7 Weathering

Topics

A. What is the definition of weathering? What is regolith?

B. What is physical weathering? How does physical weathering facilitate chemical weathering? What are four examples of physical weathering, and what is the definition of each?

C. What are six examples of chemical weathering, and what is the definition of each? What are a couple of health problems associated with clay eaters of the rural South? What ore of an industrial metal is produced by leaching? How can oxidation destroy structures and threaten lives? How does pyrite form within lake or marine sediments? What two problems can be caused by the oxidation of pyrite? How do caves and landscapes in limestone country form? What are the two reasons why caves form at the top of the saturated zone? How is it that a cave appears to migrate from below the water table to above the water table?

D. What is the definition of soil? What are three general factors that determine the character of any soil? How did the distribution of soils, which reflect differences in bedrock on which they form, influence ethnic emigration of farmers in Fayette County, Texas? What is the geologic setting of champagne in France? How have the dynamics of soil development been assessed in the Glacier Bay National Park, Alaska, area?

A. Weathering defined

Definition—Everyone knows about weathering. It's the fading and peeling of paint. It's the deterioration of masonry buildings and monuments. It's the wear and tear on *all* things exposed to 'the elements.' Geologically speaking, weathering is the physical and chemical alteration of rock and sediments through the effects of air, moisture, heat, cold, and organic matter.

Weathering consists of all those processes that convert rock into **regolith**—the loose, unconsolidated surface material that rests on the bedrock from which it developed (Fig. 7.1). In engineering parlance, regolith is earth material that can be moved with a bulldozer or front-end loader. (If explosives are required, the material is likely to be called *bedrock*.) While this is a practical definition of regolith, it includes unconsolidated *sediments* that are not products of *in situ* weathering, and, so, are not part of the regolith.

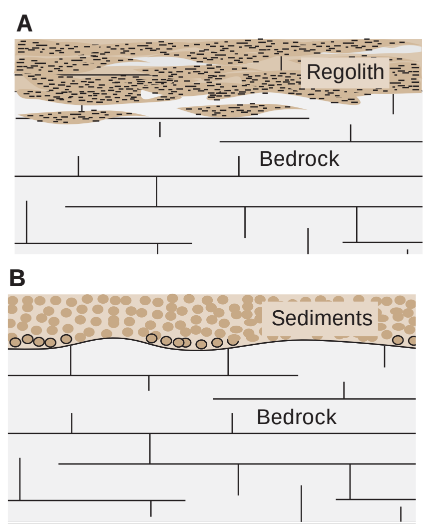


Figure 7.1 A Bedrock overlain by regolith. **B** Bedrock overlain by sediments.

Genetically, regolith is *dynamic* in that it is constantly in a state of observable *change*, whereas bedrock and sediments are, by comparison, relatively stable.

Q7.1 The nature of the boundary with bedrock serves to distinguish regolith from sediments. Describe the difference in the boundaries between (A) bedrock and regolith, and (B) bedrock and sediments, in Figure 7.1.

The bad and the good—A downside of weathering is repainting your home and refurbishing masonry. But there's an upside to weathering, most importantly the production of soil, without which Planet Earth would be barren.

There are two broad types of weathering, (a) **physical weathering** and (b) **chemical weathering**.

B. Physical weathering

Definition—*Physical weathering* is simply the breaking of rocks—making little rocks out of big rocks. Because chemical weathering (which we will get to shortly) is a *surface* process, physical weathering facilitates chemical weathering by increasing a rock's surface area-to-volume ratio (Fig. 7.2).

Q7.2 In Figure 7.2, if A is one unit area, how many unit areas are in B? In C? In D?

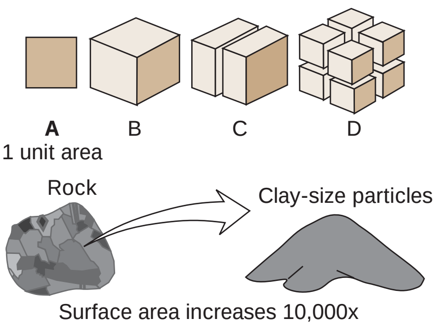


Figure 7.2 Breakdown of rock increases its surface area-to-volume ratio. A rock broken down into clay-size particles increases in surface area approximately 10,000 times.

Salt and sugar are granulated so that they dissolve more easily in foods. (Can you imagine waiting for a cube of halite to do its thing sitting atop a fried egg?) There are several mechanisms in nature that work toward granulating rocks. Four geologically significant mechanisms are:

- exfoliation
- root wedging
- frost wedging
- landslides

You can probably envision the last three of these four mechanisms of physical weathering, but the first item, *exfoliation*, might be new to you.

Exfoliation

Igneous rocks that crystallize from magmas at depths of tens of kilometers do so under immense pressures. In cases where such rocks are later uplifted and stripped (through erosion) of their overlying burden, the release of pressure results in expansion and 'blistering' of the rock into scaly sheets. These sheets are eventually stripped away by erosion as well, thereby sculpting such igneous bodies into domes. This kind of physical weathering is called **exfoliation** (Latin *folio*, leaf). At least one skin-care product is advertised as causing your face to exfoliate, i.e., flake off, revealing the real you. Granite is especially susceptible to exfoliation. Well-known examples of granite domes include Stone Mountain, Georgia, and Enchanted Rock, Texas. (Stone Mountain appears in the satellite photograph on page 73.) Swarms of multiple domes occur in Yosemite National Park, California; at Rio de Janeiro, Brazil (Fig. 7.3); and at Pusan, Korea.

Addendum—Chemical weathering that changes silicate minerals into clay minerals is accompanied by swelling, and so perhaps contributes to the exfoliation process.

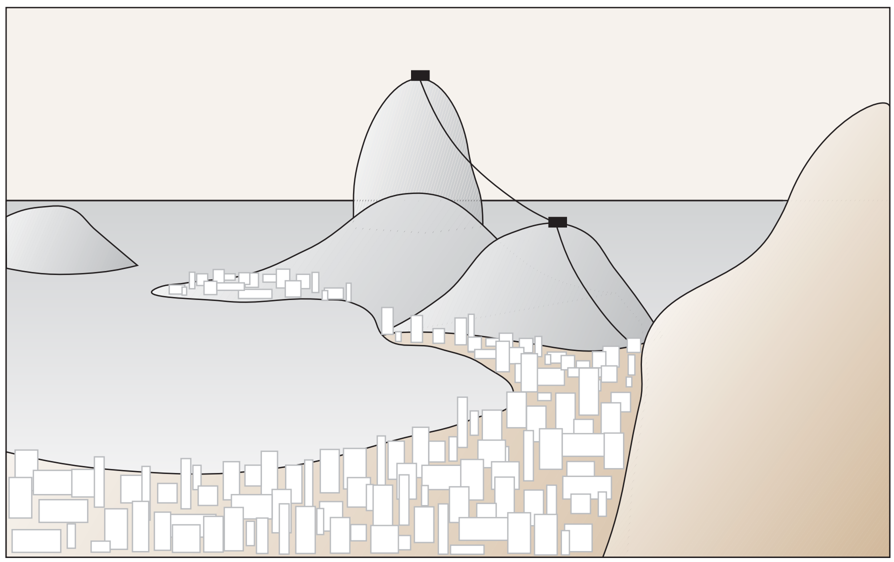


Figure 7.3 A sketch of the harbor at Rio de Janeiro, Brazil from an airplane window. The highest of these imposing granite domes is called Sugarloaf. A cable car connects two of these domes with the city below.

Root wedging

Tree roots can find their way into cracks and crevices within rocks and pry them apart as they grow. Considerable damage can be done to sidewalks, driveways, patios, and the like (Fig. 7.4). There have been cases where fatal landslides have been thought to have been caused, at least in part, by the wedging action of tree roots (Fig. 13.15 on page 242).

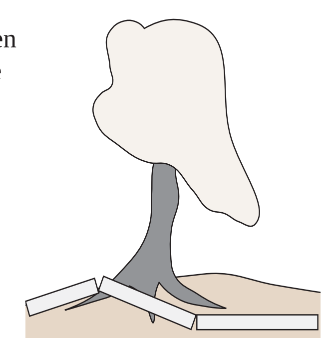


Figure 7.4 Tree roots have the capacity to disrupt sidewalks, driveways, streets, and parking lots as well as breaking rocks.

