

The lithosphere is the upper part of the earth. It includes the crust and the solid portion of the mantle. Lithosphere interacts with atmosphere, hydrosphere, and biosphere and produces the pedosphere (the soil with its biotic and abiotic components). The lithosphere contains rocks, minerals, and soils. It is made up with more than 100 chemical elements, but most of them are rare. Only eight elements—oxygen (O), silicon (Si), aluminum (Al), iron (Fe), calcium (Ca), sodium (Na), potassium (K), and magnesium (Mg)—constitute more than 99% of its volume. In the earth's crust, these elements generally form crystalline solid compounds of definite chemical composition which are known as minerals. Chemically, minerals may be sulfides, sulfosalts, oxides and hydroxides, halides, carbonates, nitrates, borates, sulfates, phosphates, and silicates. Most rock-forming minerals are, however, aluminosilicates of Ca, Mg, Na, and K because these elements are most abundant. Minerals are aggregated into rocks. Rocks may be igneous, sedimentary, and metamorphic. Igneous rocks are formed by solidification of magma or lava, sedimentary rocks are formed by lithification of sediments or by precipitation from solution and consolidation of remnants of plants and animals, and metamorphic rocks are formed from preexisting rocks by the change temperature and pressure in the solid state. By the action of natural forces over geological time, rocks and minerals are disintegrated and decomposed into new minerals and new compounds such as salts, acids, bases, and soluble substances. The processes are collectively known as weathering. However, the effects of rocks and minerals on mature soils are usually temporary. Their effects are profound in young and immature soils. Eventually, similar soils may develop from dissimilar rocks depending on other soil-forming factors.

## 2.1 Lithosphere Is the Outermost Part of the Earth

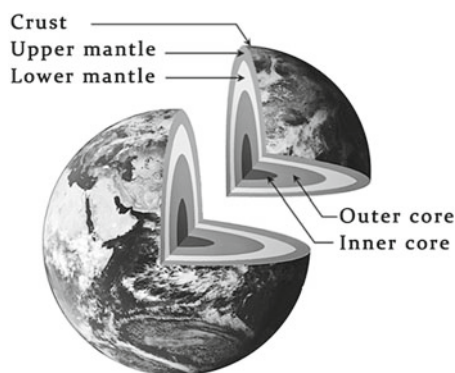
There are four concentric zones in the earth's interior (Fig. 2.1). The innermost zone is called the inner core which is a solid, spherical mass of iron, having a radius of 1,216 km.

Above it is the outer core which is a layer of molten liquid rich in nickel and iron. It is about 2,270 km thick. The outer core is overlain by the mantle, which is solid but soft. The mantle is about 2,900 km thick. The crust is the outermost zone and is the hardened exterior of the earth. It varies in thickness from about 5–50 km. The uppermost part of the earth, the crust, and a part of the mantle which is hard, consolidated, and brittle together constitute the lithosphere (from Gk "*lith*" meaning rock). It extends about 100 km down the continental surface (Holmes 1979).

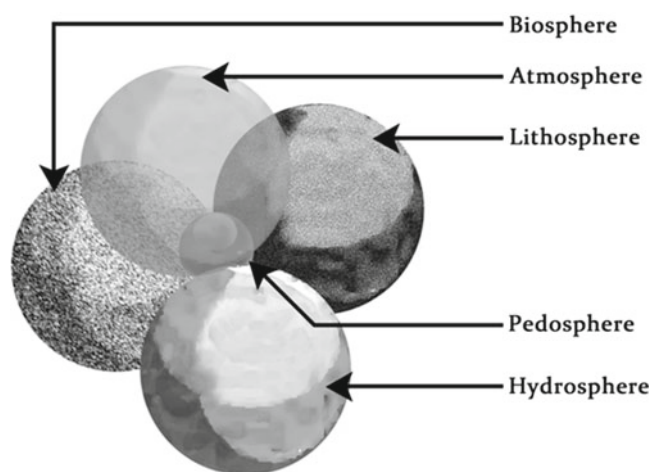
## 2.2 Lithosphere Interacts with Atmosphere, Hydrosphere, and Biosphere to Form the Pedosphere

Due to its unique position in space, the lithosphere continually interacts with atmosphere, hydrosphere, and biosphere and produces the pedosphere (Juma 2001). Pedosphere includes soils and their living and nonliving components. Figure 2.2 represents the interactions among these spheres.

