2 Matter and Minerals

Adapted by Lyndsay R. Hauber & Joyce M. McBeth (2018) University of Saskatchewan from Deline B, Harris R & Tefend K. (2015) "Laboratory Manual for Introductory Geology". First Edition. Chapter 7 "Minerals" by Randa Harris, CC BY-SA 4.0.

2.1 INTRODUCTION

Have you used a mineral yet today? While many people may initially say no, answer these questions: Have you brushed your teeth? Have you eaten anything that might contain salt? Did you put on make-up this morning, or do you have painted fingernails or toenails? Have you used a cellphone? What about a car, bike, or public transportation? If you have done any of those things, you have used at least one mineral, and in many cases you have used a great number of minerals. Minerals are very useful and common in everyday products, but most people do not even realize it.

A **mineral** is defined as a naturally occurring, inorganic solid, with a definite chemical composition and a characteristic crystalline structure. By naturally occurring, it means that anything man has created does not count as a mineral (e.g. Figure 2.1). To be an inorganic solid, the mineral must not be composed of the complex carbon molecules that are characteristic of life and must be in the solid state, rather than vapor or liquid. This means that water, a liquid, is not a mineral, while ice, a solid, would be, as long as it is not man-made. A definite chemical composition refers to the chemical formula of a mineral. For most minerals, this does not vary (e.g. halite is NaCl), though some minerals have a range of compositions, since one element can substitute for another of similar size and charge (e.g. olivine is $(Mg,Fe)_2SiO_4$, and the magnesium and iron content can vary). The atoms within minerals are lined up in an orderly fashion, so that the characteristic crystalline structure is just an outward manifestation of the internal atomic arrangement.

Figure 2.1 | Synthetic Bismuth.
Source: Philippe Giabbanelli (2010) CC BY-SA 3.0

Minerals are not only important for their many uses, but also as the building blocks of rocks. In this lab, you will lay the foundation for all the future rock labs in the course. Correct mineral identification is critical in geology, so work through this lab carefully. There are several thousand minerals, but we will focus on only twenty-one of the most common ones.

2.1.1 Learning Outcomes

After completing this chapter, you should be able to:

- Know the definition of a mineral
- Understand the many different physical properties of minerals, and how to apply them to mineral identification
- Be able to distinguish mineral cleavage from mineral fracture
- Identify 21 minerals

2.1.2 Key Terms

- Cleavage
- Crystal Form
- Fracture
- Hardness
- Lustre
- Mineral
- Specific Gravity
- Streak
- Tenacity

2.2 PHYSICAL PROPERTIES

Identifying a mineral is a little like playing detective. Minerals are identified by their physical properties. How would you describe the mineral in Figure 2.2? You may say that it is shiny, gold, and has a particular shape. Each of these descriptions is a physical property (shiny is lustre, gold is colour, shape is crystal form). Physical properties can vary within the same minerals, so caution should be applied when identifying minerals. For example, colour is a property that is not a very realistic diagnostic tool in many cases, as some minerals, such as Quartz, can come in a variety of colours (e.g. Figure 2.3). Occasionally, colour can be helpful, as in the case of olivine, which is said to be "olive green", a light to dark green (e.g. Figure 2.4). We will cover each of the physical properties in detail to help you identify the minerals.

Figure 2.2 | Describe this mineral. Source: Randa Harris (2015) CC BY-SA 3.0

Figure 2.3 | Examples of the different varieties of quartz (jasper, rose quartz, smoky quartz, agate, amethyst, citrine, and petrified wood), demonstrating the difficulty of identifying this mineral.
Source: Randa Harris (2017) CC BY-SA 3.0

Figure 2.4 | The mineral olivine has an "olive green" colour.
Source: Joyce M. McBeth (2018) CC BY 4.0

