

IGNEOUS ROCKS

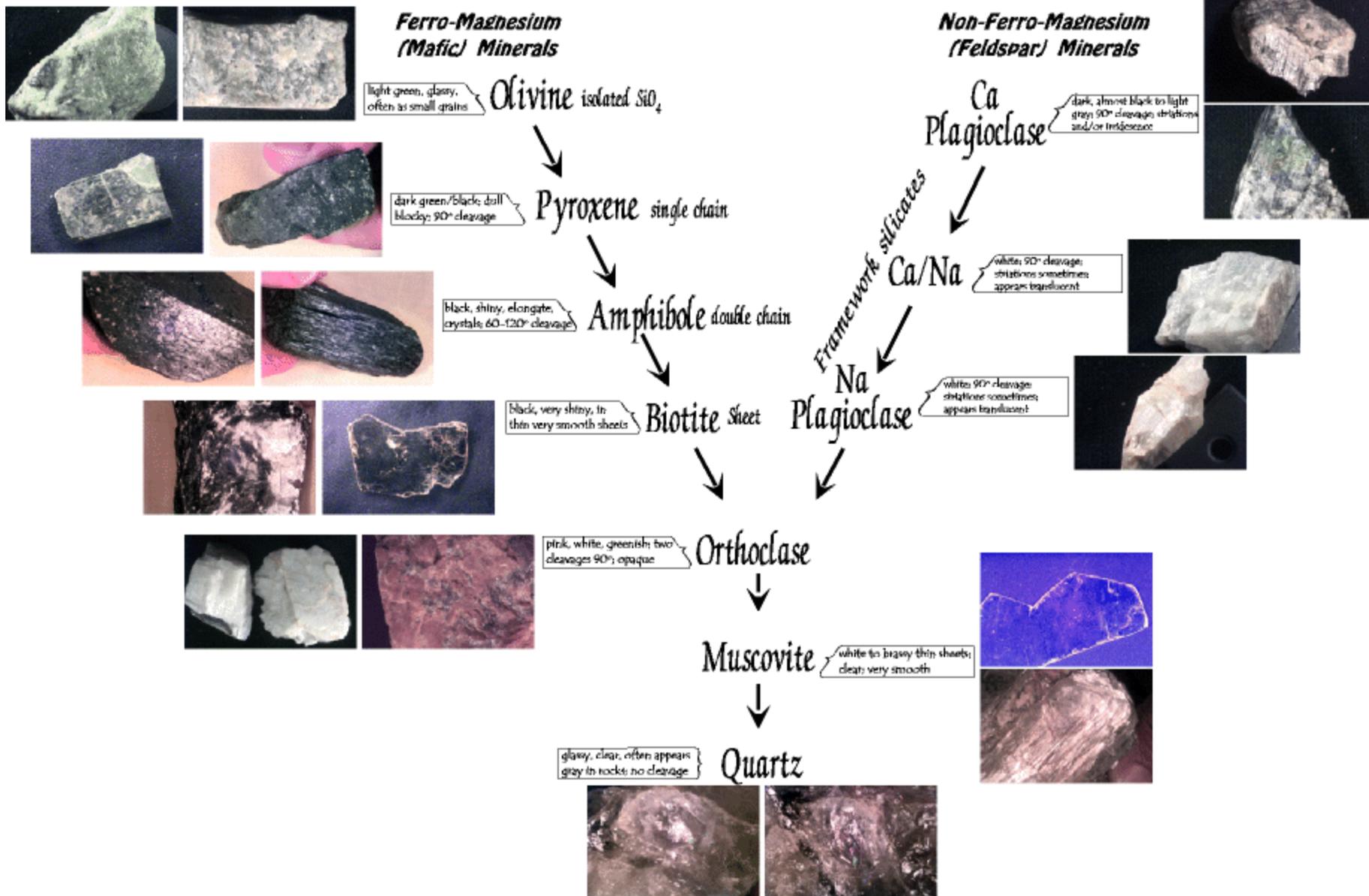
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James Madison University

May, 2008

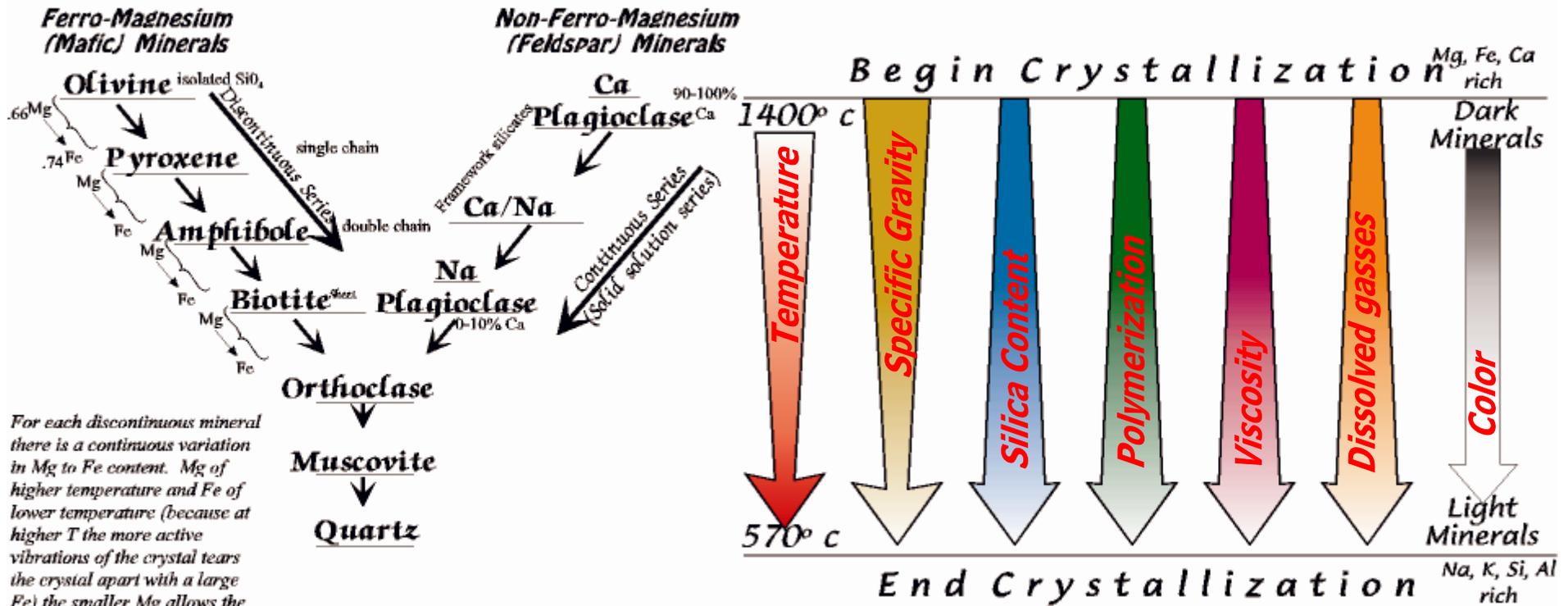
BOWEN'S REACTION SERIES

AND THE IGNEOUS ROCK FORMING MINERALS



Bowen's Reaction Series and

Trends in a Cooling Magma of Rock Forming Minerals



For each discontinuous mineral there is a continuous variation in Mg to Fe content. Mg of higher temperature and Fe of lower temperature (because at higher T the more active vibrations of the crystal tears the crystal apart with a large Fe) the smaller Mg allows the crystal to pull tighter and resist fragmentation.

- Anorthite 90-100%
- Bytownite 70-90%
- Labradorite 50-70%
- Andesine 30-50%
- Oligoclase 10-30%
- Albite 0-10%

Hawaiian Volcano
11% maximum
50-90% steam
CO₂, CO, N,
SO₂, SO₄, HS,
HCl, HF

IGNEOUS ROCKS

The Two Most Abundant Rocks on Earth



Light colored and coarse

Granite



Basalt

Dark colored and fine

TWO IDEAL MAGMAS

Mafic Magma

Felsic to Intermediate
Magma

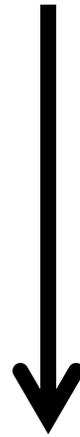
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<i>Example</i>	<i>Basalt</i>	<i>Granite</i>
<i>Color</i>	<i>Dark (gray/black)</i>	<i>Light (white/pink)</i>
<i>Position in Reaction Series</i>	<i>Top of Reaction Series</i>	<i>Bottom of Reaction Series</i>
<i>Mineral Composit.</i>	<i>Pyroxene, Ca Plagioclase; Olivine (trace)</i>	<i>Na Plagioclase/ Orthoclase Quartz; trace mafics</i>
<i>Grain Size Cooling History</i>	<i>Fine grained, rapid cooling at Earth's surface</i>	<i>Large grained, slow cooling deep under ground.</i>
<i>Location</i>	<i>Ocean Basins</i>	<i>Continents</i>
<i>Spec. Grav.</i>	<i>High</i>	<i>Low</i>
<i>Lava Char.</i>	<i>Very hot, low viscosity</i>	<i>Cool, sticky</i>

Igneous Rocks are classified and identified three different ways.

