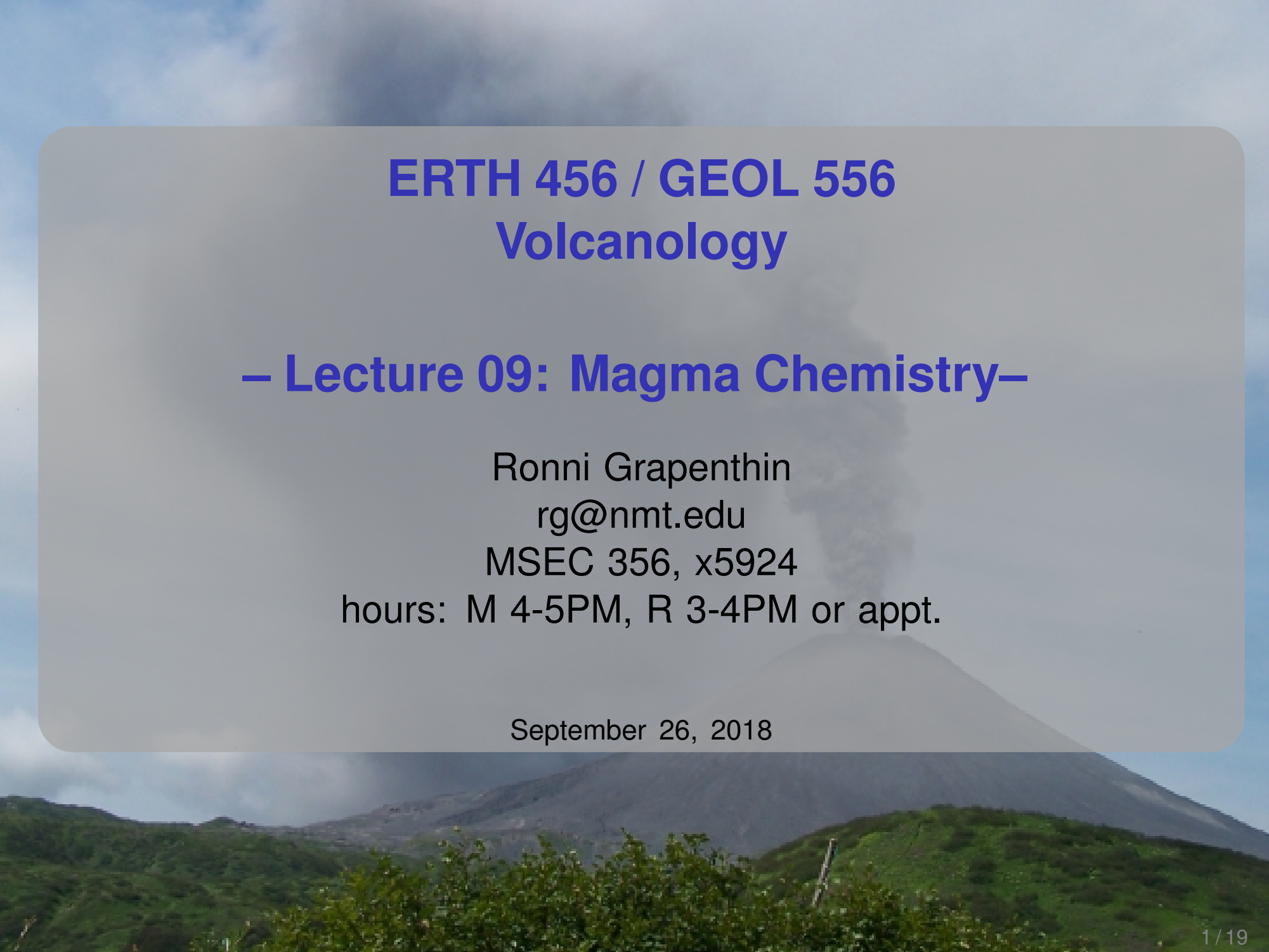

ERTH 456 / GEOL 556
Volcanology

– Lecture 09: Magma Chemistry–

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hours: M 4-5PM, R 3-4PM or appt.

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What is magma?

What is magma?

Mixture of:

- melt (liquid rock)
- crystals (solids)
- volatiles (gases)

Chemical Composition of Magma

- Major elements >1 wt% of rock
- Minor elements between 1-0.1 wt% of rock
- Trace elements <0.1 wt%

Major/Minor Elements in Magma

- Oxygen (O)
- Silicon (Si)
- Aluminum (Al)
- Calcium (Ca), Potassium (K), Sodium (Na), Iron (Fe), Titanium (Ti), Magnesium (Mg)

- Hydrogen (H), Sulfur(S), Chloride (Cl), Fluorine (F)

Charges in Magma

- Elements exist as electrically charged ions in magma
- most as positively charged cations with charges from +1 . . . +4
- Oxygen negatively charged anion -2
- Having both cations and anions results in molecule formation (electrically neutral, oxides)

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Examples:

- Silicon: +4 charge, bonds with 2 oxygens: SiO_2
- Magnesium: +2 charge, bonds with 1 oxygen: MgO
- Aluminum: +3 charge, 2 Al bond with 3 O: Al_2O_3