2.2.1 Hardness

Hardness refers to the resistance of a mineral to being scratched by a different mineral or other material and is a product of the strength of the bonds between the atoms of a mineral. Whatever substance does the scratching is harder; the item scratched is softer. Hardness is based off a scale of 1 to 10 created by a mineralogist named Friedrich Mohs (e.g. Figure 2.5). Mohs' scale lists ten minerals in order of relative hardness. Each mineral on the scale can scratch a mineral of lower number. Your mineral kit comes with several items of a known hardness. The glass plate has a hardness of 5.5, the iron nail has a hardness of 4 , the copper coin has a hardness of 3, and your fingernail has a hardness of 2.5. If you can scratch a mineral, then it would be softer than your fingernail, so therefore its hardness would be <2.5. When trying to scratch a surface, use force, but be cautious with the glass plate. **ALWAYS lay the glass plate on a flat surface rather than holding it in your hand in case it breaks.** Do not confuse mineral powder with a scratch – use your finger to feel for a groove created by a scratch (mineral powder is left behind when a soft mineral scratches a harder surface). Materials of similar hardness have difficulty scratching each other, so that, for example, your fingernail may not be able to always scratch biotite, which has a hardness of 2.5.

Number	Mineral	Relative Hardness
1	Talc	(softest mineral)
2	Gypsum	2.5 – Fingernail
3	Calcite	3 – Copper Coin
4	Fluorite	4 – Nail
5	Apatite	5.5 – Glass Plate
6	Orthoclase Feldspar	
7	Quartz	
8	Topaz	
9	Corundum	
10	Diamond	(hardest mineral)

Figure 2.5 | Mohs' Scale of Hardness
Source: Randa Harris (2015) CC BY-SA 3.0

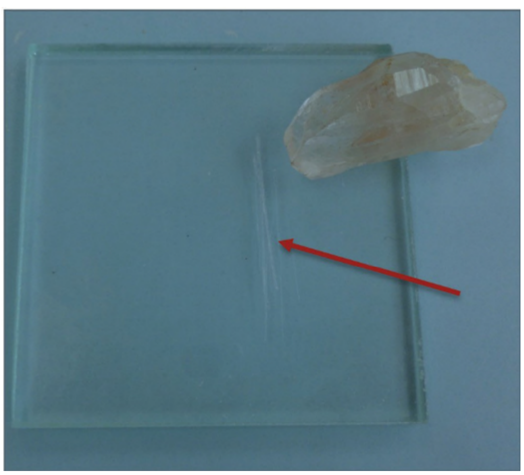

Figure 2.6 | An example of a scratch made by the mineral quartz on a streak plate. The red arrow is pointing to the scratch. Quartz, therefore, is harder than glass.
Source: Randa Harris (2015) CC BY-SA 3.0

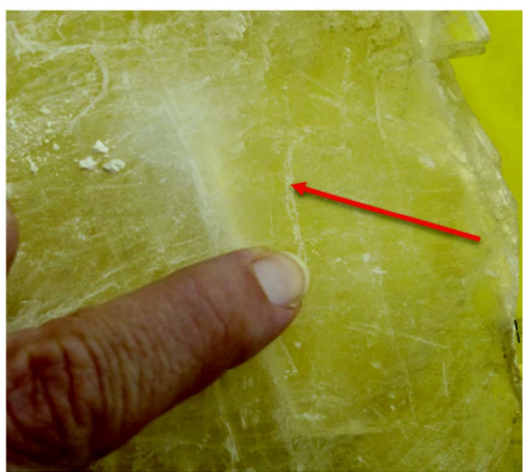

Figure 2.7 | An example of a scratch made by a fingernail on the mineral gypsum. The red arrow is pointing to the scratch. Gypsum, therefore, is softer than a fingernail.
Source: Randa Harris (2015) CC BY-SA 3.0

2.2.2 Crystal Form

This property refers to the geometric shape that a crystal naturally grows into, and is a reflection of the orderly internal arrangement of atoms within the mineral. If minerals have space to grow when they are developing, they will display their **crystal form**. These ideal growth conditions do not always occur, however, so many minerals do not display their ideal crystal form due to crowded conditions during growth. Examples of crystal form are shown in Figure 2.8.

