3.1 How and where do rocks form?

Abraham Werner?
“Neptunist”! rx precip. from ocean—“flood oriented”

Then came James Hutton…
“Plutonist”! Scottish “gentleman farmer”, observer, “father of modern geology”…

John Playfair & Charles Lyell spread Hutton’s ideas…Uniformitarianism; Earth has hot interior; geology requires deep time…

3.4 How are the rock classes related to one another?

The Rock Cycle
Processes link types
Plate tectonics is driving force

Why study rocks?
- 3.1 How and where do rocks form?
- 3.2 Can rocks be classified according to the processes that form them? (environments!)
- 3.3 How do we determine rock origins?
- 3.4 Rock classes & the rock cycle?
Why study rocks?

Objectives: In this chapter we will …

Learn the basics of rock formation and the relationships among rock types

Learn how to classify rocks and the factors that lead to geologic classification systems

3.1 How and where do rocks form?

If we look closely at the loose materials under our feet what might we expect to find?

Consider a beach along a sandstone cliff.

Fig 3.2a

3.1 How and where do rocks form?

But what else can we tell from observing?

The quartz grains are small, and very round

Even the dark grains are roundish, if small

and the shell fragments, while flat, have rounded edges. What processes are involved? Watch the waves moving the sand …

Fig 3.2b

3.1 How and where do rocks form?

Water coming from a spring atop a rock. The entombed trees bear evidence that a rock-forming process is ongoing...

The rock around the spring itself appears to be made of layered crystalline material with sponge-like holes.

Fig 3.3

3.1 How and where do rocks form?

So, we know for some rocks

They are made from bits of other rocks and/or organically derived mineral-like matter (shells)...

An abrasive process moves and reshapes the fragments...

Fragments of older rock consolidate into new rock with a mineral cement

Fig 3.3b
3.1 How and where do rocks form?
- So, we now know that some other rocks:
  - Form by precipitation of minerals from water…
  - These minerals cement together other loose sediments, OR…
  - These precipitating minerals intergrow

- At a volcano lava quickly “freezes” into rock. That rock (bottom left) is made of very small mineral crystals. Other rocks coughed up from deep within the volcano (bottom right) show mosaics of larger crystals and banded structures.

3.1 How and where do rocks form?
- Rocks around a volcano form by much different processes than in the previous examinations of sediments and sedimentary rocks
  - Minerals in these rocks have angular shapes
  - Must have crystallized in place from molten rock
  
- Both the spring and volcano have intergrown crystals, but the origins of crystals are different

3.2 Can rocks be classified according to the processes that form them?
- **Classification** is a central theme of science
- Our observations of external processes at Earth’s surface show that active surface processes produce minerals and hence rocks
- **Internal processes** – observations of rocks unassociated with surface processes must be related to some other group of phenomena

- Most natural rocks are aggregates of mineral grains.
- Many rocks originate from observable processes on or near Earth’s surface.
- The presence of rocks that are not related to surface processes suggests a relation to internal processes.

3.2 Can rocks be classified according to the processes that form them?

The three classes of rocks: sedimentary, igneous, and metamorphic

<table>
<thead>
<tr>
<th>Classification</th>
<th>Some examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedimentary</td>
<td>Biogenic (e.g., shells of organisms), chemical precipitation, mechanical weathering</td>
</tr>
<tr>
<td>Igneous</td>
<td>Magma cool and solidify (e.g., volcanic rocks), differentiation of magma (e.g., granitic rocks)</td>
</tr>
<tr>
<td>Metamorphic</td>
<td>Rocks subjected to high temperatures and pressures (e.g., metamorphic rocks)</td>
</tr>
</tbody>
</table>

Table 3.1: The Genetic Classification of Rocks
3.2 Can rocks be classified according to the processes that form them?

**Sedimentary Rocks**
- Formed by deposition and precipitation of materials coming from the breakdown of older rocks
- Weathering breaks down and/or dissolves parts of a rock
  - Dissolved ions
  - Clastic sediment

**Sedimentary rock formation:**
- Chemical reactions
- Physical processes
- Physical weathering
- Chemical weathering
- Solution
- Liquefaction
- Discharge
- Solution
- Deposition
- Compression
- Gravitation
- Sorting
- Bedding
- Cross-bedding
- Biochemical processes
- Calcification
- Dolomitization
- Algal mats
- Clay films
- Detrital rocks
- Chemical rocks
- Metamorphic rocks

**Lithification:**
- Sediments of either type accumulate in layers, compress under their own mass and/or what buries them, and, with cements, form a hardened mass

**Igneous rocks**
- Form from molten magma
- Volcanic rocks form above ground = extrusive
- Plutonic form below ground = intrusive

**Metamorphic rocks**
- Rocks that have changed
  - Increased temperature (but not melted)
  - Increased pressure
  - Presence of hot fluids (chemical reactions)
- Changes to:
  - Shape and/or orientation of crystals
  - The minerals

**Regional metamorphic rocks**
- Occur across vast regions => convergent plate boundaries

**Contact metamorphic rocks**
- Thermally driven and common along boundaries of igneous intrusions or under lava flow zones

**Hydrothermal metamorphic rocks**
- Driven by hot-fluid chemical changes
- Often associated with previous types
3.2 Can rocks be classified according to the processes that form them?

Classic regional metamorphic structures in Scotland

Note bands, but also that they are folded back on one another, attesting to the pressure that drives such change.

3.2 Can rocks be classified according to the processes that form them?

Rocks can be classified descriptively or genetically. The three classes of rocks are genetic categories...

- **Igneous** rocks crystallize as intergrown mineral masses from the molten state in extrusive or intrusive fashion...
- **Sedimentary** rocks derive from weathering of previously existing rocks as particles or dissolved ions. Clastic sed. rocks form from the fragments, and chemical sed rocks from the dissolved portion...
- **Metamorphic** rocks form by the reaction of preexisting rocks in the presence of heat, pressure, fluids, or combinations thereof, producing new minerals and rocks.

3.3 How do we know ... how to determine rock origins?

How do geologists use observations of rocks to infer process?

- The "3-class" genetic grouping is "new" (only ~200 yr old--Prior to the current genetic groups, there were competing thoughts)
- **Descriptive** classes require only keen observation and sufficient adjectives.

3.3 How do we know ... how to determine rock origins?

**Neptunism**: Abraham Werner (1749–1817) believed that all rocks derived from processes of chemical precipitation.

Concluded that the bottom layers of Earth's rocks were least soluble and thus first to precipitate (primitive rocks), and that they were overlain by stratified rocks and finally "washed deposits" of loose materials. Volcanic activity was caused by coal fires underground melting rock overhead.

3.3 How do we know ... how to determine rock origins?

**Vulcanism** (or plutonist) -- the belief that most rocks were formed by igneous-like origins.

- Championed by James Hutton (1726–1797)
- Noted that veins of "Primitive Rock" extended up into the "Stratified Formations" and that the boundaries of contact with the latter were "baked."
- Posited that layered rocks were mainly lava flows of some kind.

3.3 How do we know ... how to determine rock origins?

So how did geologists resolve these competing views? Competing views met in the middle --Hypothesized and tested the observations they made...

**Neptunists**, led by A. Werner, asserted that nearly all rocks came from precipitates. Agreed with a view by many at the time, that Earth was internally cold...

**Vulcanists**, following Hutton, used careful observation to refute Neptunists' claims by demonstrating the presence of igneous rocks and showing evidence of Earth's internal heat...
3.4 How are the rock classes related to one another?

- *Igneous rocks* are made from any rocks that have melted and recrystallized.
- *Sedimentary rocks* come from weathered bits of other preexisting rocks.
- *Metamorphic rocks* are preexisting rocks that have changed.
- Thus, all three rock types are connected in some manner.

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The Rock Cycle

Processes link types  

Plate tectonics is driving force