

occur. Their geological relations are well expressed by the following grouping:

Talcoose or Magnesian Section. — Magnesia is the principal or only base in these species. They are usually soft, greenish and highly infusible; and are common alteration products of the augite, hornblende, chrysolite, and other original constituents of basic eruptive rocks.

Talc (41, 46) is a very typical member of this section, being soft, greasy and usually greenish and foliated (41), although sometimes white and massive (46). It is found chiefly in an impure form in steatite or soapstone; and the clear, foliated talc occurs principally in irregular veins traversing this rock.

Serpentine (42) is a protean mineral, occurring in many forms and colors; but this compact, green variety is the one of greatest geological importance. In composition it is like talc with more water and twenty per cent. less of silica. Although it must be regarded as sometimes original and essential, yet it is, as stated, a common secondary constituent of basic eruptive rocks, and a very important accessory constituent of crystalline limestone and dolomite.

Chlorite (47) is a very basic species and contains alumina and iron as well as magnesia. Like serpentine, it is a very common secondary mineral; but in chlorite schist we must regard the mineral, whatever its origin, as original and essential with reference to that particular species of rock. Chlorite is especially characterized by its dark green color and finely foliated structure.

Argillaceous or Aluminous Section. — Kaolin or clay is the chief constituent of this section, although it

includes several less abundant species which agree with kaolin in containing little or no magnesia and in having been derived directly or indirectly from the feldspars and allied minerals.

Kaolinite or *Kaolin* (43, 48), the most abundant of all the hydrous silicates, is similar to serpentine in composition, except that alumina takes the place of magnesia. Pure kaolin is white, but it is usually colored by impurities, the chief of which are the iron oxides, as in the second specimen, and carbon. It is the basis of all clays and slates; and, although produced in every instance by the decomposition of other aluminous minerals, especially the feldspars, it must usually be regarded as an original as well as an essential constituent of the rocks in which it chiefly occurs — the clays and slates. It is, however, an important accessory constituent or impurity of the limestones, iron ores, coals, sandstones, and other rocks.

Pinite (44) is a much less abundant mineral than kaolin, although having a similar origin, resulting, however, from the partial, instead of the complete, decomposition of feldspathic minerals. It is compact and greenish, resembling serpentine, but with a chemical composition, as just stated, between feldspar and kaolin. *Pyrophyllite* (49) exhibits similar characters, but contains no alkalis.

Glauconite (50) forms the rock greensand, which is chiefly this mineral in rounded grains. It is also a common accessory in other sedimentary rocks. It is especially characterized by its soft, granular or earthy texture and dark green color. Chemically it is distin-

guished by the large proportion of potash, which makes it a valuable fertilizer.

Micaceous Section. — This section includes the hydrous silicates of alumina and potash or soda having also a highly foliated or micaceous character. The only important species are the hydromicas.

Hydromica (45) is the name of a family of hydrous silicates corresponding in composition and physical characters, in a general way, with the micas. The particular species shown is *Margarodite*, but in geology it is not usually important, even when possible, to distinguish the various species, and they are conveniently classed together under the common name hydromica. This is a prominent rock-constituent, and, although often derived from anhydrous species, it may be properly regarded as both original and essential in the rocks in which it chiefly occurs.

CALCAREOUS GROUP. — This very natural group, which ranks next in abundance to the silicates, includes the carbonates of lime and magnesia, the sulphate and the phosphate of lime; or all of the important compounds of these alkaline earths not belonging to the silicates.

These species are contrasted with most of the silicates by their greater softness and solubility. The carbonates, especially, dissolve freely, with effervescence, in common acids, and dissolve much more readily than most other rock-forming minerals, except halite, in natural waters. With the exception of the crystallized form of apatite, they occur chiefly as both original and essential constituents of rocks; although the carbonates and sulphates are quite common alteration products, in the rocks, of the basic silicates.

Carbonates of Lime and Magnesia. — The three carbonates of lime and magnesia all crystallize in rhombohedrons, with rhombohedral cleavage, and agree very closely in physical characters.