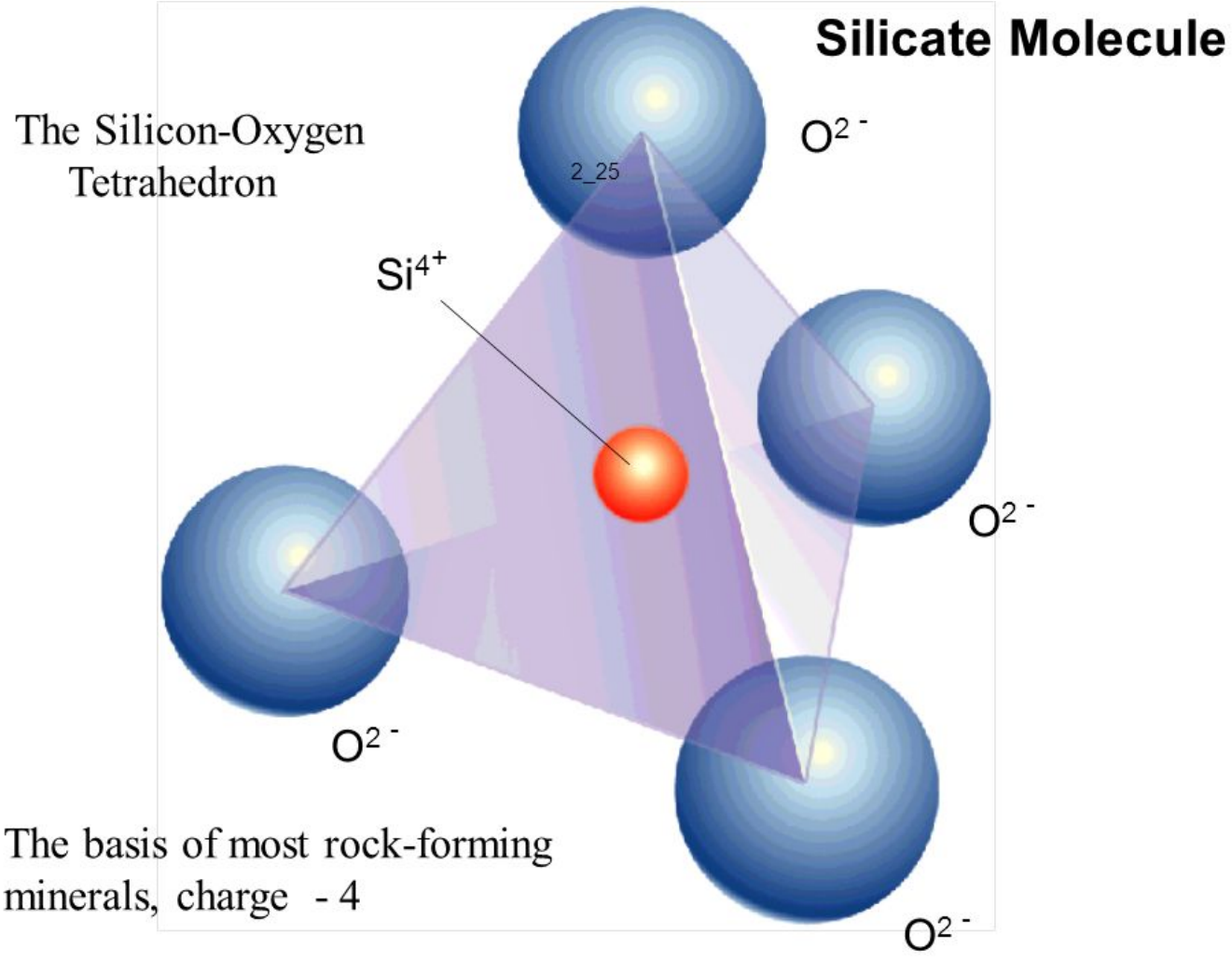
Example Compositions

Compound	Rhyolite (wt%)	Basalt (wt%)
SiO_2	73.2	49.2
TiO_2	0.2	2.3
Al_2O_3	14.0	13.3
FeO	1.8	12.0
MgO	0.4	10.4
CaO	1.3	10.9
Na_2O	3.9	2.2
K_2O	4.1	0.5
P_2O_5	0.1	0.2

N. Dunbar

In melt . . . Silica Tetrahedron

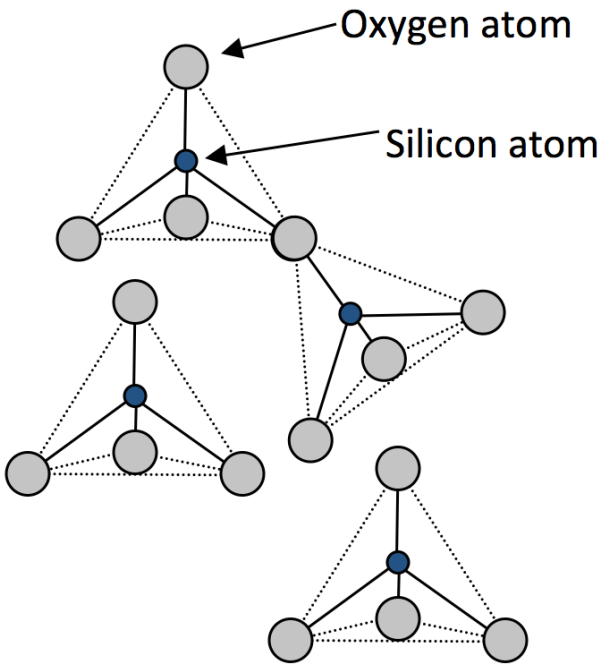
Silica as SiO_4 anion with -4 charge in tetrahedron form:



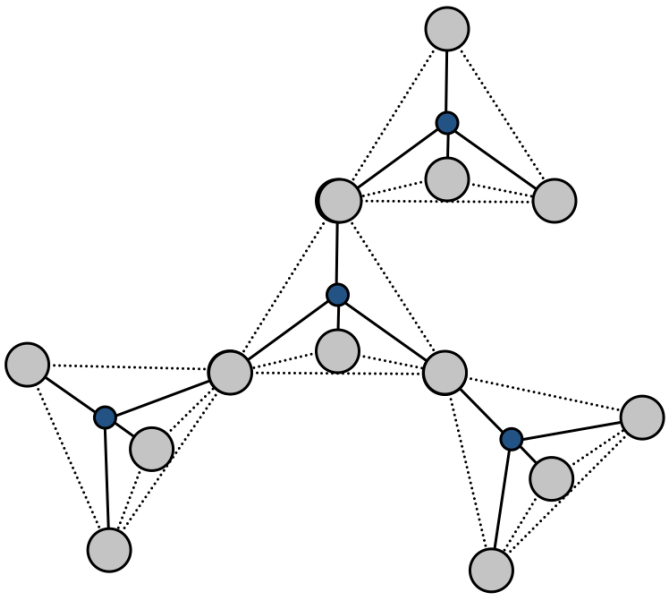
hydrasystemsllc.com

In melt . . . Polymerization

Basalt configuration

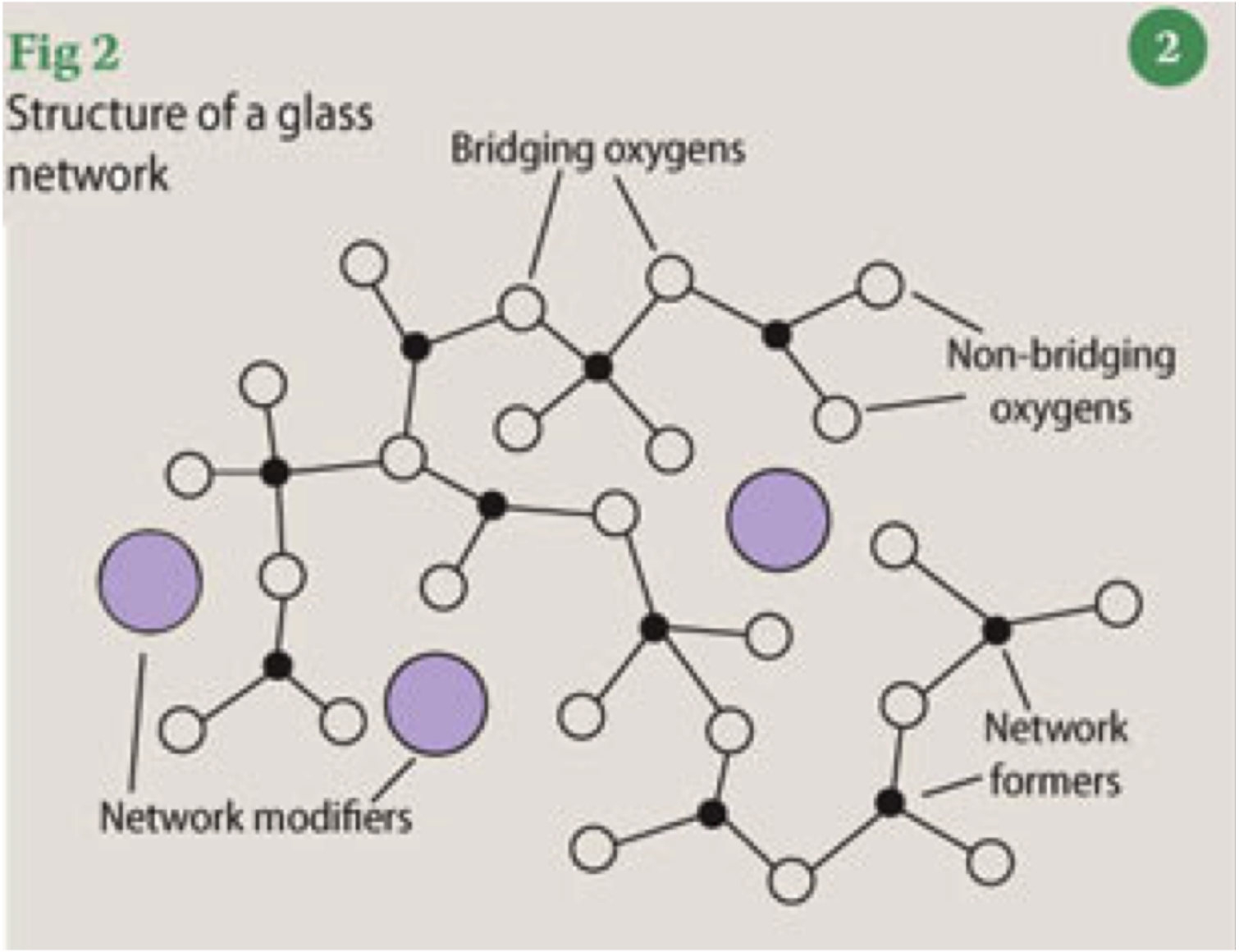


Rhyolite configuration



N. Dunbar

In melt . . . Polymerization

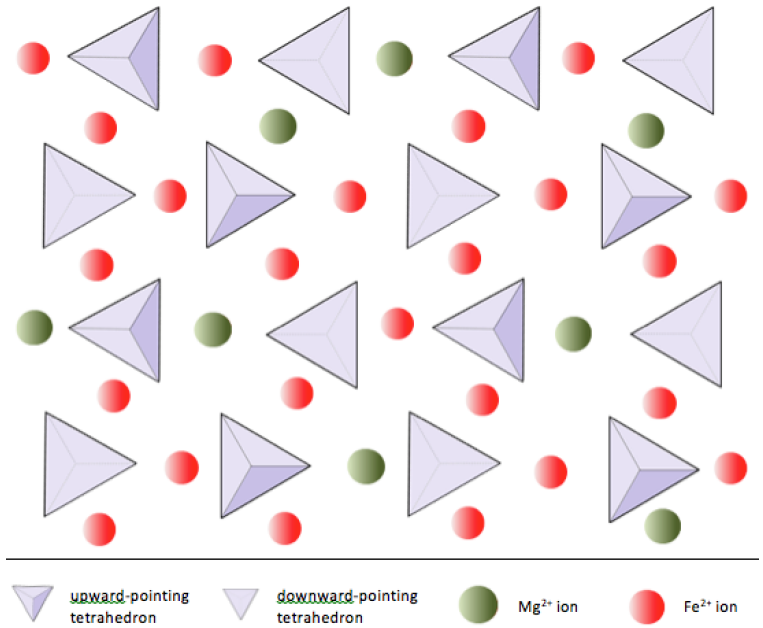


http://www.rsc.org/images/Coleman-fig2_tcm18-68268.jpg

