Europe to Asia? Explain the irregular outline of Eurasia. (*G*) How has the continent form influenced man?

16. State the distribution of the ocean water: its general distribution; the subdivisions, starting from the Southern Ocean; the meaning of land and water hemispheres. What obstacles have been overcome?

SUGGESTIONS. — (1) In a small jar seal up a plant, being careful to have it well watered, and see if it grows after the oxygen is exhausted. (2) Place a candle in a fruit jar, light it and see if it burns after the oxygen is used up. (3) Why are there holes beneath the flame of a lamp? (4) Have some oxygen generated in the chemical laboratory, and place in it a smouldering piece of cloth. Explain the change that occurs. (5) How deep is the soil in your vicinity? Find some cut — a cellar, railway cut, or stream valley, — where bed rock is seen beneath the soil. How thick is the soil? Of what is it composed? What kind of rock underlies it? Is the line between rock and soil a sharp line? (6) To illustrate the three states of matter: freeze some water. Melt the ice, then evaporate the water over the fire. Where does the water go? Place some water in a shallow pan in a room and watch it from day to day. Where does it go? What becomes of the water that you pour on plants? Of that sprinkled on the city pavements? (7) Stir mud and water together. Have you ever seen a stream resembling the muddy water? Where did the mud come from? Where was it being carried? (8) Carefully weigh a piece of chalk. Soak it in water and weigh it again. Why the difference? Most rocks will illustrate the same thing, but, being less porous, not so well as chalk. (9) Place some salt in water and stir it once in a while. Where has the salt gone? After twenty-four hours pour the water off and evaporate it. Do you find the salt? Chalk, marble, and many mineral substances will dissolve as the salt did, but in smaller quantities. (10) See if there are fossils in the rocks of your neighborhood. If so, find out if they once lived in the sea. What do they prove? (11) In a shallow pan of water build three ridges of pebbles and clay, as high as you can, forming a triangular outline to represent the mountain skeleton of North America. With a sprinkling pot wear them partly down. Draw off the water with a siphon, then make a sketch map of the miniature continent, marking on it the position of the mountain ridges. Compare it with an outline map of North America.

Reference Books. — See references at end of Chapters III, X, and XII; also MILL, *International Geography*, Appleton & Co., New York, $3.50.

CHAPTER III.

CHANGES IN THE EARTH'S CRUST.

17. Relation of Man to the Land. — In a railway journey from Atlantic City, east of Philadelphia, to Chicago a great variety of land forms may be seen. First the seashore; then a lowland plain; then a hilly country; then a wild mountain region, with long ridges separated by broad valleys; then a rugged plateau, with rivers deeply set between steeply rising, wooded banks; then the open plains. Besides these large features many smaller ones are noticeable — rivers, creeks, brooks, rapids, waterfalls, floodplains, lakes, narrow gorges, broad valleys; in fact, all the great variety of land forms to be found in a large area of diversified country.

The careful observer will also note the following facts regarding settlement and industry. The steeper hill and mountain sides are still forested (Fig. 85), and lumbering is the only industry on their rocky slopes. Few houses are seen in the narrow valleys, though here and there a fall has given the site to a mill, or even to a town; and, in a few places, there is some industry connected with the production of valuable minerals from the mountain rocks. On the other hand, the open plains and low hills, both to the east and west of the mountains, are everywhere inhabited; houses are almost always in sight, woods are scattered, farms are seen on every hand, and the land is dotted with villages, towns, and cities.

This route passes three of the largest eleven cities in the United States, — Chicago the second in size, Philadelphia the third, and Pittsburg the eleventh. One is a sea port, one a lake port, and one a river port.

These few facts indicate that there is a relation between the form of the land and the industries of the people. Every educated person should know the causes which operate to so modify the form of the land as to adapt it to different industries. This inquiry belongs to physical geography, or, as it is often called, *physiography*. To truly appreciate this subject it is necessary to carry our inquiry back far enough to understand some geological facts and principles; and to this the present chapter is largely devoted.

Summary. — *There are great differences in the land surface from place to place, and consequently in the industries of man. Physical Geography, or Physiography, studies the causes for these differences and their relation to one another.*

18. Rocks of the Crust.[1] — The many different kinds of rocks in the earth's crust are included in three large classes, — *sedimentary*, *igneous*, and *metamorphic*.

(A) *Sedimentary Rocks.* — Rock fragments — pebbles, sand, and clay — are washed into seas and lakes by rain, rivers, and waves. They settle in the quiet water, the coarser fragments sinking to the bottom first. The motion of the water, agitated by waves and currents, keeps the finer fragments suspended for a longer time, and they therefore sink to the bottom farther from shore. Thus the water assorts the rock fragments according to size.

On some days the waves and currents are weak, on others strong; sometimes the rivers bring little sediment, at other times much. These differences in currents, and in materials supplied, cause the deposit of layers of different kinds, one on another. Each layer is of the kind that waves and currents are able to bring (Fig. 35).

Such layers are called *strata* (singular, *stratum*), and the rock is said to be *stratified*. Some strata are thin, others thick. Sometimes only one stratum is seen in a cliff, while in

[1] Appendix C contains a description of common minerals and rocks.

FIG. 31. — A shale cliff in a gorge. Some of the layers are slightly more sandy than the clay shales which form most of the cliffs.

FIG. 32. — A gravel bank, with some layers partly consolidated, and therefore standing out from the face of the bank.

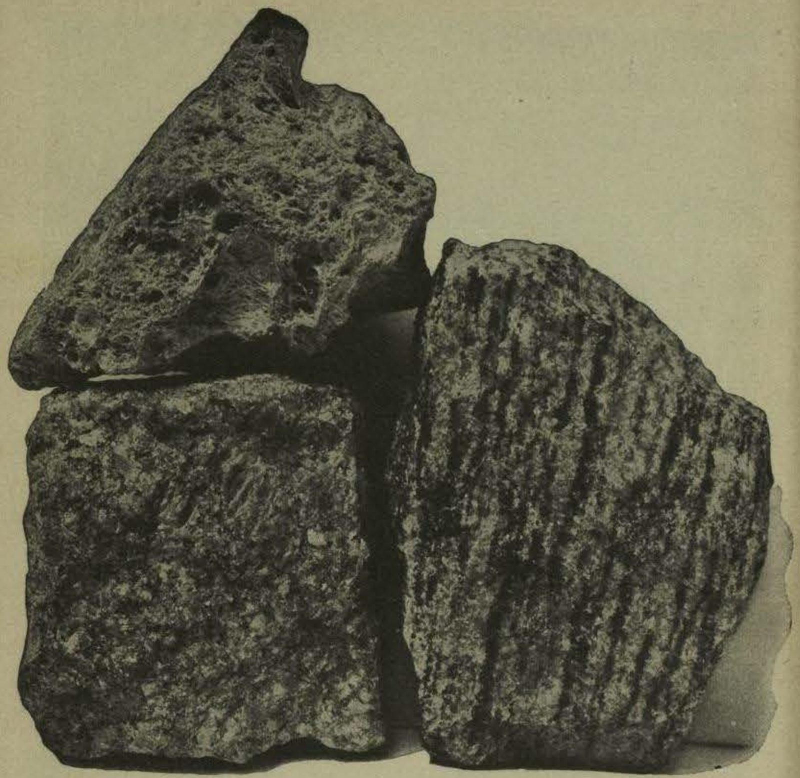

FIG. 33. — Granite, lower left hand figure; pumice, upper left hand; gneiss, right hand.

