Quiz 3 – Tuesday Feb 9th 3:35 to 4:00 pm

- *UNDERSTAND ROCKS AND MINERALS*
  - *Minerals and Crystals and how they effect engineering properties*
  - *Rock and Mineral Classification Systems*
  - *Genesis of Igneous, Sedimentary, and Metamorphic Rocks, and how this effects engineering properties*
- *UNDERSTANDING GLACIERS*
  - *Supraglacial Deposits and their properties: (Moraines, Outwash Sand/Gravel, Kames, Kettles)*
  - *Subglacial Deposits and their properties (Eskers, Drumlins, Lodgement Till)*
  - *Stratified and Unstratified Deposits*
  - *Key Puget Sound Glacial Periods and their timing (Vashon, Olympia)*
  - *Key Continental Glaciations (Laurentide)*
- *RESOURCES FOR STUDYING*
  - *Waltham Chapters on Igneous, Sedimentary, and Metamorphic Rocks*
  - *Wikipedia pages for rock classification and glacial geology (links on web site)*
  - *Quiz 3 Notes (below)*
  - *Course notes (on our website), particularly:*
    - *Minerals Lecture 2009*
    - *Rock and Mineral Lecture 2009*
    - *Rock and Mineral Classification Spreadsheet*
    - *Derek Booth Puget Geology 2009*
    - *Puget Sound Glacial Geology*

CEE 437 Quiz 3 Study Guide

Minerals: Lecture 7, Waltham 2, 4, 5, 29 – for quick look at problems of soluble minerals)

General notes: On the quiz you will given terms and asked to define them or give their significance. The goal is recognition more than memorization. Terms to know are given in **bold**.

Format will be same as past two quizzes – some short concept questions, a table of 10 vocabulary items and 2-3 sketch and describe questions.

There will be one stereonet question where you will be given a net with some information and asked to make some statement about it.

Definition of Mineral

Define **mineral** and give examples of geologic materials that are not minerals.

How do **anisotropic** crystal properties influence microcrack formation? How are crystals anisotropic and how can this anisotropy affect rock properties? (see appendix)

Silicate Minerals (Lecture 7)

What is the **silicon tetrahedron**? What are some the crystal structures of silicate rocks?

Key silicate groups –

- **Ferromagnesians** – Where Fe and Mg go (olivine: isolated tetrahedra, pyroxene: single chain and amphibole:double chain)
  - How do Fe and Mg content correlate with melting temperature (positive high), crystal structure (less more organized), and weatherability (positive high)?
- **Sheet silicates – mica and clay (really important group)**
  - Know the basic structure of sheet silicates including tetrahedral layer and octahedral layer
  - Why are they important for engineering?
  - What are the basic layer structures of sheet silicates?
  - How do micas influence properties of metamorphic rocks?
  - Recognize clay as a weathering product of many other silicates
- **Framework silicate** – all tetrahedra corners bond with other tetrahedra
  - **Feldspars-** Framework with openings for cations
  - Major component of igneous and high grade metamorphic rocks
  - Plagioclase – Ca, Na feldspar , Orthoclase – K Feldpar
  - **Quartz -** Tight Framework, pure SiO_2
  - Why is it abundant in sediments? Why is it a weathering "survivor"?

What is **differentiation** (a process natural process that sorts materials geographically) and what are some its processes in the rock cycle?

Igneous crystallization and melting (see appendix)–

gravity settling - high temperature minerals (high in Fe, Mg and low in Si) freeze and settle leaving a melt that is enriched in Si and relatively depleted in Fe and Mg.

Preferential weathering

Weathering preferentially breaks down higher FgMg minerals, and converts much of the rest to Oxides (iron oxides, rust), and clays

Main products of weathering are clays and quartz

Sedimentary processes

(Not on quiz but covered later) Sedimentary processes transport materials further based on grain size – sands and gravels stay closer to sediment sources, clays transport much further to quieter water (eg lakes and further offshore in the sea). This does come up here with respect to the major glacial units of a glacial advance.