In minerals . . . Olivine

The -4 charge of the Silicon Molecule must be balanced when forming minerals:

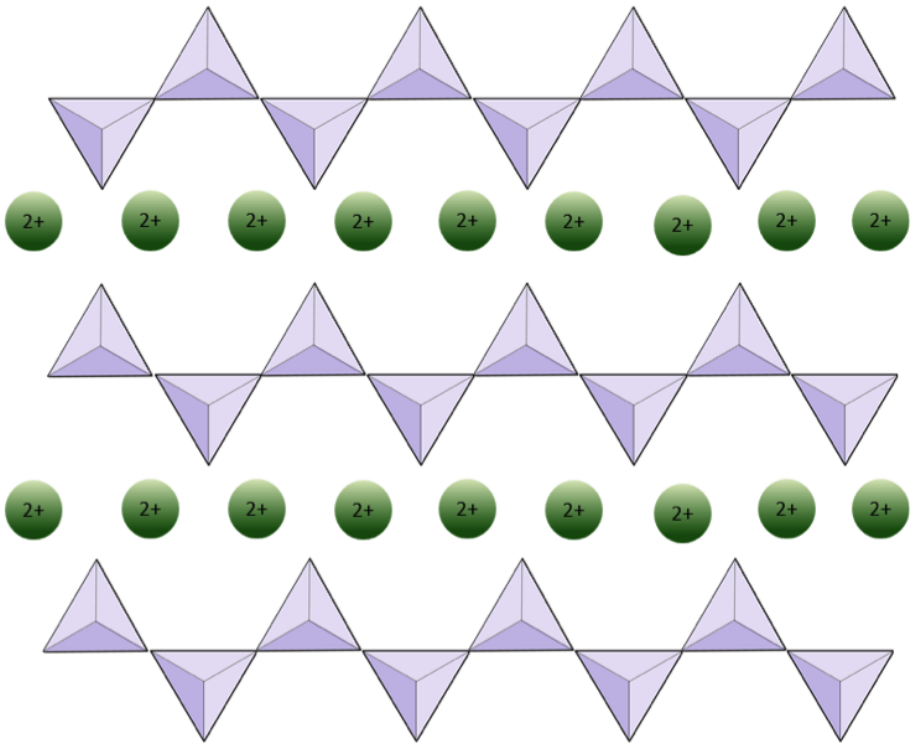
- Two +2 cations (Magnesium, Iron - close in radius) – Mg_2SiO_4, Fe_2SiO_4, or $(Mg,Fe)_2SiO_4$
- silica tetrahedra not bonded to each other (opposed to most silicate minerals)