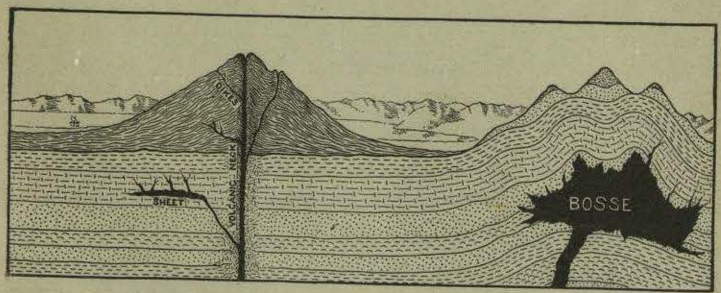

FIG. 34. — To illustrate the origin of igneous rocks. The cone on the left is a volcano, made of lava and volcanic ash.

other cliffs there are strata of different kinds (Fig. 31), possibly shale, sandstone, conglomerate, and limestone.

When the sediment is deposited, it is loose and unconsolidated, like a gravel bank. The pressure of other layers, deposited above, and the action of percolating water, slowly bind the fragments together, forming solid rock. The percolating water dissolves mineral substances in one place, carries them on, and deposits some around the sediment grains. This binds, or cements, the rock

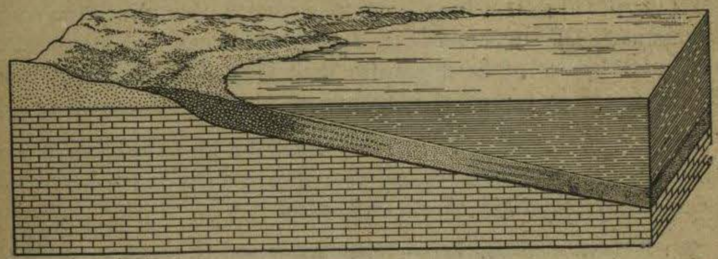

FIG. 35. — To illustrate the deposit of sedimentary rocks. On the extreme left are coarse pebbles; on the extreme right, clay; in the middle, sand. Some layers of pebbles were dragged out to the sand area when the currents and waves were strong; and some sand layers were stratified with the clay strata.

fragments together. The most common rock cements are the common soluble minerals, carbonate of lime, oxide of iron, and quartz. One may often see the process of cementing in a gravel bank (Fig. 32) where a white coating of carbonate of lime has been deposited on some of the pebbles.

Summary. — *Sedimentary rocks are in layers, or strata, formed by the assorting power of waves and currents, which vary in strength and carry finer particles farther from shore than the coarser particles. By pressure and the deposit of mineral cements, the loose rock fragments are bound together, forming solid rock.*

(B) *Igneous Rocks.*[1] — These rocks have risen from within the earth in a melted state. In some cases each eruption produces a lava flow, which cools to form a thick, massive layer of solid rock. In other cases the violence of the eruption

[1] See also Chapter VII.

blows the lava into bits of volcanic ash or porous pumice (Fig. 33). Lava and ash usually build a cone around the volcanic vent or neck (Fig. 34). Such beds are usually less regular and more massive than sedimentary strata.

Much lava fails to reach the surface. Such *intruded* igneous rock is found in various positions, cutting across the sedimentary and other rocks. A narrow crack filled with lava forms a *dike* (Fig. 34); a mass of lava thrust between strata forms an intruded *sheet* or *sill* (Fig. 34); large, irregular masses, rising into the cores of mountains, form *bosses* (Fig. 34). Pikes Peak and many other peaks are bosses of hard granite rock (Fig. 33), brought to light by the wearing away of the layers into which they were intruded.

Summary. — *Igneous rocks are formed by the cooling of melted lava, some at the surface, in the form of lava flows and volcanic ash, some as intruded dikes, sheets, and bosses.*

(C) *Metamorphic Rocks.* — When subjected to great pressure, or heat, or both, rocks are changed, or *metamorphosed.* By metamorphism limestone is altered to marble; shale to slate; and sandstone to quartzite. The change may go so far that, as in the case of *gneiss* (Fig. 33) and *schist*, it is often impossible to tell the nature of the original rock. Metamorphic rocks are especially common among mountains where, during the mountain formation, the strata have been subjected to great pressure and heat. These changes have bent, folded, broken, and twisted the layers (Fig. 46), and often completely altered the rocks from their original condition.

Summary. — *When subjected to heat, pressure, or both, as among mountains, rocks are greatly altered or metamorphosed.*

(D) *Resistance of Rocks.* — All minerals, when exposed to the weather, are attacked by the elements; but there is much difference in the rate at which different ones wear away. Quartz, for example (Appendix C), is hard, only slightly soluble, and does not decay; feldspar is hard and does not dissolve, but decays without great difficulty; calcite is both soft and easily soluble.

The rate of decay of rocks depends in large part on the kind of minerals of which they are composed. Sandstone and quartzite (Appendix C), made mainly of quartz, are usually very durable rocks; and so is granite, which is mostly quartz and feldspar. On the other hand, limestone and marble, made of calcite, are easily destroyed.

The decay of minerals and rocks is due largely to the action of water (p. 38). Hence dense and massive rocks, like gneiss and granite, are not so easily disintegrated as porous or friable ones, like shale and schist, into which water enters easily. Because of these facts weak rocks are worn away, forming valleys, while durable rocks are left standing to form hills, ridges, and peaks (Fig. 38).

Summary. — *Some minerals and rocks are durable, others weak. Therefore, as the land wears down, valleys are formed where the rocks are weak; hills, ridges, and peaks where they are more durable.*

19. Changes in Level of the Land. —The old ideas, that the hills are everlasting and that the land is firm and stable, are now known to be incorrect. On the contrary, the land is ever changing. Hills are slowly wearing away, valleys are being deepened, and the waste is being carried to the sea.

In addition to this, the crust of the earth is slowly rising in some places and sinking in others. By these movements sea bottoms have been raised to form parts of continents; mountains have been formed; and lands have been lowered beneath the sea. The explanation of these changes is the slow cooling and contraction of the heated interior (pp. 17 and 99).

Evidence of such changes in level during past ages is abundantly preserved in the rocks. Beaches and coral reefs are found many feet above the sea; and fossil remains of ocean animals are entombed in the strata, even of mountains. There is also full proof that changes of level are now in progress. For example: a part of the Scandinavian peninsula, north of

Stockholm, has risen 7 feet in 150 years; the Netherlands are slowing sinking; the coast of New Jersey is sinking at the rate of about 2 feet a century; Eskimo houses in Greenland have been lowered into the sea; the land around the Great Lakes is slowly rising; and in 1822, and again in 1835, the coast of Chile was raised 2 to 4 feet. Hundreds of similar cases are known (Fig. 37).

