HANDBOOK FOR THE DEPARTMENT OF GEOLOGY IN THE U. S. NATIONAL MUSEUM.

PART I.—GEOGNOSY.—THE MATERIALS OF THE EARTH'S CRUST.

By GEORGE P. MERRILL, *Curator.*

INTRODUCTORY.

The history of the Geological Department of the National Museum may be said to date from the appointment of Dr. George W. Hawes as curator in 1880, after the completion of the new building. Prior to this time, owing to the limited amount of space that could be devoted to the department in the Smithsonian building, the collections were necessarily small. They were also of a very miscellaneous character, the principal material of real value from a lithologic or geologic standpoint which they were found to contain being a collection of 300 specimens of rocks from France, purchased in 1869 from Louis Saeman in Paris, and a similar collection of 148 specimens of rocks of Saxony, received in 1863 from the Royal Mining School of Freiberg, Saxony. There was, it is true, much material that might have been of value had there been any accurate data concerning it; but owing to the necessarily limited time and space that had been devoted to the care of these collections, in many cases nothing could be learned in regard to them, or if anything, the information was so meager as to be practically valueless. This was especially true of much of the material received from the various United States geological surveys and exploring expeditions.

At the time Dr. Hawes entered upon his duties as curator he also assumed charge of that branch of the Tenth Census relating to the quarrying industry of the United States. To this work he gave almost his entire attention, and the present building and ornamental stone collection is largely the result of his exertions in this direction. Dr. Hawes' connection with the Museum was, however, too short to allow the department to become fully organized, and at the time of his death matters were still in a state of great confusion owing to the large amount of material that had accumulated and the extent of the work undertaken, but necessarily uncompleted. The extensive collections received from Philadelphia at the close of the Centennial Exhibition in 1876 were still unpacked and unassorted, as were also those received from the various United States geological surveys that existed prior to the present organization.

To the Centennial Exhibition of 1876, the Tenth census (1880), the United States Land Office and the various United States geological surveys and exploring expeditions the department is largely indebted for whatever material it possessed prior to 1882. The time since the death of Dr. Hawes and the organization of the three departments of mineralogy, metallurgy, and lithology and physical geology from the one department of geology and mineralogy as it then existed, and the very recent reconsolidation of the department of metallurgy with that of lithology and physical geology, has been too short for more than a beginning to be made.

The handbook herewith presented is designed to be one of a systematic series, dealing as will be observed with but the first of the four divisions into which the science of geology is ordinarily divided.*

As at present arranged the collections of this division are installed in what it is hoped may ultimately prove to be temporary cases. Entering the hall from the east end, from the department of mammals, the visitor finds the first case of the series, that containing the elements and rock forming minerals, immediately upon his or her left. In this and all cases following the exhibits are so arranged that the observer, beginning with the extreme upper left corner, proceeds from left to right as in reading a book, each half case representing a page and each row of specimens a line of printed matter. The drawers in the lower portion of the cases are utilized for storage of material designed for study rather than exhibition. A list of the more important collections contained in these storage or table cases, as they are called, is given towards the close of this paper. (See pp. 589-591.)

In preparing the exhibit the idea advanced by Dr. G. B. Goode to the effect that a museum should consist of a series of labels illustrated by specimens has been ever kept in mind. Otherwise expressed the Curator has striven to make the department but a profusely illustrated text book in which the objects themselves serve as illustrations, and the text, reduced to a minimum amount, is furnished by the labels.

In arranging the exhibits under their various heads I have followed substantially the plan as laid down in Professor Geikie's text book,†

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*Two handbooks relating to the economic exhibits of the department have already appeared. The first, entitled The Collection of Building and Ornamental Stones in the United States National Museum, a handbook and catalogue, was prepared by the present writer and was issued in Part II of the Smithsonian Report for 1885-'86. The second, entitled Preliminary Descriptive Catalogue of the Systematic Collections in Economic Geology and Metallurgy, was prepared by Mr. F. P. Dewey, formerly curator of metallurgy, and will be published as a Bulletin. A "Preliminary Handbook of the Department Geology," in the form of a pamphlet of some fifty pages has also been prepared by the present writer and was issued as an appendix to the Museum report for 1888-89.