Frost wedging

H_2O is peculiar in that it is less dense in its solid state (ice) than it is in its liquid state (water). So water expands upon freezing—approximately 9%. If this were not true, our world would be uninhabitable because ocean basins would freeze solid and chill Earth to intolerable levels. That's the good news about water/ice. The bad news is that the expansion of water upon freezing bursts unheated water pipes and automobile radiators low on antifreeze.

The freezing of water is an effective mechanism of physical weathering. Like tree roots, water finds its way into cracks in rocks, then, upon freezing, wedges the rock apart (Fig. 7.5).

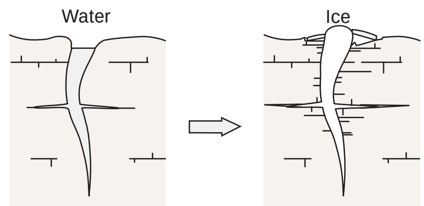


Figure 7.5 Water expands upon freezing with sufficient force to shatter rocks.

The *frequency* of freezing and thawing is important, so frost wedging is most effective where the number of yearly freeze-thaw cycles is high, say, in a climate where water freezes at night and melts during the day.

Q7.3 (A) Where would you expect frost wedging to be most effective during winter months—in coastal Ecuador, in Antarctica, or in Ohio?

The effect of frequency in the freeze-thaw cycle can be apparent from a car window. North of the Tropic of Cancer, shadows invariably occur on the north sides of objects (Fig. 7.6)—which brings to mind a familiar orienteering axiom, 'Moss grows on the north sides of trees.' The reason: The north sides are the shady sides, and so retain more moisture for thirsty mosses. In our Western Hemisphere, the Tropic of Cancer runs through central Mexico, so all of our conterminous 48 states are north of that latitude.

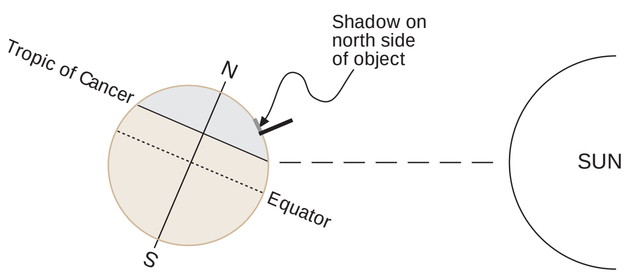


Figure 7.6 The Tropic of Cancer is the latitude where on June 22 the sun is directly overhead (i.e., at its *zenith*). North of that latitude shadows are invariably on the north sides of objects.

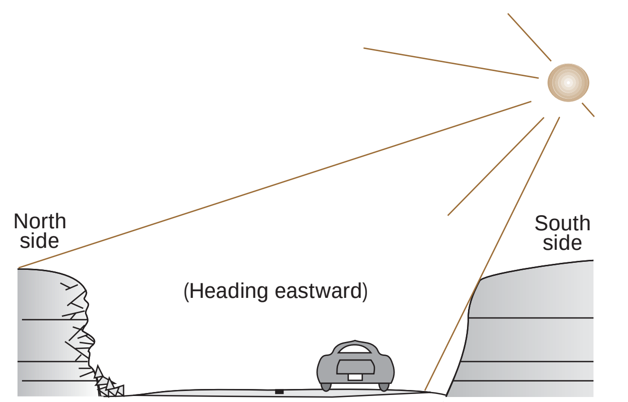


Figure 7.7 Rocks exposed in roadcuts decades old commonly exhibit a greater degree of frost wedging on the *north* sides of *east-west* highways than on the south sides.

Q7.4 Rocks exposed in roadcuts on the north sides of east–west highways are commonly more weathered (rubbly) than those on the south sides (Fig. 7.7). Why is that? *Hint:* What would happen in the situation illustrated in Figure 7.7 when rocks are wet and the daytime high temperature is, say, 30 °F on a cloudless day?

Q7.5 Less obvious is the greater degree of weathering that might be apparent on the east sides of north-south highways (Fig. 7.8). What is the reasonable explanation for that? *Hint:* A clue is imbedded in Figure 7.8.

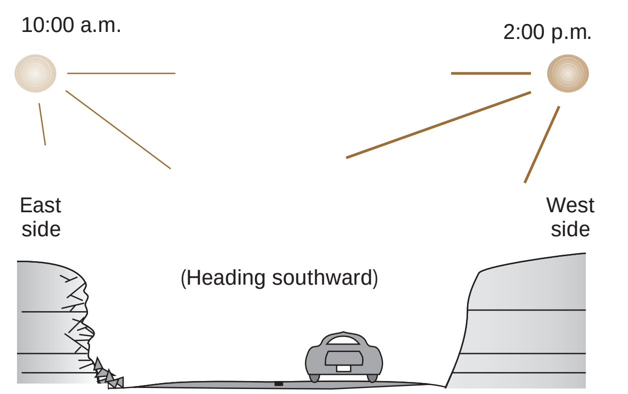


Figure 7.8 Rocks exposed in roadcuts a few decades old commonly exhibit a greater degree of frost wedging on the *east* sides of *north-south* highways.

C. Chemical weathering

Its importance—As stated on the first page of this exercise (page 117), the most important product of weathering in general, and of chemical weathering in particular, is *soil*. Two ounces of average rock are required to provide, through chemical weathering, the necessary phosphorus, iron, and calcium to produce sufficient soil–to produce sufficient grass–to produce the cow–to produce one pound of beef (Fig. 7.9).

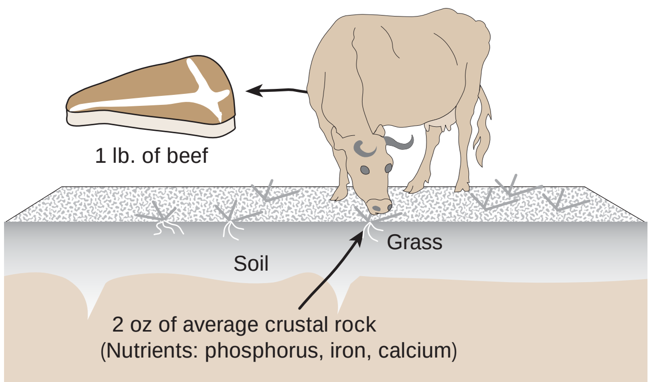


Figure 7.9 Chemical weathering derives the necessary phosphorus, iron, and calcium in one pound of beef steak from two ounces of average rock of Earth's crust.

Definition—Chemical weathering is the chemical alteration of minerals, a broad subject that can be subdivided into the following five processes:

• hydrolysis • leaching • oxidation • reduction • dissolution

Hydrolysis

Hydrolysis (the *splitting of water* into H^+ and OH^-) occurs when water reacts with a silicate mineral to form both soluble products and relatively insoluble products. The soluble products include the following family of metal ions:

potassium (K^+)
sodium (Na^+)
calcium (Ca^{++})
magnesium (Mg^{++})
iron ($Fe^{++,\ +++}$)

…plus the relatively insoluble family of clays ($AlSiO_n$), which are negatively charged.

The hydrolysis reaction can be written in generalized form as follows, with **Me** indicating unspecified metal ions:

Me = unspecified metal ion (K, Na, Ca, Mg, Fe)

$$\mathbf{Me}AlSiO + H_2O \longrightarrow \mathbf{Me} + OH + HAlSiO_n\overset{?}{\mathbf{Me}}$$

(Silicate) (Water) (Dissolved ions) (Clay, with or without **Me**)

About the hydrolysis of orthoclase feldspar—Notice in the reaction at the bottom of the left column that unspecified metal might or might not remain in residual clay. This depends on the thoroughness of hydrolysis. In regions of moderate rainfall (e.g., U.S. Midwest), hydrolysis of orthoclase feldspar fails to put all of the potassium in solution, so residual clay contains some of the feldspar's potassium (Fig. 7.10). Call this 'common clay.'

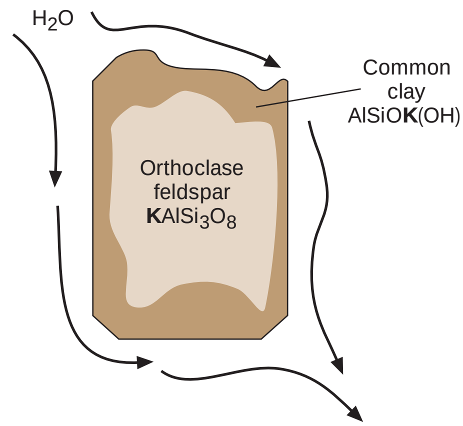


Figure 7.10 Generalized hydrolysis of an orthoclase feldspar crystal in a region of moderate rainfall. Residual common clay retains some of the potassium in the orthoclase.

