GG101 Final Exam Review

- Final Exam info:
  - **Tuesday, December 15th** 12-2pm
  - 100 multiple choice/true-false questions
  - Covers material from all lectures (comprehensive)
  - 1 hand-written page “cheat sheet” allowed (double-sided ok)
- Things to help you study:
  1. Lecture notes (posted on web)
  2. Old midterms and practice exams (posted on web)
  3. Homework assignment questions
  4. Assigned reading
Class Website

http://www.soest.hawaii.edu/GG/FACULTY/smithkonter/GG_101/
Our Solar System Consists Of:

- 1 unordinary star
- 8 classical planets
- 5 dwarf planets
- 240+ known satellites (moons)
- Millions of comets and asteroids
- Countless particles; and interplanetary space

Earth, the Sun, and other objects in the Solar System originated at the same time from the same source and have evolved in varying ways since then.
Our Sun

• Solar core is site of **nuclear fusion**.

• H is converted to He, which has less mass.

• Mass differential is expelled as energy (light and heat).

• The Sun is getting “lighter” through time.

• The Sun has enough fuel to last another 4 to 5 billion years.
Terrestrial Planets

Terrestrial planets are small and rocky, with thin atmospheres, silicate & metallic shells.

Main components: O, Fe, Si, Mg, Ca, K, Na, Al
Gas Giant Planets

Gas Giant planets are massive with thick atmospheres.

Main components: He, H, CO$_2$, H$_2$O, N$_2$, NH$_3$, CH$_4$
Early Heat Within The Earth

Early Earth began to heat as the last collisions subsided

1. Initial heat from impacts (bombardment)
2. Collisions produced heat that was stored (rock good insulator)
3. Radioactivity
4. Gravitational contraction
Earth’s Core

- Iron mixed with nickel, oxygen – metallic
- 3500 km thick

- **Outer core**: liquid; convects heat & generates a magnetic field
- **Inner core**: solid; over 4,300°C
Earth’s Core & Magnetic Field

- Fluid motion of liquid iron in the outer core generates Earth’s magnetic field
Earth’s Mantle

- Made of solid rock: Silicate (silicon + oxygen)
- 2900 km thick
- Moves heat around through convection
- Mantle rock also deforms as a fluid

Like Silly Putty, behaves as a:
- Solid – over short time
- Fluid – over long time
Earth’s Crust

**Continental Crust** (~35 km thick)
- Formed early in Earth’s history
- Rocks less dense than mantle rocks
- Is essentially “floating” on the mantle

**Oceanic Crust** (~7 km thick)
- Is currently being formed
- Is denser than continental crust (more iron + magnesium)

Like floating ice extends deeply below water level
What is a Mineral?

Minerals are natural, inorganic, solid crystalline compounds with a definite (but variable) chemical composition.

- natural occurrence
- inorganic
- solid

- has a crystalline structure*
- has a definite chemical composition*
Olivine \((\text{Mg,Fe})_2\text{SiO}_4\)

Copper \((\text{Cu})\)

Ice \((\text{H}_2\text{O})\)

Halite \((\text{NaCl})\)

Salt

Pyrite \((\text{FeS}_2)\)

Fool’s Gold

Gypsum \((\text{CaSO}_4)-2(\text{H}_2\text{O})\)
Silicates (Si + O)

• Si & O are most common elements
• Fundamental unit: silicate tetrahedron (4-sided pyramid)
  • -1 Si + 4 O atoms

Most silicates are formed from cooling magma.

Under special conditions, rare silicates may crystallize

Garnet: high temp & pressure
Carbonates

- Contain carbonate anion \( (\text{CO}_3)^{-2} \)
- Form in waters saturated by calcium (oceans) and as a result of biological processes
- Examples: calcite \( \text{CaCO}_3 \) --> limestone

Calcite is calcium carbonate
limestone
Fundamental Rock Types

- **Igneous Rocks:** form when magma solidifies

- **Sedimentary Rocks:** form when sediment becomes cemented into solid rock

- **Metamorphic rocks:** form when heat, pressure, or hot water alter any preexisting rock
Types of Igneous Rocks

- **Extrusive** (volcanic) - forms when magma erupts & solidifies on the surface
- **Intrusive** (plutonic) - forms when magma solidifies within the crust
Extrusive Igneous Rocks

- **Lava:** fluid magma that flows from a crack or volcano onto Earth’s surface

- Magma cools quickly = less time for crystals to form

- Ex.: Basalt - common volcanic rock, ocean crust, few crystals
Igneous rocks are classified based on their composition and texture.