†Text Book of Geology. By A. Geikie, 2d ed., MacMillan & Co., London, 1885.

and to which frequent references will be made. A copy of this work is to be found upon the table in the exhibition hall. In the present paper, relating only to geognosy, the purely descriptive matter has been given in considerable detail since the arrangement adopted did not sufficiently correspond with that of any available publication to make references in all cases advisable. In the three sections to follow it is not anticipated so large a proportion of text will be necessary, since it is proposed to follow more closely the arrangement adopted in the usual text books, and since moreover the objects themselves are more striking in appearance and their individual characteristics more readily apparent.

GEOLOGY.

Geology is the science which treats of the earth's crust and its system of development. Physical geology is that branch of the science which treats of those geological phenomena which are attributable to physical agencies, the term physical being here introduced to distinguish the department from that of paleontological geology, which treats of the plants and animals which existed in past ages of the globe, but which now occur only as fossils or petrefactions.

The science of physical geology has been conveniently divided into four heads: (1) Geognosy, which treats of the earth's substance, the crust, and its composition; (2) dynamical geology, which treats of the agencies by which changes have been brought about in the composition and structure of the earth's crust; (3) geotectonic or structural geology, which treats of the structure of this crust, its original condition, and the structural changes which it has since undergone; and (4) historical or stratigraphic geology, which treats of the order of succession of the rocks without regard to their composition or methods of formation.

I.—GEOGNOSY.—THE MATERIALS OF THE EARTH'S CRUST.

The earth's crust is composed of mineral matter in various conditions and stages of consolidation, all of which, whether loose like sand or compact like granite, are included under the general name of rock. In the accompanying collections it has been found most convenient to treat this subject under four distinct heads: (1) The chemical elements constituting rocks. (2) The minerals constituting rocks. (3) The physical properties of rocks, as structure, color, and fracture, and (4) The kinds of rocks.

(1) THE CHEMICAL ELEMENTS CONSTITUTING ROCKS.

Although there are sixty-four elements known, but sixteen occur in any great abundance or form more than an extremely small proportion of the earth's crust. These sixteen, arranged according to their chemical properties and the order of their abundance, are as follows:

METALLOIDS	METALS.
Oxygen.	Aluminum.
Silicon.	Calcium.
Carbon.	Magnesium.
Sulphur.	Potassium.
Hydrogen.	Sodium.
Chlorine.	Iron.
Phosphorus.	Manganese.
Fluorine.	Barium.

Below is given a transcript of the labels used in this series.

Oxygen. Symbol O; atomic weight 16: This substance is a colorless, invisible gas possessing neither taste or smell. It exists in the free state in the atmosphere, of which it constitutes about one fifth by bulk, whilst in combination with other elements it forms nearly half the weight of the solid earth and eight-ninths by weight of water. It enters into combination with all the other elements, fluorine excepted, forming what are known as oxides. Thus hematite and magnetite, two very common ores of iron, are formed by the combination in different proportions of oxygen and iron.

Silicon. Symbol Si; atomic weight 28: Next to oxygen this is the most abundant of the earth's constituents. It, however, never occurs in the free state, but combined with oxygen as silica it forms more than one-half of the matter of the earth's crust.

Carbon. Symbol C; atomic weight 12: This substance occurs in the free state as graphite and the diamond, but is much more common in the impure form of common coal. Uncombined with other elements, it never exists in either a liquid or gaseous form, but in combination with oxygen as carbonic acid or carbon dioxide (CO_2) it is almost universally present in the air, rain, sea and river waters. In this form also it constitutes about one-fifth by weight of common limestone. It is also an abundant constituent of many other minerals and rocks.

Sulphur. Symbol S; atomic weight 32: Sulphur occurs in nature in both the free and combined state. In the free state it is found in volcanic regions such as Sicily, Iceland, and the Western United States. Its usual form of occurrence is in combination with the metals to form sulphides, or with oxygen and a metal to form sulphates. Sulphur and iron combine to form iron pyrites or iron disulphide (FeS_2), while sulphur, oxygen, and calcium combine to form sulphate of calcium or gypsum ($CaSo_4$).

Hydrogen. Symbol H; atomic weight 1: Hydrogen is a colorless invisible gas, without taste or smell. It occurs free in small proportions in certain volcanic gases, but its most common form is in combination with oxygen to form water (H_2O), of which it forms 11.13 per cent. by weight. It also occurs in combination with carbon to form the hydrocarbons, such as the mineral oils (petroleum, etc.) and gases.