3 Fe for each Mg, *https://opentextbc.ca/geology/chapter/2-4-silicate-minerals/*

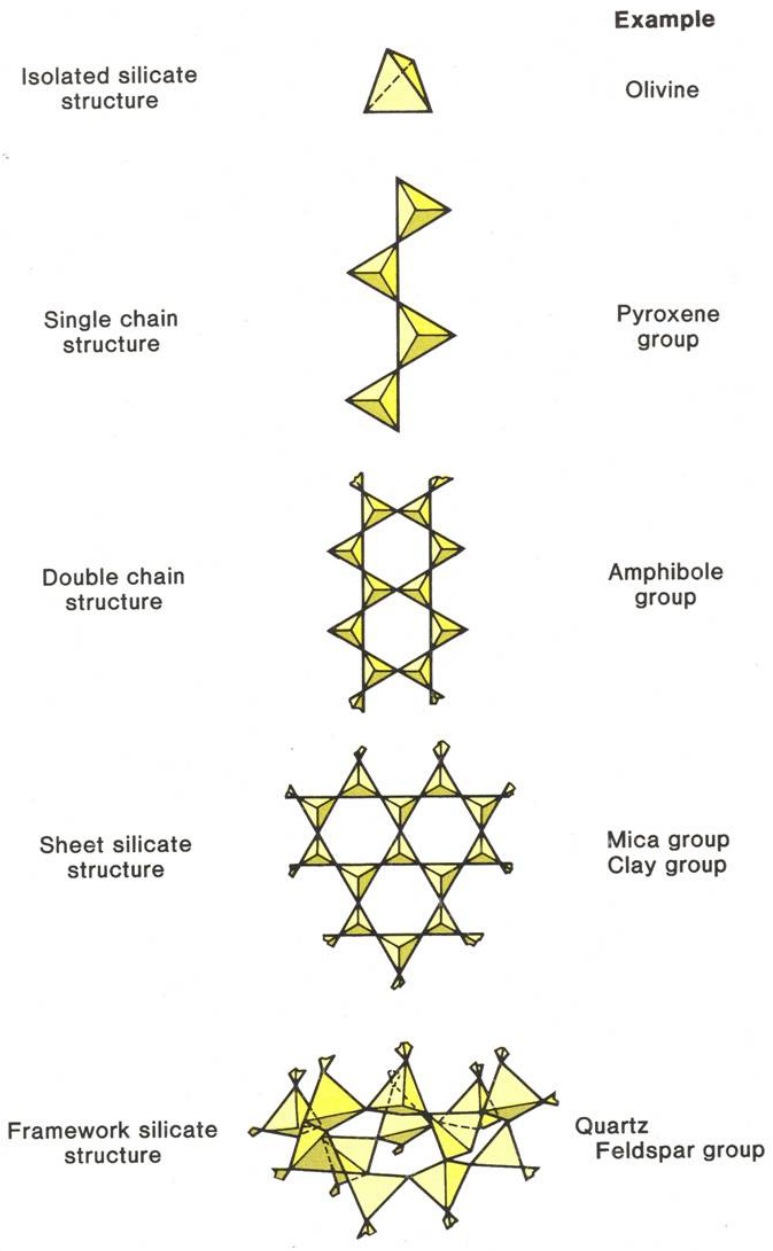
In minerals . . . Pyroxene

- Silica tetrahedra linked in single chains,
- one oxygen ion shared between neighboring tetrahedra
- fewer oxygen in the structure, lower oxygen to silicon ratio (3:1, instead of 4:1 in olivine)



e.g., $MgSiO_3$ *https://opentextbc.ca/geology/chapter/2-4-silicate-minerals/*

Silica Polymer Structures



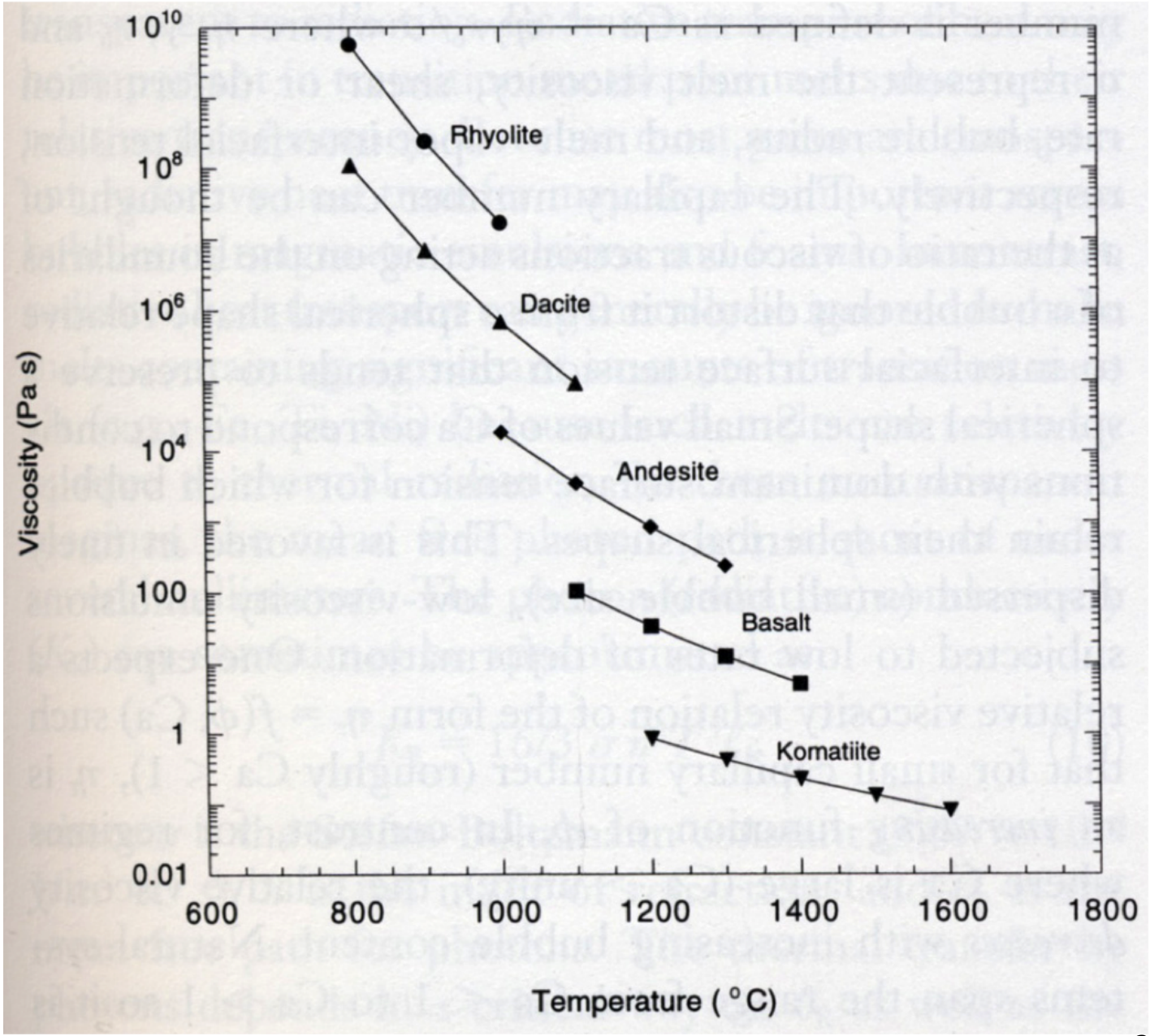
http://www.thisoldearth.net

Viscosity

Material	Viscosity (Pa s)	Wt% SiO_2	Temp. (°C)
Water	1.002×10^{-3}	–	20
ASE 30 motor oil	2×10^{-1}	–	20
Kimberlite	10^{-1}–1	30–35	~1000
Komatiite	10^{-1}–10	40–45	1400
Ketchup	$\sim 5 \times 10$	–	20
Basalt	10–10^2	45–52	1200
Peanut butter	$\sim 2.5 \times 10^2$	–	20
Crisco® shortening	2×10^3	–	20
Andesite	$\sim 3.5 \times 10^3$	~58–62	1200
Silly Putty®	$\sim 10^4$		
Tonalite 6% H_2O	$\sim 10^4$	65	950
Rhyolite	$\sim 10^5$	~73–77	1200
Granite 6% H_2O	$\sim 10^5$	75	750
Rhyolite	$\sim 10^8$	~73–77	800
Average mantle	10^{21}	–	–

