is essentially the origin of the beautiful onyx marbles (**21–22**). What has been stated for calcite might be repeated for gypsum (**22–24, 28**), and barite (**33, 35**). Apatite, in its mineral forms (**25–27**), occurs chiefly in veins, as the large and perfect crystals indicate. Fluorite (**43**) is another important vein-forming mineral, being, like calcite, barite, and quartz, a common constituent of metalliferous veins, the gangue or matrix of the ores. The vein forms of the most important of all the vein-forming minerals—quartz—are illustrated in a general way by the specimens (**41–42, 44–45**), the massive, vitreous quartz (**45**) being the most abundant. The large geode (**82**) may be regarded as a half-formed globular vein of chalcedony and crystalline quartz.

Among the ancient crystalline formations the veins consist very largely of either quartz, or quartz and various silicates, such as the feldspars, micas, etc. Of this character are the great veins of coarse or giant granite which in various parts of New England are quarried for commercial quartz (**45**), feldspar (**53–56**), and mica (**74–75**); and for crystallized cabinet minerals, such as tourmaline (**71**), beryl (**73**), etc. The large group of beryls in quartz in the Vestibule shows with what a lavish hand Nature has furnished these mineralogical store houses, while the enormous single crystal of beryl shows how favorable the conditions have been for the development of the mineral individuals. Graphic granite or pegmatite (**62–64, 72**) is a very characteristic structural feature of the less coarsely crystalline portions of the vein granite. The large specimen from Fitchburg (**65**) shows a more nearly complete section of a granite vein; and the highly micaceous specimen from the Black Hills (**61**) represents the great tin-bearing vein in which crystals of spodumene thirty to fifty feet in length and one to three feet in diameter have been observed.

PETROLOGY.

In lithology we investigate the nature of the materials composing the earth's crust — the various minerals, and aggregates of minerals, or rocks; while in petrology we consider the forms and modes of arrangement of the rock-masses, — in other words, the architecture of the earth.

Petrology is the complement of lithology, and in many respects it is the most fascinating division of geology, since in no other direction in this science are we brought constantly into such intimate relations with the beautiful and sublime in nature. The structures of rocks are the basis of nearly all natural scenery; for what we call scenery is usually merely the external expression, as developed by the powerful but delicate sculpture of the agents of erosion — rain and frost, rivers and glaciers, etc., — of the geological structure of the country. And to the practised eye of the geologist, a fine landscape is not simply a pleasantly or grandly diversified *surface*, but it has *depth*; for he reads in the superficial lineaments the structure of the rocks out of which they are carved.

But, while the magnitude of the phenomena adds greatly to the charm of the study, it also increases the difficulty of procuring suitable illustrations for the museum and class room. Nature, however, has not been wholly unmindful of our needs in this direction; for she has worked often upon a very small as well as a very large scale; many of the grandest phenomena being repeated in miniature. Thus, we observe rock-folds or arches miles in breadth and forming mountain masses, and of all sizes from that down to the minutest wrinkle. So with veins, faults, etc.; and the wonderful thing is that these small examples, which may be placed in the cabinet, are usually, except in size, exactly like the large. Now the aim in this depart-

ment of the Museum has been to secure as complete a collection as possible of these natural models; and to supplement these to only a limited extent by artificial illustrations. It is practically impossible to illustrate all the topics of petrology, without adding greatly to the artificial character of the collection by the free use of pictures and diagrams, and thus encroaching upon the proper ground of the text-book. And since the Guide is necessarily limited to the description and explanation of the objects in the collection, those desiring a more comprehensive and systematic treatment of petrology are referred to the standard text-books of the science, and to No. XII of the series of Science Guides published under the auspices of the Society.

The Petrological Collection, to which this section of the Guide relates, is contained in the two central or floor cases in Room B.

CLASSIFICATION OF STRUCTURES.

The structures of rocks divide at the outset into two classes: (1) the *original structures*, or those produced at the same time and by the same forces as the rocks themselves, and which are, therefore, peculiar to the class of rocks in which they occur (stratification, ripple-marks, fossils, etc.); and (2) the *subsequent structures*, or those developed in rocks subsequently to their formation, by forces that act more or less uniformly upon all classes of rocks, and which are, therefore, in a large degree, common to all kinds of rocks (folds, faults, joints, etc.).

The original structures are conveniently and naturally classified in accordance with the three great divisions of rocks: (1) stratified rocks, (2) eruptive rocks, and (3) vein rocks; while the subsequent structures, not being peculiar to particular classes of rocks, are properly divided into those produced by: (1) the subterranean or

igneous agencies, and (2) the superficial or aqueous agencies. The original structures, with which we begin, are illustrated by the specimens in the first case (sections 1 to 8), and the subsequent structures by those in the second case (sections 9 to 16).