Chlorine. Symbol Cl; atomic weight 35.5: Chlorine occurs free in nature only in limited amounts and in volcanic vents. Its most common form is in combination with hydrogen, forming hydrochloric acid or with the metals to form chlorides. It combines with sodium to form sodium chloride or common salt ($NaCl$), which is the most important mineral ingredient in sea water and which can usually be detected in rain and ordinary terrestrial waters. In this form also it forms extensive beds of rock salt, which are mined for commercial purposes.

Phosphorus. Symbol P; atomic weight 31: Phosphorus never occurs in nature in a free state, but is found in great abundance in combination with oxygen or one of the metals. Combined with calcium and oxygen it forms calcium phosphate, which is found in the bones of animals, the seeds of plants, and also the minerals phosphorite and apatite.

Fluorine. Symbol F; atomic weight 19: Fluorine does not occur free in nature and can be isolated by artificial chemical methods only with great difficulty. It is the only element that does not combine with oxygen. It occurs chiefly combined with calcium to form fluorspar, but traces of it are found in sea water and in the bones, teeth, blood, and milk of mammals.

Aluminum. Symbol Al; atomic weight 27.4: Aluminum is next to oxygen and silicon, probably the most abundant element of the earth's crust, of which it is estimated to form about one-twelfth. It has never been found in nature in the free state, but commonly occurs in combination with silicon and oxygen, in which form it is an abundant constituent of feldspar, kaolin, clay-slate, and many other rocks and minerals. In combination with oxygen it forms the minerals corundum, ruby, and sapphire.

Calcium. Symbol Ca; atomic weight 40: Calcium is one of the commonest and most important elements of the earth's crust, of which it has been estimated to compose about one-sixteenth. It does not occur free in nature, but its most common form is in combination with carbon dioxide, forming the mineral calcite ($CaCO_3$), or the rock limestone. In this form it is slighty soluble in water containing carbonic acid, and hence has become an almost universal ingredient of all natural waters, whence it furnishes the lime necessary for the formation of shells and skeletons of the various tribes of mollusca and corals. In combination with sulphuric acid, calcium forms the rock gypsum.

Magnesium. Symbol Mg; atomic weight 24: Magnesium does not occur free in nature, but is most commonly found in combination with carbonic acid as carbonate of magnesia forming thus an essential part of the rock dolomite. The bitter taste of sea water and some mineral waters is due to the presence of salts of magnesia. In combination with silica it forms an essential part of such rocks as serpentine, soapstone and talc.

Potassium. Symbol K; atomic weight 39.1: Potassium does not occur free in nature, but combined with silica is an important element in many mineral silicates, as, for instance, orthoclase. Granitic rocks contain from 4 to 5 per cent. of potassium salts, which on their decomposition become available for plant foods. As a chloride, potassium is always found in sea water, and as a nitrate forms the valuable natural salt commonly called niter or saltpeter.

Sodium. Symbol Na; atomic weight 23: Sodium is never found free in nature, but its most common form is in combination with chlorine forming common salt, an important ingredient of sea water. Combined with silica sodium is an important element in many mineral silicates.

Iron. Symbol Fe; atomic weight 56: Iron is the most abundant of the heavy metals, and occurs in nature both free and combined with other elements. In the free state it is found only to a limited extent in basaltic rocks and meteorites, but in combination with oxygen it is one of the most widely diffused of metals, and forms the coloring matter of a large number of rocks and minerals. In this form, too, it forms the valuable ores of iron known as magnetite and hematite. In combination with sulphur it forms the mineral pyrite FeS_2.

Manganese. Symbol Mn; atomic weight 55: Next to iron, manganese is the most abundant of the heavy metals. It occurs in nature only in combination with oxygen, in which form it is associated in minute quantities with iron in igneous rocks or in the forms known mineralogically as pyrolusite, psilomelane and wad. As the peroxide of manganese it occurs in concretionary forms scattered abundantly over the floor of the deep sea.

Barium. Symbol Ba; atomic weight 137: Barium occurs in nature combined with sulphuric acid, forming the mineral barite, or heavy spar, or with carbonic acid forming the mineral witherite.

(2) The minerals of rocks.

A rock is a mineral aggregate; more than this, it is an essential portion of the earth's crust, a geological body occupying a more or less well-defined position in the structure of the earth, either in the form of stratified beds, eruptive masses, sheets or dykes, or as veins and other chemical deposits of comparatively little importance as regards size and extent. Having considered the elements which in their various combinations go to make up the minerals, we will now consider the minerals which go to make up the rocks. The collection, it should be stated, is designed to show only those minerals commonly found in rock masses, or which make up any considerable portion of the mass of a rock of any kind. The specimens are selected, not on account of their beauty or fine crystallographic development, but ordinary forms, both crystalline and massive, are shown in their principal varieties.