Composition: *assemblage* of minerals (Si vs. Mg)
Texture: *size and arrangement* of crystals (cooling history)
The Major 7 Types of Igneous Rocks

- **Felsic**
  - Volcanic or Extrusive (aphanitic)
    - Rhyolite
  - Plutonic or Intrusive (phaneritic)
    - Granite

- **Intermediate**
  - Andesite
  - Diorite

- **Mafic**
  - Basalt
  - Gabbro

Texture vs. Composition
Composition Types

- **Felsic**: Feldspar & Silica
  Granite (large grains), Rhyolite (small)

- **Mafic**: Magnesium & Iron (Fe)
  Gabbro (large), Basalt (small)

- **Ultramafic**: High Mg & Fe
  Peridotite (mantle material, rare)

- **Intermediate**: Andesite
Weathering

- Def.: processes that decompose rocks & convert them to loose gravel, sand, clay, & soil

- Three primary types:
  - Physical
  - Biological
  - Chemical

Arches Nat’l Park, Utah

Bryce Canyon Nat’l Park, Utah
Types of Physical Weathering

- Pressure-release fracturing
- Abrasion
- Freeze-Thaw (frost wedging)
- Hydraulic Action
- Growth of Salts
Sedimentary Rocks

- Generally, made from older rocks
- Make up only ~5% of Earth’s crust, but....
- Make up 75% of all rocks exposed at the surface
Why Study Sedimentary Rocks?

• Reflect physical and chemical characteristics of source environments

• Contain direct and indirect evidence of life

• Can be interpreted to recreate Earth history

• Source of “fossil fuels”
Sedimentary Rock Types

- **Clastic** – broken down rocks (clasts)
  Ex.: sandstone

- **Chemical** – directly precipitates out of water
  Ex.: rock salt

- **Biogenic** – remains of living organisms
  Ex.: limestone, chalk, coal
Types: Chemical Sedimentary Rocks

- rock salt
- rock gypsum
- limestone
- travertine
- micrite
- dolostone
- chert

**TABLE 8.4 Chemical Sedimentary Rocks**

<table>
<thead>
<tr>
<th>Rock</th>
<th>Texture</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chert</td>
<td>Crystalline</td>
<td>Microcrystalline silica</td>
</tr>
<tr>
<td>Dolostone</td>
<td>Crystalline</td>
<td>Dolomite</td>
</tr>
<tr>
<td>Limestone</td>
<td>Can be crystalline or</td>
<td>Calcite</td>
</tr>
<tr>
<td></td>
<td>microcrystalline</td>
<td></td>
</tr>
<tr>
<td>Micrite</td>
<td>Microcrystalline</td>
<td>Carbonate mud</td>
</tr>
<tr>
<td>Rock gypsum</td>
<td>Crystalline</td>
<td>Gypsum</td>
</tr>
<tr>
<td>Rock salt</td>
<td>Crystalline</td>
<td>Halite</td>
</tr>
<tr>
<td>Travertine</td>
<td>Microcrystalline</td>
<td>Calcite from saturated fluids</td>
</tr>
</tbody>
</table>
Types: Biogenic Sedimentary Rocks

- Lithification of “organic” (plants, etc.) material
- Ex.: Coal is formed from preserved plant material in swamps
Metamorphic Rocks

- Metamorphism: process of rising temperature & pressure, or changing chemical conditions, that transforms rocks & minerals

Metamorphism tells us a rock’s tectonic history.

Metamorphic Grade:

- **Slate**
- **Phyllite**
- **Schist**
- **Gneiss**

Low Grade → High Grade
Types of Metamorphism

- Contact
- Regional
- Hydrothermal

separate processes, but can happen @ same time
Contact Metamorphism

- when magma comes in contact with basement rock at shallow depth and heats it up
- magma also brings reactive fluids
Regional Metamorphism

- When major crustal movements build mountains and deform rocks
- Rocks deformed & heated at same time
Hydrothermal Metamorphism

• Heat and pressure release chemically active fluids from rocks.
• These fluids transport heat, ions dissolve in hot water
• Reactions promote recrystallization
Common Metamorphic Rocks

- Slates
- Phyllite
- Schists
- Gneisses
New seafloor is being created as the seafloor spreads.