ORIGINAL STRUCTURES OF STRATIFIED ROCKS.

Stratification. — All rocks formed by strewing materials in water, and their deposition in successive, parallel, horizontal layers, are *stratified*; and stratification is not only the chief structure resulting from this process, but it is the most important of all rock-structures. The first specimens in this section (**1**) are good examples of distinct and regular stratification in different kinds of rocks: iron ore (**1**), mica schist (**2**), gneiss (**3–4**), sandstone (**21–23, 41**), bituminous coal (**42**), clay (**43**), and, on the fifth or bottom shelf, slate (**87**). The stratification is, however, often not apparent to the eye; as in most of the specimens on the third shelf. It shows indistinctly in the granitoid gneiss (**48**), but is wholly wanting in the marble (**47**), cannel coal (**49**), freestone (**50**), and chalk (**51**). The explanation is easily found, for any one can readily prove by an experiment with clay or fine sand in a vessel of water that if precisely the same kind of material is deposited continuously and uniformly there will be no visible stratification in the deposit, because there is nothing in the nature of the sediment or the way in which it is laid down to develop distinct lines of stratification. Continuous and uniform deposition obtains very frequently in nature, as the specimens indicate; but it rarely continues long enough to permit the

formation of thick beds or strata. Hence, while the stratification is almost always visible on the large surfaces of sandstone, slate, etc., exposed in quarries and railway cuttings, and may usually be seen in the quarried blocks, it is often not apparent in smaller masses or hand specimens, which may represent a single homogeneous layer. There is one important exception, and that is where the particles, although of the same kind, are flat or elongated. Pebbles of these forms (**61**) are common on many beaches; and since they are necessarily arranged horizontally by the action of the water, they will, by their parallelism, make the stratification of the resulting pudding-stone (**65**) visible. The same result is accomplished still more distinctly by the mica scales in many sandstones (**62**), the leaves and flattened stems of vegetation in bituminous coal (**42**), shale (**63**), and the flat shells in limestone (**66**).

Changes in a rock subsequently to its deposition will also sometimes develop or bring out the stratification where it was before invisible. Thus, the cherty limestone (**67**) was originally quite homogeneous and massive, but the segregation of the disseminated silica to form the layers of chert makes the stratification very apparent.

In all other cases, visible stratification implies some change in the conditions; either the deposition was interrupted or different kinds of sediment were deposited at different times. The first cause produces planes of easy splitting, or fissility, especially in fine-grained rocks, like shale (**64**). This shaly structure or lamination-cleavage may be due, in some cases, to pressure, but it is
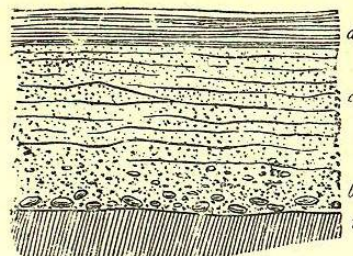

Section through sediment deposited by rain-water in a roadside pool, showing a normal gradation from coarse to fine sediment with diminishing force of current: *a*. Surface of roadway; *b*. layer of small pebbles and coarse sand; *c*. fine sand passing into *d*; *d*. the finest sand and mud.
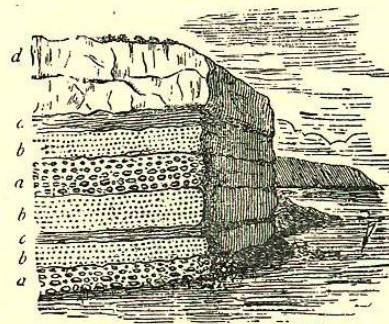

