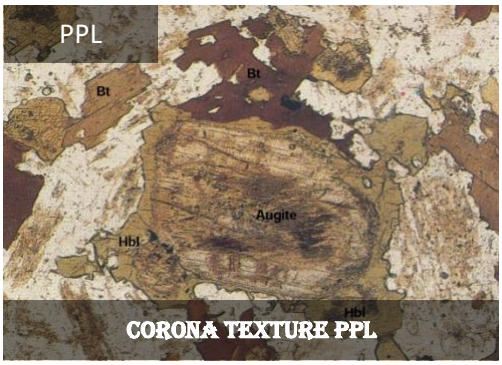
Sanidine, pyroxene & rounded leucite crystals in a Trachyte

Sanidine and Leucite crystals in a Trachyte



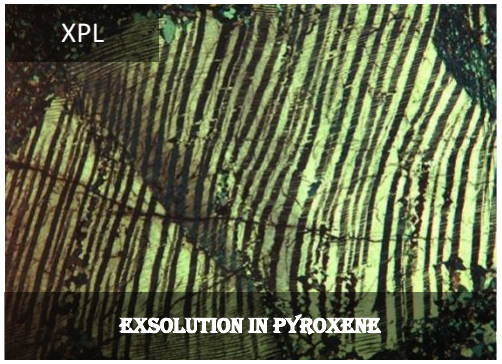
Hauyne crystal (dark) & pyroxene (green) in a foid-bearing trachyte

CORONA TEXTURE XPL



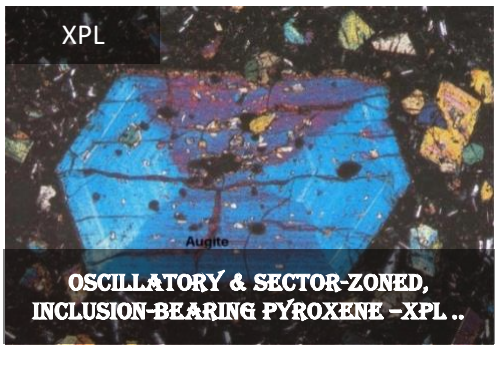
CORONA TEXTURE PPL

CORONA TEXTURE XPL
THE AUGITE IS TWINNED & ZONED



EXSOLUTION IN PYROXENE

SUBHEDRAL GRANULAR GABBRO –XPL



OSCILLATORY & SECTOR-ZONED, INCLUSION-BEARING PYROXENE –XPL ..

Mafic rocks: Plutonic Gappro & volcanic equivalents Basalt

Gabbros, diorites & their volcanic equivalents (basalts & andesites) are differ from granitoids in:

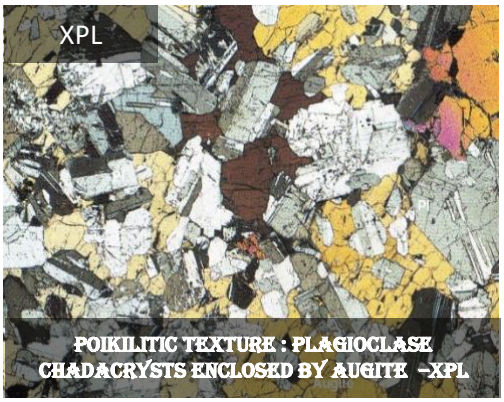
1. rich in ferromagnesian minerals (a higher color index than granites)
2. have higher content of plagioclase (> 60%) compared to K-feldspar

Diorites & gabbros differ from each other by the plagioclase continent

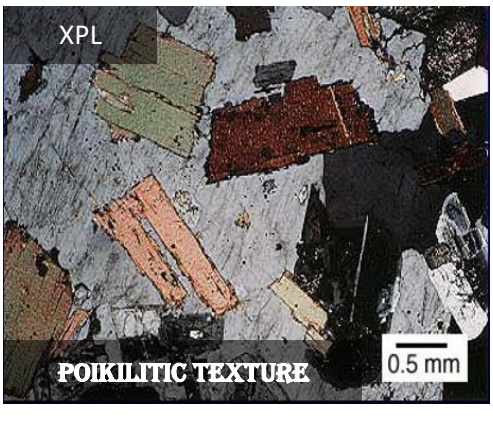
Minerals:

1. ***Plagioclase [$NaAlSi_3O_8$-$CaAl_2Si_2O_8$]***
   - carlsbad, polysynthetic Twining , lamellae
   - plagioclases ranging from labradorite to anorthite (An >50%)
2. ***Pyroxene [OPX $(Fe, Mg)_2Si_2O_6$, CPX $(Ca, Mg, Fe)_2Si_2O_6$]***
   - the **second abundant** (20-30%)
   - commonly pale brown (beige) colored, Opx 1st order interfernse color & Cpx 3rd Order interfernse color
   - relief is moderate compared to the low relief plagioclases
   - Cpx (augite) occur in tabular euhedral to subhedral, as zoned grains (in basalt), & show simple or polysynthetic twins
3. ***Olivines [$Mg2_2SiO_44$-$Fe2_2SiO_44$]***
   - is the **third component** in abundance (10%)
   - colorless (white), lacks cleavage, & common as phenocrysts
   - olivine surrounded by pyroxenes forming Corona texture
4. ***Amphiboles [$K(NaCa)_2(Ca,Fe,Mg)_5(Al,Si)_8O_{22}(OH)_2$]***
   - hornblende (brown & green) with pleochroism & the cleavage
5. ***Biotite [$K(Mg,Fe)_3(Si_4O_{10}(OH)_4$]***
6. ***Opaque [magnetite Fe_3O_4, ilmenite $FeTiO_3$]*** 3 - 8%
7. May be contain ***amounts of quartz or feldspathoids***
8. Variable amounts of ***alkali feldspars ($KalSi_3O_8$)*** are also present