In contrast, in regions of high rainfall (e.g., southeastern United States) hydrolysis of orthoclase is more thorough, and a variety of naturally refined clay (**kaolinite**) is produced (Fig. 7.11).

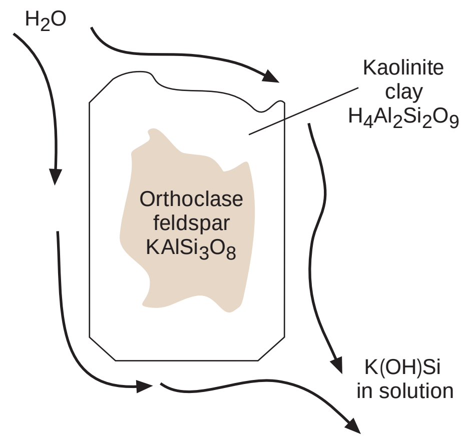


Figure 7.11 Hydrolysis of an orthoclase feldspar crystal in a region of high rainfall converts the feldspar to kaolinite clay.

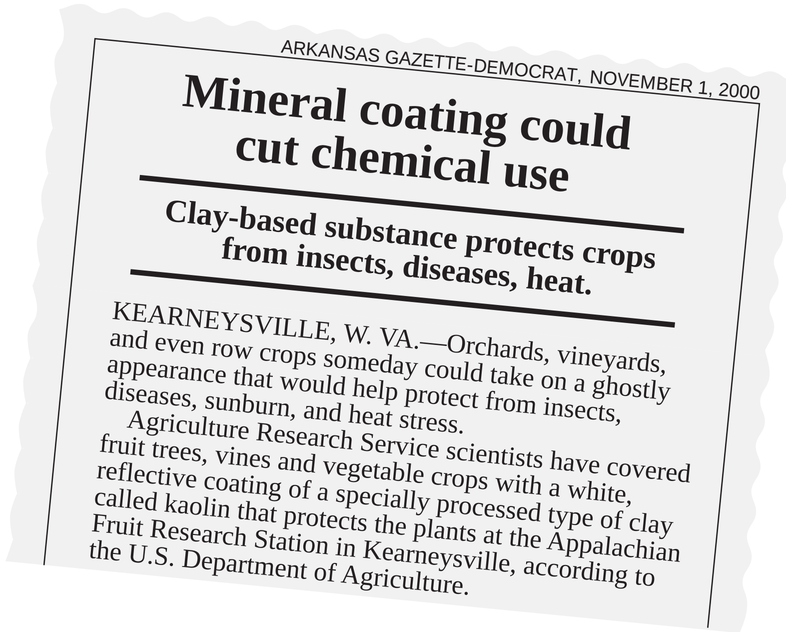
Q7.6 What is the singular difference (apparent in Figures 7.10 and 7.11) in the chemical composition of common clay and kaolinite?

Clay eaters of the rural South
Georgia kaolinite has been produced for generations for uses in innumerable industries—including those of adhesives, ceramics, glass, rubber, paint, paper, ink, pharmaceuticals, plastics, rubber, and whitewash. The most recent story about kaolinite is from the pesticide industry. Mixed with liquid pesticide and sprayed on crops, kaolinite serves as a matrix for more even distribution and for more holding power.

But clearly the most curious use of kaolinite has been that by 'clay eaters of the rural South.' The practice known as **geophagia** (earth eating) goes back at least as far Plato, who wrote of Greek women who ate clay. But don't snicker (no pun intended). Kaolinite is used in chocolate candy to minimize melting and in a variety of over-the-counter remedies for stomach disorders, including patented Kaopectate®, Di-Gel®, Rolaids®, Mylanta®, and Maalox®. It's not surprising that one of the common complaints of clay eaters is occasional constipation.

The most common clinical problem with clay eaters is anemia. Kaolinite is so impoverished in metal ions that it plucks what it can from one's blood. Also, it can coat the intestines, thereby interfering with the absorption of essential nutrients.

Q7.7 Judging from the list under Hydrolysis on facing page 120, what important metal ion is likely to be plucked from the bloodstream by kaolinite? *Hint:* This is a common 'vitamin supplement' claimed by manufacturers to restore __?__-poor blood.



ARKANSAS GAZETTE-DEMOCRAT, NOVEMBER 1, 2000

Mineral coating could cut chemical use

Clay-based substance protects crops from insects, diseases, heat.

KEARNEYSVILLE, W. VA.—Orchards, vineyards, and even row crops someday could take on a ghostly appearance that would help protect from insects, diseases, sunburn, and heat stress.

Agriculture Research Service scientists have covered fruit trees, vines and vegetable crops with a white, reflective coating of a specially processed type of clay called kaolin that protects the plants at the Appalachian Fruit Research Station in Kearneysville, according to the U.S. Department of Agriculture.

About the hydrolysis of plagioclase feldspar—Plagioclase includes sodium and calcium instead of potassium (Fig. 7.12).

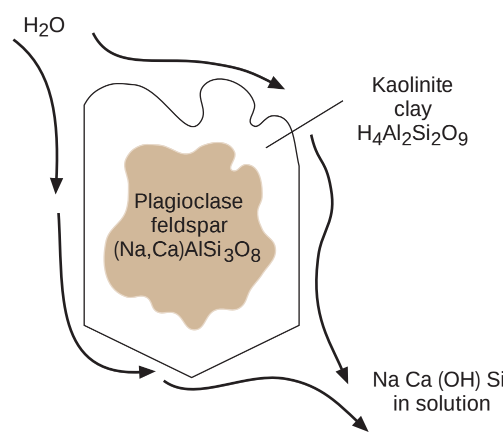


Figure 7.12 Sodium and calcium are dissolved from a plagioclase feldspar crystal to form kaolinite.

Q7.8 Given a granite (with its mix of plagioclase and orthoclase) that is subjected to moderate-to-high rainfall, the plagioclase is more likely to form kaolinite than is the orthoclase. So which metal ion(s) appear to be the more soluble—sodium and calcium, or potassium?

An interesting site for observations on clay eaters is at http://www.newhouse.com/archive/story1c012502.html.

Leaching

Leaching—another common variety of chemical weathering—is the removal, by water, of soluble elements and compounds from bedrock and regolith. These dissolved elements, which occur in all natural waters, make the water 'hard,' and can impart an unpleasant taste.

In areas of high rainfall and warm climate, leaching removes the more soluble elements and concentrates the less soluble ones as thick red soils called **laterites**. Some laterites contain valuable minerals. For example, in some tropical areas, *goethite* (FeO·OH) is mined for iron.

Clearly the most important economic mineral in lateritic soils is gibbsite [$Al(OH)_3$], the definitive mineral in the rock **bauxite** (pictured on page 65)—the ore of aluminum. Today we obtain most of our bauxite from tropical regions of South America, but during World War II, when shipping lanes in the Gulf of Mexico were threatened by German submarines, Arkansas bauxite, which formed as a soil some 50 million years ago, was mined and smelted.

Q7.9 How does bauxite differ in composition from kaolinite? *Hint:* What element present in kaolinite has been leached in the development of bauxite?

Mother Nature's problem in making bauxite is getting silicon out of the silicate mineral. Other metal ions are soluble under *acid* conditions, but silicon is soluble under *alkaline* conditions. So it requires unusually wet and warm conditions to leach silicon. The task in central Arkansas was made easier by the fact that the bedrock on which the bauxite developed consists of **syenite**—a silica-poor relative of granite. Not only is there little or no quartz in this hybrid igneous rock, but the feldspars are low in silicon as well.

Oxidation

The good and the bad—Oxidation and hydration of iron contribute to colorful landscapes, but these same processes can destroy structures and threaten lives (Fig. 7.13).

Oxidation of iron to form **hematite** (aka rust) is…

$$4Fe + 3O_2 \longrightarrow 2Fe_2O_3$$
(red hematite)

Hematite occurs in intense hues and tints of red. It has been the paint pigment of choice for Native Americans and others around the world.

When water combines with hematite, **limonite** forms, adding hues of yellow to Nature's palette. That reaction is…

$$Fe_2O_3 + H_2O \longrightarrow Fe_2O_3 \cdot H_2O$$
(yellow limonite)

Q7.10 Rocks in fresh roadcuts are commonly gray to brown in color, but after a few decades reds and yellows begin to appear. Why? *Hint:* What elements in the atmosphere and surface water are at work here?