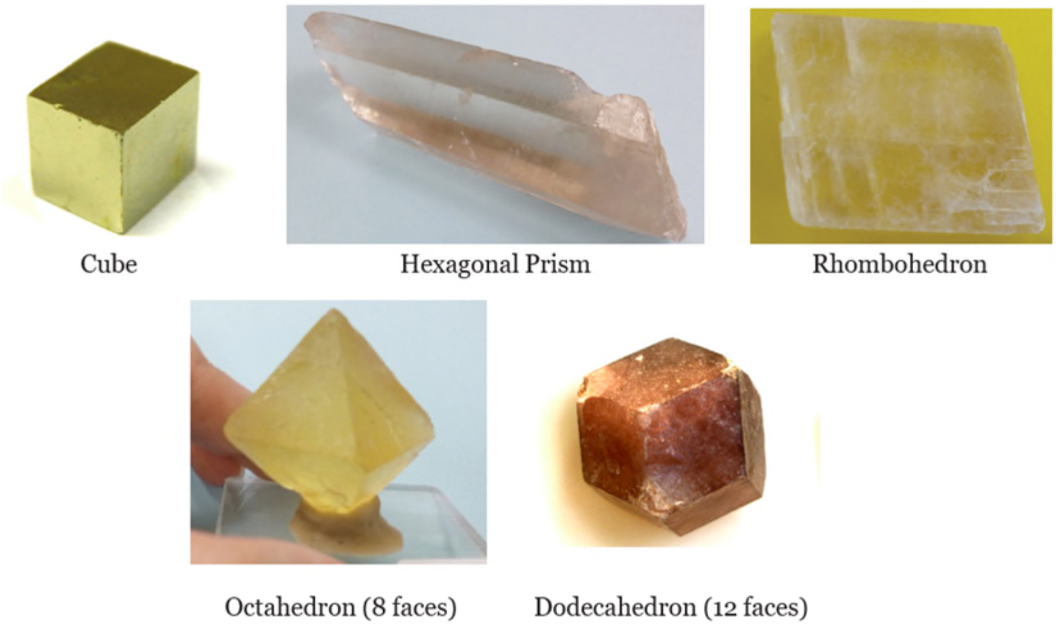

Figure 2.8 | Examples of crystal form.
Source: Lyndsay Hauber & Joyce M. McBeth (2018) CC BY 4.0, after Randa Harris (2015) CC BY-SA 3.0

2.2.3 Cleavage

As minerals are broken (such as with a rock hammer, for example), some may cleave, or break, along smooth flat planes known as **cleavage**. These flat surfaces are parallel to directions of weakness within the crystal. All the bonds among the atoms within a mineral may not be of the same strength, so that when a mineral is broken, it breaks along these zones of weakness. This results in flat cleavage planes. Minerals with perfect cleavage break along a smooth, flat plane, while those with poor cleavage break in a more irregular fashion. Some minerals do not contain zones of weakness either because all of the bonds are the same strength or the weaker bonds are not aligned within a plane. If this is the case it will not have cleavage, but rather breaks in a random and irregular fashion. Make sure to distinguish cleavage from crystal form. Crystal form occurs as a mineral *grows*, while cleavage only forms as a mineral *breaks*. See Figure 2.9 for the main types of cleavage and an example of each.