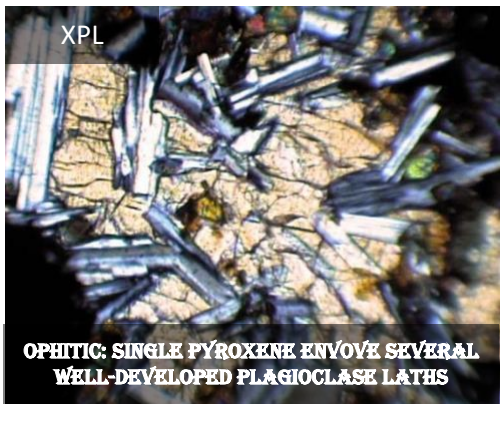
POIKILITIC TEXTURE



POIKILITIC TEXTURE : PLAGIOCLASE CHADACRYSTS ENCLOSED BY AUGITE –XPL



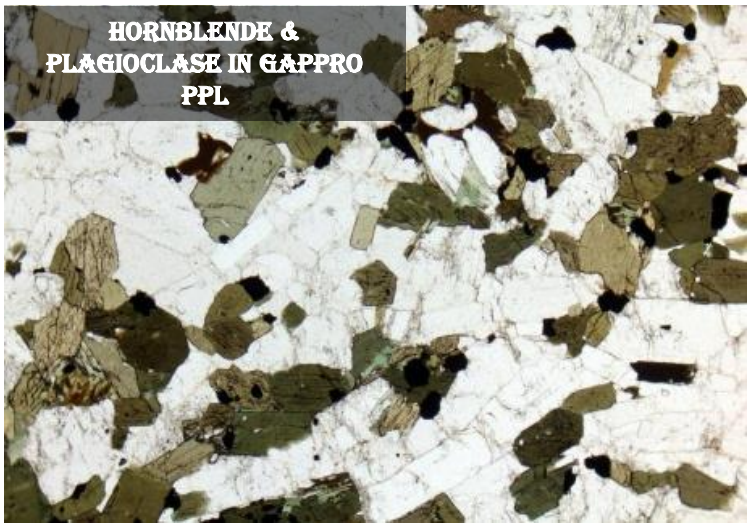
POIKILITIC TEXTURE



OPHITIC: SINGLE PYROXENE ENVOVE SEVERAL WELL-DEVELOPED PLAGIOCLASE LATHS


GABBRO XPL
GRANULAR OLIVINE GABBRO
Augite
Augite
Pl
Pl


GABBRO PPL
GRANULAR OLIVINE GABBRO
Ol
Pl
Augite
Augite
Pl


HORNBLENDE &
PLAGIOCLASE IN GAPPRO
PPL


HORNBLENDE &
PLAGIOCLASE IN GAPPRO
XPL


BASALT PPL
VAR. THOLEIITIC BASALT
Cpx

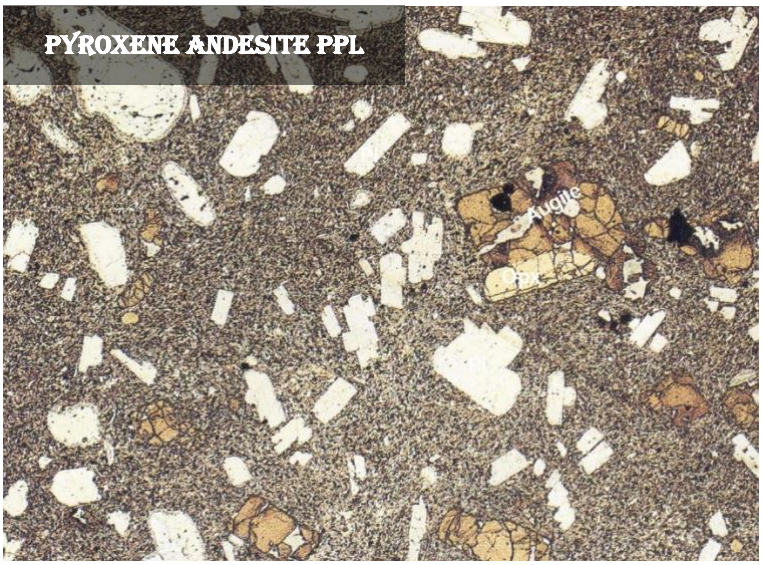

BASALT XPL
VAR. THOLEIITIC BASALT
Pl
Pl

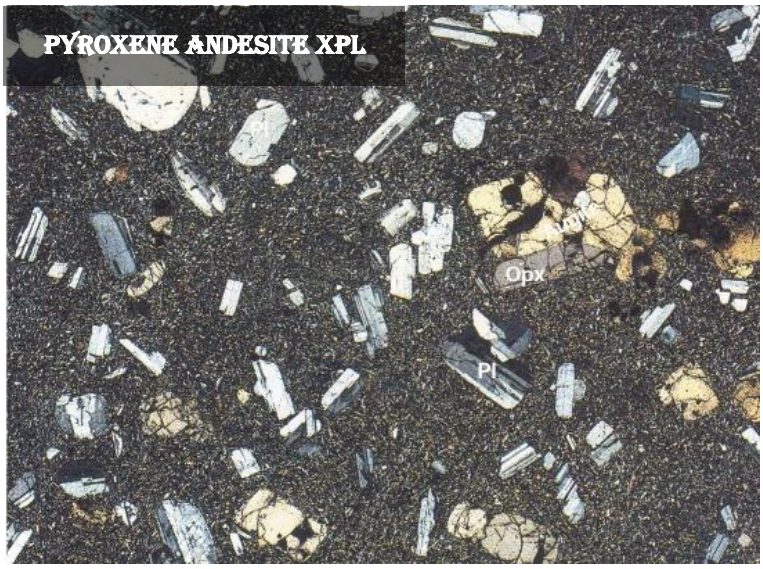

AMYGDALOIDAL BASALT XPL


AMYGDALOIDAL BASALT PPL
Cal

Intermediate rocks: Plutonic diorite & volcanic equivalents Andisite

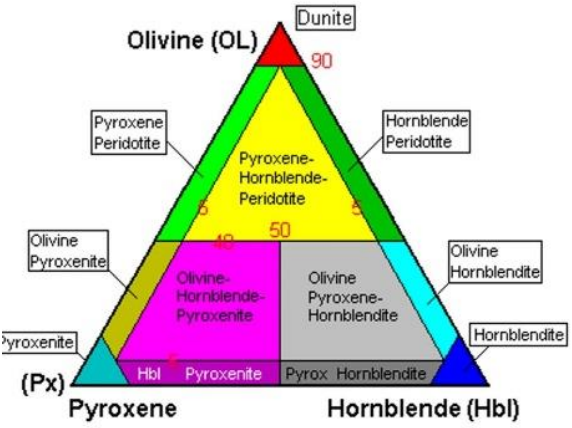
- Minerals: such as mafic rocks
  1. ***Plagioclase [$NaAlSi_3O_8$-$CaAl_2Si_2O_8$]*** An < 50%
     - the plagioclase is of andesine variety (An=30-50%)
  2. ***Pyroxene [OPX $(Fe, Mg)_2Si_2O_6$, CPX $(Ca, Mg, Fe)_2Si_2O_6$]*** (20-30%)
  3. ***Olivines [$Mg2_2SiO_44$-$Fe2_2SiO_44$]*** rare in diorites & andesites
     - olivine surrounded by pyroxenes forming the Corona texture
  4. ***Amphiboles [$K(NaCa)_2(Ca,Fe,Mg)_5(Al,Si)_8O_{22}(OH)_2$]*** hornblende
     - common in intermediate rocks (andesite & diorite)
     - amphiboles surrounding pyroxenes forming corona texture
  5. ***Biotite [$K(Mg,Fe)_3(Si_4O_{10}(OH)_4$]*** associated with amphibole
  6. ***Opaque [magnetite Fe_3O_4, ilmenite $FeTiO_3$]*** 3 - 8%
  7. May be contain ***amounts of quartz or feldspathoids***
  8. Variable amounts of ***alkali feldspars ($KalSi_3O_8$)*** are also present

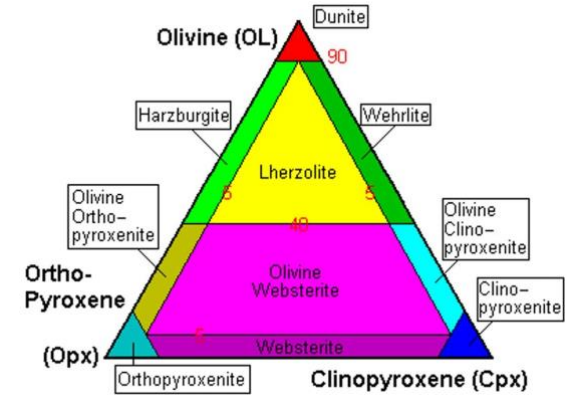


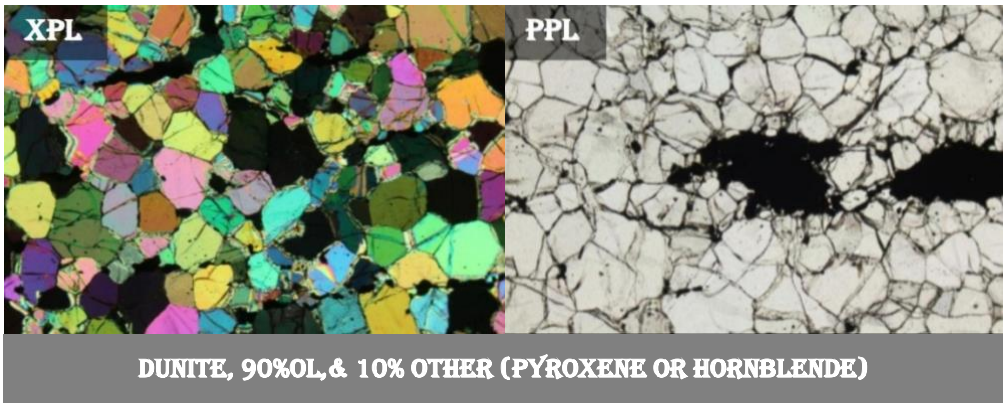


Ultramafic rocks: peridotite

- UM: Rocks containing > 90% ferromagnesian minerals
- classified on the basis of dark minerals
- If the ferromagnesian minerals consist only of Ol & Px, they are classified on the basis of their contents of Ol, Opx (enstatite, hypersthene) & Cpx (augite)
- If hornblende is present the classification is based on the relative amounts of Ol, Px & Am
  - ➢ Rocks consisting of > 90%Ol are dunite
  - ➢ Rocks consisting of > 90%Px are pyroxeniteor
  - ➢ Rocks consisting of > 90%hornblende: hornblendite
- **Serpentine**: formed due to olivine altration, PPL: yellow or green
- **Opaque minerals (magnitite & chromite)**: black: PPL

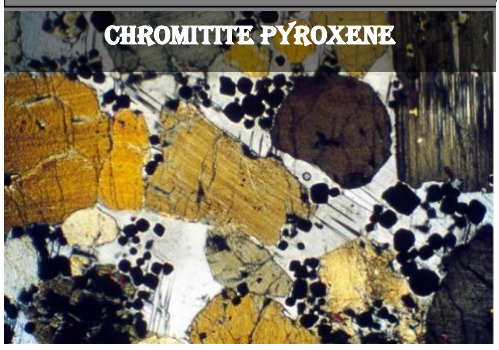




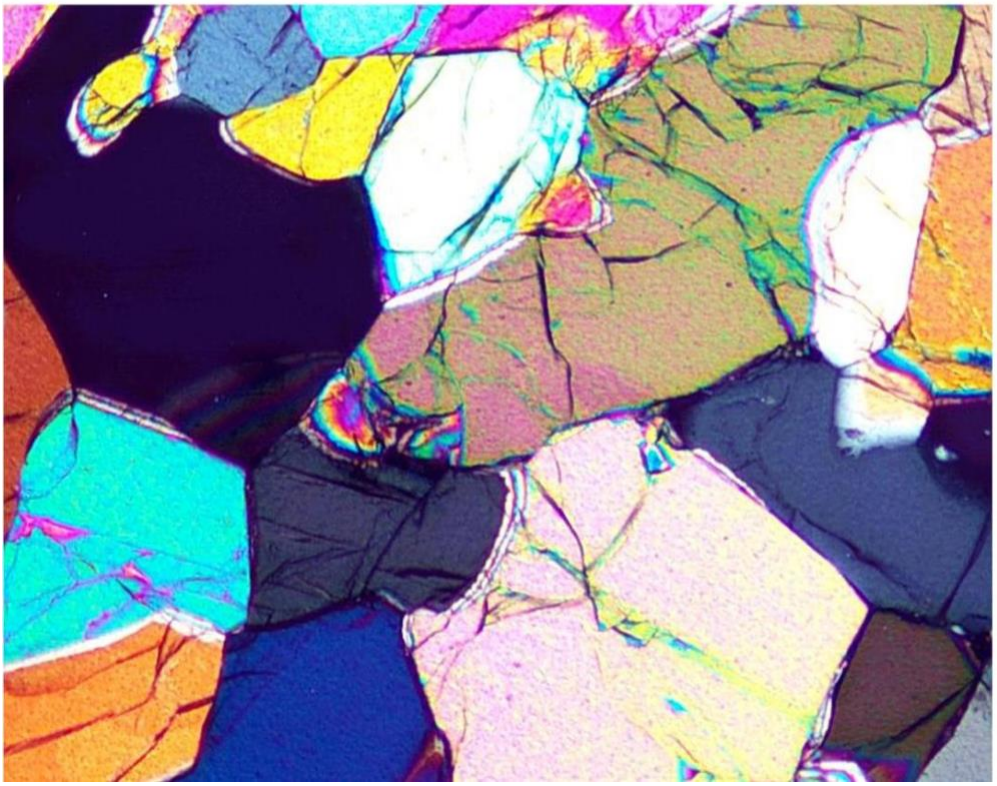


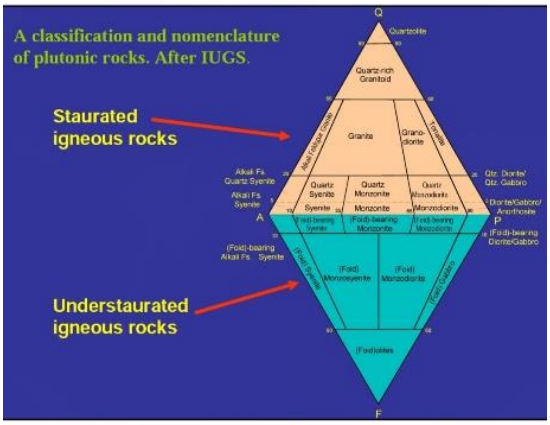
DUNITE, 90%OL,& 10% OTHER (PYROXENE OR HORNBLENDE)