1. Texture (grain sizes) and color.
2. Texture (grain sizes) and percent mineral content – the Modal classification.
- ~~3. Chemistry – percent abundance of the cations like iron, potassium, etc. the Normative classification~~

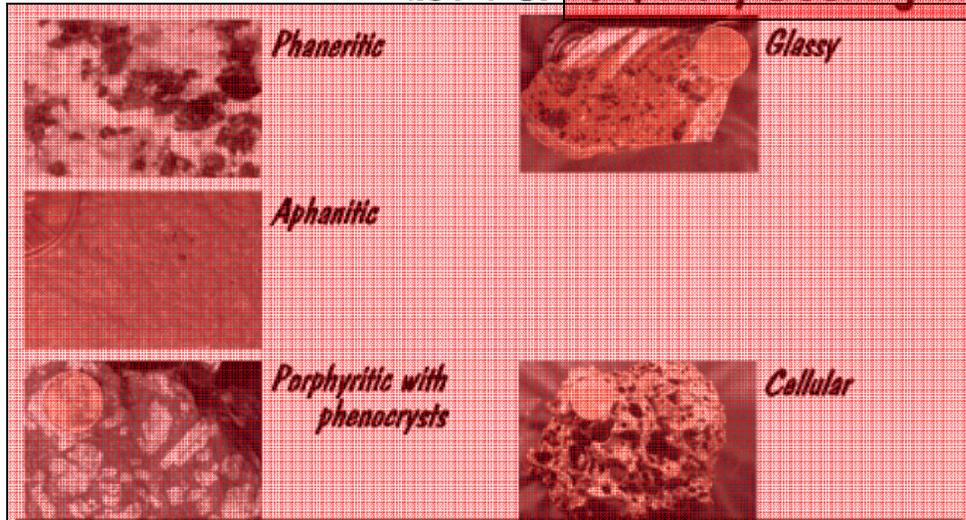
A simple first approximation



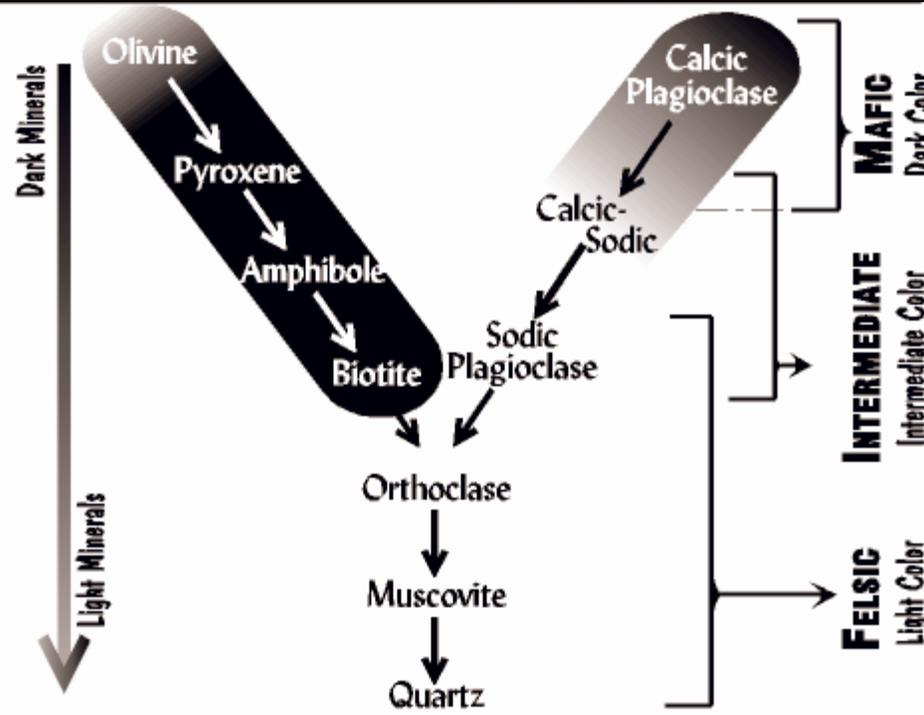
The way geologists work with them

Bowen's Reaction Series and Igneous Rock Classification

Based on **Texture/Cooling History** and **Color/Composition**



Cooling History		
SLOW	FAST (and Two Stage)	VERY FAST
Texture		



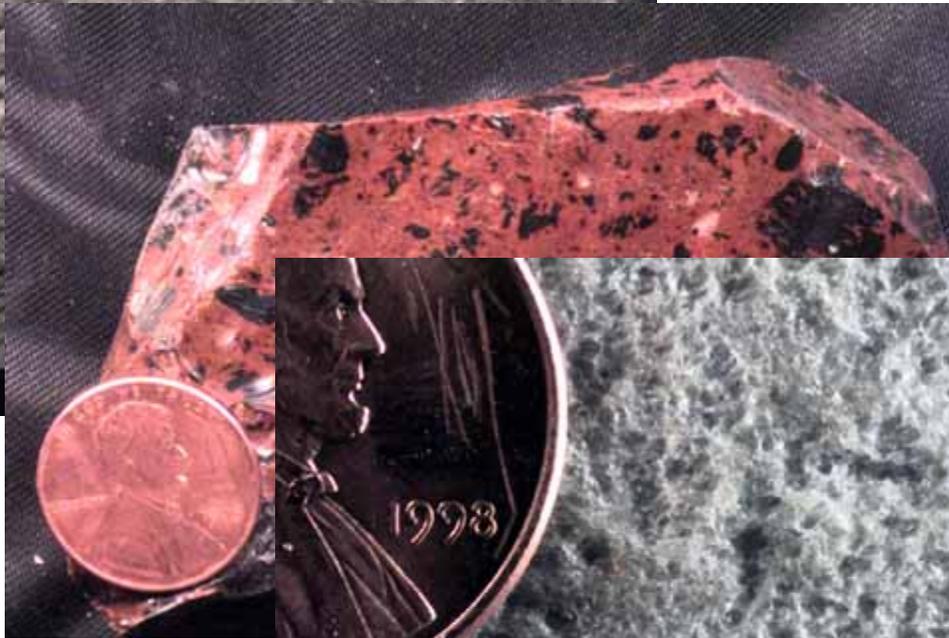
Igneous Rock Textures



Phaneritic
Coarse grained



Aphanitic
Fine grained



Glassy



Cellular



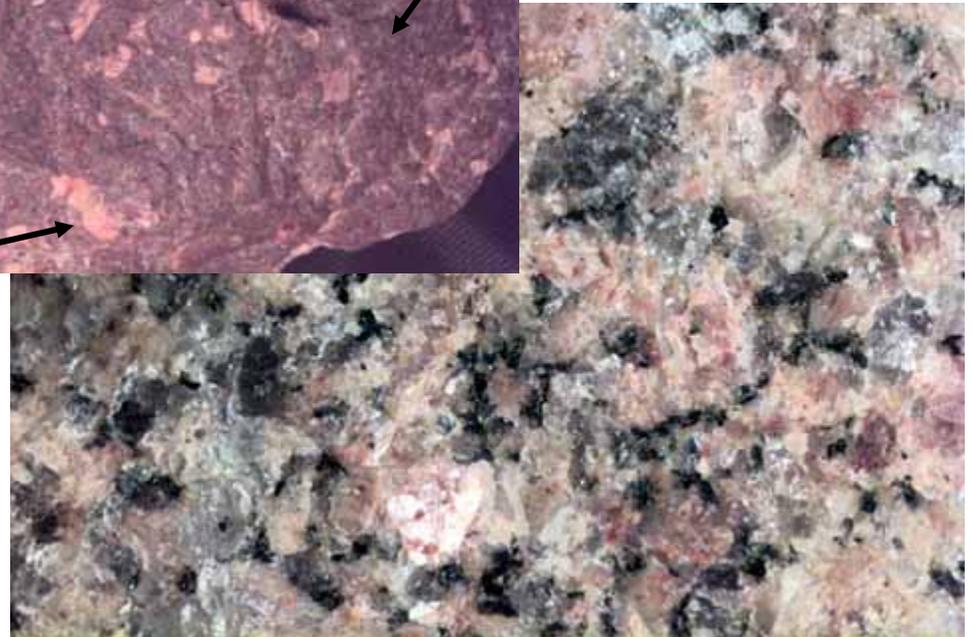
Aphanitic

Porphoritic



*Groundmass
Or matrix*

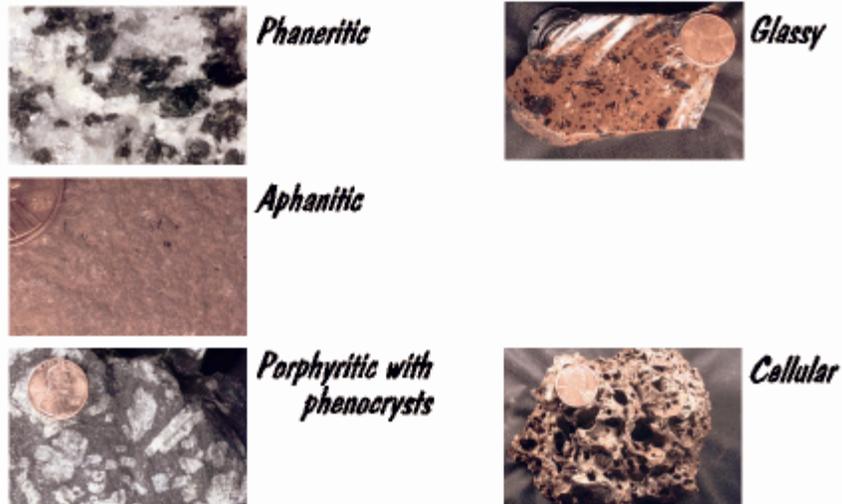
Phenocryst



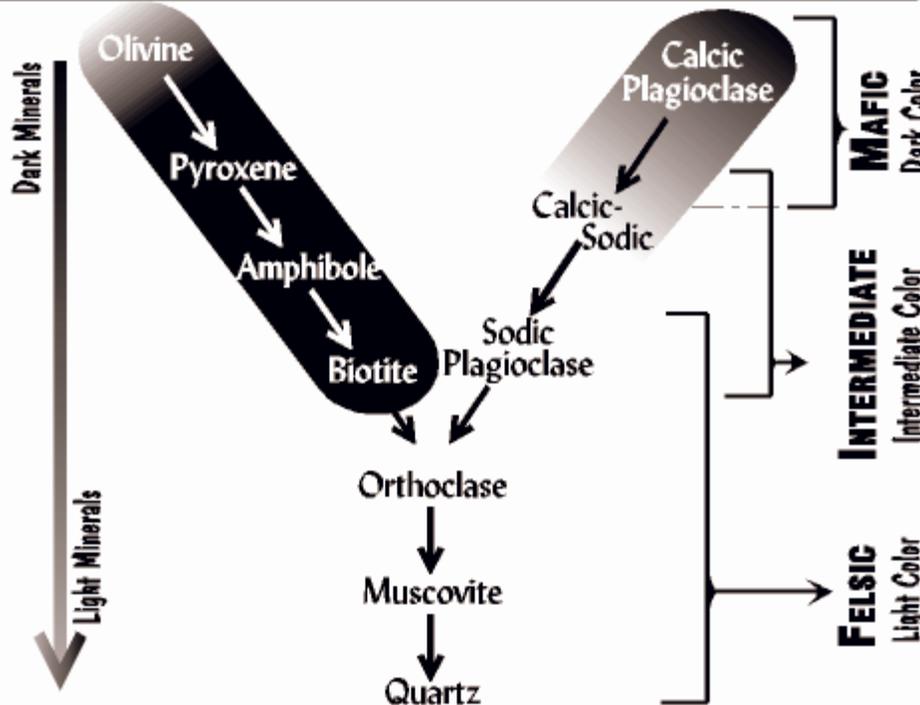