These changes of level are of two kinds: (1) rapid and local, where mountains are now growing, as in Japan and western South America; and (2) slow and widespread, where large areas slowly swing up or down, as in northeastern America (p. 208). While in some places the lands are sinking, as a general rule they are rising. This has been true for long periods of the past; and, as a result, the continents are very largely made of sedimentary strata that were deposited in ancient seas.

Summary. — *The surface of the land is slowly wearing away; it is also being raised here and lowered there. There are both local rapid movements and a slow swinging up or down of large areas. On the whole, the continents have been rising, and this is why they are so largely made of sedimentary strata.*

20. Disturbance of the Strata. — The sedimentary strata are deposited in nearly horizontal layers parallel to the sea floor (Figs. 35, 43). When added to the land these strata are usually raised by slow, broadly extended movements which only slightly disturb the original horizontal position (Fig. 31). The plains of the Atlantic coast and the Mississippi valley, and the plateaus of the West, have such horizontal strata.

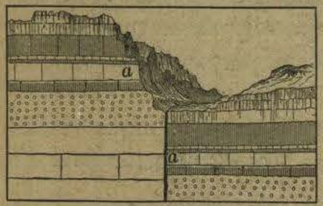

Fig. 36. — A fault. The same layer (*a a*) stands at different levels on the two sides of the fault plane.

Among mountains, on the other hand, the strata are folded and broken by the great pressure. In such cases the layers are no longer horizontal, but are tilted at all angles (Fig. 38).

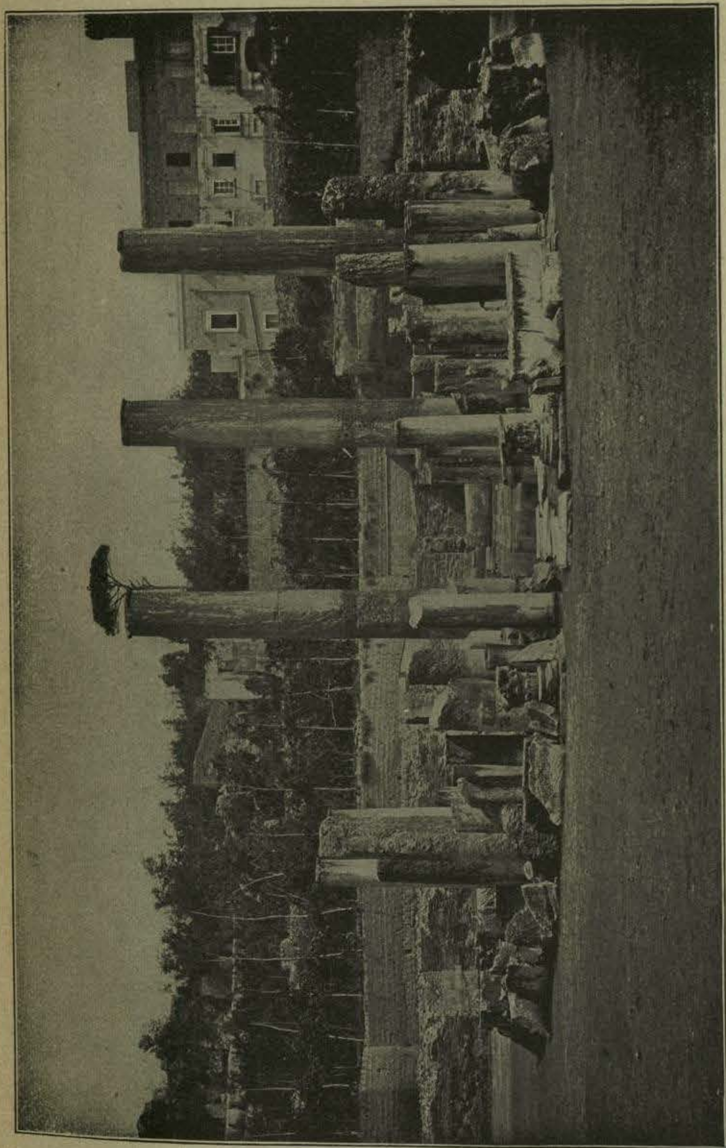

Fig. 37. — The columns of Jupiter Serapis at Puzzoli (Fig. 202), on the Bay of Naples, Italy. These ruins of an old temple, built on dry land, were lowered beneath the sea, then raised to their present position. Notice the rough surface in the marble columns, reaching about to the height of the wall. This is due to a shellfish (Lithodomus) which bores into the rocks along the Mediterranean coast. These borings prove that the columns have stood beneath sea level up to that point.

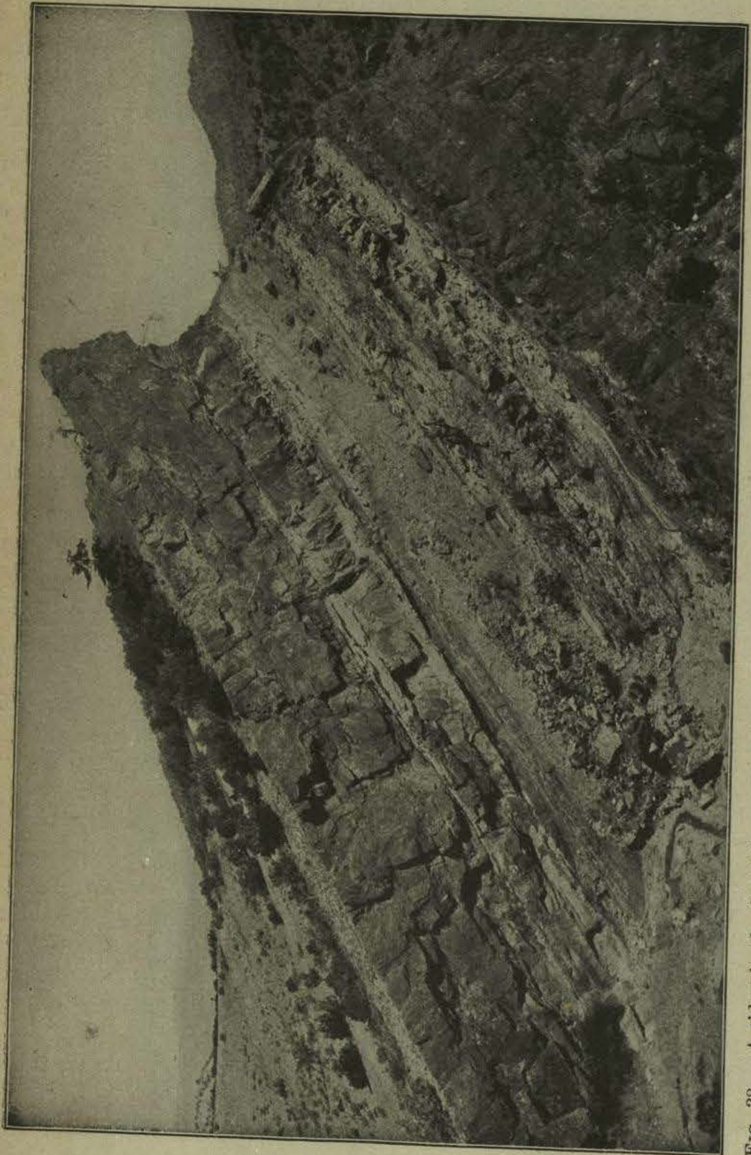

Fig. 38. — A ridge in the foothills of the Rocky Mountains. These rock strata were deposited in the sea in a horizontal position, then tilted during the growth of the mountains. They prove change in level as a result of mountain growth. The upper layer is harder than the others, and hence resists the weather better. This is why it stands up so sharply while the weaker layers below are more rapidly crumbling away.