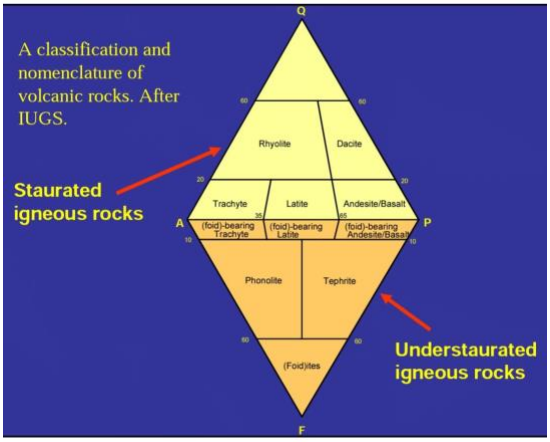
pyroxenite

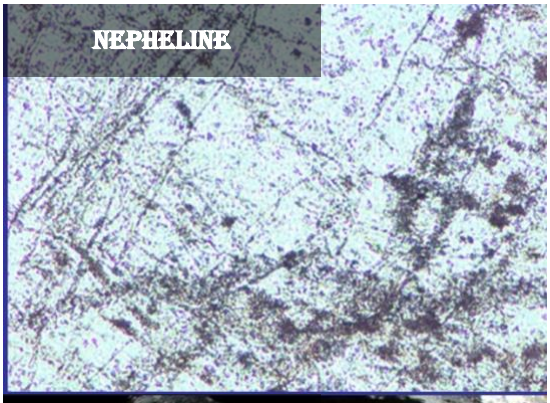


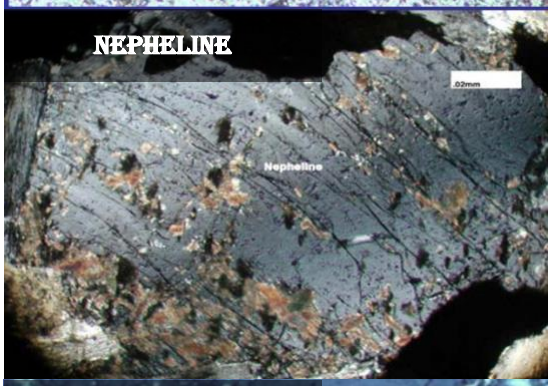
Spinel lherzolite

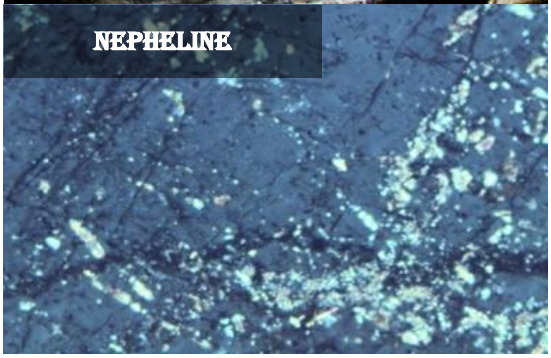






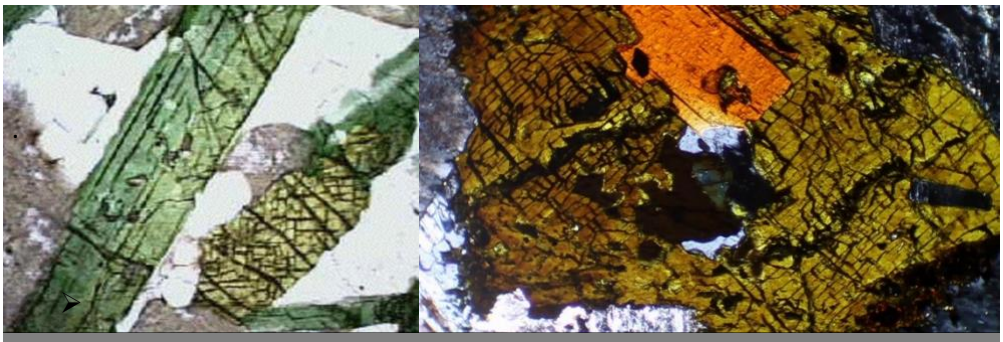


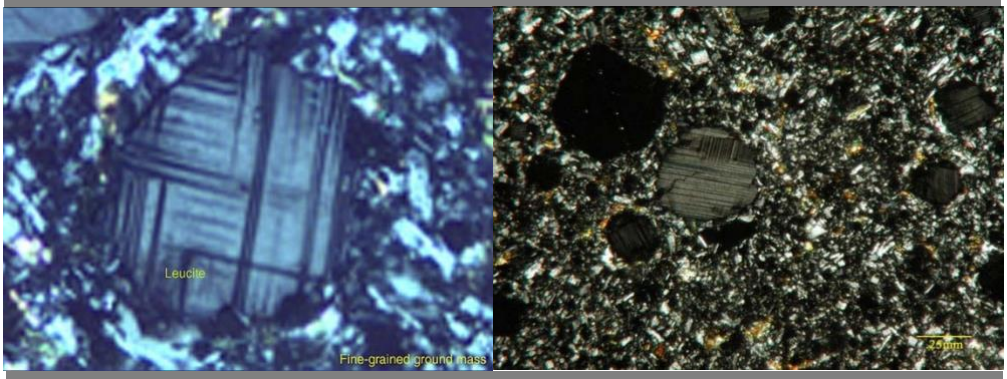




Saturated, Undersaturated, & Oversaturated syenite, basanites

- **Undersaturated** rocks have feldspathoid rether than quartz
- **Saturated** has no quartz or feldspathoid (completely plagioclase)
- **Oversaturated** has quartz rether than feldspathoid
- Feldspathoids such as **leucite & nepheline**
- how to differentiate Nepheline from quartz*:* **nepheline is uniaxial – ve** but **quartz is uniaxial +ve**
- The igneous rocks with feldspathoids composition:
  - rich in alkalis (**alkaline igneous),** pyroxenes, & amphiboles
  - alkali pyroxene **(aegirine: Found in felsic peralkaline plutonic rocks such as alkali granite, & syenite, Green),** alkali amphibole (riebeckite)
  - **Leucite**: euhedral, rounded, complex twinning, & low birefringence
- **Aegirine-augite (alkali-pyroxene):**
  - Found in felsic peralkaline plutonic rocks (alkali granite, & syenite)
  - Green, undersaturated





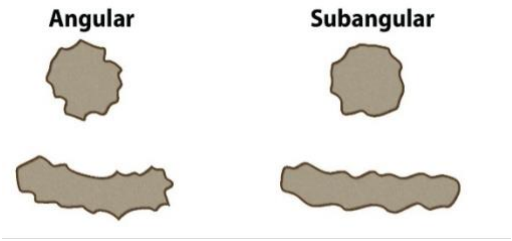
Monzonite

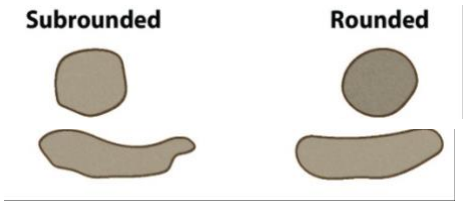
- holocrystalline, medium-to coarse-grained, hypidiomorphic
- biotite, phlogopite (green or brown); aegerine-augite; plagioclase, K-feldspar; opaques; carbonate; apatite; sphene

Basanites

- alkali basalts or feldspathoid bearing basalts)

Nepheline-sodalite syenite large crystals is aegirine-augite (yellow to green in PPL) & sodalite (black in XPL)





Conglomerates & Breccias

- **Terrigenous** "From the Earth": clastic sedimentary rocks, Composed of clasts of pre-existing rocks & minerals, & referred as:
  - **Detrital**: Formed by pre-existing rocks by Erosion or weathering
  - **Epiclastic**: derived from the surface
  - **Silisiclastic:** Because most terrigenous clastic rich in quartz & silicate

- **Clast formed by physical weathering:** eroded & transported by mass wasting, wind, water, or ice & deposited as **Discrete** (unconsolidated fragments that eventually lithified)

- **Terrigeneous sediments divided into 3 distinct groups based on the basis of clast diameter**: Conglomerate & breccia, Sandstone, & mudrock

- **Conglomerates (roundstone or Puddingstone)**: a lithified gravel made up of rounded to subrounded clasts whose diameters exceed 2 mm
  - are consolidated gravels (granules, pebbles, cobbles, & boulders)

Conglomerates classification	
Oligomictic (monomictic, orthoquartzose)	**Consists single type of fragment of resistant rocks (e.g granite, rhyolite..),** & minerals as quartz, & cherts
Polymictic (Petromict)	**Composed of fragment (clast) with different composition** of metastable & unstable rocks (basalt, slate, & Limestone)

- **Breccias(sharpstone)**: lithified rubble made up of angular clasts > 2mm

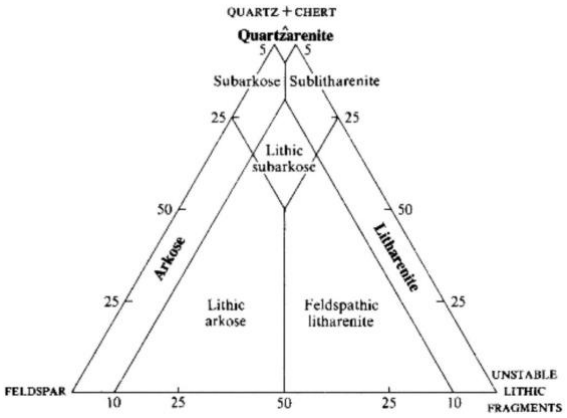
- Most clasts on conglomerates & breccias are fragments of rocks & minerals produced by the **disintegration of bedrock,** which occur as **coarser-grained fragments & finer-grained matrix** filling the space between fragments

- Clasts are glued together by siliceous, calcareous, or ferruginous cement

- Three principal categories of clasts are Distinguished:
  1. Mineral fragments that occur as major component
  2. Mineral fragments that occur as accessory Mineral
  3. Fragments of rocks

2 Distinctive varieties of Conglomerates & breccias which defined on the basis of their texture	
Orthoconglomerates (True conglomerates)	consist of **gravel-sized framework grains** Matrix (sand or finer) **< 15%**
Paraconglomerate	Consist of **> 15%matrix (sand & Mudrocks)** Matrix commonly 50%
Extraformational Vs intraformational conglomerates & breccias	
Intraformational	Have interior (intrabasinal) source, so clasts have same composition as matrix
Extraformational	Derived from area outside the depositional basin so clasts have different composition from matrix

Sandstones, Greywackes, & Mudstones



Udden-Wentworth Classification

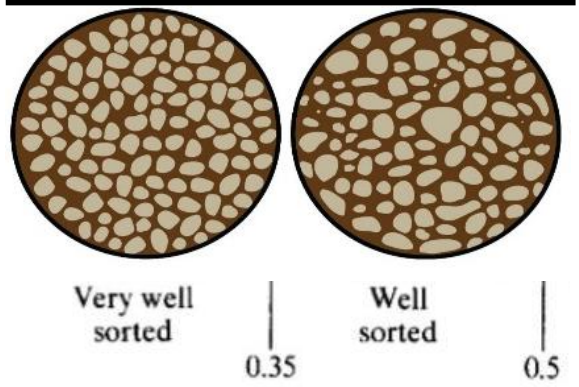
The classifications of sandstones is based on 3 components: namely silica (quartz, chert), feldspar & lithic fragments

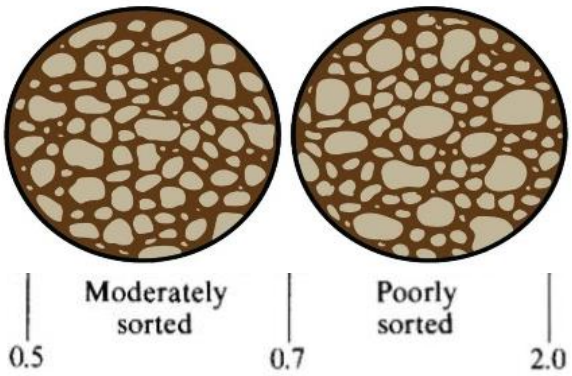
	Name	Millimeters	Micrometers	ϕ
GRAVEL		4096		−12
	Boulder	256		−8
	Cobble	64		−6
	Pebble	4		−2
	Granule	2		−1
SAND	Very coarse sand	1		0
	Coarse sand	0.5	500	1
	Medium sand	0.25	250	2
	Fine sand	0.125	125	3
	Very fine sand	0.062		4
SILT	Coarse silt	0.031	31	5
	Medium silt	0.016	16	6
	Fine silt	0.008	8	7
	Very fine silt	0.004		8
	Clay			

The standard grain size distribution of clastic sediments in mm, µm & Φ

Φ = – log (grain size in mm)