Phaneritic

Bowen's Reaction Series and Igneous Rock Classification Based on Texture/Cooling History and Color/Composition

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Cooling History		
SLOW <i>1000's of years</i>	FAST (and Two Stage) <i>Days to months/years</i>	VERY FAST <i>Hours to days</i>
Texture		
PHANER-ITIC	APHAN-ITIC or Porphyritic	GLASSY to CELLULAR
GABBRO	BASALT	SCORIA
DIORITE	ANDE-SITE	
GRANITE	RHYO-LITE	OBSIDIAN PUMICE



Igneous Rock Classification

By Texture and Color . . .

Is convenient . . .

. . . And a place to start . . .

But, it is not a very good classification

Primarily because the color of a rock by itself has no meaning.

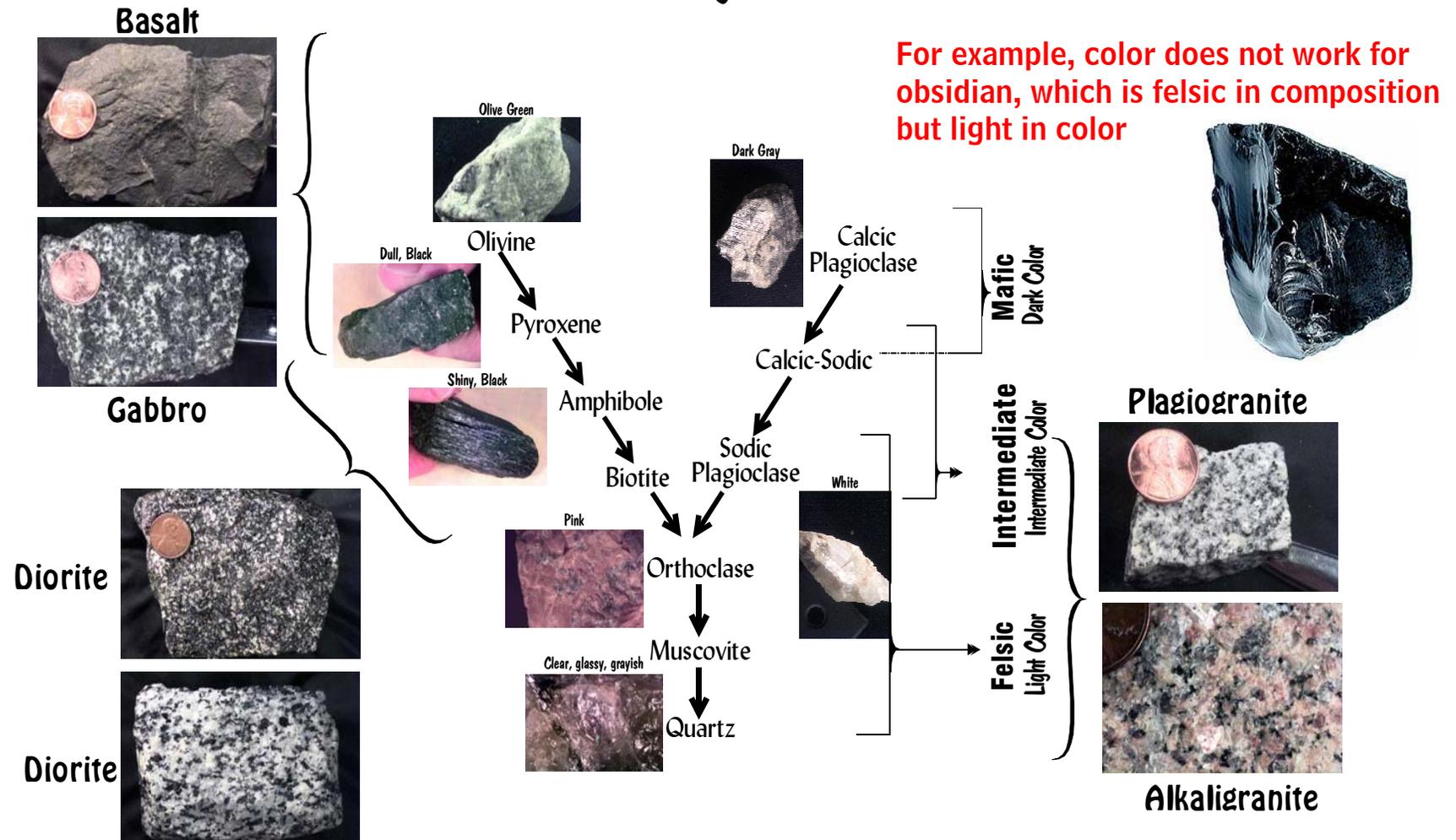
There is no theory of rock color, nothing in chemistry or physics that explains why color should change systematically from the top to bottom of Bowen's Reaction Series

