Classification of Igneous Rocks

Textures:

Glassy- no crystals formed

Aphanitic- crystals too small to see by eye

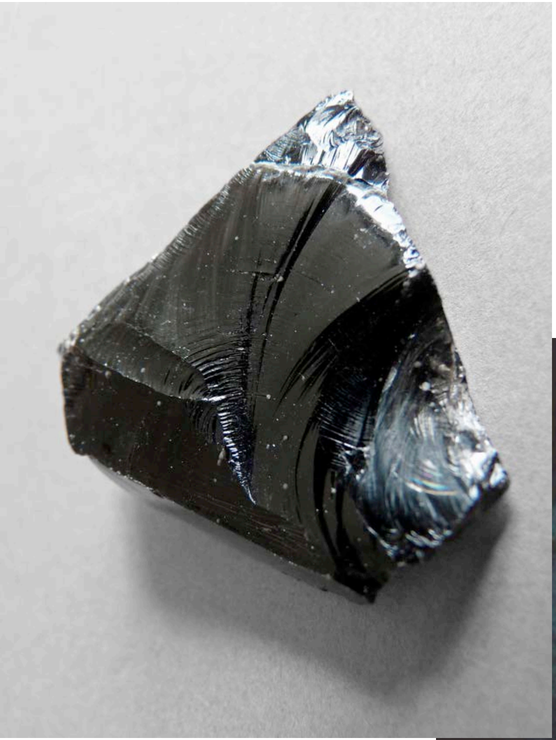
Phaneritic- can see the constituent minerals

- Fine grained- < 1 mm diameter
- Medium grained- 1-5 mm diameter
- Coarse grained- 5-50 mm diameter
- Very coarse grained- > 50 mm diameter

Porphyritic- bimodal grain size distribution

Pyroclastic- amalgamated igneous fragments

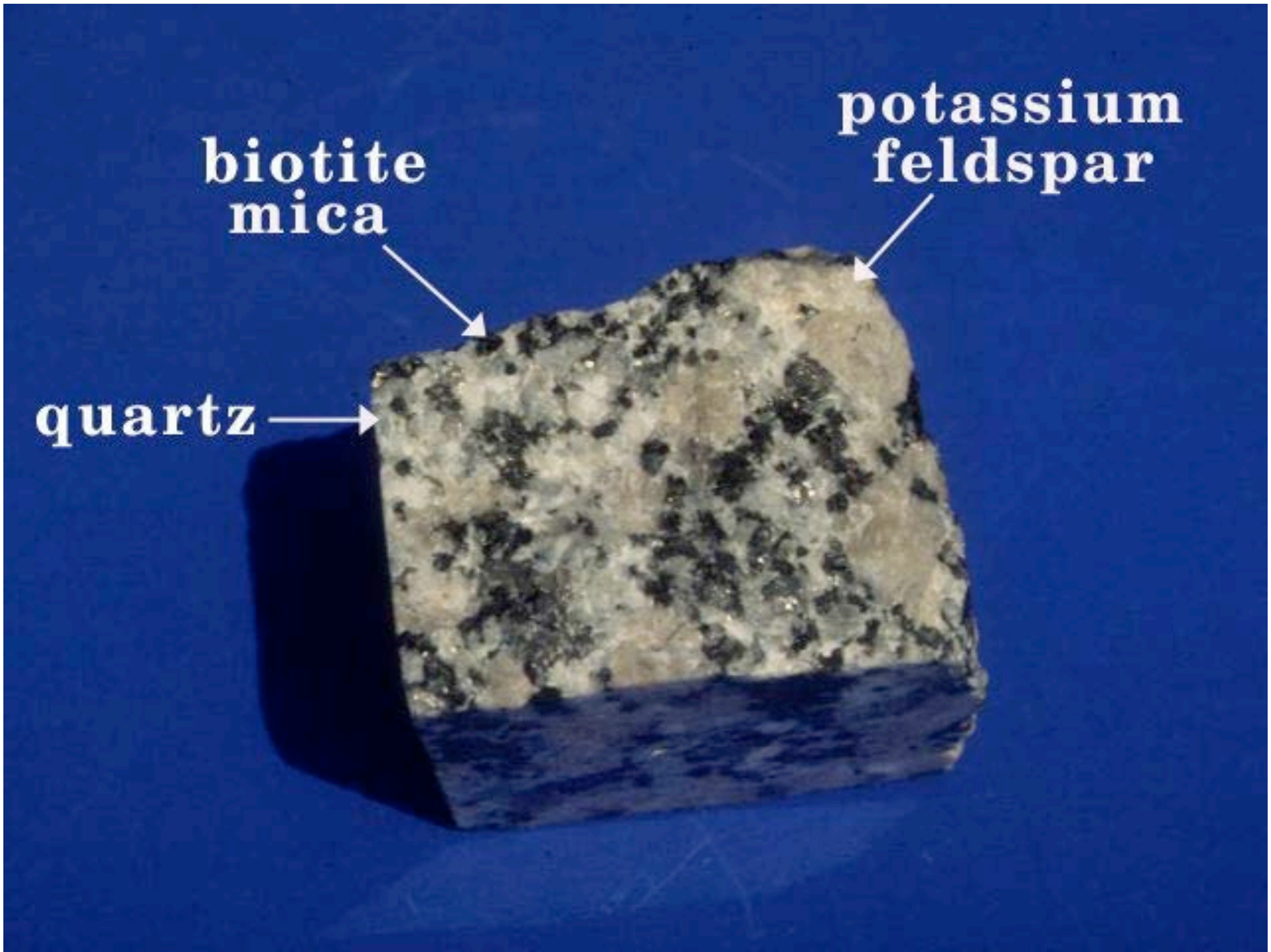
Glassy → cooled *very* rapidly



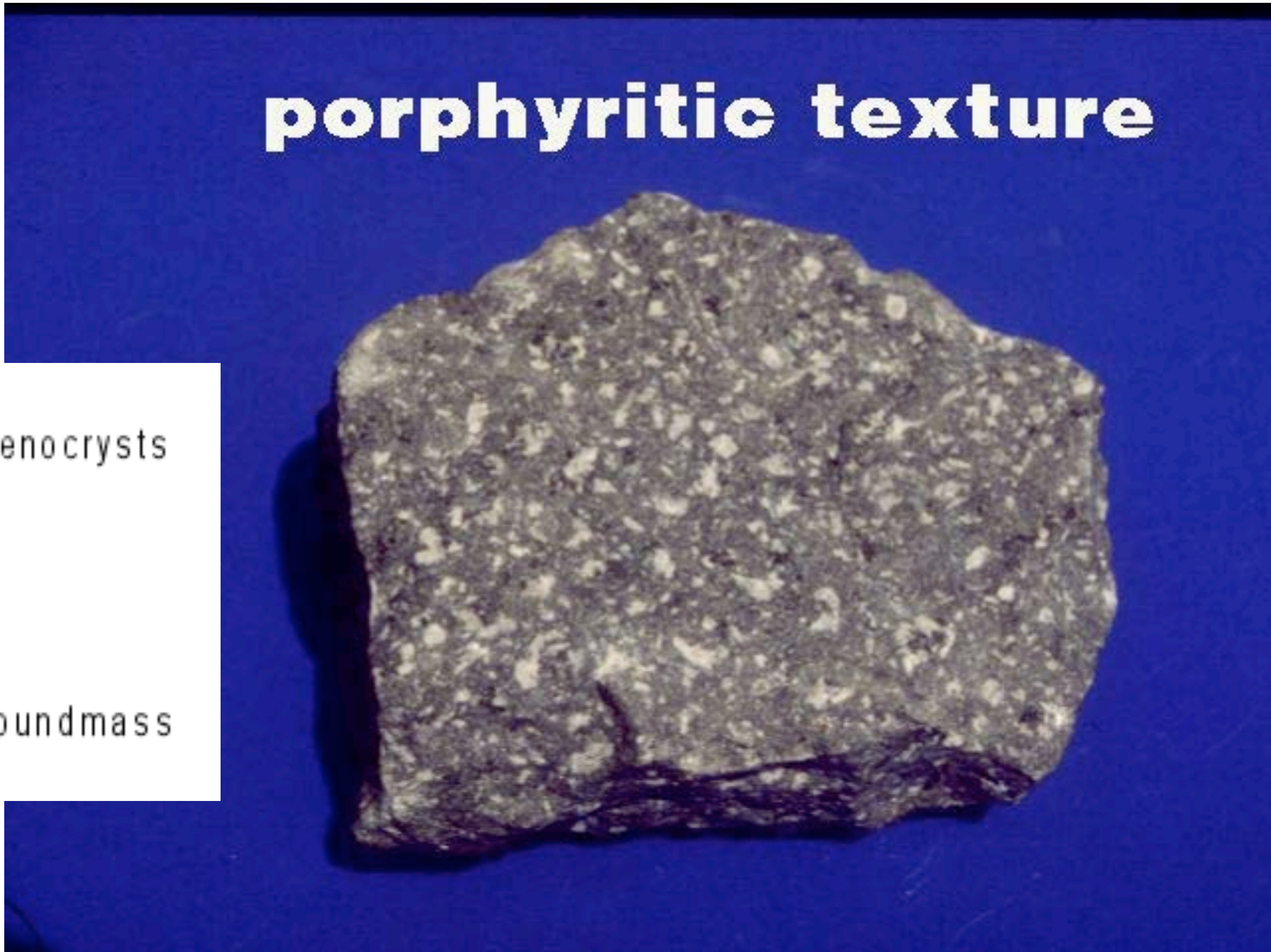
Glassy-skinned pillow lava

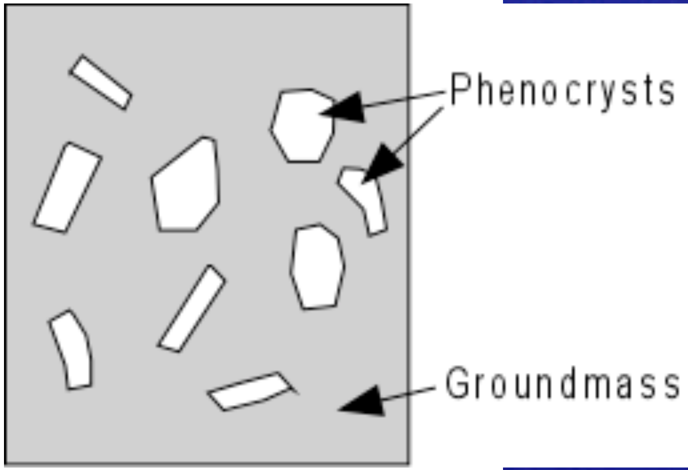
Aphanitic → crystallized rapidly (volcanic/extrusive)

Phaneritic → crystallized slowly (plutonic/intrusive)

