			Unconsolidated.	*Consolidated.*
Sedimentary or Stratified Rocks.	Mechanically Formed.	*Conglomerate Group.*	Gravel.	Conglomerate.
		Arenaceous Group.	Sand.	Sandstone.
		Argillaceous Group.	Clay.	Slate.
		Volcanic Group.	Volcanic Dust and Sand.	Volcanic Tuff and Agglomerate.

					Metamorphic Group (Silicates). Acidic.	Basic.
Sedimentary or Stratified Rocks.	Chemically and Organically Formed.	*Coal Group.*	*Iron-ore Group.*	*Calcareous Group*	Feldspathic (Gneisses).	Gneiss. Syenite.	Diorite. Norite.
		Peat. Lignite. Bit. Coal. Anthracite. Graphite. Asphaltum.	Limonite. Hematite. Magnetite. Siderite.	Limestone. Dolomite. Magnesite. Gypsum. Rock-salt.	Non-feldspathic (Schists).	Mica Schist. Hornblende Schist. Talc Schist.	Amphibolite. Chl. Schist. Greensand. Serpentine.
			Siliceous Group. Tripolite. Chert. Flint. Geyserite Novaculite.				

Eruptive or Unstratified Rocks.	Plutonic or Dike	This part of the classification is a blank, for the reason that no important eruptive rocks are known which are chiefly composed of minerals belonging to the classes of Native Elements, Chlorides, Oxides, Sulphates, or Carbonates; i. e., nearly all eruptive rocks, so far as known, are principally composed of minerals belonging to the class of Silicates.	Feldspathic.	Granite. Syenite.	Diorite. Diabase.
	Volcanic.		Feldspathic.	Rhyolite. Trachyte.	Andesite. Basalt.
				Obsidian.	Tachylite.
				Petrosilex. Felsite.	Porphyrite. Melaphyr.

Descriptions of Rocks.

1.—Sedimentary or Stratified Rocks.

1. Mechanically-formed or Fragmental Rocks.—These consist of materials deposited from *suspension* in water, and the process of their formation is throughout chiefly mechanical. The materials deposited are mere fragments of older rocks, worn from the surface of the land by the agents of erosion; and, if the fragments are large, we call the newly deposited sediment gravel; if finer, sand; and if impalpably fine, clay. These fragmental rocks cannot be classified chemically, since the same handful of gravel, for instance, may contain pebbles of many different kinds of rocks, and thus be of almost any and variable composition. Such chemical distinctions as can be established are only partial, and the classification, like the origin, must be mechanical. Accordingly, as just shown, we recognize three principal groups based upon the sizes of the fragments; viz.:—

(1) Conglomerate group.
(2) Arenaceous group.
(3) Argillaceous group.

This mode of division is possible and natural, simply because, as has been explained in the Guide to Dynamical Geology (p. 71), materials arranged by the mechanical action of water are always assorted according to size. When first deposited, the gravel, sand, and clay are, of course, perfectly loose and unconsolidated; but in the course of time they may, under the influence of pressure, heat, or chemical action, attain almost any degree of consolidation, becoming *conglomerate*, *sandstone*, and

slate, respectively. The pressure may be vertical, where it is due to the weight of newer deposits; or horizontal, where it results from the cooling and shrinking of the earth's interior or tidal friction, *i. e.*, from the same great causes involved in the formation of mountains, rock-folds, and slaty cleavage. (See Dynamical Geology, pp. 28-30.) The heat may result from mechanical movements, or contact with eruptive rocks; or it may be due simply to the burial of the sediments by newer deposits, which, it will be seen, must virtually bring them nearer to the great source of heat in the earth's interior, on the same principle that the temperature of a man's coat, on a cold day, is raised by putting on an overcoat. The effect of the heat, ordinarily, is simply drying, coöperating with the pressure to expel the water from the sediments; but, if the temperature is high, it may bake or vitrify them, just as in brick-making. Sediments are consolidated by chemical action when mineral substances, especially calcium carbonate, the iron oxides, and silica, are deposited between the particles by infiltrating waters, cementing the particles together. This principle may be demonstrated experimentally by taking some loose sand or gravel and wetting it repeatedly with a saturated solution of some soluble mineral, like salt or alum, allowing the water to evaporate each time before making a fresh application. The interstices between the grains and pebbles are gradually filled up, and the material soon becomes a firm rock. But the student should clearly understand that, in geology, gravel, sand, and clay are just as truly *rocks* before their consolidation as after. It is plain, then, that in each group of fragmental rocks we must recognize an unconsolidated division and a consolidated division.