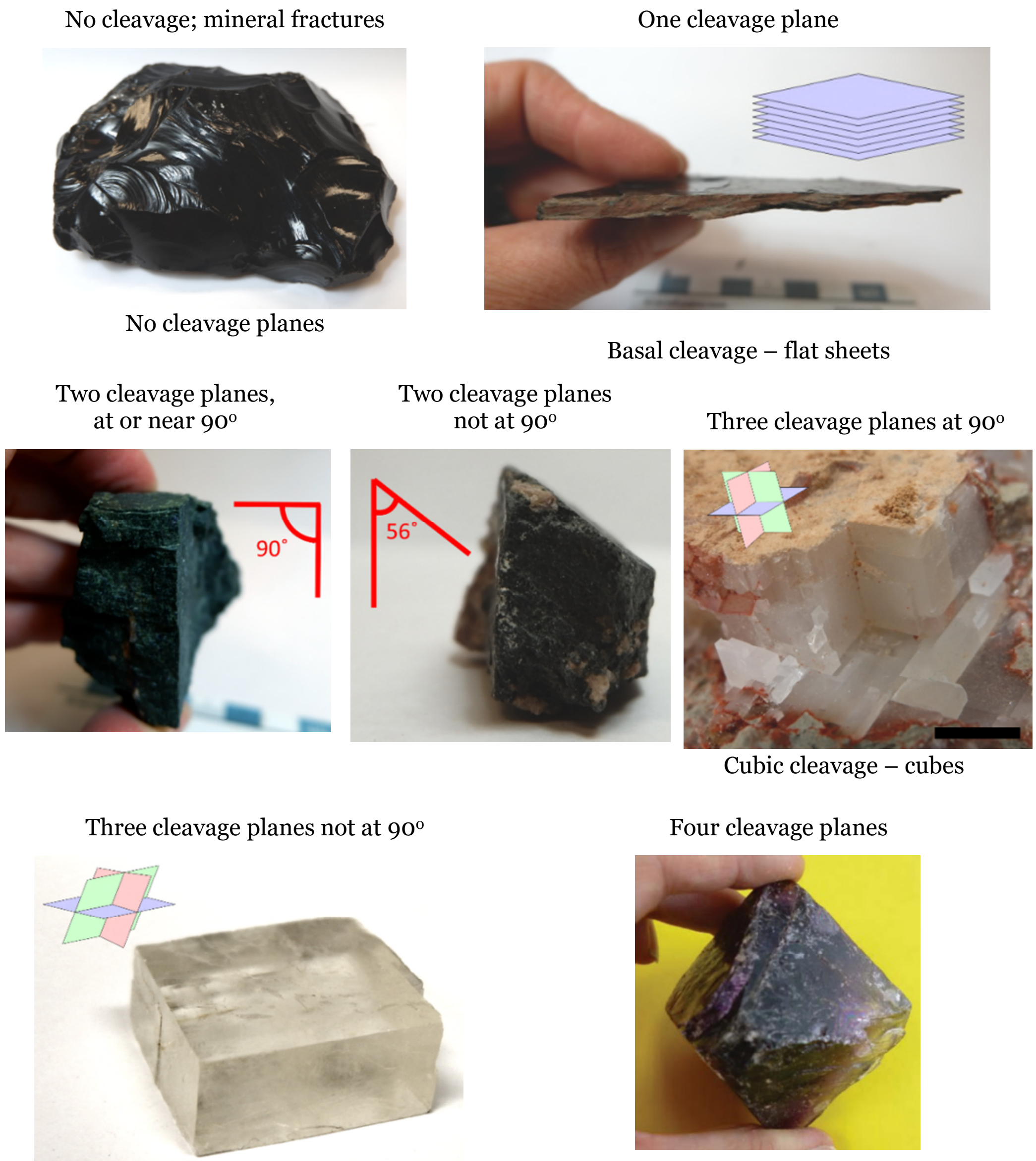

Figure 2.9 | Main types of cleavage, along with illustrations indicating the cleavage angles and directions.
Source: Lyndsay Hauber & Joyce M. McBeth (2018) CC BY 4.0, after Randa Harris (2015) CC BY-SA 3.0

A mineral may have one or more cleavage planes. Planes that are parallel are considered the same direction of cleavage and should only count as one. One direction of cleavage is termed basal cleavage. Minerals that display this cleavage will break off in flat sheets. Two directions of cleavage is termed prismatic, while three directions of cleavage at 90° is referred to as cubic. A mineral with four directions of cleavage is termed octahedral. With 2 or more cleavage planes present, it is important to pay attention to the angle of the cleavage planes. To determine the angle of cleavage, look at the intersection of cleavage planes. Commonly, cleavage planes will intersect at 60°, 90° (right angles), or 120°. Be cautions when you see a flat surface on a mineral - not every flat surface is a cleavage plane. Crystal faces can be flat, but remember they form as a mineral grows, while cleavage forms as a mineral breaks. The crystal form of quartz is a hexagonal prism, with nice flat sides. But when quartz is hit with a rock hammer, it breaks in an irregular fashion and does not exhibit cleavage. Also use caution when trying to distinguish the minerals pyroxene and amphibole. Both minerals are black or greenish-black, with similar hardness, making them difficult to tell apart. You must observe the cleavage angles to tell them apart. Cleavage angles in pyroxene are near 90º, so expect it to look boxy and form right angles, while cleavage angles in amphibole are 60º and 120º, so expect a more bladed or pyramid like appearance (e.g. Figure 2.10).