Q7.11 These reds and yellows are especially apparent along fractures within rocks. Any idea why? *Hint:* Consider fractures as pathways for an important substance.

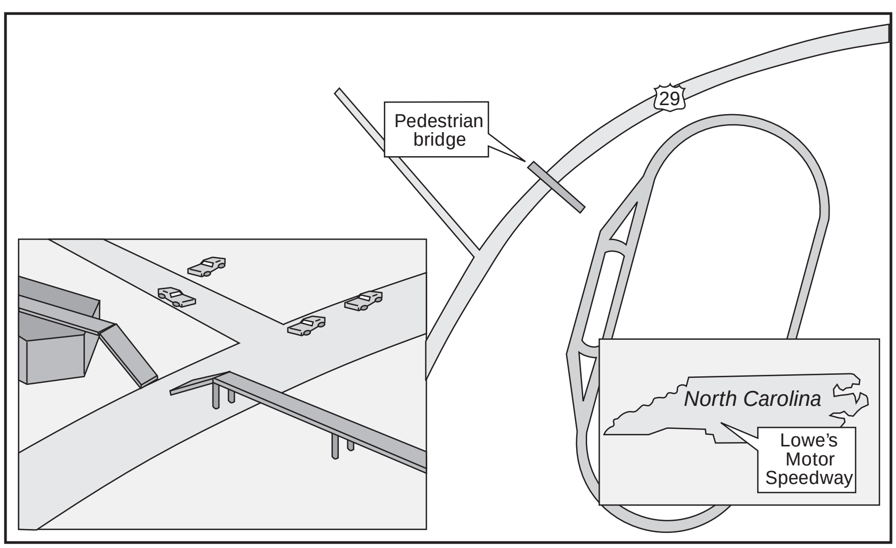

USA TODAY, MAY 22, 2000

Investigators detect corrosion in collapsed bridge

Walkway packed before collapse

CHARLOTTE, N.C.—State officials said Sunday that they found signs of corrosion in the steel bands in a pedestrian walkway that snapped as hundreds of people were leaving a stock-car race Saturday night. There were no fatalities, but 170 people remained in critical condition Sunday.

Figure 7.13 Corroded (oxidized) cables were blamed by some for contributing to the collapse of a pedestrian walkway at a North Carolina race car track.



Reduction

Reduction of iron—Decaying organic matter requires oxygen for its slow 'burn.' If there is insufficient free oxygen (within water and/or air), decaying organic matter can pluck oxygen from *hematite* (Fig. 7.14), thereby **reducing** the iron oxide and turning it gray.

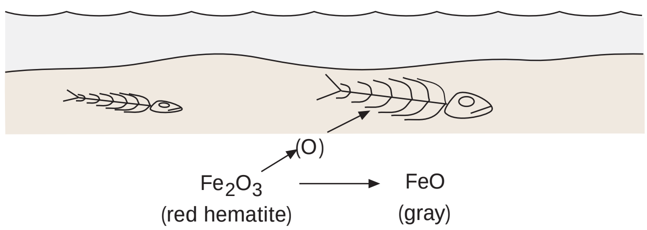


Figure 7.14 Within lake and marine sediments, decaying organic matter can acquire essential oxygen through the reduction of iron oxide.

Q7.12 Why do you suppose that sedimentary rocks crowded with fossils are seldom red in color? *Hint:* What is the postmortem (L. *post mortem*, after death) history of a fossil?

Reduction of sulfate—Decaying organic matter can also obtain essential oxygen by reducing *sulfate* ions, thereby liberating iron, which then combines with sulfur to form pyrite (Fig. 7.15).

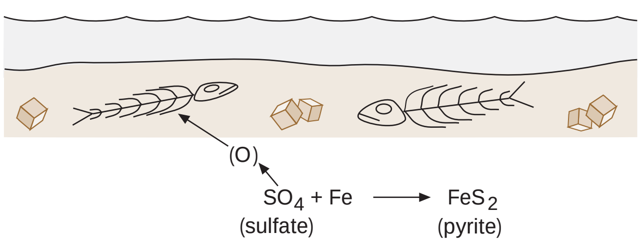


Figure 7.15 Within environments like that in Figure 7.14, decaying organic matter can also reduce sulfate in its search for essential oxygen.

Q7.13 Coal deposits are commonly rich in pyrite. Why is that? *Hint:* How does coal form? (This topic is covered in the exercise *Metamorphic Rocks* on page 110.)

Oxidation of pyrite—sulfuric acid problems

Building discoloration—When pyrite within sedimentary rocks is exposed to the atmosphere, it oxidizes to sulfuric acid and hematite (Fig. 7.16).

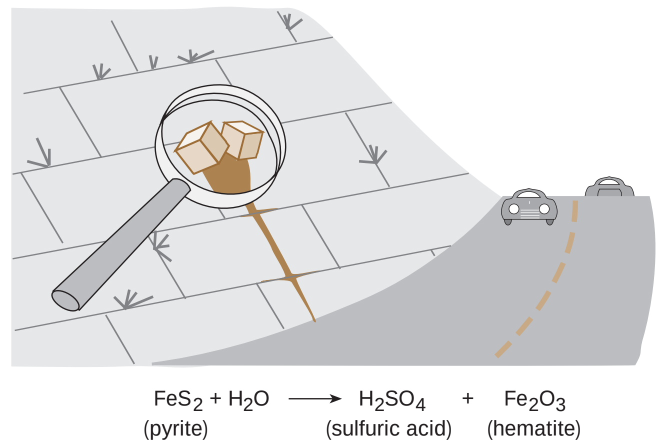
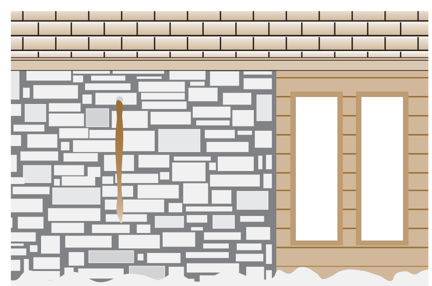


Figure 7.16 Geochemistry from a car window. Oxidation of pyrite within this limestone has left a tell-tale streak of red hematite. The sulfuric acid has either evaporated or gone into the nearest creek.

If pyrite is overlooked in the choosing of building stones (and of gravel for concrete), unsightly hematitic stain can result (Fig. 7.17). Epoxy sealer applied to the pyrite, along with acid cleaning of the rock, can mitigate the problem.

Figure 7.17 This decorative limestone has become stained with hematite that resulted from oxidation of a pod of pyrite.



Acid mine waters—Some ponds within abandoned coal strip-mines exhibit exceedingly high amounts of sulfuric acid, owing to the oxidation of pyrite (Fig. 7.18). The pH of one sample of water oozing from such a pond was 2.3.

Q7.14 Guess which item has a pH of precisely 2.3: tomatoes, lemon juice, baking soda, or beer? The answer is on the following page. Don't peek until after you have tried.

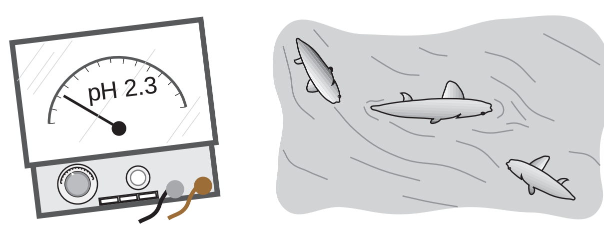


Figure 7.18 The pH of water oozing from coal strip-mine ponds can kill fish when it accidentally finds its way into streams.

Dissolution (and cave development)

The biggest natural history story about dissolution is the dissolving of limestones to form caves. The very landscapes associated with caves have been carved in large part through the process of dissolution. But first, a qualifier: Gypsum (as in Almería, Spain) and salt (as along Dead Sea shores) are even more soluble than limestones, but gypsum and salt comprise a small fraction of land areas. Usually, when one hears of a solution landscape, 'limestone country' comes to mind.