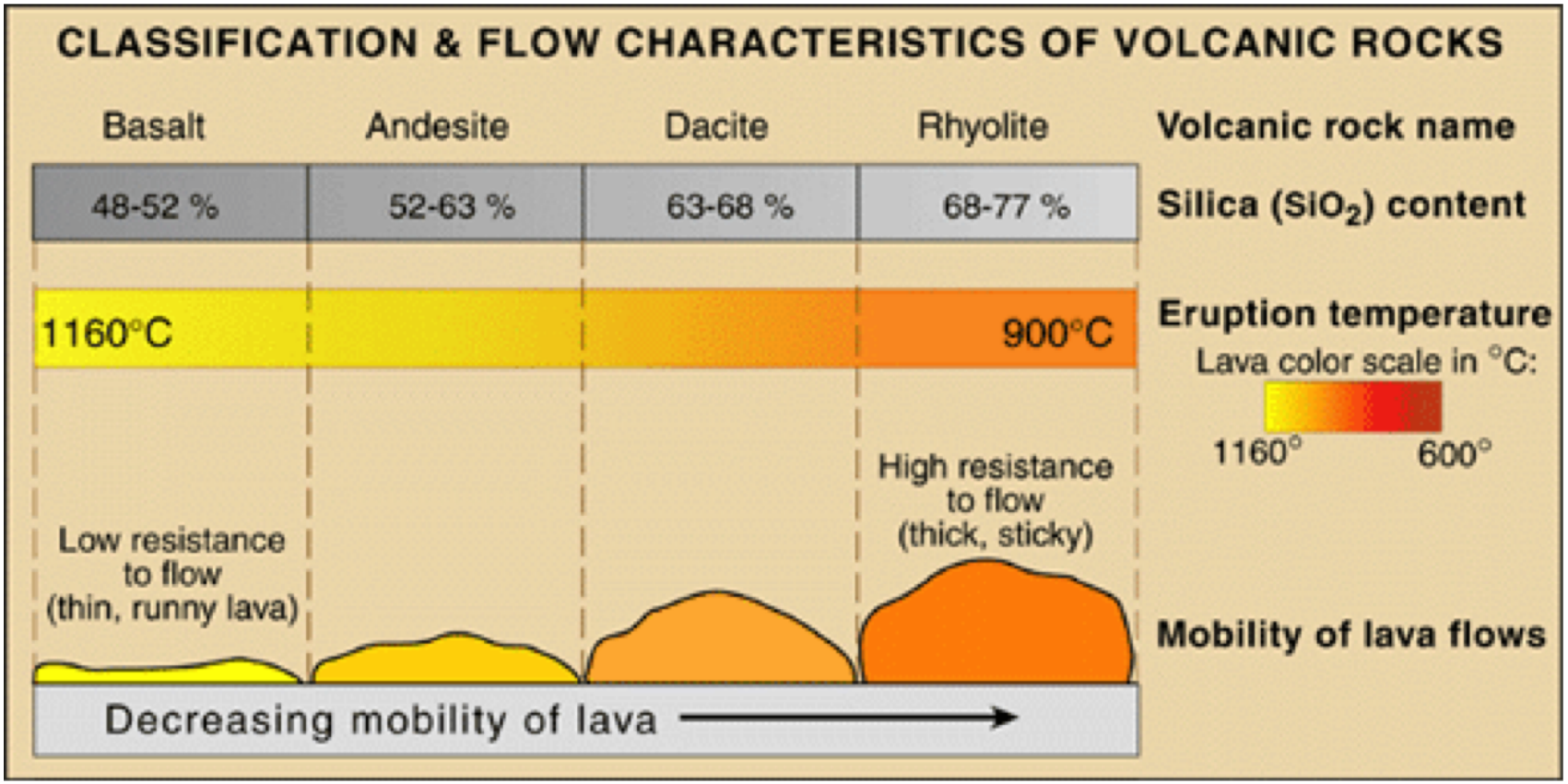
From Philpotts and Ague, Igneous and Metamorphic Petrology, 2009