Section showing strata and laminæ. and alternations of coarse and fine sediments due to varying conditons of deposition: *a*. Conglomerate; *b*. sandstone; *c*. shale; *d*. limestone.
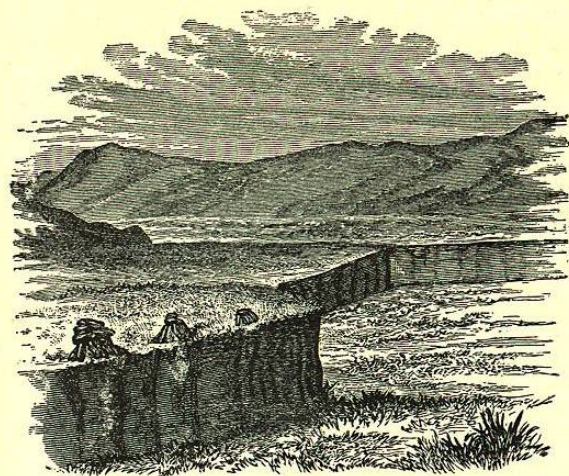
Section of a peat-bog. The peat is underlain by clay, corresponding to the underclay or floor of a coal-seam.
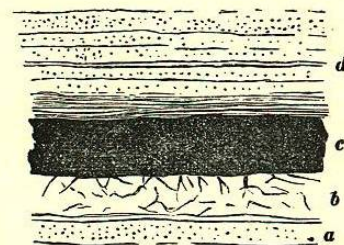
Section of a coal-seam, with its roof and floor: *a*. Sandstone and shale; *b*. underclay (fireclay), forming floor or pavement of coal; *c*. coal; *d*. shale and sandstone forming roof of coal.
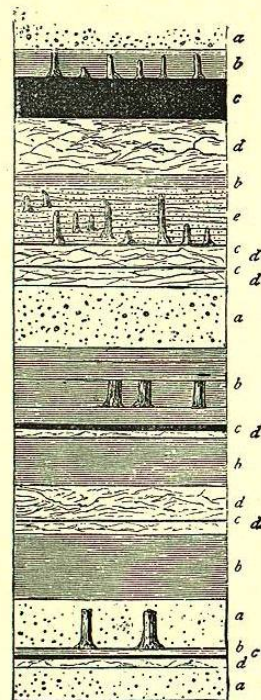
Section of a part of the Cape Breton coal-field, showing seven ancient soils, with remains of as many forests: *a*. Sandstones; *b*. and *e*. shales; *c*. coal-seams; *d*. underclays or soils.
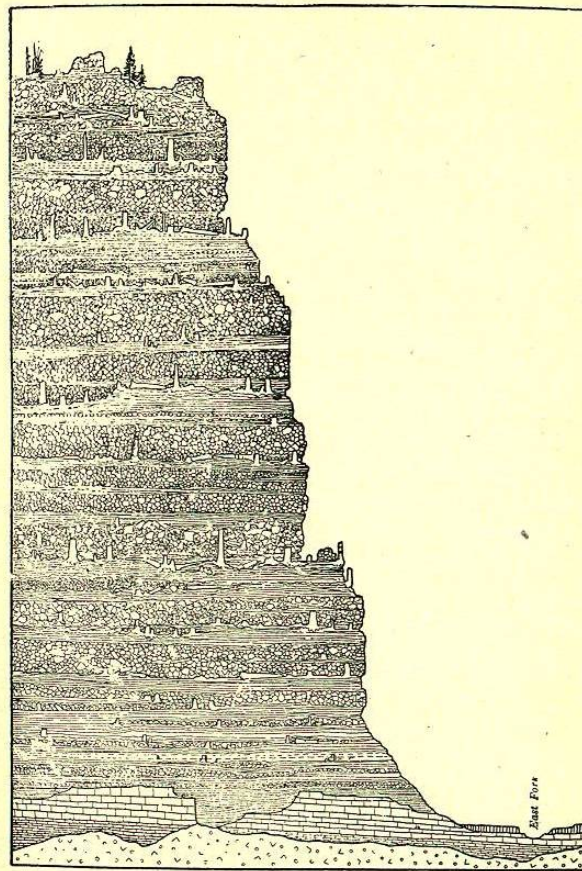
Section of Amethyst Mountain, Yellowstone National Park. The mountain consists of a base of Archaean granite and Carboniferous limestone overlain unconformably by 2700 feet of Tertiary strata, chiefly of volcanic origin. The coarse beds are conglomerate and breccia; and the alternating beds of finer material are sandstones and shales bearing the abundant silicified remains of fossil forests.

commonly understood to mean that each thin layer of clay became partially consolidated before the next one was deposited upon it, so that the two could not perfectly adhere; although the imperfect adhesion of the layers must be attributed in many cases to the deposition between them, at times when the water is unusually quiet, of slight films of finely divided mica, organic detritus, etc. These parallel planes of easy splitting are, however, by themselves, of little value as indications of stratification, since the lamination-cleavage is not always easily distinguished from true slaty cleavage (roofing slate), and parallel jointing structures developed subsequently to the deposition of the sediments and quite independent of the stratification. The second cause, or variations in the kind of sediment, gives alternating layers differing in color, texture, and composition, as is seen in most of the specimens of sandstone, slate, coal, iron ore, gneiss, etc. already referred to; and of all the indications of stratification these are the most important and reliable.