The mineral composition of rocks, it may be stated, "is greatly simplified by the wide range of conditions under which the commonest minerals can be formed, thus allowing their presence in rocks of all classes and of whatever origin. Thus quartz, feldspar, mica, the minerals of the hornblende or pyroxene group can be formed in a mass cooling from a state of fusion; they may be crystallized from solution, or be formed from volatilized products. They are therefore the commonest of minerals and rarely excluded from rocks of any class, since there is no process of rock formation which determines their absence." Moreover, most of the common minerals, like the feldspars, micas, hornblendes, pyroxenes, and the alkaline carbonates possess the capacity of adapting themselves to a very considerable range of compositions. In the feldspars, for example, the alkalies, lime, soda, or potash may replace each other almost indefinitely, and it is now commonly assumed that true species do not exist, but all are but isomorphous admixtures passing into one another by all gradations, and the names albite, oligloclase, anorthite, etc., are to be used only as indicating convenient stopping and starting points in the series. Hornblende or pyroxene, further, may be pure silicates of lime and magnesia, or iron and manganese may partially replace these substances. Lime carbonate may be pure, or magnesia may replace the lime in any proportion. These illustrations are sufficient to indicate the reason of the great simplicity of rock masses as regards their chief constituents, and that whatever may be the composition of a mass within nature's limits, and whatever may be the conditions of its origin, the probabilities are that it will be formed essentially of one or more of a half a dozen minerals in some of their varieties.

But however great the adaptability of these few minerals may be they are, nevertheless, subject to very definite laws of chemical equivalence. There are elements which they can not take into their composition, and there are circumstances which retard their formation while other minerals may be crystallizing. In a mass of more or less accidental composition it may, therefore, be expected that other minerals will form, in it may be, considerable numbers, but minute quantities.* It is customary to speak of those minerals which form the chief ingredients of any rock, and which may be regarded as characteristic of any particular variety, as the essential constituents, while those which occur in but small quantities, and whose presence or absence does not fundamentally affect its character, are called *accessory* constituents. The accessory mineral which predominates, and which is, as a rule, present in such quantities as to be recognizable by the unaided eye, is the *characterizing* accessory. Thus a biotite granite is a stone composed of the essential minerals quartz and potash feldspar, but in which the accessory mineral biotite occurs in such quantities as to give a definite character to the rock. The minerals of rocks may also be conveniently divided into two groups, according as they are products of the first consolidation of the mass or of subsequent changes. This is the system here adopted. We thus have:

(1) The original or primary constituents, those which formed upon its first consolidation. All the essential constituents are original, but

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* Hawes, the Minerals of Building Stones, Rep. Tenth Census, vol. x, p. 4.

on the other hand all the original constituents are not essential. Thus, in granite, quartz and orthoclase are both original and essential, while beryl and zircon or apatite, though original, are not essential.

(2) The secondary constituents are those which result from changes in a rock subsequent to its first consolidation, changes which are due in great part to the chemical action of percolating water. Such are the calcite, chalcedony, quartz, and zeolite deposits which form in the druses and amygdaloidal cavities of traps and other rocks.

Below is given a list of the rock-forming minerals arranged as above indicated; only the more important of these are exhibited. Although these are sufficiently described as regards their chemical and crystallographic properties in any of the mineralogies, it has been found necessary to label them very fully in order to indicate their relations and their comparative importance in the rocks of which they form a part. It is not deemed essential that the matter of these labels be reproduced here, though the following is inserted as a sample:

MAGNETITE. Magnetic Iron Ore.

Composition: $FeO+Fe_2O_3$=iron sesquioxide 68.97 per cent.; iron protoxide 31.03 per cent.

Crystalline System: Isometric.

Occurs as an original constituent in many schists and granites; in the latter usually in minute crystals visible only with the microscope. It is almost invariably present in many igneous rocks, such as diorite, diabase, and basalt, and frequently occurs in immense beds, forming a valuable iron ore.

Original minerals.

1. Quartz.
2. The Feldspars.
    - 2*a*. Orthoclase.
    - 2*b*. Microcline.
    - 2*c*. Albite.
    - 2*d*. Oligoclase.
    - 2*e*. Andesite.
    - 2*f*. Labradorite.
    - 2*g*. Bytownite.
    - 2*h*. Anorthite.