The continents move apart as new seafloor expands the ocean basin.

The magnetic field is "frozen" in the newly-created seafloor.

Oceanic crust preserves a record of Earth’s magnetic polarity at the time the crust formed.
Ages of the Ocean Floor

- Seafloor ages vary from 0 to ~160 Ma with a distinctive pattern.
- Oldest seafloor is much younger than most of continental crust.

Ma = Million years ago

1 billion years = 1 Gyr
1 million years = 1 Myr
1 thousand years = 1 kyr
Ages of Continental Rocks

- Age of the Earth: 4.5 Gyr
- Oldest continent rocks: 3.8 Gyr
- Youngest continent rocks: 250 Myr
Three types of plate boundaries

- Divergent (move apart)
- Convergent (come together)
- Transform (move side by side)
Divergent Boundary

As two plates continue to move apart, the rock in the seafloor grows older as its distance from the rift zone increases.
Convergent Plate Boundaries

• Plates collide
• Subduction zones
• We observe:
  1) Trench
  2) Volcanoes
  3) Earthquakes

• Examples
  - Peru-Chilean Coast
  - Alaskan Coast
  - Sumatran Coast
Transform Plate Boundary

- Plates slide by
- Transform faults
- We observe:
  1) Offset surface features
  2) Earthquakes

- Examples
  - San Andreas Fault
  - North Anatolian Fault (Turkey)
Hot Spots

- sometimes marked by chain of islands
- less common than plate-boundary volcanoes
- different composition (deep source)
Three Common Types of Magma:

**BASALTIC**

Basaltic lava **flows** easily because of its low viscosity and low gas content.

The low viscosity is due to low silica content.

- **Aa** - rough, fragmented lava blocks called “clinker”
- **Pahoehoe** - smooth, shiny, and ropy surface
Three Common Types of Magma:

**ANDESITIC**

- Erupts explosively because it has **high gas content**
- It is viscous and therefore traps gas.
- High viscosity is related to **high silica content**

Mount St. Helens, 1980
Three Common Types of Magma:

RHYOLITIC

- Erupts catastrophically because it has high gas content.
- It is viscous and therefore traps gas, builds pressure and explosively erupts.
- High viscosity → high silica content
Shield Volcano

- Low silica, low gas magma originates in the mantle.
- Fluid, basaltic lava results in “Aa” and “Pahoehoe”.
- Low viscosity creates broad, gentle slopes.
- **Phreatomagmatic eruptions** occur when lava contacts water (rapid expansion of steam).
3 Types of Mountains

Volcanic Mountains:
Built by accumulation of volcanic materials

Fold and Thrust Belts:
Built by compression stresses

Fault Block Mountains:
Built by extensional stresses
Stress can be:

- Tensional (stretching)
- Compressive (shortening)
- Shear (side-to-side)
Major Types of Faults

Dip-Slip and Strike-Slip faults

(a) Normal fault

(b) Reverse fault

(c) Thrust fault

(d) Left lateral strike-slip fault

(e) Right lateral strike-slip fault

Dip-Slip Faults

Strike-Slip Faults
Fold and Thrust Mountains

- Collision of India with Eurasia caused compressive stresses.
- These stresses raised the Himalayas and Tibet.
Fault Block Mountains: Tensional Stresses
What Are Earthquakes?

Earthquakes result from slow buildup of elastic strain, and its sudden release – like bending a ruler until it breaks.

Elastic Rebound Theory
Two Types of Seismic Waves

1. **Body Waves**: travel through the body of the Earth (P & S)
   - Waves compress and pull rocks in the direction of movement,
   - Change the **volume & shape** of material

2. **Surface Waves**: travel along the outer layer of the crust (Love and Raleigh)
   - Ground rolls like a water wave
   - Waves travel slowly and cause the most damage.
Traveling S- and P-waves through the Earth.
Tsunamis are NOT tidal waves

Tsunamis are seismic sea waves caused by earthquakes, landslides, eruptions of island volcanoes.
How old is that rock?

- **Relative age**: order of events
  
  Relative dating tells us **what order** things happened, but not how many years ago they happened.

- **Absolute age**: age in years
Radioactive Half-Life

- Def.: time it takes for 1/2 of radioactive atoms in a sample to decay

- “Parent” decays to “daughter”
  (potassium-40) (argon-40)

- Potassium-40 half-life
  = 1.3 billion years
The Greenhouse Effect Determines Earth’s Heat Budget

The Greenhouse Effect

Some sunlight that hits the earth is reflected. Some becomes heat.

