MINERALS AND ROCKS

The number of mineral masses forming rocks of usual occurrence is so small, and the composition of those so simple, that a very limited knowledge of these sciences [mineralogy and petrology] is sufficient for all introductory purposes, as far as the general outlines of Geology are concerned. —Conybeare & Phillips, 1822

a8 Minerals and mineraloids < rock components >

> In hindsight, it is easy to understand why both the ancient Greeks, who attempted analysis without synthesis, and the alchemists, who believed they could sustain synthesis without analysis, were doomed to failure. —Gautam Radhakrishna Desiraju.[2]

A naturally occurring, inorganic, solid with a composition expressible as a chemical formula is a *mineral* when crystalline or is a *mineraloid* when amorphous (non-crystalline). In short, a mineral is naturally occurring, inorganic, and crystalline. Long-range structural order sets crystal (a victory of enthalpy over entropy)[3] apart from amorphous solids (glasses, cherts, jet, and some earthy solids). The smallest representative piece of a mineral (its defining crystal geometry and constituent atoms found by X-ray analysis) is the *unit cell*. Within Earth's crust, nine common minerals are:

quartz
orthoclase } feldspars
plagioclase }
muscovite mica
biotite mica }
amphibole }
pyroxene } ferromagnesians
olivine }
garnet

That these minerals are silicates (or aluminosilicates when aluminum substitutes for silicon in the crystal structure) is unsurprising as Earth's crust is made almost entirely of the elements *oxygen* (O), *silicon* (Si) (*Note*: *silica* is the compound *silicon dioxide*, SiO_2) and *aluminum* (Al) (***Figure a8.1***). At high temperatures and pressures, these elements combine and dominate Earth's internal chemistry.

Minerals are silicates when they contain covalently (*see* Topic *a9*) bonded groups of four oxygen atoms about one silicon atom in their crystal structure. Silicate chemistry involves reactions between silicon-oxygen tetrahedra (monomers) with themselves to form pairs, rings, chains, double chains, sheets and three dimensional linkages (polymers) and these with metals. The products are the variety of silicate minerals (that include quartz, which is silicon dioxide, and aluminosilicates in which, as in the feldspars (***Figure a8.2***), there are polymer linkings of aluminum- and silicon-oxygen tetrahedra). Amphibole and the micas are hydrated aluminosilicates. Most silicate minerals crystallize at the temperatures and pressures of Earth's interior and when exposed at Earth's surface are unstable and (with some exceptions such as quartz) react with gases of the air and water. That is, they weather chemically and the products are clays (which are hydrated aluminosilicates), colloidal silica (hydrated silica), and nonsilicates (the most common being carbonate, halide, oxide, sulfide, and sulfate salts).

Minerals not abundant but often present in crustal rocks are called *accessory minerals*: apatite, "coltan" *in situ* in weathered-granite soils, garnet, ilmenite, magnetite, rutile, titanite, and zircon (all of which resist chemical weathering), and pyrite and pyrrhotite (which promote weathering and produce bright-colored gossans of yellow limonite, brown goethite, and red hematite). Quartz-sands of the continents usually include durable accessory minerals that can become hydraulically concentrated as is so of garnet, magnetite, ilmenite, and rarer alluvial diamonds and gold nuggets and flakes. The black-sand beaches of volcanically active Hawaii are fragments of basalt whereas those of the volcanically inactive Hawaiian island Oahu are of magnetite and ilmenite mineral grains released by prolonged weathering of its basaltic rocks to clay and salts otherwise.

At Earth's surface, common minerals and mineraloids (that are stable because they are the products of weathering themselves) are:

minerals: clay
calcite
gypsum
halite and bitterns
goethite and hematite
quartz and durable accessory minerals (residual)

mineraloids: cryptocrystalline quartz (opal, chert, agate, jasper)
limonite

Frank Wigglesworth Clarke (1847-1931), Chief Chemist to the US Geological Survey from 1884 to 1925, systematized the collection and chemical analysis of minerals, rocks, and ores, in the first of five editions of *The Data of Geochemistry*, 1908.[4] Christian Schonbein (1799-1868), the discoverer of ozone, coined the word "geochemistry" in 1838.[5]

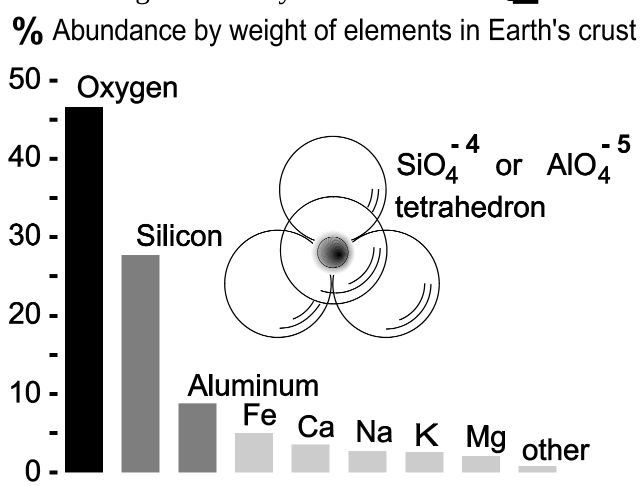

Figure a8.1 [6] Abundance of elements by weight in Earth's crust and a diagram of how four oxygen atoms and a silicon (or aluminum) atom pack as a tetrahedral monomer.

Atoms of nonmetals in compounds occupy larger volumes than do metal atoms.

Of Earth's crust, oxygen is 47% by weight and 94% by volume.

Among "other" on Earth is hydrogen, which by weight and volumetrically is rare even though present in water (H_2O).

In the universe as a whole, atoms of elements present by count are, as of now, hydrogen 90%, helium 9%, and all the other elements are relatively rare.[7]

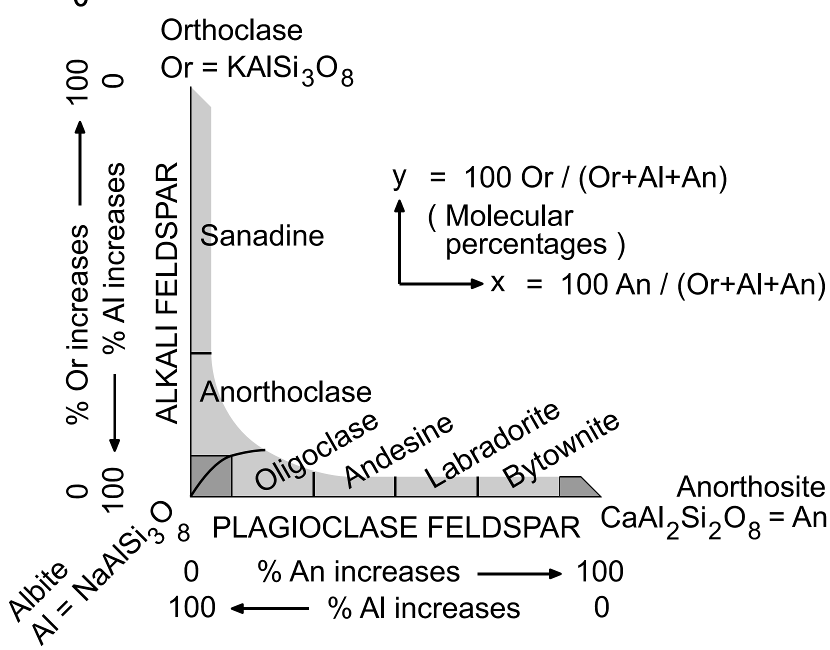

Figure a8.2 [8] Compositions of named feldspars.