Original minerals—Continued.

3. The Amphiboles.
    - 3*a*. Hornblende.
    - 3*b*. Tremolite.
    - 3*c*. Actinolite.
    - 3*d*. Arvedsonite.
    - 3*e*. Glaucophane.
    - 3*f*. Smaragdite.
4. The Monoclinic Pyroxenes,
    - 4*a*. Malacolite,
    - 4*b*. Diallage,

Original minerals—Continued.

4. The Monoclinic Pyroxenes—Cont'd.
    - 4*c*. Augite.
    - 4*d*. Acmite.
    - 4*e*. Aegerite.
5. The Rhombic Pyroxenes.
    - 5*a*. Enstatite (Bronzite).
    - 5*b*. Hypersthene.
6. The Micas.
    - 6*a*. Muscovite.
    - 6*b*. Biotite.
    - 6c. Phlogopite.
7. Calcite.
8. Dolomite.
9. Gypsum.
10. Olivine.
11. Beryl.
12. Tourmaline.
13. Garnet.
14. Vesuvianite.
15. Epidote.
16. Zoisite.
17. Allanite.
18. Andalusite.
19. Staurolite.
20. Fibrolite.
21. Cyanite.
22. Scapolite.
23. Apatite.
24. Elæolite and Nepheline.
25. Leucite.
26. Cancrinite.
27. The Sodalite Group.
    - 27*a*. Sodalite.
    - 27*b*. Hauyn (nosean).
28. Zircon.
29. Chondrodite.
30. Cordierite.
31. Topaz.
32. Corundum.
33. Titanite (sphene).
34. Rutile.
35. Menaccanite.
36. Magnetite.
37. Hematite.
38. Chromite.
39. The Spinels.
    - 39*a*. Pleonast.
    - 39*b*. Picotite.
40. Pyrolusite.
41. Halite (common salt).
42. Fluorite.
43. The Elements.
    - 43*a*. Graphite.
    - 43*b*. Carbon.

Original minerals—Continued.

43. The Elements—Continued.
    - 43*c*. Iron.
    - 43*d*. Copper.
44. The Metallic Sulphides.
    - 44*a*. Galena.
    - 44*b*. Sphalerite.
    - 44*c*. Pyrrhotite.
    - 44*d*. Marcasite.
    - 44*e*. Pyrite.
    - 44*f*. Chalcopyrite.
    - 44*g*. Arsenopyrite.

Secondary minerals.

1. Quartz.
    - 1*a*. Chalcedony.
    - 1*b*. Opal.
    - 1*c*. Tridymite.
2. Albite.
3. The Amphibole Group.
    - 3*a*. Hornblende.
    - 3*b*. Tremolite.
    - 3*c*. Actinolite.
    - 3*d*. Uralite.
4. Muscovite (Sericite).
5. The Chlorites.
    - 5*a*. Jefferisite.
    - 5*b*. Ripidolite.
    - 5*c*. Penninite.
    - 5*d*. Prochlorite.
6. Calcite (and aragonite).
7. Wollastonite.
8. Scapolite.
9. Garnet.
10. Epidote.
11. Zoisite.
12. Serpentine.
13. Talc.
14. Kaolin.
15. Pectolite.
16. Laumontite.
17. Prehnite.
18. Thomsonite.
19. Natrolite.
20. Analcite.
21. Datolite.
22. Chabazite.
23. Stilbite.
24. Heulandite.
25. Harmotome.
26. Magnetite.
27. Hematite.
28. Limonite.
29. Siderite.
30. Pyrite.
31. Pyrrhotite.

(3) Physical and chemical properties of rocks.

Under this head are here grouped several small series of rocks designed to show (1) the structure of rocks—the manner in which their various constituent parts are associated or grouped together to form rock masses; (2) the specific gravity of rocks; (3) the chemical composition; (4) the color, and (5) the fracture and manner of breaking.

I.—The structure of rocks.