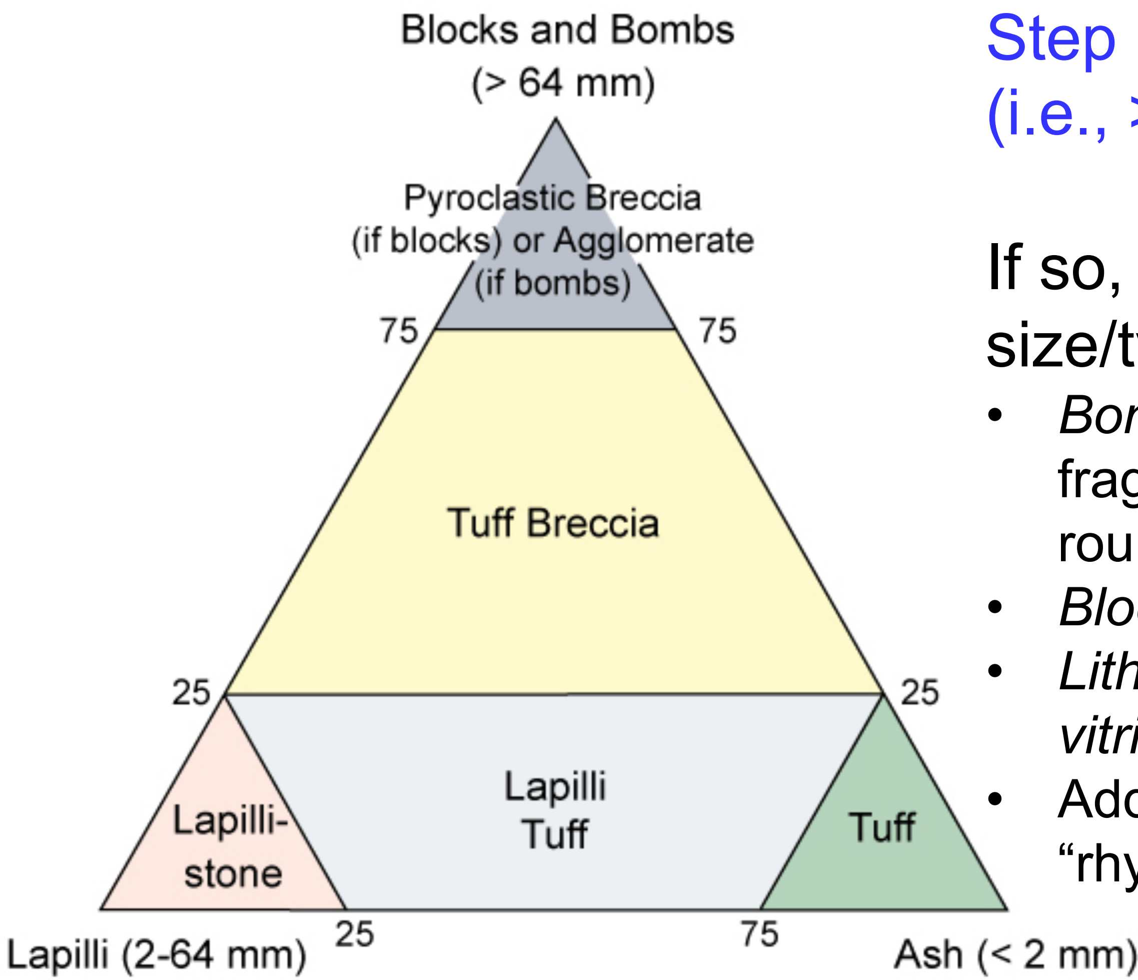


Porphyritic
→ 2 phases of crystallization





Classification of Igneous Rocks



Step 1: Is rock pyroclastic (i.e., >75% pyroclasts)?

If so, name based on clast size/type

- *Bombs* molten during fragmentation, typically rounded/stretched
- *Blocks* angular or broken
- *Lithic* mostly rock fragments; *vitric* mostly glass; or *crystal*
- Add composition if known, e.g., "rhyolitic tuff"

Figure 2.5. Classification of the pyroclastic rocks. After Fisher (1966) Earth Sci. Rev., **1**, 287-298.

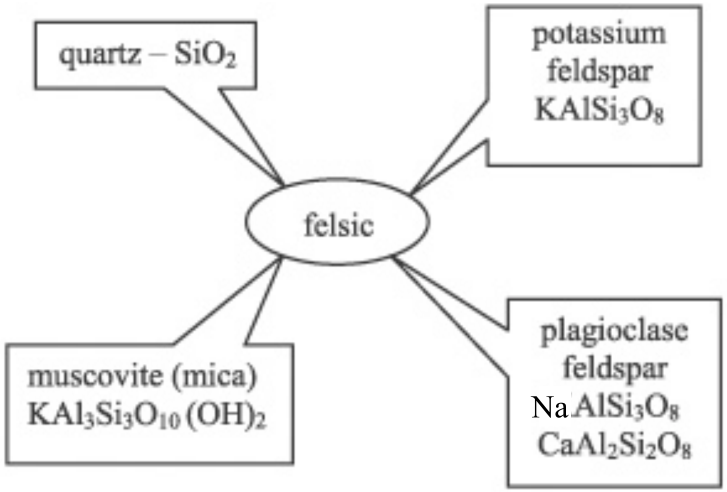
Compositional Classification

The number of different rock type names used by working petrologists is huge (e.g., check out Table 2.1 in your text).

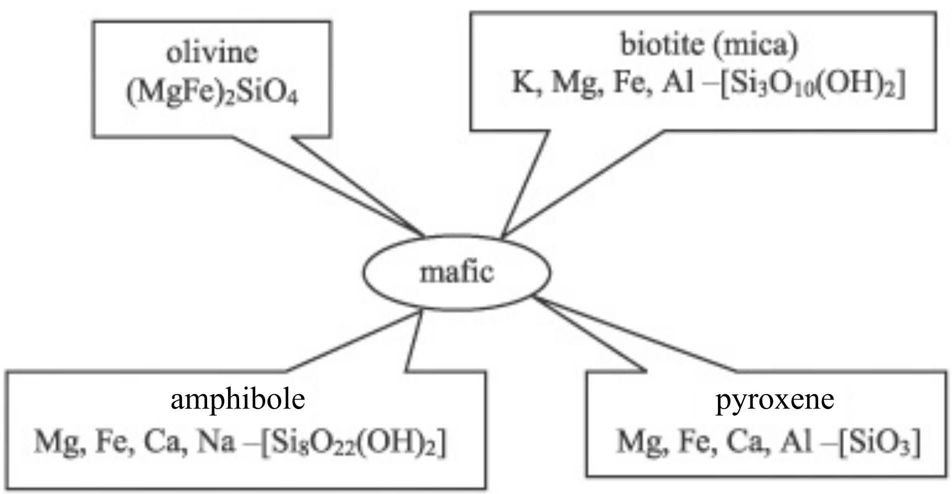
This is partly due to people mixing old and new terminology; we will try to stick to IUGS systemized nomenclature.

… and also due to rare compositions, e.g. highly alkaline rocks (<1% of Earth's igneous rocks, but comprising ~50% of IUGS names!)

Compositional Classes: Felsic v. Mafic



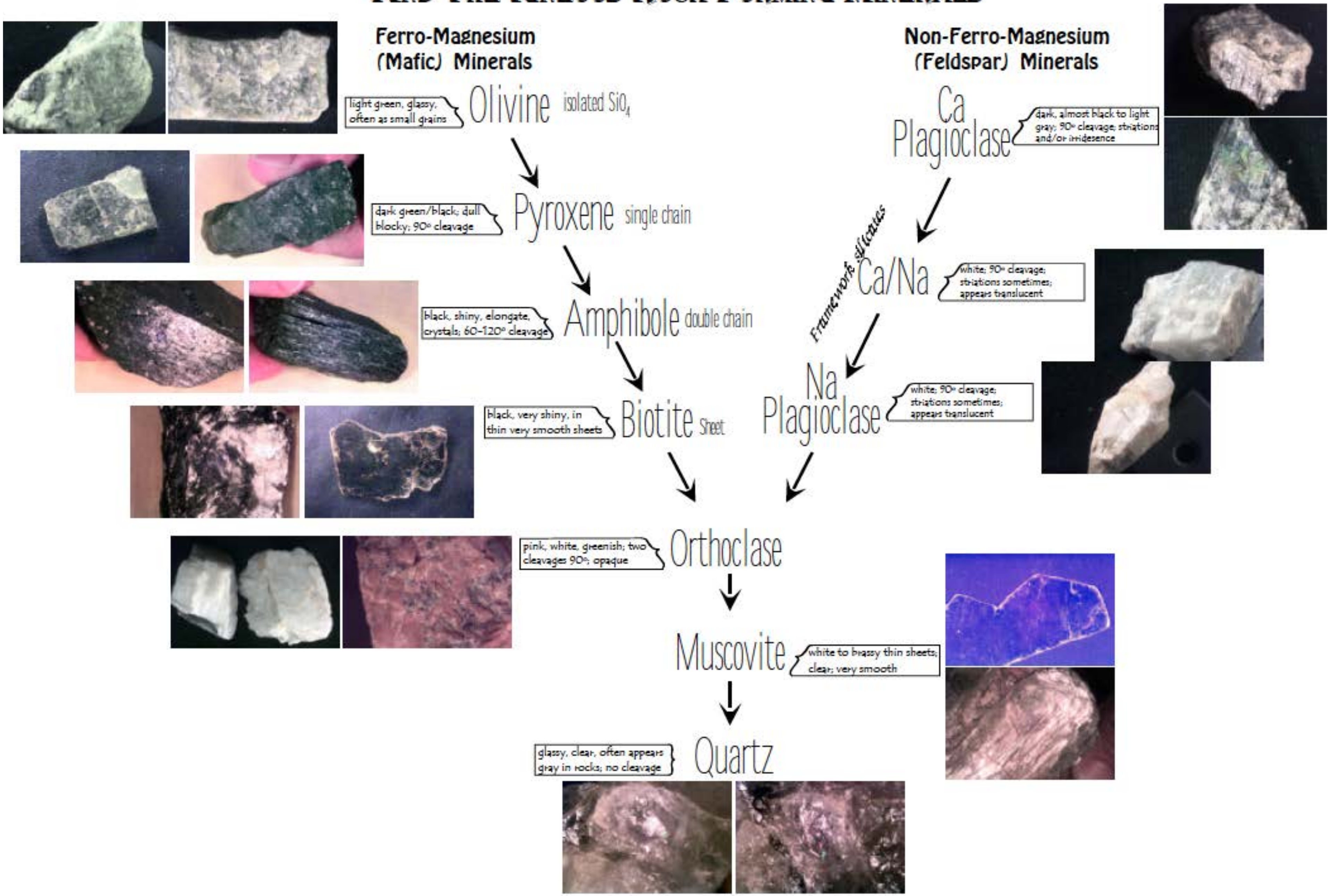
Mostly light
(but remember obsidian)