(1) *Conglomerate Group.*— The rocks belonging in this group we know before consolidation as *gravel*, and after consolidation as *conglomerate*.

Gravel.— The pebbles, as we have already seen, are usually, though not always, well rounded or water-worn; and they may be of any size from coarse grains to bowl-

ders. The specimens (**1–4, 6–7**) are typical examples of gravel of fine to medium texture, chiefly from the beaches in this vicinity. Since granitic and felsitic rocks predominate among the harder rocks of this region, they are also, as the specimens show, very prominent constituents of our gravel and shingle beaches.

Conglomerate. — Consolidated gravel. Clay can be very thoroughly hardened by the direct action of heat or pressure; and when, as in the case of our Roxbury pudding-stone, the paste or finer material of the conglomerate is largely argillaceous, we may fairly suppose that the hardening or consolidation of the rock has been affected mainly through the induration of the clay in which the pebbles are imbedded, by pressure, aided more or less by a higher temperature, the process being illustrated by the specimen of concrete (**81**), on the bottom shelf, in which mortar takes the place of clay. In other cases, however, where we have beaches of clean pebbles and sand, with little or no clay, it is evident that the consolidation of the rock must be attributed chiefly to chemical action. Several of the specimens (**5, 8–9**) are clear illustrations of recent formation. In fact, there are many places in meadows, and in the neighborhood of springs, where pebbles are being gradually coated and cemented by iron oxide or carbonate of lime; and the formation of conglomerate from gravel can thus be actually witnessed. The specimen from Cuba (**21**), is a recent marine conglomerate cemented by carbonate of lime. It was formed in the immediate vicinity of a coral reef, where the water, flowing over the broken coral, is often saturated with carbonate of lime. The large spec-

imen (**27**), from Panama, N. Y., is a splendid example of a recently formed quartzose conglomerate with an abundant ferruginous cement. Many of the older conglomerates are very imperfectly cemented (**22, 26**); and it is instructive to compare the pebbles afforded by the disintegration of such specimens (**23**), with those still imbedded in the rock, and with the pebbles now forming on the beach (**6**). We recognize two principal varieties of conglomerate based on the forms of the pebbles. If, as is usual, these are well rounded and water-worn, the rock is true *pudding-stone* (**26–27** and most of the specimens); but, if they are angular, or show but little wear, it is called *breccia* (**25, 29–31, 47–49**). Pudding-stone is the prevailing type. It is formed on beaches and bars, and wherever there is much mechanical movement and consequent wear; while breccia is formed in those comparatively exceptional places where angular fragments detached from the ledges and cliffs by the frost, etc., fall, or are carried, into deep or still water, beyond the reach of the surf, and thus slowly accumulate without becoming rounded.

Conglomerates are also classified, according to the nature of the predominant pebbles, as quartz (**22–24, 26–30**), slate (**21**), jasper (**47–49**), limestone (**25, 31, 46, 52**), granite (**44**), etc.; and, according to the nature of the cementing substance, as calcareous (**5, 8, 21, 42**), ferruginous (**9, 27, 29**), siliceous (**24, 47–49**), argillaceous (**61**), etc. The ferruginous cement may usually be recognized by the reddish or brownish color; the calcareous cement causes the stone to effervesce freely in strong acid; while the siliceous cement gives very strong,

light-colored stones; and the argillaceous cement is known by the dark color and slaty character of the matrix. In the cupriferous conglomerate from Lake Superior (**43**), native copper forms a part of the cement.