Calcite, carbonate of lime, is by far the most abundant mineral not belonging to the group of silica and the silicates. It is the principal, and only essential, constituent of all kinds of limestone. Calcite embraces many varieties, only those of greatest geological interest being represented by the specimens. The most typical or perfect calcite is seen in *Iceland spar* (61), so remarkable for its strong double refraction. The next specimen (66) shows the cleavage equally well, but is less transparent, representing more closely, except in its coarse and perfect crystallization, calcite as it occurs in the crystalline limestones or marbles (62). Chalk (67), although composed largely of microscopic shells, is essentially an amorphous form of calcite, and, with the admixture of clay and other impurities, represents calcite as it occurs in the compact and earthy forms of limestone. Calcite plays an important role in the organic world, being the principal constituent of the shells (64), and skeletons (68), of the lower animals. The great geological significance of these organic forms of calcite will be appreciated when it is understood that limestones are formed chiefly through the accumulation of these calcareous organisms (shells, corals, etc.) on the sea-floor.

Calcite is especially characterized by its rhombohedral cleavage, softness, and ready effervescence with cold, dilute acid. The most characteristic microscopic feature is the repeated

twinning, shown in the figure (63), which closely resembles the repeated twinning of the plagioclase feldspars.

Dolomite (65) the double carbonate of lime and magnesia, is so similar to calcite in most respects that it is only necessary to note the points of difference.

Dolomite, although a vastly abundant mineral, is much rarer than calcite, and never occurs in organic forms. It is a little harder and heavier than calcite, does not exhibit the repeated twinning structure, and dissolves less readily with acids. It forms the rock dolomite, of which the specimen is a coarsely crystalline, pure example.

Magnesite (69), the carbonate of magnesia, is a comparatively rare species which differs from dolomite very much as that does from calcite. It is often intimately associated with serpentine, and appears then as an alteration product of that mineral. The massive beds of pure magnesite, however, are original chemical deposits from the waters of the ocean. Magnesite is usually quite compact, resembling chalk, but much harder.

Sulphate of Lime.—The hydrous sulphate of lime—gypsum—is the only one of the numerous native sulphates of special geological interest. The most of the species in this class are extremely soluble and found only in solution.

Gypsum (61-62) is chiefly, like dolomite and magnesite, a chemical precipitate from the waters of the ocean, and hence original and essential; but it is formed to some extent, also, by the alteration of limestone and of the basic lavas. Gypsum is especially characterized by its softness and lightness; and it is readily distinguished from the carbonates by these characters and by its not effervescing in acid. The clear, crystalline variety *selenite* (61), remarkable for its perfect cleavage and transpar-

ency, occurs chiefly in veins; while the great beds of gypsum are built up chiefly of the compact or finely crystalline form (62), which, when pure and translucent, is known as *alabaster*.

Phosphate of Lime.—The native phosphates, like the sulphates, are very numerous; but, as before, there is only one species of special geological interest, the phosphate and chloride of lime. This, however, occurs in such diverse forms as to be really equivalent to a group of species.

Apatite (63-64), like calcite and silica, belongs to both the organic and inorganic kingdoms. As a distinctly crystallized, typical mineral (64), it occurs chiefly as an accessory, in veins and in metamorphic and eruptive rocks. Through the decay of these rocks, it becomes a constituent of soils and of natural waters; and in this form it is appropriated by the plants which form the food of the higher animals. This does not explain why the skeletons of the higher animals are chiefly composed of apatite, instead of calcite and silica, as in the lower forms of life, but it shows how the animals obtain the apatite, which not only forms their bones (63), but is also found in their excrement. Both the bones and the excrement may, under favorable conditions, accumulate so as to form important deposits of guano and other forms of phosphate rock, which are so valuable as fertilizers.

HALOID GROUP.—The haloid minerals are mainly soluble in water, and among all the native chlorides, bromides, iodides, and fluorides, only one, *chloride of sodium*, is found in the solid form in sufficient abundance to merit attention here.

Halite or *Rock-salt* (65) exists chiefly in solution in the waters of the ocean, of which it forms nearly three per cent.; and it is found in the solid form in the rocks only where, through the oscillations of the earth's crust, portions of the sea have been detached from the main body and have gradually evaporated to dryness. The most prominent characteristics of halite are its cubic form and cleavage, its softness, lightness, ready solubility, and saline taste.

