3.1 How and where do rocks form?

Consider a beach along a sandstone cliff. If we look closely at the loose materials under our feet what might we expect to find?

If we look closely we see minerals of various sorts. Bits of shell; calcite or aragonite. Small glassy grains of quartz. Some few dark grains of magnetite.

But what else can we tell from observing?

The quartz grains are small, and very round. Even the dark grains are roundish, if small. The shell fragments, while flat, have rounded edges. What processes are involved? Watch the waves moving the sand...
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 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

3.1 How and where do rocks form?

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.

Fig 3.4

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

3.1 How and where do rocks form?

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?

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

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

**Igneous Rocks**

Identification

- **Igneous rocks**
  - Form from molten magma...
  - Volcanic rocks form above ground = extrusive...
  - Plutonic form below ground = intrusive
3.2 Can rocks be classified according to the processes that form them?

- Layered extrusive rocks
- Massive plutonic rock bodies

Fig 3.7

**Rock Identification is based on:**
- Composition
- Texture

What minerals make up the rock?
What is the shape, size and orientation of the mineral grains that make up the rock?

Major Difference: Crystalline (below) vs. fragmental (left)

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**Igneous Composition**

- Mafic
  - Richer in Magnesium and Iron (Fe) and poorer in silica; example, basalt.
- Felsic
  - Richer in feldspar and quartz, and thus richer in silica; example, rhyolite.

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**Igneous Textures - Crystalline**

Aka: phaneritic
- Coarse Grained

Aka: aphanitic
- Fine Grained

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**Igneous Textures - Crystalline**

- Porphyritic
- Glassy
- Vesicular
Igneous Textures – volcaniclastic or fragmental
Made of rock fragments rather than crystals

Igneous Rocks
Mafic
- Gabbro
Intermediate
- Diorite
- Granodiorite
Felsic
- Granite

Increasing silica

Grain Size:
Plutons and Volcanoes

Ultramatic Rock
- Dunite

Name this Igneous Feature...
Igneous Dike

Figure 4.7a
Dikes are steeply inclined intrusions that cut across sedimentary layers, if present. This basalt dike in the Grand Canyon, Arizona, cuts across red sedimentary layers. Notice the geologist (circled) standing on the dike for scale.
Plutonic Structures

Inclusions: Xenoliths

Source: William E. Ferguson

Why do we find Plutons at the Surface?

Sierra Nevada Mountains Batholith, California

Some basalt flows feature columnar joints formed when the rock contracts while cooling (as seen in Figure 4.8b). This thick lava flow is the highlight for visitors to Devil’s Postpile, California.

Devils Tower, Wyoming, resulted from erosion that exposed magma that solidified in the conduit of an eroded volcano. The long, thinning rock columns formed when the cooling rock contracted.
Intermission: Quiz
What Can you say about the history of this rock?

Basalt
Magma produced by partial melting of the mantle that erupted from a volcano at a divergent zone or hot spot.

http://itc.gwu.edu/faculty/tweiland/basalt.jpg

Intermission: Quiz
What Can you say about the history of this rock?

Gabbro
Magma produced by partial melting of mantle that cooled underground (plutonic) at a divergent zone or hot spot.

Granite
Magma produced by partial melting of the continental crust that cooled underground (plutonic) at a subduction zone or continental hot spot.

Andesite
Magma produced by partial melting of the mantle, ocean crust & continental crust, that erupted from a volcano at a subduction zone.

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

Fragments form clastic sedimentary rock

Dissolved ions form chemical sedimentary rocks
- Precipitates – such as halite
- Generally carbonates, halides, some oxides also are the cement for clastic materials

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

- **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

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

- **Three classes of metamorphic rocks**
  - **Regional metamorphic rocks** ex = schist & gneiss
    - Pressure-driven; occur across vast regions => convergent plate boundaries
  - **Contact metamorphic rocks** ex = hornfels
    - 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.

3.3 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.

- 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.

The Rock Cycle

Processes link types

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