Lab 3 - Identification of Silicate Minerals

Introduction

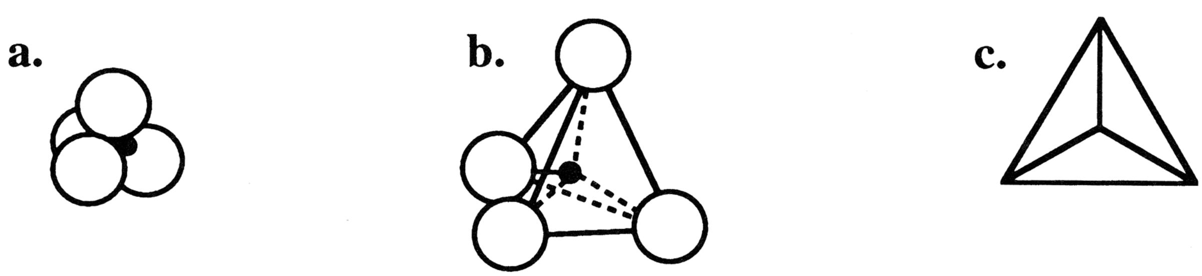
Silicate minerals or the "rock forming" minerals are those that make up the majority of the rocks in the earth's crust. Although there are hundreds of different types of rocks that make up the earth's crust , there are only a few minerals, 15 or so, that make up most of the crustal rocks. The identification of these minerals is, therefore, vital in order to be able to recognize different types of rocks.

Classification of Silicate Minerals

The basic compositional unit of all silicate minerals is the silicon-oxygen tetrahedron (often abbreviated Si-O tetrahedron). It consists of one silicon cation (Si^{-4}) surrounded by 4 oxygen anions (O^{-2}) in a 4-sided pyramid arrangement known as a tetrahedron. The diagram below illustrates three different ways of viewing a silicon-oxygen tetrahedron. Chemically the silicon-oxygen tetrahedron has a net electrical charge of -4:

$$(SiO_4)^{-4}$$

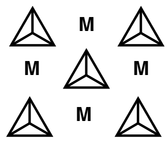
Since minerals are chemical compounds which can not have an electric charge, this charge is balanced by the addition of metals, which are all positively charged. Different arrangements of metals and tetrahedrons within a silicate mineral's crystal structure create the major subclasses of silicate minerals. Each subclass has a general set of physical properties which aid in the recognition of silicate minerals within a given subclass.



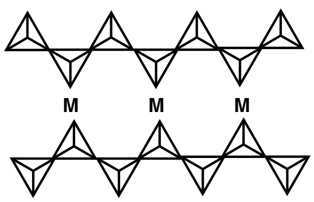
Three illustrations of the silicon-oxygen (Si-O) tetrahedron. Four oxygens anions (open circles) surrounding a small silicon cation (small solid circle). a. true atomic view, b. expanded view to show the tetrahedral (4-sided pyramid) shape, c. schematic view used in further figures.

Silicate Mineral Subclasses

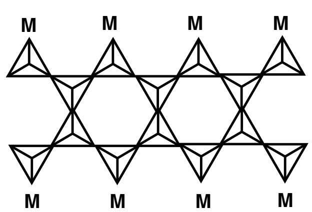
M = metal,  = Si-O tetrahedron



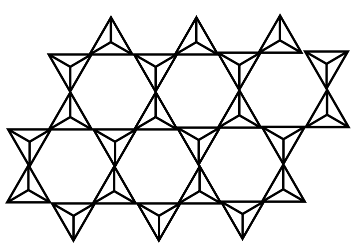
Isolated Tetrahedra Silicates
- Olivine
- Garnet
- Kyanite



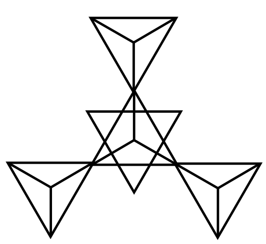
Single Chain Tetrahedra Silicates
- Augite



Double Chain Tetrahedra Silicates
- Hornblende



Sheet Tetrahedra Silicates
- Muscovite
- Biotite
- Talc
- Chlorite
- Clays



Framework Tetrahedra Silicates
- Orthoclase
- Sodium Plagioclase
- Calcium Plagioclase
- Quartz

Isolated Tetrahedra Silicates

The structure of the isolated silicates subclass is that each tetrahedra is surrounded by metals and so is “isolated” from other tetrahedra. The chemical bonds that connect the metals to the tetrahedra are very strong covalent bonds. So, in general, isolated silicates tend to be very hard ($H > 6$) and tend to lack cleavage (such as olivine and garnet). Kyanite is the oddball of this subclass since, although it is very hard in the long direction of its tabular crystals, it does have cleavage (but fair to poor cleavage only).