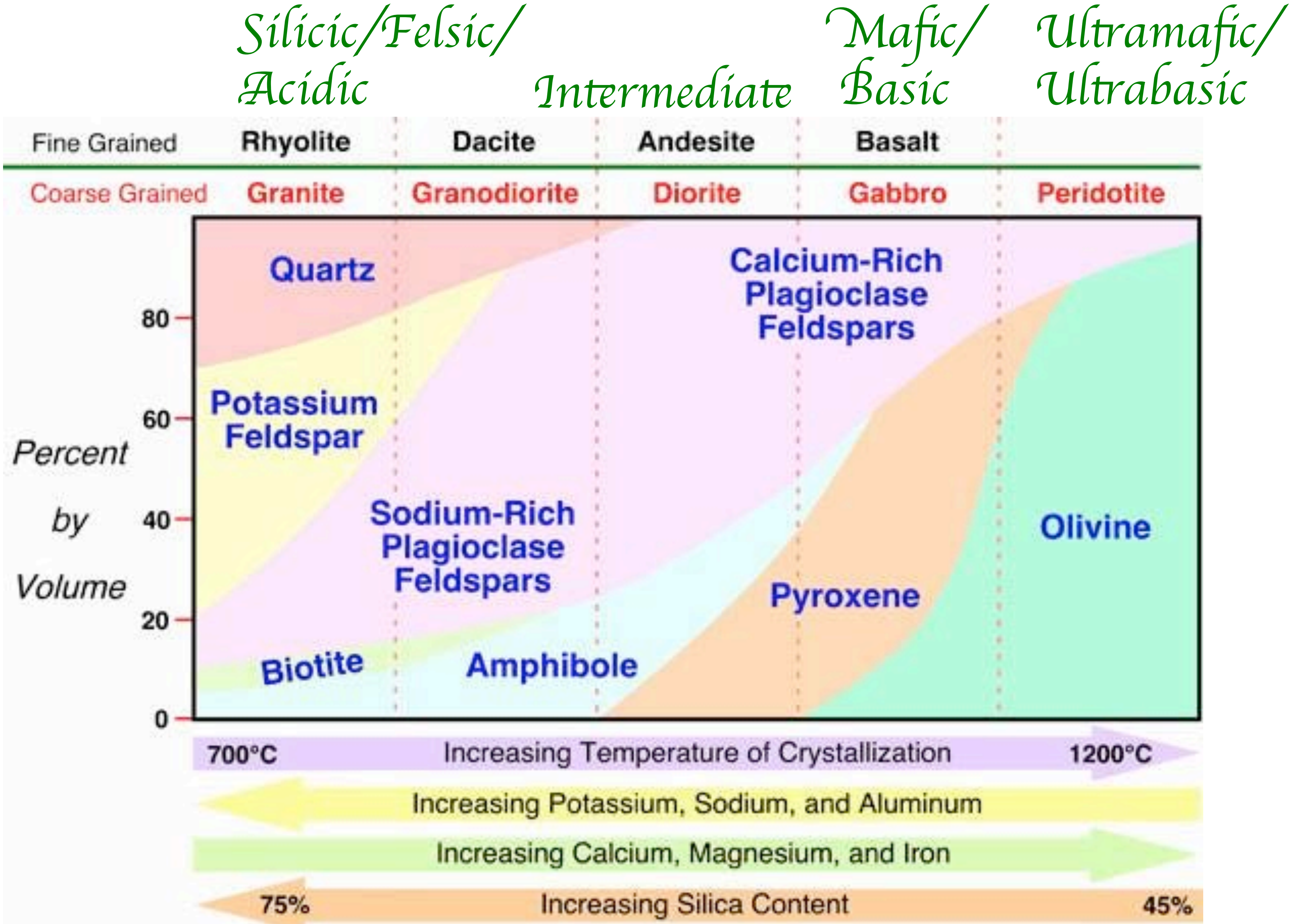
Mostly dark

Refers to individual minerals or to rocks dominated by them

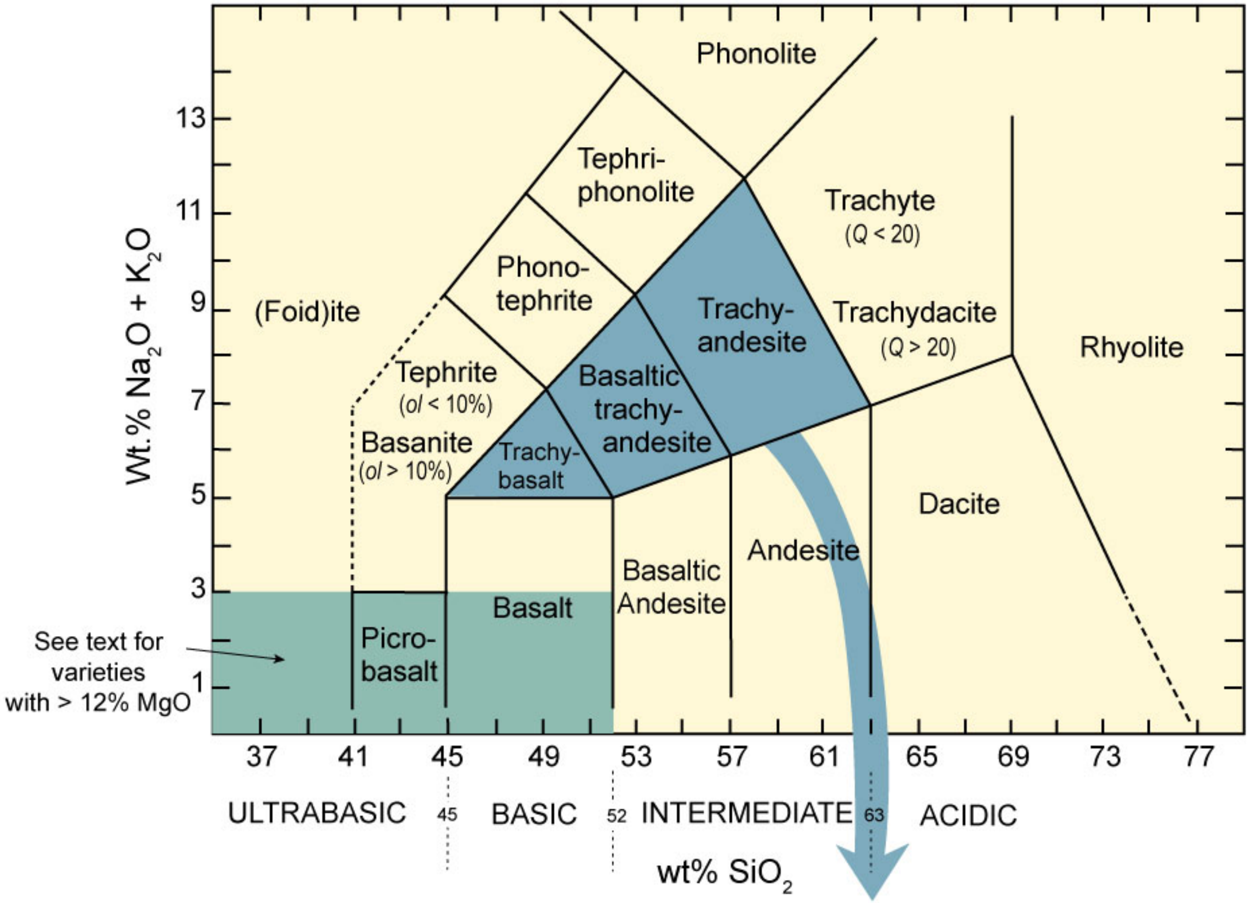
Bowen's Reaction Series
And The Igneous Rock Forming Minerals



Igneous rocks: the low-alkali set



Classification of Igneous Rocks



Step 2: Is rock glassy or aphanitic (i.e., can't determine minerals)?

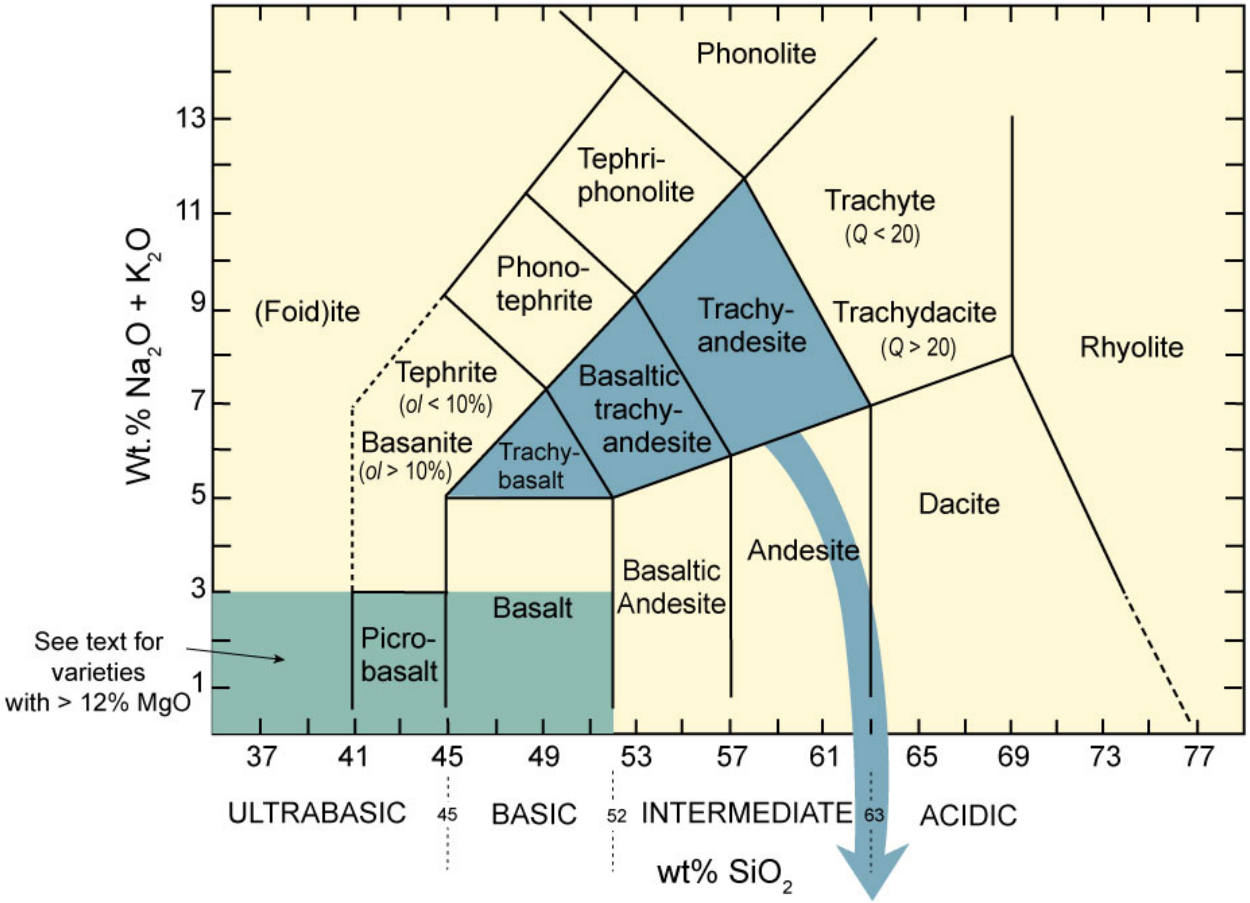
If so, name based on total alkali/SiO_2 (TAS)

- *<3% alkali, high-Mg rocks called* picrites *or* komatiites

Further subdivisions of shaded fields	Trachybasalt	Basaltic Trachyandesite	Trachyandesite
$Na_2O - 2.0 \geq K_2O$	Hawaiite	Mugearite	Benmoreite
$Na_2O - 2.0 < K_2O$	Potassic Trachybasalt	Shoshonite	Latite

Figure 2.4. A chemical classification of volcanics based on total alkalis vs. silica. After Le Maitre (2002) . Igneous Rocks: A Classification and Glossary of Terms. Cambridge University Press.