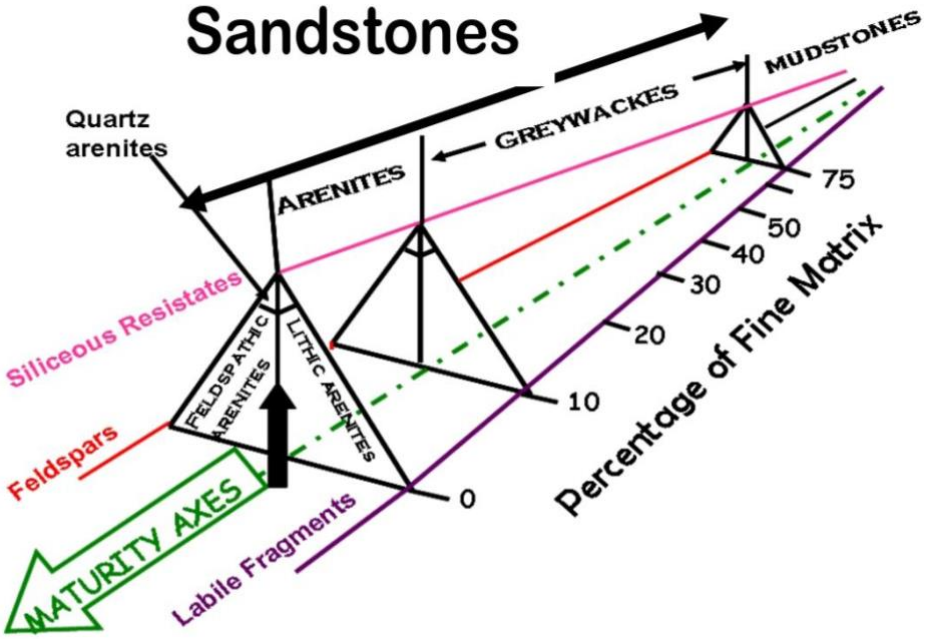
Fine stippled signature indicate silt & clay sized particles, & The different classes are differentiated on the basis of the standard deviation





The degrees of sorting of clastic sediments <0.35 very well-sorted, 0.35 – 0.5 well-sorted, 0.5 – 0.7 moderately sorted, 0.7 – 2.0 poorly sorted, & > 2.0 very poorly sorted

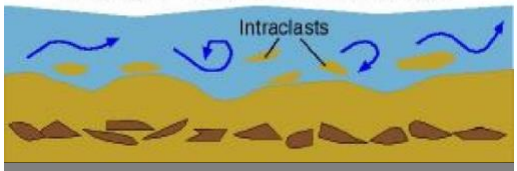
- Conglomerates studied in the field (hand-specimens) due to large grain size of their constituents, While the sandstones will be studied both in hand specimen & in thin sections
- Dott (1964) classification for clastic sediments: based on the percentage of fine matrix (very fine grained silt and clay sized particles)



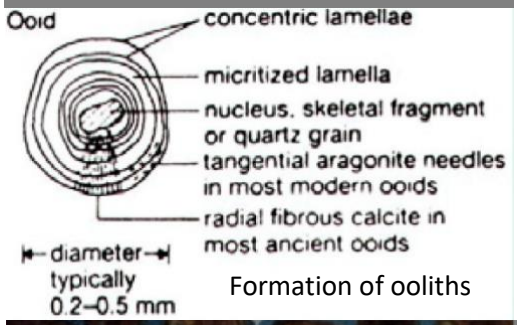
- The mudstone with matrix > 75% include siltstone, claystones, & shales
- Cements in sandstone & greywacke: silica, calcite, dolomite, & Fe-oxide

Limestones & Dolostones (Carbonates)

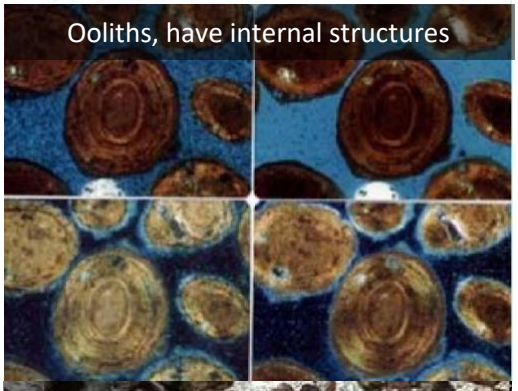
Erosion of weakly cemented substrate



Formation of allochems



Formation of ooliths

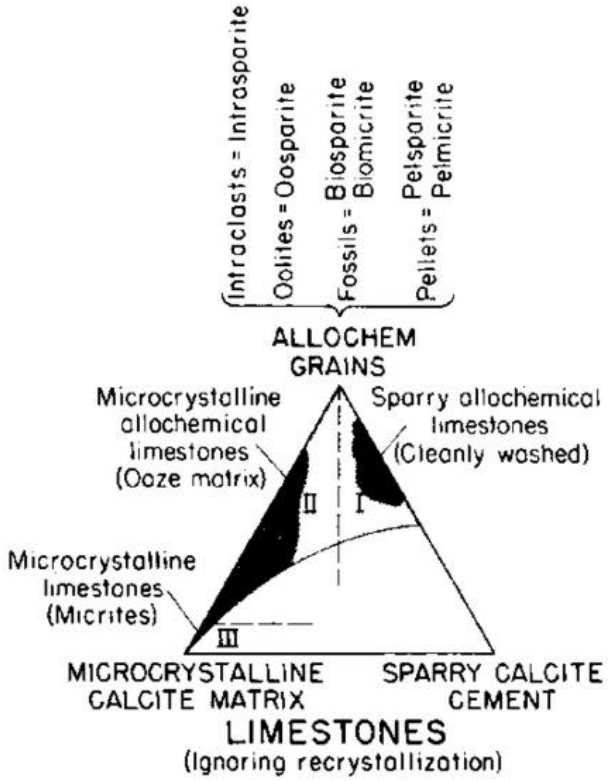


Ooliths, have internal structures

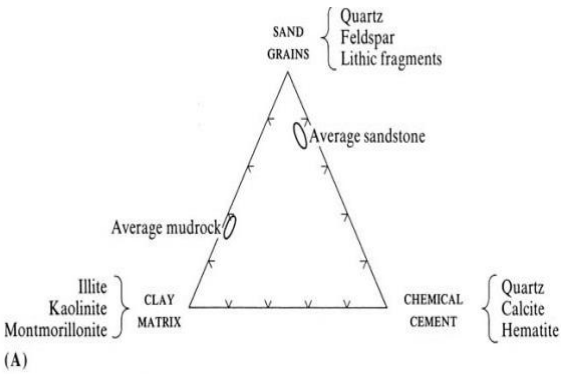
- Make up 10-15% of sedimentary rocks (limestone more abundant)
- Importance of limestones (carbonate rocks) :
  1. Excellent indicators of depositional environments
  2. integral to study of past environments & earth history
  3. Important reservoirs for oil & gas
- **Limestone ($CaCO_3$)** Chemical, & Bio., **Dolomite ($CaMg(CO_3)_2$)** Chemical

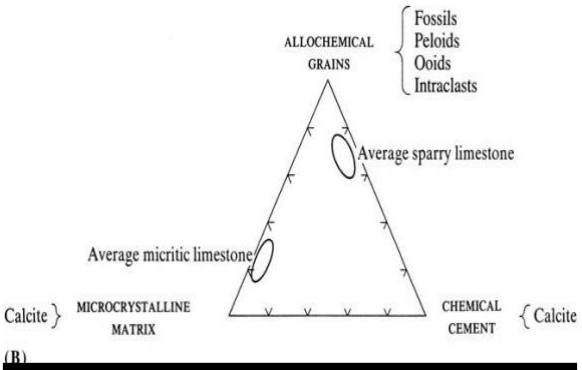
Carbonate rocks mainly composed of	
Micrite	Is a Microcrystalline calcite (clay size <0.004mm) or Limemud, with subtranslucent matrix, formed by chemical or biochemical ppt, & deposition in low energy environment
Sparite (cement)	Clear granular (sugary) calcite (>0.004 mm), with orthochemical material, formed by precipitation or recrystallization of micrite, & deposited in interstitial spaces of carbonate sediments (indicates original void space)
Biolithic	organisms bound together by precipitated material in situ
Allochems (Intraclast)	Transported chemical or biochemical precipitates, with an irregularly grains, formed by syndepositional erosion of partially lithified sediment Include intraclasts, ooliths, peloids, & bioclast (skeletal Particle)
Allochems (Intraclasts)	
Ooliths	<2 mm, Concentrically laminated carbonate structures
Pisolites	>2 mm, Same as Oolites, but different in size
Oncolites	> 1-2 cm, spheroidal stromatolites
Pelloids	sand-sized carbonate particles without an internal structure
Skeletal Particles (bioclasts)	Fossils, broken shell fragments, Marine invertebrates

- Carbonate Rock Classification is Based on depositional texture (mainly proportion of allochems), & there are 2 main classification schemes
  1. **Folk**: % & type of allochem, Micrite vs sparite matrix
  2. **Dunham**: Abundance of allochems (ratio grains : mud), Original components bound together
     - Calm deposited vs agitated water
     - Mud-bearing vs mud-free sediment
     - Grain vs mud support
     - Original components bound together (biological)



- Depositional texture recognizable



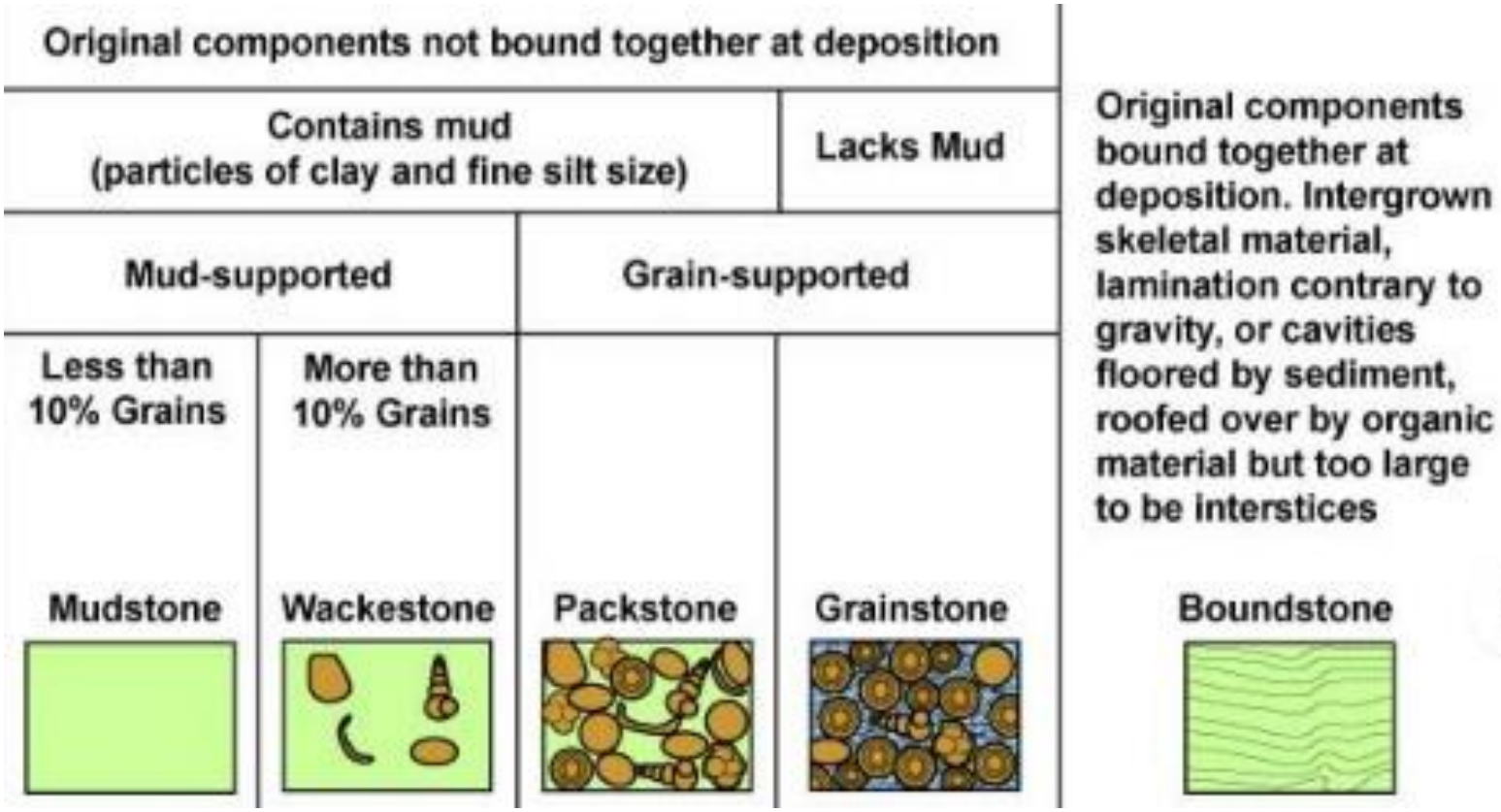


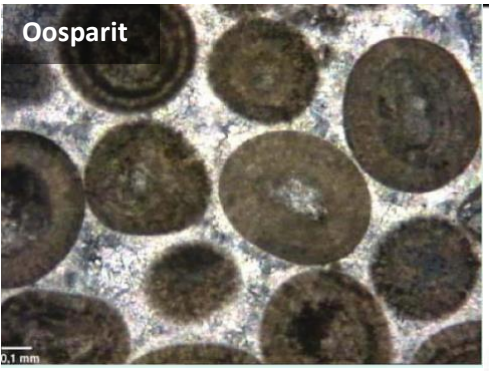
Grains (allochems): gravel, sand, & silt-size carbonate particle (>30 micron) form the framework in mechanically deposited limestone, equivalent to quartz, feldspar, & lithic fragments in sandstones