Single Chain Tetrahedra Silicates

The term ‘polymerize’ means to create complex chemical structures by repeating simpler structures. Si-O tetrahedra can polymerize by sharing oxygens between tetrahedra. In a single chain silicate, each tetrahedron shares 2 oxygens with its neighbors, thus creating long chains of tetrahedra. Individual chains are bonded to each other by rows of metals to create a crystalline structure. Oxygen sharing is a very strong covalent bond, so the chains are hard to break. This makes the single chain silicates fairly strong (most have $H = 6$). However, the metals that hold the chains do so with weak ionic bonds. This introduces a prismatic cleavage at nearly 90^o (roughly 88^o by 92^o). Augite is the most common of the single chain silicates.

Double Chain Tetrahedra Silicates

These silicates share ~ 3 oxygens with each other in long sets of double chains separated by rows of metals. Like single chain silicates, this subclass tends to be quite hard ($H = 6$) and have prismatic cleavage. The double chain structure causes a strong angle in the prismatic cleavage such that the cleavage planes meet at 56^o by 124^o. Cleavage fragments of hornblende, the most common double chain silicate tend to have a diamond shape perpendicular to their long direction because of this angled prismatic cleavage.

Sheet Tetrahedra Silicates

In this silicate subclass, each tetrahedron shares 3 oxygens with its neighbors creating infinite sheets of silicate tetrahedra. These sheets are then stacked up like pages in a book with the individual sheets held together by metals and or by water molecules. Although the individual sheets are strong, the bonds that hold the sheets together are Van der Waal’s Forces, the weakest known chemical bonds. Because of these extremely weak bonds, sheet silicates tend to be very soft ($H = 1$ to 2.5) and all have one good direction of cleavage. Clays are microscopic-sized sheet silicates, and far too small to see cleavage, but are nonetheless some of the softest known minerals. Talc, biotite and muscovite are the 3 common sheet silicates found in rocks.

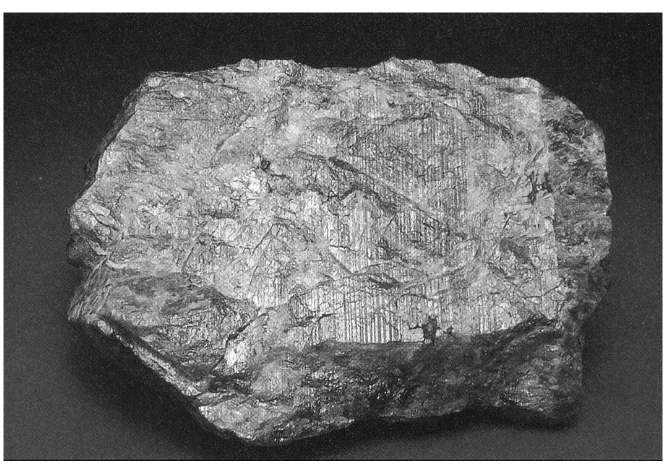
Framework Tetrahedra Silicates

Each Si-O tetrahedron in a framework silicate shares all 4 of its oxygens with neighboring tetrahedra. When absolutely pure, this creates one of the most abundant minerals in the earth’s crust; quartz (SiO_2). Quartz is a very hard mineral ($H = 7$) and has conchoidal fracture owing to the covalent bonding between all shared oxygens.

When metals are jammed in between the three dimensional structure of a framework silicate, they introduce weaknesses in the structure and create another extremely abundant group of rock forming minerals; the feldspars.

Feldspars are further separated chemically into 2 groups; potassium feldspars and plagioclase feldspars. Potassium feldspars (the most common of which is orthoclase, or more properly, orthoclase feldspar) are mainly pink, but may also be gray, red, orange and rarely green. Close examination of orthoclase cleavage fragments reveals small, wavy growth lines called perthitic intergrowths; caused by minute amounts of sodium impurities in the orthoclase crystal structure. The plagioclase feldspars are a complex group of framework silicates whose chemistry can vary from pure sodium varieties (generally white) to pure calcium varieties (very dark gray). All plagioclase feldspars grow as groups of thin plates that look like tiny books stacked on a book shelf. The edges of these ‘books’ appear as thin parallel lines on cleavage fragments and on crystal faces. These tiny lines are called striations and are a diagnostic physical property of all plagioclase feldspars. Orthoclase feldspar lacks these striations. All feldspars, orthoclase and plagioclase vaieities alike, have prismatic cleavage at 90^o and all feldspars have a hardness of 6.

Perthitic intergrowths on a cleavage surface of orthoclase feldspar.



Striations on a cleavage surface of sodium plagioclase feldspar.

Identification of Silicate Minerals

Mineral identification of silicate minerals is similar to that of nonsilicates with one very important exception; there are NO metallic silicate minerals. The nonmetallic luster of these minerals can vary from vitreous (or glassy) to pearly to satiny to dull, but none are metallic. This means that streak is not a useful property for the identification of nonsilicates and should be avoided because although nonmetallic minerals may give a light-colored streak, it is inconsistent from sample to sample.