Atmosphere is the layer of gases and vapor that surrounds the earth. It consists of a mixture of the gases, nitrogen (78.084% by volume), oxygen (20.9476%), water vapor (variable), carbon dioxide (0.0314%), and inert gases such as argon (0.934%) and some other rare gases (Lide 1996). Carbon dioxide critically controls the temperature and the climate on the earth. Biosphere is part of the earth's space in which organisms live, interact, and form ecosystems. It includes the primary producers, consumers, decomposers, and transformers. Hydrosphere is the total body of water that exists on or close to the earth's surface. Hydrosphere includes surface water and groundwater. The lithosphere and biosphere, respectively, impart mineral and organic inputs to soil. Lithosphere, biosphere, hydrosphere, and atmosphere together also provide other material and energy inputs, and set conditions for soil development.



**Fig. 2.1** Zones in the earth's interior



**Fig. 2.2** Interactions of lithosphere, biosphere, atmosphere, and hydrosphere to produce the pedosphere

**Table 2.1** Elemental composition of the earth's crust

Element	Percent by weight <sup>a</sup>
Oxygen	46.6
Silicon	27.7
Aluminum	8.1
Iron	5.0
Calcium	3.6
Sodium	2.8
Potassium	2.6
Magnesium	2.1

<sup>a</sup>Source: <http://hyperphysics.phy-astr.gsu.edu/hbase/tables/elabund.html>

minerals are formed by two or more elements. On the basis of their origin, minerals may be divided into primary and secondary minerals. Minerals formed during solidification of magma or lava are called primary minerals, and minerals formed by alteration of the primary minerals and by resynthesis and recrystallization during weathering are secondary minerals. Chemically, the broadest groups of minerals are sulfides, sulfosalts, oxides and hydroxides, halides, carbonates, nitrates, borates, sulfates, phosphates, and silicates (Bishop et al. 2001). For their relative abundance in the earth's crust, silicon and oxygen are found as the major constituents of most minerals. The simplest form is the oxide of silicon,  $\text{SiO}_2$ . The most common mineral with this formula is quartz. However, the most abundant minerals in rocks of the earth's crust are the silicates. Since the third abundant element in the earth's crust is aluminum, most minerals are aluminosilicates of one or more of the remaining elements.

## 2.3 Eight Chemical Elements Constitute the Bulk of the Earth's Crust

Almost a 100 chemical elements are found in the earth's crust, but only a few makes up its bulk. Table 2.1 shows the abundance of some common elements of the earth's crust.

## 2.4 Chemical Elements in the Earth's Crust Form Minerals Under Natural Conditions

Only a few elements may be present in pure elemental forms in the earth's crust. They are called native elements. They include copper, gold, lead, mercury, nickel, platinum, and silver. They are found in ores. Most of the elements remain in different combinations as minerals. A mineral is defined as a naturally occurring, inorganic, crystalline solid that has a definite chemical composition (or a definite compositional range). Many minerals are composed of only one element; for example, diamond and graphite are composed of carbon alone. Most

## 2.5 Silicate Minerals Are Important Rock and Soil Constituents

Important silicate minerals of rocks and soils include quartz, feldspars, pyroxenes, amphiboles, mica, and olivines. Quartz ( $\text{SiO}_2$ ) is dominant in all types of rocks and coarse fraction of soils; feldspars include framework silicates, which, in addition to silicon, aluminum, and oxygen, contains potassium, sodium, or calcium. Those that contain potassium are called potassium feldspars such as orthoclase ( $\text{KAlSi}_3\text{O}_8$ ) and microcline. Sodium and calcium containing feldspars are plagioclase feldspars, such as albite ( $\text{NaAlSi}_3\text{O}_8$ ) and anorthite ( $\text{Ca}_2\text{Al}_2\text{Si}_2\text{O}_8$ ) and their intergrades. Pyroxenes have the general formula  $(\text{Na,Ca,Mg,Fe,Al})_2\text{Si}_2\text{O}_6$ . Augite, enstatite, hypersthene, diopside, rhodonite, etc., are important members of the pyroxene family. Amphibole is the family name of another very large and complex group of minerals. Hornblende  $[\text{Ca}_2,\text{Na}(\text{Mg,Fe}^{2+})_4(\text{Al,Fe,Ti})(\text{Al,Si})_8\text{O}_{22}(\text{O},-\text{OH})_2]$  is the main rock-forming mineral of the family. Mica includes minerals with a sheet silicate structure. The two most common micas are biotite or black mica  $[\text{K}(\text{Mg,Fe})_3(\text{AlSi}_3\text{O}_{10})$