Did you guess correctly the answer to Q7.14 at the end of preceding page 123?

pH value

0 hydrochloric acid (HCl)
battery acid

1

2 stomach acid (1.0–3.0)
lemon juice (2.3)

3 vinegar, wine, soft drinks, beer
orange juice, some acid rain

4 tomatoes, grapes

banana (4.6)
5 black coffee, shaving lotions
bread
normal rainwater
6 urine (5–7)
milk (6–6)
saliva (6.2–7.4)
7
pure water
blood (7.3–7.5)
8 egg white (8.0)
seawater (7.8–8.3)

9 baking soda
phosphate detergents
Clorox, Tums
10
soap solutions
milk of magnesia
11 household ammonia (10.5–11.9)
nonphosphate detergent

12 washing soda (Na_2CO_3)

hair remover
13
oven cleaner

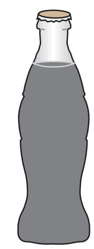
14 sodium hydroxide (NaOH)

Our subject, dissolution, begins with carbon dioxide (CO_2), which occurs in two vast reservoirs—the atmosphere and soils.
Supplying carbon dioxide to the atmosphere reservoir are (as you probably know):

- forest fires
- volcanoes
- decay of organic matter
- burning of organic fuels (coal and petroleum)
- respiration by animals

Supplying carbon dioxide to a soil reservoir is (as you might know):

- respiration by plant roots and soil fauna



Carbon dioxide combines with atmospheric moisture to form carbonic acid (H_2CO_3)—the same compound that imparts the tangy character of soda pop.

About respiration by plants—Surely you know about *photosynthesis*—that remarkable process whereby plants synthesize inorganic compounds into organic compounds in the presence of sunlight. But do you know about *respiration* by plants? Yes, respiration. It's true that plants are known for (a) taking in carbon dioxide, (b) making carbohydrates, and (c) expelling oxygen; whereas animals are known for (a) taking in oxygen, (b) burning carbohydrates, and (c) exhaling carbon dioxide. This is the grand *symbiosis* that keeps the biosphere perking. But plants also respire. In fact, plant roots only respire, thereby contributing to the soil CO_2 reservoir. Root-produced carbon dioxide combines with soil water to add to the carbonic acid in rainwater (Fig. 7.19).

Q7.15 Dissolution of limestone is facilitated by a humid climate. What are the two things associated with humid climates that promote the dissolution of limestone? *Hint:* These two things, both of which can be easily observed from a car window, are illustrated in Figure 7.19.

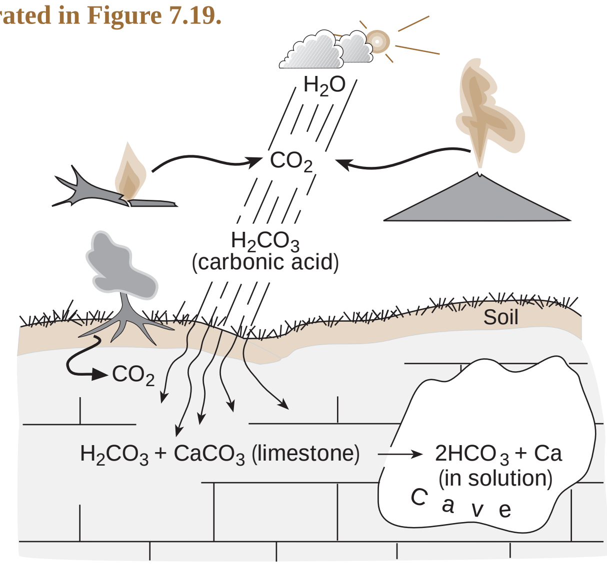
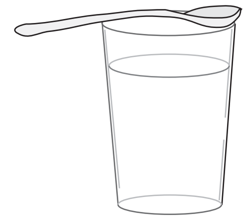


Figure 7.19 Carbonic acid reacts with limestone (which consists of the mineral calcite) to produce bicarbonate ions and calcium in solution—forming caves and shaping landscapes. (The soil on a dissolution landscape consists of a residue of insoluble material within the limestone; e.g., clay and other insolubles.)

Cave evolution



Where caves form—Caves commonly develop at the top of the saturated zone, just beneath the water table (Fig. 7.20). There are two reasons for this. The first reason has to do with the distribution of carbonic acid.

Q7.16 (A) Where within the saturated zone do you suppose the concentration of carbonic acid is greater—shallow or deep? (B) Why do you say that? (C) Which of the two histograms in Figure 7.20 appears to represent the distribution of carbonic acid—the gray or the brown?

Before describing the second reason for why caves develop just beneath the water table, imagine adding a tablespoon of table salt (NaCl) to a glass of water, stirring the water vigorously to thoroughly dissolve the salt, and then letting this salt water stand overnight.

Q7.17 (A) On the following morning, what would you imagine to be the distribution of the sodium and chlorine ions within the water? *Hint:* Dissolved ions have mass, just like solids. (B) Where within the water in the glass should it be easier to dissolve additional salt, shallow or deep? (C) Which of the two histograms in Figure 7.20 do you suppose represents the distribution of dissolved ions—the gray or the brown?

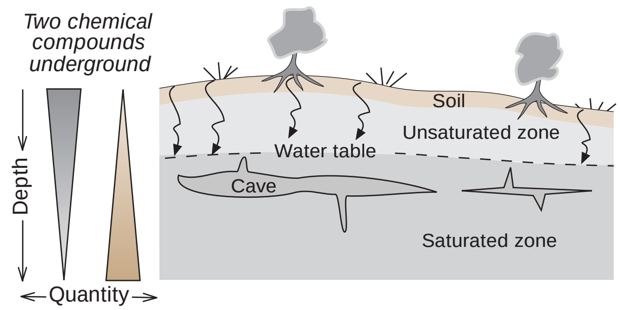


Figure 7.20 Two variables, plotted as histograms, account for the fact that caves most commonly develop at, or near, the top of the saturated zone, i.e., just beneath the water table.

Caves empty, caves fill—Dissolution that *produces* caves occurs within the saturated zone, whereas the *filling* of caves—through the precipitation of cave deposits (aka *speleothems*)—occurs within the unsaturated zone (Fig. 7.21).

Q7.18 How is it that a cave is born within the saturated zone, but then somehow finds its way into the unsaturated zone? *Hint:* The answer is evident in Figure 7.21.

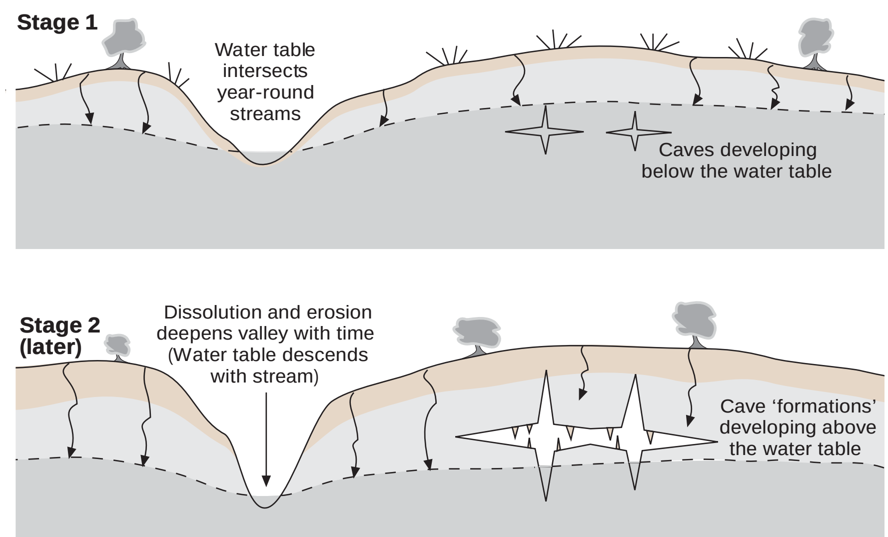


Figure 7.21 Two stages showing the evolution of a cave, from its incipient development to its being occluded with cave deposits.

Halite crystallizes from evaporating salt water. So is this the way in which calcite cave deposits develop (i.e., through the evaporation of cave water)? Probably not. Humidity within most caves approaches 100%, so evaporation is insignificant. Instead, a chemical reaction is believed to be involved.

On facing page 124 we saw that the *dissolution* of limestone (calcite) begins with the *adding* of CO_2 to water to produce carbonic acid. So what might happen if CO_2 were *removed* from calcite-rich carbonic acid—like bubbles escaping from soda pop? Escape of CO_2 drives the following reaction to the right, resulting in the **precipitation** of calcium carbonate (calcite):

$$2HCO_3 + Ca \quad CO_2\uparrow + H_2O + CaCO_3\downarrow$$

Q7.19 Agitation (as in shaking) liberates CO_2 from soda pop. So what one or two actions of cave water do you think might be accompanied by agitation of the water? *Hint:* We're looking for a simple cause of turbulence…as in the case of rain water.