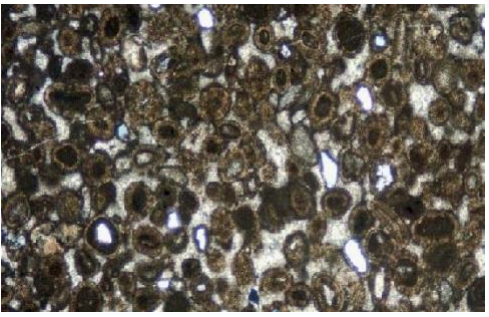
Carbonate Rock Classification

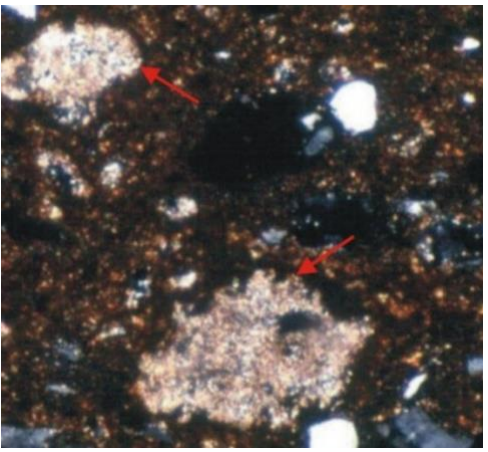
1. Presence or absence of lime mud
2. Calm waters allow for the accumulation of lime mud & ndicates the absence of current induced agitation
3. Grain Support: self supporting framework (fluid circulation, diagenesis)
4. Grain kind: standard microfacies types
5. Grain size, rounding, & coating: hydrologic interpretations
6. Biogenically ppt masses bound at time of deposition: Boundstone, Organic framework, Laminations not consistent with gravity (stromatolite), & Roof over sediment filled cavities

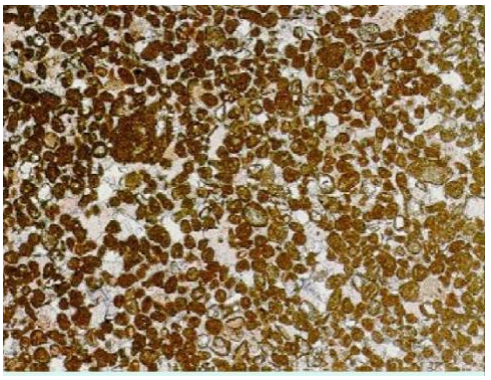
- Limestone is recognized in the outcrop & hand-specimen by its softness & with diluted cold HCl: $CaCO_3 + 2HCl \rightarrow Ca^{2+} + 2Cl^- + CO_2 + H_2O$.
  - Dolomite reacts visibly, only when powdered, with the HCl.
  - dolomite commonly weathers with a dull brownish yellow appearance because it usually contains some ferrous iron as substitute for Mg in the crystal lattice.
- most limestones can be described by:
  1. the type of clastic **GRAINS**
  2. the presence or absence of calcium carbonate mud matrix
  3. the presence or absence of coarse crystalline Ca-carbonate cement
- The **matrix** in limestone is the calcium carbonate mud that binds the allochemical grains to lithify the sediment
- Microcrystalline (1-5 microns) matrix is called **micrite** (calcite mud)
- **microspar** is applied when the calcium carbonate matrix is 5-15 microns
- **Calcite cement** is applied when the size of the calcite is > 20 (0.02 mm)
- Classification of limestones is based on textural variation since mineralogical variations are lacking!



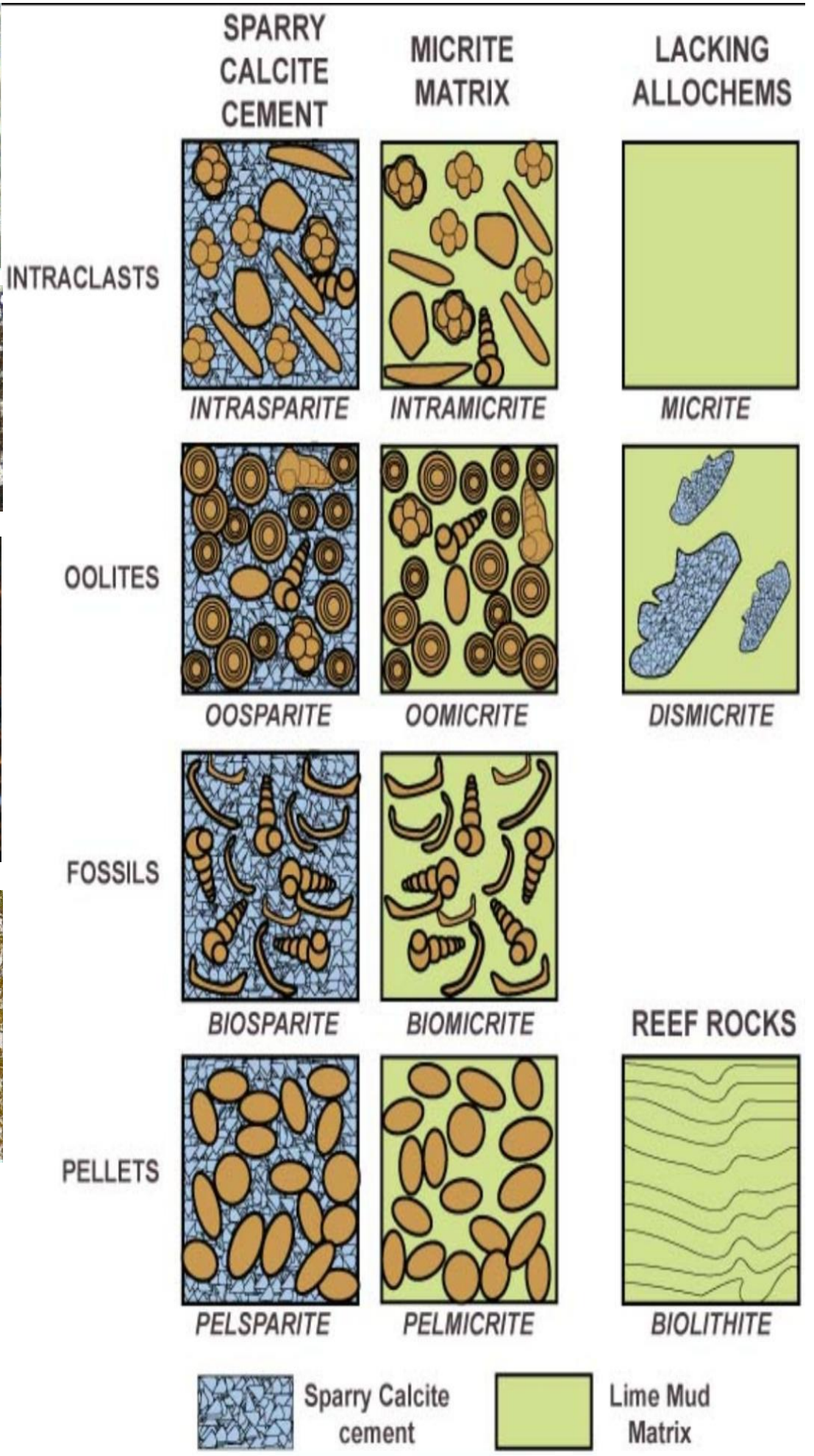








Oolitic limestone is made up largely of sand-sized, rounded pellets of Calcium carbonate, which are formed in warm shallow water where Carbonate sediment is moved about by currents



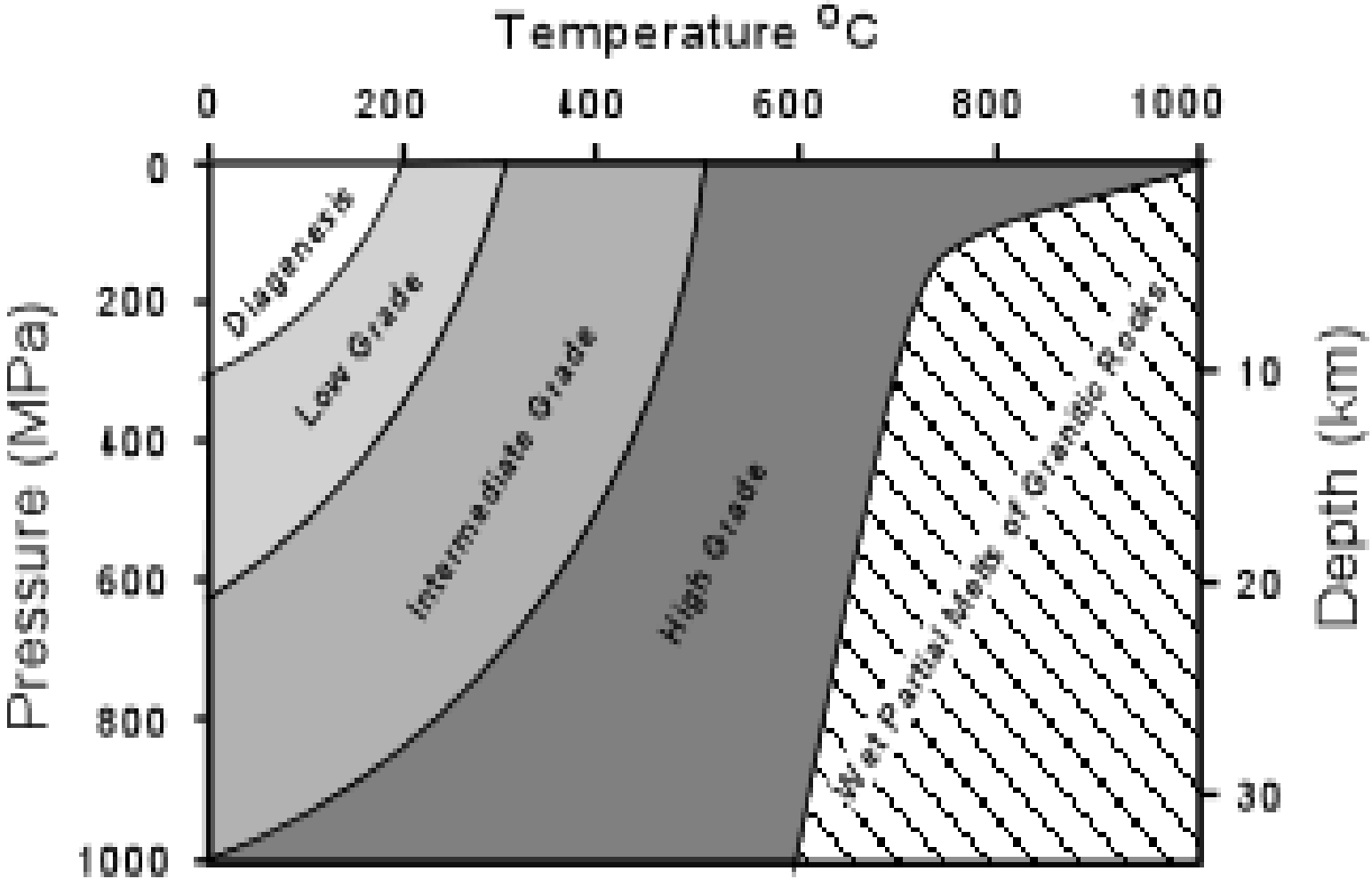
Metamorphic Rocks

- **Metamorphism (change form)**: is a mineralogical & structural changes in response to change physical & chemical conditions (T, P, & Composition) at depths below zones of weathering & diagenesis
- the changes in mineral & texture result from change P, T, chemical env.
- Diagenesis: change in form that occurs in sedimentary rocks