Other Important Minerals

Carbonates –

Calcite ($CaCO_3$) also **Dolomite** (Mg substitutes for 50:50 for Ca)

Main minerals of limestone and rock dolomite

Sedimentary rock mainly derived from reefs and biologic processes in tropical areas

Important component in groundwater – common fracture filling and sedimentary rock cement

SOLUBLE! Readily dissolves and re-precipitates – Formation of caves and sinkholes

Halides, Sulfates – **Halite** (NaCl), **Gypsum/Anhydrite** ($CaSO_4$)

Formed from evaporation of seawater. Even more soluble than carbonates – major sinkhole and collapse problems when near surface dissolving in groundwater

Gypsum-Anhydrite transition – at depth normally anhydrous – hydrates near surface with serious volumetric changes

Sulfides – key ore minerals, **Pyrite** (FeS_2) Unstable at surface, source of acid drainage

Rock Classification and properties

Igenous

Classification based on composition and crystal size (implied crystallization at depth or on surface)

Mafic vs Felsic (Basic vs Acidic)

Mafic/Basic

High Fe Mg, Low Si , oceanic crust, lavas low viscosity (flow well and spread, shield volcanoes)

Basalt as extrusive, gabbro as intrusive

Felsic/Acidic

low Fe Mg, Hi Si, continental crust, lavas viscous, gassy and explosive, composite volcanoes

Granite as intrusive, **rhyolite** as extrusive, more commonly extrusives are **pyroclastic** (Greek for fire, broken stuff),eg **tuff** for ash fall, also **pumice**

Ultramafic

Mantle (subcrustal) rock – types peridotite, usually altered to serpentine weak,anistropic rock with engineering issues – state rock of California

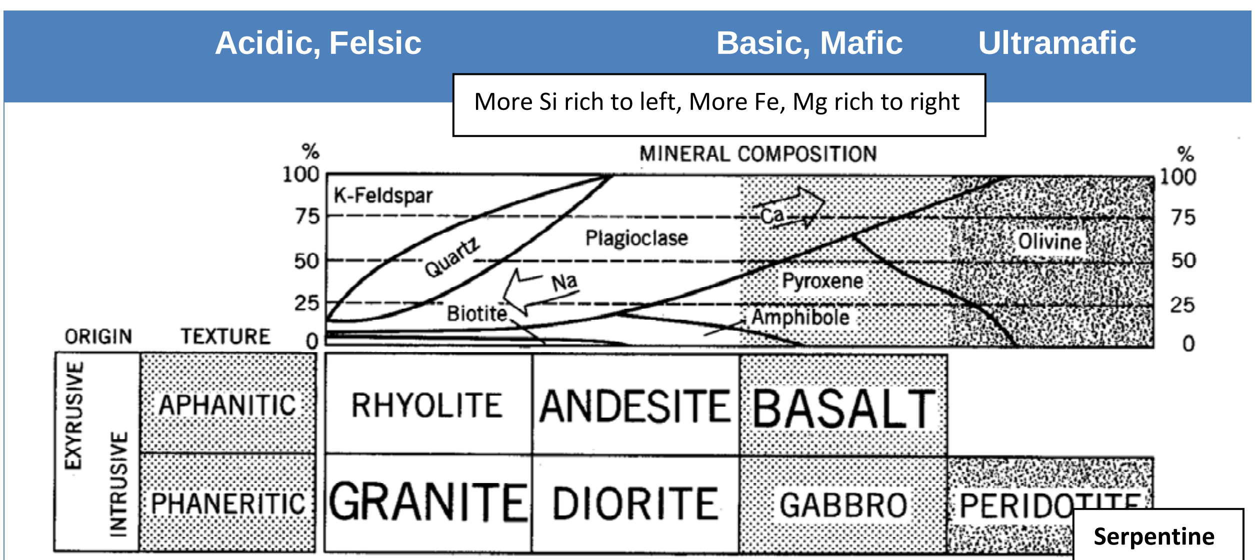


Figure 6.6 Mineral composition of basic, intermediate, and acidic rocks; the relative line weights indicate the relative abundances of the different rock types in the crust. (From U.S. Geological Survey.)

Rock names on this chart considered **bold**

Some intrusive igneous structures (Waltham page 4):

Dikes – crosscutting intrusion along a fracture (Dyke is an English spelling)

Sills – intrusions that follow bedding planes or other stratification

Batholiths, Plutons – Bodies ofplutonic igneous rock (matter of scale – batholiths are larger but terms are largely interchangeable for our purposes)

Contrast the strength, porosity , and hydraulic conductivity of basalt flow top, granite, ash fall tuff, serpentine (actually pretty low permeability but weak and anisotropic).