Classification of Igneous Rocks



Further subdivisions of shaded fields	Trachybasalt	Basaltic Trachyandesite	Trachyandesite
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$Na_2O - 2.0 < K_2O$	Potassic Trachybasalt	Shoshonite	Latite

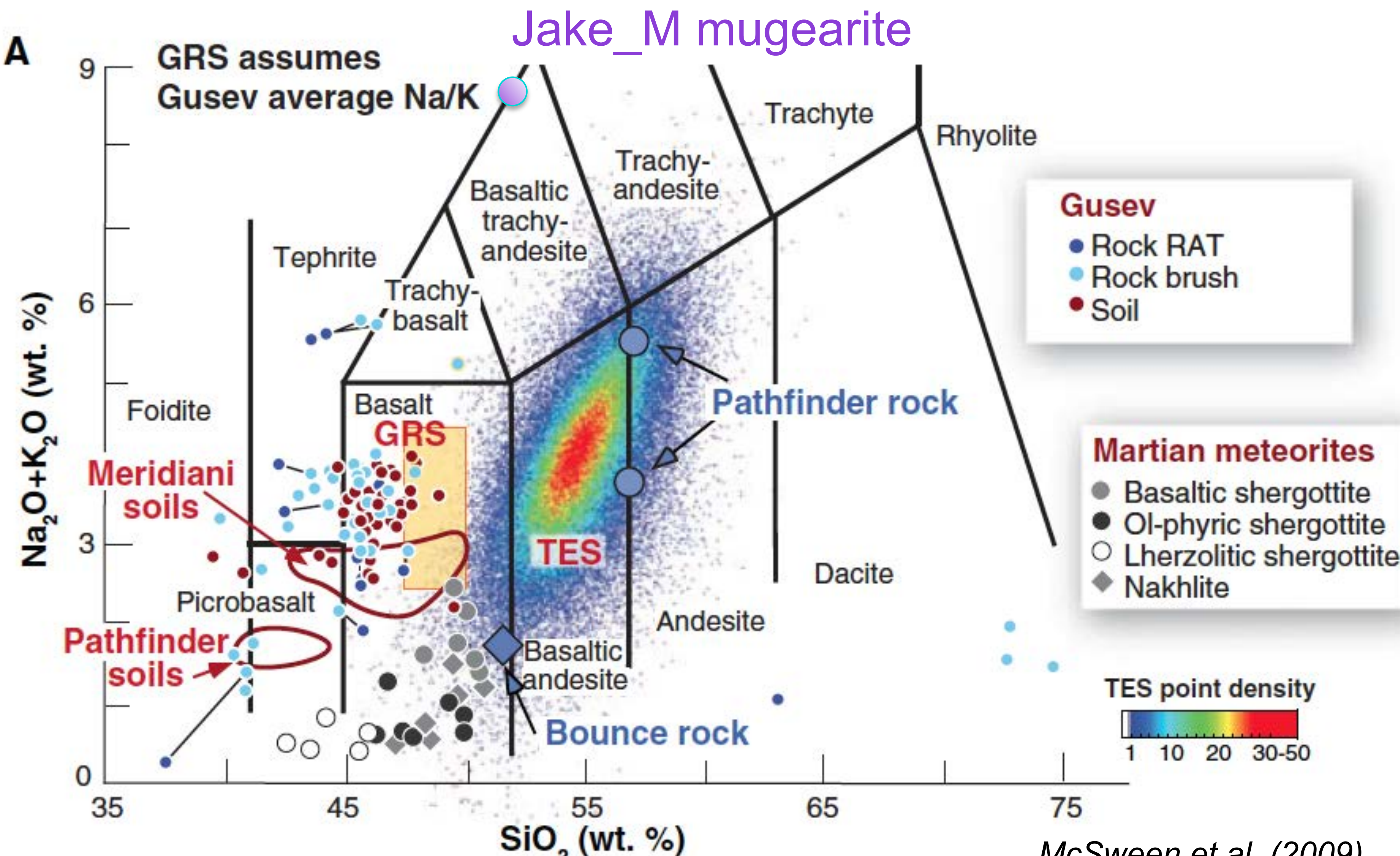
Recently found on Mars; what is it??

wt%	JM avg	JM avg
SiO_2	51.75	51.75
TiO_2	0.91	0.91
Al_2O_3	15.96	15.96
Cr_2O_3	0.00	0.00
Fe_2O_3	0.00	1.94
FeO	11.66	9.91
MnO	0.17	0.17
MgO	3.61	3.61
CaO	6.76	6.76
Na_2O	6.39	6.39
K_2O	2.23	2.23
P_2O_5	0.56	0.56

Stolper et al. (2013)

Figure 2.4. A chemical classification of volcanics based on total alkalis vs. silica. After Le Maitre (2002) . Igneous Rocks: A Classification and Glossary of Terms. Cambridge University Press.

Mars: A basaltic world(?)



McSween et al. (2009)

Caveat: alteration can also change bulk chemistry

1. Primary minerals
    - Olivine: $(Mg,Fe)_2SiO_4$
    - Pyroxene: $(Ca,Mg,Fe)SiO_3$
    - Plagioclase: $CaAl_2Si_2O_8$ – $NaAlSi_3O_8$

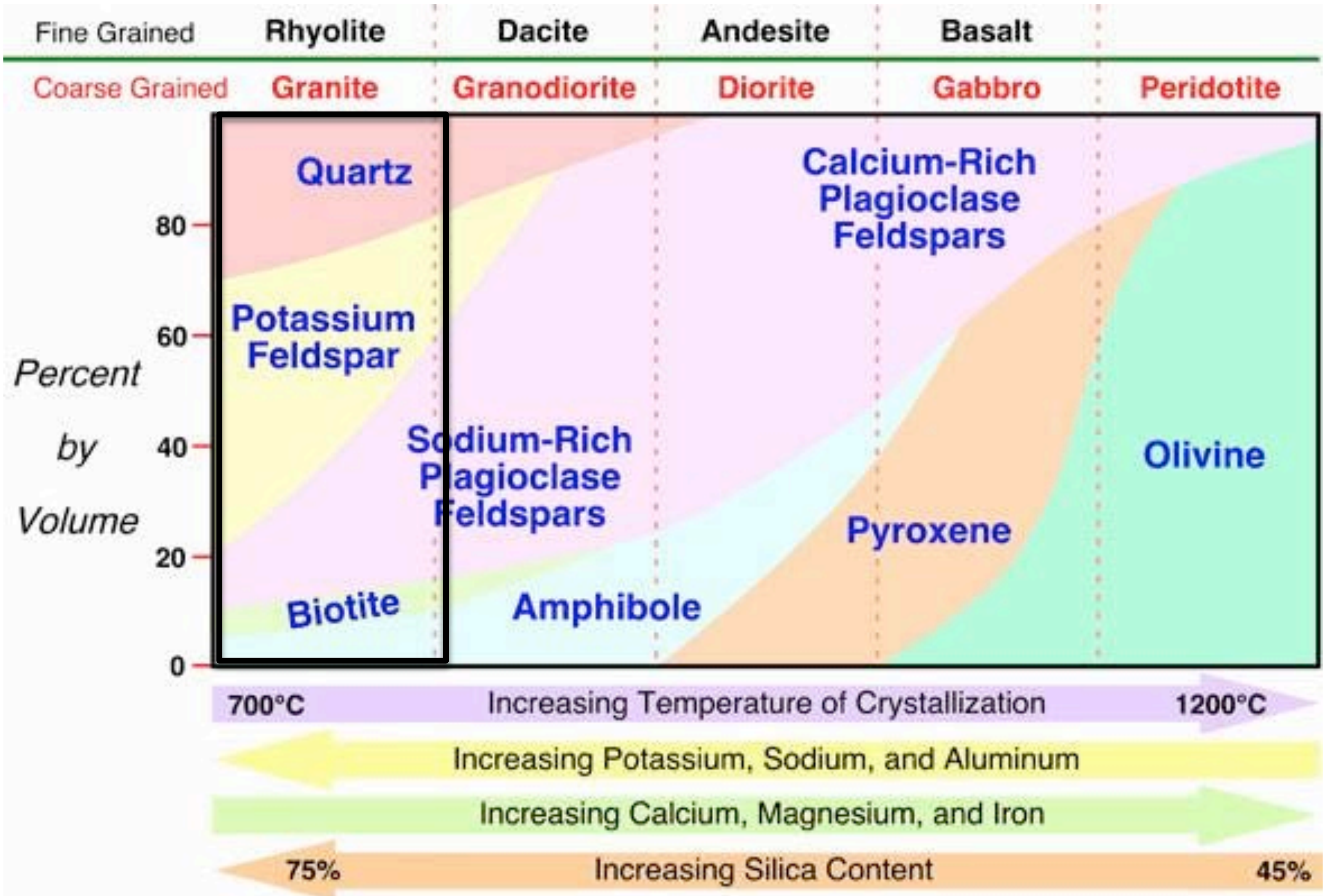
2. Oxides
    - Hematite: Fe_2O_3

3. Salts
    - Halite: NaCl
    - Gypsum: $CaSO_4 \cdot 2H_2O$
    - Calcite: $CaCO_3$

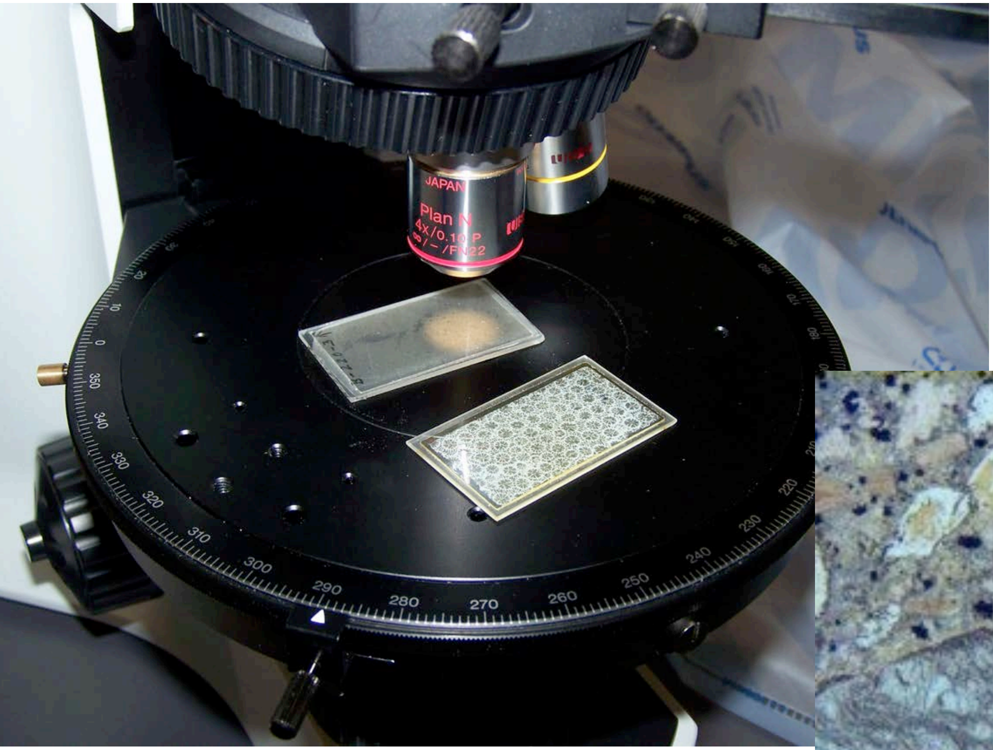
4. Secondary silicates (incl. phyllosilicates—e.g., clays)
    - Kaolinite: $Al_2Si_2O_5(OH)_4$
    - Nontronite: $Fe_2(Al,Si)_4O_{10}(OH)_2Na_{0.3} \cdot nH_2O$