Viscosity



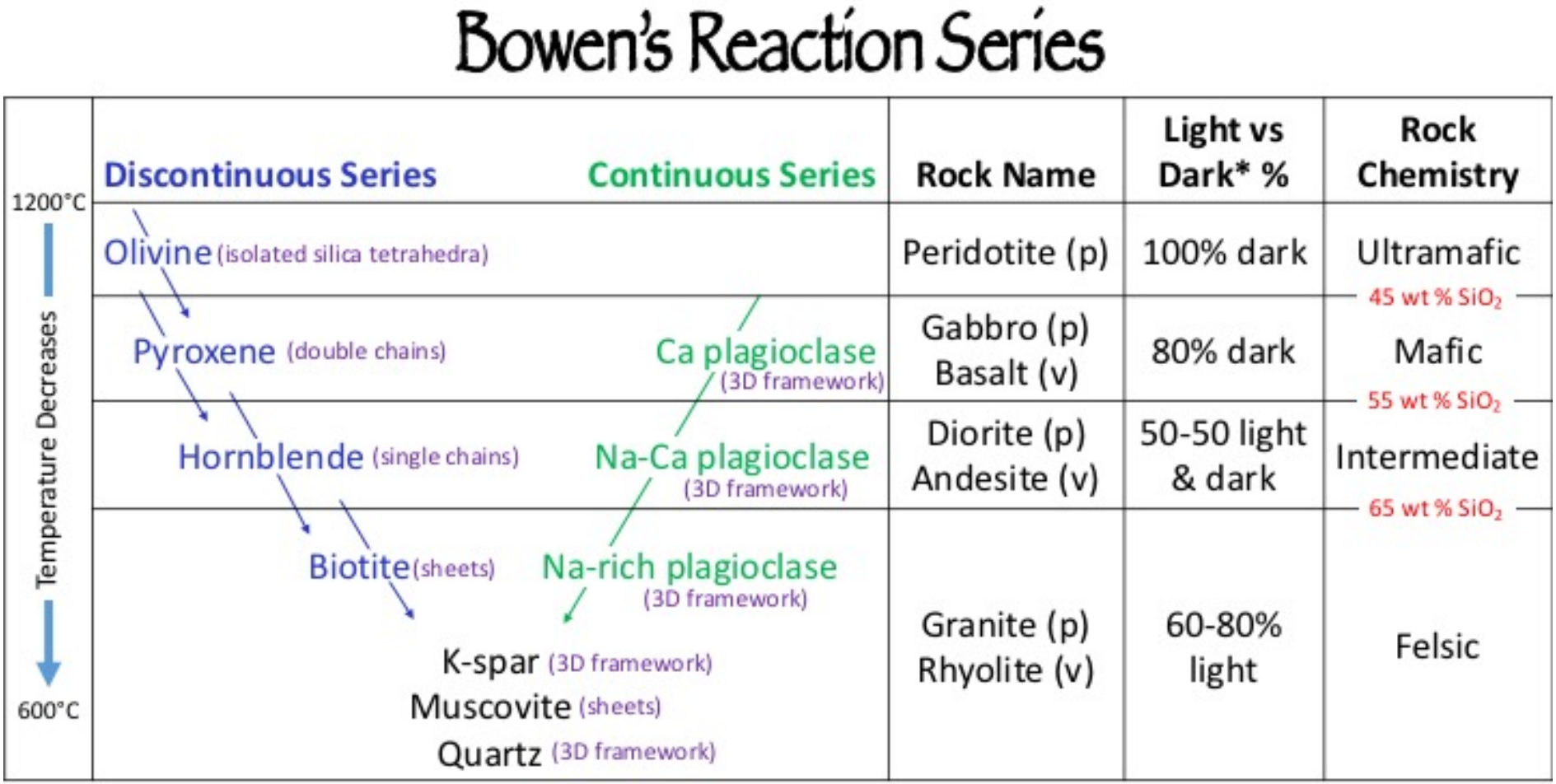
Spera et al., 2000

Flow Characteristics



https://www.e-education.psu.edu/geosc30/node/720

Classification - Fractional Crystallization - Bowen's Reaction Series



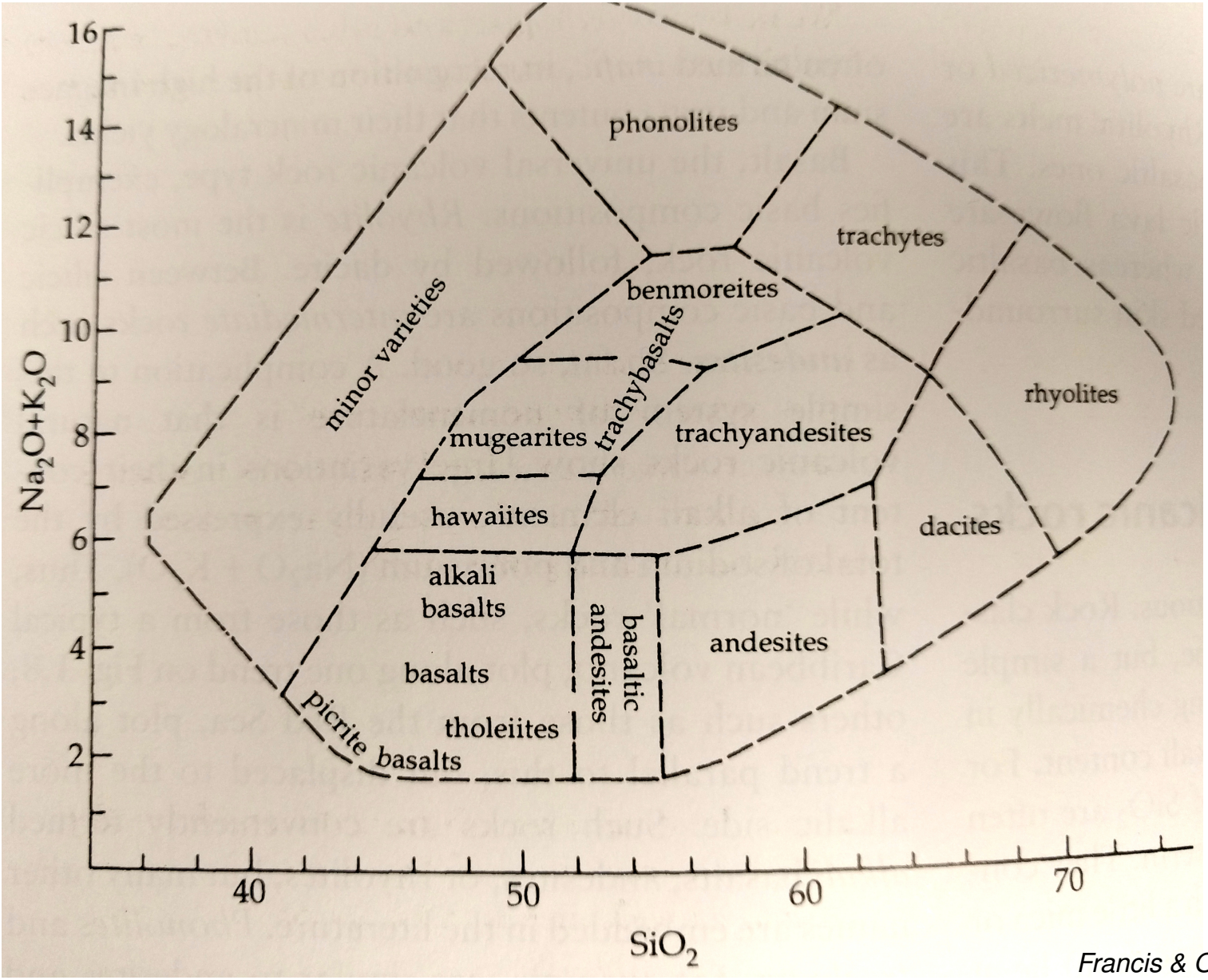
*Light minerals refer to nonferromagnian silicates (do not contain Fe or Mg) which are typically light in color
Dark minerals refer to ferromagnisian silicates (contain Fe and Mg) which are typically dark in color