(OH)<sub>2</sub> and muscovite or white mica [KAl<sub>2</sub>(AlSi<sub>3</sub>O<sub>10</sub>)(OH)<sub>2</sub>]. Olivines are magnesium and magnesium–ferrous-containing orthosilicates. They have the general formula (Mg,Fe)SiO<sub>4</sub>. Silicate minerals containing Mg and Fe such as biotite, pyroxene, amphibole, and olivine are called ferromagnesian or mafic minerals. They are usually dark colored (dark greenish to black). Others, such as quartz, feldspars, and muscovite, are nonferromagnesian minerals. Silicate minerals are important sources of plant nutrients; weathering of these minerals releases soluble-base cations such as K<sup>+</sup>, Ca<sup>2+</sup>, and Mg<sup>2+</sup>.

## 2.6 Some Other Minerals Are Also Abundant in Soil

Other kinds of minerals include carbonate minerals such as calcite (CaCO<sub>3</sub>), magnesite (MgCO<sub>3</sub>), and dolomite (CaCO<sub>3</sub>·MgCO<sub>3</sub>); hydroxide minerals such as gibbsite [Al(OH)<sub>3</sub>], boehmite [AlO(OH)], and goethite [FeO(OH)]; oxide minerals such as hematite (Fe<sub>2</sub>O<sub>3</sub>), magnetite (Fe<sub>3</sub>O<sub>4</sub>), ilmenite (FeTiO<sub>3</sub>), pyrolusite (MnO<sub>2</sub>), and zircon (ZnO<sub>2</sub>SiO<sub>2</sub>); phosphate minerals such as apatite [Ca<sub>5</sub>(PO<sub>4</sub>)<sub>3</sub>·(F,Cl,OH)]; sulfate minerals such as gypsum (CaSO<sub>4</sub>·2H<sub>2</sub>O); and sulfide minerals such as chalcocite (Cu<sub>2</sub>FeS<sub>2</sub>), galena (PbS), and pyrite (FeS<sub>2</sub>). They are found in soils and in abundance in some rocks. For example, limestone is dominated by calcite, and the rock phosphate is mainly composed of apatites. Limestone parent materials produce calcareous soils, and apatite is the most important natural source of phosphorus. Most commercial phosphate fertilizers are manufactured from rock phosphate-containing apatite. The most important secondary minerals are the clay minerals such as kaolinite, smectite, vermiculite, illite, and chlorite (Sect. 8.3.1). Clay minerals are abundant in the finer fraction of soil and influence almost all its physical and chemical properties. Soils rich in clay minerals, especially smectites and vermiculites, are fertile and may be productive if properly drained.

## 2.7 A Few Minerals Constitute the Bulk of the Earth's Crust

Most of the several thousands of minerals that have so far been identified are rare. Only about 100 minerals constitute the major mineral components of rocks. Most of these minerals are also relatively uncommon. The bulk of the earth's crust is made up with a few silicate minerals (Fig. 2.3).

Feldspars constitute more than 50%, including 39% as plagioclase and 12% as orthoclase (Plummer et al. 2001). Quartz and pyroxene also contribute similar proportions to orthoclase. Olivine constitutes only 3%. For this, high proportions of quartz and feldspars are found in soils.

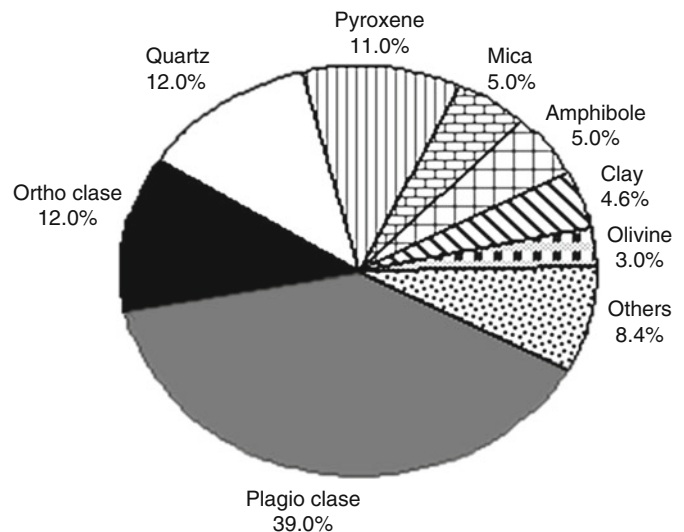


Fig. 2.3 Relative abundance of minerals in the earth's crust

## 2.8 Rocks Are Aggregates of Minerals

Rocks are the naturally occurring hard and consolidated inorganic materials of the earth. Coal and some limestone have, however, developed from plant and animal remains. Igneous rocks originate through the solidification of lava on the surface or magma in the interior of the earth. Flow of magma through preexisting igneous or sedimentary rocks gives rise to metamorphic rocks. Igneous and metamorphic rocks are weathered and form sediments which are deposited and lithified later into sedimentary rocks usually at a place different from its origin.

