How do oceans and continents differ?

The average ocean depth is 3000m.

If the Earth’s surface is 30% land and 70% ocean, why is there any land at all?

Why are there not just a few little islands?

Ocean crust is thin, dense, and young.

Continent crust is thick, light, and old.
Polymerization of Silica

- Each Si atom is surrounded by 4 oxygens.
- Polymerization is the degree to which the oxygens are shared with other Si atoms.
- Polymerization is the number of Si-O-Si bonds per tetrahedron.
  - Olivine has none: isolated SiO$_4$ groups
  - Pyroxene has 50% shared: SiO$_3$ chains
  - Mica has has 75% shared: Si$_2$O$_7$ sheets
  - Quartz and feldspar have 100% (Si,Al)O$_2$ framework.

MAGMA

- Magma is the term for any molten silicate material, whether below the surface or on top.
- Volcanic rocks are erupted on the surface.
  - Volcanic rocks are fine-grained (<1 mm)
- Intrusive igneous rocks crystallize from magma below the surface.
  - Intrusive igneous rocks are coarse-grained (>1 mm)
  - Pegmatites are very coarse-grained (>1 cm)
Igneous Rocks:
Learning Goals

- What does ‘igneous’ mean?
- Composition
- Mineralogy
  - Mantle
  - Oceanic Crust
  - Continental Crust
- Igneous Fractionation
  - How the chemistry evolves

Intrusive Igneous Rocks

- Composition
- Mineralogy
- Geologic Setting
  - Mantle
  - Oceanic Crust
  - Continental Crust
- Igneous Fractionation
  - How the chemistry evolves

Igneous Rock Compositions

- Rock compositions are described in weight percents of oxides:
  - SiO₂, MgO, FeO, Al₂O₃, etc
- The principal variation in igneous rock compositions is silica (SiO₂) content.
- The degree of polymerization of silica increases with silica content. (in both crystals and melt).

Igneous Rock Compositions

- Igneous rocks vary in composition (SiO₂ content)
  - ultramafic (~40 wt%) (peridotite)
  - mafic (45-55%) (gabbro / basalt)
  - intermediate (55-65%) (diorite/andesite)
  - silicic (65-75 wt %) (rhyolite/granite)
- The mantle is peridotite (ultramafic).
- The ocean crust is gabbro (mafic).
- The continents are granite (silicic)

Igneous Rock Names and Compositions

<table>
<thead>
<tr>
<th>Composition Name</th>
<th>Intrusive Rock Name</th>
<th>Volcanic Rock Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultramafic</td>
<td>Peridotite</td>
<td>(Komatiite)</td>
</tr>
<tr>
<td>Mafic</td>
<td>Gabbro</td>
<td>Basalt</td>
</tr>
<tr>
<td>Intermediate</td>
<td>Diorite</td>
<td>Andesite</td>
</tr>
<tr>
<td>Silicic (felsic)</td>
<td>Granite</td>
<td>Rhyolite</td>
</tr>
</tbody>
</table>

Igneous Rock Mineralogy

- Peridotite (Ultramafic)
  - Olivine ((Mg,Fe)₂SiO₄)
  - Pyroxene ((Mg,Fe,Ca)SiO₃)
- Gabbro (Mafic)
  - Feldspar (CaAl₂Si₂O₈)
  - Pyroxene ((Mg,Fe,Ca)SiO₃)
  - Garnet (Mg₃Al₂Si₃O₁₂) or Spinel (MgAl₂O₄)
Igneous Rock Mineralogy

- Diorite (Intermediate)
  - Feldspar (CaAl₂Si₂O₈)
  - Feldspar (NaAlSi₃O₈)
  - Pyroxene ((Mg,Fe,Ca)Si₂O₅)
  - Mica
    \( K(Mg,Fe,+)_{2}(Si,Al)_{4}O_{10}(OH)_{2} \)

- Granite (Silicic)
  - Quartz (SiO₂)
  - Feldspar (NaAlSi₃O₈)
  - Feldspar (KAl₂Si₃O₈)
  - Mica (biotite)
    \( K(Mg,Fe,+)_{2}(Si,Al)_{4}O_{10}(OH)_{2} \)
  - Mica (muscovite)
    \( (KAl)_{2}(Si,Al)_{4}O_{10}(OH)_{2} \)

Igneous Rock Names and Compositions

- **Intrusive Rock Name**
  - Ultramafic
  - Mafic
  - Intermediate
  - Silicic (felsic)

- **Granite**
  - Peridotite
  - Gabbro
  - Diorite
  - Granite

- **Volcanic Rock Name**
  - (Komatitite)
  - Basalt
  - Andesite
  - Rhyolite

Geologic Settings

- **Compositions**
  - Ultramafic
  - Mafic
  - Intermediate
  - Silicic (felsic)

- **Where?**
  - Mantle
  - Oceanic
  - Subduction Zones
  - Continental Mass

There appear to be 13 major plates that cover the globe.