Lava and metamorphic rocks (p. 34) are also common in mountain regions. For these reasons mountain rocks are far more complex in kind and position than those of plains.

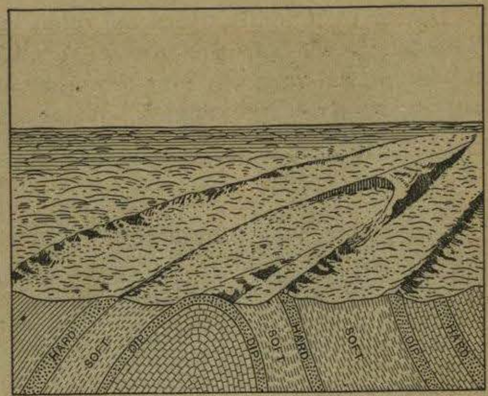

Fig. 39. — An anticline.

Various names have been given to the forms assumed by the disturbed mountain strata. A break in the rocks, accompanied by movement on one side, is known as a *fault* (Figs. 36, 44). An arched upfold of the strata is known as an *anticline* (Figs. 39, 45); a downfold is a *syncline* (Fig. 40). In an anticline the rocks incline, or *dip* (Figs. 38, 39, 45), both ways from the axis of the fold; in a syncline they dip *toward* the axis (Fig. 40). Where a fold has a dip in only a single direction it is called a *monocline* (Fig. 41). Some folds are very regular or *symmetrical* (Fig. 45); others are quite *unsymmetrical* (Fig. 42); and in some, the folding has gone so far that the folds are actually *overturned* (Figs. 42, 48). In very intense folding the strata are sometimes *crumpled* (Fig. 46).

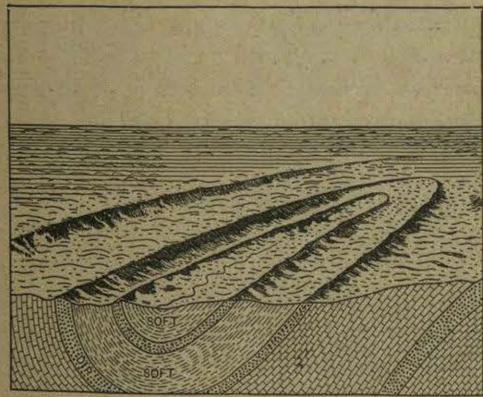

Fig. 40. — A syncline.

During their uplift, rocks are often cracked by the strains. These cracks are called *joint planes* (Figs. 47, 75). The joint planes usually extend vertically into the strata, and consist of two sets, meeting nearly at right angles. Water readily enters along these natural planes of splitting (Fig. 51), which therefore aid in disintegrating the rocks. Joint planes are of great importance in quarrying, for they make natural breaks which aid in splitting out blocks of stone.

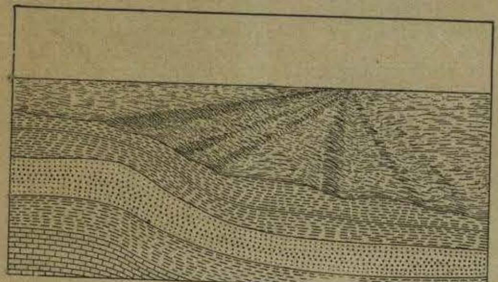

Fig. 41. — A monocline.

Summary. — *In plains and plateaus the uplifted stratified rocks are commonly left in nearly their original horizontal position; but in mountains they are folded and faulted. Joint planes, or natural planes of breakage, are also produced by the strains.*

21. Agents of Weathering. — When exposed to the air, rocks crumble and fall apart as wood and nails do. This disintegration, or *weathering*, is due to the action of various agencies, the most important of which are percolating water, air, and the action of animals and plants. These agencies do

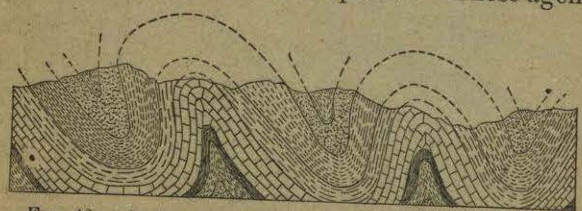

Fig. 42. — Section of unsymmetrical and overturned folds.

some of their work by dissolving and decaying minerals, some by mechanical means, as when rocks are ruptured by frost.

Summary. — *Rocks crumble, or weather, by the mechanical and chemical action of percolating water, air, and animals and plants.*

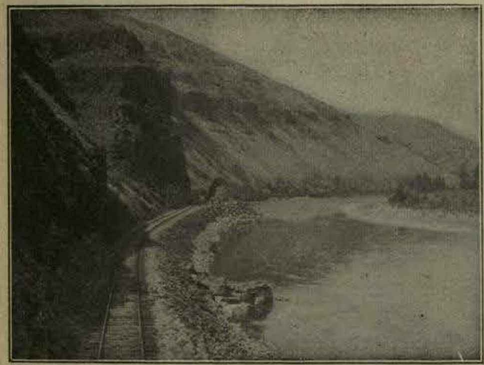

Fig. 43. — Horizontal strata in the West. A hard layer, standing out as a low cliff, may be seen in the foreground and far along the hillside.

Fig. 44. — A fault. Notice that the layers do not match on the two sides of the fault plane.

Fig. 45. — A symmetrical anticline.

FIG. 46. — Crumpled layers in Canada. Notice how contorted they are.

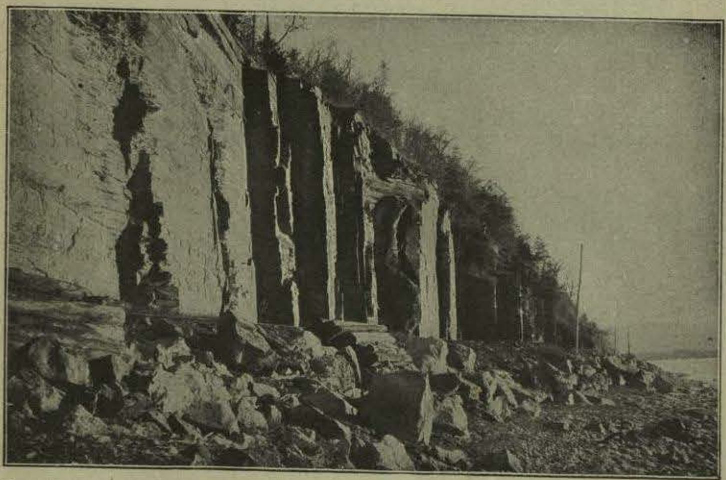

FIG. 47. — Joint planes on the shores of Lake Cayuga, New York. The two sets, almost vertical, meet at nearly right angles. The smooth faces of the cliff are due to the fact that the rock has cleaved away from it along the joint planes.

