writers to an indurated clay requiring to be ground and mixed with water before it acquires plasticity.

When clay has been deposited intermittently so as to assume a thinly stratified or fissile structure, it receives the general name of *Shale*. Under this term are included all laminated and indurated clays which are capable of being split along the lines of deposit into hard leaves. They present almost endless varieties of texture and composition, passing on the one hand into clays, on the other into flagstones and sandstones, or again, through calcareous gradations into limestone, or through ferruginous varieties into clay-ironstone, and through bituminous kinds into coal. An important variety, known as *Oil-shale*, and containing so much bituminous matter that it is now extensively used as a source for the manufacture of solid paraffin and mineral oils is described in the next section.

Flinty-slate (*Lydian-stone*, *Hornstone*) is siliceous shale or mudstone which has been indurated into an exceedingly compact flinty mass, breaking with a conchoidal or splintery fracture, and usually of dark colours, black, brown, and red, more rarely white.

Clay-slate is a compact close-grained, very hard, fissile argillaceous rock, dull lead-blue, grey, green, red, purple, or black in colour, splitting into thin leaves which are not those of original deposit but those produced by a superinduced cleavage. In this case the rock has been affected by great lateral pressure, whereby its particles have been forced to adjust themselves with their longer axes perpendicular to the direction of pressure. This rearrangement has imparted to the rock a fissility wholly independent of original lamination. The possession of this cleavage is the distinctive character of a true slate.

(*c.*) *Rocks formed of the Debris of Plants.*—These have sometimes been produced by the decay and entombment of vegetation on the spot where it grew, sometimes by the drifting of the plants to a distance and their consolidation there. In the latter case, they may be mingled with inorganic sediment, so as to pass into carbonaceous shale.

Peat is vegetable matter, more or less decomposed and chemically altered, found in boggy places and elsewhere where marshy plants grow and decay. It varies from a pale yellow or brown fibrous substance, like turf or compressed hay, in which the plant remains are abundant and conspicuous, to a compact dark-brown or black material, resembling black clay when wet and some varieties of lignite when dried. The nature and proportions of the constituent elements of peat, after being dried at 100° C., are illustrated by the analysis of an Irish example which gave—carbon, 60·48; hydrogen, 6·10; oxygen, 32·55; nitrogen, 0·88; while the ash was 3·30.

There is always a large proportion of water which cannot be driven off even by drying the peat. In the manufacture of compressed peat for fuel this constituent, which of course greatly lessens the value of the peat as compared with an equal weight of coal, is driven off to a great extent by chopping the peat into fine pieces, and thereby exposing a large surface to evaporation. The ash varies in amount from less than 1·00 to more than 65 per cent., and consists of sand, clay, ferric oxide, sulphuric acid, and minute proportions of lime, soda, potash, and magnesia.

Lignite is compressed and chemically altered vegetable matter, often retaining a lamellar or ligneous texture, and stems with woody fibre crossing each other in all directions. It varies from pale brown or yellow to deep brown or black. Some shade of brown is the usual colour, whence the name *brown coal*, by which it is often known. It occurs in beds chiefly among the Tertiary strata, under conditions similar to those in which coal is found in older formations. It may be regarded as a stage in the alteration and mineralization of vegetable matter intermediate between peat and true coal.

Coal, the most completely mineralized form of vegetable matter, occurs as a black (sometimes dark-brown), brittle, usually lustrous substance, intercalated in beds between strata of sandstone, shale, fireclay, &c., in geological formations of Palæozoic, Secondary, and Tertiary age. The word coal is rather a popular than a scientific term, as it is indiscriminately applied to any mineral substance capable of being used as fuel. Strictly employed it ought only to be used with reference to beds of fossilized vegetation, the result either of the growth of plants on the spot or of the drifting of them thither.