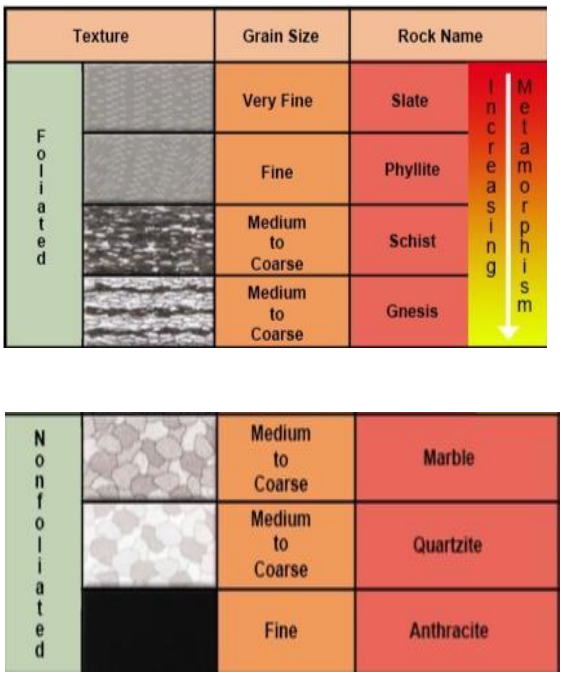
Processes	T [°C]	P [Mega Pa]	P [kbar]
Diagenetic Processes	< 200	< 300 Mpa	< 3
Metamorphism Processes	> 200 - 750	> 300	> 3

- Rocks subjected to higher T, & P as buried in the Earth, burial take place as a result of tectonic processes (continental collisions, subduction)
- The upper limit of metamorphism occurs at the P-T of melting point, Once melting begins the process changes to an igneous process rather than a metamorphic process
- As T-P increases the rock undergoes ***prograde metamorphism*** or ***grade of metamorphism***
- ***Metamorphic grade***: T-P condition under which metamorphic rock form

Grade	T [°C]	P [Mpa]	Characterized by
Low	200 – 320	< 600	Abundance of hydrous minerals
Medium	320 - 500	<1000	Hydrous become less hydrous (losing H_2O)
High	> 500	>1000	Abundance of Anhydrous minerals



Classification of Metamorphic Rocks



- **Classification of metamorphic rocks is based on**: mineral assemblage, texture, protolith, & bulk chemical composition of the rock
- **Textural term based on individual mineral that bounded by crystal face**
  - **Idioblastic**: minerals that are bounded by their own crystal faces
  - **Xenoblastic**: minerals that show none of their own crystal faces
- **Foliation:** caused by a preferred orientation of sheet silicates, All could be ***porphyroblastic*** (i.e. contain porhyroblasts)
  - Slatey cleavage → slate foliation
  - phyllitic foliation → phyllite, shistose foliation → schist
  - **Gneiss**: rock shows a banded texture without a distinct foliation
- **Crystalloblastic series:** examination of metamorphic rocks
  - metamorphic minerals can be listed in a sequence in order of their tendency to be idioblastic (each mineral tends to develop idioblastic surfaces against any mineral that occurs lower in the series)
  - This series can enable us to determine the origin of a given rock
- **porphyroblastic** textures: large grains set in a fine groundmass
- **granoblastic** texture, where similar-sized grains have typical 120° grain boundary intersection
- **Index minerals** minerals form under restricted range of T, & P & are recorded in similar lithologies subjected to the same conditions

Types of Metamorphism

Crystalloblastic series

Rutile, sphene, magnetite

Tourmaline kyanite, staurolite, garnet, andalusite

Epidote, zoisite, lawsonite, forsterite

Pyroxenes, amphiboles, wollastonite

Micas, chlorites, talc, stilpnomelane, prehnite

Dolomite, calcite

Scapolite, cordierite, feldspars

Quartz

- **Three types of metamorphism:**
  1. Contact metamorphism (by heat, recrystallization)
  2. Dynamic metamorphism (by pressure)
  3. Regional metamorphism (by both heat & pressure)

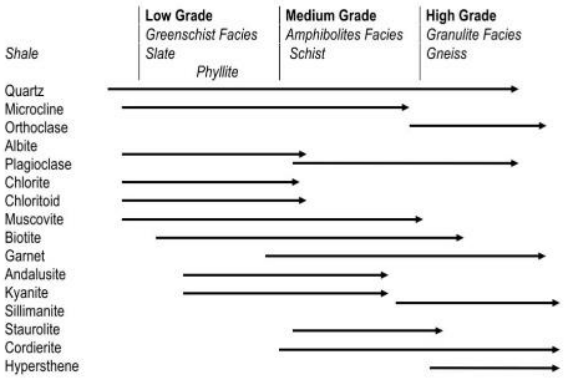
Cataclastic Metamorphism mechanical deformation, when 2 bodies of rock slide past one another along a fault zone

- Heat is generated by the friction of sliding rocks, & the rocks tend to be mechanically deformed, being crushed & pulverized, due to the shearing
- Isn't common metamorphism type & restricted to a narrow zone along which the shearing occurred

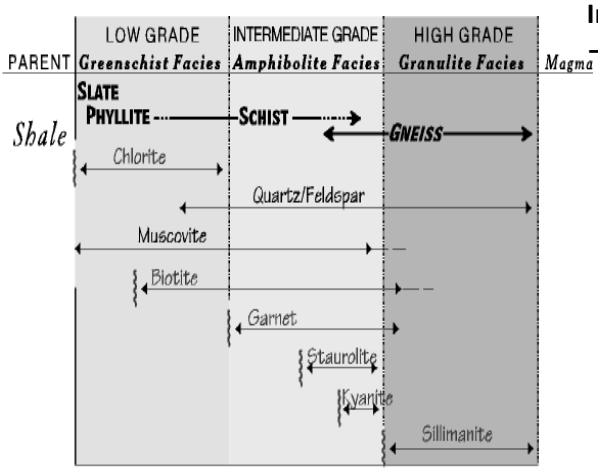
Burial Metamorphism as sedimentary rocks are buried to depths of several hundred meters, T > 300^{o}C develop in the absence of differential stress

- New minerals grow, but the rock doesn't appear to be metamorphosed
- The main minerals produced are Zeolites
- Burial metamorphism overlaps with diagenesis, & grades into regional metamorphism as T & P increase

Contact metamorphic rocks



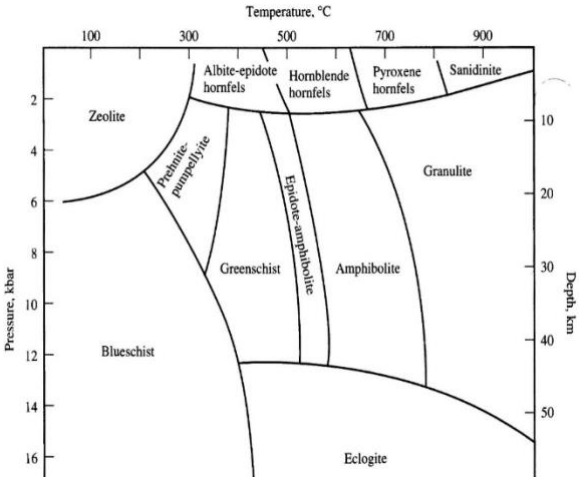
- **Low:** Chlorite
- **Low-Medium:** Mica (Biotite & Muscovite), Garnet, &Kyanite
- **Medium:** Staurolite
- **Medium-High:** Andalusite
- **High Grade:** Sillimanite



- **Contact Metamorphism**: occurs adjacent to igneous intrusions & results from high T associated with the igneous intrusion (as heat transferred from intrusion to the surrounding rocks by conduction or convection)
- ***metamorphic*** or ***contact aureole***: zone surrounding the intrusion where metamorphism occur
- Contact metamorphism characteristic by: high T, low P, fine-grained non-foliation (***hornfels, marble***), granoblastic texture, porphyroblastic texture, & Poikiloblastic texture
- The aureoles around granitic batholiths (700-850C) are wider than around gabbroic bodies (900-1100C) due to the large amounts of fluids associated with granitic magmas compared to dry gabbroic magmas
- Contact Metamorphism involves recrystallization of a minerals
- **Marbles** $CaCO_3$, derived from dolomite & limestones, & can have other minerals (diopside pyroxene, amphiboles, olivine, graphite, & garnet)
- **Index minerals**

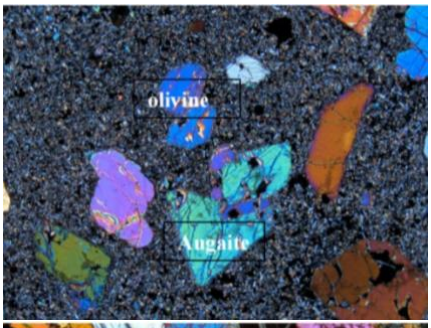
In the case of metapelitic compositions from lowest to highest T chlorite-muscovite → biotite →andalusite-garnet → staurolite-kyanite → sillimanite
In the case of metamafic compositions from lowest to highest T Chlorite → tremolite → hornblende- clinopryoxene-orthopyroxene-olivine

Regional Metamorphic Rocks (metapelitic)



- **Regional Metamorphism:** occurs over large areas,
- Regional Metamorphism characteristic by: deformation under non-hydrostatic or differential stress conditions, foliated (***slate, phyllite, schist, & gneis***)
- differential stres result from tectonic forces that produce compressional stresses in the rocks, such as when 2 continental masses collide
- Compressive stresses result in folding of rock & thickening of the crust, which tends to push rocks to deeper levels (higher T-P)
- **Shales (mud rocks, pelitic rocks)** are the sedimentary rocks with the most diverse composition (cryptocrystalline)
- metamorphic zonation based on the metarmorphic products of shales, & schistosity is the most characteristic feature of these rocks when regionally metamorphosed, due to the presence of a direction of maximum stress along the subduction zones
- The penetrative schistosity is defined by the parallel arrangement of platy phyllosilicates (chlorite, muscovite, biotite) & of prismatic minerals