Sedimentary Rocks

Rocks formed from sediments that are transported by

Classification based on sediment type and grain size

Types:

Siliciclastic (broken up silicate materials) classified by grain size

Argillaceous (argile, Latin root for clay)

Clays → **Shale** (implies easy breaking on bedding), **Mudstone**, **Claystone**

Arenaceous (Latin for sand)

Silt → **siltstone**

Sand → **sandstone**

Rudaceous (Latin for gravel?)

Gravel → **conglomerat**e (if rounded), **breccia** if angular (breccias are also important as rocks in faults)

IMPORTANT POINT – Sediments turn into sedimentary rock mainly by cementation. The properties can vary widely depending on the type and extent of the process.

Carbonate (limestone, dolomite, made of broken up pieces of carbonate stuff mainly from reefs and other biogenic tropical places)

Also classified but size but we won't go into the details

Evaporite – see mineral descriptions above

Other

Organics, Coal, peat

Non crystalline silica – chert (formed from deep sea accumulations of silica shells of micro-organisms or by chemical replacement from groundwater circulation in other rocks, e.g. petrified wood)

Metamorphic Rocks (Waltham 5)

Rock that is formed by recrystallization under temperature and pressure without melting. **Regional metamorphism** is due to burial, **contact metamorphism** is due to local high temperature near an igneous melt)

Type depends on the source material and grade (how high the pressure and temperature).

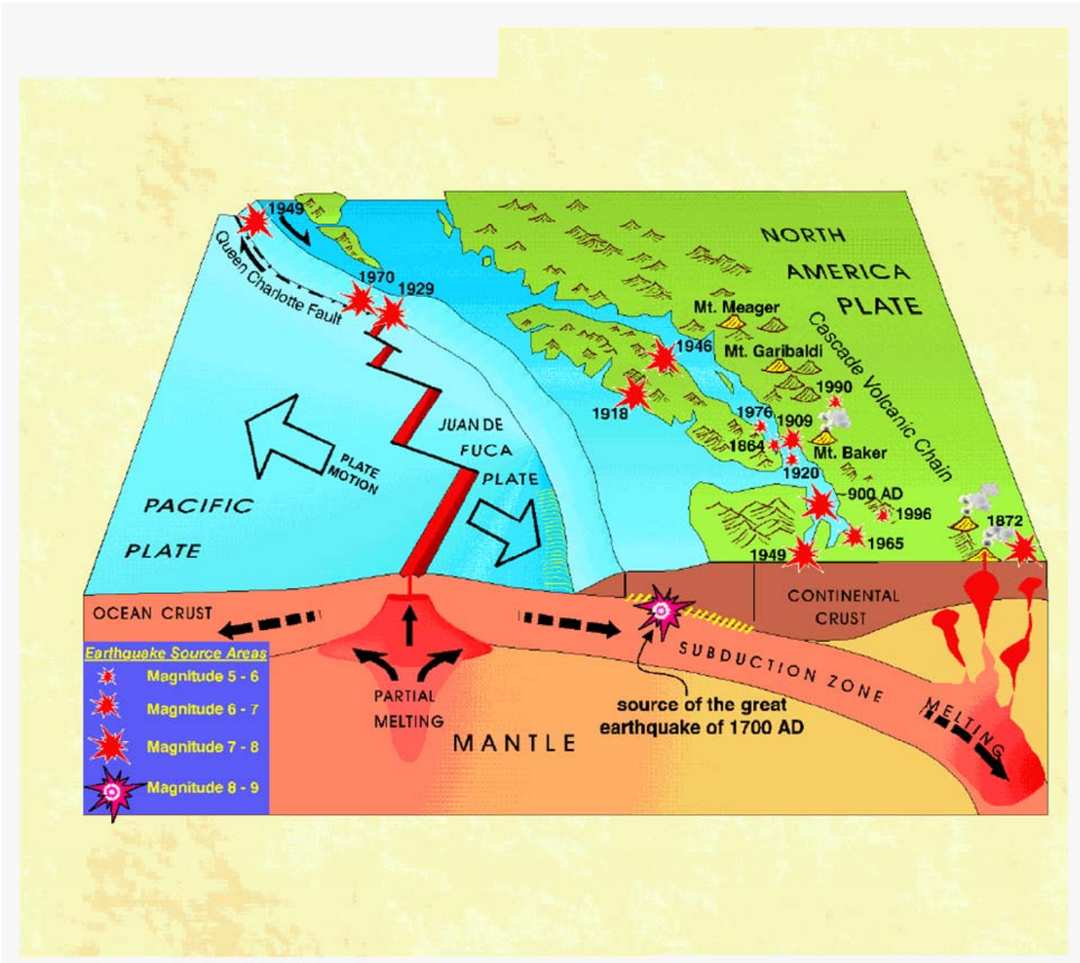
Clay rock and weathered volcanics – clays recrystallize to micas, by increasing grade:

Slate – dull, black, no visible crystals
Phyllite – satin sheen from micas, no visible crystals
Schist – visible mica crystals (biotite – black FeMg rich mica, muscovite, white mica)
Gneiss – recrystallization to quartz, feldspar, and mica – granite-like composition but strongly banded

IMPORTANT: Foliation is the preferred alignment of crystal grown under pressure. Foliation is a major source of rock property anisotropy.

Relationships of Rocks to Plate Tectonics (Waltham 9)

On a diagram like the one below be prepared to show where sediments, mafic rocks, ultramafic rocks, granites, composite volcanoes might be expected.



Glaciers and Glaciation

Define: **Supraglacial vs Subglacial** (sediments that form above versus those that form underneath the glacial load)

General Concepts –

What was the general period of glaciation in the geologic time scale – when did it end?

How do glacial deposits influence geological materials and their distribution in the Puget Sound area?

Contrast the properties of a subglacial (lodgement)**till** from the till that might be found in a moraine

> **Moraine** – deposit formed at the sides and at the termination of a glacier where major melting is taking place – hint – Subglacial till has a wide range of grain sizes from clay to large boulders and highly compacted; moraine material is well washed of fines and not compacted

What is the basic glacial stratigraphy (layer sequence) a single advance using the last advance (Vachon) as an example. How do these materials influence slope stability? Know the sequence of Vachon State (glacial advance) unit – from oldest to youngest and bottom to top:

> **Lawton Clay** – lake sediment, far in advance of glacier,
>
> **Esperance Sand** – outwash sand deposited from melt water in front of glacier
>
> **Vashon Till** – mix of wide range of grain sizes – well compacted
>
> Note: These are common materials in bluffs all around Puget Sound, landslides commonly focus on Esperance – Lawton contact

Define:

> **Esker** – gravel deposit formed in subglacial channel with form of a stream bed (though having raised topography)
>
> **Drumlin** – streamlined landforms formed under glacier
>
> **Kam**e- gravel deposit in form of mound formed below a crack or crevasse in glacier

Contrast **alpine** and **continental glaciations,** what occurred in the Puget Sound area (both)

Appendix

Differentiation through Melting Point Relationships -

In igneous rocks, what is the relationship of SiO_2 content to melting point and degree of Si tetrahedron bonding? If you start with a mantle/oceanic crust (high Fe, Mg, Ca, low Si, K, Na) and start to melt it, crystals with the high Fe, Mg start to settle out (they are denser than the liquid). The liquid becomes enriched in Si and the components that are not being removed (this see rocks that reflect this on the field trip). The minerals will be olivine, pyroxene and Ca-feldspar making rocks like basalt and gabbro and (for very high FeMg, peridotite).

This is happening at spreading centers/divergent boundaries in the ocean. At convergent plate boundaries like here in Washington, the ocean crust and accumulated sediments are being taken to depth. They heat up, their melting points are lowered by water, and they start to melt. The low melting components melt first with a liquid rich in Si, Na, K and low in Fe Mg. This is erupted in volcanoes or freezes at depth to form granitic plutons and batholiths.

How Mineral Properties Affect Microcracking

(1) In a rock with an aggregate of crystals, either different minerals or the same mineral with crystals in different orientations, there will be elastic "mis-matches" along the boundaries between the grains/crystals. If deformed or heated, each crystal expands and contracts different amounts in different directions creating stresses that cause cracking (mostly Mode I). The microcracking of rock profoundly affects it as a materials (why it is so much weaker in tension than compression).

(2) If there is preferred alignment of orientation of crystals that have very anisotropic properties, they will impart an overall anisotropy to the rock properties. The most extreme examples of this are metamorphic rocks derived from clays – the slate-phyllite-schist series (from lower to higher degree of metamorphism). Here the preferred alignment of micas makes the rock very anisotropic.