A. *Macroscopic structure.*—It is the object of this exhibit to show all the more typical forms of rock and structure. In other words, to illustrate by means of specimens the meanings of certain words and phrases in common use in geologic nomenclature, but whose exact significance or force is poorly comprehended by the public at large. In this collection the rocks are divided into four primary groups. That is, they represent four primary types of structure, each of which in its turn exhibits a more or less parallel series of secondary structures. These types of structure are (1) crystalline; (2) vitreous or glassy; (3) colloidal, and (4) clastic or fragmental. The first of these (1), of which granite and crystalline limestone are selected as types (Specimens Nos. 35966 and 26679), are composed wholly of crystals or crystalline granules without trace of cementing material or glassy matter. Rocks of the second group (2), of which obsidian is the type (Specimen 29631, from Mono Lake, California), are made up wholly or in great part of amorphous glass. This structure is confined to rocks of volcanic origin. Rocks of this class pass by insensible gradations through microlitic, felsitic, and micropegmatitic stages into holocrystalline forms. Rocks of the third class (3), the collodial, are completely amorphous, and have a jelly or glue-like structure. This structure is less common than the others, and is found only in rocks of chemical origin. It is illustrated by the siliceous sinter (Pealite, No. 28964) from the Yellowstone Park; Semi Opal from Louisiana (No. 38612); Flint nodule (No. 38012), from the chalk cliffs of England; and the green serpentine (No. 39038) from Montville, New Jersey.

Rocks of the fourth group (4), of which sandstone is selected as the type, are composed wholly of fragments of pre-existing rocks, the individual particles being held together by (1) cohesion, or (2) by a cement composed of silica, iron oxides, carbonate of lime or clayey matter. A coarse Triassic rock from Deerfield, Massachusetts (No. 26144), illustrates this type of structure.

The exhibit is arranged as follows:

1. Types of crystalline rocks:	
(I) Tourmaline granite, Minot, Maine.	35966
(II) Crystalline limestone, Danville, New Jersey.	26679
(1) Granular structure:	
Dolomite, Lee, Massachusetts.	27004
(2) Compact structure:	
(*a*) Lithographic limestone, St. Louis, Missouri.	26719
(*b*) Felsitc, Marblehead Neck, Massachusetts.	35955

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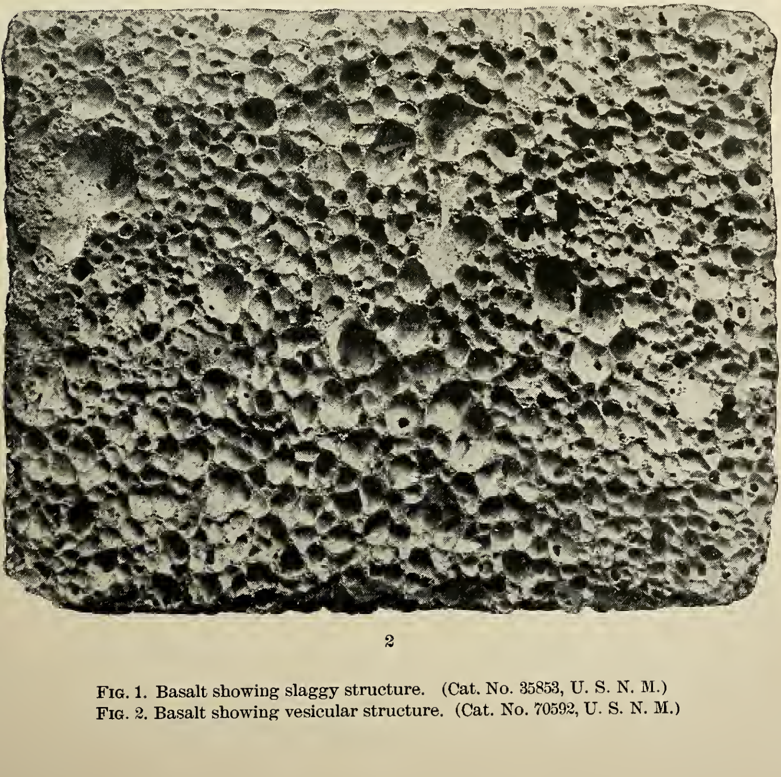

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FIG. 1. Basalt showing slaggy structure. (Cat. No. 35853, U. S. N. M.)
FIG. 2. Basalt showing vesicular structure. (Cat. No. 70592, U. S. N. M.)