On account of its coarse and irregular texture the stratification of conglomerate can rarely be observed in small masses; but the rounded, water-worn form of the pebbles is usually sufficient to show that it is an aqueous or water-formed rock — a consolidated gravel-beach or bar. Similarly, it is always in order to look for fossils in sedimentary rocks, since all parts of the sea are inhabited by animals or plants; but they are rarely observed in conglomerate. The explanation of their absence is found chiefly in the fact that the hard parts, the shells and skeletons, of organisms are unable to resist the violent mechanical action of the surf and marine currents, which wear away even the hard fragments of quartz and granite. The organic bodies are pulverized and completely destroyed by the ceaseless grinding of the pebble or shingle beach. Such fossils as occur in conglomerate are usually in a fragmentary condition, and are well illustrated by the coralline fragments in the conglomerate from Maine (**50**) and by the angular and water-worn fragments of bone in the so-called bone-breccia (**41, 82**).

The jasper breccia from the Huronian rocks north of Lake Huron (**47–49**) is one of the most striking and beautiful of all the varied forms of conglomerate. The third specimen of this rock is from the drift of southern Michigan, showing how these rocks of unique character and limited distribution may be used in tracing the movement of the great ice-sheet.

The large specimen from Nevada (**29**) is a good example of a recently formed breccia, angular fragments of quartzite having become cemented by iron oxide. The mass of recent limestone breccia (**31**) was formed in a quarry where the quarry water trickled over loose fragments of limestone.

The specimens of quartzose conglomerate on this shelf (**22–24, 26–28**) represent very extensive formations in the Middle

States. The limestone conglomerate from Maryland has been used as an ornamental stone under the name Potomac marble.

Specimen (**52**) is an interesting limestone conglomerate from the Black Hills. The remaining specimens on this shelf represent various minor varieties of conglomerate which are sufficiently explained by the labels. The specimens on the next shelf are in part typical examples of the pudding-stone and breccia so extensively developed in the vicinity of Boston, and in part of the distinctly metamorphic conglomerates observed in connection with some of the older, crystalline formations. The pebbles of the metamorphic conglomerates have been usually, as in these specimens, flattened and elongated by enormous pressure, and the matrix has also become highly micaceous and crystalline.

(2) *Arenaceous Group.* — The conglomerate group passes insensibly into the arenaceous group; for, from the coarsest gravel to the finest sand, the gradation is unbroken, and every sandstone is merely a conglomerate on a small scale.

Sand.— Like gravel, sand may be of almost any composition, but as a rule it is siliceous; quartz, on account of its hardness and the absence of cleavage, being better adapted than any other common mineral to form sand.

The first specimens (**1–2**) are typical beach sands, consisting chiefly of quartz, but with occasional grains of feldspar, mica, etc. Magnetite is a very common constituent (**3**) and often occurs by itself, forming the black or so-called iron sands (**4**). Garnet and other hard minerals are also often present. The specimen (**5**) from the beach on Marblehead Neck is a nearly equal mixture of quartz, magnetite, and garnet. And nearly pure garnet sands (**6**) are occasionally found. The older sands,

which have become buried under newer deposits, are often colored by limonite (**7**) or hematite (**8**). The admixture of broken shells and coral gives the calcareous sands or marls (**9**).

Sands formed wholly of comminuted organic remains (**10**) are not true sands, in the geological sense, since they have not been formed by the mechanical wearing away of older rocks; and by their consolidation we obtain limestone and not sandstone.

Sandstone.—Consolidated sand. The consolidation or hardening of sand to form sandstone, like the consolidation of gravel to form conglomerate, although due to some extent to the hardening by pressure and heat of clay that is often mixed with the sand, is effected chiefly by chemical action, *i. e.*, by the deposition from solution between the grains of sand of iron oxide, carbonate of lime, silica, etc.; and sandstone, like conglomerate, may thus be made artificially by the percolation through sand of mineral solutions.

The ferruginous sand from Hingham (**11**) is partially cemented by the abundant iron oxide; but a better, although semi-artificial example is seen in the next specimen (**12**). The cement in this case is iron oxide resulting from the rusting of an iron spike in the planking of a wreck which was buried in the sand.