22. Work of Underground Water. — A portion of each rain sinks into the soil, and part of it percolates into the rocks, for underground water is able to enter even the densest of rocks. Some of this water enters along joint planes (Figs. 51, 54); some between the rock grains; and some along the cleavage planes of the minerals.

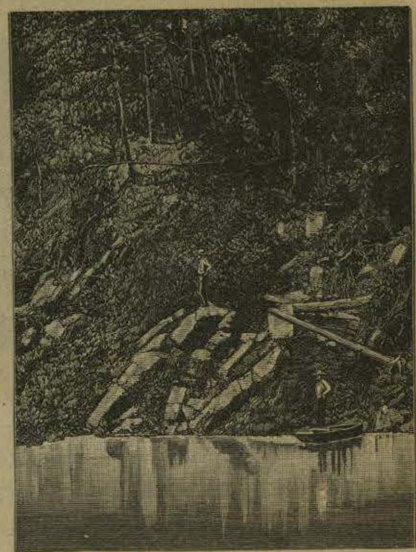

FIG. 48. — A small, overturned fold — both a syncline and an anticline.

In moist climates, shallow wells find this underground water even in rock; and upon it farms and entire towns and villages depend for drinking water. It is underground water, too, that the roots of plants seek in the soil. Without it they die. Its presence is further shown by springs, which are places where underground water rises to the surface in some quantity (p. 59).

Underground water finds many mineral substances which it is able to take away in solution. Its power of solution is greatly increased by carbon dioxide, and other substances, which it obtains from the air and from decaying vegetation.

Aided by oxygen, carbon dioxide, and other substances, the underground water also causes changes in composition of many minerals. These changes are not very unlike that which causes a shiny nail, when exposed to dampness, to decay to a yellow, powdery iron rust. By these changes some substances are produced which the percolating water can carry off in solution. The roots of plants seek and obtain some of these soluble mineral products, which are *plant food.* This decay, together with removal of portions, causes minerals and rocks to crumble.

In cold climates the mechanical work of water is of importance in disintegrating rocks. The water, in the soil, in the joint planes, and in the microscopic rock crevices, freezes in winter. When water freezes it must expand; and, as a bottle breaks when water freezes in it, so in winter the rocks are often broken by frost action. This frost work is an important agent of rock disintegration (Figs. 49, 52, 54).

FIG. 49.—A mountain top, showing the rock shattered by frost action.

Summary. — *Water percolates into soil and even rock. It dissolves some minerals, changes others, and thus causes the rocks to disintegrate. In cold climates, frost also aids in disintegration.*

23. Influence of Air in Weathering. — Warming causes rocks to expand, and cooling causes them to contract. A fire built against a rock, for example, causes it to expand and crack. In hot deserts the warming of rocks by day, and cooling by night, are important means of disintegrating them.

The oxygen and carbon dioxide of the air, taken underground by water, help in the work of disintegration; they also cause changes in damp soil and rock at the surface.

Summary. — *Air helps in rock disintegration by its changes in temperature and by supplying oxygen and carbon dioxide.*

24. Organisms as Agents of Weathering. — The roots of plants help to pry rock materials apart. In their search for water and

plant food, the roots and tiny rootlets enter any crevice to be found (Fig. 53). On growing larger they exert such a pressure on the walls of the crevices as often to rupture them. In this way soil is pulverized and rocks broken apart.

The ash left when wood is burned is largely mineral matter that the roots have taken as plant food. This proves that plants remove mineral substances from the soil and rock, and therefore that they help in disintegration. They aid also by supplying carbon dioxide and organic acids to water which, on soaking into the soil, passes through decaying vegetation.

Animals are likewise effective agents of weathering. This is especially true of burrowing animals, such as earthworms, moles, ants, woodchucks, and prairie dogs. They stir up the soil, thus making it more open to the entrance of water; they bring soil to the surface, thus exposing it to the weather; and some, like the earthworms, take soil into their stomachs, grinding it a little as it passes through. Earthworms are among the most important of agents in soil preparation.

Summary. — *Weathering is aided by plant roots, which pry off fragments and remove mineral substances; by carbon dioxide and organic acids, supplied from decaying vegetation; and by the action of burrowing animals, especially earthworms.*

25. Rate of Weathering. — Because the weather has completely destroyed their form, it has been necessary to replace certain stone ornaments (gargoyles) that were placed on the Lincoln Cathedral, in England, about seven centuries ago. On the other hand, delicate scratches on rocks, made by glaciers not less than 5000 years ago, are still perfectly preserved wherever they have been covered by a foot or two of soil (Fig. 289). These facts show that the rate of weathering is slow, but that it varies with circumstances.

The *nature of the rock* is one cause for difference in the rate of weathering. Some rocks disintegrate quickly, others slowly.

Another cause for variation is *climate.* Where there is little moisture, as in deserts, there can be little change due to frost, solution, or decay, and weathering is, therefore, very slow. An obelisk (Fig. 50), which had stood for over 3000 years in the desert climate of Egypt, began to decay so rapidly when removed to the damp climate of New York that it was necessary to protect it with a glaze. In cold climates, frost action is very active; in hot, damp climates the abundant vegetation supplies organic substances to the warm percolating water, greatly aiding it in its work of changing and dissolving the minerals.

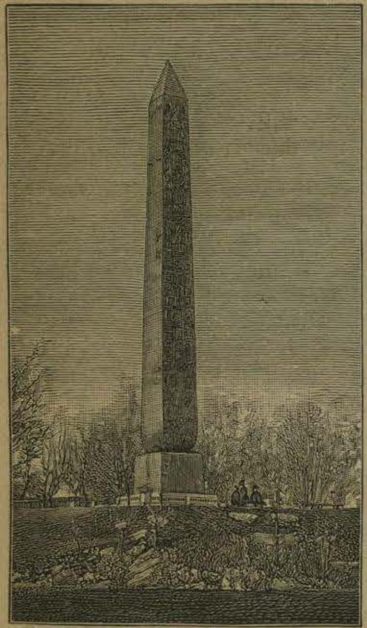

Fig. 50. — The Obelisk in Central Park.