These specimens also illustrate well the division of stratified rocks into strata and laminae. A layer composed throughout of essentially the same kind of rock, as conglomerate or sandstone and showing no marked planes of division, is usually regarded as one *stratum* or *bed*; while the thinner portions composing the stratum and differing slightly in color, texture, or composition, and the thin sheets into which the shaly rocks split, are the *laminae* or *leaves*. The geological record is written chiefly in the sedimentary rocks; and the formations, strata, and laminae may be regarded as the volumes, chapters, and pages in the history of the earth. It is especially important to note in this connection that every line of stratification and every change in the

character of the sediments is due to some change of correspond-
ing magnitude in the conditions under which the rock was
formed. The slight and local changes in the conditions occur
frequently and mark off the individual laminae and strata, while
the more important and wide-spread changes determine the
boundaries of the groups of strata and the geological forma-
tions.

Strata are subject to constant lateral changes in tex-
ture and composition, *i.e.*, a bed or formation rarely
holds the same lithological characteristics over an ex-
tended area.   There are some striking exceptions, espec-
ially among the finer-grained rocks, like slate, limestone,
and coal, which have been deposited under uniform con-
ditions over wide areas. It is the general rule, how-
ever, particularly with the coarse-grained rocks, which
have been deposited in shallow water, near the land,
that the same continuous stratum undergoes great
changes in thickness and lithological character when fol-
lowed horizontally. A stratum of conglomerate becomes
finer grained and gradually changes into sandstone,
which shades off imperceptibly into slate, and slate into
limestone, etc. Where the stratum is conglomerate, its
thickness will usually be much greater and more variable
than where it is composed of the finer sediments. The
rapidity of these changes in certain cases is well shown
by the parallel sections in the drawing (**44**). These
represent precisely the same beds, as the connecting
lines indicate, at points only twenty feet apart.

When we glance at the conditions under which stratified
rocks are now being formed, it is plain that all strata must ter-
minate at the margin of the sea in which they were deposited,
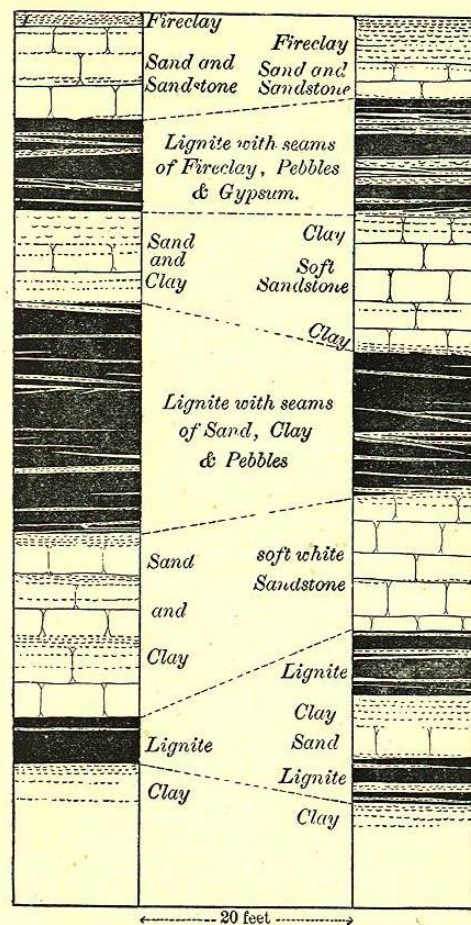
Parallel vertical sections on the face of Pulpit Rock, near Colorado
Springs, through identical strata and only twenty feet apart, illustrating
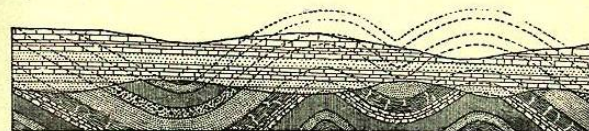rapid lateral changes in the character of strata.

Overlap and unconformity of strata.
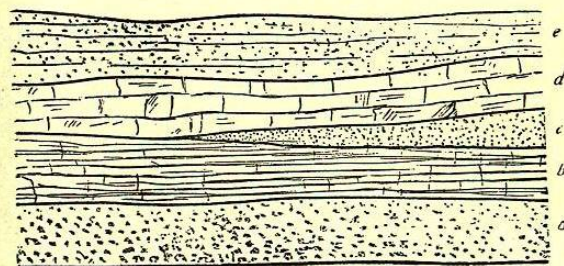
Interposition of strata.

Interposition, overlap and unconformity.

Ideal section of a true unconformity. The series of strata represented in the lower half of the figure were, after the deposition of the entire series, bent into mountain folds and raised above the sea, after which the resulting land surface was deeply denuded, and the whole area was then depressed again beneath the sea to receive the undisturbed strata represented in the upper half of the figure.