We find in nature every gradation between perfectly loose sand and the hardest and strongest sandstone. Some of these intermediate forms, the easily crumbling or friable sandstones, are represented by the next specimens (**21–22, 26**). The remaining specimens on this shelf have been selected as illustrations of the visible

stratification of sandstones. The stratification is indicated by planes of easy splitting or cleavage in the shaly sandstones (**27–28, 31**) and by layers of varying color or texture in the banded sandstones (**24–25, 29–30, 32–33**). The specimens from the Black Hills (**32–33**) are especially fine examples of distinct and regular banding.

There are many varieties of sandstone depending upon differences in composition, texture, cement, etc. As regards the texture of sandstones, we may pass by insensible steps from the coarsest kinds or gritstones, which are really fine conglomerates, the grains of sand being more properly small pebbles, to varieties like the freestones and flagstones, which are sometimes almost impalpably fine and pass into slates. Many of these grades are represented by the specimens. The essential structural similarity of sandstones and conglomerates is very clearly shown by the drawing (**23**), which represents a sandstone magnified. The cementing materials are commonly either: ferruginous (iron oxides), giving red or brown sandstones; calcareous, forming soft sandstones, which effervesce with acid if the cement is abundant; or siliceous, making very strong, light-colored sandstones.

The first specimens on the third shelf (**41–42, 46–47**) are typical examples of ferruginous sandstones. When the cementing iron oxide is deficient, it is very likely to undergo segregation, so as to give the stone a variegated or blotched appearance (**43–44, 48–49**). The distinctly calcareous sandstones are well represented (**51–52**). In the next two specimens (**53–54**) the cement is chiefly kaolin or clay. The first represents the common flagstone, a fine grained, argillaceous variety which splits easily into very regular layers or slabs.

A more exceptional cementing substance is seen in the next specimen (**50**) from the vicinity of the Pitch Lake in Trinidad. It is saturated with asphaltum, which binds the grains of sand together. The architectural variety known as freestone (**45, 50**) is merely a fine grained, light-colored, uniform sandstone, not very hard, and breaking with about equal freedom in all directions.

The gypsiferous and phosphatic sandstones (**61, 66**) may be regarded as varieties of calcareous sandstone, phosphate of lime and gypsum partially replacing calcite.

Sandstones, unlike conglomeraes, have often been deposited under comparatively quiet conditions, and are consequently not infrequently fossiliferous. The next three specimens (**67–69**) illustrate the prevailing modes of preservation of the fossils, which, except in the newest sandstone, are usually in the form of molds and internal casts. Sandstones are essentially porous rocks; and the water percolating through the strata gradually dissolves out the fossils, so that we find in all the older sandstones, not the fossils themselves, but the cavities (moulds) which they occupied.

Arkose (**62**) is essentially a recomposed granite, *i.e.*, a sandstone which is largely composed of the debris of granite—quartz, feldspar and often mica or hornblende—and consequently resembles granite more or less in appearance.

Quartzite.—This name is commonly applied to the older or metamorphic sandstones. Strictly speaking, the typical quartzite is an unusually hard sandstone, *i.e.*, one in which grains of quartz are combined with an abundant siliceous cement (**8 –82, 86–87**). The next specimen (**91**) is an admirable illustration of the intimate way in which quartzite and common sandstone are often interstratified, the conversion of sandstone into

quartzite in such cases being due mainly to the solution and segregation of microscopic siliceous shells and other organisms existing in the stone. The drawings (**83**) representing the appearance of thin sections of quartzite under the microscope, throw considerable additional light upon the origin of this rock.

First the siliceous cement is deposited from solution upon the grains of quartz in such a way as to tend to restore the crystalline form of the quartz; and, second, by the continuance of this secondary enlargement of the grains the interstices become completely filled up; and the accurately fitting grains are interlocked or dove-tailed together to form a nearly continuous and homogeneous mass of quartz.