Exposure is also of importance in determining the rate of weathering. Even a thin soil cover protects the rock from the weather. Rock fragments, loosened by weathering, remain on level surfaces and gentle slopes, forming a protecting soil blanket. But on steep slopes, from which the fragments fall away as fast as they are loosened, the rock is kept constantly exposed to the elements (Figs. 54, 57). Therefore, cliffs, precipices, and mountain slopes are places of relatively rapid weathering. That the rocks are crumbling is proved by the fact that every now and then a fragment falls from the cliffs (Fig. 57); but, even in the most favorable places, weathering is so slow that one might see no great change in a lifetime. Centuries are required for great changes.

Summary. — *Even under the most favorable conditions, weathering is very slow. Its rate varies with the rock, climate, exposure, and steepness of slope. Steep slopes are especially favorable because the falling away of loosened fragments leaves the rocks exposed.*

26. Results of Weathering. — Without question, the most important result of weathering is the formation of soil.

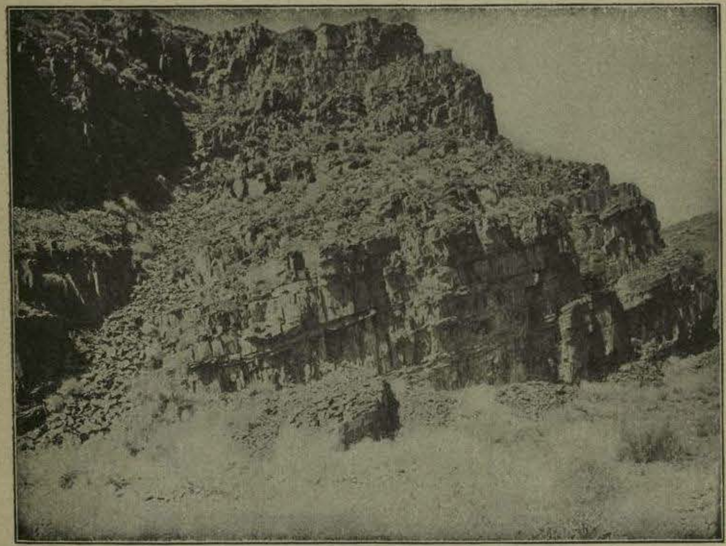

Fig. 51. — A shattered rock surface showing many cracks into which water is able to enter.

Fig. 52. — Percolating water seeping out of the rock and freezing.

Fig. 53. — The roots of a tree prying open the rock of a ledge.

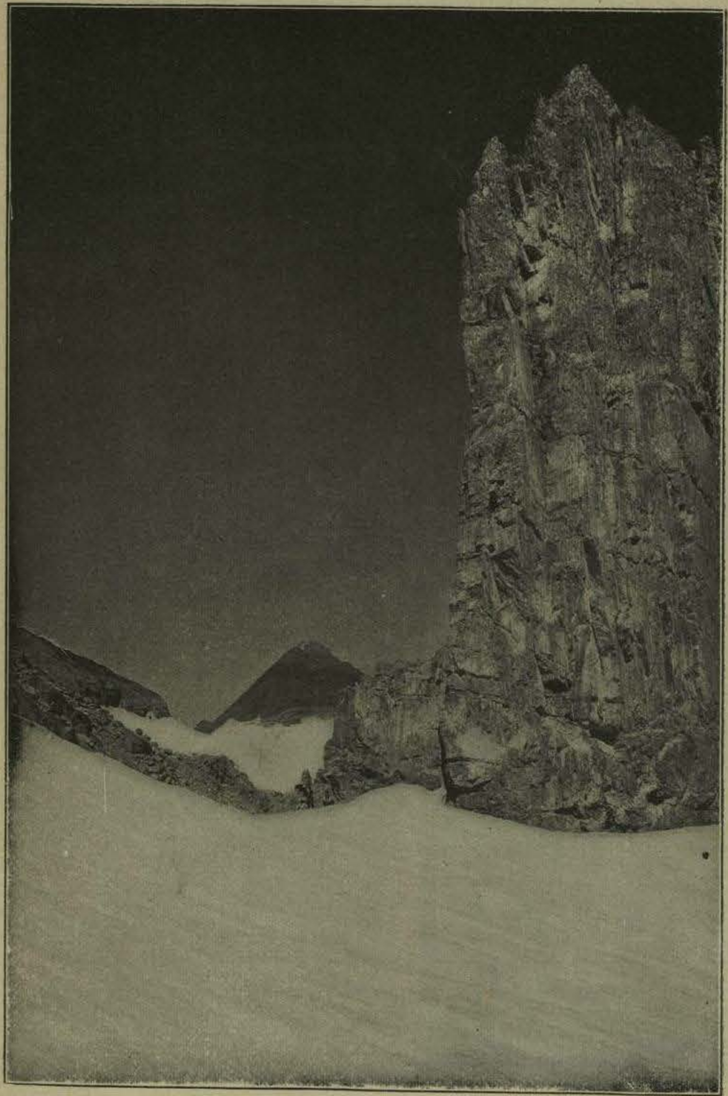

FIG. 54. — A steep peak in the high Alps where frost action is powerful. Notice the many cracks in the rock. Water enters along these, and every now and then a fragment breaks away and falls to the base.

While some of the crumbling rock is removed in solution, there is a remnant, or *residue*, which cannot be dissolved. This remnant forms *residual soil* (Figs. 55, 56), which sometimes mantles the rock to a depth of over a hundred feet. A large part of the land is covered by residual soil, resting on the rock whose decay produced it. Other kinds of soil are those brought by wind, by rivers, and by glaciers. Such soils are not residual, but transported.

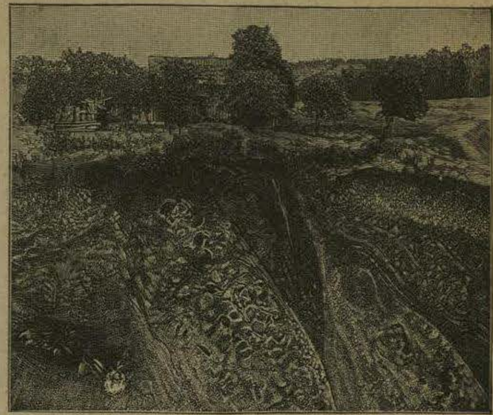

FIG. 55. — Residual soil. A few rounded pieces of solid rock remain, not yet completely disintegrated.

Weathering supplies mineral substances for underground water

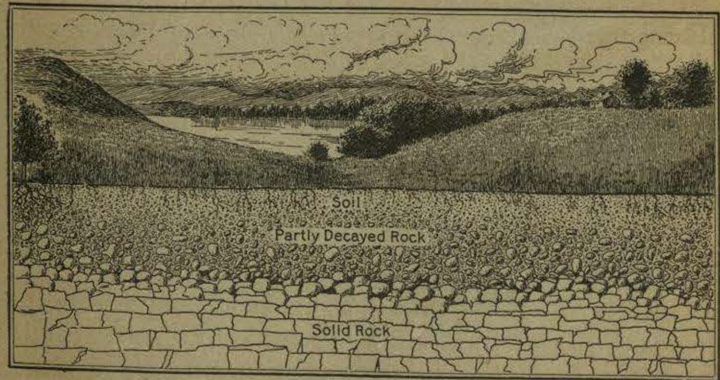

FIG. 56. — A diagram to illustrate the formation of residual soil. Notice that the soil is finer near the surface, where roots and earthworms penetrate, and that it grades downward into solid rock.

to remove in solution. It is this that gives "hardness" to water, and the valuable properties to many mineral springs. One of the most common of these dissolved mineral substances is carbonate of lime, which supplies corals and shell-bearing animals with the lime from which beds of limestone are made in the sea.