D. Soils and human geography

Soil defined—There is no topic that universally impacts humans more than the subject of soil. Not only do soils act as storehouses for water and nutrients essential for plants—which provide food—but soils also play a role in maintaining air quality and filtering contaminants from groundwater.

Q7.20 Name two uses of plants in addition to food.
***Hint:* You can probably see both from your desk.**

Soil and regolith—As pointed out on page 117, the term *regolith* conveys the connotation of *process*, specifically the progressive breakdown of bedrock through various weathering processes. Soil is the most dynamic part of the regolith, commonly exhibiting several *horizons* (Fig. 7.22) in various stages of development. Soil scientists define soil as *layers of weathered, unconsolidated material that contains organic matter sufficient for supporting plant life*, whereas others simply define soil as *that part of the regolith that supports rooted plants*. The limits and character of a regolith are important to an engineer preparing a construction site, whereas the limits and character of a soil are important to a farmer.

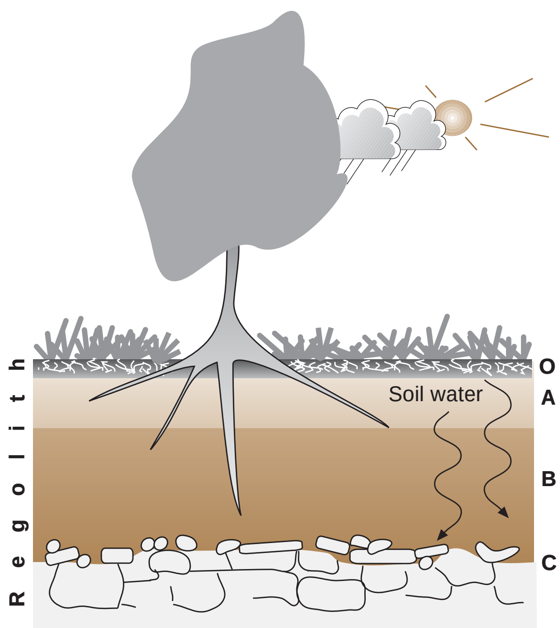
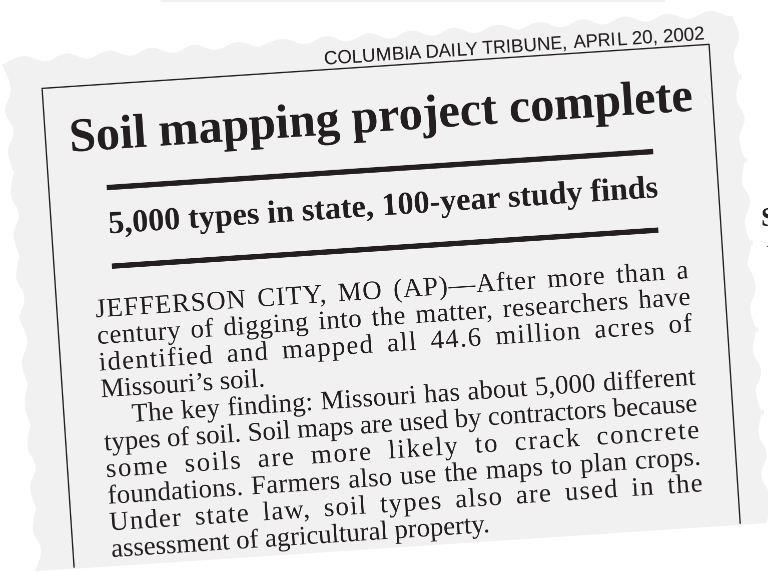


Figure 7.22 A humid region typically supports soil with four horizons (O, A, B, and C). Boundaries separating horizons are transitional in nature.



COLUMBIA DAILY TRIBUNE, APRIL 20, 2002

Soil mapping project complete

5,000 types in state, 100-year study finds

JEFFERSON CITY, MO (AP)—After more than a century of digging into the matter, researchers have identified and mapped all 44.6 million acres of Missouri's soil.

The key finding: Missouri has about 5,000 different types of soil. Soil maps are used by contractors because some soils are more likely to crack concrete foundations. Farmers also use the maps to plan crops. Under state law, soil types also are used in the assessment of agricultural property.

Soil surveys—Soil scientists recently reported that there are 5,000 different types of soil in the state of Missouri. (This gives you some idea of how seriously soil scientists view their work.) Even reducing that number down to the *12 major soil orders* involves more detail than an introductory geology course warrants. So we will look at only a few of those orders.

USDA, Natural Resources Conservation Service/Soil Survey Division is at www.nssc.nrcs.usda.gov.

Four factors in soil development

Judging from the fact that there are 5,000 varieties of soils in Missouri, there must be innumerable factors that determine the character of any one soil. Dominant factors include:

(1) Bedrock—What you begin with influences what you end with.

Q7.21 Recall the importance of a certain bedrock (described under Leaching on page 122) that was important in the development of the only bauxite ore in the United States. Name that rock.

(2) Climate—Differs with elevation, latitude, and the proximity of seacoasts. Climate explains differences among the three soil profiles in Figure 7.23.

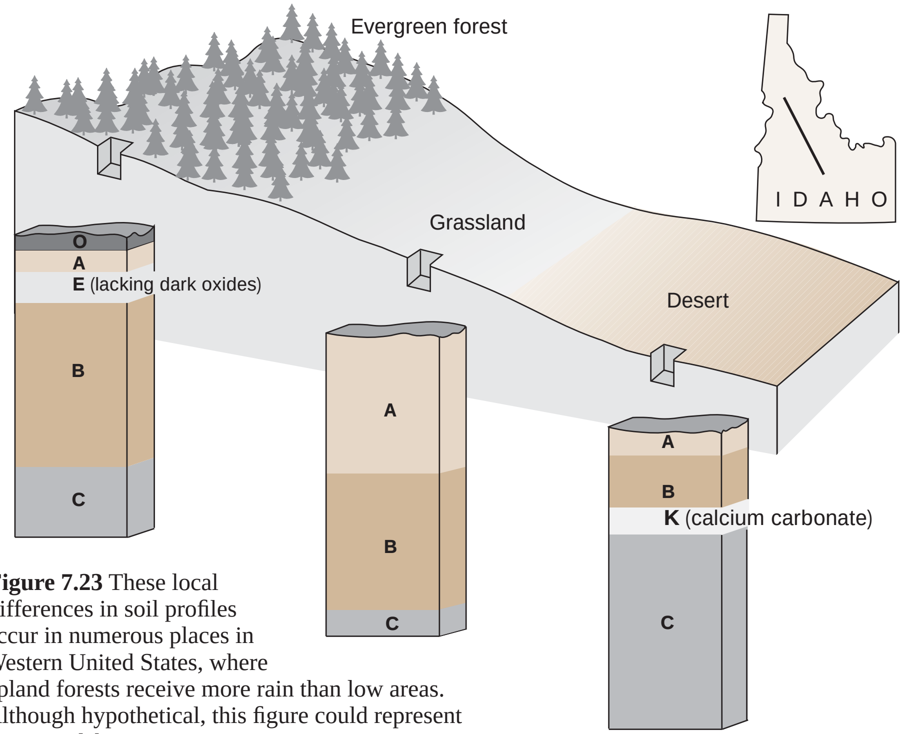


Figure 7.23 These local differences in soil profiles occur in numerous places in Western United States, where upland forests receive more rain than low areas. Although hypothetical, this figure could represent western Idaho.

On a larger scale, climate explains the difference in soils of Eastern United States as compared with those of Western United States (Fig. 7.24). Because of high rainfall, eastern states are characterized by **high-aluminum** soils. (Again, recall the leached laterite soils described on page 122.) In contrast, western states are characterized by **high-calcite** (i.e., calcium carbonate) soils.