The next specimens (**88–89**) are somewhat micaceous and schistose, splitting in thin layers and forming the variety often called quartz schist, which forms a connecting link between quartzite and mica schist. In fact the quartzites may be classified with the truly metamorphic rocks—the gneisses and schists—almost as properly as with the sandstones. Itabirite (**84**) is an interesting variety of quartz schist in which specular hematite takes the place of mica. The specimen from Nantasket (**90**) owes its induration to the influence of streams of lava, which flowed over the sand while it was still unconsolidated.

Itacolumite or flexible sandstone (**92** and **13** on the top shelf) is, perhaps, the most interesting form of metamorphic sandstone. The flexibility is shown to the best advantage in the more slender upper specimen. This rock derives its name from Mt. Itacolumi, in Brazil; and it is an interesting fact that the diamonds of that country are usually so intimately associated with the flexible sandstone that it has been called the *mother-stone* of the diamond.

(3) *Argillaceous Group.*—Just as the conglomerate group shades off gradually into the arenaceous group, so we find it difficult to draw any sharp line of division between the arenaceous group and the argillaceous, but we pass from the largest pebble to the most minute clay-particle by an insensible gradation. Although clay, like sand and gravel, may be of almost any composition, yet it usually consists chiefly, sometimes entirely, of the mineral kaolin. The fragmental rocks are thus composed principally of two minerals, quartz and kaolin,—the former predominating in the conglomerate and arenaceous groups, and the latter in the argillaceous group. In like manner, while the conglomerate and arenaceous rocks are always visibly fragmental, the argillaceous group is characterized by the compact texture.

Clay.—Pure clay, or kaolin, is white and impalpable, like China clay (**1**); but pure clays are the exception. They often become coarse and gritty by the admixture of sand, forming loam; and they also usually contain more or less carbonaceous matter, which makes black clays or mud (**7**); or ferrous oxide, which makes blue clays (**8**); or ferric oxide, which makes red, brown, and yellow clays (**2–4, 9**).

By mixing these coloring materials in various proportions, almost any tint may be explained. Clays are sometimes calcareous, from the presence of shells and shell-fragments or of pulverized limestone (**5–6, 10**). These usually effervesce with acid, and are commonly known as marl. It is the calcareous material in a pulverulent and easily soluble condition that makes the marls valuable as soils.

The residual clays of the South, which are commonly red, are represented by the specimen (**11**) from Trinidad; while the

next specimens (**12–13**) are typical examples of the glacial clays of the North. The fire clays (**14**) are especially characterized by their freedom from iron oxide and alkaline substances, or those materials that tend to make clays fusible. They often underlie beds of coal, and may be regarded as the soil in which the coal-plants grew.

Slate.—Consolidated clay. We find all degrees of induration in clay. It sometimes, as every one knows, becomes very hard by simple drying; but this is not slate, and probably no amount of mere drying will change clay into slate; for, when moistened with water, the dried clay is easily brought back to the plastic state. To make a good slate, the induration must be the result of pressure, aided probably to some extent by heat. True slate, then, is a permanently indurated clay, which will not readily become plastic when wet. Several of the specimens on the second shelf are instructive examples of semi-lithified clays. Two of these (**32–33**) illustrate the usual mode of occurrence of fossils in clays, the enclosed shells being undissolved and almost unbroken. A third specimen (**27**) is a well-dried residual clay from the floor of a great limestone cavern. The celebrated pipe-stone clay of Minnesota (**26**), is strictly intermediate between clay and slate, although belonging to one of the oldest geological formations. The iron oxide in this clay may act as a cementing substance; but the next two specimens (**22–23**) owe their induration to the heat resulting from the burning of beds of lignite. What may be regarded as the two most normal examples of semi-lithified clay (**21, 31**) have probably been consolidated chiefly by pressure; the first shows the fissile structure so

characteristic of shales, and the second the joint-structure of true slates.

The remaining specimens on this shelf are very typical examples of slate. They not only exhibit the characteristic textures and colors, but are also very distinctly stratified. The visible stratification may take the appearance of (1) a distinct banding, due to the alternation of layers differing in color or texture (**28–29**); or (2) a fissile structure, as in shale (**24, 25, 30**), the rock splitting readily in thin layers parallel with the bedding. Many slates, however, are so homogeneous that the stratification is scarcely visible in small specimens, as the remainder of the collection shows.