FERRUGINOUS GROUP.—Iron is so strongly contrasted, especially in its high specific gravity, dark color, and magnetism, with all the other chemical elements of which rocks are chiefly composed, that the mineral species in which it is the chief or only metallic element constitute a very natural geological group. This group embraces the sulphide, several oxides, and the carbonate of iron; and it is in their origins, associations, and modes of occurrence, rather than in their more strictly mineralogical features, that these can be described as closely related.

Sulphide of Iron.—The sulphides are, as a class, heavy, metallic minerals, of vast economic importance, embracing a large proportion of metallic ores; but the common bisulphide of iron—pyrite—is the only species of much importance as a constituent of rocks.

Pyrite or *Iron Pyrites* (81-82), is a metallic, pale yellow, hard, heavy species, crystallizing in the isometric system and occurring as an accessory in nearly all classes of rocks, but especially in the slates and the basic eruptive rocks. The crystals are usually either six-sided (cubes) (81) or twelve-sided (pyritohedrons) (82).

Although pyrite is hard enough to strike fire with steel, to which circumstance it owes its name (pyrite or fire stone), it is readily decomposed by oxidation to the insoluble oxide of iron or the soluble sulphate of iron; and it is in this way an important cause of the disintegration and discoloration of rocks. In certain rocks, especially in marls and clays, the same chemical substance often crystallizes in orthorhombic forms as the species *marcasite*, which is generally similar to pyrite but decomposes much more readily.

Oxides of Iron.—The various oxides of iron are, after silica or quartz, the only oxides occurring abundantly in the rocks. They are chiefly original and essential, forming solid beds of iron ore; but are also very common accessory constituents in a great variety of sedimentary and eruptive rocks. They are, as a rule, hard, heavy, metallic, dark-colored, insoluble and, unlike pyrite, but little affected by the action of the elements.

Limonite (83-84) is the hydrous sesquioxide of iron, containing about 60 per cent. of the metal. Although never crystalline, it occurs in a variety of forms, the purer kinds being either botryoidal and fibrous (83) or stalactitic (84). It is a common pseudomorph, especially after the sulphide of iron. Its specially distinguishing features are the yellow streak and the absence of magnetism.

Hematite (85-87) is the anhydrous sesquioxide of iron, with 70 per cent. of the metal. It crystallizes in flat rhombohedrons having a brilliant metallic luster—*specular hematite* (85). The crystals are often flattened to thin scales as in the *micaceous hematite* (87). When not distinctly crystalline, the purer forms are commonly botryoidal and fibrous (86), resembling limonite. It agrees

with limonite, also, in not being attracted by the magnet, but is distinguished by its red streak.

Menaccanite or *Titanic Iron Ore* (88) is like hematite with a variable proportion of the iron replaced by titanium. It is very similar to hematite in form and physical properties, except that it is slightly magnetic and the streak is darker. It also never occurs in earthy forms; but is found very generally with magnetite in basic metamorphic and eruptive rocks.

Magnetite or *Magnetic Iron Ore* (89-90) is the combined protoxide and sesquioxide of iron, containing 72.4 per cent. of iron. It is the richest of all the iron ores, and the only one containing enough iron to make it strongly magnetic. It is always crystalline (isometric system), and is farther distinguished by a black streak. As an ore, *i. e.*, as an original and essential constituent, it is usually massive and granular (89), each grain being an imperfect crystal; while as an original and accessory constituent it is commonly in distinct and isolated octahedrons (90).

Carbonate of Iron.—Mineralogically, the carbonates of lime, magnesia, and iron are very homogeneous, except that the latter is heavier and darker colored than the former; but geologically we find that the carbonate ore of iron is formed under essentially the same conditions as the uncrystalline oxide ores and is, to a large extent, associated with the same classes of sedimentary rocks.

Siderite (91-92) is found in several distinct forms. The crystallized or sparry siderite (91), found chiefly in veins, is the purest; but it is less abundant than the

compact or concretionary argillaceous and carbonaceous varieties (92), occurring in stratified deposits.