The best approach to the identification of a silicate mineral is to first place it into it's proper silicate mineral subclass and then check hardness, cleavage, color, special properties closely to narrow down the name. Group properties for the silicate subclasses are as follows:

Isolated Silicates	- H = 6.5 or greater, conchoidal fracture (except kyanite)
Single Chain Silicates	- H = 6, prismatic cleavage at approximately 90^{o}
Double Chain Silicates	- H = 6, prismatic cleavage not at 90^{o}
Sheet Silicates	- H = 2.5 or less, one good direction of cleavage
Framework Silicates	- H = 7, conchoidal fracture (a variety of quartz) - H = 6, prismatic cleavage at 90^{o}

Since quartz is one of the most abundant of the rock forming minerals, you should further identify the variety of quartz that you have using the following criteria:

COLOR	VARIETY
- clear crystals	Rock Crystal
- purple	Amethyst
- red	Rose Quartz
- white	Milky Quartz
- gray to black	Smoky Quartz
- fine-grained red	Jasper
- fine-grained white to light gray	Chert
- fine-grained dark gray to black	Flint
- fine-grained banded	Agate

H.	Cleavage / Fracture	Other Properties	Name
Soft	basal (good)	H = 1; SG = 2.82; white, pale green or gray in color; soft and soapy feeling to the touch	**Talc**
	basal, but not visible do to their microscopic size	H = 1 to 1.5; SG = variable, soft and powdery feel; earthy smell when breathed on; irregular lumps with no apparent cleavage	**Clays**
	basal (good)	H = 2.5; SG = 2.8; transparent in thin sheets; highly elastic in thin sheets; clear to silvery colored	**Muscovite**
	basal (good)	H = 2.5; SG = 2.9 - 3.4; translucent to opaque in thin sheets; highly elastic in thin sheets; dark brown to black in color	**Biotite**
	basal (poor)	H = 2.5; SG = 2.7 - 3.3; dark green in color; flexible in thin sheets; plastic-looking, tends to have a ‘crushed’ appearance	**Chlorite**
Med	prismatic (fair) at 90^o	Platey to tabular crystals; H = 4 in the long direction, 7 in the short; light gray to pale blue in color	**Kyanite**
Hard	prismatic (fair) at 90^o	H = 6; SG = 2.56,’flesh’ pink to light gray in color; contains perthitic intergrowths (irregular or wavy color markings) due to crystal growth	**Orthoclase (K-feldspar)**
	prismatic (fair) at 90^o	H = 6; SG = 2-6 - 2.75; dirty white in color; striations present on cleavage fragments	**Sodium Plagioclase**
	prismatic (fair to poor) at 90^o	H = 6; SG = 2-6 - 2.75; dark gray in color; some parts may show a play of colors; striations present on cleavage fragments	**Calcium Plagioclase**
	prismatic (fair to poor) at 90^o	H = 6; SG = 3.2 - 3.6; dark green in color; cleavage fragments are stubby	**Augite (pyroxene)**
	prismatic (fair to poor) NOT at 90^o	H = 6; SG = 3 - 3.4; long, jet black cleavage fragments; commonly with tiny biotite flakes in the fragments; cleavage at 56^o and 124^o	**Hornblende (amphibole)**
	irregular fracture	H = 6.5 - 7, SG = 3.2 - 3.4; granular masses that are fine-grained light green; ‘sugary-looking’ in appearance;	**Olivine**
	conchoidal fracture	H = 6.5 - 7.5; SG = 3.6 - 4.3; color varies but dark red and reddish brown most common; crystals are rounded and 12-sided with diamond-shaped faces	**Garnet**
	conchoidal fracture	H = 7; SG = 2.65; breaks like glass, very fine-grained with very sharp breaks; commonly light gray (chert), dark gray to black (flint) or reddish brown (jasper)	**Quartz (fine-grained)**
	conchoidal fracture	H = 7; SG = 2.65; looks and breaks like glass; when pure is clear, but may be any color; may show 6-sided crystals with pointed ends	**Quartz (crystalline)**

SILICATE MINERAL FORM

Mineral Name	Two Characteristic Physical Properties

Lab 3 - Silicate Minerals

1. What elements are present in all silicate minerals?

2. How are the silicon and oxygen atoms arranged within a silicate mineral?

3. What is the electrical charge of a silicon-oxygen tetrahedron?

4. Can minerals have a positive or negative electrical charge?

5. What type of chemical bonding links silicon-oxygen tetrahedra together? Is this a weak or strong type of chemical bonding?

6. What type of bonding dominates between silicon-oxygen tetrahedron and metal atoms in single-chain tetrahedra silicates?

7. The framework tetrahedra silicate mineral quartz is bonded together exclusively by which type of chemical bonding?

8. Is quartz hard and lacking significant cleavage? Does this answer make sense based on your reply to question #7?

9. What type of chemical bonding binds the sheets in a sheet tetrahedra silicate? Is this a weak or strong type of chemical bonding?

10. What type of cleavage do all sheet tetrahedra silicate minerals have?

11. Does it make sense that sheet tetrahedra silicate minerals tend to be soft? Explain in detail.

12. How does one discern the difference between the minerals muscovite, biotite and chlorite?

13. Why does all quartz specimens not form large beautiful crystals?

14. Precisely how does one tell the difference between the minerals augite and hornblende? Think about clues that could be helpful on the upcoming mineral quiz.

15. Describe the difference between irregular and conchoidal fracture.