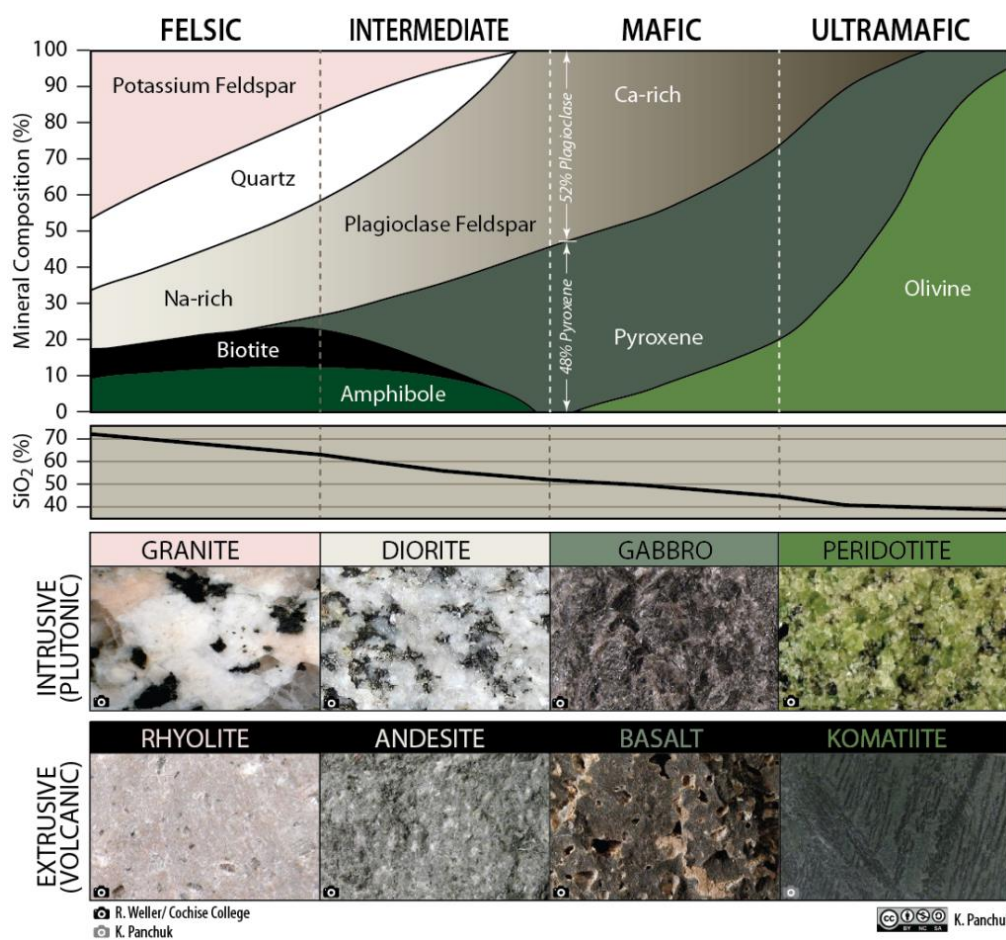


Classification of Igneous Rocks

Classification By Mineral Abundance

Igneous rocks can be divided into four categories based on their chemical composition: felsic, intermediate, mafic, and ultramafic. The diagram of Bowen's reaction series (Figure 7.6) shows that differences in chemical composition correspond to differences in the types of minerals within an igneous rock. Igneous rocks are given names based on the proportion of different minerals they contain. Figure 7.13 is a diagram with the minerals from Bowen's reaction series, and is used to decide which name to give an igneous rock.



7.13 Classification diagram for igneous rocks. Igneous rocks are classified according to the relative abundances of minerals they contain. A given rock is represented by a vertical line in the diagram. In the mafic field, the arrows represent a rock containing 48% pyroxene and 52% plagioclase feldspar. The name an igneous rock gets depends not only on composition, but on whether it is intrusive or extrusive. *Source: Karla Panchuk (2018) CC BY-NC-SA 4.0, modified after Steven Earle (2015) CC BY 4.0 [view source](#) and others, with photos by R. Weller/Cochise College. Click the image for links to photos and notes on image construction. [High-resolution version](#).*

To see how Figure 7.13 works, first notice the scale in percent along the vertical axis. The interval between each tick mark represents 10% of the minerals within a rock by volume. An igneous rock can be represented as a vertical line drawn through the diagram, and the vertical scale used to break down the proportion of each mineral it contains. For example, the arrows in the mafic field of the diagram represent a rock containing 48% pyroxene and 52% plagioclase feldspar. An igneous rock at the boundary between the mafic and ultramafic fields (marked with a vertical dashed line) would have approximately 20% olivine, 50% pyroxene, and 30% Ca-rich plagioclase feldspar by volume.