http://geology1403.blogspot.com/2016/10/bowens-reaction-series-relationship.html

Classification - Texture

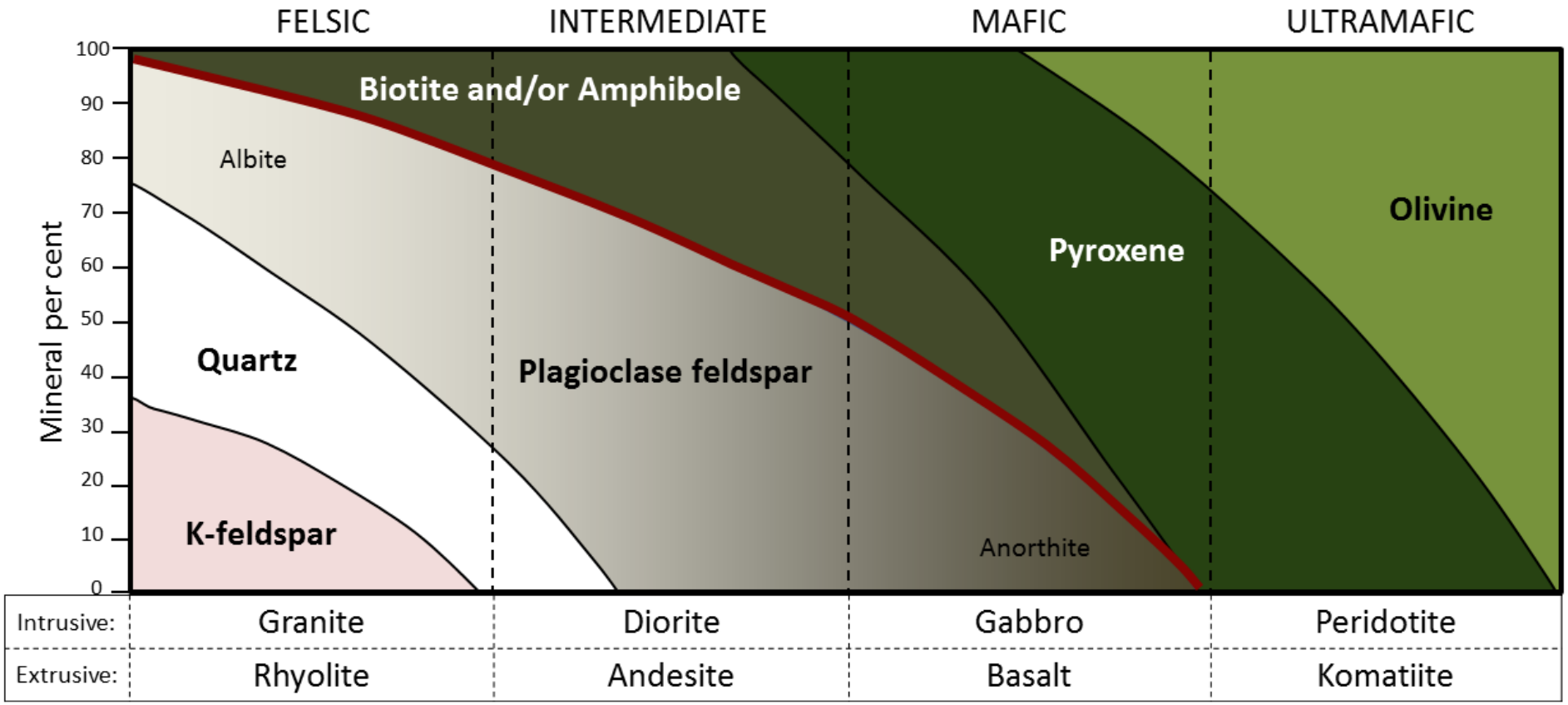
- glassy: no crystals found
- aphanitic: crystals too small to see by eye
- phaneritic: minerals are visible by eye
  - fine grained: $<$ 1 mm diameter
  - medium grained: 1-5 mm diameter
  - coarse grained: 5-50 mm diameter
  - very coarse grained: $>$ 50 mm diameter
- porphyritic: bimodal grain size distribution
- pyroclastic: amalgamated igneous fragments

Classification - Composition



Francis & Oppenheimer

Classification - Simplified Composition



https://opentextbc.ca/geology/chapter/3-4-classification-of-igneous-rocks/