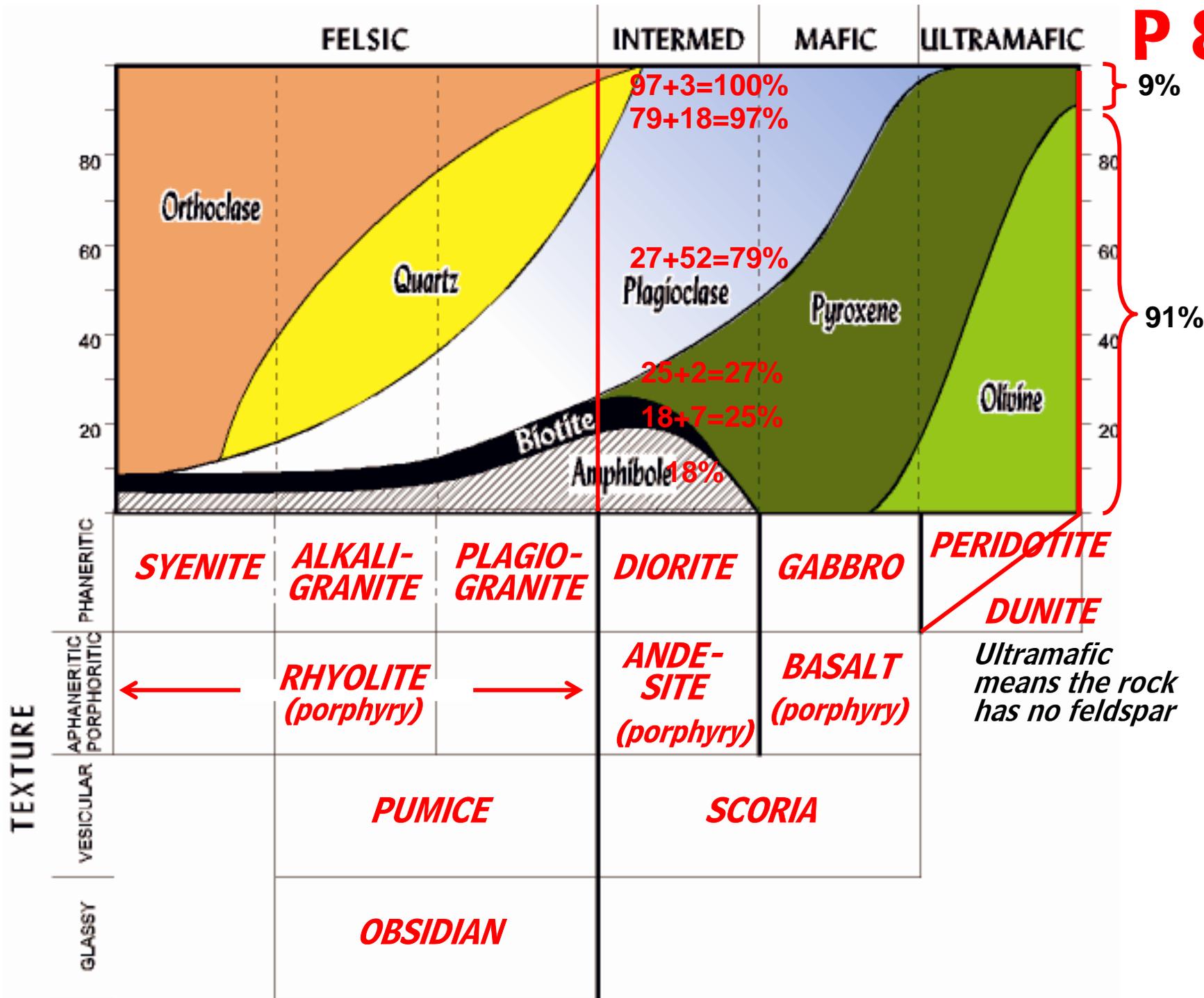
IGNEOUS ROCK CLASSIFICATION

Modal Classification

By Texture and percent mineral content

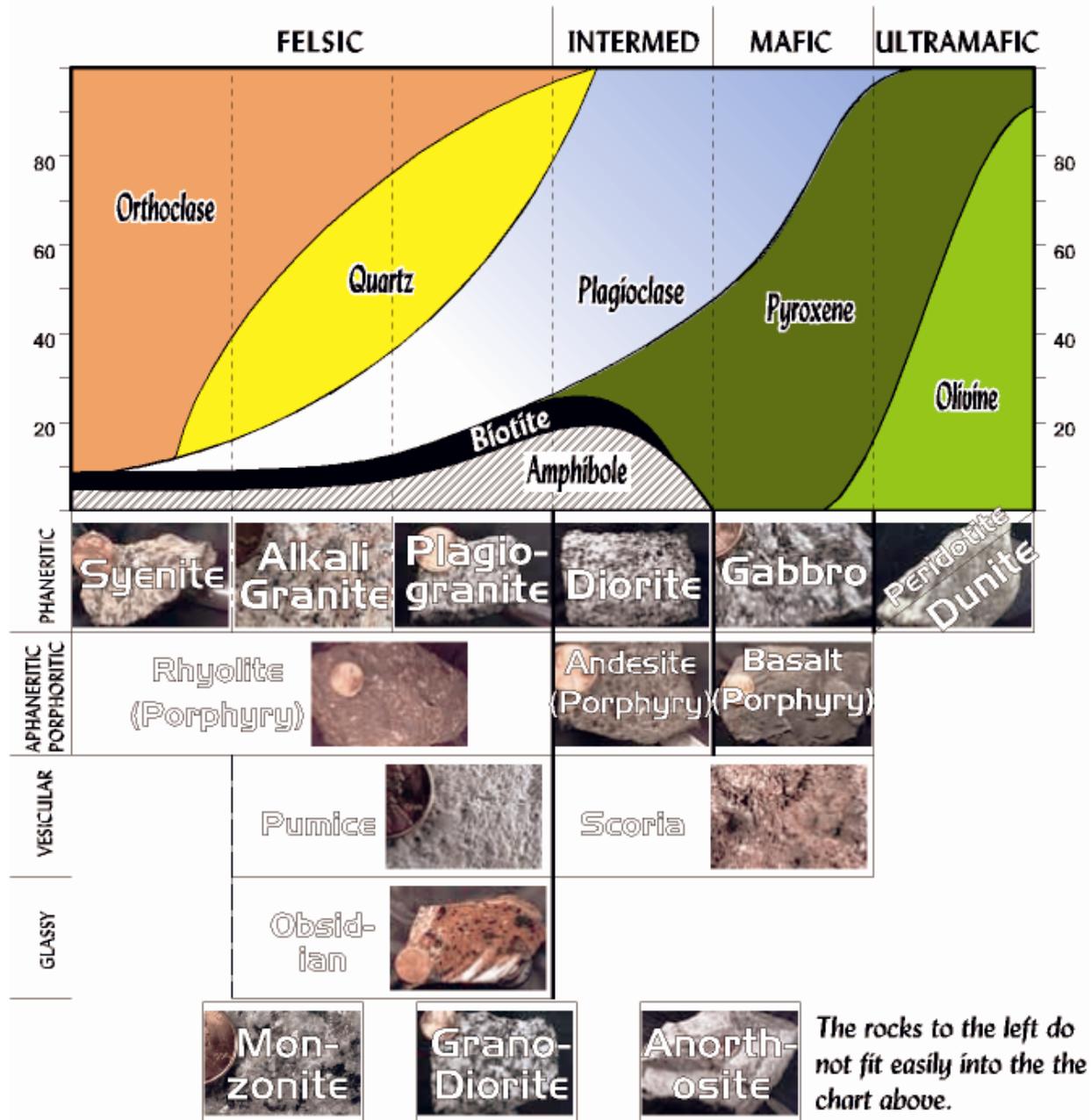
Bowen's Reaction Series And Igneous Rock Classification