1. Types of crystalline rocks—Continued.	
(3) Massive structure:	
Diabase, Goose Creek, Loudoun County, Virginia.	28116
(4) Stratified structure:	
(*a*) Limestone, East Conshohocken, Pennsylvania.	26983
(*b*) Sandstone, Summit County, Utah.	70595
(5) Foliated or schistose structure:	
Gneiss, Lawrence, Massachusetts.	26547
(6) Fluidal or fluxion structure:	
(*a*) Quartz porphyry, Milton, Massachusetts.	35946
(*b*) Rhyolite, High Rock Cañon, Nevada.	35441
(7) Porphyritic structure:	
(*a*) Porphyrite, Shasta County, California.	70594
(*b*) Quartz porphyry, Marblehead Neck, Massachusetts.	35960
(8) Vesicular structure:	
(*a*) Basalt, Ice Cave, Butte, Utah.	70592
(*b*) Andesite, Portugal.	37926
(9) Amygdaloidal structure:	
(*a*) Melaphyr, Brighton, Massachusetts.	35940
(*b*) Melaphyr, Oclnitz, Saxony.	36133
(10) Slaggy structure:	
Basaltic lava, Hawaiian Islands.	35853
(11) Concretionary structure:	
Kugeldiorite, Corsica.	36054
(12) Dendritic structure:	
Limestone, England.	29113
(13) Botryoidal structure:	
Hematite, Cleater Moor, Cumberland, England.	36085
(14) Fibrous structure:	
(*a*) Asbestus, Charlottsville, Virginia.	28109
(*b*) Gypsum, Nova Scotia.	37624
(15) Radiated structure:	
Wavellite, Garland County, Arkansas.	36104
(16) Columnar structure:	
Columnar calcite.	36787
(17) Brecciated structure:	
Felsite breccia, Marblehead Neck, Massachusetts.	35952
(18) Cavernous structure:	
Dolomite, Chicago, Illinois.	27508
2. Types of vitreous rock:	
I. Black Obsidian, Mono Lake, California.	29631
(1) Fluidal or fluxion structure:	
Obsidian, Glass Buttes, Oregon.	35921
(2) Vesicular structure:	
Obsidian Pumice, Mono Lake, California.	29630
(3) Porphyritic structure:	
Porphyritic Obsidian, Yellowstone National Park.	28888
(4) Perlitic structure:	
Perlite, Schemnitz, Hungary.	36134
(5) Spherulitic structure:	
Obsidian, Yellowstone National Park.	18969
(6) Capillary structure:	
Peles Hair, Volcano of Kilauea, Hawaiian Islands.	8902

3. Types of colloidal rock:	
(I) Siliceous sinter, (Pealite), Yellowstone National Park.	28964
(II) Opal, Rapides Parish, Louisiana.	38612
(III) Flint, England.	36012
(IV) Serpentine, Montville, New Jersey.	39038
(1) Tufaceous structure:	
Calc tufa, Yellowstone National Park.	72861
(2) Botryoidal structure:	
Chalcedony after coral, Florida.	39051
(3) Concretionary structure:	
(*a*) Oölitic limestone, Cache Valley, Utah,	35305
(*b*) Pisolitic limestone, Pyramid Lake, Nevada.	35306
(*c*) Siliceous concretions, Yellowstone National Park.	12888
(4) Cellular structure:	
Buhr stone, Sebastopol, Georgia.	36051
4. Types of fragmental rock:	
I. Coarse sandstone, Deerfield, Massachusetts.	26144
(1) Granular structure:	
Sandstone, Berkshire, Massachusetts.	72798
(2) Compact structure:	
Sandstone, Hingham, Massachusetts.	35939
(3) Laminated structure:	
(*a*) Slate, Poultney, Vermont.	27183
(*b*) Sandstone, Fort Collins, Colorado.	35998
(4) Banded structure:	
Shale baked by trap dike, Deckertown, New Jersey.	36767
(5) Concretionary structure:	
Coquina, St. Augustine, Florida.	28662
(7) Conglomerated structure:	
Conglomerate, Beltsville, Maryland.	25647
(9) Brecciated structure:	
(*a*) Calcareous Breccia, Vituland, Italy.	36109
(*b*) Siliceous Breccia, Yellowstone National Park.	37924

The following show the types of labels used in these series:

Vitreous Rocks.

VESICULAR STRUCTURE.

Obsidian Pumice.

MONO LAKE, California. 29,630.

Collected by G. K. GILBERT, 1883.