A rock can be composed of one mineral or of a large number of different minerals. Limestone and marble are composed mainly of calcite (CaCO<sub>3</sub>) and rock phosphate of apatite [Ca<sub>5</sub>(PO<sub>4</sub>)<sub>3</sub>·(F,Cl,OH)] with some other impurities. Most rocks are, however, assemblages of several different minerals. Igneous rocks are composed of primary minerals, predominantly silicate minerals. Sedimentary rocks contain some original primary minerals and at the same time possess some altered and newly synthesized secondary minerals.

## 2.9 Igneous Rocks Are Formed by Solidification of Magma and Lava

Hot, molten, igneous material within the earth's interior is called magma. When magma erupts on the earth's surface, it is called lava. Magma originates generally in the asthenosphere and rises toward the surface of the earth through lines of weakness, fractures, fissures, joints, etc. On its way to the surface through the crust, magma exerts tremendous pressure and heat, and modifies (or metamorphoses) the adjacent rocks. However, magma may solidify at very great depths or

near the surface. When solidification occurs near the surface, the rock is called hypabyssal rock. When solidification occurs deep within the earth, the rock is called plutonic or intrusive rock. Granite, gabbro, and diorite are examples of intrusive rocks. Igneous rocks are sometimes found to overlap sedimentary and metamorphic rocks. Many intrusive rocks, such as granite, have been exposed at the surface of the earth by uplift, erosion, and weathering. At present, there are many fertile soils that have developed from weathering products of granite.

When lava erupts on the earth's surface, volatile materials present in it generally escape, and the molten material forms the type of igneous rocks known as volcanic or extrusive rocks. Examples of extrusive rocks are basalt, rhyolite, and andesite; they are all fine-grained rocks. Lava cools relatively rapidly on the surface and very slowly beneath. The rate of cooling has a profound influence on the grain size of the minerals in rocks. Larger minerals form due to slow cooling, and smaller minerals develop by rapid cooling. Therefore, extrusive rocks are generally fine textured, and intrusive rocks are coarse textured. Some rocks may be of mixed textures. Sometimes lava may cool so rapidly that crystallization process does not take place. The resulting rocks are glassy or obsidian. Igneous rocks having silica content <45% are called ultramafic (serpentine, peridotite), between 45 and 55% mafic (basalt, gabbro), between 55 and 65% intermediate (amphibolite, andesite), and >65% silicic or felsic rocks (granite, rhyolite); soils have developed from all these igneous rocks and volcanic ashes.

## 2.10 Sedimentary Rocks Are Mainly Formed by Lithification of Sediments

There are three modes of sedimentary rock formation: (1) lithification of sediments containing fragments of preexisting rocks, (2) precipitation from solution (i.e., chemically formed), or (3) consolidation of remnants of plants and animals (i.e., organically formed). Sedimentary rocks containing fragments of earlier rocks are known as clastic sedimentary rocks. The fragments may be rock pieces, such as pebbles of granite or shale, and individual mineral grains, such as sand-sized quartz and feldspar crystals. Clastic sedimentary rocks may be classified as coarse-grained, medium-grained, and fine-grained sedimentary rocks. Coarse-grained sedimentary rocks include conglomerate formed by cementation of rounded gravels and pebbles, and breccia formed by cementation of angular fragments. Medium-grained sedimentary rocks include sandstone formed by cementation of sand grains and siltstone formed by cementation of silt-sized particles. Examples of fine-grained sedimentary rocks are shales which are formed by cementation of clay-sized particles. Mudstone is formed by cementation of

silt- and clay-sized particles together. Chemically formed sedimentary rocks include carbonate-containing rocks, such as limestone, which is composed of the mineral calcite ( $\text{CaCO}_3$ ), dolostone composed of the mineral dolomite ( $\text{CaCO}_3 \cdot \text{MgCO}_3$ ), chert composed of hard reprecipitated silica, and rock salt composed of halite ( $\text{NaCl}$ ). Many limestones are formed from consolidation of  $\text{CaCO}_3$ -rich shells of marine organisms. Other organically formed sedimentary rocks include coal and peat. Plants, animals, and their remnants are sometimes preserved and silicified beneath earth's surface. These are called fossils.

