Igneous Rocks

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Igneous Rocks

- Igneous rocks are formed by the cooling of molten rock.

- There are two major states of molten rock: Magma and Lava.
  - **Magma** is a form of molten rock that exists below the Earth's surface.
  - **Lava** is the term given to magma once it reaches the Earth's surface, usually in the form of a volcanic eruption.

- There are two major classifications of igneous rocks:
  - **Intrusive igneous rocks**
  - **Extrusive igneous rocks**

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What are Rocks?

- Most rocks are an aggregate of one or more minerals and a few rocks are composed of non-mineral matter.

- There are three major rock types:
  1. **Igneous**
  2. **Metamorphic**
  3. **Sedimentary**

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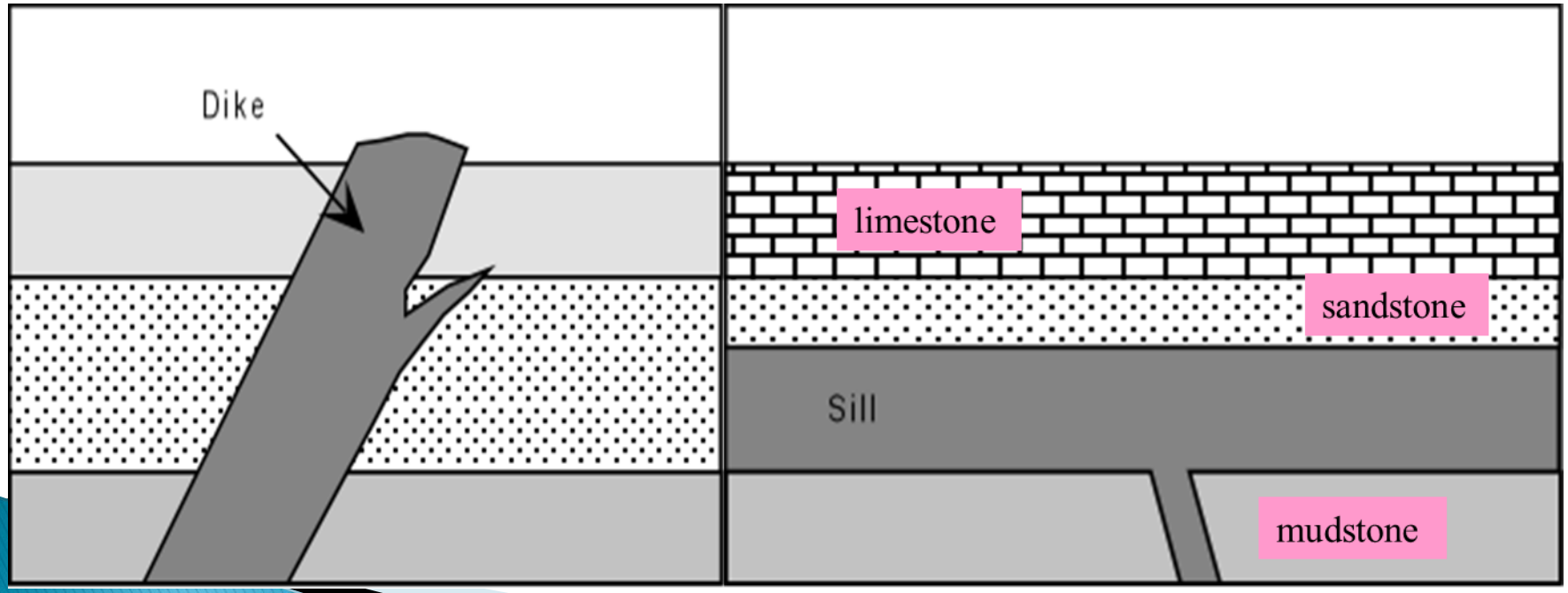
Intrusive igneous rocks

- Intrusive igneous rocks are formed by magma that cools below the Earth's surface.
- Intrusive igneous rocks generally cool very slowly deep below the earth's surface or as the magma is rising to the earth's surface.
- Plutonic rocks .pluton (greek god of underworld)

Types of intrusive /plutonic rocks

- Commonly observed forms of Plutonic (intrusive) rocks observed in the field are:
- Dykes
- Sills
- Laccoliths
- Bysmaliths
- Batholiths
- Phacoliths
- Lopolith
- Volcanic necks
- Chonoliths

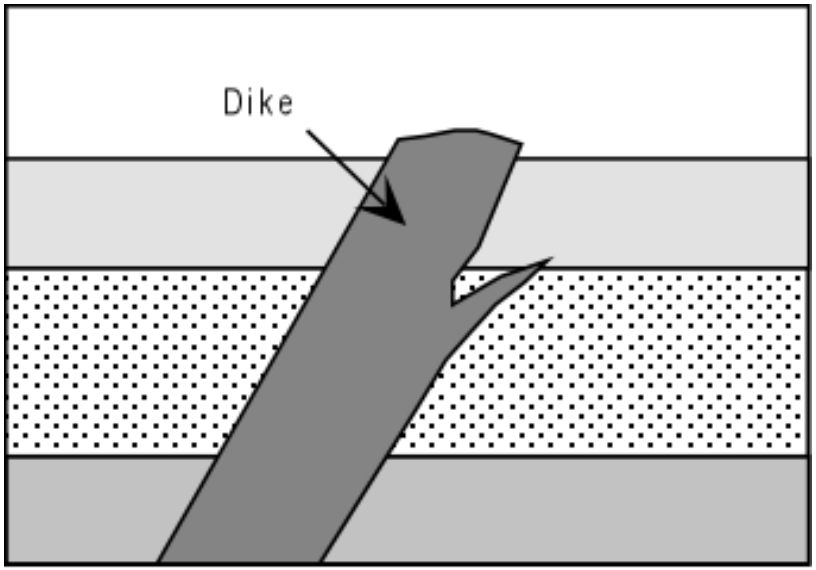
- Based on the attitudes of the associated country rocks the forms are called either as ***Concordant (parallel) or Discordant (prependiculer).***

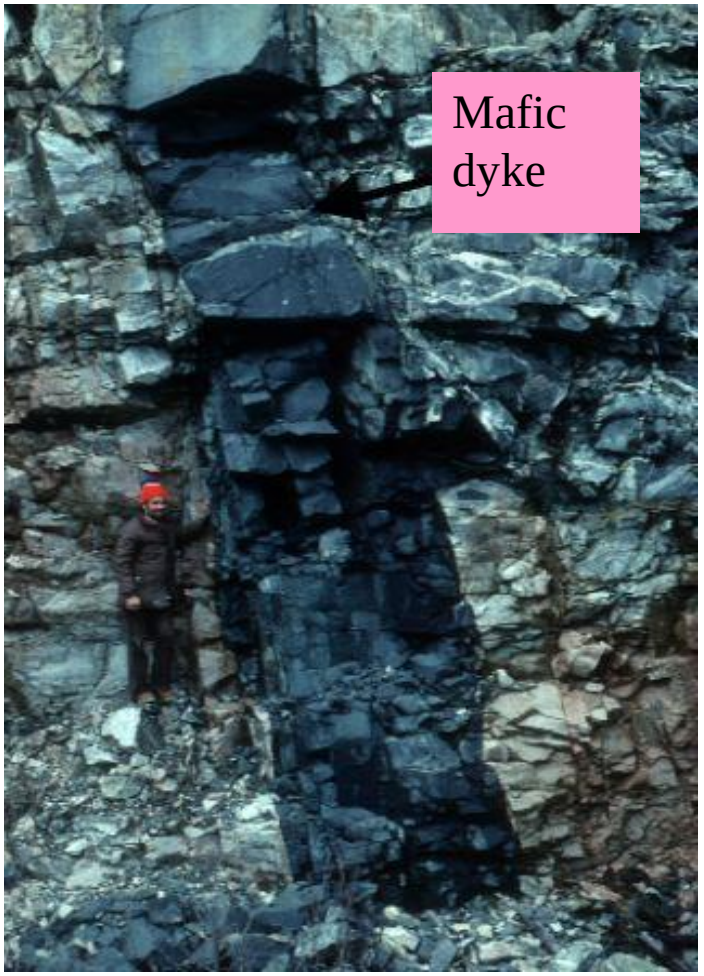


DYKES

- They are discordant
- Cut across the bedding of the rocks in which they intrude
- Vertical to steeply inclined and sheetlike body (extensive in lateral dimension)
- Thickness vary widely from an inch upto hundred of feet
- Injected through fractures, joints, and weak planes

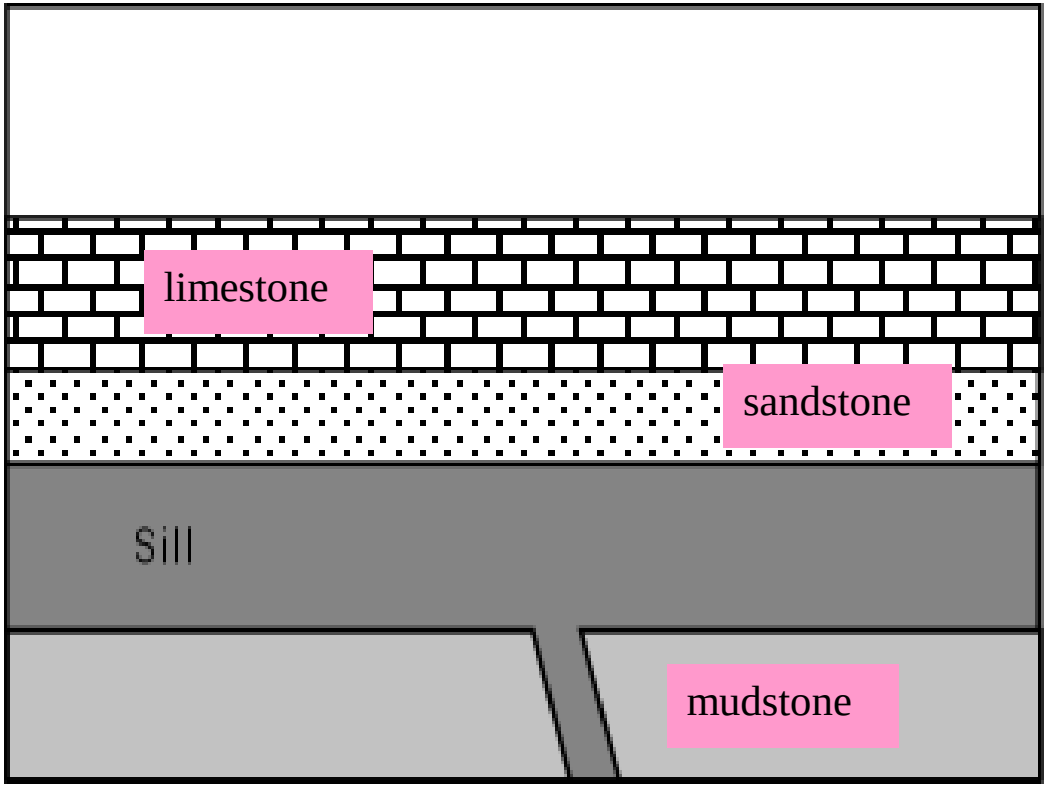
- Quartz-Dolerite dykes of Midland valley of Scotland are about 50-60 km long and upto 30m thick. Few places some dykes are very short upto few meters and as thin as few cm.





Sills

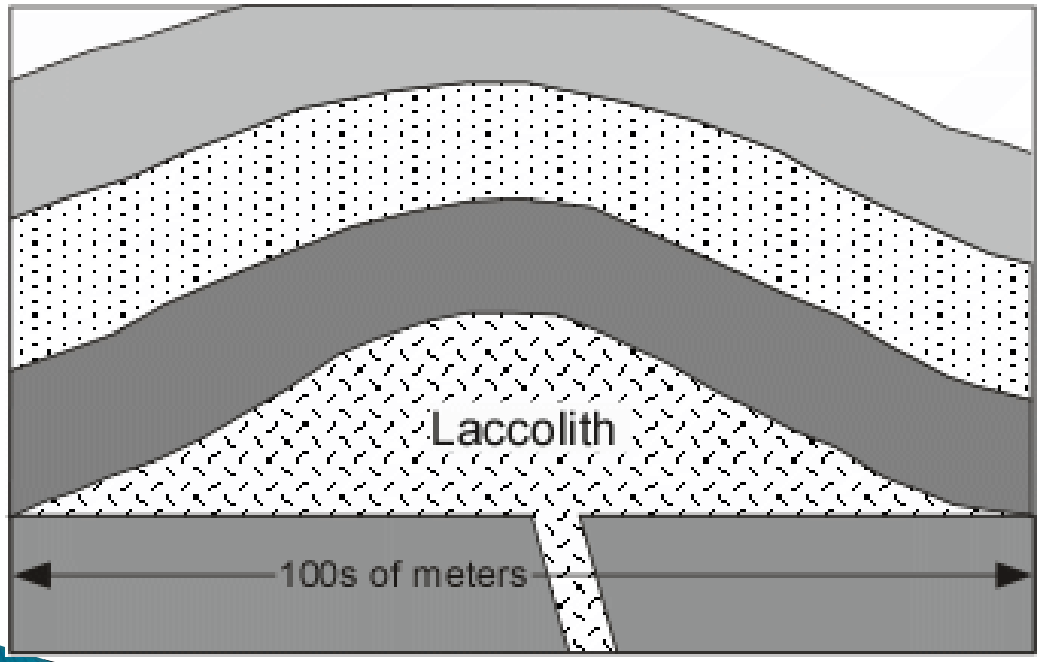
- Sills are relatively thin tabular sheet like body that penetrates parallel to the bedding planes
- Laterally it may extend for 100s of km and upto 10 km in width.
- Lateral extend mainly depends on the hydrostatic force, temperature, degree of fluidity or viscosity, weight of overlying sediment column.



Spreads parallel to the bedding planes of the rocks, hence concordant in nature.

LACCOLITHS:.

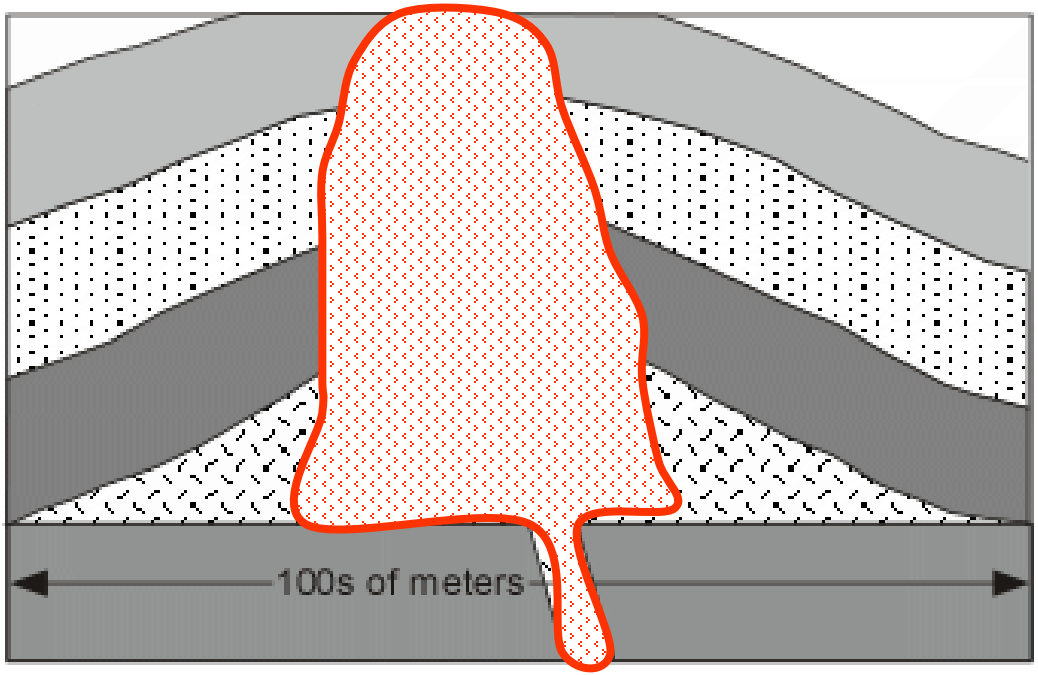
It is a concordant body, with flat bottom and convex upward. It is dome shaped.



- When viscous magma is injected rapidly along the bedding, as it cannot spreads it pushes up the overlying layers and keep on piling up.
- It causes folding of the overlying rock layers.

BYSMALITH:

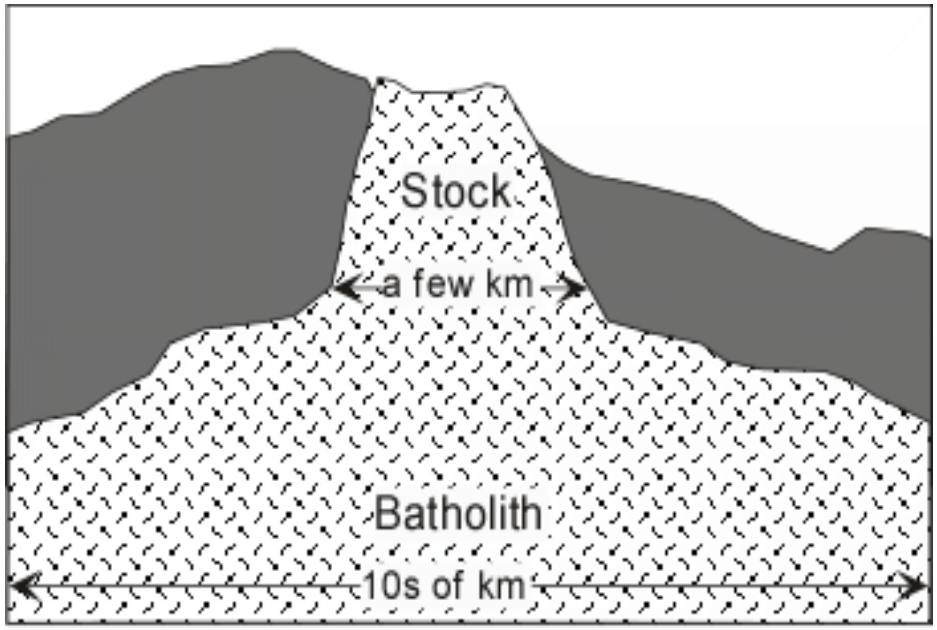
- It is cylindrically shaped body.
- It is developed when highly viscous magma is injected, because the lateral spreading along the bedding is less it acquires to move upwards and form cylindrical shape.
- Causes breaking of overlying rock layers.

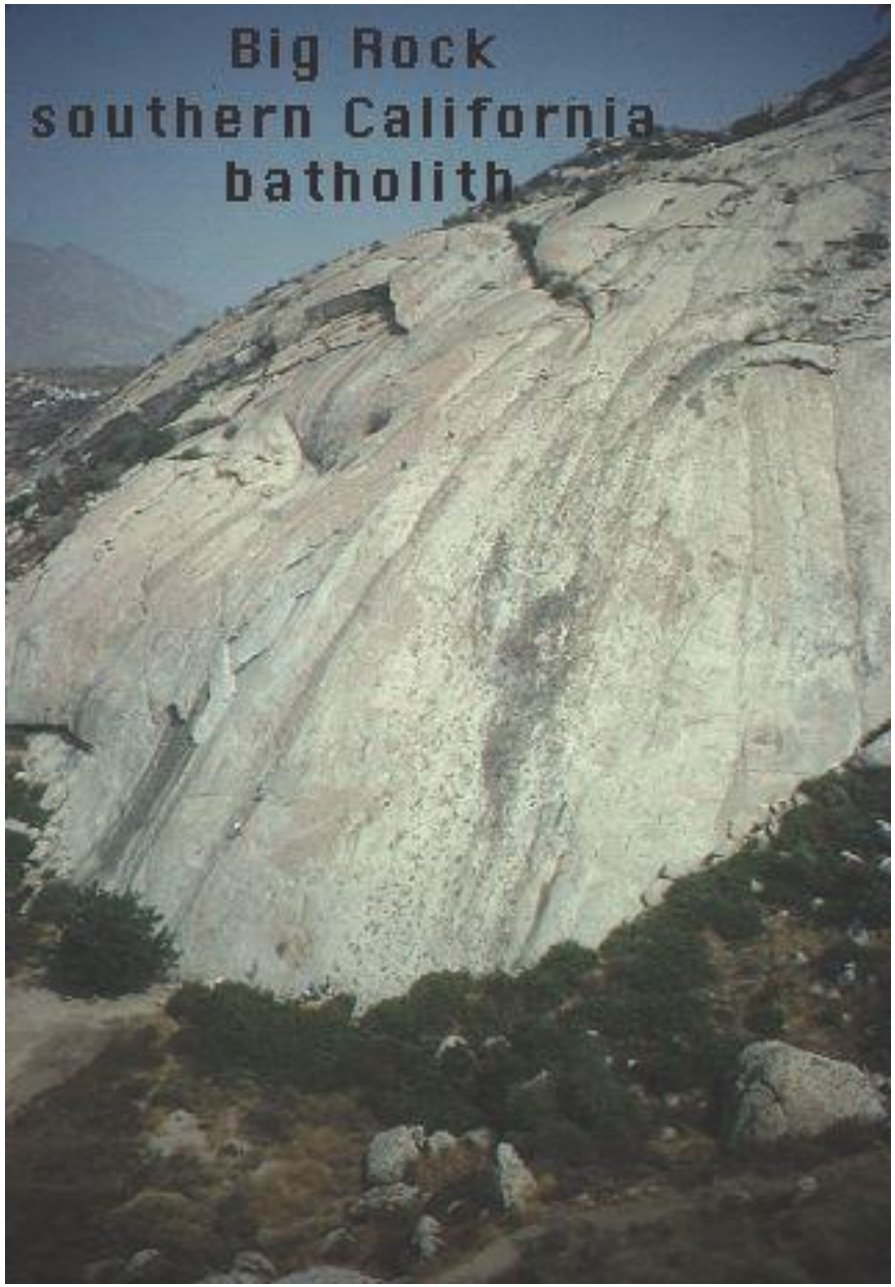


BATHOLITHS:

- These are the largest kind of plutons, irregular in shape and occupies large area.
- Their side sloping away from each other which makes them larger and large downwards extending to greater depth.

- Their occurrence is commonly associated with the mountain-building process

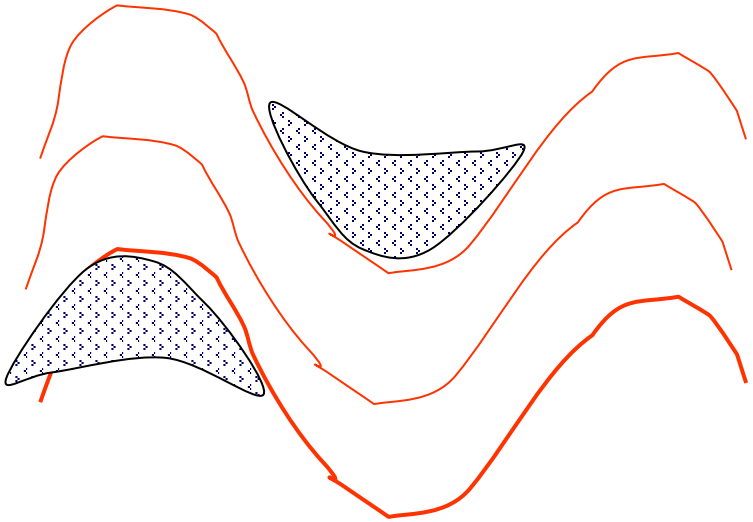




Stocks: ***Are smaller irregular bodies with 10 km in maximum dimension, and are associated with batholiths.***

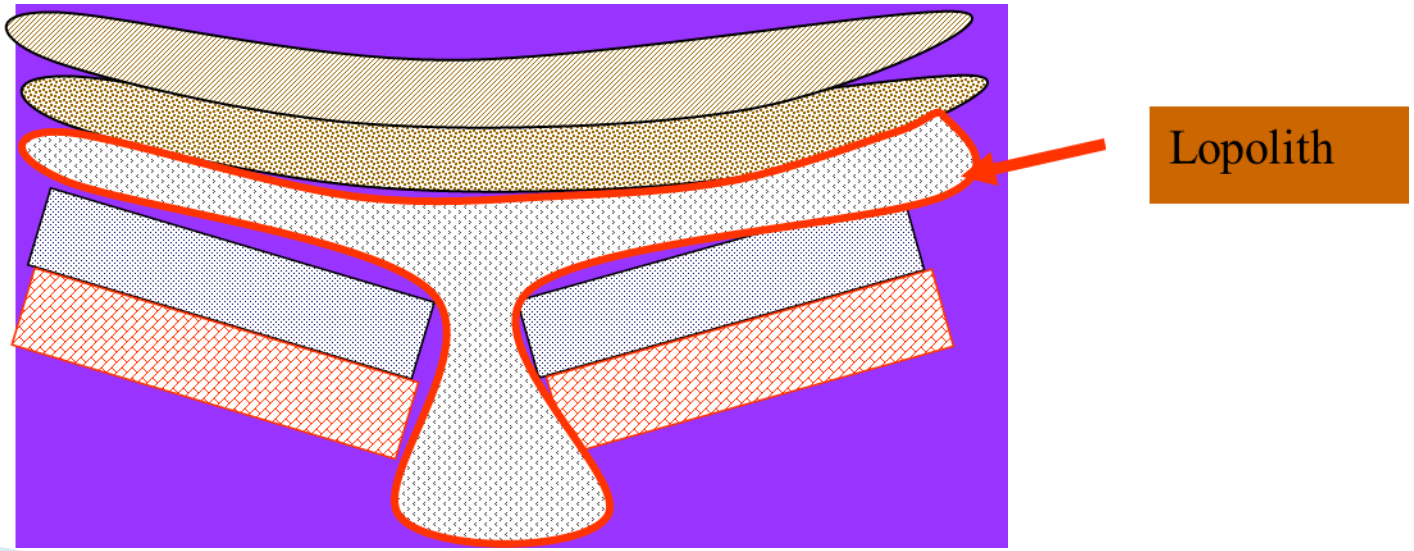
PHACOLITHS

These are concordant bodies that occurs along the crests and troughs of the folded sedimentary strata.



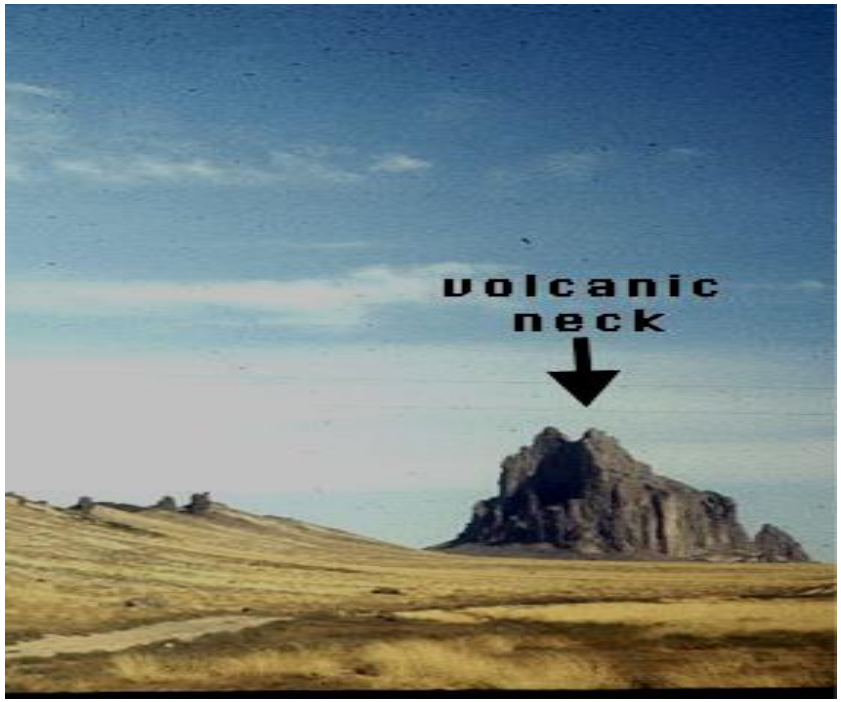
LOPOLITHS

These are basin or saucer-shaped concordant bodies with top nearly flat and convex bottom



VOLCANIC NECK or VOLCANIC PLUGS:

It is cylindrical conduit that fed magma upward to a volcanic vent or it is a conduit of the ancient volcano. Vary in diameter from a few 100s of m to a kilometer or more. These are filled up with crystalline rocks. Shape-circular, elliptical or irregular.



Texture

- Texture is a term used to describe the size, shape, and arrangement of interlocking crystallized mineral grains in an igneous rock.

- Two major factors affect the size of crystal grains in an igneous rock:

  - 1) Rate at which molten rock cools; slow or fast
  - 2) Amount of dissolved gases or fluids in the magma.

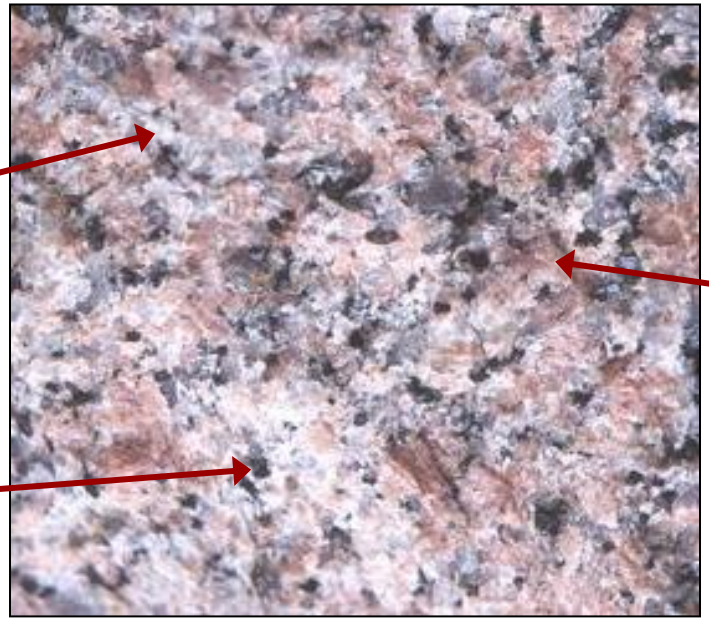
Igneous Rock Textures

- Phaneritic (Intrusive)
- Aphanitic (Extrusive)
- Porphyritic (Intrusive and Extrusive)
- Vesicular texture (Extrusive)
- Glassy (Extrusive)

Phaneritic Texture

- **Phaneritic (Intrusive)**
  - **Phaneritic rocks are coarse-grained rocks which form below the Earth's surface.**
  - **The individual crystals are relatively even-sized and large enough for scientists to identify the different mineral grains that compose the rock.**

Granite rock with a phaneritic texture



Quartz Crystals:
(White)

Feldspar Crystals:
(Pink)

Biotite Crystals:
(Black)

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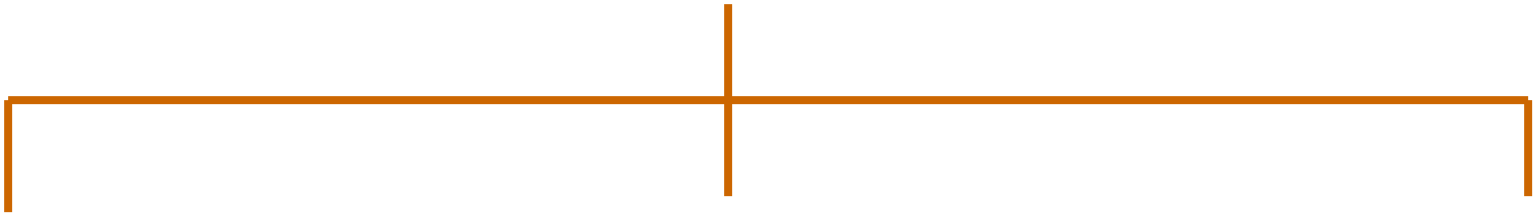
PHANERIC TEXTURE

Is characterized by LARGE SIZE MINERALS which can be easily seen by Naked eye (size at least 2mm or greater)



Coarse-grained Phaneric
- > 5mm

Medium-grained Phaneric
- 1 mm - 5mm

Fine-grained Phaneric
<1 mm

Aphanitic Texture

- Aphanitic rocks are very fine-grained and contain crystals that are too small to distinguish without the aid of a magnifying lens.
- Aphanitic rocks are often described by how light or dark the rock appears. Lighter colored aphanitic rocks contain mostly non-ferromagnesian silicate minerals. Darker colored aphanitic rocks contain mostly ferromagnesian silicate minerals.

Porphyritic Texture

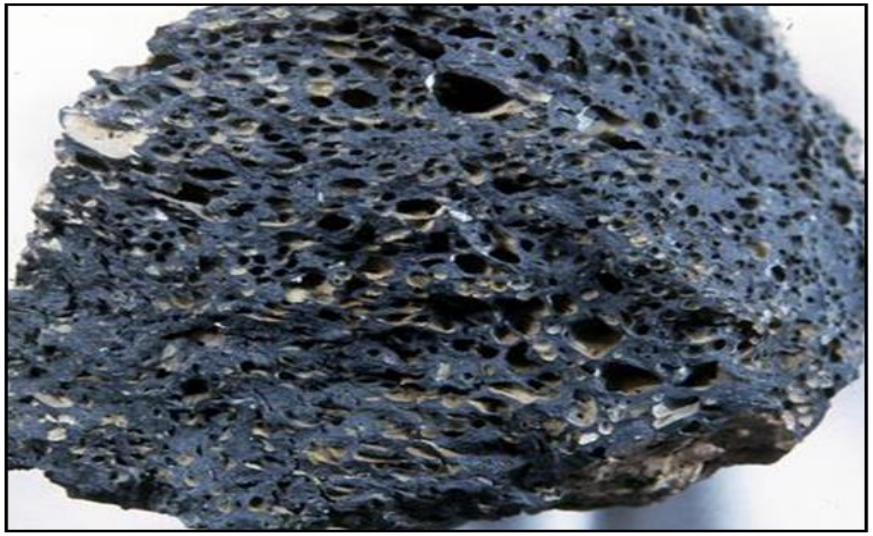
- Porphyritic rocks contain both coarse- and fine-grained textures indicating different environmental conditions which formed the rock.
- The coarse grains in a porphyritic rock develop as the magma is cooling below the surface of the earth.
- The fine-grained component of a porphyriic rocks forms when the magma or lava cools faster.
- The large coarse-grained crystals are referred to as phenocrysts.
- The small fine-grained crystals are referred to as groundmass.

Rhyolite rock with porphyritic texture containing phenocrysts of olivine and pyroxene and a gabbro groundmass.

Vesicular Texture

Aphanitic rocks may also contain vesicles of remnant gas that give the rock a vesicular texture. Vesicles form when the rock cools very quickly and preserves the openings formed by the expansion of trapped gas bubbles.

Basalt rock with an aphanitic



Glassy Texture

- Glassy textured rocks are formed by very rapid cooling of magma.
- Glassy rocks often form from magmas with high silica content that arranges into long chainlike structures before crystallization occurs. These silica chains increase the viscosity of the magma and it once it eventually cools it forms a glassy textured rock.
- Glassy rocks can be considered amorphous because they have no crystalline structure.
- Glassy rocks are classified by the amount of glass contained by the rock:
  - Glass-bearing: 0-20% glass
  - Glass-rich: 20-50% glass
  - Glassy: 50 – 100% glass
- Obsidian is a common glassy rock.

Obsidian rock with a glassy texture and conchoidal fractures

What happens to molten rock as it cools?

- When the temperature of molten rock begins to drop there is a loss of energy that causes ions to slow down. As the ions slow down, they group together and arrange themselves into orderly crystalline structures. This process is referred to as crystallization.
- During crystallization, the silicon and oxygen atoms are the first to link together forming silicon-oxygen tetrahedrons, which are the building block of all silicate minerals.
- As crystallization continues, these individual silicon-oxygen tetrahedrons join with one another, and other ions, to form the basic structure of most minerals and igneous rocks.
- Environmental conditions including temperature and the presence of water or gases during crystallization affect the composition, the size, and the arrangement of the mineral grains.
- The size and arrangement of mineral crystals, also referred to as grains, define the texture of the rock.
- Geologists use mineral and textural classifications to infer information about the environmental setting in which different igneous rocks are formed.

Crystal Size and Cooling Rates

- **Slower cooling rates produce larger individual crystals in the rock**
  - **Intrusive igneous rocks generally cool very slowly and tend to have large crystals that produce a course-grained rock.**
  - **Phaneritic rocks are coarse-grained rocks which contain individual crystals that are relatively even in size and large enough for scientists to identify the different mineral grains that compose the rock.**

- **Faster cooling rates produce smaller individual crystals in the rock**
  - **Extrusive igneous rocks tend to cool quickly and are characterized by smaller grains that produce a fine-grained rock.**
  - **Aphanitic is the term used to describe very fine grained rocks.**

- **Porphyritic textured rocks contain both a coarse and fine-grained texture.**
  - **The coarse grains in a porphyritic rock begin to develop as the magma is cooling below the surface of the earth. Following eruption or exposure to lower temperatures, the remaining magma or lava cools very quickly and forms minerals with fine-grained textures. As a result, porphyritic textures contain both coarse- and fine–grained minerals.**

Igneous Rocks Mineral Composition

- The chemical composition of the magma during cooling determines the mineral composition of the crystallized rocks.
- 98% of all magma is composed primarily of silicate (SiO_2) ions joined with aluminum (Al), calcium (Ca), sodium (Na), potassium (K), magnesium (Mg), and iron (Fe) ions.
- Magma may also contain trace amounts of other elements such as titanium (Ti), manganese (Mn), gold (Au), silver (Ag), and uranium (U).
- During crystallization the minerals combine to form two major groups of silicate minerals, these include the dark-colored ferromagnesian silicates which crystallize at high temperatures and the light-colored nonferromagnesian silicates which crystallize at lower temperatures.

Ferromagnesian Silicates

- Ferromagnesian silicates crystallize at higher temperatures than non-ferromagnesian silicates.
- Ferromagnesian silicates contain greater amounts of iron (Fe) and magnesium (Mg) and less silica ($Si\ O_2$) than non-ferromagnesian silicates .
- Ferromagnesian minerals are generally dark in color and can be greenish, black, or dark grey.
- Common ferromagnesian silicate minerals include olivine, pyroxene, amphibole, biotite, hornblende, augite, and peridote.

Gabbro rock with olivine (yellowish crystals) and Pyroxene (darker crystals) phenocrysts

Non-Ferromagnesian Silicates

- Non-ferromagnesian silicates crystallize at lower temperatures that ferromagnesian silicates.
- Non-ferromagnesian silicates contain greater amounts of potassium (K), sodium (Na), and calcium (Ca) in combination with more silica (Si $O_{2)}$ than ferromagnesian silicates.
- Non-ferromagnesian minerals are generally light colored, and may be white, pink, or light grey.
- Common non-ferromagnesian silicate minerals include quartz, muscovite, and feldspars.

Granite composed of non-ferromagnesian silicates including feldspar (pink crystals) and quartz (white crystals).

Igneous Rock Categories: Felsic to Mafic

Felsic

Mafic

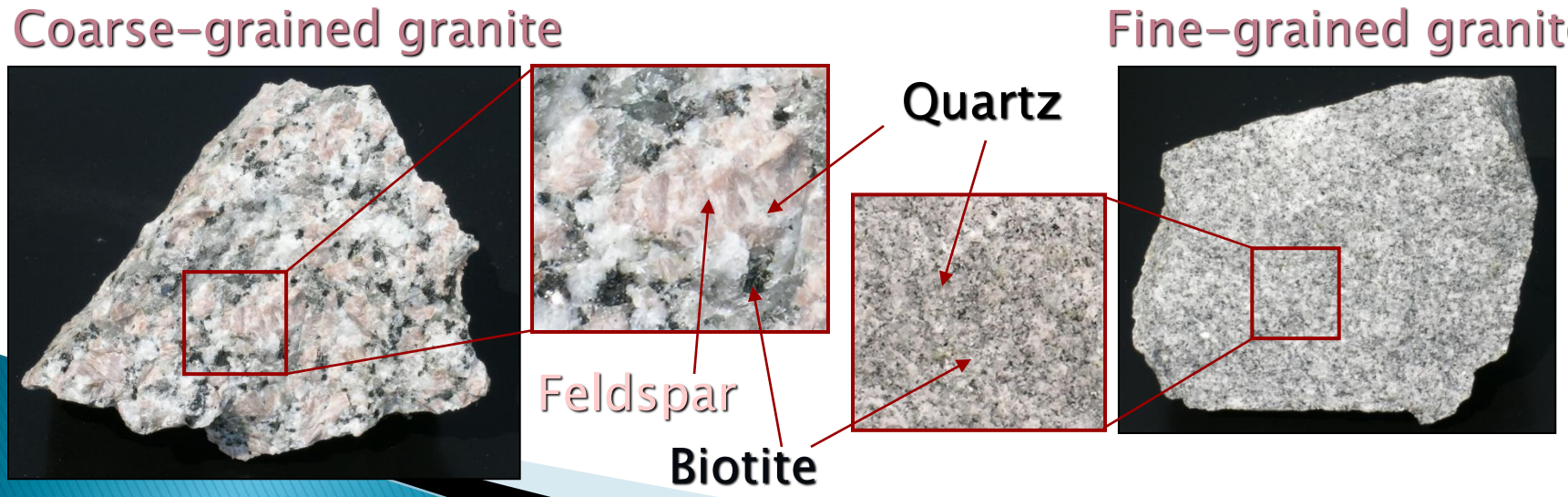
- Igneous rocks are divided into three broad groups Granitic, Basaltic, and Andesitic depending on their proportion of felsic (light-colored) to mafic (dark-colored) minerals.
- **Granitic rocks** contain more light-colored feldspars and silica than dark- colored minerals. Because of the high feldspar and silica content of Granitic rocks, geologists refer to them as being felsic (*fel* for *fel*dspar and *si* for *si*lica).
  - The primary minerals in granitic rocks include quartz, feldspar, biotite, and amphibole.
  - Granitic rocks make up about 70% of the Earth's crust.
- ***Basaltic rocks*** contain mostly darker silicate minerals and calcium-rich plagioclase feldspar and little quartz. Because of the high percentage of ferrromagnesian minerals in basaltic rocks, geologist refer to them as mafic (*ma* for *ma*gnesium and *f* for *f*errum).
  - Basaltic rocks are dark colored and tend to be more dense than granitic rocks.
- **Andesitic rocks** have a composition between granites and basalts.
  - They generally contain about 25% dark silicate minerals (amphibole, pyroxene, and biotite mica) with the remaining 75% consisting of plagioclase feldspar.

Igneous Rocks

- Granite
- Pumice
- Obsidian
- Gabbro
- Basalt
- Diorite
- Tuff

Granite

- Granite is a felsic intrusive igneous rock and has either a phaneritic or porphyritic texture.
  - Granite cools very slowly and often forms large masses of rock that are referred to as plutons or batholiths.
- Granite usually contains about 20-50% quartz, 30-60% feldspar, and the remaining 5-10% darker minerals such as biotite.
  - The quartz grains are usually spherical in shape and are a white to grayish color.
  - The feldspars grains are mostly potassium and sodium rich varieties with individual rectangular shaped grains. The feldspars are often white, grey, or pinkish in color depending on the chemical composition.
  - The remaining darker minerals usually consist of muscovite, biotite and amphibole and are generally black.



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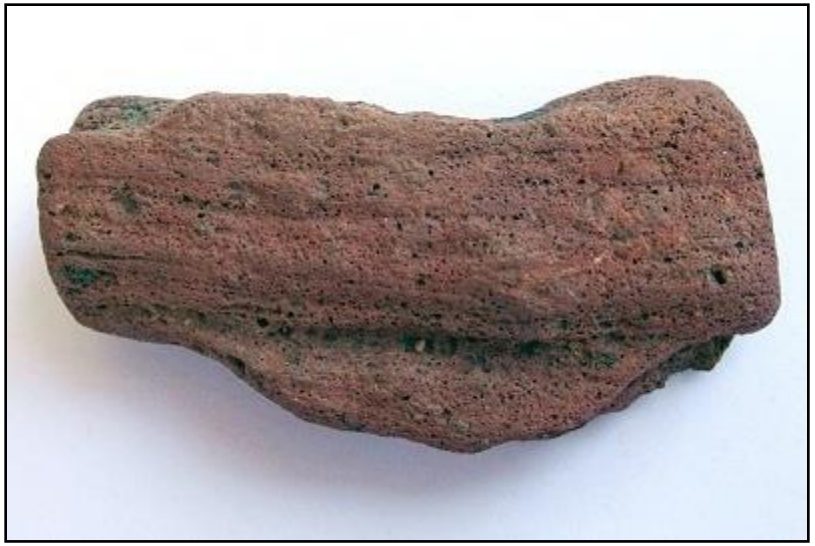
Pumice

- Pumice is a felsic, extrusive igneous rock with a glassy, vesicular texture formed from a combination of rapid cooling and a high gas content.
- Pumice forms in similar condition as obsidian, and the two can often be found in close proximity.
- Pumice is so light from the presence of lots of gas bubbles pockets that it often floats when placed in water.

Pumice with a vesicular texture



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Obsidian

- Obsidian is a felsic, extrusive igneous rock with a glassy texture.
- Obsidian forms very quickly from the rapid cooling of silica-rich lava.
- Unlike other minerals and rocks, the ions that form obsidian are unordered, or amorphous, meaning they have no structure, and as a result it produces a conchoidal fracture when broken.
- Thin sections of obsidian appear translucent and it is the presence of various metallic ions that give it an overall dark appearance.

Obsidian

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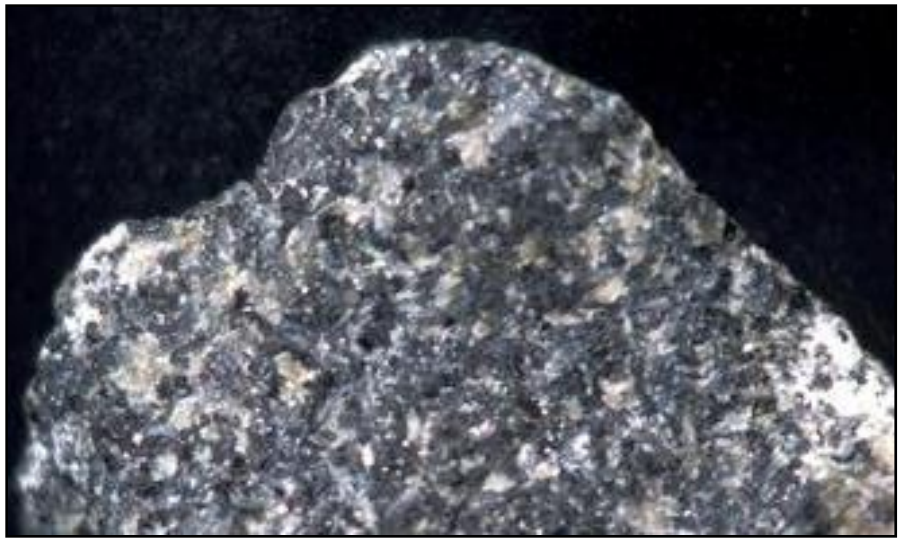
Gabbro

- Gabbro is a mafic, intrusive medium to coarse-grained igneous rock with a phaneritic texture.
- Gabbro is composed primarily of pyroxene, with calcium-rich plagioclase feldspar and small amounts of olivine and amphibole.
- Large gabbro intrusions are often sources of economically valuable nickel, chromium, and platinum.

Medium-grained gabbro



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Basalt

- Basalt is a mafic, extrusive fine-grained dark green to black volcanic rock with a porphyritic texture.
- Basalt is composed primarily of pyroxene, and calcium-rich plagioclase with small amounts of olivine and amphibole.

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Diorite

- Diorite is an intermediate, intrusive igneous rock with a predominantly coarse-grained phaneritic texture .
- Diorite is composed of quartz, sodium-rich plagioclase, and amphibole or biotite.
- The composition of diorite looks similar to granite, except that diorite contains a greater concentration of darker mafic minerals.

http://www.mii.org/index.html

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Tuff

- Tuff is an extrusive, pyroclastic rock composed of an aggregate of tiny ash fragments ejected during volcanic eruption.
- A mixture of various other extrusive rock fragments may weld with tuff making a cemented mass of ash and other rock/mineral fragments.
- Tuff may also be used as a descriptor along side other rocks depending on the relative concentration of rock to ash ratio, for example a rhyolite tuff.

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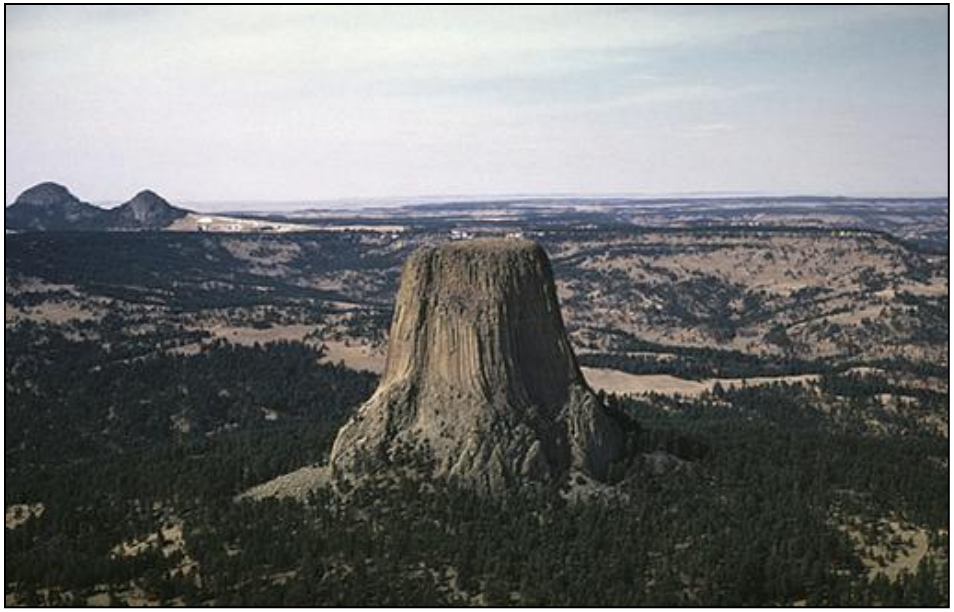
Igneous Rocks in the Landscape

Devils Tower at Devils Tower National Monument in Wyoming is an intrusive igneous rock formation that is exposed from millions of years of weathering and erosion of the surrounding landscape.



Mount Rushmore in the Black Hills of South Dakota is a Precambrian igneous, granitic batholith.

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