Figure 2.10 | Comparison of cleavage angles between amphibole and pyroxene. Amphibole has cleavage angles at or near 60º and 120º, and pyroxene has angle at or near 90º. Source: Joyce M. McBeth (2018) CC BY 4.0, after Randa Harris (2015) CC BY-SA 3.0

2.2.4 Fracture

When minerals do not break along cleavage planes, but rather break irregularly, they are said to **fracture**. Commonly fracture surfaces are either uneven or conchoidal, a ribbed, smoothly curved surface similar to broken glass (e.g. Figure 2.11).

Figure 2.11 | This piece of igneous rock called obsidian has been hit with a hammer and is displaying conchoidal fracture. Source: Joyce M. McBeth (2018) CC BY 4.0

2.2.5 Lustre

Lustre refers to the appearance of the reflection of light from a mineral's surface. It is generally broken into two main types: metallic and non-metallic. Minerals with a metallic lustre have the colour of a metal, like silver, gold, copper, or brass (e.g. Figure 2.12). While minerals with a metallic lustre are often shiny, not all shiny minerals are metallic. Make sure you look for the colour of a metal, rather than for just a shine. Minerals with non-metallic lustre do not appear like metals. They may be vitreous or glassy (e.g. Figure 2.13A), earthy or dull (e.g. Figure 2.13B), waxy (e.g. Figure 2.13C), greasy or oily, etc.

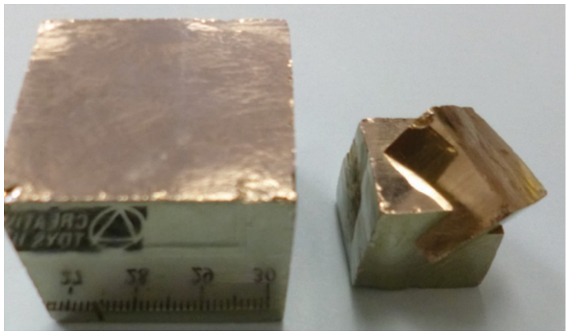

Figure 2.12 | Examples of the metallic lustre of pyrite, also known as "fool's gold."
Source: Randa Harris (2015) CC BY-SA 3.0

Figure 2.13A | Example of a vitreous, or glassy, lustre.
Source: Randa Harris (2015) CC BY-SA 3.0

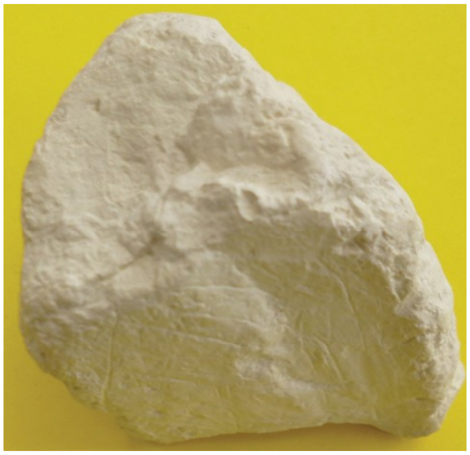

Figure 2.13B | Example of an earthy, or dull. lustre.
Source: Randa Harris (2015) CC BY-SA 3.0

Figure 2.13C | Example of a waxy lustre.
Source: Randa Harris (2015) CC BY-SA 3.0

2.2.6 Streak

Streak is an easily detectable physical property. It refers to the colour left behind on an unglazed piece of porcelain when a mineral is rubbed along its surface. A streak plate is included in your rock and mineral kit to test this property. Often a mineral will have a streak of a different colour than the colour of the mineral (e.g. pyrite has a dark grey streak, Figure 2.14). Some minerals will have a white streak, which is difficult to see along the white streak plate. If you rub a mineral along the streak plate and do not see an obvious streak, wipe your finger along the streak plate. A mineral with a white streak will leave a white powder behind that will rub on your finger (e.g. Figure 2.15).