NATIVE CARBON AND HYDROCARBONS.—The hydrocarbons are of organic origin, and the native carbon or graphite may usually be classed in the same way, since it has certainly been derived chiefly from the hydrocarbons. This group includes essentially three things—native carbon or *graphite* (81-82), the *coals* (83-84), and the *bitumens* (85).

Graphite is crystalline, foliated, soft, black, metallic and has a very smooth or greasy feel. It is found in beds and veins, and also as an accessory in various sedimentary and eruptive rocks. The *coals* and *bitumens* are also chiefly essential, but still, in the carbonaceous slates, limestones, etc., they must be regarded as accessory.

TEXTURES OF ROCKS.

Texture (grain) is a general name for those smaller structural features of rocks which can be studied in *hand specimens*, and which depend upon the *forms* and *sizes* of the *constituent particles* of the rocks and the *ways* in which these are *united*.

By "constituent particles" are meant, not the molecules of matter composing the rocks, but those particles or masses, usually of sensible size, the coming together or development in association of which has made the rock, as, for instance, the pebbles in conglomerate, grains of sand in sandstone, crystals

¹ These two sections are to be regarded as one, the specimens on each shelf continuing across from the third section to the fourth, with one set of numbers; the odd decades on the left, and the even decades on the right.

CLASSIFICATION OF TEXTURES.

Primary Textures.		The constituent particles of rocks are either			
		Macroscopic, in which case they are		or Microscopic, in which case they are, under the microscope,	
		or		or	
		Fragments	Crystals	Visible	Invisible.
Fragmental.		Crystalline.	Compact.	Vitreous.	
Banded.		Banded Fragmental.	Banded Crystalline.	Banded Compact.	Banded Vitreous.
Schistose or Shaly.		Shaly Fragmental.	Schistose Crystalline.	Shaly Compact.	
Porphyritic.			Porphyritic Crystalline.	Porphyritic Compact.	Porphyritic Vitreous.
Concretionary.		Concretionary Fragmental.	Concretionary Crystalline.	Concretionary Compact.	Concretionary Vitreous.
Vesicular.			Vesicular Crystalline.	Vesicular Compact.	Vesicular Vitreous.
Amygdaloidal.			Amygdaloidal Crystalline.	Amygdaloidal Compact.	
Tufaceous.				Tufaceous Compact.	
Friable or Earthy.		Friable Fragmental.	Friable Crystalline.	Earthy Compact.	

Secondary Textures.

Classification of the Sedimentary Rocks.

		Groups	Unconsolidated	Consolidated	Crystalline
Clastic	Hydro-clastic	Rudaceous	Gravel and Rubble	Conglomerate (Puddingstone and Breccia)	Meta-Conglomerate
		Arenaceous	Sand and Grit	Sandstone (Brownstone and Freestone)	Quartzite
		Argillaceous	Clay and Mud	Slate (Shale and Mudstone)	Argillite and Phyllite
	Pyro-clastic	Volcanic	Volcanic Cinders and Ashes	Agglomerate and Tuff	Meta-Agglomerate Meta-Tuff
Organic and Chemic	Calcareous	Coral, Shells, Calcareous mud, etc.	Limestone and Dolomite	Marble	
		Calcareous Tufa	Travertine		
		Bones, etc.	Guano	Phosphate Rock	
	Siliceous	Chemical Precipitates	Gypsum Salt	Alabaster Rock Salt	
		Tripolite	Flint and Chert	Novaculite	
		Geyserite			
	Carbonaceous	Peat Petroleum	Coals Asphalts	Graphite	
	Ferruginous	Bog Ore and Ochre	Limonite Red Hematite	Magnetite Specular Hematite	
		Clay Iron Stone	Spathic Iron		
	Silicate	Greensand	Greensand		

Classification of the Igneous Rocks.