Classification By Grain Size

The name an igneous rock gets also depends on whether it cools within Earth (an **intrusive** or **plutonic** igneous rock), or whether it cools on the Earth’s surface after erupting from a volcano (an **extrusive** or **volcanic** igneous rock). For example, a felsic *intrusive* rock is called **granite**, whereas a felsic *extrusive* rock is called **rhyolite**. Granite and rhyolite have the same mineral composition, but their grain size gives each a distinct appearance.

The key difference between intrusive and extrusive igneous rocks—the size of crystals making them up—is related to how rapidly melted rock cools. The longer melted rock has to cool, the larger the crystals within it can become. Magma cools much slower within Earth than on Earth’s surface because magma within Earth is insulated by surrounding rock. Notice that in Figure 7.13, the intrusive rocks have crystals large enough that you can see individual crystals—either by identifying their boundaries, or seeing light reflecting from a crystal face. A rock with individual crystals that are visible to the unaided eye has a **phaneritic** or **coarse-grained** texture. The extrusive rocks in the second row have much smaller crystals. The crystals are so small that individual crystals cannot be distinguished, and the rock looks like a dull mass. A rock with crystals that are too small to see with the unaided eye has an **aphanitic** or **fine-grained** texture. Table 7.1 summarizes the key differences between intrusive and extrusive igneous rocks.

Table 7.1 Comparison of Intrusive and Extrusive Igneous Rocks

	Magma cools within Earth	Lava cools on Earth’s surface
Terminology	Intrusive/ plutonic	Extrusive/ volcanic
Cooling rate	Slow: surrounding rocks insulate the magma chamber.	Rapid: heat is exchanged with the atmosphere.

Table 7.1 Comparison of Intrusive and Extrusive Igneous Rocks

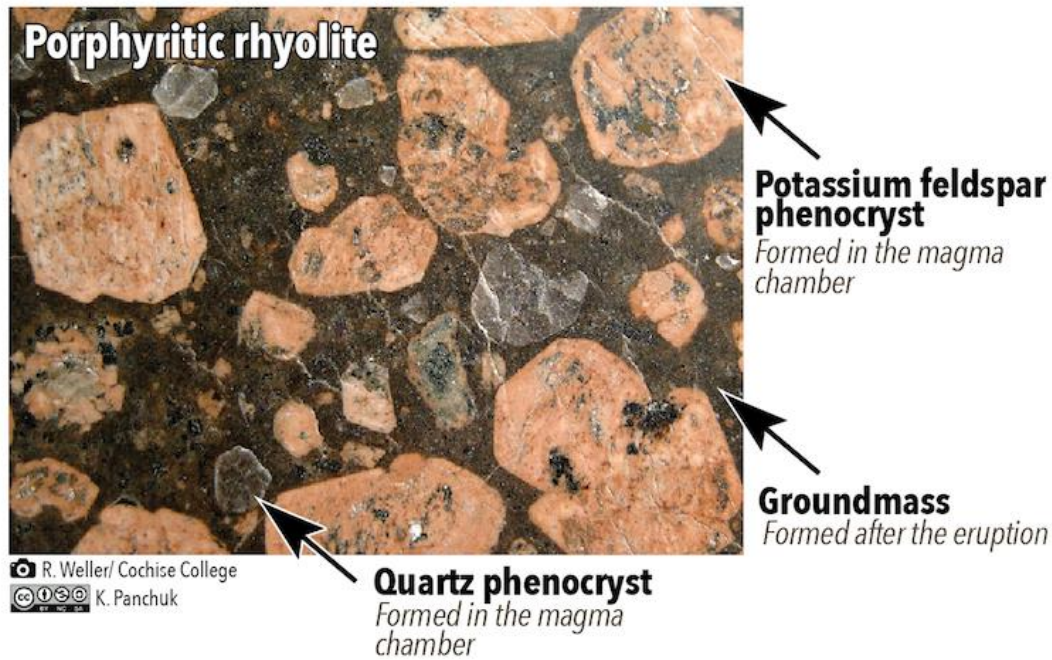
	Magma cools within Earth	Lava cools on Earth's surface
<i>Texture</i>	Phaneritic (coarse-grained): individual crystals are large enough to see without magnification.	Aphanitic (fine-grained): crystals are too small to see without magnification.