For the pictures (On the left of the page) give the rock name & texture

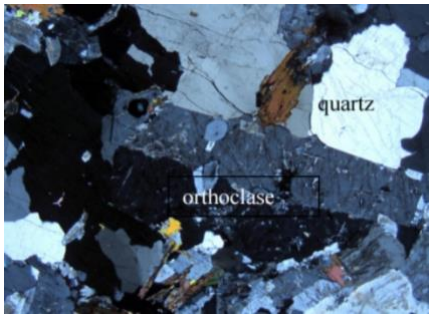


Rock 1

- **Rock**: Pyroxene Andesite
- **Classification**: Volcanic rocks (Extrusive), Intermediate
- **Mineral Composition:** Augite (Cpx) & Ol is phenocrysts
- **Texture:** Porphyritic texture (porphyritic phaneritic)
- Holocrystaline, Allotriomorphic, Melanocratic (Melano-andisite)

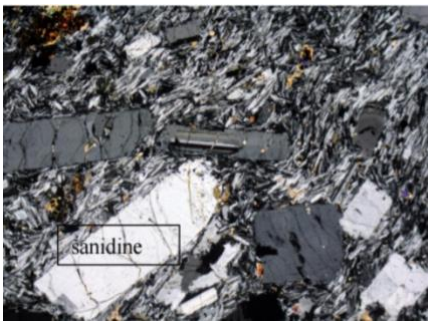
Rock 2

- **Rock:** Gabbro
- **Mineral Composition:** Olivine, Plagioclase, pyroxene (augite), olivine, amphibole (hornblende), opaque minerals
- **Classification:** Plutonic "intrusive", Mafic "Basic", Course-grained
- **Texture:** Phaneritic, Medium- to Coarse- grained phaneritic
- **Mineral texture:** cross hatching twinning, polysynthetic twinning, exsolution lamellae
- Holocrystaline, Hypidiomorphic, Mesocratic (Meso-Gappro)



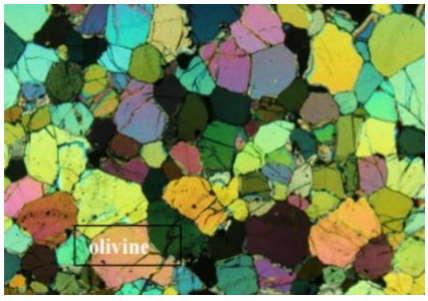
Rock 3

- **Rock:** Granite
- **Composition:** quartz, alkali feldspar, biotite, opaque mineral + glass
- **Classification:** Felsic, plutonic "intrusive", & Coarse-grained
- **Texture:** Porphyritic, medium- to coarse-grained phaneritic, Serial (grain size increase in a NE direction), Granular texture
- **Other terms:** Allotriomorphic, Hypocrystalline, leuco-granite



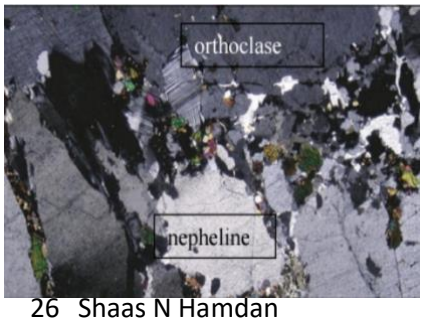
Rock 4

- **Rock:** Tachyte
- **Composition:** feldspar laths & phenocryst (Sanidine to orthoclase), the brown crystals may be biotite
- **Classification:** Felsic, volcanic "extrusive", fine-grained
- **Texture:** Trachytic (parallel to subparallel arrangement of feldspar laths, Porphyritic, phenocryst, Serial (grain size increase in SW direction)
- **Other:** Hypidiomorphic, Holocrystaline, Leucocratic (leucotrachyte)



Rock 5

- **Rock:** Dunite (&may be lherzolite rich in olivine "90% > Ol > 40%")
- **Classification:** peridotite, Ultramafic, asthenosphere rocks, plutonic
- **Composition:** Ol, Px (Cpx, Opx), minor opaque (comaite, magnetite)
- **Texture:** medium grained phaneritic
- **Other:** Holocrystaline, Allotriomorphic, & Melanocratic (Melanodunite)



Rock 6

- **Rock:** Nepheline-syenite
- **Classification:** Undersaturated, plutonic
- **Composition:** Blake may be sodalite, nepheline, alkali-feldspar, green crystals may be aegirine-augite, & brown may be biotite, lack of quartz (due to percense of nepheline "feldspathoid")
- **Some orthoclase crystals has a polysynthetic twinning**
- **Texture:** Porphyritic, medium- to coarse- grained phaneritic
- **Other terms:** Holocrystaline, Allotriomorphic, Leucocratic

1. Aphenitic rocks:
   a. **are extrusive igneous rocks** b. are intrusive igneous rocks.
   c. cool very rapidly deep within the earth d. None of the above
2. Which of the following is the correct order from most silicic to mafic
   a. olivine – K feldspar – pyroxene – quartz
   b. Na feldspar – quartz – biotite – olivine
   c. olivine – Na feldspar – K feldspar – quartz.
   d. **none of the above**

1. Molten rock inside the earth is called _____ & on the surface _____
   a. lava, magma. b. Lava, extrusive. c. intrusive, magma. d. **Magma, lava**
2. Which of the following is NOT a common component of igneous rocks?
   a. quartz b. Feldspar. c. Olivine d. Pyroxene. e. **Garnet**
3. The type of feldspar that contains either Ca or Na is called:
   a. K-feldspar. b. **Plagioclase**. c. Calcite. d. Olivine. e. granite
4. Which of the following lists of igneous rocks contain rock types that belong together in the same group?
   a. **basalt; andesite; rhyolite** (volcanic) b. basalt; gabbro; diorite
   c. gabbro; diorite; dacite d. granite; diorite; basalt
5. a volcanic & a corresponding plutonic have same chemistry
   a. **trachyte, syenite** b. andesite, granite c. syenite, trachyt
   d. rhyolite, basalt e. Rhyolite, diorite
6. An igneous rock that have a very small crystals are cooled very slowly
   a. true b. **False** Hint. Cooled rapidly
7. Foid syenite is composed of the minerals; quartz, K-feldspar, & olivine.
   a. true b. **False** Hint. Composed of feldspathoid rether than quartz
8. The type of plagioclase present in Gabbro is
   a. albite b. Orthoclase C. Oligoclase D. Sanidine E. **non of the above**
9. What is the percentage of alkali-feldspar in Tonalite?
   a) **< 10** b) 10% - 30% c) 50% - 70 d) > 70

State 2 methods to differentiate between Opx & Cpx under microscope

1. Index color: Opx has 1st order interferense color (colourless in plane polarized light), Cpx has 2nd order interferense color (pale green colour in plane polarized light)
2. Extinction θ: Opx parallel, Cpx inclined (or oblique) extinction

Give a possible name of the following rocks based on the given composition. (Minerals arranged according to their Vol% in the rock)

1. quartz, orthoclase, microcline, albite, Biotite
   granite, or Rhyolit (felsic rocks in general)
2. orthoclase, quartz, plagioclase, aegirine
   Syenite, or Trachyte (felsic rocks in general)
3. olivine, orthopyroxene, clinopyroxene
   Dunite, or other peridotite (ultramafic rocks with > 40%Ol)

Name 3 types of textures that can show intergrowth crystallization of minerals. For each texture state the names of minerals involved?

1. **Exsolution intergrowth:** between quartz & plagioclase pheldspar
2. **Graphic intergrowth:** between quartz & K-feldspar
3. **Myrmekite:** Graphic intergrowths of plagioclase & quartz
4. **Poikilitic**: such as **ophitic**, enclosure of plagioclase laths by augite
5. **Interstitial or Intergranular**: Cpx fills gaps between plagioclase
6. **Graunular or granitic**: The grain-size is more or less uniform with euhedral, subhedral, & anhedral grains

Contact metamorphic rocks

What sequence of shale pass (higher grades of metamorphism)?

1. Shale, phyllite, gneiss, schist, slate, partial melting
2. Shale, phyllite, gneiss, slate, schist, partial melting
3. Shale, phyllite, slate, schist, gneiss, partial melting
4. Shale, slate, phyllite, gneiss, schist, partial melting
5. **Shale, slate, phyllite, schist, gneiss, partial melting**

What is order of index mineral appearance from low grade to high grade?

1. Chlorite, biotite, muscovite, garnet, staurolite, sillimanite
2. **Chlorite, muscovite, biotite, garnet, staurolite, sillimanite**
3. Chlorite, muscovite, biotite, garnet, sillimanite, staurolite
4. Muscovite, biotite, garnet, staurolite, sillimanite, chlorite
5. Muscovite, chlorite, biotite, garnet, staurolite, sillimanite

What silicate mineral is found in metamorphic rock of all grades?

1. Biotite 2. Sandstone **3. Feldspar** 4. Garnet 5. muscovite

Which of the following is a common characteristic of metamorphic rocks?

1. cross-bedding 2. fossils **3. index minerals** 4. lack of foliation

What is the usual orientation of foliation?

1. Horizontal, same as sedimentary rocks 2. Random orientaion
3. Vertical & parallel to stress **4. Vertical & perpendicular to stress**

Which of the following rock types is the most abundant in the Earth's crust?

1.sedimentary 2.igneous 3.metamorphic **4.Sedimentary & Igneous**

Scientists classify rocks by _____

1.Color 2.Mass-volume **3. Composition-texture-size** 4. (1+3)

Which of the following index minerals forms at highest metamorphic grade

1. Chlorite **2. Sillimanite** 3. Biotite 4. Garnet 5. Orthoclase

Which of the following rocks is a characteristic contact metamorphism?

1. quartizite 2. Chlorite schist 3. Gneiss 4. Non of them

A rock rich in pyroxene & anorthite with minor amount of olivine is called

1.Amphibolite 2.Hornfels 3.Eclogite **4.Gabbro** 5.Non of them

Shale refers to a rock formed from _____

1. Sand sized 2. Plant remains **3. Clay minerals** 4. Carbonate

A feldspar rich sandstone is called _____

1. Arkose 2. Litharenite 3. Quartz arenite 4. Shale 5. Greywacke

Which of the following minerals not found in silica undersaturated rocks?

1. Biotite 2. Nepheline 3. Leucite **4. Quartz** 5. Orthoclase

As early-crystallizing mineral is surrounded by a thin rim of a late-forming:

1. Sub-ophitic 2. Graphic **3. Corona** 4. Poikilitic 5. Perthitic

Ophitic texture is a typical _____ texture

1. Gabbroic 2. Granitic 3. Exsolution 4. (2+3) 5. Non of them

Sedimentary rock changed to slate during regional metamorphism?

1. Breccia 2. Conglomerate **3. Shale** 4. Limeston 5. Greywacke

A coarse-grained rock, consist of equal proportions of alkali feldspar & plagioclase & minor quartz would be called

1. Syenite 2. Basanite 3. Diorite **4. Monzonite** 5. Non of them

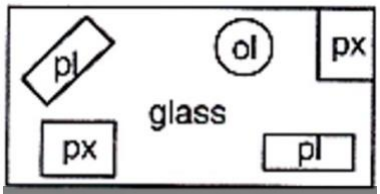


Diagram 1

Which of the following rock types is depicted in the diagram 1?