Igneous Fractionation: Peridotite-basalt-granite

- **Partial Melting**
  - Rocks have a melting interval of several hundred degrees C.
  - First melt is rich in silica, water and trace elements.

- **Fractional Crystallization**
  - First-formed crystals low in silica settle to the bottom.
Peridotite Partial Melting

First melt at 3-mineral junctions

Melt composition is different from host

Melt is less dense
Melt flows when pockets touch

Peridotite + Basalt Melt

(a) Early crystallization

Crystals form from magma cooling and settle to floor of chamber
Crystals from early cooling accumulate

Igneous Fractionation:
Layered Mafic Intrusion

Granite Outcrop

Intrusive forms

- **Pluton**: Any large discordant intrusion at depth
  - Batholith: large > 100 km$^2$
  - Stock: small < 100 km$^2$
- **Dike**: Tabular non-conformable
- **Sill**: Tabular conformable

Dikes:
- Tabular discordant

Sills:
- Tabular conformable
How do oceans and continents differ?

- **Oceanic crust is:**
  - Thin (~7 km)
  - Dense (~3.1 g/cm³)
  - Mafic (45-50% SiO₂)
  - Young (< 200 my)
- **Continental Crust is:**
  - Thick (>30 km)
  - Light (~2.7 g/cm³)
  - Silicic (> 60% SiO₂)
  - Old (> 1000 my)

Difference is result of partial melting and fractional crystallization.

- Mid ocean ridge makes basalt from peridotite.
- Partial melting at subduction zones makes andesite from basalt.

Terms

- Polymerization
- Magma
- Pegmatite
- Igneous Fractionation
- Partial melting
- Fractional Crystallization
- Ultramafic
- Mafic
- Intermediate
- Silicic
- Peridotite
- Gabbro
- Diorite
- Granite
- Pluton
- Stock
- Batholith
- Dike
- Sill
Assignment

• Grotzinger Chapter 5

• Sedimentary Rocks

Clicker Question

• What is the most likely geologic setting in which conglomerate was deposited?
  – A. Continental alluvial fans
  – B. Continental deserts and beaches
  – C. Shallow-water marine
  – D. Deep-water marine
  – E. Reefs

Clicker Question

• What is the most likely geologic setting in which sandstone was deposited?
  – A. Continental alluvial fans
  – B. Continental deserts and beaches
  – C. Shallow-water marine
  – D. Deep-water marine
  – E. Reefs

Clicker Question

• What is the most likely geologic setting in which shale was deposited?
  – A. Continental alluvial fans
  – B. Continental deserts and beaches
  – C. Shallow-water marine
  – D. Deep-water marine
  – E. Reefs (Tropical Shallow Marine)

Crust and Mantle

Lithosphere and Asthenosphere

Clicker Question 1

• The term for any molten silicate material on or below the Earth's surface is:
  – A. Granite
  – B. Basalt
  – C. Magma
  – D. Pegmatite
  – E. Lava
Clicker Question 1
• The term for any molten silicate material on or below the Earth’s surface is:
  – A. Granite
  – B. Basalt
  – C. Magma
  – D. Pegmatite
  – E. Lava

Clicker Question 2
• The most abundant element in the Earth is:
  – A. Hydrogen
  – B. Oxygen
  – C. Magnesium
  – D. Silicon
  – E. Iron

Clicker Question 2
• The most abundant element in the Earth is:
  – A. Hydrogen
  – B. Oxygen
  – C. Magnesium
  – D. Silicon
  – E. Iron

Clicker Question 3
• The composition of the mantle is said to be:
  – A. Ultramafic
  – B. Mafic
  – C. Intermediate
  – D. Silicic
  – E. Sedimentary

Clicker Question 3
• The composition of the mantle is said to be:
  – A. Ultramafic
  – B. Mafic
  – C. Intermediate
  – D. Silicic
  – E. Sedimentary

Clicker Question
• Any small or large discordant intrusion at depth is known as a
  – A. Pluton
  – B. Batholith
  – C. Stock:
  – D. Dike
  – E. Sill
Clicker Question

• Any small or large discordant intrusion at depth is known as a
  – A. Pluton
  – B. Batholith
  – C. Stock:
  – D. Dike
  – E. Sill

Clicker Question

• A small conformable intrusion between and parallel to sedimentary layers is known as a
  – A. Pluton
  – B. Batholith
  – C. Stock:
  – D. Dike
  – E. Sill

Clicker Question

• A small conformable intrusion between and parallel to sedimentary layers is known as a
  – A. Pluton
  – B. Batholith
  – C. Stock:
  – D. Dike
  – E. Sill

Clicker Question

• A small discordant intrusion that cuts across sedimentary layers is known as a
  – A. Pluton
  – B. Batholith
  – C. Stock:
  – D. Dike
  – E. Sill

Clicker Question

• A small discordant intrusion that cuts across sedimentary layers is known as a
  – A. Pluton
  – B. Batholith
  – C. Stock:
  – D. Dike
  – E. Sill