What this means is that two igneous rocks comprised of exactly the same minerals, and in the exactly the same proportions, can have different names. A rock of intermediate composition is **diorite** if it is coarse-grained, and **andesite** if it is fine-grained. A mafic rock is **gabbro** if it is coarse-grained, and **basalt** if fine-grained. The coarse-grained version of an ultramafic rock is **peridotite**, and the fine-grained version is **komatiite**. It makes sense to use different names because rocks of different grain sizes form in different ways and in different geological settings.

Does This Mean an Igneous Rock Can Only Have One Grain Size?

No. Something interesting happens when there is a change in the rate at which melted rock is cooling. If magma is cooling in a magma chamber, some minerals will begin to crystallize before others do. If cooling is slow enough, those crystals can become quite large.

Now imagine the magma is suddenly heaved out of the magma chamber and erupted from a volcano. The larger crystals will flow out with the lava. The lava will then cool rapidly, and the larger crystals will be surrounded by much smaller ones. An igneous rock with crystals of distinctly different size (Figure 7.14) is said to have a **porphyritic** texture, or might be referred to as a **porphyry**. The larger crystals are called **phenocrysts**, and the smaller ones are referred to as the **groundmass**.

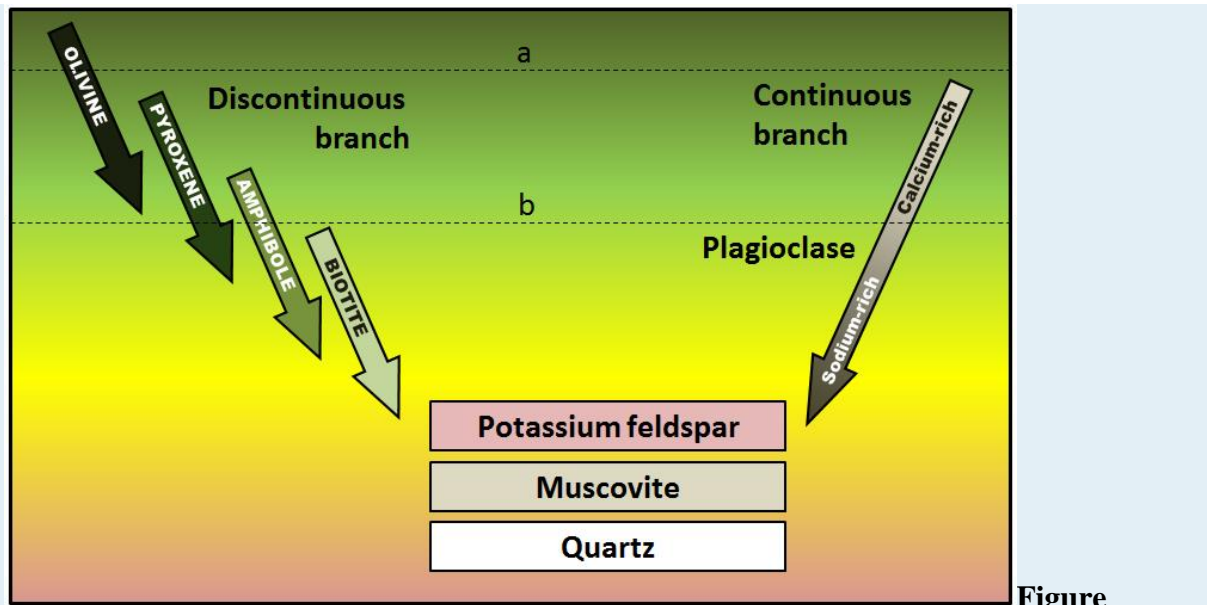


Figure

7.14 Porphyritic rhyolite with quartz and potassium feldspar phenocrysts within a dark groundmass. Porphyritic texture (when different crystal sizes are present) is an indication that melted rock did not cool at a constant rate. *Source: Karla Panchuk (2018) CC BY-NC-SA 4.0. Photo by R. Weller/Cochise College (2011) [view source](#)*

Exercise: Which Mineral Will the Phenocryst Be?