Increasing water alteration ↓

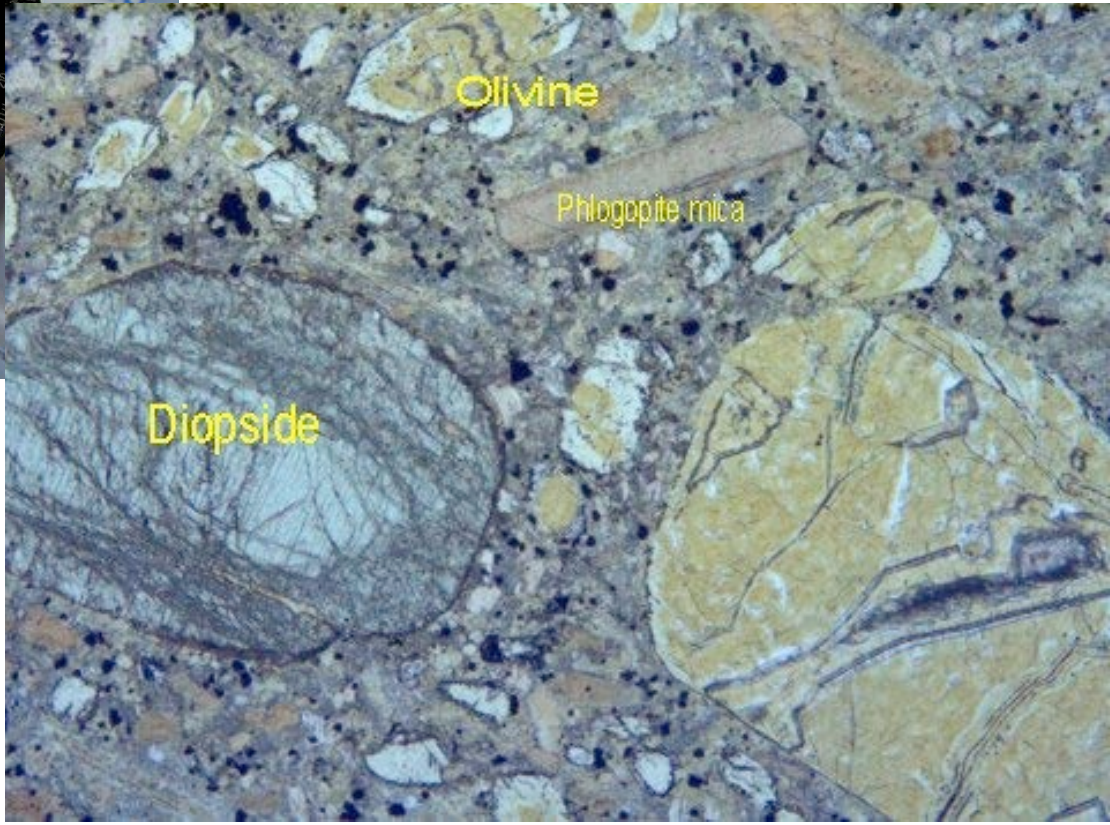
New: remotely sensed rocks w/ <5% mafics



Rock classification based on mineralogy



Step 3: If possible, determine the ***modal mineralogy…***



Can estimate abundances from hand samples, but thin section "point counting" is more accurate

Mineral-based Classification of Volcanic Rocks

Step 4: Calculate…

Q' = % quartz (or other polymorph)

A' = % alkali feldspar ($An_{<5}$)

P' = % plagioclase feldspar

F' = % feldspathoids (abbrev. 'foids')

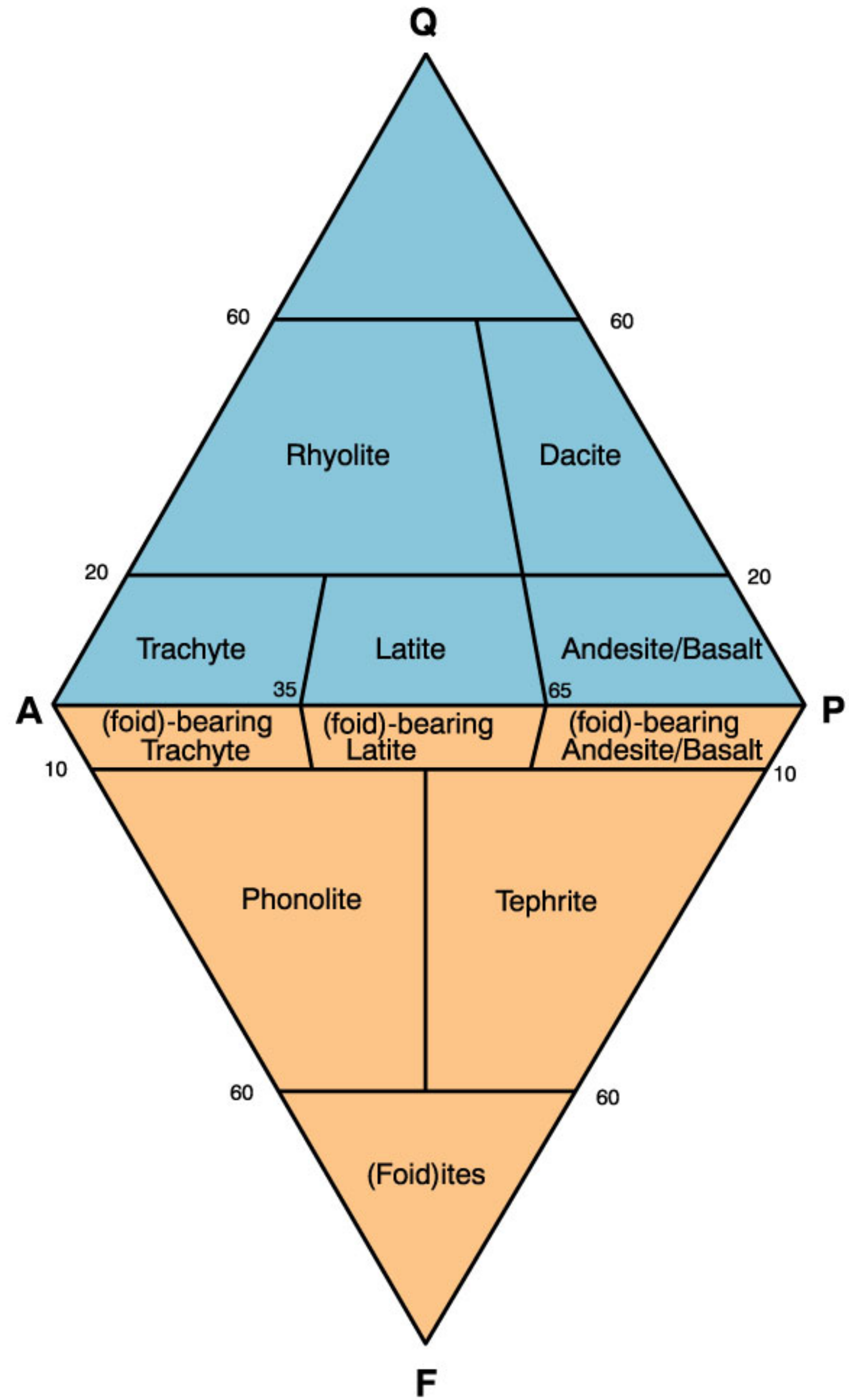


Figure 2.3. A classification and nomenclature of volcanic rocks. After IUGS.

Feldspathoids

- Typically contain more Al than the feldspars
- Important constituents of some types of silica-poor igneous rocks

Examples

- Nepheline $(K,Na)AlSiO_4$: “stuffed” version of tridymite
- Leucite $KAlSi_2O_6$

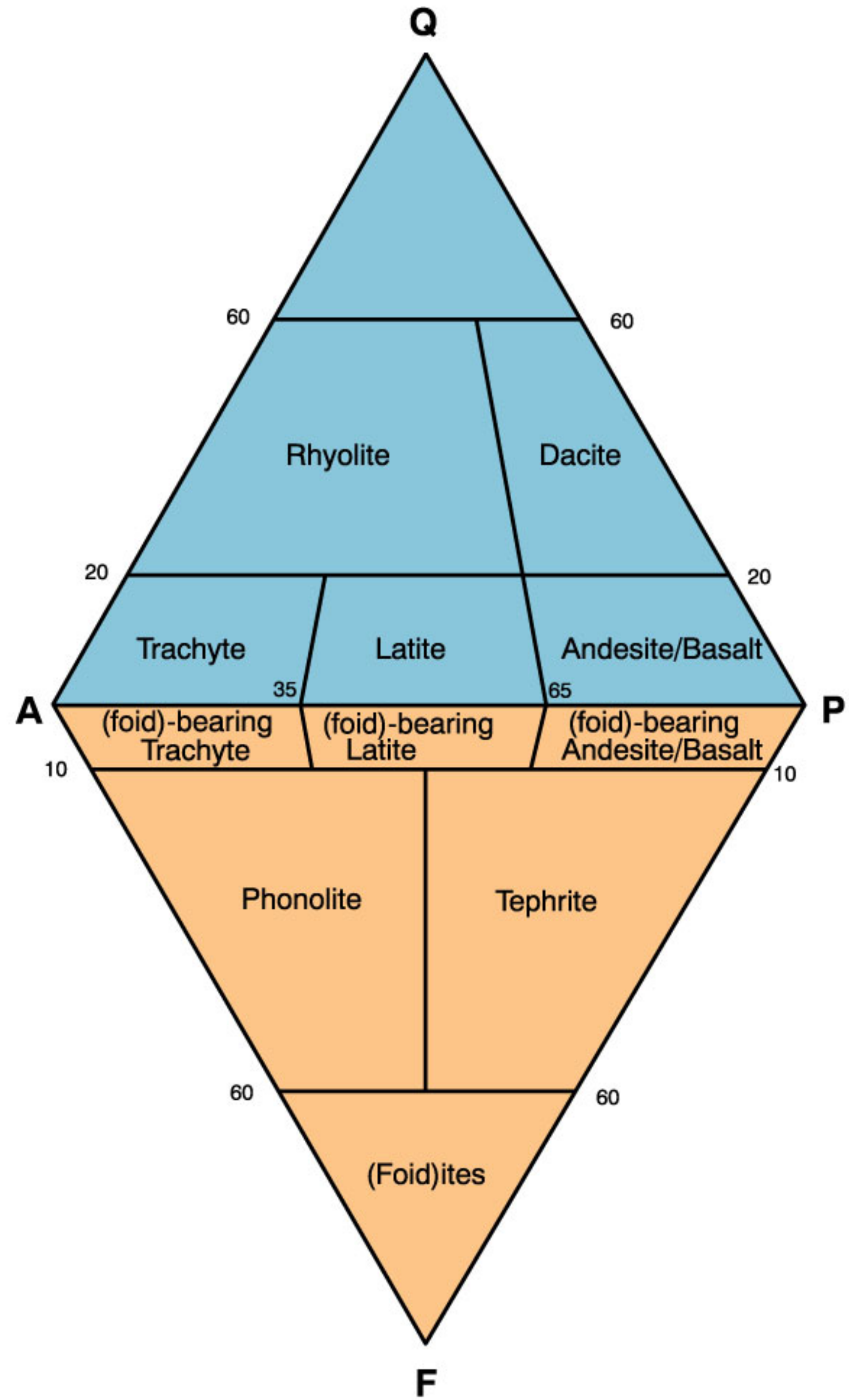
Mineral-based Classification of Volcanic Rocks

Step 5:

If Q’ + A’ + P’ + F’ > 10% then **normalize** these to exclude all other phases (including all mafics!)