## 2.11 Metamorphic Rocks Are Formed from Preexisting Rocks by Change in Solid State

Metamorphic rocks are formed from preexisting rocks (igneous, sedimentary, or other metamorphic rocks) by the change in solid state either in texture or mineralogical composition through the action of heat, pressure, chemically active solution, etc. Thermal or contact metamorphic rocks are formed during intrusion of magma and found along margins of intrusive bodies, while regional metamorphic rocks occupy large areas and reveal much uplift and erosion after their formation. All types of preexisting rocks may undergo metamorphism.

## 2.12 Sedimentary Rocks Predominate in the Earth's Surface While Igneous Rocks in the Crust

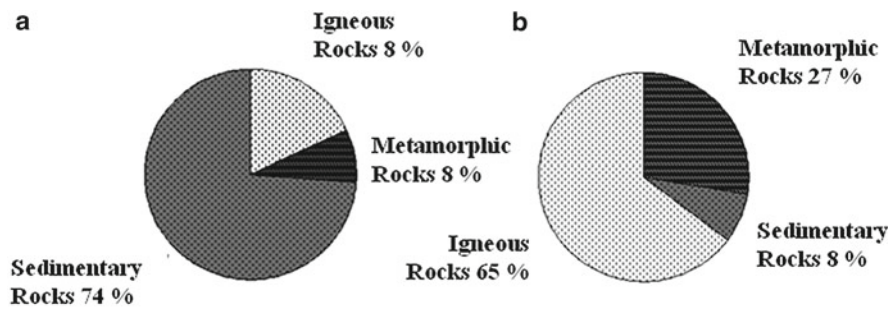
Sedimentary rocks predominate in the petrological composition of the surface of the earth, but igneous rocks are more abundant when the entire crust is considered. Figure 2.4a shows relative abundance of different rocks within 5 km of the earth's surface, and Fig. 2.4b shows rock composition of the earth's crust.

## 2.13 Soil Characteristics Differ on Rock and Mineral Sources

Rocks and minerals produce parent materials, and they may have influences in determining characteristics of the resulting soils. This has been discussed well in Sect. 3.5 in relation to factors of soil formation. Now, some characteristics of soils likely to develop from different rocks are mentioned:

- **Volcanic Ash:** Volcanic ash deposits are fine grained and weather relatively easily. Plants may invade a new deposit of volcanic ash within only a few years. The resulting soils are fine textured and usually rich in organic matter and plant nutrients. They are fertile soils. Volcanic ash





**Fig. 2.4** Abundance of rocks in the earth's surface (a) and earth's crust (b)

soils are named Andisols in Soil Taxonomy of the USDA (Chap. 4). These soils are found exclusively in regions where active and recently extinct volcanoes are located. The soils cover about 124 million ha or 0.84% of the world's land surface (Leamy 1984).

- **Granite:** Granite is a coarse-grained rock and contains on an average about 25% quartz and 65% orthoclase with some small amounts of mica and hornblende. Soils developing from granite are usually sandy in the initial stage. After further soil development, feldspar grains weather into fine-grained clay minerals. Most soils from granite are friable, permeable, acidic, and low in base status with low nutrient contents. However, Jusop et al. (1995) observed that soils from granite in wet zone are low in pH and exchangeable cations, while soils in the dry zone are high in pH and exchangeable bases. Nielsen (2004) observed that most soils developed from granite in Australia are loose and deep, but with little cohesion or consolidation and susceptible to erosion.
- **Basalt:** Basalt is a fine-textured rock. Basalt is rich in ferromagnesian and calcic plagioclase minerals. These minerals weather relatively easily to fine-grained clay minerals. The resulting soils are usually fine textured. Under moderate intensity of weathering, for example, in temperate regions, a good amount of the minerals persist and maintain a high base status in soil. In well-drained and humid conditions, 1:1-type clay minerals (e.g., kaolinite, halloysite) and sesquioxides predominate. Soils developed from tertiary basalts in New South Wales were found to be deep, well-drained, red and with variable amounts of hematite, goethite, and gibbsite (Norris and Pickering 1983). Soils have low CEC and high phosphate sorption (Jenkins and Morand 2002). Most of them are Ultisols; some may be Oxisols (Chap. 4).
- **Sandstone:** In sandstone, more than 50% materials are sand sized, mainly quartz, with impurities including feldspar and mica, and such cementing agents as silica, iron, and lime. Soils formed from sandstone are coarse textured, acidic, and poorly fertile. However, the characteristics of

soils depend on the types of sandstones (grain size, mineralogical composition). Fine-grained sandstones are difficult to weathering, whereas coarse-grained sandstones are less resistant to weathering. So, soils developed from fine sandstones are shallower than soils developed from coarse-grained sandstones (Szafrank and Sklodowski 2006).