IGNEOUS ROCK CLASSIFICATION

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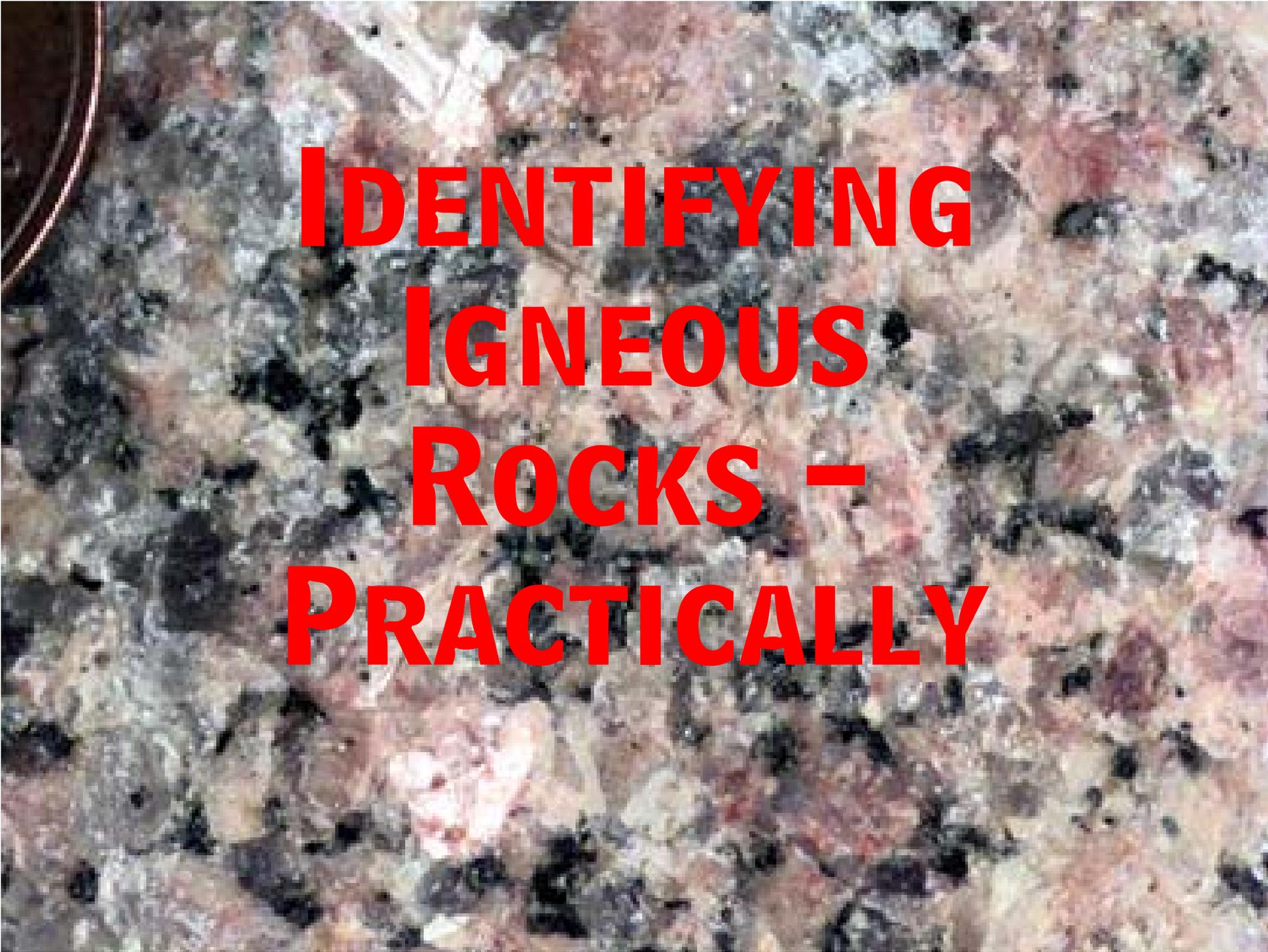
Igneous Rock Classification In Bowen's Reaction Series