Rock fragments, loosened from cliffs by weathering, gather at the base, forming *talus slopes* (Figs. 57, 66). Occasionally great masses are loosened, falling as *landslides* or *avalanches* (Figs. 58, 161, 162). There is also a very slow, almost imperceptible movement of rock fragments down even gentle slopes. It is this that makes the streams muddy.

These rock fragments are used by the rivers as tools (Fig. 57) in cutting their valleys; and, on reaching the sea, they are deposited as beds of sedimentary rock (p. 32). By this removal of rock fragments and dissolved mineral substances, supplied by weathering, valleys are being slowly broadened.

Finally, weathering is a delicate tool of rock sculpturing. It easily discovers which rocks are weak, and which durable; and, by removing the weaker rocks faster, it etches the durable strata into relief (Figs. 38, 59). The importance of this fact is more fully shown in later chapters.

Summary. — *Among the important results of weathering not already described are,* (1) *the formation of residual soil, or soil of rock decay;* (2) *the supply of soluble mineral substances to water;* (3) *the formation of talus and avalanches;* (4) *the supply of cutting tools to rivers;* (5) *the supply of materials for the formation of sedimentary strata;* (6) *valley broadening; and* (7) *rock sculpturing.*

27. The Agents of Erosion. — Besides weathering, which disintegrates the rock, thus preparing it for removal, there are several agents of *erosion* which remove and deposit rock fragments. The work of these agents is fully stated in other chapters and now requires mere mention.

These agents are: (1) *wind*, especially active along the coast (p. 215) and in deserts (p. 87), where there is little vegetation

FIG. 57. — Talus at the base of a cliff (Black Canyon of the Gunnison, Colorado), falling into a torrential river which carries much of it away. As these rock fragments are rolled along the river bed they help to wear the rock away and thus aid in deepening the valley.

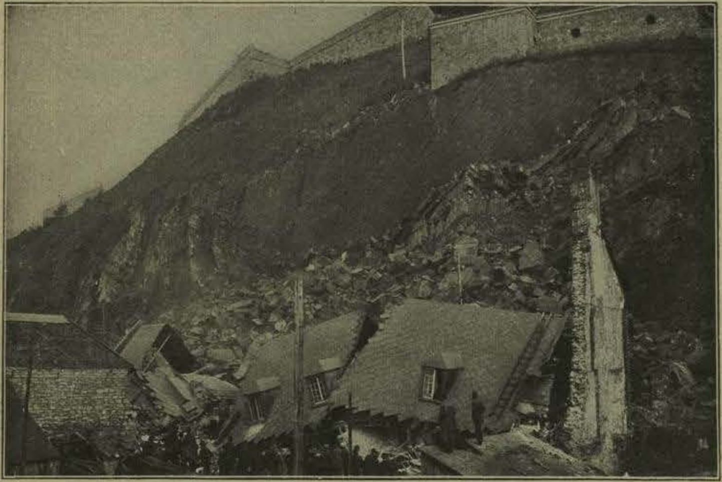

FIG. 58. — An avalanche at Quebec, just beneath the fortress, which destroyed a number of houses.

FIG. 59. — A view in the Colorado Canyon, where the cliffs have been sculptured by weathering and erosion, bringing the hard rocks into relief, and giving the softer strata more gentle slopes.

to protect the soil; (2) *rivers* (Chapter IV), everywhere at work removing materials supplied by weathering, and at the same time often deepening their own valleys with the rock fragments that they carry; (3) the *ocean*, whose waves, tides, and currents attack the land along the coast (Chapter XI), and in which sediment washed from the land is deposited (pp. 33, 176); (4) *lakes*, which resemble oceans (p. 220); and (5) *glaciers* (Chapter VIII), at present important only in high mountains and in the frigid zones.

Summary. — *The agents of erosion — wind, rivers, ocean, lakes, and glaciers — remove and deposit rock fragments.*

28. Denudation. — The combined work of the agents of weathering and erosion may be called *denudation*. By denudation the lands are being sculptured (Fig. 59) and their general level lowered. If the material removed by the Mississippi River were taken equally from every part of its drainage area, the surface of the valley would be lowered one foot in 6000 years.

Opposed to this tendency to wear the land away is the constant change in level of the land (p. 35), by which plains are being raised above the sea, plateaus made higher, and mountains uplifted (21). These uplifts are continually giving denudation new work to perform. Were it not for this elevation of the land, it is probable that the continents would have long since been reduced nearly to sea level; for the age of the earth is very great.

Summary. — *Denudation is the combined work of weathering and erosion. It tends to lower the land; but, though the age of the earth is great, frequent uplift has prevented it from lowering the continents to the condition of a level plain.*

29. Age of the Earth.[1] — No one knows how old the earth is. But all who have studied the question are agreed that it cannot be less than many millions of years, and most geologists hold that it must be at least a hundred million years. The evidence of this vast age cannot be stated in an elemen-

[1] For a list of the geological periods, see Appendix D.

tary book; but the following facts may help the student to understand why it seems a necessary conclusion.

So slow is the work of denudation that a person living by a river side, or on the seashore, may see no notable change, even in a lifetime; yet careful study will show that slow changes are in progress. Geological study has proved that slow changes have accomplished great results in the past; and this could not have happened unless there had been a great length of time involved.

Among these evidences of great changes are the following. The Colorado River has slowly cut a canyon over a mile in depth. Lofty mountain ranges once existed where New York and Philadelphia now stand; but they have been slowly worn away. Volcanoes have also been worn down to their very roots. To have slowly accomplished these great results demands vast periods of time. Sedimentary rocks furnish evidence leading to the same conclusion. It requires years for a layer of sediment a foot thick to be deposited; yet some sections reveal 40,000 feet of strata that were deposited in ancient seas.

From these geological facts the conclusion that the earth is vastly old seems inevitable; and the inference is supported by evidence furnished by physicists and biologists. Consequently, all geologists and physical geographers are now as convinced on this point, as astronomers are that the sun and stars are millions of miles away. To really appreciate the conclusions reached in the following pages, the student must start out with the same belief.

Summary. — *Evidence furnished by geologists, physicists, and biologists proves that the age of the earth is many millions of years.*

Topical Outline, Questions, and Suggestions.

Topical Outline. — 17. **Relation of Man to the Land.** — Changes noted on a railway journey: larger features; smaller features; industries; cities; relation between land form and industries.

18. **Rocks of the Crust.** — Three divisions. (A) *Sedimentary rocks:* manner of deposit; terms used; consolidation. (B) *Igneous rocks:* on

the surface; intruded into the crust. (C) *Metamorphic rocks:* cause; results; metamorphism in mountains. (D) *Resistance of rocks:* differences in minerals; in rocks; effect on land form.