As a magma cools below 1300°C, minerals start to crystallize within it. If the magma is then erupted, the rest of the liquid will cool quickly to form a **porphyritic** texture. The rock will have some relatively large crystals (**phenocrysts**) of the minerals that crystallized early, and the rest will be very fine-grained or even glassy. Using the diagram shown here, predict what phenocrysts might be present where the magma cooled as far as line **a**. Which would be present where magma cooled to line **b**?



7.15 Bowen's reaction series. Source: Steven Earle (2015) CC BY 4.0 [view source](#)

Classifying Igneous Rocks According to the Proportion of Dark Minerals

If you are unsure of which minerals are present in an intrusive igneous rock, there is a quick way to approximate the composition of that rock. In general, igneous rocks have an increasing proportion of dark minerals as they become more mafic (Figure 7.16).

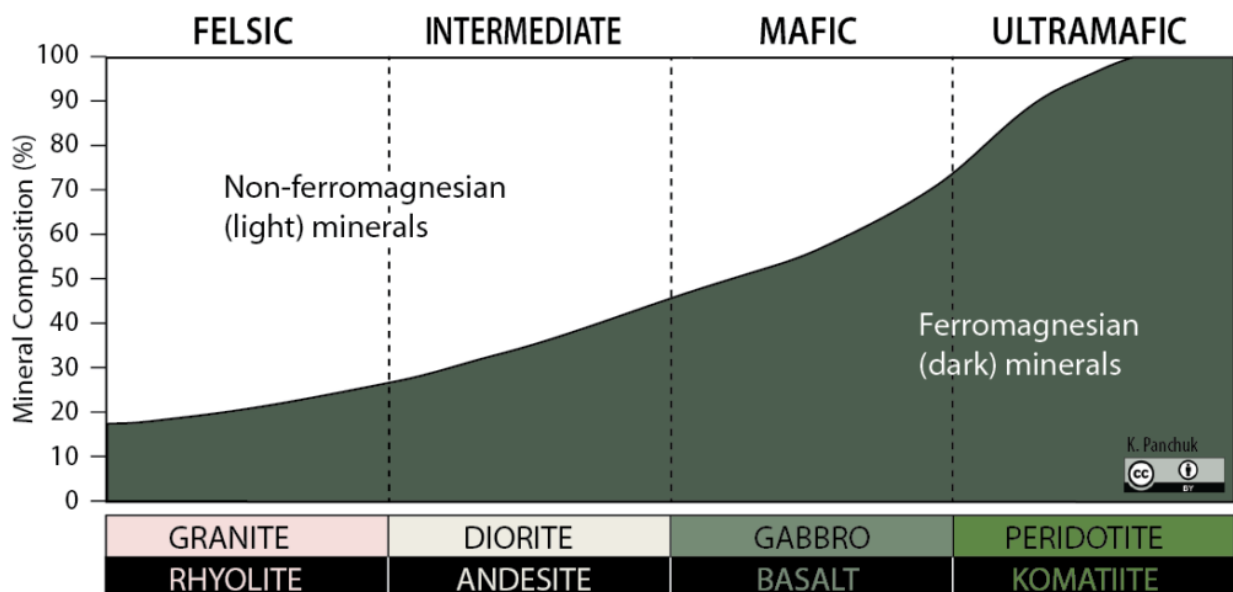


Figure 7.16 Simplified igneous rock classification according to the proportion of light and dark (or ferromagnesian) minerals. Source: Karla Panchuk (2018) CC BY 4.0, modified after Steven Earle (2015) CC BY 4.0 [view source](#)

The dark-coloured minerals are those higher in iron and magnesium (e.g., olivine, pyroxene, amphibole, biotite), and for that reason they are sometimes referred to collectively as **ferromagnesian** minerals. By estimating the proportion of light minerals to dark minerals in a sample, it is possible to place that sample in Figure 7.16. Graphical scales are used to help visualize the proportions of light and dark minerals (Figure 7.17).

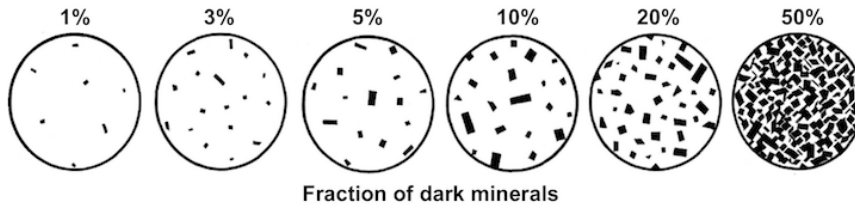


Figure 7.17 A guide for estimating the proportion of dark minerals in an igneous rock. *Source: Karla Panchuk (2018) CC BY 4.0, modified after Steven Earle (2015) CC BY 4.0 [view source](#)*

It is important to note that estimating the proportion of dark minerals is only approximate as a means for identifying igneous rocks. One problem is that plagioclase feldspar is light-coloured when it is sodium-rich, but can appear darker if it is calcium-rich. Plagioclase feldspar is not ferromagnesian, so it falls in the non-ferromagnesian (light minerals) region in Figure 7.16 even when it has a darker colour.