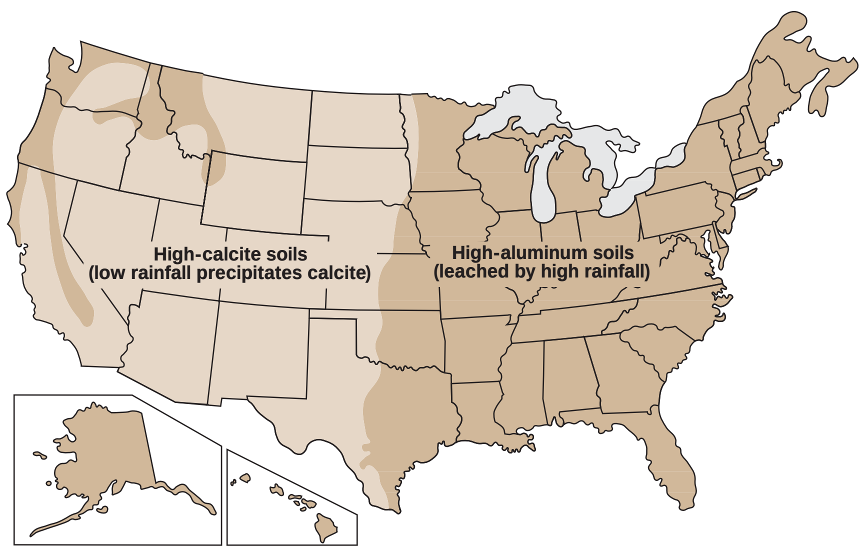
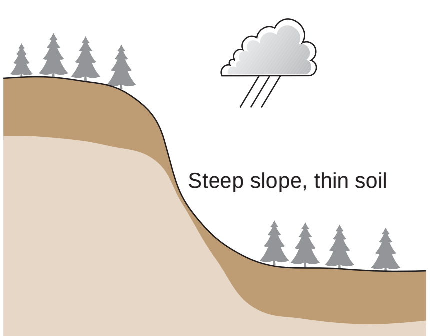


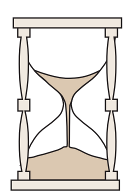
Figure 7.24 This continental distribution of soil types reflects a difference in rainfall. Eastern states are relatively humid, whereas western states are relatively dry.

Q7.22 Ref. Figure 7.24. Why the patchy occurrences of high rainfall in the northwest? *Hint:* Look again at the caption to Figure 7.23.

(3) Slope—Steep slopes lose soil through erosion.



(4) Time—Soil development is a process. Given a particular set of conditions, the longer the time, the thicker the soil.



Soils and human geography

A cursory examination of the general highway map of Fayette County, Texas, (Fig. 7.25) reveals two areas that differ markedly in the abundance roads.

Q7.23 Identify the map feature that separates these two areas from each other.

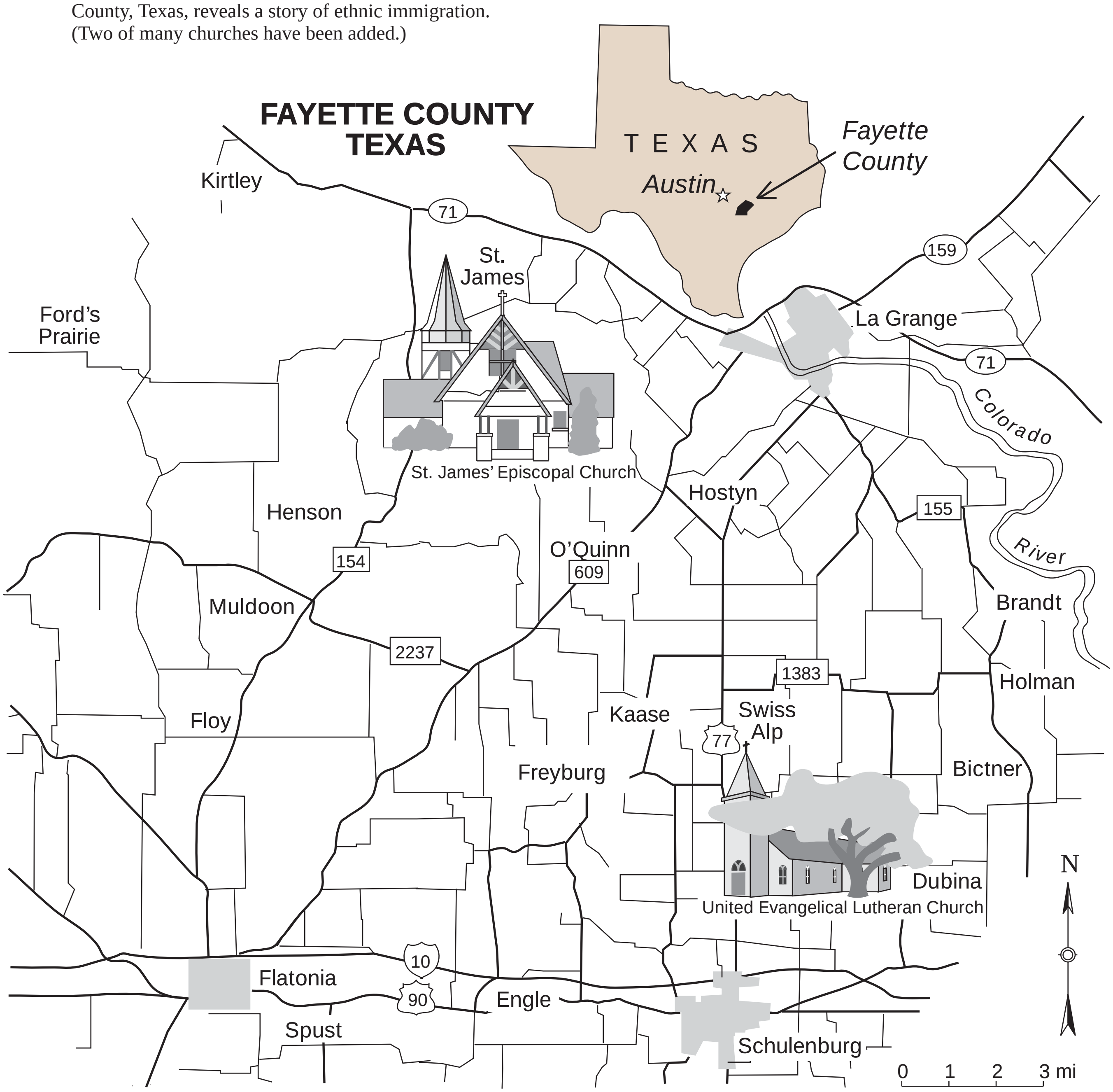
FYI—As you might surmise, the greater abundance of roads correlates with a greater degree of agricultural development.

Q7.24 Relative to the map feature asked for in Q7.23, where, in broad map terms, is the more fertile soil in Fayette County (NW, NE, SW, SE of the map feature)?

In the area of more fertile soil, examine the names of towns and the name of the church near Dubina.

Q7.25 (A) What ethnic group of immigrant farmers appears to have arrived first in Fayette County? (B) What ethnic group arrived second?

Figure 7.25 The general highway map of Fayette County, Texas, reveals a story of ethnic immigration. (Two of many churches have been added.)



Bedrock of Fayette County—The geology of Fayette County appears on the geologic map on page 189 at coordinates H-8. The bright yellow pattern labeled Te3 equates with the Catahoula Formation, and the light purple pattern labeled Tm equates with the Oakville Formation.

The Oakville Formation is characterized by thick soil that ranges from neutral to moderately alkaline. Water-holding capacity is high. In contrast, the Catahoula Formation exhibits moderately thick to thin soil developed on weakly to strongly cemented volcanic ash. It ranges from moderately acid to neutral. Water-holding capacity is low to moderate. In sum, Oakville Formation soil fertility is superior to that of the Catahoula Formation.

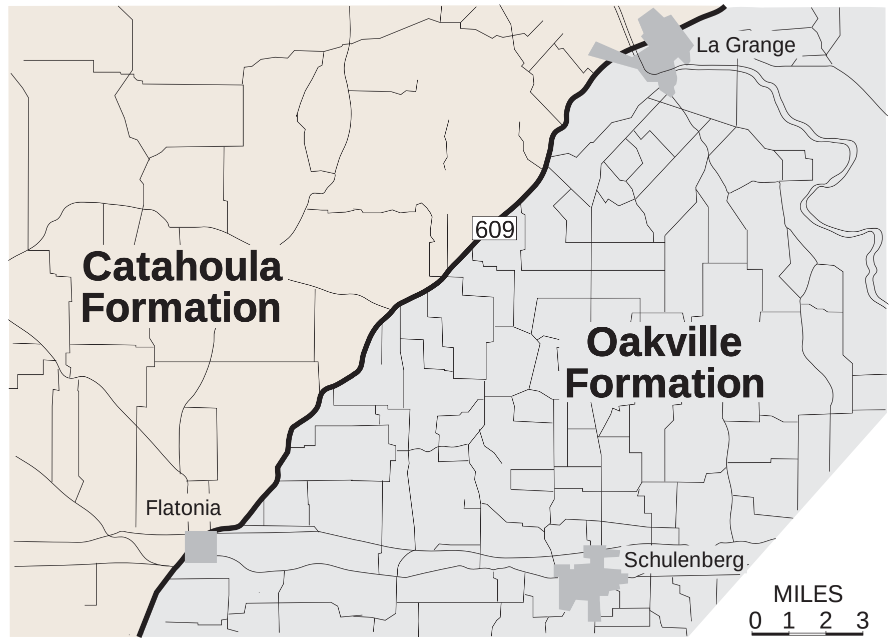


Figure 7.26 The bedrock geology of Fayette County, Texas, consists of the Catahoula Formation blanketed in part by the Oakville Formation. Both tilt gently into the Gulf of Mexico Basin, so on this map we view their up-turned edges.

