GY303 Igneous & Metamorphic Petrology

Rock Classification Systems
Igneous Rock Classification Systems

- Mineral content and proportions (mineral modes)
- Rock geochemistry
- Texture
- Tectonic environment
Subdivisions of Igneous Rocks

- Volcanic: form at or near the earth’s surface
- Hypabysal: intrude at a depth less than 1 km
- Plutonic: intrude at a depth greater or equal to 1 km
- Extrusive: lava flows or ash flows/falls that are deposited on the surface
- Intrusive: intrude the lithosphere without penetrating to the earth’s surface
Mineralogical Classifications

- Percent and type of feldspar
- Presence or absence of quartz, feldspathoids or olivine
- Percentage and type of ferromagnesian minerals (i.e. felsic, mafic, etc.)
- Grain size and texture of rock (aphanitic, phaneritic, porphyrytic, etc.)
Mineralogical Classification Diagrams: Felsic

- IUGS Felsic Ternary diagram with 3 most common minerals at apices
- Accessory minerals >= 10% modify the base name
- Extrusive equivalents in parentheses
Mineralogical Classification Diagrams: Mafic

- Minerals modes must be recalculated to ternary percentages

Mode
40% Pl, 20% Pyx, 20%
Ol, 10% Mt, 10%
Sphene

P=40/80 x 100= 50%
Pyx=20/80 x 100=25%
Ol=20/80 x 100= 25%
Special Compositional & Textural Terms

- **Diabase**: hypabyssal mafic rock usually occurring in dikes and/or sills
- **Trondhjemite**: felsic igneous rock that is dominantly Na-plagioclase
- **Plagiogranite**: includes trondhjemite and quartz diorite
- **Plagisyenite**: equivalent to IUGS monzosyenite
- **Quartz Monzonite**: falls within the IUGS granite field. Used by North American geologists
- **Keratophyre**: Na trachyte in which albite or oligoclase dominate; associated with sea water alteration
- **Spillite**: basalt altered by sea water such that the Ca-plagioclase is replaced by Na-plagioclase
  
  \[ \text{Na}^+ + \text{Si}^{4+} \text{CaAl}_2\text{Si}_2\text{O}_8 = \text{Ca}^{2+} + \text{Al}^{3+} + \text{NaAlSi}_3\text{O}_8 \]
Special Compositional and Textural Terms Continued

- Lamprophyre: dark-colored (melanocratic) dike rock containing euhedral mafic phenocrysts (Ol ± Pyx ± Bi ± Hbl)
- Serpentinite: altered ultramafic rock found where sea water has reacted with mantle peridotite (producing actinolite ± tremolite)
- Komatiite: ultramafic lava flow, usually Precambrian in age and contains spinifex texture
- Carbonatite: carbonate magma believed to be generated in the mantle wedge above subduction zones; Kimberlites are a special type
- Pegmatite: a very coarse grained granite; generated by hydrothermal systems
- Aplite: a Q + Alkali Feldspar rock that has a equigranular texture with anhedral grains
- Obsidian: volcanic glass, felsic in composition
- Porphyry: contains > 50% phenocrysts by volume
Special Compositional & Textural Terms continued

- **Pumice**: frothy volcanic glass, usually has density less than water
- **Scoria**: extrusive volcanic rock that is composed of > 50% vesicles (void space)
- **Tuff**: fine grained, fragmented volcanic rock that results from the eruption of viscous magma; usually the major component of ash flows and ash falls
- **Volcanic breccia**: large angular fragments surrounded by an ash matrix that is produced during the explosive eruption of a volcano
Chemical Classifications of Igneous Rocks

- SiO$_2$ (silica) percentage by weight
- Note that SiO$_2$ is considered here as a chemical component- not the mineral phase quartz

<table>
<thead>
<tr>
<th>%SiO$_2$</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;66%</td>
<td>Felsic</td>
</tr>
<tr>
<td>66-52%</td>
<td>Intermediate</td>
</tr>
<tr>
<td>52-45%</td>
<td>Mafic</td>
</tr>
<tr>
<td>&lt;45%</td>
<td>Ultramafic</td>
</tr>
</tbody>
</table>
Chemical Classification of Igneous Rocks cont.

- C.I.P.W Normative mineralogy: a theoretical mineralogy calculated from a weight % oxides chemical analysis
- Derived from publication in 1906 by Cross, Iddings, Pierce and Washington (USGS)
- Intended to allow comparison of fine-grained extrusive rock to intrusive igneous rocks.
- Assumes that the magma is “dry”, and that the Fe2+/Fe3+ is the same in all ferromagnesian minerals
Limitations of Normative Mineralogy Calculations

• Does not calculate hydrous mineral phases that may be a significant proportion of actual rock (i.e. mica, amphibole, epidote, etc.)
• Assumes a constant Fe/Mg ratio, for all minerals
• Assumes a Fe2+/Fe3+ ratio because analytical instruments typically do not detect differences in Fe oxidation state
Aluminum Saturation

- Classification is indexed to the degree of Al2O3 abundance as indicated by normative mineralogy.
Alkali-Lime Index

- Weight percent oxide plot of SiO$_2$ versus Na$_2$O+K$_2$O (Alkalis) on one y axis, and CaO (Lime) on another y axis
Igneous Rock Associations: Mafic & Ultramafic

• Mafic & Ultramafic Associations
  – Ophiolites: peridotite, serpentinite, gabbro, diabase dikes, pillow basalt, spillite
  – Continental Rift: Flood alkali basalts, basalt-rhyolite flows (bimodal volcanics), syenite, diabase dikes
  – Precambrian shield: Gabbroic layered intrusions (lopoliths), anorthosite
Igneous Rock Associations: Intermediate & Felsic

- Volcanic Arc: andesite – dacite – rhyolite sequences from trench to arc (i.e. > SiO2 content with distance from trench) (Calc-Alkaline series)
- High viscosity magma: pyroclastic eruptive style
- Batholithic magmatic arc: diorite – granodiorite – monzonite – granite sequence with distance from trench (Calc-Alkaline series)
- Base of overriding plate: anorthosites
Igneous Rock Associations: Alkaline Igneous Rocks

• Continental Rift: Syenite – Nepheline Syenite – Carbonatite intrusives; alkali basalt; trachyte – phonolite volcanics; diabase dikes

• Continental Hot Spots: Trachyte – Phonolite volcanics; Alkali basalt flood basalts

• Oceanic Hot Spots: Alkali basalt
Exam Summary

• Know how to work through CIPW norm calculation worksheet with rules
• Know rock associations with tectonic environments
• Know definitions of classification terms (i.e. Trodhjemite, porphyry, etc.)
• Be able to discuss SiO2/Al2O3 saturation relative to CIPW norm calculations
• Be able to plot from point counts the composition of an igneous rock on an IUGS Ternary diagram