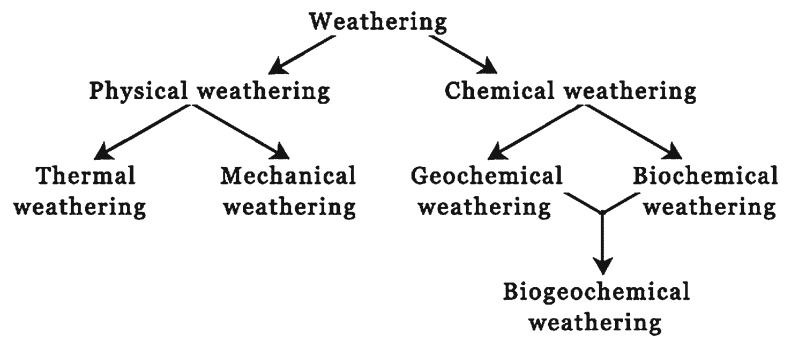
- **Limestone:** Limestone rocks contain mainly calcite ( $\text{CaCO}_3$ ) with considerable impurities of other carbonates, silt, clay, quartz, and iron. Resulting soils are generally clayey. In warm humid climates, the Ca and Mg and bicarbonate ions are almost completely removed. USDA (1997) observed that most soils developed from limestone in the Limestone County of Texas were clay and clay loam with some sandy loams.

## 2.14 Weathering Is the Disintegration and Decomposition of Rocks and Minerals

The processes involved in the disintegration (fragmentation, splitting, detachment, etc.) and decomposition (a chemical change leading to the formation of simpler products) of rocks and minerals are collectively called weathering. Rocks are weathered by the action of such natural forces as heat, water, wind, glacier, organisms, chemical reactants, etc. The changes are either physical or chemical, or both. When rocks are only changed physically without any alteration of the chemical composition, the process is known as physical weathering. When the chemical and mineralogical composition of rocks are altered, or when a mineral is decomposed into soluble and insoluble products or gives rise to a different mineral, the process is called chemical weathering.

The principal agents of physical weathering are heat, water, wind, glaciers, and organisms. The most remarkable physical weathering is caused by temperature. It may be regarded as thermal weathering. Other physical weathering processes may be included in mechanical weathering. Chemical weathering occurs by reactions of minerals with acids, bases, salts, ions, etc., or even with water. Organisms produce carbonic acid and other

**Fig. 2.5** Types of weathering



organic acids which actively participate in chemical alteration of rocks. Chemical weathering is, therefore, sometimes divided into geochemical weathering and biochemical weathering. Together they bring biogeochemical weathering (Fig. 2.5). Weathering of rocks and minerals produces parent materials of mineral soils.

### 2.14.1 Thermal Weathering Is Caused by Variation in Temperature

Expansion and contraction of rocks due to fluctuation in temperature cause thermal weathering. Rocks and minerals expand when heated by solar radiation and contract when cooled. Rocks expand during the day and contract at night. More expansion occurs during summer than in winter. But not all parts of the rock body are equally exposed to heat. So, different parts of rock expand and contract at different rates. Different minerals expand and contract at different rates as well. Since a rock is usually composed of a variety of minerals, and they expand and contract differently, internal pressures are created when rocks expand or contract. Due to this internal pressure, a rock on the earth's surface is ultimately fragmented after prolonged exposure to fluctuations of temperature.

Exfoliation is a process of thermal weathering which occurs in layered rocks, rocks with approximately homogeneous composition at different zones, or rocks expanding almost at similar rates up to a depth. The outer part of a boulder is expanded and contracted usually at higher rates than the inner parts and may be detached in thin layers. In this process, a thin layer of rock is detached from the rock body, resembling the peeling up of onions.