19. **Changes in Level of the Land.** — Slow wearing away; movements of the crust; cause; proofs, — from rocks, from present changes; instances; two classes of movements; effect on continents.

20. **Disturbance of the Strata.** — Original position; position in plains; in mountains; fault; anticline; syncline; dip; monocline; unsymmetrical fold; overturned fold; crumpling; joint planes; importance.

21. **Agents of Weathering.** — Agents at work; nature of process; result.

22. **Work of Underground Water.** — Entrance of water; proof of its presence, — wells, plant roots, springs; solution; substances aiding solution; changes in minerals; result; plant food; frost action.

23. **Influence of Air in Weathering.** — Heat and cold; effect of oxygen and carbon dioxide.

24. **Organisms as Agents of Weathering.** — (*a*) Plants: mechanical work of roots; removal of mineral substances; aid to underground water. (*b*) Animals: kinds; work done; earthworms.

25. **Rate of Weathering.** — Illustrations of differences in rate; effect of rock; of climate, — arid, damp, cold, warm and damp; of exposure, — gentle slopes, steep slopes; slowness of weathering.

26. **Results of Weathering.** — Residual soil; other soils; dissolved mineral substances; talus; avalanches; supply of tools to streams; formation of sedimentary strata; valley broadening; rock sculpturing.

27. **The Agents of Erosion.** — Winds; rivers; ocean; lakes; glaciers.

28. **Denudation.** — Definition; tendency; effect of uplift.

29. **Age of the Earth.** — Probable age; reasons for belief; illustrations; importance of grasping the conception.

Questions. — 17. What land forms are seen on a journey from Philadelphia to Chicago? What relation between land forms and industries?

18. What are the three divisions of rocks? (A) How are rock fragments assorted by water? What is the meaning of the terms strata, stratum, and stratified? How are stratified rocks consolidated? (B) In what conditions are igneous rocks accumulated on the surface? Describe three kinds of igneous intrusions. (C) What is the nature of metamorphism, and its results? Why is it so common in mountains? (D) How do minerals vary in durability? What two conditions influence the rate of rock disintegration? What effect has this on the form of the land?

19. What changes are in progress on the earth's surface? What evidences are there of past and present changes of level? What is the nature of these movements? What effect has this on the continents?

20. Why are the strata of plains commonly horizontal? What is the condition in mountains? Define fault; anticline; syncline; dip; monocline. Draw diagrams to illustrate symmetrical, unsymmetrical, and overturned folds. What are joint planes? Of what importance are they?

21. What are the agents of weathering and how do they work?

22. How does underground water enter the rocks? What proofs are there of its presence? In what two ways does it work chemically in disintegrating the rocks? How does it work mechanically?

23. In what ways is the air effective as an agent of weathering?

24. In what ways do plants aid in weathering? Animals?

25. Give illustrations of differences in rate of weathering. State the three chief causes for differences. What effect has exposure?

26. How is residual soil formed? What other kinds of soil are there? State the other effects of weathering.

27. What work is accomplished by the agents of erosion?

28. What is denudation? How is it opposed?

29. What evidence is there that the age of the earth is great?

SUGGESTIONS. — (1) Imitate sedimentation in a glass dish. Place sand, pebbles, and clay in the dish with water. Stir vigorously and let it settle. Sprinkle on the water a handful of sand, clay, and pebbles. (This experiment may be made even more effective if a mixture of sand, pebbles, and clay is made to represent land, then washed with a sprinkling pot into a glass aquarium partly filled with water.) Where does the finest material settle? Are the layers horizontal? Vary the rate of washing and observe what happens. (2) Even if the rocks and minerals in Appendix C are not studied, specimens of quartz, feldspar, calcite, sandstone, limestone, granite, and marble should be studied. The last four can be obtained readily, probably in a stone yard. The three minerals may be purchased from a mineral dealer for a very small sum. Do not get valuable specimens, but buy by the pound and break it up for class use. Study the characteristics mentioned in the Appendix. (3) Are the rocks of your neighborhood horizontal or tilted? If the latter, can you find folds or faults? Describe what you find. Look for joint planes and study them; take their direction with a compass; does water escape from them? Are there any quarries in which they are of use? (4) Find specimens of rock in the fields, or elsewhere, showing weathering. What signs of weathering do you find? Are there red or yellow stains? What causes them? (5) To prove that water expands on freezing, fill a bottle with water and freeze it. Even a toy cannon, plugged tightly, would break. (6) Place a thin piece of stone in a fire. Does it crack? Heat another small piece slowly, then cool it quickly by placing it in cold water. These experiments illustrate the expansion with heat and contraction with cold, though of course in nature the changes are not so great as this. (7) Look for illustrations of roots prying rocks apart. This may best be seen on cliffs where trees are growing. Tell what you see. (8) Watch the earthworms. The "casts" left when they are driven out of the swollen ground after a heavy rain are made of earth from their stomachs. What evidence do you find that earthworms help in weathering? Darwin considered them of enough importance to write a book on them. (9) If you live in a glaciated country (Fig. 270), look for glacial scratches recently uncovered. Are they fresh? Why? Look for others uncovered for a longer time. Are they fresh? Why? (10) Study the soil of your vicinity carefully and tell its characteristics. (11) If you can find a cliff, look for a talus slope. Of what is it made? Are the fragments angular or round? Are they all of the same kind of rock as the cliff? Have any fragments been removed by water? Have any fallen recently? Go there in spring, when the frost is coming out of the ground, and see if there have been recent falls. (12) If the water of your vicinity is hard, find out if mineral is deposited in tea kettles or in engine boilers. Perhaps the teacher of chemistry may suggest a way of proving that there is mineral in the water. (13) Are any of the streams that you know receiving rock waste from the valley sides? When does most come? Watch the streams to see. Does this sediment prove that denudation is now in progress? Would much change take place in a year? In a century? In a million years? Think of this carefully.

Reference Books. — LYELL, *Principles of Geology*, 2 vols., Appleton, New York, 1877 (out of print), $8.00; GEIKIE, *Text-book of Geology*, Macmillan Co., New York, 4th edition, 1903, $10.00; DANA, *Manual of Geology*, American Book Co., New York, 1895, $5.00; LECONTE, *Elements of Geology*, Appleton & Co., New York, 1903, $4.00; TARR, *Elementary Geology*, Macmillan Co., New York, 1902, $1.40; SCOTT, *Introduction to Geology*, Macmillan Co., New York, 1902, $1.90; GEIKIE, *Class Book of Geology*, Macmillan Co., New York, 1886, $1.10; BRIGHAM, *Textbook of Geology*, Appleton & Co., New York, 1901, $1.40; MERRILL, *Rocks, Rock Weathering, and Soils*, Macmillan Co., New York, 1897, $4.00; SHALER, *Origin and Nature of Soils* (p. 219), 12th Annual, U. S. Geological Survey, Washington, D.C.