Composition Texture	Acid < —		> Basic	
	Orthoclase		Plagioclase	
	Biotite (or) (and) Hornblende		Augite (or) (and) Biotite	
	+ Quartz	— Quartz + Quartz + Quartz — Quartz	— Olivine + Olivine — Olivine + Olivine	Tachyrite
Amorphous	Obsidian Pitchstone, Pumice, Perlite, Spherpente Vitrophyre			
Cryptocrystalline (Felsite)	Felsite Felsite Porphyry			
Oligocrystalline	Rhyolite	Trachyte Phonolite	Dacite	Andesite
Plutonic	Acid Porphyry			
	Granite	Syenite Nepheline-Syenite	Diorite	
	Holocrystalline Microcrystalline Macrocrystalline	Acid Granophyre Acid Pegmatite		
Megacrystalline				
Per cent. of Silica.	80 to 65	65 to 50	70 to 50	55 to 45
		Basalt Dolerite		Augite Limburgite
		Basic Porphyry		Pyroxenite Peridotite
				Basic Granophyre Basic Pegmatite

Classification of the Calcareous Rocks.

Subgroup	Process	Unconsolidated	Consolidated	Crystalline
		Corals and Shells	Reef Rock	
Carbonates	Organic	Calc Gravel	Calcirudite	Marble
		Calc Sand	Calcarenite	
		Calc Mud	Calcilutite	
		Calc Tufa	Travertine	
Phosphates	Organic	Bones, etc.	Guano	Phosphate Rock
Sulphates and Chlorides	Chemic	Precipitates	Gypsum	Alabaster
			Salt	Rock Salt

Classification of the Metamorphic Rocks.

	Acid	Orthoclase+Quartz	Granitic Gneiss
		Orthoclase—Quartz	Syenitic Gneiss
Gneisses (Feldspathic)	Basic	Plagioclase+	Dioritic Gneiss
		Hornblende	Gabbroitic Gneiss
	Micaceous	Plagioclase+	
		Augite	
Schists (Non-feldspathic)	Calcareous (Anhydrous)	Anhydrous	Mica Schist
			Staurolite Schist
			Chiastolite Schist
			Fibrolite Schist
	Magnesian (Hydrous)	Hydrous	Hydromica Schist
			Sericite Schist
		Amphibole	Tremolite Schist
			Actinolite Schist
	Pyroxene		Hornblende Schist
			Amphibolite
	Foliated		Pyroxenite
			Talc Schist
	Compact		Chlorite Schist
			Serpentine

of quartz, feldspar, and mica in granite, etc. As indicated in the definition, textures may be classified according to the sizes, the forms, and the modes of arrangement, of the constituent particles. But of these three modes of division, that based upon size is the most fundamental, especially if we draw the line at the limit of visibility of the particles.

Primary Textures of Rocks.

If the particles are macroscopic, they may be divided according to form; and undoubtedly the most important distinction to be noted here is that between crystals and crystalline particles on the one hand, and irregular or water-worn fragments on the other. Thus, as shown in the collection and in the table, we arrive at a definition of two of the most important textures—the *fragmental* and the *crystalline*. There are numerous varieties of each of these, based upon peculiarities in the forms or sizes of the particles. Thus among the fragmental textures we have the *arenaceous* texture (1), the *conglomerate* or *puddingstone* texture (2), the *breccia* texture (3), the *shelly* texture (4) where the rock is made up of broken shells, etc; and the crystalline rocks may be *finely crystalline* (5-6), or *coarsely crystalline* (7-8).

If the particles are microscopic, we cannot, of course (without using the microscope), divide them according to form; but, paradoxical as it may seem, they can be divided according to size. We can distinguish those rocks in which the particles are merely minute, becoming visible under the microscope, *i. e.*, those rocks in which the texture is simply very finely fragmental or very finely crystalline, from those in which the constitu-

ent particles (accidental impurities and inclosures aside) are, for aught that we can determine, of molecular smallness, not being resolved by the highest powers of the microscope. The rocks of the first class, of which common clay (13), clay-slate (11), black marble (14), and novaculite (12), are good examples, are called *compact*; and those of the second class, presenting, as in obsidian, etc. (15-18), a perfectly continuous and lustrous surface, are termed *vitreous*.

The four textures which we have now defined, and which, it will be observed, are determined entirely by the *forms* and *sizes* of the constituent particles, are called the primary textures; because every rock *must* possess one of them. We cannot conceive of a rock which is neither fragmental, crystalline, compact, nor vitreous; but it is not rare to find two of these primary textures, as the vitreous and crystalline, or compact and crystalline, combined in the same rock.

Secondary Textures of Rocks.