E.g., Q = 100 * Q’ / (Q’ + A’ + P’)

[Note either Q’ or F’ will be 0]



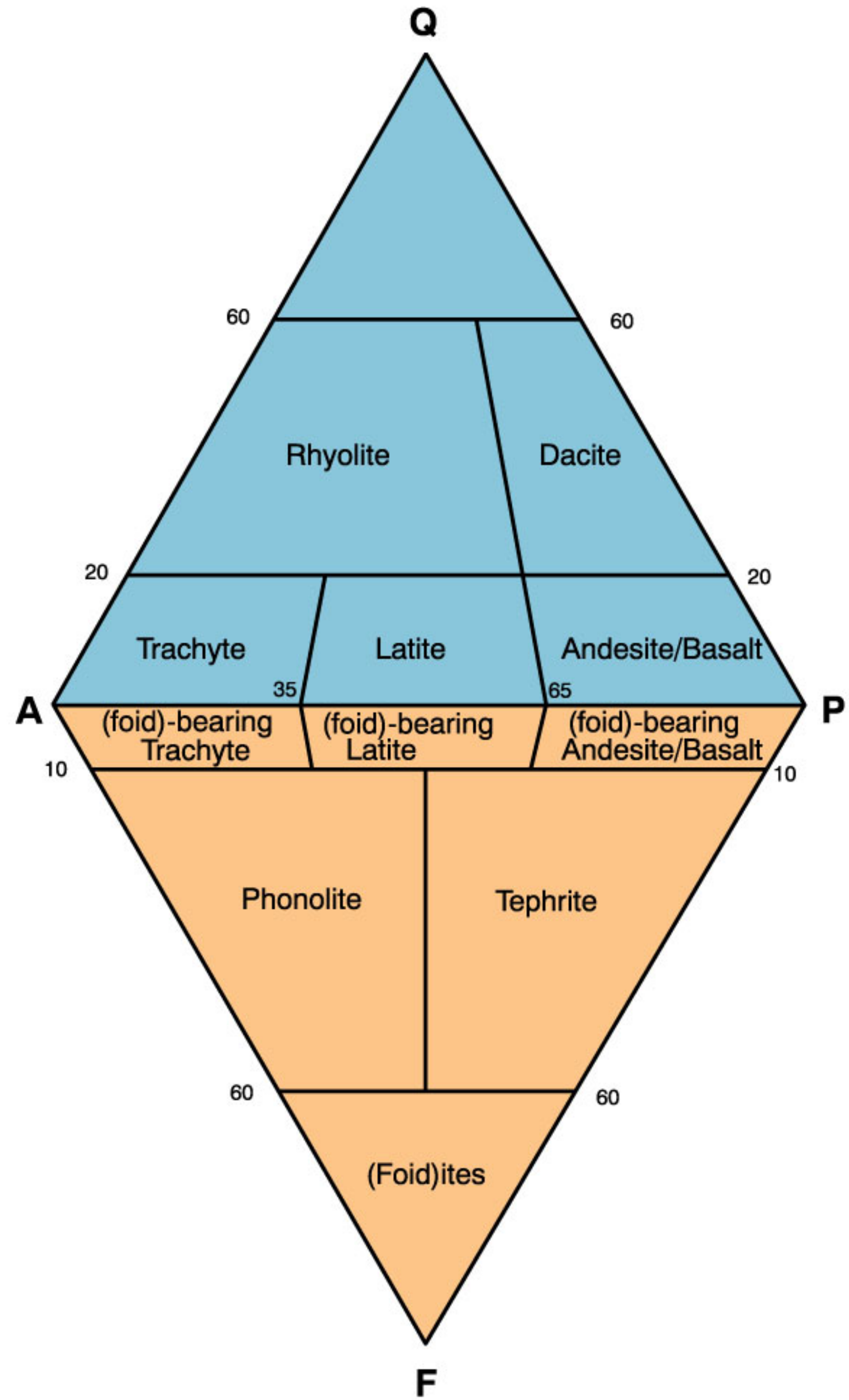
Mineral-based Classification of Volcanic Rocks

Step 6:

Determine name from Q or F, and feldspar ratio:
100P/(P+A) → left-to-right position

If andesite/basalt:
Basalt defined by <52% SiO_2, and/or “color index” (% dark minerals) > 35%

Replace “foid” with the specific mineral, e.g. nepheline



Mineral-based Classification of Plutonic Rocks

Steps are analogous…

If diorite/gabbro:
Gabbro defined by plagioclase with $An_{>50}$

But for >90% mafics, need a different chart…

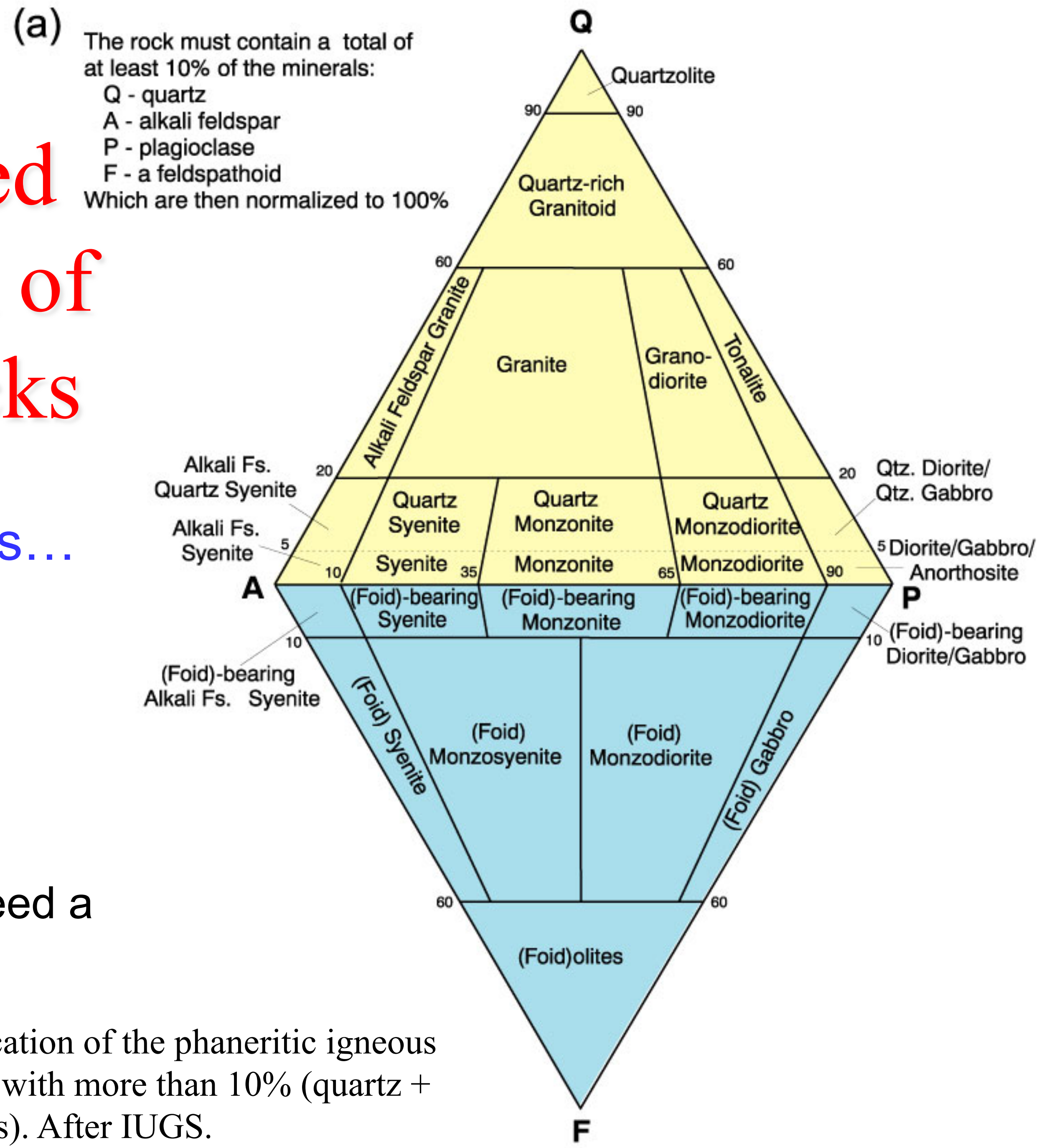


Figure 2.2a. A classification of the phaneritic igneous rocks: Phaneritic rocks with more than 10% (quartz + feldspar + feldspathoids). After IUGS.