The following analyses show the chemical constituents in some of the principal varieties of coal :—

	Caking Coal.	Splint Coal.	Cannel Coal.	Anthracite.
Carbon	86·75	79·58	66·4	91·44
Hydrogen	5·24	5·50	7·54	3·46
Oxygen }	6·61	8·33	10·84	2·58
Nitrogen }		1·13	1·36	0·21
Earthy substances	1·40	5·46	13·82	2·31
Specific gravity	1·28	1·31	1·27	1·39

Diatom-earth is a siliceous deposit formed chiefly of the frustules of diatoms. It is laid down both in salt and in fresh water. Wide tracts of it are now being deposited on the bed of the South Pacific. In Virginia, United States, an extensive tract occurs covered with diatom-earth to a depth of 40 feet. It is used as a polishing or tripoli powder.

Oil shale (*Brandschiefer*) is shale containing such a proportion of hydrocarbons as to be capable of yielding mineral oil on slow distillation. This substance occurs as ordinary shales do, in layers or beds, interstratified with other aqueous deposits, as in the Scottish coal-fields. It is in a geological sense true shale, and owes its peculiarity to the quantity of vegetable (or animal) matter which has been preserved among its inorganic constituents. It consists of fissile argillaceous layers, highly impregnated with bituminous matter, passing on one side into common shale, on the other into cannel or parrot coal. The richer varieties yield from 30 to 40 gallons of crude oil to the ton of shale. They may be distinguished from non-bituminous or feebly bituminous shales (throughout the shale districts of Scotland) by the peculiarity that a thin paring curls up in front of the knife, and shows a brown lustrous streak. Some of the shales in the Lothians are crowded with the valves of ostracod crustaceans, besides scales, coprolites, &c., of ganoid fishes (*Palæoniscus*, *Amblypterus*, *Megalichthys*, &c.); and it is possible that the bituminous matter may in some cases have resulted from animal organisms, though the abundance of plant remains indicates that it is probably in most cases of vegetable origin. Under the name "pyroschists" Sterry Hunt classes the clays or shales (of all geological ages) which are hydrocarbonaceous, and yield by distillation volatile hydrocarbons, inflammable gas, &c.

(*d.*) *Rocks formed of Animal Remains.*—These may be formed on land, as in bone caves, but most abundantly under water, as on the bottom of lakes and of the sea. They may be calcareous, siliceous, or phosphatic.

Limestone.—Besides the limestones resulting from the deposition of chemical precipitates of carbonate of lime, there is another important series derived from the remains of organisms, either by growth on the spot, or by accumulation as mechanical sediment. Limestone so originating has often been so altered that it cannot always be distinguished from that which has been chemically produced, especially when it has been exposed to the action of percolating acidulated water, for in that case a crystalline texture is gradually superinduced, by which the original organic structures in the mass are wholly or in great part obliterated. Limestone composed of the remains of living organisms forms thin layers and massive beds. In some instances, as in that of the English and Irish Mountain Limestone, it occurs in masses several thousand feet thick, which extend for hundreds of square miles, and form the rock out of which picturesque valleys, gorges, hills, and table-lands have been excavated. Limestone may be either of fresh water or of marine origin. Some of the more common and important varieties may be here enumerated :—