Exercise: Classifying Igneous Rocks by the Proportion of Dark Minerals

The four igneous rocks shown below have differing proportions of ferromagnesian silicates (dark minerals). Estimate the proportion of dark minerals using the guide in Figure 7.17, and then use Figure 7.16 to determine the likely rock name for each one.

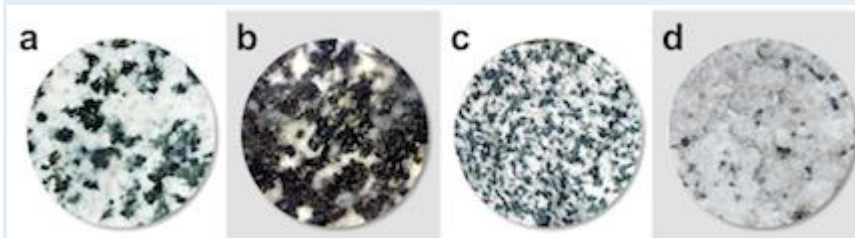
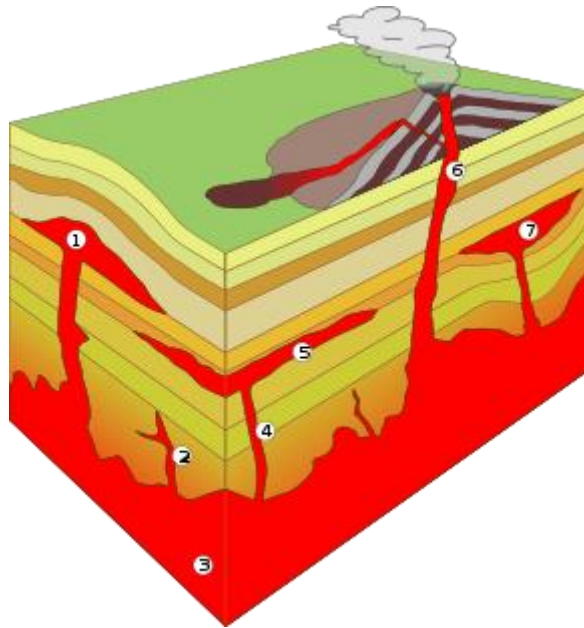


Figure 7.18 Identify these rocks by estimating the proportion of dark minerals in each sample. *Source: Karla Panchuk (2018) CC BY 4.0, modified after Steven Earle (2015) CC BY 4.0 [view source](#)*

Classifying Igneous Rocks When Individual Crystals Are Not Visible

The method of estimating the percentage of minerals works well for phaneritic igneous rocks, in which individual crystals are visible with little to no magnification. If an igneous rock is porphyritic but otherwise aphanitic (e.g., Figure 7.14), the minerals present as phenocrysts give clues to the identity of the rock. However, there are cases where mineral composition cannot be determined by looking at visible crystals. These include volcanic rocks without phenocrysts, and glassy igneous rocks.