Classification of Mafic Intrusive Rocks

A simplified version…

E.g., orthopyroxene gabbro should really be "norite" **

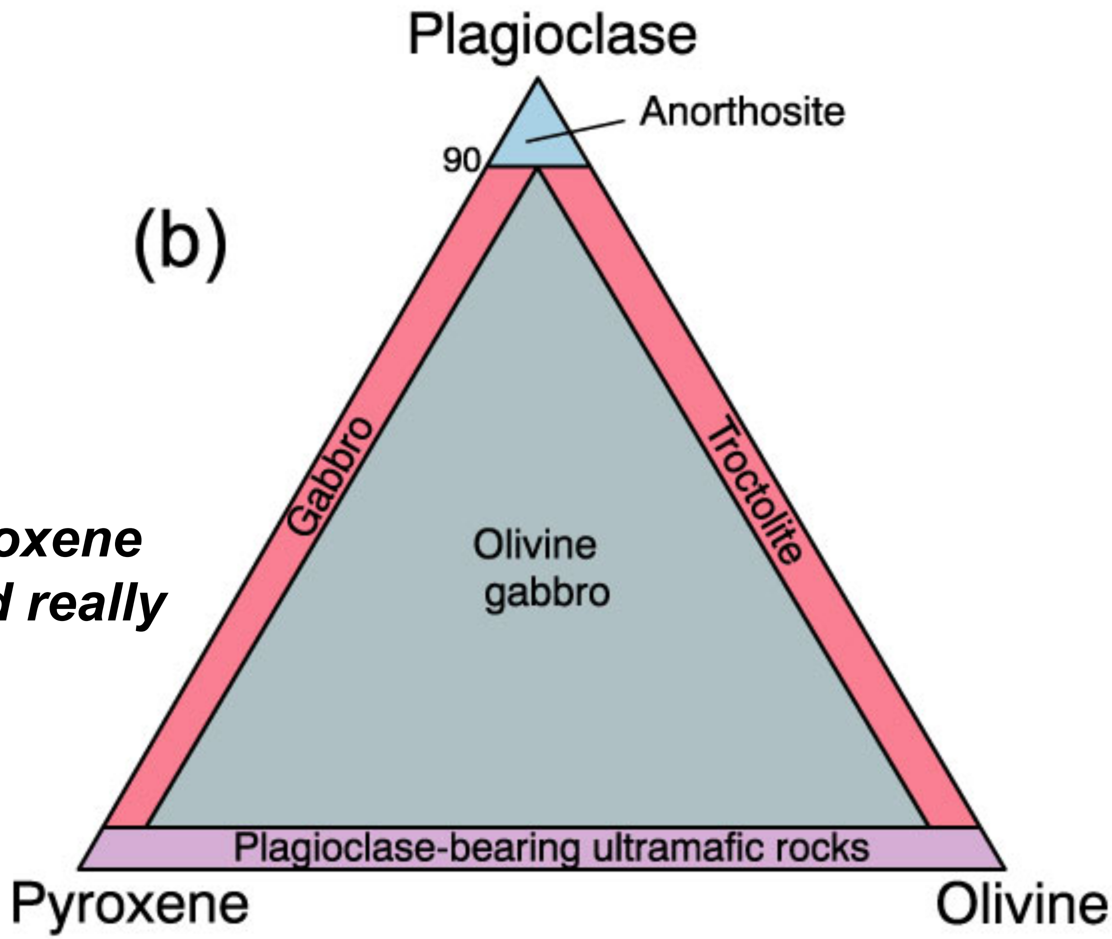


Figure 2.2b. A classification of the phaneritic igneous rocks: Gabbroic rocks. After IUGS.

Classification of Ultramafic Intrusives

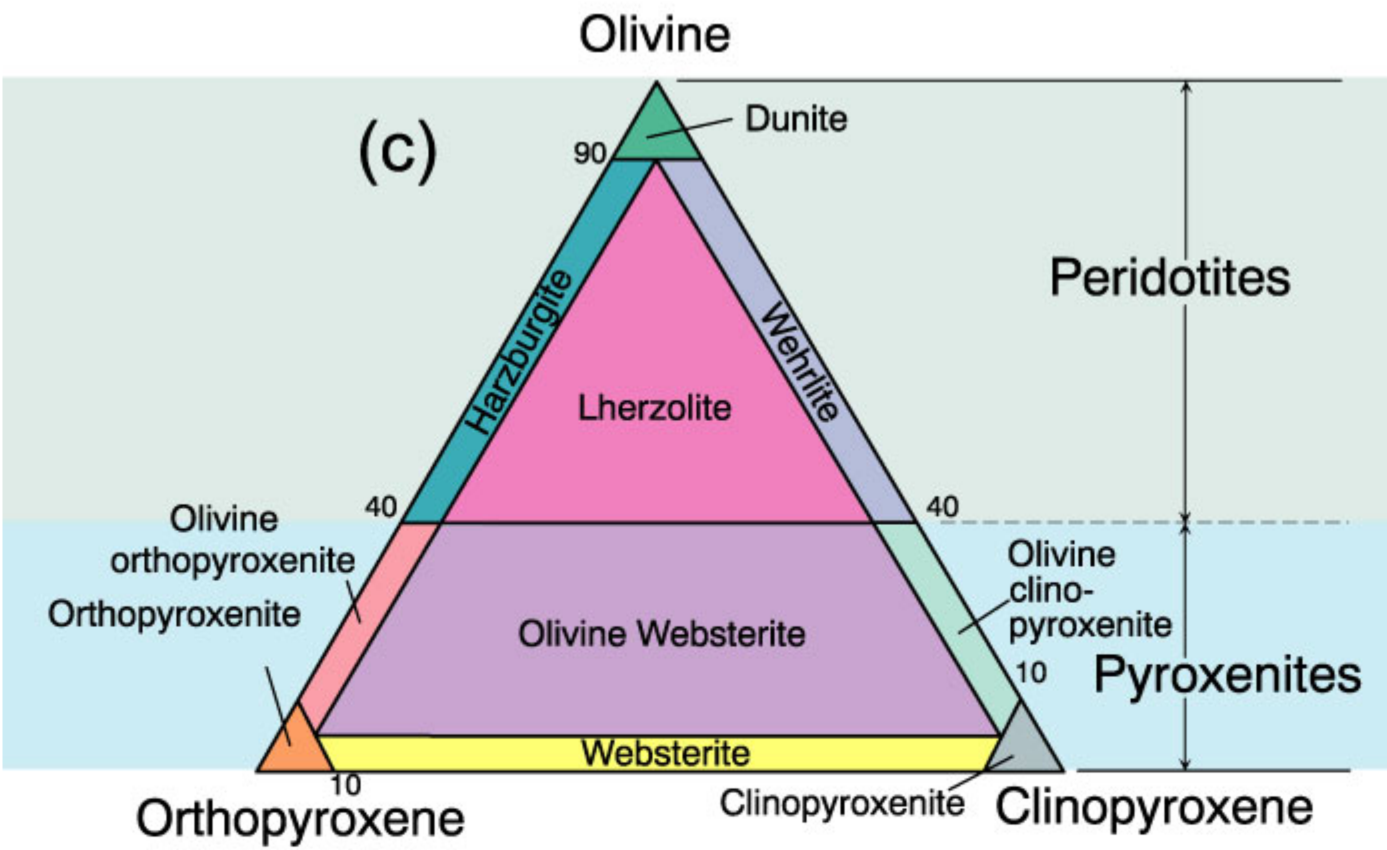


Figure 2.2c. A classification of the phaneritic igneous rocks: Ultramafic rocks. After IUGS.

An example…

Modal mineralogy of 18% qtz, 32% plag, 27% K-spar, 12% biotite, 8% hornblende, 3% opaques

Q' + A' + P' = 77 > 10

Renormalize →
Q = 23, P = 42, A = 35

100P/(P+A) = 55

→ ***granite *****

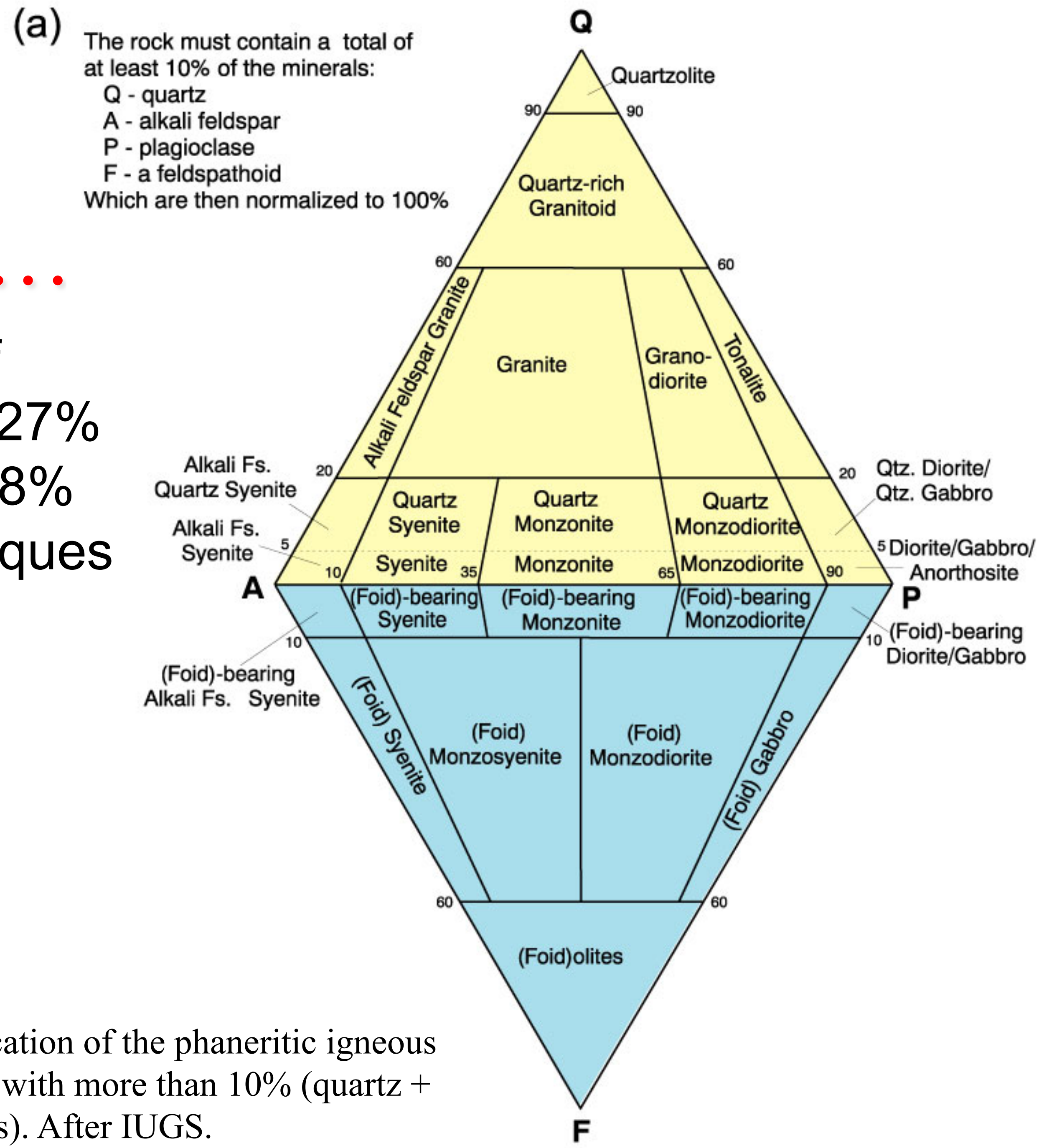


Figure 2.2a. A classification of the phaneritic igneous rocks: Phaneritic rocks with more than 10% (quartz + feldspar + feldspathoids). After IUGS.

Another example

Modal mineralogy of 11% nepheline, 2% plag, 70% K-spar, and other mafic/accessory phases

??

