Mineralogy Boot Camp Session #2

Mineralogy and Elemental Abundance

Minerals are composed of chemical elements, the basic building blocks of matter. Although over 5,000 different minerals have currently been identified, the most commonly-occurring minerals in the crust are composed of just a few of the 92 naturally-occurring elements. Only eight elements, listed in Table 1, are used to build about 99% (by weight) of the minerals in Earth's crust.

Oxygen is by far the most abundant element in the crust. As shown in the second column of Table 1, oxygen by itself makes up nearly half of the crust (or 94% of the crust if one is just counting atoms, not relying on their weight). Silicon makes up over one-quarter of the crust, so together with oxygen, three-fourths of Earth's crust is composed of just two elements. The six other common elements (hereby defined as having a crustal abundance of over 1%), along with their relative abundances, are listed in Table 1.

Comparing the chemical composition of the whole Earth (Table 1, third column) to just the crust, one can see that a slightly different small set of eight elements comprise the vast majority of this planet. Iron and nickel are the main ingredients of Earth's core and thus are significantly enriched as compared to their average abundance in the crust. In addition, sulfur is particularly abundant in Earth's outer core and thus is elevated over 1% abundance despite its low average concentration in the crust. Sodium and potassium are enriched enough in the crust to occur at above 1% average abundance, but are significantly less common in the mantle and core.

Table 1. Earth's Common Chemical Elements

Element	Percent abundance in Earth's crust (by weight)	Percent abundance in whole Earth (by weight)
Oxygen (O)	46.1	30.1
Silicon (Si)	28.2	15.1
Aluminum (Al)	8.2	1.4
Iron (Fe)	5.6	32.1
Calcium (Ca)	4.2	1.5
Sodium (Na)	2.4	0.125
Magnesium (Mg)	2.3	13.9
Potassium (K)	2.1	0.014
Sulfur (S)	0.035	2.9
Nickel (Ni)	0.008	1.8
All other elements combined	Less than 0.9	Less than 1.1

Most economically important elements, such as copper (Cu), lead (Pb), and gold (Au), occur in the crust at very low levels (measured in parts per million (ppm), where 10,000 ppm = 1%). For those three example elements, the average concentration in the crust for copper is 60 ppm, for lead is 14 ppm, and for gold is 0.004 ppm. These elements become valuable when geologic processes in the crust cause them to become more concentrated. Other, more abundant elements rarely concentrate because the atomic size and charge allows them to easily substitute at low levels for more common elements in numerous mineral structures. For example: strontium (Sr), which has a crustal abundance of 370 ppm, frequently substitutes for calcium; rubidium (Rb), which has a crustal abundance of 90 ppm, frequently substitutes for potassium.

The large abundance of oxygen and silicon in Earth's crust means that the vast majority of minerals in the crust are classified as *silicate* minerals. Silicates are minerals that use the silica tetrahedron (a framework of four oxygen atoms surrounding one silicon atom) as a basic building block in their atomic structure. Estimates have been made that the crust consists of nearly 95% silicate minerals (see Figure 1). In addition to the silica tetrahedra, these minerals are built primarily using the six other common elements (Al, Fe, Ca, Na, Mg, and K).

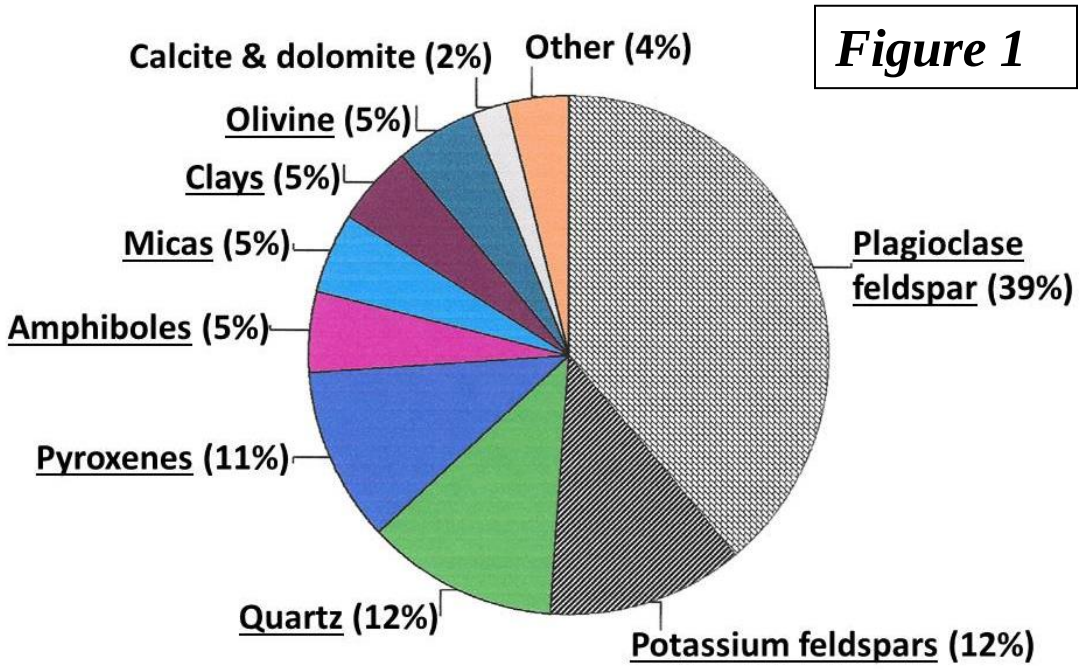

Figure 1 is a pie chart representing the relative abundances of the most common minerals of Earth's crust. All silicate minerals are underlined. Examples of *potassium feldspars* include orthoclase and microcline. *Pyroxenes* include minerals such as augite. *Amphiboles* include minerals such as hornblende. *Micas* include minerals such as biotite and muscovite. *Clays* include minerals such as kaolinite. *Calcite* and *dolomite* are classified as *carbonate* minerals, which do not use silica tetrahedra in their structure. The *Other* category also includes less abundant silicate minerals.