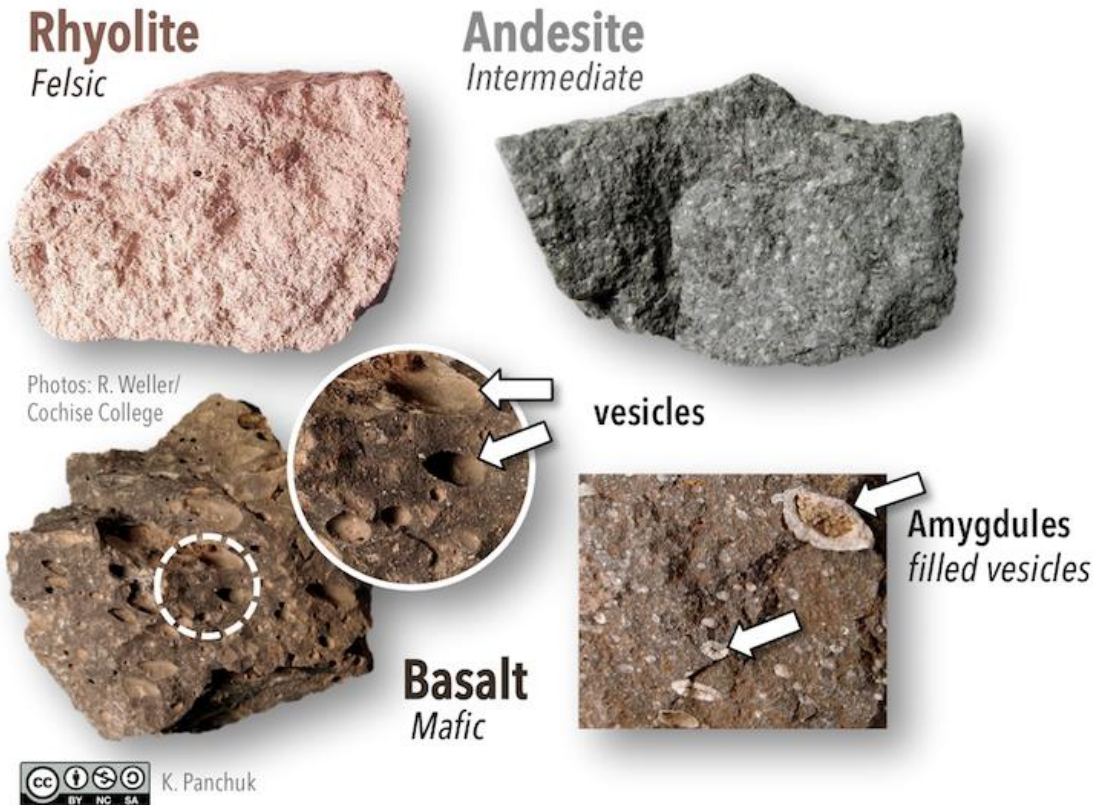
Basic types of intrusions:

1. [Laccolith](#)
2. Small [dike](#)
3. [Batholith](#)
4. Dike
5. [Sill](#)
6. [Volcanic neck](#), pipe
7. [Lopolith](#)

Note: As a general rule, in contrast to the smoldering volcanic vent in the figure, these names refer to the fully cooled and usually millions-of-years-old rock formations, which are the result of the underground magmatic activity shown.

Volcanic Rocks Without Phenocrysts

In the absence of visible crystals or phenocrysts, volcanic rocks are be classified on the basis of colour and other textural features. As you may have noticed in Figure 7.13, the colour of volcanic rocks goes from light to dark as the composition goes from felsic to mafic. Rhyolite is often a tan or pinkish colour, andesite is often grey, and basalt ranges from brown to dark green to black (Figure 7.19).



Figure

7.19 In volcanic igneous rocks, individual crystals are not visible. Colours change from light to dark as the composition of the rocks go from felsic to mafic. Vesicles and amygdules are common characteristics of basalt. *Source: Karla Panchuk (2018) CC BY-NC-SA 4.0. Photos by R. Weller/ Cochise College. Click the image for links to photos.*

Basalt often shows textural features related to lava freezing around gas bubbles. When magma is underground, pressure keeps gases dissolved, but once magma has erupted, the pressure is much lower. Gases dissolved in the lava are released, and bubbles can develop. When lava freezes around the bubbles, **vesicles** are formed (circular inset in 7.19). If the vesicles are later filled by other minerals, the filled vesicles are called **amygdules** (box inset in Figure 7.19).

Glassy Volcanic Rocks

Crystal size is a function of cooling rate. The faster magma or lava cools, the smaller the crystals it contains. It is possible for lava to cool so rapidly that no crystals can form. The result is called **volcanic glass**. Volcanic glass can be smooth like **obsidian** or vesicular like **scoria** (mafic) and **pumice** (felsic; Figure 7.20). Pumice can float on water because of its low-density felsic composition and enclosed vesicles.

Photos: R. Weller/Cochise College

Obsidian



K. Panchuk
CC BY-NC-SA

Vesicular rocks



Scoria

Red colour from oxidation
of iron during weathering



Pumice

Close-up view
showing vesicles

Figure

re 7.20 Glassy volcanic rocks. Obsidian has a glassy lustre, but scoria and pumice are highly vesicular. *Source: Karla Panchuk (2018) CC BY-NC-SA 4.0. Photos by R. Weller/Cochise College. Click the image for links to photos*