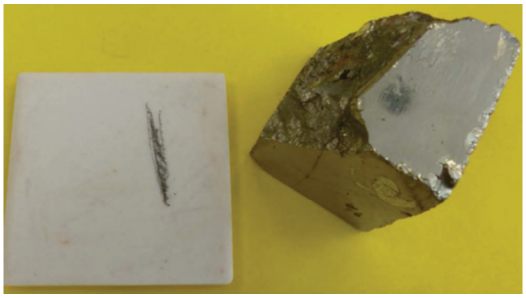

Figure 2.14 | An example of the dark grey streak left behind when pyrite is rubbed along a streak plate.
Source: Randa Harris (2015) CC BY-SA 3.0

Figure 2.15 | An example of the white streak (on finger) left behind when fluorite is rubbed along a streak plate.
Source: Randa Harris (2015) CC BY-SA 3.0

2.2.7 Special Physical Properties

Several minerals have unique properties that aid in their identification. **Tenacity** refers to the way a mineral resists breakage. If a mineral shatters like glass, it is said to be brittle (like quartz), while minerals that can be hammered are malleable (e.g. Figure 2.16).

Figure 2.16 | Copper, which can be hammered into thin sheets, is malleable.
Source: Randa Harris (2015) CC BY-SA 3.0

Figure 2.17 | Muscovite mica, which bends but returns to its original shape, is elastic.
Source: Randa Harris (2015) CC BY-SA 3.0

Minerals may be elastic, in which they are flexible and bend like a plastic comb, but return to their original shape (e.g. Figure 2.17). Sectile minerals are soft like wax, and can be separated with a knife (e.g. gypsum).

Some minerals react when dilute hydrochloric acid is placed on them. Carbonate minerals (minerals that include CO_3 in their chemical formula) will effervesce or fizz when acid is applied to them. When you test a mineral with acid, be cautious and use just a drop of the acid. Use your magnifying glass to look closely for bubbles (e.g. Figure 2.18). The acid is very dilute and will not burn your skin or clothing, but wash your hands after use. Also make sure that you rinse with water and wipe off the acid from the minerals that you test.

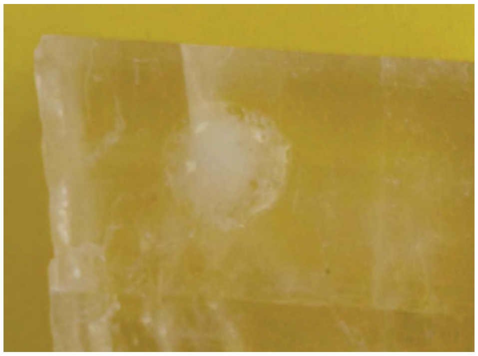

Figure 2.18 | Note the effervescing acid bubbles at the red arrow on this piece of calcite.
Source: Randa Harris (2015) CC BY-SA 3.0

Minerals may be magnetic, and this property is simply tested by seeing if your nail is attracted to a mineral. Magnetite is an example of a magnetic mineral. The mineral halite is simply table salt, so it will taste salty. Sphalerite will release a sulphuric smell when streaked, and talc will feel soapy when touched.

Specific gravity is the ratio of a mineral's weight to the weight of an equal volume of water. A mineral with a specific gravity of 2 would weigh twice as much as water. Most minerals are heavier than water, and the average specific gravity for all minerals is approximately 2.7. Some minerals are quite heavy, such as pyrite with a specific gravity of 4.9-5.2, native copper, with a specific gravity of 8.8-9.0, and native gold at 19.3, which makes panning useful for gold, as the heavy mineral stays behind as you wash material out of the pan.