### 2.14.2 Mechanical Weathering Is Caused by Water, Glacier, Wind, and Organisms

Alternate wetting and drying is an important process of mechanical weathering. Many rocks absorb water and swell when wetted and shrink when dried. Expansion and contraction in volume due to alternate wetting and drying create stresses that break up rocks into pieces. Water may accumulate in fractures and joints of rocks. When the temperature is

lowered below the freezing point, ice is formed. Volume of ice increases by 9% and exerts tremendous lateral pressure on surrounding rocks. For this pressure, already fractured rocks are divided into several fragments. It is sometimes called frost wedging. Another type of mechanical weathering by freezing water is known as frost heaving, by means of which rock fragments are lifted upward. Flowing water has a considerable cutting action. Presence of suspended materials and rock fragments in water highly increases the capacity of this cutting action. By the water flow, the suspended materials roll and collide and disintegrate themselves as well as the walls and beds of rocks through which they travel. Large bodies of ice slowly moving along slopes are called glaciers. Glaciers forming on already weathered surfaces contain variously sized rock fragments including boulders. When glaciers flow down slope, ice begins to melt, and the rock fragments shatter one another. The flowing glaciers tend to or do smash whatever rock they find obstructing their way.

When an overlying rock is removed due to weathering and erosion, the underlying rock expands due to release of pressure. This might cause the underlying rock split. Another weak weathering agent is the wind. However, the presence of suspended particles increases the abrasive power of wind. Abrasion by wind over a long time may considerably weather rock surfaces. Large rock masses at higher elevation are pulled down by the gravity, and they may be detached. Deposition of such materials on piedmont and foothill are called colluviums. Plants may extend their roots in rock fractures and crevices. When they grow, the roots exert lateral pressure. Many burrowing animals ingest sand and gravel, and as this material passes through their gut, it gets physically comminuted (Suzuki et al. 2003).

### 2.14.3 Chemical Weathering Brings Chemical Changes in Rocks and Minerals

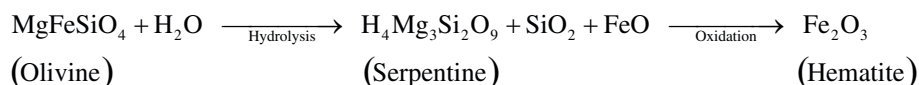
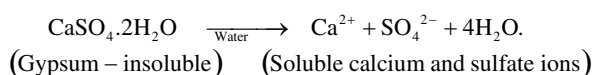
The main processes of chemical weathering are solution, hydration, hydrolysis, oxidation, reduction, carbonation, and other acid reactions. Minerals are not ordinarily soluble in water. For hundreds of years of wetting and for the presence of natural acids in water, which accelerates dissolution, minerals are

slowly dissolved in natural water. However, many minerals particularly iron and aluminum oxides are hydrated by the binding of water to their molecules. Hydrolysis is probably the most effective chemical weathering process by which minerals are decomposed. During hydrolysis, water molecule splits into hydrogen and hydroxyl ions, and the hydrogen replaces a cation from the mineral structure. Due to this replacement, the mineral becomes susceptible to decomposition by further hydrolysis or other chemical reactions. Some minerals are oxidized; some others are reduced depending on the conditions. Carbonation is a very active and common chemical weathering process. Most carbonation processes are biochemical in nature. Carbonic acid is naturally produced by dissolution of  $\text{CO}_2$  in water. Carbon dioxide is available from the atmosphere and as products of microbial and root respiration. Carbonic acid dissolves many minerals. Many other inorganic and organic acids are available in nature. Nitric acid may be present in rainwater. Sulfuric acid is produced by oxidation and hydrolysis of pyrite.

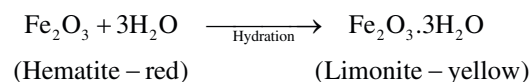
Plants and their associated microbiota directly impact chemical weathering by generating chelating compounds, by modifying pH through production of  $\text{CO}_2$  and organic acids, by altering the exposed surface areas of minerals via nitrification, and by affecting the residence time of water (Drever 1994). Of these, the production of organic acids may be the most important contribution to biochemical weathering in soils. These acids can either be released directly from the organism or be derived as by-products of organic decomposition.

### 2.14.3.1 Examples of Geochemical/Biochemical/ Biogeochemical Weathering

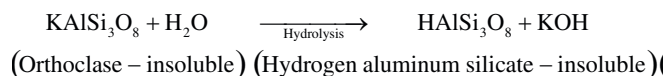
#### Solution



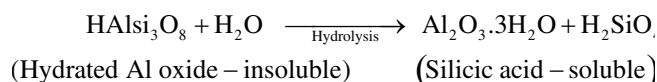
#### Hydration



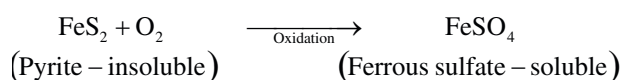
#### Hydrolysis



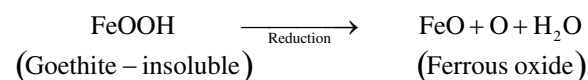
On further hydrolysis,



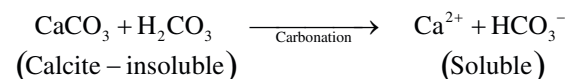
#### Oxidation



#### Reduction



#### Carbonation



The processes of chemical weathering may operate simultaneously, or one process may follow another.