1. Basalt 2. Rhyolite 3. Andesite 4. Gabbro 5. Diorite

Hint. Thioliitic basalt

Which of these metamorphic rocks breaks along foliation lines?

1. Gneiss 2. Marble 3. Quartzite **4. Schist** 5. Diorite

What type of metamorphism exhibits high temperature but low pressure?

1. Contact 2. Fault zone 3. Regional 4. Dynamic

During metamorphism a quartz arenite will change into what type of rock?

1. Slate 2. Marble 3. Schist 4. Gneiss **5. Non of them**

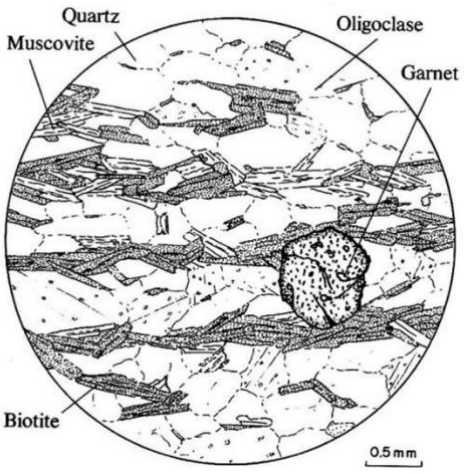
Which rock of the following is highly sorted

1. Conglomerate 2. Arkose 3. Breccias 4. Greywacke **5. Qz arenite**

A rock that consists of detrital quartz, alkali feldspar & about 25% matrix of silt & clay-sized particles is called **Greywacke**

Conglomerates consist of gravel-sized framework grains. Matrix (sand or finer) is less than 15%. Known as **Orthoconglomerate or True conglomerate**

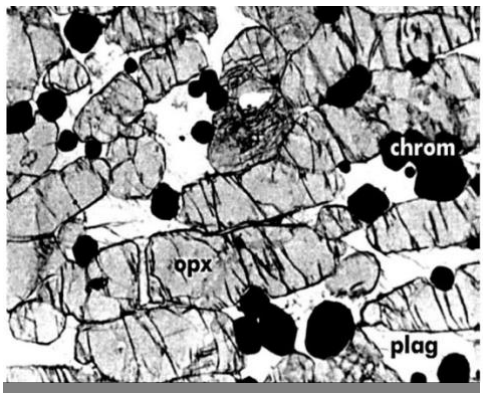
The intrusive compositional equivalent of andesite is **diorite**



Pictures (1): metamorphic rock under the microscope

See pictures (1) & answer the questions

1. Name for this the rock: **Garnet-Biotite Schist**
2. Type of metamoprphism: **Regional metamorphism**
3. metamorphic grade: **Medium Grade**
4. Protolith: **Shales**
5. Main textural features: **Idioblastic, shistose foliation (due to orientation of Micas), porphyroblastic**



Pictures (2): Igneous rock under the microscope

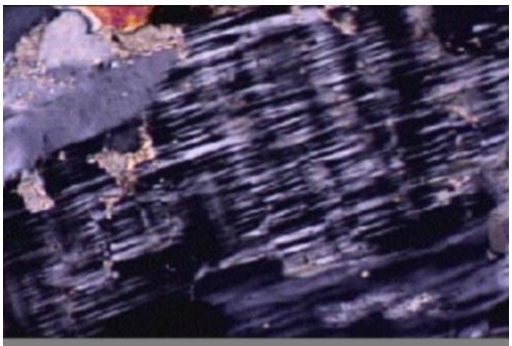
See pictures (2) & answer the questions

1. What type of plagioclase present? **High T (Ca-rich) plagioclase from Labradorite to Anorthite**
2. What is the order of crystallization? **Plagioclase, Pyroxene, Chrom (Respectively)**
3. This rock is (felsic, intermediate basic, ultramafic)? **Mafic (Basic)**
4. Texture **Phaneritic, Poikilitic, Holocrystaline, Hypidiomorphic**
5. possible name of this rock? **Gabbro**

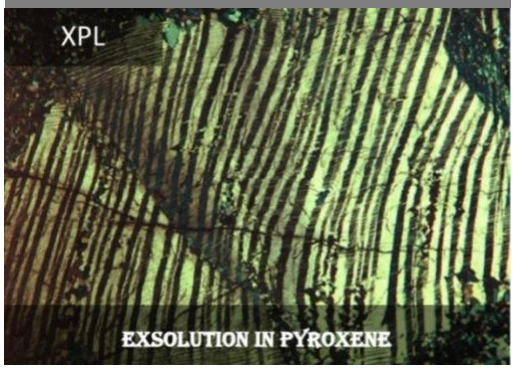
Match each rock with its first-order metamorphic equivalent

Protolith	Metamorphic rock
1. Basalt	**A. Amphibolite**
2. Conglomerate	**B. Gneiss**
3. Dolostone	**C. Marble**
4. Limestone	**D. Metaconglomerate**
5. Granite	**E. Quartzite**
6. Sandstone	**F. Slate**
7. Shale	

(1 & A), (2 & D), (3 or 4 & C), (5 & B), (6 & E), (7 & F)



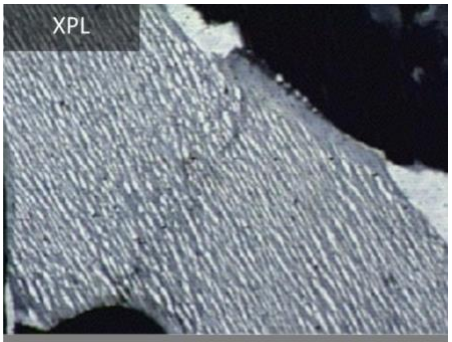
CROSS-HATCHED ('TARTAN') TWINNING IN MICROCLINE



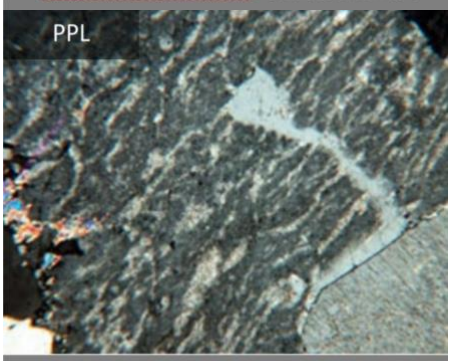
EXSOLUTION IN PYROXENE

State differences between the following

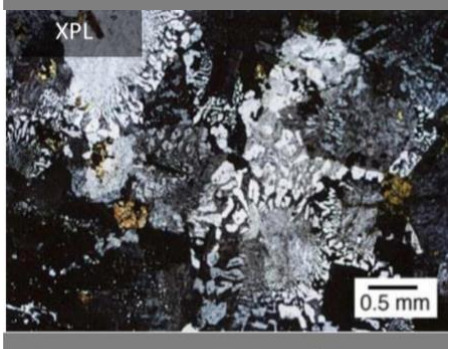
Composition of Sandstone	Composition of Limestone
Quartz SiO_2 Feldspar (K, Na)$AlSi_3O_8$ Lithic fragments	Calcite $CaCO_3$ Dolomite $CaMg(CO_3)_2$
Monomictic conglomerate	**Polymictic conglomerate**
Consists single type of fragment formed by stable rocks consist of quartz (e.g granite, rhyolite..)	Composed of a variety of fragment (clast) types (metastable & unstable such as basalt, slate, limestone)
Granite	**Syenite**
20 – 60% Qz plagioclase 35% - 65%	feldspar (up to 90%), <5%Qz, less plagioclase (10 – 35%)
Poikilitic	**Poikiloblastic**
Late formed mineral completely surrounded by a crystal of early formed mineral in igneous rocks	Late formed mineral completely surrounded by a crystal of early formed mineral in metamorphic
Porphyritic	**Porpheroblastic**
Large crystal (phenocryst) in finer grain groundmass in igneous	Large crystal (phenocryst) in finer grain groundmass in metamorphic
Ooids	**Peliods**
Have an internal structures <2 mm	Lack of internal structure Silt to fine grained



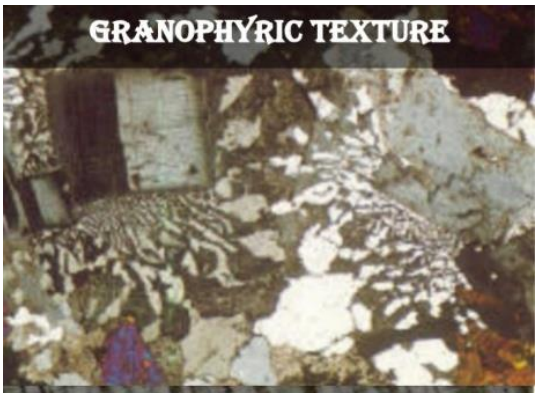
PERTHITETEXTURE IN MICROCLINE



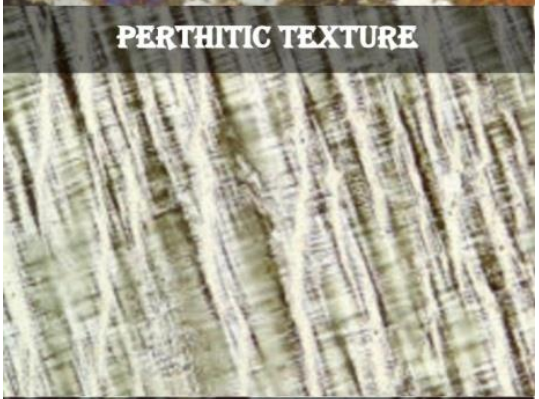
PERTHITETEXTURE IN MICROCLINE



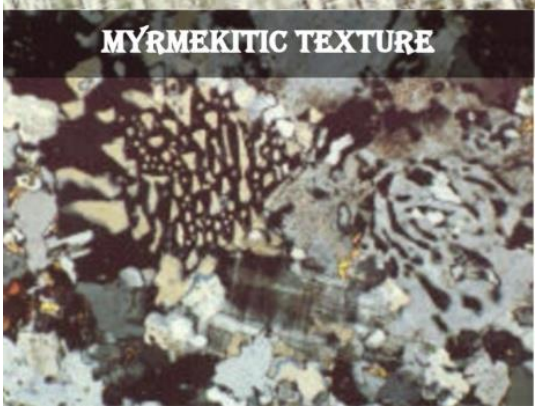
MICROGRAPHIC TEXTURE (QUARTZ + K-FELDSPAR)



GRANOPHYRIC TEXTURE

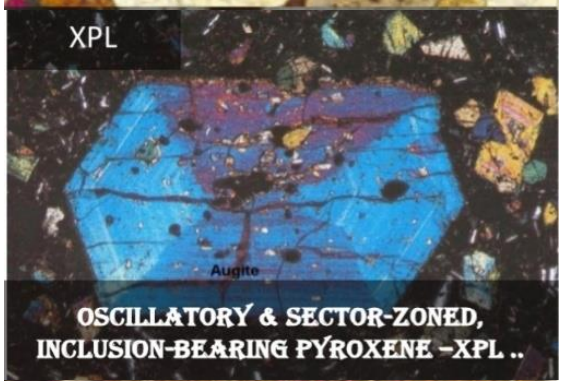


PERTHITIC TEXTURE



MYRMEKITIC TEXTURE

ANTIPERTHITIC TEXTURE



OSCILLATORY & SECTOR-ZONED, INCLUSION-BEARING PYROXENE –XPL ..

CORONA TEXTURE