In addition to at least one of the primary textures, a rock may or may not possess one or more of what are called *secondary* textures. These are determined by the way in which the particles are united, the mode or pattern of the arrangement, etc. The number of secondary textures is rather indefinite; but all the more important kinds are illustrated in the collection. In some rocks, several secondary textures are combined with the same primary texture. The collection and table, however, are constructed to show only the possible combinations of one secondary with a primary texture.

The most important secondary texture is the *laminated*. This exists where the constituent particles, whatever their forms or sizes, are arranged in more or less regular and parallel bands or layers. We may distinguish two principal kinds of laminated texture, according as the lamination is or is not accompanied by easy splitting or cleavage. *Banded* is a suitable name for the texture, in the absence of easy splitting. But, where easy splitting exists, lithologists have found it convenient to distinguish between the easy splitting of crystalline rocks on the one hand and of the fragmental and compact rocks on the other: the term *schistose* being applied and restricted to the former, and the term *shaly* to the latter. We may also properly distinguish between both these and the easy splitting that is independent of, and usually at variance with the layers varying in composition, color, or texture, *i. e.*, slaty cleavage or slaty texture properly so-called.

The specimens on the second shelf not only illustrate these different varieties of the laminated texture, but also like the table, show their relations to the primary textures. Thus the specimens in the first group are fragmental, as their position under that primary texture indicates; and they teach us that fragmental rocks may be either banded (21-22) or shaly (23-24). Similarly, the specimens in the second group teach us that crystalline rocks may be banded (25-26) or schistose (27-28). While from the third group we learn that compact rocks may be banded (33-34), shaly (31) or slaty (32); and the specimens of obsidian (35-36), shows that vitreous rocks may be banded.

We have the *porphyritic* texture when *separate* and *distinct crystals* of any mineral, but most commonly of feldspar, are enclosed in a relatively fine-grained base or matrix, which may be either crystalline, compact or vitreous, but rarely fragmental. In all cases of porphyritic texture, the primary texture is, in part at least, crystalline, and it may be wholly so. Nevertheless, crystals alone do not make the porphyritic texture, but that, as with all secondary textures, depends very largely upon the mode of arrangement of the constituent particles. This texture, as stated, occurs commonly in association with the crystalline (41-42), compact (51-52), and vitreous (53), but rarely with the fragmental.

The *concretionary* texture exists when one or more constituents of a rock have the form, in whole or in part, not of distinct angular crystals, but of rounded concretions, the concretions taking the place in this texture of the isolated crystals in the porphyritic texture. This texture is of common occurrence in connection with the fragmental (43) and compact (54-55) textures; and the nodules of mica in granite (44) show that it may occur with the crystalline texture; while spherulitic obsidian (56) is a good example of its association with the vitreous texture.

The *vesicular* texture refers chiefly to the rounded or bubble-shaped cavities formed by the steam in many volcanic rocks. These steam holes or vesicles occur in vitreous or glassy lavas (73-74), very commonly in finely crystalline or compact lavas (71-72), and occasionally in the more coarsely crystalline kinds (63-64). A somewhat similar texture, which may be called the

cellular texture, is often developed in fragmental (61-62) and compact rocks by the dissolving out of small fossils and crystals.

The *amygdaloidal* texture is produced when, in the course of time, the vesicles of common lava become filled with various minerals deposited by infiltrating waters. The name is from the Latin *amygdalum*, an almond, in allusion to the ellipsoidal form of the vesicles, or amygdules, as they are called after being filled. The amygdaloidal texture is thus necessarily preceded by the vesicular, and is limited to the same classes of rocks, almost all kinds of amygdaloidal rocks being compact as regards their primary texture (75-76).

The *tufaceous* texture is found in the tufas, or the rocks which, in their most typical developments, have been formed by the deposition of mineral matter from solution over and among moss and other kinds of vegetation. It bears some resemblance to the vesicular structure; but as the specimen (95) shows, it is essentially a mineral network, reticulated rather than vesicular.