For example, hydration and carbonation may occur at the same time, or oxidation may follow hydrolysis as

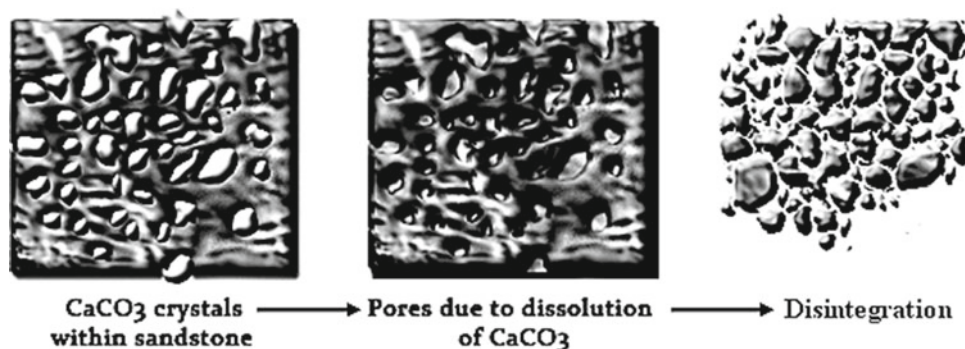
### 2.14.4 Physical and Chemical Weathering May Enhance Each Other

In nature, physical and chemical weathering operates individually or concurrently. In most cases, one accelerates the other. For example, when a large rock body is fragmented, it is more easily acted upon by chemical reactants. When some minerals in a rock are dissolved, it is more easily fragmented (Fig. 2.6).

However, the kind of weathering process that would dominate depends on the rocks and minerals themselves and on the environmental conditions at which weathering is taking place. Physical weathering dominates in extremely dry and cold conditions, and chemical weathering predominates in warm humid conditions.

### 2.14.5 The Rate of Weathering Varies with Minerals and Climate

Weathering of rocks generally begins slowly and accelerates as the rock breaks up and more surface area is exposed to attack. As weatherable minerals disappear by decomposition, weathering becomes slower again. It is accelerated by biological activity and due to removal of weathering products through leaching. Under similar conditions, different minerals weather at different rates. Generally, the more complex the mineralogical composition is, the more easily the mineral weathers. Plagioclase weathers more rapidly than orthoclase. Hornblende weathers fairly rapidly. Quartz is very resistant to weathering. Jackson et al. (1948) suggested the sequence of susceptibility of common minerals to



**Fig. 2.6** Chemical weathering favors physical weathering

weathering as gypsum, halite > calcite, dolomite, aragonite > olivine–hornblende, diopside > biotite, glauconite, nontronite > albite, anorthite, microcline > quartz > illite, muscovite > hydrous mica > montmorillonite (smectite) > kaolinite, halloysite > gibbsite, boehmite > hematite, goethite, and limonite > anatase. A particular rock or mineral, however, weathers at different rates in different climatic conditions. Chemical weathering is low in areas where water and temperature are low. The rate of weathering is higher in warmer and moister areas. In the humid tropics, not only the rate of weathering is rapid but also the weathering products are lost quickly. Alfisols, Oxisols, and Ultisols (Chap. 4) are highly weathered and leached soils of the humid tropics. Also the products of weathering to be found in a soil depend on minerals themselves and the conditions of weathering (Ollier 1975). However, weathering is a continuous process; it proceeds even after the formation of the parent material and during pedogenesis.

## Study Questions

1. Distinguish between primary and secondary minerals with examples. Mention the most abundant mineral groups of the earth's crust
2. Which minerals are found abundantly in the coarser and finer fractions of the soils?
3. Give examples of two mineral sources for each of the plant nutrients K, Ca, Mg, Fe, P, and S
4. Distinguish between plutonic and volcanic rocks. Why do the minerals of these two types differ in their grain size?
5. Explain biogeochemical weathering. With examples, distinguish between hydration and hydrolysis

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