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**Feldspar
Absent
Rocks**



Feldspar Dominated Rocks

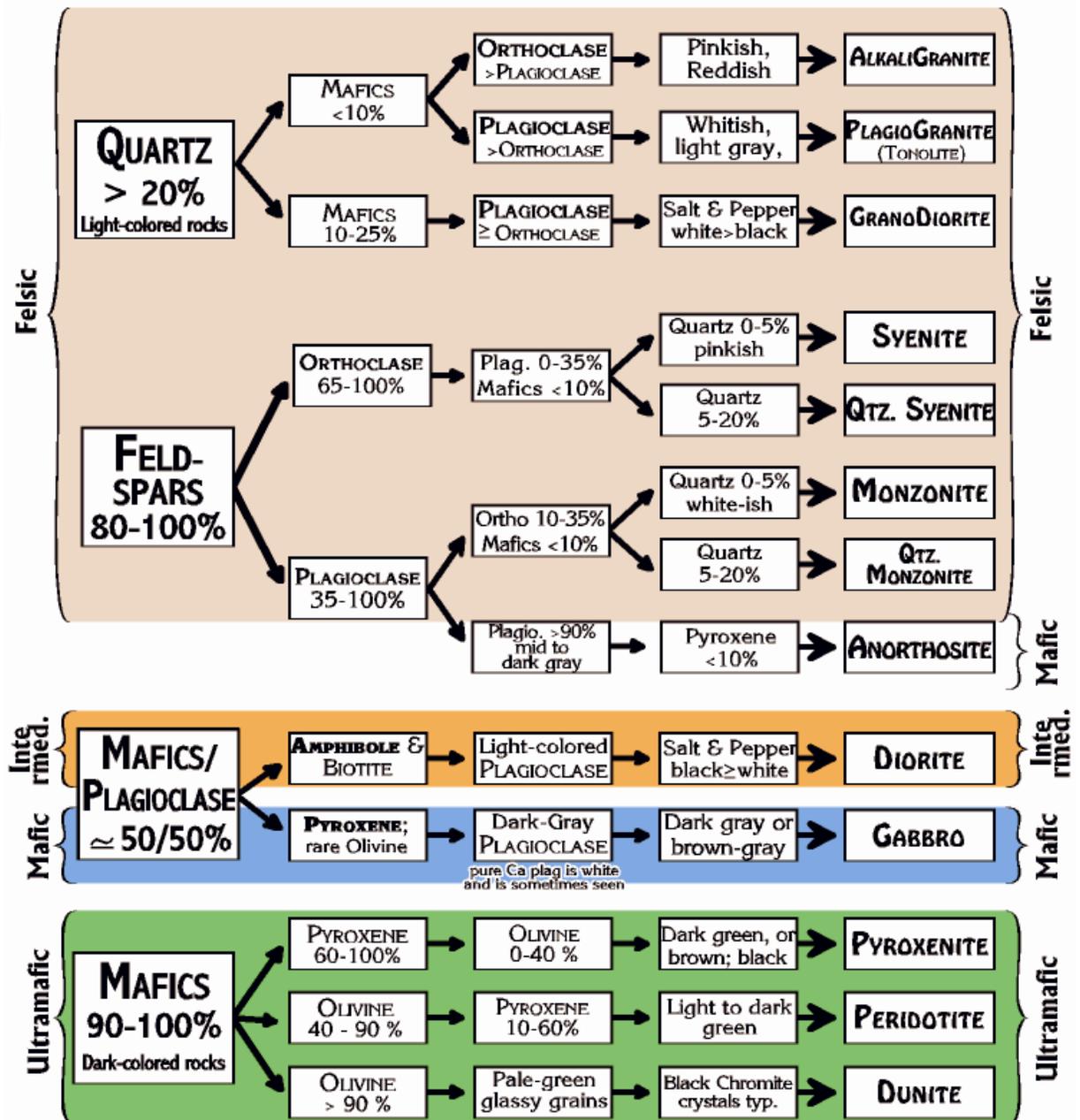


**IDENTIFYING
IGNEOUS
ROCKS –
PRACTICALLY**

Modal Classification Of Igneous Rocks

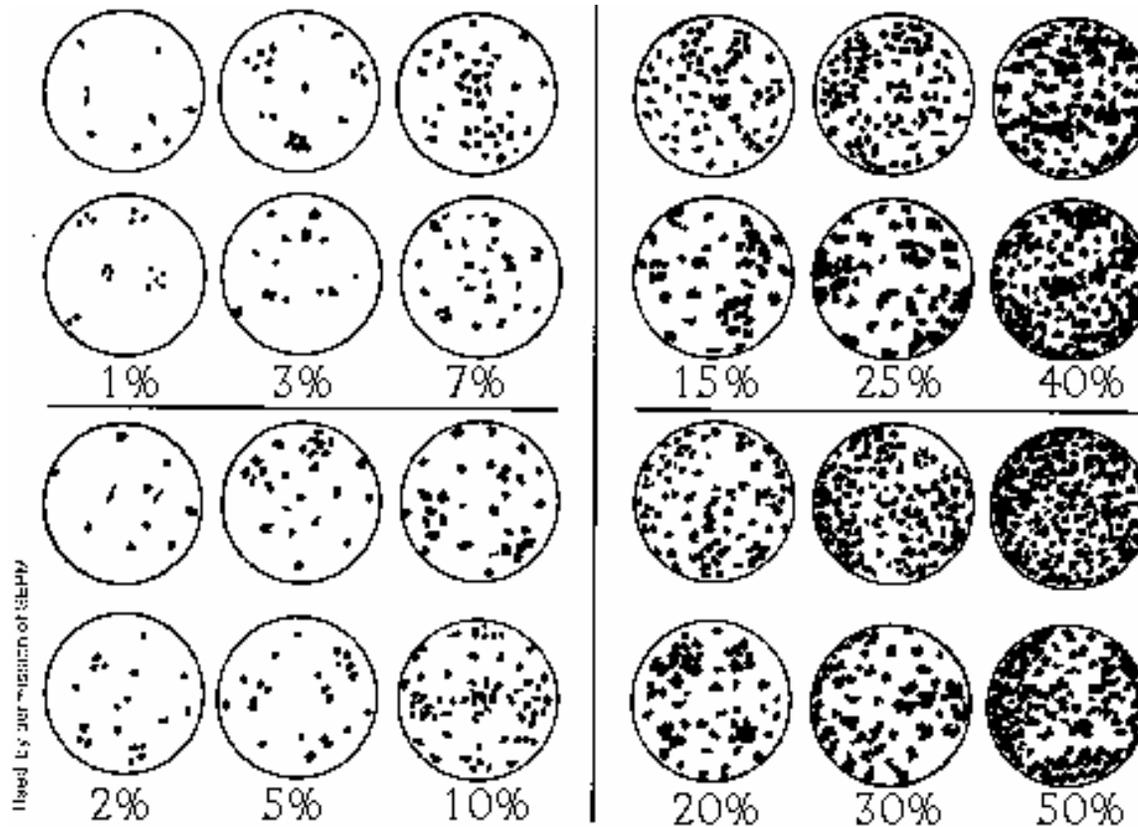
Based on percent mineral abundance

MINERAL COMPOSITION KEY FOR PHANERITIC IGNEOUS ROCKS



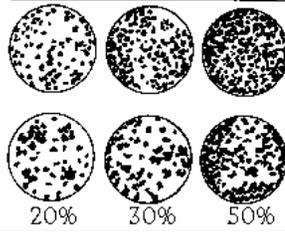
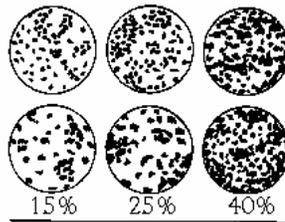
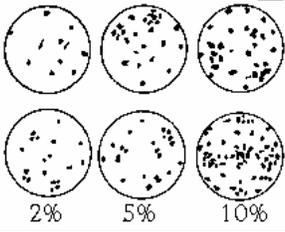
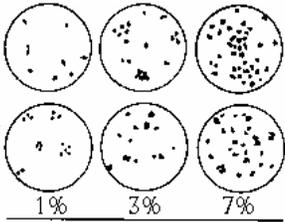
Modal Classification Of Igneous Rocks

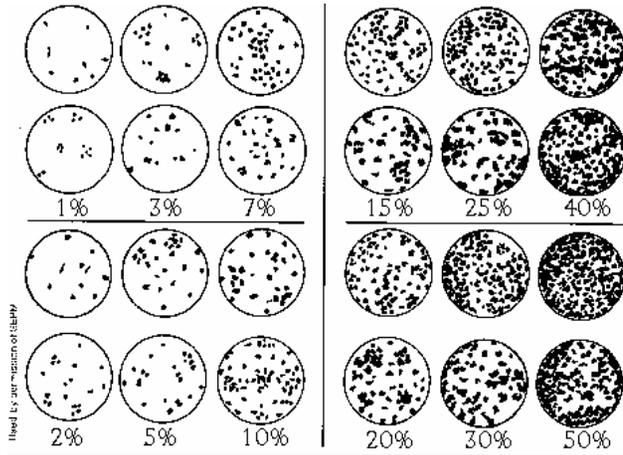
Based on percent mineral abundance



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Alkaligranite:

> 20% quartz,
 Orthoclase dominates; plagioclase possible;
 Mafics (biotite/amphibole) < 5%

Ilmenite grain percentage of diorite



1%



3%



7%



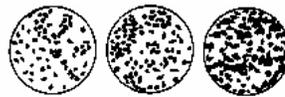
2%



5%



10%



15%



25%



40%



20%



30%



50%

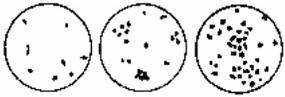




Alkaligranite:

**> 20% quartz,
Na plagioclase dominates;
Mafics (biotite/amphibole) < 5%**

Image by permission of USAP



1% 3% 7%



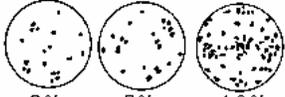
15% 25% 40%

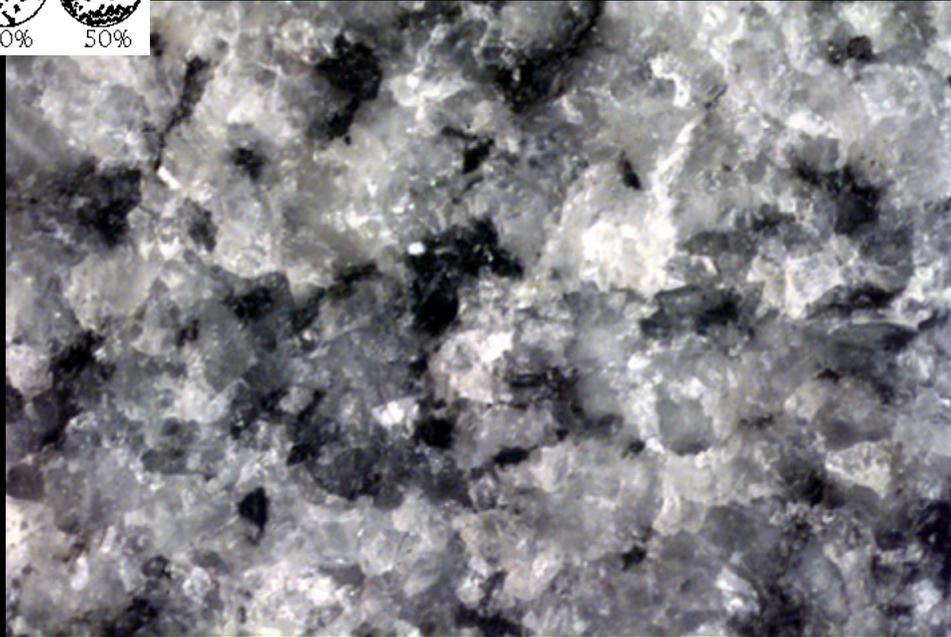
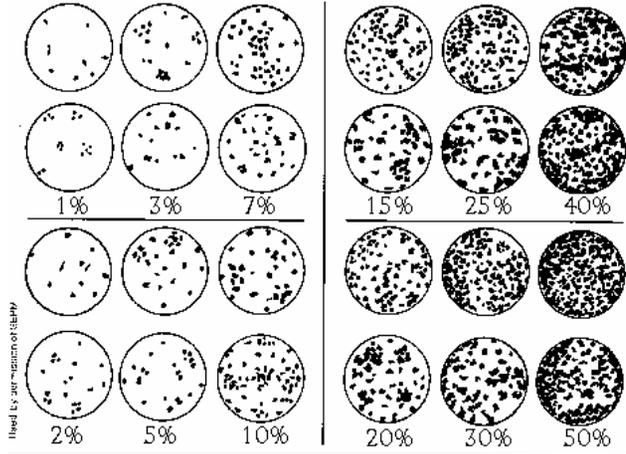