➔ ***nepheline syenite *****

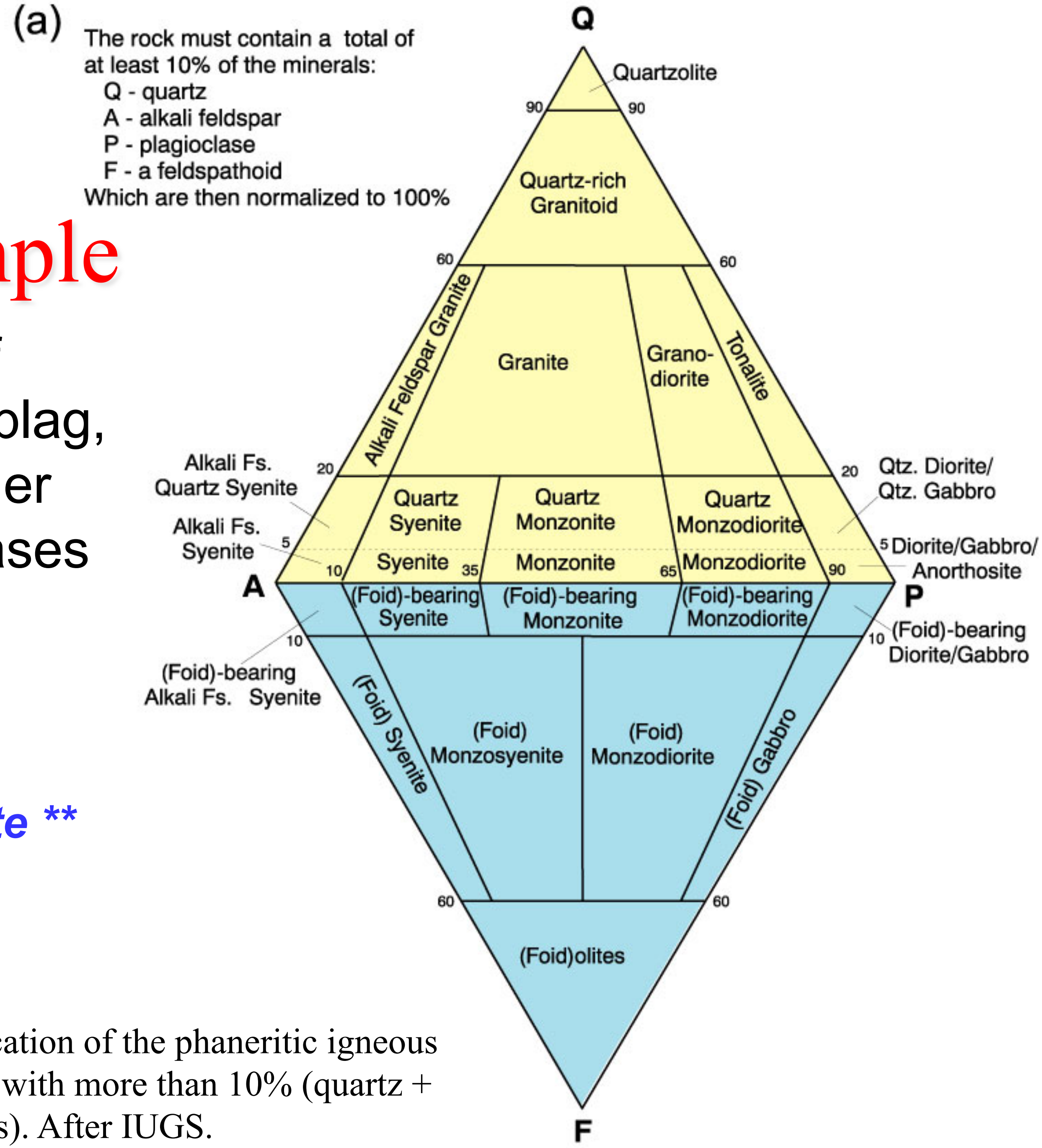


Figure 2.2a. A classification of the phaneritic igneous rocks: Phaneritic rocks with more than 10% (quartz + feldspar + feldspathoids). After IUGS.

Revisiting the effects of H_2O

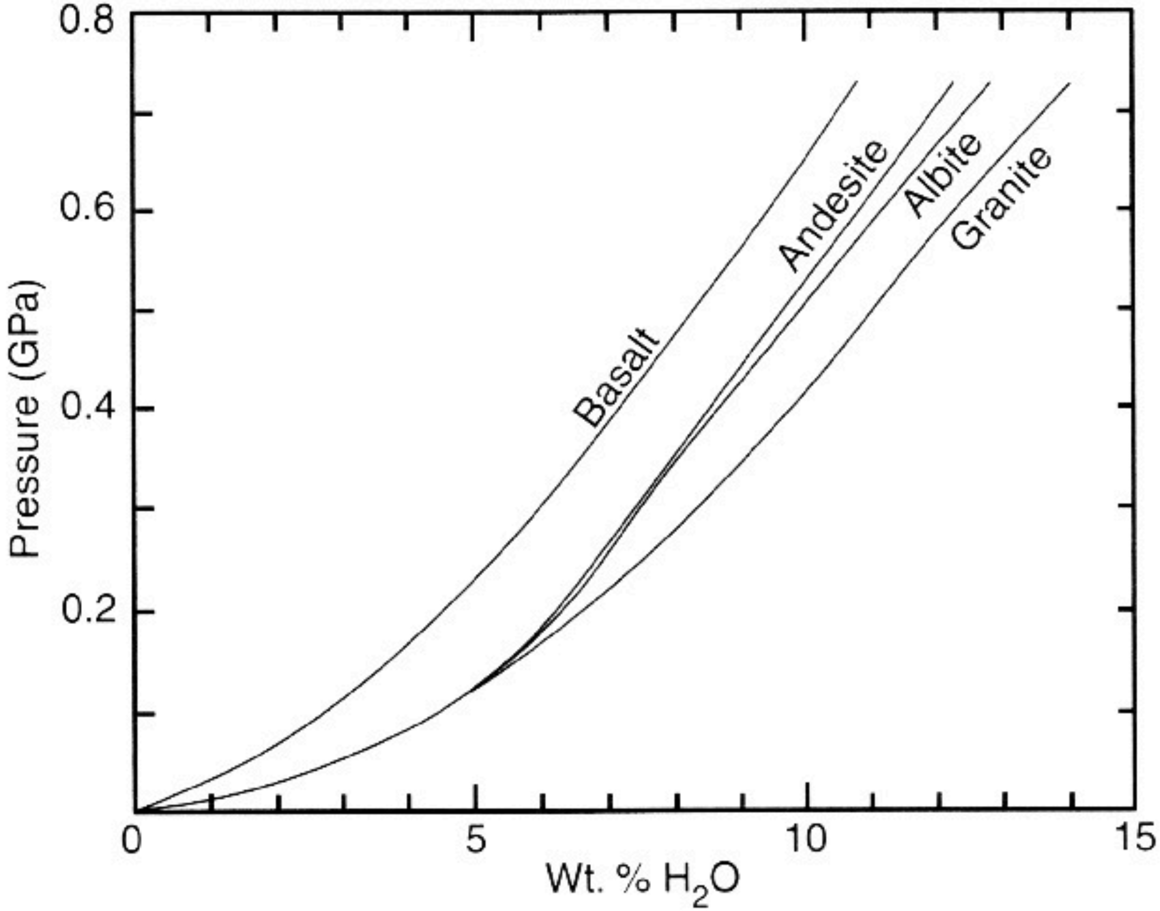


FIGURE 7.18 The solubility of H_2O at 1100°C in three natural rock samples and albite. After Burnham (1979). Copyright © reprinted by permission of Princeton University Press.

H_2O solubility in melt increases with P, SiO_2

($H_2O \rightarrow OH^- + H^+$, breaks -Si-O-Si- to form -Si-OH and HO-Si?)

— assumes SiO_4 polymers in melt

Note 10 wt% H_2O is >50 mol% !

2-3 wt% more realistic

Dry and water-saturated solidi for some common rock types

All solidi are greatly lowered by water, and the P-T curves become non-monotonic

More silicic melts tend to be wetter → more likely to recrystallize in plutons during ~isothermal ascent

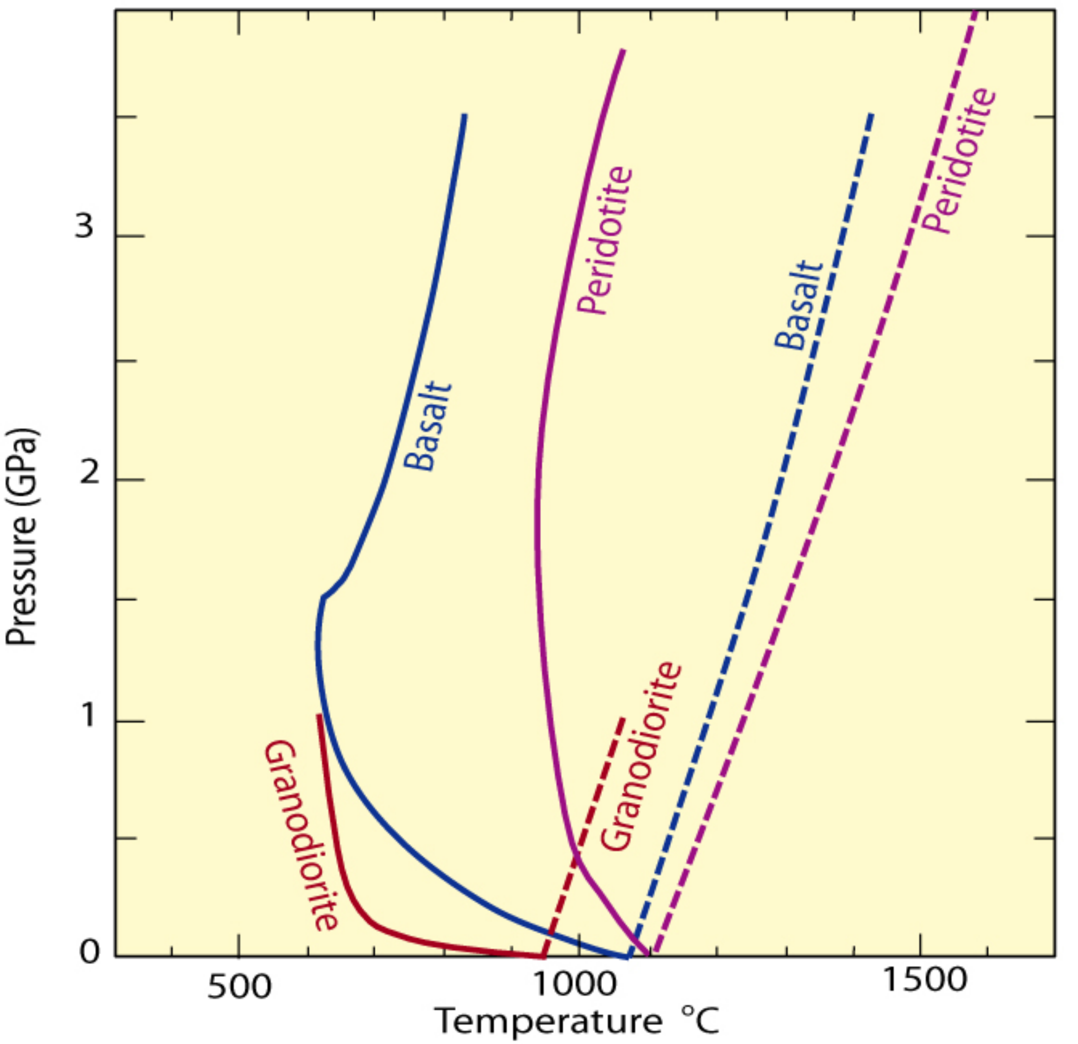


Figure 7-21. H_2O-saturated (solid) and H_2O-free (dashed) solidi (beginning of melting) for granodiorite (Robertson and Wyllie, 1971), gabbro (Lambert and Wyllie, 1972) and peridotite (H_2O-saturated: Kushiro *et al.*, 1968; dry: Hirschman, 2000).