All the secondary textures illustrated so far are determined by the mode, *i.e.*, the pattern, of the arrangement of the constituent particles; but there are two important varieties depending on the strength of the union of the particles. These are the *firm* or *strong*, which is illustrated by nearly all the specimens, and the *friable* or *earthy*, which is shown in the remaining specimens on the bottom shelf. Friable and earthy are not strictly synonymous terms; but the former is properly restricted to fragmental (81-82) and crystalline (83-84), and the latter to compact (91-92) and vitreous (93-94) rocks.

SYSTEMATIC LITHOLOGY.

In this section we have to illustrate: first, the *Classification of Rocks*; and, second, the *Descriptions of Rocks or Descriptive Lithology*.

CLASSIFICATION OF ROCKS.

The classifications of rocks which have been proposed at different times are almost as numerous as the rocks themselves. Some of these are obviously artificial, as when we classify stones according to their uses, etc. But we want something more scientific, a *natural* classification; that is, one based upon the natural and permanent characteristics of rocks. Rocks have been classified according to chemical composition, mineralogical composition, texture, color, density, hardness, etc.; but these arrangements, taken singly or all combined, are inadequate.

A *natural* classification may be defined as a concise and systematic statement of the natural relations existing among the objects classified. Now the most important relations existing among rocks are those due to their different origins. We must not forget that lithology is a branch of geology, and that geology is first of all a *dynamical* science. The most important question that can be asked about any rock is, not *What* is it made of? but *How* was it made? What were the general forces or agencies concerned in its formation? Rocks are the material in which the earth's history is written,

and what we want to know first concerning any rock is what it can tell us of the condition of that part of the earth at the time it was made and subsequently.

The geological agencies, as has been explained in the *Guide to Dynamical Geology* (p. 27), may be arranged in two great classes: first, the igneous or subterranean agencies, originating in the central or interior heat, and producing the eruptive or unstratified rocks; and, second, the aqueous or superficial agencies, originating in the solar heat, and producing the sedimentary or stratified rocks. Hence, we want to know first of any rock whether it is of igneous or aqueous origin. Then, if it is a sedimentary rock, whether it has been formed by the action chiefly of mechanical, chemical, or organic forces. And, if it is an eruptive rock, whether it has cooled and solidified below the earth's surface in a fissure, and is a dike or plutonic rock; or has flowed out on the surface and cooled in contact with the air, and thus become an ordinary lava or volcanic rock.

Here we have the outlines of the classification which is illustrated by the collection in sections 5 and 6. Each important type or species is represented by one or more examples; and the whole may be regarded as essentially an epitome of the main systematic collection of rocks, which occupies sections 7-23, inclusive. The details of the classification, except so far as they are self-explanatory, may be most profitably considered in connection with the descriptions of the successive groups of rocks in the following pages.

CLASSIFICATION OF ROCKS.

Sedimentary or Stratified Rocks.	MECHANICALLY FORMED.		Unconsolidated.		Consolidated.	
	Conglomerate Group.		Gravel.		Conglomerate.	
	Arenaceous Group.		Sand.		Sandstone.	
Sedimentary or Stratified Rocks.	Argillaceous Group.		Clay.		Slate.	
	Volcanic Group.		Volcanic Dust and Sand.		Volcanic Tuff and Agglomerate.	
	Coal Group.		Iron-ore Group.		Calcareous Group.	
Sedimentary or Stratified Rocks.	Metamorphic Group (Silicates).		Acidic.		Basic.	
	Peat. Lignite. Bit. Coal. Anthracite. Graphite. Asphaltum.		Limonite. Hematite. Magnetite. Siderite. Siliceous Group.		Limestone. Dolomite. Magnesite. Gypsum. Rock-salt.	
	Tripolite. Chert. Flint. Geyserite. Novaculite.		Feldspathic (Gneisses).		Gneiss. Syenite.	
Sedimentary or Stratified Rocks.	Non-feldspathic (Schists).		Mica Schist. Hornblende Schist. Talc Schist.		Amphibolite. Chl. Schist. Greensand. Serpentine.	
	Feldspathic.		Granite. Syenite.		Diorite. Diabase.	
	Feldspathic.		Rhyolite. Trachyte. Obsidian. Petrosilex. Felsite.		Andesite. Basalt. Tachylite. Porphyrite. Melaphyr.	
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.			
	VOLCANIC.					

Section 7.

DESCRIPTIONS OF ROCKS.

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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