Coral-rock is limestone formed by the continuous growth of coral-building polyps. This substance affords an excellent illustration of the way in which organic structure may be effaced from a limestone entirely formed from the remains of once living animals. Though the skeletons of the reef-building corals remain distinct on the upper surface, those of their predecessors beneath them are gradually obliterated by the passage through them of percolating water dissolving and redepositing carbonate of lime. This same action may be observed among the stalactites of a damp vault, in which, though the successive rings of growth are preserved, a crystalline divergent structure is superinduced, which traverses these rings from the centre outward. We can thus understand how a mass of crystalline limestone may have been produced from one formed out of organic remains without the action of any subterranean heat, but merely by the permeation of water from the surface. *Crinoidal* (*Encrinite*) *Limestone* is a rock composed in great part of joints of encrinites, with *Foraminifera*, corals, and mollusks. It varies in colour from white or pale grey, through shades of bluish-grey (sometimes yellow or brown, less commonly red) to a dark-grey or even black colour. It is abundant among Palæozoic formations, being especially characteristic of the lower part of the Carboniferous system. *Chalk* as a lithological term is applied to a white soft rock, meagre to the touch, soiling the fingers, formed of a fine calcareous flour derived from the remains of *Foraminifera*, echinoderms, mollusks, and other marine organisms. It occurs in massive beds, and covers a great part of the south-east and east of England. In Ireland and elsewhere it assumes a firmer grain and various colours, so as to pass into some of the numerous varieties of compact white limestone. *Shell-Marl*, a soft white, earthy, or crumbly deposit, is formed in lakes and ponds by the accumulation of the remains of shells and *Entomostraca* on the bottom. When such calcareous deposits become solid compact stone they are known as *fresh-water* (*lacustrine*) *limestone*. These are generally of a smooth texture, and either dull white or pale grey, their fracture only slightly conchoidal, rarely splintery. *Ooze* is a mud of organic origin found covering vast areas of the floor of the Atlantic and other oceans. Some of it is calcareous and formed wholly or mostly of the remains of *Foraminifera*, particularly of forms of the genus *Globigerina*; hence this deposit has been termed foraminiferal or globigerina ooze. Sometimes it is mainly siliceous, consisting of the remains of *Radiolaria* (Radiolarian ooze) or of diatoms (Diatom ooze). These deposits are further referred to in the section of this article which treats of the geological aspects of the ocean. *Shell-sand* is a sand composed in great measure or wholly of comminuted shells, found commonly on a low shelving coast exposed to prevalent on-shore winds. This deposit when thrown above the reach of the waves and often wetted by rain, or by trickling runnels of water, is apt to become consolidated into a mass, owing to the solution and redeposit of lime round the grains of shell.

Flint and *Chert* are siliceous rocks (which, though not strictly fragmental, may be conveniently placed here) found in nodules and layers in limestones of many different geological ages. Flint is a dark horny substance, breaking with a splintery to conchoidal fracture. It is particularly abundant in the chalk formation. Chert is an impure flint, containing more clay or lime with the silica. These substances seem in some cases to have had a directly organic origin, having been secreted from sea-water by the living organisms; in other cases, where for example we find a calcareous shell, or echinus, or coral, converted into silica, it would seem that the substitution of silica for lime has been effected by a process of chemical pseudomorphism either after or during the formation of the limestone.[1]

(*e.*) *Volcanic Fragmental Rocks* form an interesting group composed of the loose materials ejected from volcanic vents. In their typical condition they consist merely of consolidated volcanic debris, including bombs, scoriæ, ejected blocks, sand, lapilli, and dust. It is evident, however, that, when these materials were deposited in water, there would necessarily be a limit beyond which they would not extend, and where they would be mingled with and would insensibly pass into ordinary non-volcanic sediment. Hence we may expect to find transitional varieties between rocks formed directly from the results of volcanic explosion and ordinary sedimentary deposits. Moreover, as these fragmental volcanic masses usually consist almost wholly of the detritus of different lavas, which have been blown into fragments in the volcanic chimneys, we may expect to find, on the other hand, a passage from them into rocks derived from consolidated lava-beds by ordinary aqueous erosion. (See part iv.)

Volcanic Conglomerate is a rock composed mainly or wholly of rounded or subangular fragments of any volcanic rocks in a paste derived chiefly or wholly from the same materials, usually exhibiting a stratified arrangement, and often found intercalated between successive sheets of lava. In most cases conglomerates of this kind have been formed by the accumulation of materials ejected from volcanic vents; occasionally, as just remarked, they may have resulted from the aqueous erosion of previously solidified lavas, or from a combination of both these processes. There does not appear at present to be any satisfactory method of always determining the exact mode of formation, except that well-rounded and smoothed stones will almost certainly indicate long-continued water-action rather than trituration in a volcanic vent.

The volcanic conglomerates may receive different names according to the nature of the component fragments: thus we have *basalt-conglomerates*, where these fragments are wholly or mainly of basalt, *trachyte-conglomerates*, *porphyrite-conglomerates*, *phonolite-conglomerates*, &c.

Volcanic Breccia resembles volcanic conglomerates, except that the stones are angular. This angularity indicates an absence of aqueous erosion, and, under the circumstances in which it is found, usually points to volcanic explosions. There is a great variety of breccias, as *basalt-breccia*, *diabase-breccia*, &c.