Few rocks are richer in fossils than clay and slate; and these prove that they are stratified rocks. The fossils are not only numerous, but also, as already observed, exceptionally well preserved (**32–33**).

The argillaceous sediments are deposited in deep and quiet waters, and under conditions so tranquil that even the most fragile organic remains usually become buried without being broken; and after their burial are rarely removed by solution, as in the arenaceous sediments, because the impervious nature of clayey sediments prevents the free circulation of water. The consequence is that the fossils are not only found perfect in form, but being, as it were, hermetically sealed, we also find the fossils themselves and not simply their moulds or casts.

The carbonaceous slates and shales are well illustrated by the next specimens (**41–42, 46–47**) and these also show, in the carbonized vegetable forms (ferns, etc.), the source of the carbon. The slate with annelid trails from Frenchman's Bay (**42**) shows how perfectly even

such slight indications of life are preserved in these fine grained rocks.

Pyrite (**48**) is one of the most common accessory minerals in slate. Through the weathering of the pyritiferous slates and the oxidation of the pyrite, alum—the double sulphate of alumina and iron—is formed, giving the so-called alum slates (**49–50**). The other specimens on this shelf require no special explanation. The older and more altered forms of slate, like the quartzites, afford a more or less gradual passage into the true metamorphic rocks. The most important structural feature of the older slates is the slaty cleavage, which has its best development in the roofing slates (**61–63**, etc.).

These rarely show the stratification distinctly, for it is a remarkable fact that the thin layers into which they split are entirely independent of the bedding. The cleavage has been developed in the slate, subsequently to its deposition, by pressure; and its relations to the stratification are very clearly exhibited in the roofing slates known as ribbon slates (**62**), which show bands of a different color or texture across the flat surface. These bands are the true bedding, and indicate the absolute want of conformity between this structure and the cleavage. The roofing slates are also a good illustration of the variety of colors possible in this class of rocks.

Porcelainite.—This term and *semi-porcelainite* are applied to clay and slate which have been baked or vitrified by heat, so as to have the hardness and texture of porcelain. The specimens from Trinidad and Bohemia are very typical examples of this natural porcelain (**81–82**) and also of the semi-porcelainite (**85–86**). The heat required for the formation of these specimens as well as

of the fine series of melted clays from the Bad Lands of the Yellowstone (**89–92**) was afforded by the combustion of beds of lignite interstratified with the beds of clay. The remaining specimens are the product of volcanic heat, deposits of clay or slate having been covered or penetrated by masses of lava or trap.

(*4*) *Volcanic group.*—It is a well-known fact that many volcanic eruptions are more or less explosive in character; and that the lava ejected during these explosive eruptions is largely in the form of dust and fragments. The distribution of these fragmental forms of lava is determined largely by the violence of the eruptions and by the force and direction of the air currents. The larger and heavier fragments usually fall upon the slopes of the volcano, or over the immediately adjacent country, and often to a considerable depth. Thus the Roman city of Pompeii was completely buried, in the year 79, by fragments of pumice from Vesuvius. The finer and lighter material, the volcanic dust, on the other hand, is spread far and wide over the surrounding regions. We have an extreme example in the great eruption of Krakatoa, in 1883, since the dust thrown out by this stupendous explosion was apparently diffused through the entire atmosphere of the earth, and formed a deposit of sensible thickness over a very large part of the earth's surface. Many volcanoes are, like Mt. Vesuvius, composed largely, in some cases almost wholly, of lava which has been ejected in the solid form as dust and fragments, the steepness of the cones increasing with the proportion of the solid ejectamenta.

The fragments vary in size from the finest and most impalpable dust, which floats in the atmosphere for many days or months, to masses weighing several tons. Whether large or small, they are especially characterized by their highly angular forms; by being composed wholly of volcanic materials; and when they have fallen on the land, or beyond the influence of water, fragments of all sizes are mixed together indiscriminately.