B. Microscopic structure.—Shown by twelve transparencies in the windows.

The circular transparencies in the windows are designed to show the microscopic structure and mineral composition of the more common types of rocks. In preparing the transparencies a small chip from each rock was ground so thin as to be transparent (from $\frac{1}{500}$ to $\frac{1}{600}$ of an inch), and then after being mounted between thin slips of glass was photographed through a microscope and between crossed nicol prisms. From the negatives thus prepared further enlargements were made by

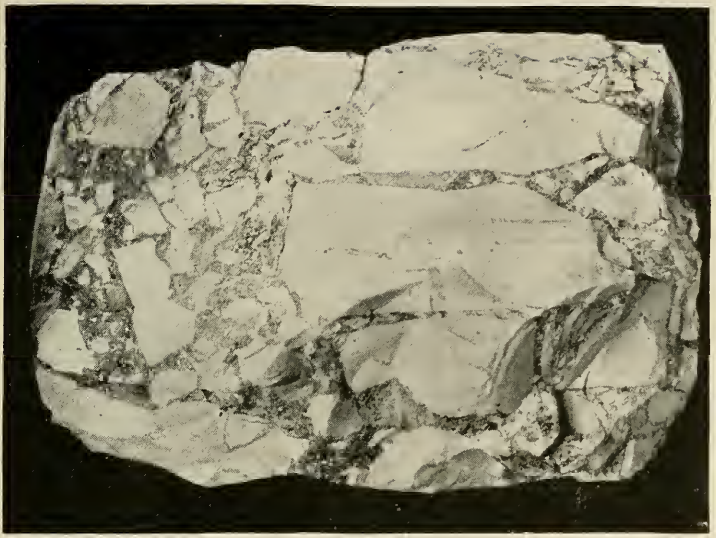

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FIG. 1. Chert breccia cemented by zinc blende. (Cat. No. 72794, U. S. N. M.)

FIG. 2. Felsite breccia formed of felsitic fragments embedded in a matrix of the same composition. (Cat. No. 35961, U. S. N. M.)

means of a solar camera, the final print being on glass and 1 foot in diameter; that is, that portion of the stone, which is in reality about one-fourth of an inch in diameter, is here made to appear 1 foot in diameter. These illustrations were then painted by hand, the artist taking his colors from an examination of the section itself under the microscope. The colors of the various minerals, it will be observed, are not always the true colors of the minerals themselves, but rather the color they assume when, after being cut at different angles with their optic and crystallographic axes, they are viewed by means of polarized light. Such colors are therefore somewhat misleading at first, but are rendered necessary for the purposes of identification and to bring out sharply the lines of separation between one mineral and another, and thus show the structure and composition of the rock. Owing to the thinness of the section (which is about $\frac{1}{500}$ of an inch) it would appear in ordinary light, *i. e.*, light not polarized, nearly colorless or with only dark flecks and faint tinges of color here and there.

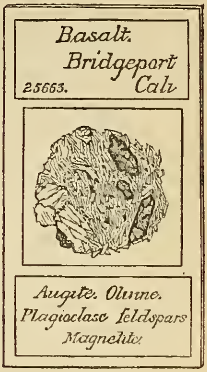

Fig. 89.
MOUNTED THIN SECTION OF ROCK AS PREPARED FOR THE MICROSCOPE.

This process of preparing thin transparent sections from rocks and studying them by means of a compound microscope is of comparatively modern origin, having come into general use only within the past dozen years. Although the practice of grinding down thin sections of fossils was followed to some extent by H. Witham as early as 1831, the importance of its application to minerals and rocks does not appear to have been fully realized until as late as 1858, when Dr. H. C. Sorby announced the results obtained by him in examining thin sections of simple minerals. Since this latter date the progress has been steady and rapid, and has given a fresh impetus to geological research.

The efficiency of the method is based upon the fact that every crystallized mineral has certain definite optical properties, *i. e.*, when cut in such way as to allow the light to pass through it, will act upon this light in a manner sufficiently characteristic to enable one working with an instrument combining the properties of a microscope and stauroscope to ascertain at least to what crystalline system it belongs, and in most cases by studying also the crystal outlines and lines of cleavage the mineral species as well. To enter upon a detailed description of the method by which this is done would be out of place here, since it involves the subject of polarization of light and other subjects which must be studied elsewhere. The reader is referred to any authoritative work on the subject of light, and to Mr. J. P. Idding's translation of Professor Rosenbusch's work on optical mineralogy.*

This method is of value, not merely as an aid in determining the min-

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* Microscopic Physiography of Rock-making minerals, Wiley & Son, New York.

eralogical composition of a rock, but also, and what is often of more importance, its structure and the various changes which have taken place in it since its first consolidation. