

## Optional GEOL 103 Writing Assignment: Igneous Rocks and Processes

1) Assuming the original magma compositions are the same, explain how an intrusive and an extrusive rock from a magma would differ. Use the rate of cooling in your explanation. Explain how the terms phaneritic, aphanitic, and porphyritic, and how a rock with each of these compositions would form. Intrusive rocks would have larger crystals (large enough to see w/ naked eye = phaneritic texture) because the crystals have time to grow. Extrusive rocks would have no crystals or small crystals (too small to see w/ naked eye = aphanitic texture) because the crystals lack time to grow. A porphyritic texture means a rock has two distinct crystal sizes. With a porphyritic/phaneritic texture, the smaller crystals would still be visible, and such rock would have cooled slowly for a while, then more rapidly, but all still underground. With a porphyritic/aphanitic texture, the smaller crystals would not be visible, and such rock would have cooled slowly for a while, then the lava would probably have been extruded and cooled quickly.

2) Igneous rocks are mainly classified by mineralogical composition and texture.

3) Explain how vesicles form in igneous rocks. Do they form in some intrusive and some extrusive rocks? Why?

Vesicles are semi-round holes that form when gases escape from lavas as pressure is released, so they form in extrusive rocks.

4) Why do some igneous rocks have glassy textures?

Glassy textures usually form when pyroclastic material is ejected from a volcano into the air. The extrusive rocks and particles such as pumice, ash, and obsidian are formed during very rapid cooling, allowing no crystal growth.

5) What is the main difference between the rock pairs: basalt/gabbro, andesite/diorite, rhyolite/granite?

These rock pairs have the same range of chemical compositions, but cooled fast/slow and thus the extrusive/intrusive equivalents of each other.

6) Explain the meaning of the terms felsic, intermediate and mafic. How do these terms relate to the color of igneous rocks (be careful, color is completely diagnostic for these terms)? Instead of thinking in terms of rock color, how should we best think of these terms?

These terms really relate to chemical composition, not color, although dark minerals *tend* to be more mafic – there are exceptions; e.g., the olivine in a peridotite is an ultramafic mineral although it can be rather light green. Also, K-spar can be fairly deep pink/red, but it is felsic.

Felsic = high Si, Na, K. Mafic = high Fe, Mg, Ca. Intermediate rocks have compositions in between felsic and mafic.

7) Explain the diagram below in your own words. Relate it to Bowen's Reaction Series. Note that this diagram is similar to Fig 4.4 in your text.

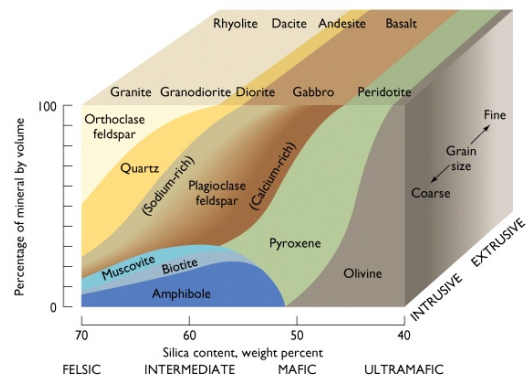
Diagram shows the for a given rock

x-axis: relative silica ( $\text{SiO}_2$  – not the mineral quartz) concentration, and therefore whether rocks are felsic to ultramafic

y-axis: percent minerals found in intrusive rocks

going into the page: grain size, which is a function of cooling rate and determines whether we interpret a rock as intrusive or extrusive

E.g., we would expect an diorite to be an intermediate rock with little or no quartz or pyroxene, no K-spar or olivine, lots of plag containing both Na and Ca, some amphibole and lesser amounts of muscovite and biotite. An andesite would be the extrusive equivalent, but some of the minerals might not be visible to the naked eye.



8. Explain Table 4.3 in your own words.

Table 5.3 list factors that affect melting. T & P increase with depth. Increasing T favors melting; Increasing P favors the solid state, so these factors compete. Most of the lithosphere (not near igneous intrusions) is not hot enough to melt. The asthenosphere (immediately below the lithosphere) partially melts because it is warm enough and the pressure is not so great to keep it completely solid. The mesosphere (the part of mantle below the asthenosphere) has a similar composition to the asthenosphere, but the pressure is great enough to prevent partial melting in most of it.

Rocks that contain water (which can be tied up in minerals such as micas and amphiboles [hornblende is an example]) melt at lower T than rocks without water. Felsic composition minerals and rocks melt at lower T than more mafic minerals and rocks.

9. Explain partial melting in your own words. What happens to the composition in terms of the elements Si, Na, K, Mg, Fe, and Ca of A) the original rock that partially melts, and B) the new rock that forms from the magma resulting from partial melting?

Felsic composition minerals and rocks melt at lower T than more mafic minerals and rocks. Rock A becomes enriched in Fe, Mg, and Ca, and depleted in Si, Na, and Ca. The Si, Na, and Ca partitions preferentially (not completely) into the partial melt, and this magma usually rises, becoming displaced from Rock A. Therefore rock B is enriched in Si, Na, and Ca, and depleted in Fe, Mg, and Ca relative to both the original rock and rock A after the partial melting.

Does (A) become more felsic or mafic than it was originally? More mafic.

Does (B) become more felsic or mafic than (A)? More felsic

10. Discuss the magma or lava compositions in Figure 4.11 using the term felsic, intermediate, and mafic. Be able to explain your reasoning.

Magma and lava near the island arc result from partial melting of basaltic/gabbroic mafic rocks in the downgoing lithospheric plate, perhaps mixed with some Si-rich sediments on the sea floor. The resulting magma is usually mafic to intermediate.

Magma and lava at the mid-ocean ridge result from partial melting of peridotitic ultramafic rocks in the mantle. The resulting magma is mafic. The uppermost rocks would be basalt, underlain by gabbro of about the same composition, but with crystals large enough to see because of slower cooling. See also Fig. 4.12 and 4.13 for more detail.

Magma and lava at the hot spot result from partial melting of peridotitic ultramafic rocks in the mantle. The resulting magma is mafic.

Magma in the continental rocks result from partial melting of basaltic/gabbroic mafic rocks in the downgoing lithospheric plate, perhaps mixed with some Si-rich sediments on the sea floor. The resulting magma can range from mafic to felsic – it can also partially melt some of the continental lithosphere, which is more felsic.

11. Explain the formation of the Palisades Sill (Fig 4.5), and how the magma composition changed as the magma cooled. Use Bowen's reaction series and the term "fractional crystallization." Why did basalt form at the top and bottom of the sill? Why is the layer above the lower basalt mostly composed of olivine? Why are there layers with different plagioclase feldspar compositions?

A mafic magma intruded into a sandstone, pushing apart the sandstone. Heat from the upper and lower margin of the sill was quickly lost to the sandstone, "chilling" the upper and lower margins and forming a basalt, even though basalt is usually extrusive. The basalt composition probably represents the approximate original magma composition.

Fractional crystallization explains the rest of the sill's cooling history. Bowen's Rxn Series predicts that ultramafic olivine crystals formed first at high T, removing Fe and Mg from the melt, and leaving the melt somewhat enriched in Si. These olivine crystals sank slowly to the bottom. Bowen's Rxn Series then predicts that pyroxene and Ca-rich plagioclase feldspar would form at a lower T, and these two minerals settled out and make up most of the middle layer, further enriching the melt in Si and Na. Bowen's Rxn Series then predicts that the remaining rather felsic melt should crystallize at lower T, forming Na-rich plagioclase feldspar.

12. How do dikes, sills, and batholiths form? Why can we sometimes see them at the earth's surface, and sometimes not?

Magmas intruded into pre-existing "country rock" pushing it apart. Large bodies of magma that cannot push their way to the surface cool deep underground and result in batholiths. Magmas that form sills squeeze concordantly (parallel to the country rock [often between bedding planes of sedimentary rock]). Magmas that form dikes squeeze into weak planes at an angle to the orientation of the country rock. Dikes take advantage of fractures and faults in the country rocks. Dikes can sometimes push their way all the way to the surface. Otherwise, we see these dikes, sills, and batholiths at the surface after they have cooled, and overlying rock has been stripped off by erosion.