Volcanic Agglomerate is the name given to a tumultuous assemblage of blocks of all sizes up to masses several yards in diameter. It is met with in the "necks" or pipes of old volcanic orifices. The stones and paste are commonly of one or more volcanic rocks, such as basalt or porphyrite, but they include also fragments of the surrounding rocks, whatever these may be, through which the volcanic orifice has been drilled. As a rule agglomerate is devoid of stratification; but sometimes it includes portions which have a more or less distinct arrangement in beds of coarser and finer detritus, often placed on end or inclined in different directions at high angles.

[1] Hull and Hardman on Chert, *Trans. Roy. Dub. Soc.*, new ser., vol. i. 71, 1878.

Volcanic Tuff.—This general term may be made to include all the finer kinds of volcanic detritus, ranging on the one hand through coarse gravelly deposits into conglomerates, and on the other into exceedingly compact fine-grained rocks formed of the finest and most impalpable kind of volcanic dust. Some tuffs are full of microlites or imperfect forms of crystallization derived from the lava which has blown into dust. Others are formed of small rounded or angular grains of different lavas with fragments of various rocks through which the volcanic funnels have been drilled. Minutely cellular grains, as if derived from the ebullition of very fluid glassy lava like palagonite, constitute much of the tuff in some of the volcanic necks of Carboniferous age in central Scotland. Some tuffs have consolidated under water, others on dry land. As a rule they are distinctly stratified. Near the original vents of eruption they commonly present rapid alternations of finer and coarser detritus indicative of successive phases of volcanic activity.

The tuffs may be subdivided according to the nature of the lava from the disintegration of which they have been formed. Thus we have *felsite-tuffs*, *trachyte-tuffs*, *basalt-tuffs*, *pumice-tuffs*, *porphyrite-tuffs*, *palagonite-tuffs*. Some varieties have received special names. *Trass* (*Ducksteín*, *Tuffstein*) is a compact yellow pumiceous tuff which has filled up some of the valleys of the Eifel region and is largely quarried as an hydraulic mortar. *Peperino* is an Italian tuff of late geological date, full of separate crystals of augite and other minerals.

PART III.—DYNAMICAL GEOLOGY.

Under this section is included the investigation of those processes of change which are at present in progress upon the earth, whereby modifications are made on the structure and composition of the crust, on the relations between the interior and the surface, as shown by volcanoes, earthquakes, and other terrestrial disturbances, on the distribution of oceans and continents, on the outlines of the land, on the form and depth of the sea-bottom, on climate, and on the races of plants and animals by which the earth is tenanted. It brings before us, in short, the whole range of activities which it is the province of geology to study, and leads us to precise notions regarding their relations to each other, and the results which they achieve. A knowledge of this branch of the subject is thus the essential groundwork of a true and fruitful acquaintance with the principles of geology, seeing that it necessitates a study of the present order of nature, and thus provides a key for the interpretation of the past.

The whole range of operations included within the scope of inquiry in this branch of the science may be regarded as a vast cycle of change, into which we may break at any point, and round which we may travel, only to find ourselves brought back to our starting-point. It is a matter of comparatively small moment at what part of the cycle we begin our inquiries. We shall always find that the changes we see in action have resulted from some that preceded, and give place to others which follow them.

At an early time in the earth's history, anterior to any of the periods of which a record remains in the visible rocks, the chief sources of geological action probably lay within the earth itself. The planet still retained a great store of its initial heat, and in all likelihood was the theatre of great chemical changes, giving rise, perhaps, to manifestations of volcanic energy somewhat like those which have so marvellously roughened the surface of the moon. As the outer layers of the globe cooled, and the disturbances due to internal heat and chemical action became less marked, the influence of the sun, which must always have operated, would then stand out more clearly, giving rise to that wide circle of superficial changes wherein variations of temperature and the circulation of air and water over the surface of the earth come into play.

In the pursuit of his inquiries into the past history and into the present *régime* of the earth, the geologist must needs keep his mind ever open to the reception of evidence for kinds and especially for degrees of action which he had not before imagined. Human experience has been too short