CO₂ and other gases in the atmosphere trap heat, keeping the earth warm.
Greenhouse Gases

Carbon Dioxide:  Most abundant, long-lived
Methane:        Powerful greenhouse gas, short-lived
CFCs:           Being phased out
Ozone:          Very short lived
Nitrous Oxide:  Increasing
The Ice Ages

- Caused by changes in **solar radiation**
- Changes in atmospheric carbon dioxide **were caused by** the temperature changes.
Earth’s atmospheric temperature has risen by about 0.9°C in the past 100 years.

- Atmospheric CO$_2$ is greater now than it ever has been in the past 800 yrs.
- Earth is warmer now than at any time in the past 1,300 years.
Global Sea Level Rise

![Graph showing global sea level rise with a linear trend line and a slope of 3.26 mm/yr.](image-url)
A glacier is a river of ice.

Glaciers can range in size from:
- **100s of m** (mountain glaciers)
- **100s of km** (continental ice sheets)

Most glaciers are 1000s to 100,000s of years old!
<table>
<thead>
<tr>
<th>Source</th>
<th>Total Water</th>
<th>Fresh Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceans</td>
<td>96.6%</td>
<td></td>
</tr>
<tr>
<td>Ice</td>
<td>1.7%</td>
<td>69.6%</td>
</tr>
<tr>
<td>Groundwater</td>
<td>1.7%</td>
<td>30.1% (more than half is salty)</td>
</tr>
<tr>
<td>Rivers &amp; Lakes</td>
<td>0.007%</td>
<td>0.27%</td>
</tr>
</tbody>
</table>
Groundwater is found where the crust is porous.
Groundwater flows in response to gravity and hydraulic pressure.

Velocity of flow ranges from m/day to cm/century.

- Depends on pressure gradient (slope of water table).
- Depends on permeability of the rocks.
Coastal processes are driven by:
wind, waves, tides, sea-level change, & currents

The coastal zone is a dynamic environment that is constantly changing
Lunar Tide

- Gravitational pull from the Moon
- Gravity and Earth’s rotation create two tides every day
# Five Recognized Oceans

Average ocean depth is 3800 m (about the length of Manoa Valley)

<table>
<thead>
<tr>
<th>Ocean</th>
<th>Area (km²)</th>
<th>Average Depth (m)</th>
<th>Greatest Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Ocean</td>
<td>166,240,977</td>
<td>4,637</td>
<td>Mariana Trench: 11,033 m deep</td>
</tr>
<tr>
<td>Atlantic Ocean</td>
<td>86,557,402</td>
<td>3,926</td>
<td>Puerto Rico Trench: 8,605 m deep</td>
</tr>
<tr>
<td>Indian Ocean</td>
<td>73,426,163</td>
<td>3,963</td>
<td>Java Trench: 7,725 m deep</td>
</tr>
<tr>
<td>Southern Ocean</td>
<td>20,327,000</td>
<td>4,000 to 5,000</td>
<td>Southern end of the South Sandwich Trench: 7,235 m deep</td>
</tr>
<tr>
<td>Arctic Ocean</td>
<td>13,224,479</td>
<td>1,204</td>
<td>Eurasia Basin: 5,450 m deep</td>
</tr>
</tbody>
</table>
Surface Currents

- Driven by prevailing winds
- The Coriolis Effect turns currents right in the north and left in the south
- Circulation forms 5 Gyres in the ocean basins
- The gyres circulate heat.
The Continental Margin

**Continental Shelf:** the flat, submerged edges of continents

**Continental Slope:** the sloping edges of continental shelf

**Continental Rise:** transition from continental to oceanic crust
Nuʻuanu landslide ~ 2 Million years ago

Big gap in flank, large “bumps” on the seafloor

Largest (Tuscaloosa) is multiple miles across, >> thousand ft tall

Debris stretches nearly 100 miles
Other landslides around the islands

17 large landslides in principal Hawai‘i region

Represents ~6 million yrs (= 1 every 350,000 yrs)

Two Kinds:

1. slumps (prolonged, progressive formation)

2. catastrophic debris avalanches

Debris avalanches are likely to produce huge tsunami locally, but Would tsunami be Pacific-wide?
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