20% 30% 50%



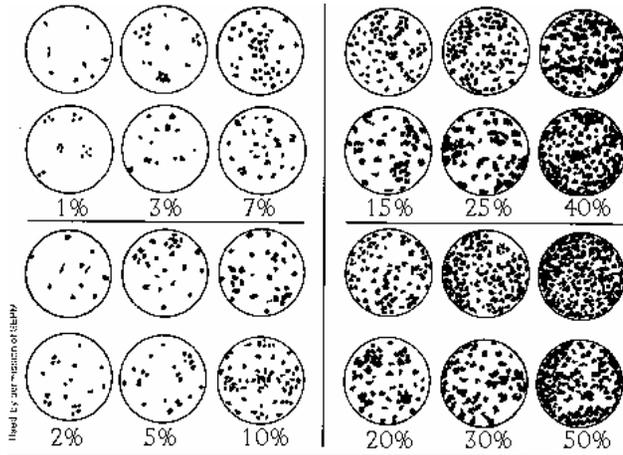
2% 5% 10%





Quartz and Na plagioclase often hard to tell apart

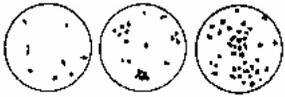




Plagiogranite:

> 20% quartz,
 Na plagioclase dominates; orthoclase possible but
 may be absent;
 Mafics (biotite/amphibole) < 5%

Image by permission of SHAPY



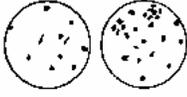
1%



3%



7%



2%



5%



10%



15%



25%



40%



20%



30%



50%

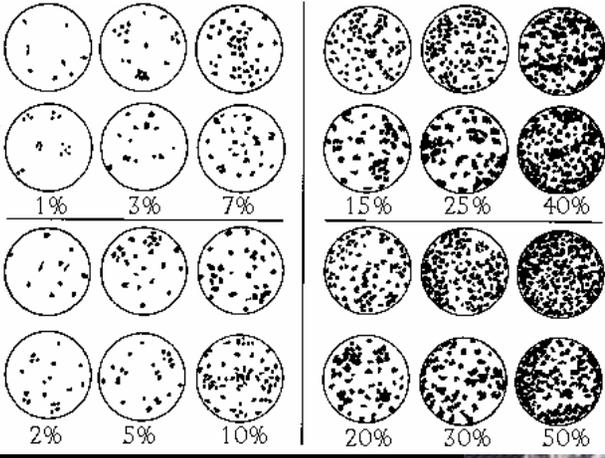




Diorite:

**0 - 5% quartz,
Na plagioclase and amphibole in
about equal amounts**

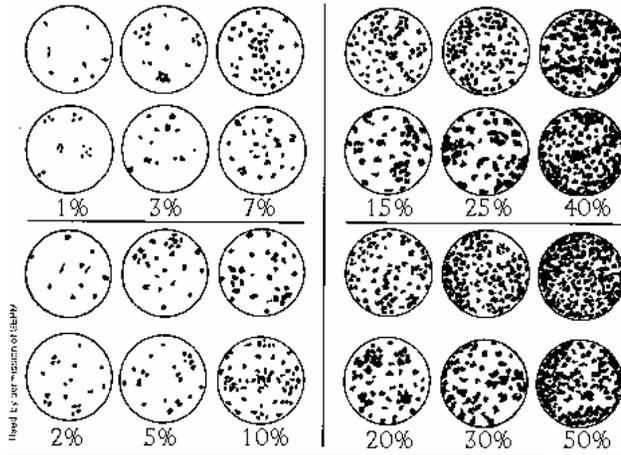
Figure 1.3.1: Percentages of clasts





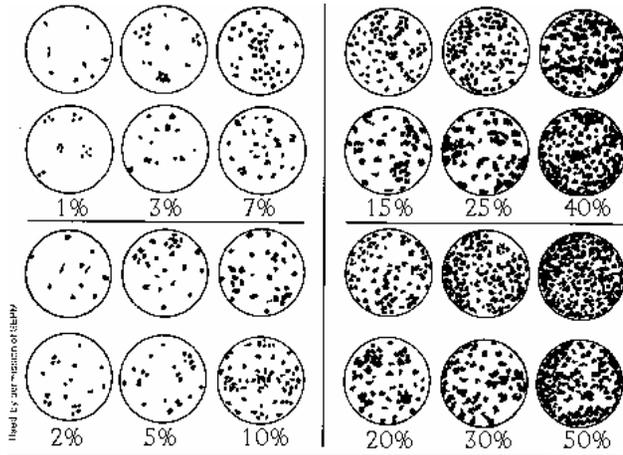
Diorite:

0% quartz,
Na plagioclase and amphibole in about equal
amounts; this is a darker version but light and dark
colors are still about equal.



Gabbro:

No quartz,
Ca/Na to Ca plagioclase and
pyroxene in about equal amounts



Gabbro:

No quartz,
Ca/Na to Ca plagioclase and
pyroxene in about equal amounts



Gabbro:

No quartz,
Ca/Na to Ca plagioclase and
pyroxene in about equal amounts



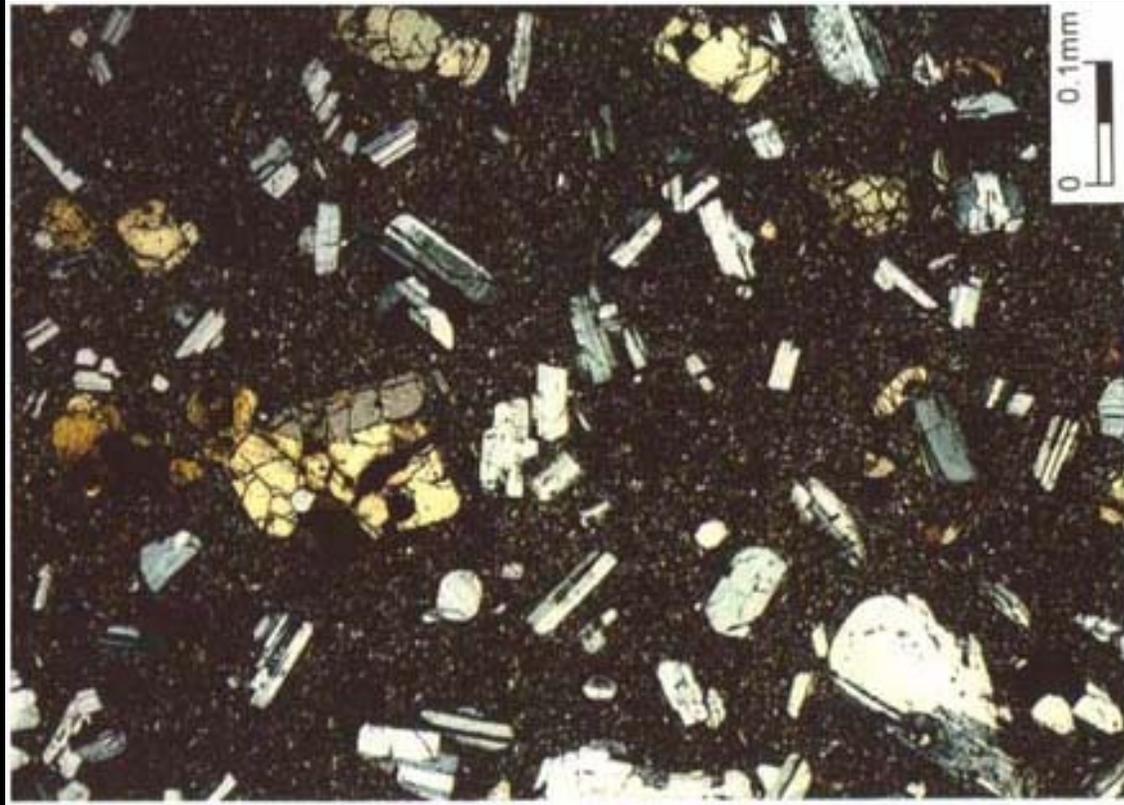
Rhyolite:

Minerals cannot be identified in hand specimen



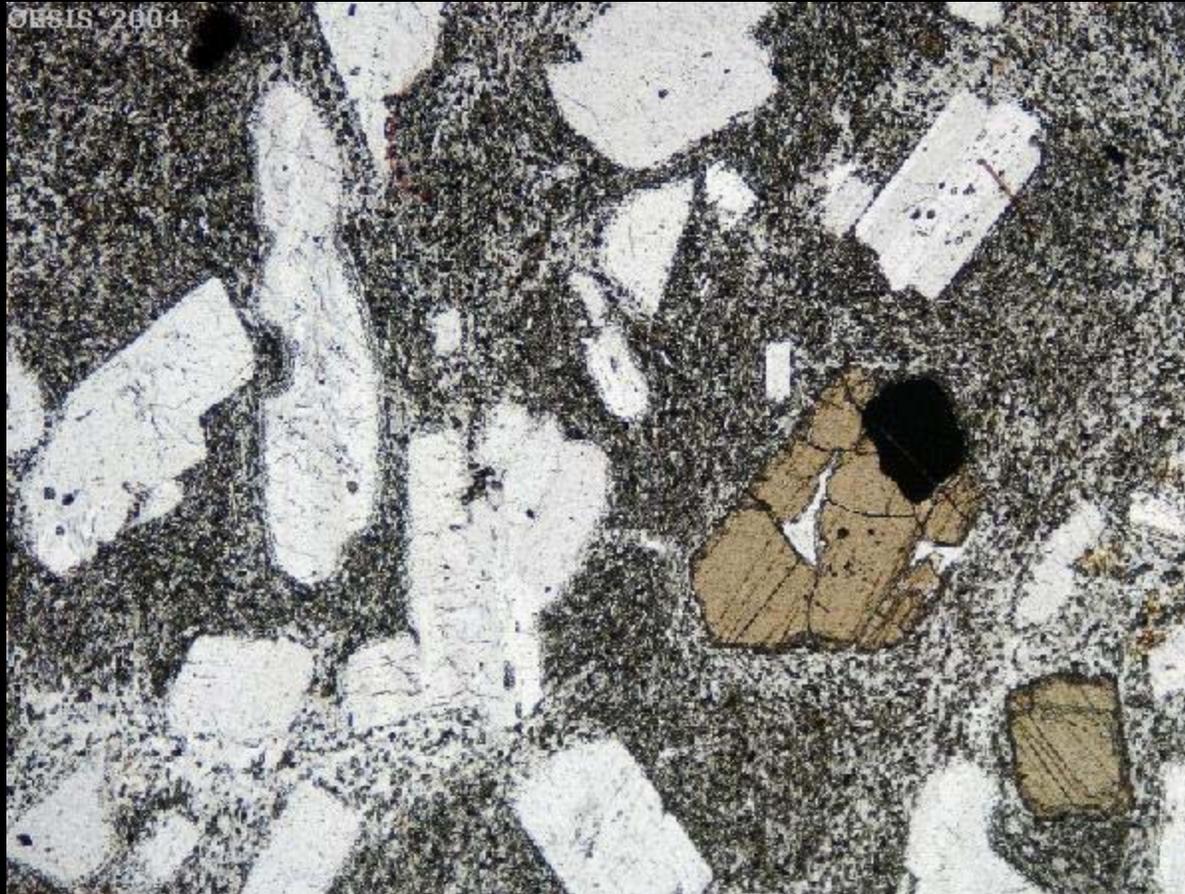
Rhyolite porphyry

Minerals cannot be identified in fine grained groundmass, but phenocrysts of orthoclase are visible



Andesite porphyry

Minerals cannot be identified in fine grained groundmass, but phenocrysts of amphibole are visible



Andesite porphyry

Minerals cannot be identified in fine grained groundmass, but phenocrysts of amphibole are visible



Andesite porphyry

Minerals cannot be identified in fine grained groundmass, but phenocrysts of amphibole are visible



Basalt

Minerals cannot be identified in hand specimen, but come from the top of Bowen's Reaction Series





Basalt

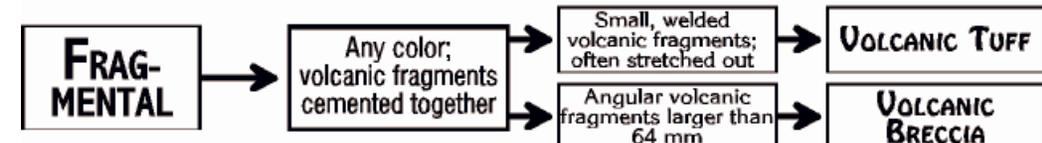
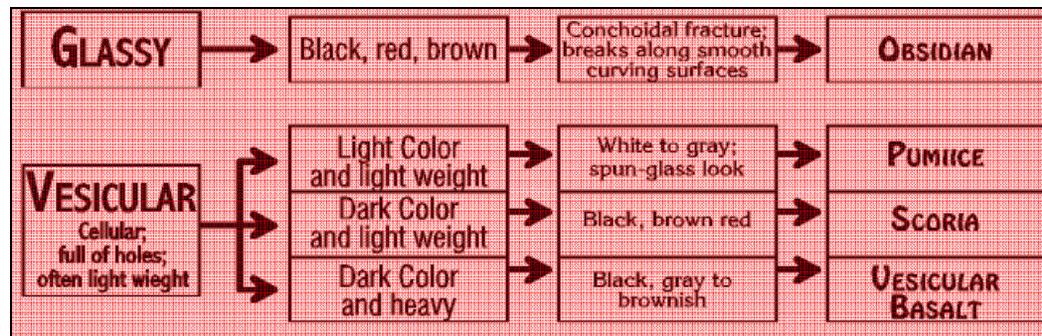
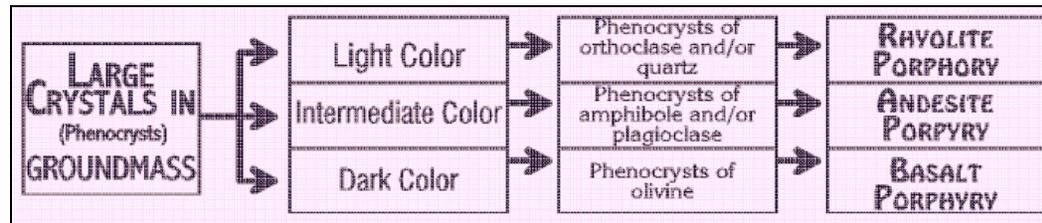
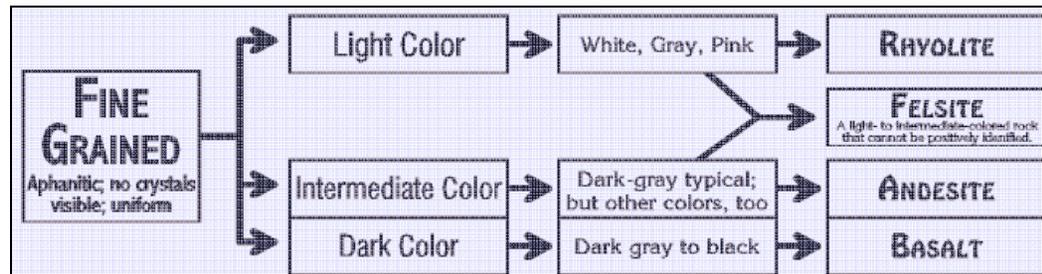
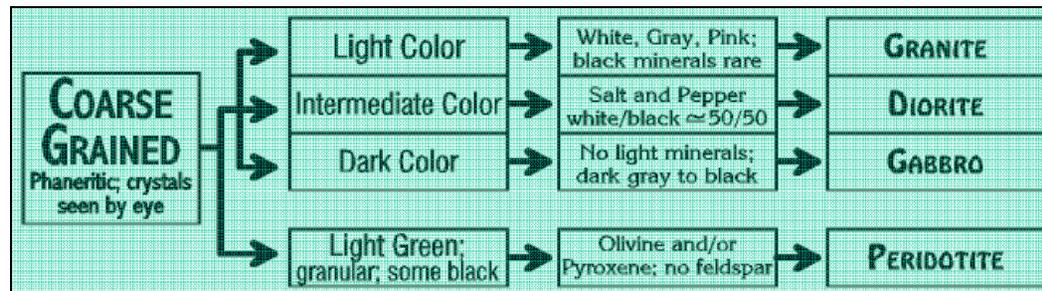
Minerals cannot be identified in hand specimen, but come from the top of Bowen's Reaction Series



Basalt porphyry

Phenocrysts are a Ca rich plagioclase

COLOR/TEXTURE KEY PHANERITIC IGNEOUS ROCKS





Obsidian: (volcanic glass)

No minerals are present since this cooled too fast for them to form.



Pumice: (volcanic glass with gas escape)

No minerals are present since this cooled too fast for them to form.



Pumice: (volcanic glass with gas escape)

No minerals are present since this cooled too fast for them to form.



Vesicular Basalt (with gas escape)



Scoria (glass with gas escape)



Photo by the Kiwi Photo Blogger - Nigel Parker
http://kiwiphotoblogger.blogspot.com/2005_03_01_kiwiphotoblogger_archive.html

Scoria (glass with gas escape)