The condensation of steam and copious precipitation of water which are important features of many volcanic eruptions, as well as subsequent rains, often wash the lighter volcanic dust or ashes down to lower levels and distribute them in more or less distinct and horizontal layers. In other cases, where the eruptions are submarine, or the fragments fall directly into the sea, they are subjected to the sorting action of water and become mixed in varying proportions with the ordinary sediments accumulating in successive strata on the ocean floor. In still other cases the volcanic materials are washed off the land by rivers and the surf, and, passing thus through the mill of the ocean-beach, the larger fragments, especially, become more or less rounded or water-worn before they are assorted and deposited by the water.

In their origin, the fragmental ejectments are, of course, volcanic; and there are important reasons why they should be classified with the ordinary volcanic rocks, the lavas ejected in a liquid form. Practically, however, it is often more convenient to associate the fragmental volcanic rocks with the mechanically-formed or fragmental sedimentary rocks, since, as explained in the preceding paragraph, it is often difficult or impossible to distinguish between the fragments which have been ejected by volcanic agency from the interior of the earth and more or less worn, assorted, and stratified by water; and those fragments which are wholly of aqueous origin, having been worn directly by the action of water from the ledges of the land. This distinction is not even theoretically possible, on account of the complete blending by admixture on the ocean-floor of the fragments of unlike origin.

Although, as explained, the volcanic fragmental rocks are usually less perfectly assorted than the ordinary mechanical sediments, they may be classified in the same way: first, according to the sizes of the fragments; and, second, according to the degrees of consolidation. It is customary, however, as the labels indicate, to call the unconsolidated materials simply volcanic dust and sand; and the consolidated volcanic tuff and agglomerate.

Volcanic Dust and Sand.— These unconsolidated materials are very commonly known, also, as volcanic ashes. Although this term is misleading, so far as the origin of these rocks is concerned, a glance at the upper shelf in this section will show that it is a good descriptive name. The entire range of texture, from the finest to the coarsest, may be exhibited in the products of a single volcano, as shown by the specimens from Mt. Vesuvius (**1–4**). The coarser of these specimens, as well as those from Germany, Utah, and California (**5–6, 11–12**), illustrate the essentially angular forms of the fragments, the wearing action of water being conspicuous by its absence. As indicated on the labels, it is usually possible, where the characters have not been obliterated by decomposition, to determine the kind of solid lava from which the detritus has been derived. The specimens of pumice dust from old lake basins in Nebraska and Montana (**8–10**) are good examples of fine material which has been transported by air currents and finally arranged in stratified deposits by the action of water.

Volcanic Tuff and Agglomerate.— The specimens on the lower shelves of this section embrace a very typ-

ical series of the consolidated volcanic ashes. These are for the most part soft, earthy-looking rocks, which are distinguished from the ordinary mechanical sediments, (sandstone, etc.), among other ways, by the readiness with which they are decomposed on exposure to the weather. It is to this influence, also, that we owe the rather characteristic buff and pink tints of the specimens. The cementing material is usually argillaceous, although, as the specimen from the Sandwich Islands (**31**) shows, it may consist of iron oxide, carbonate of lime, or other substance deposited by infiltrating waters. The fossiliferous specimens (**32, 51**) show very clearly that the materials have been strewn and deposited in some quiet body of water.

The brown specimens on the bottom shelf, from the Sandwich Islands (**81–82**) represent the so-called palagonite tuffs, which are really solid lava which has been speedily and completely decomposed by the acid vapors accompanying the eruption. This shelf also shows some rather ancient and more indurated and metamorphosed tuffs and agglomerates from the vicinity of Boston and elsewhere. The old volcanic rocks of the Boston Basin embrace a very fine series of the fragmental forms, but that the eruptions were largely submarine is indicated by the beautiful stratification often observed (**83–84**) and by the perfect blending of the volcanic with the ordinary water-worn sediments (**85–88.**)

2. Chemically and Organically formed Rocks.— It has been already explained (p. 81) that from a geological point of view the differences between chemical and organic deposition are not great, the process

being essentially chemical in each case; and since the limestones and some other important rocks are deposited in both ways, it is evidently not only unnatural, but frequently impossible, to separate the chemically from the organically formed rocks. Unlike the fragmental rocks, the rocks of this division not only admit, but require, a chemical classification. Therefore our arrangement will be essentially the same as for the groups of rock-forming minerals, but in the reverse order, thus:—

(1) Coal group.
(2) Iron ore group.
(3) Siliceous group.
(4) Calcareous group.
(5) Metamorphic group (Silicates).