Q7.26 What is the age of volcanic activity that influenced that part of present-day Texas, Eocene or Miocene? (See map legend, page 188.)

The geology of champagne

Grapevines require little in the way of soil fertility. More important are sunny hillsides and good drainage. But in the famous Champagne region of France (Fig. 7.27) a particular bedrock nutrient is a welcomed supplement.

A part of French Law known as *Appellation contrôlée* requires wine distributors to be faithful to the region of origin when labeling products. So one can be sure that French champagne comes from the northeast margin of the Paris Basin, where Cretaceous chalks are rimmed by bluffs of Tertiary clay and lignite coal. Grapevines prefer the superior drainage of the Cretaceous chalk, while at the same time benefiting from a particular nutrient washed down from Tertiary lignite above.

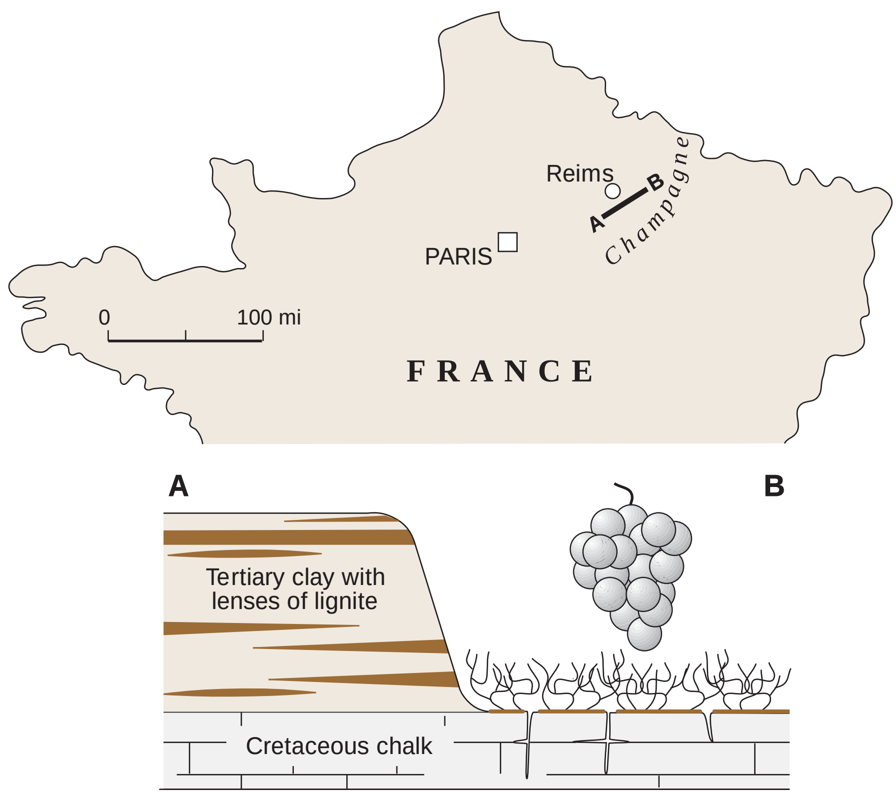


Figure 7.27 It is said that champagne grows with its feet in the Cretaceous and its head in the Tertiary. Vineyards benefit from good drainage in the Cretaceous chalk, plus an essential nutrient washed down from Tertiary lignite.

Q7.27 Judging from the description of lignite in Figure 6-5 on page 110, what could this elemental nutrient possibly be? *Hint:* It is an essential basic building block in organic compounds.

Soil development and forest succession

There is another variable in soil development in addition to the four variables examined on page 127. That variable is **substrate**.

Plants make their own bed as it were through the production of carbonic and organic acids and through the accumulation of decaying organic matter.

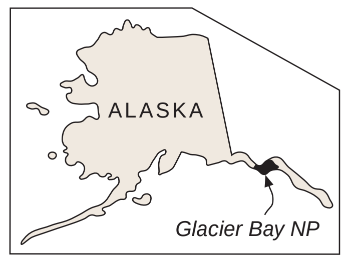
Dynamics of substrate development can be illustrated with a succession of cores collected from within soils developing on the heels of a retreating glacier in Glacier Bay National Park, Alaska (Fig. 7.28). The melting glacier deposited its sediment load, forming a carpet of glacial *till* (i.e., clay, silt, sand, gravel). The porous till has acted much like a regolith in facilitating soil development. So, despite the cold climate of Glacier Bay, the development of soil, and of the plants that the soil supports, has been rapid in the context of geologic time:

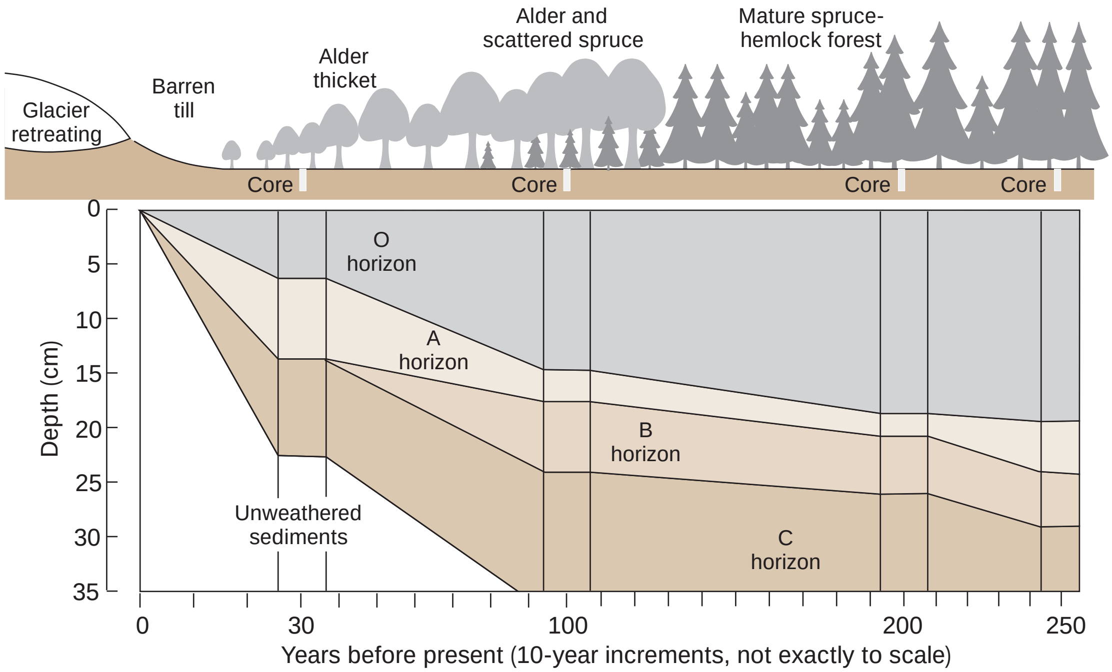
- Within a few years—'A' soil horizon.
- After 50 years—'B' soil horizon.
- After 100 years—A mature forest.

Q7.28 After 30 years of development, (A) which horizon was the thickest? (B) Which horizon was yet to develop?

Q7.29 Judging from their relative thicknesses, which horizon appears to be the most essential for the development of the mature spruce-hemlock forest—O, A, or B?

Figure 7.28 This is a cross-section based on a series of four cores collected from soil profiles near Glacier Bay NP, Alaska. This is a snapshot of the development of soil during the past 250 years. (Look back at Figure 7.22 on page 126 for descriptions of soil horizons if needed.)





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ANSWER PAGE

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