Section of a series of sedimentary rocks originally deposited horizontally on the sea-bottom.
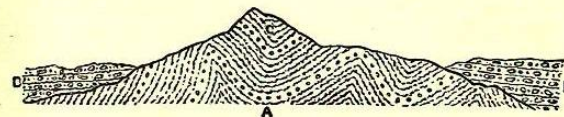
Section of a mountain formed of crumpled strata, A, which have been folded before the deposition of the horizontal beds, B, producing an unconformity between the two series.
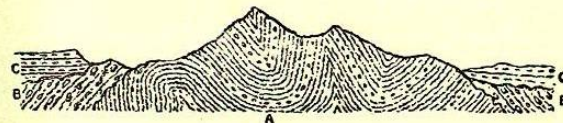
Double unconformity. Section of a mountain in which the strata, A, were upheaved before the deposition of the series, B, and the latter before the series, C.
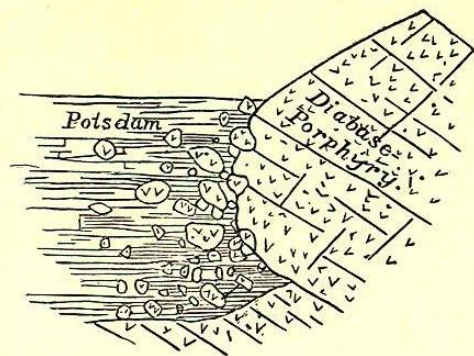
Unconformable contact of the Potsdam sandstone and diabase-porphyry of the Keweenawan series, at Taylor's Falls, Minn.
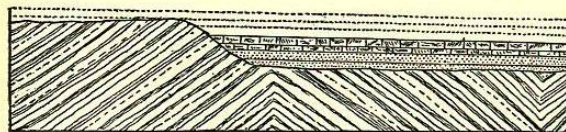
Section of an unconfomity where the upper formation has been denuded from the higher portion of the ancient land surface and left upon its lower portion.

Section of a river valley in the region of the Upper Mississippi, showing the modern terrace deposits resting in parallel position, but still unconformably, upon the ancient Silurian strata.
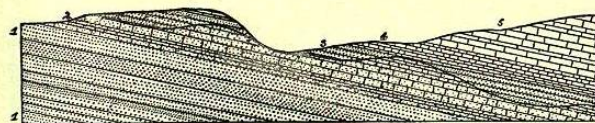
Section showing a parallel unconformity with subsequent tilting of the strata: 1. Postdam sandstone; 2. Lower Magnesian limestone; 3. St. Peter's sandstone; 4. Trenton limestone; 5. Galena limestone.

Section showing a typical unconformity, with outliers of the newer formation.

Section showing an unconformity where the older formation has been tilted and faulted, and then eroded, before the deposition of the newer formation.

Section of a typical unconformity, with subsequent tilting and faulting of the strata. St. Lawrence River, Canada. 1. Gneiss; 2. Potsdam sandstone.
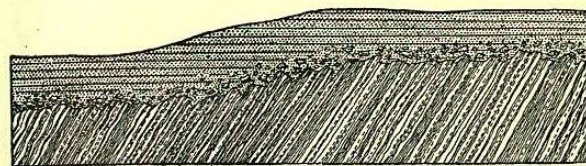
Section near Norway, Mich., showing the Potsdam sandstone unconformably overlying the Huronian series.
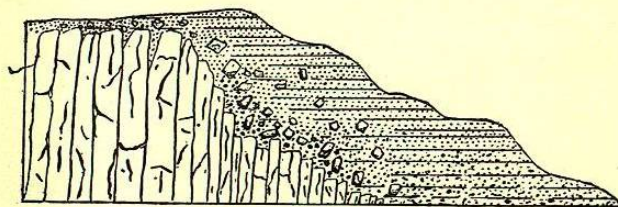
Unconformable contact of the Potsdam sandstone (horizontal) and Huronian quartzite (vertical), Baraboo River, Wisconsin.
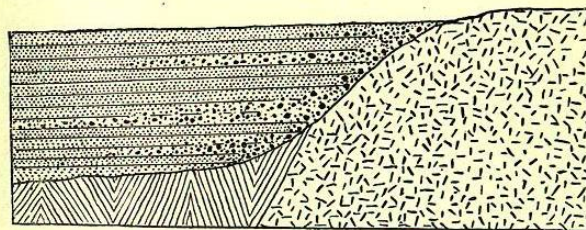
Section showing unconformity and the irregular distribution of fragments of the older rocks in the newer.