The silicates are placed last, notwithstanding their great importance, on account of their metamorphic character and because they afford the student a more natural passage from the sedimentary to the eruptive rocks, the latter consisting almost wholly of silicate minerals. Most of the silicate rocks are mixed, *i. e.*, are each composed of several minerals; but some silicate rocks and all the rocks of the other divisions are simple, each species consisting of a single essential constituent.

(1) *Coal Group.*— The rocks of this group are entirely of organic origin and include two allied series, which may always be regarded as simply the more or less completely transformed tissues of plants and animals, viz.:— *coals* and *bitumens.*

The chemical and physical conditions favorable for the formation and accumulation of these two series of hydrocarbons have been explained on pages 74–75. It

was shown that, in the coal series, the vegetation is, during the lapse of time, changed in succession to peat, lignite, bituminous coal, anthracite, and graphite. The coals, indeed, make a very beautiful and perfect series, whether we consider the composition, there being a gradual, progressive change from the composition of ordinary woody fiber in the newest peat to the pure carbon in graphite; or the degree of consolidation and mineralization, since there is a gradual passage from the light, porous peat, showing distinctly the vegetable forms, to the heavy crystalline graphite, bearing no trace of its vegetable origin. The coals also make a chronological series, graphite and anthracite occurring only in the older formations, and lignite and peat in the newer, while bituminous coal is found in formations of intermediate age.

Peat. — Although not a typical coal, peat is properly the first member of the coal series. This incipient coal, or coal in the process of formation, is well represented by the specimens on the upper shelf (**1–5**). They show very clearly that peat is partially carbonized and more or less comminuted and compressed vegetation, and, to some extent, that the vegetable forms are chiefly such as are characteristic of bogs and marshes.

Brown Coal and Lignite — The specimens on the next shelf (**21–29**) show that these two forms of coal are essentially similar and that they are intermediate in character between peat and the most typical coals, such as bituminous coal, since, while the woody structure is well preserved externally, as in peat, internally they are black, lustrous and highly mineralized, as in bituminous

coal. The specimens (**23, 25**) from high latitudes are interesting as indications of a milder climate in those regions at the time when the beds of fossil fuel were forming.

Bituminous Coal. — This is the middle term of the coal series, and as the specimens on the third shelf (**41–46**) show, it is usually very distinctly stratified. The surfaces transverse to the stratification planes are clean and lustrous, showing no vegetable forms or structure; while the surfaces parallel with the bedding are usually dull, soft and often marked by vegetable forms as well as by the woody structure or grain. From a good specimen of bituminous coal we may thus learn two important facts: first, that it is a stratified rock; and, second, that it is of vegetable origin.

The coals in general are extremely infusible as well as insoluble bodies; but the so-called caking coals (**42**) are bituminous coal which softens in the fire. Besides the mineral matter or ash originally in the wood from which the coal was derived, all kinds of coal contain more or less of mechanical sediment such as clay and fine sand which was washed into the peat bog while the coal was slowly accumulating. Cannel coal (**43, 46**), which has a dull and uniform surface, conchoidal fracture, and rarely shows stratification lines or vegetable forms, is also distinguished by a very high percentage of ash. It may be usually regarded as a consolidated carbonaceous mud.

Pyroschist. — From cannel coal it is but a step to pyroschist (**47–49**), which may be regarded as intermediate between coal and slate. It is a coal containing so large a proportion of ash, chiefly in the form of clay, that it is of no value as fuel; or a slate which is so highly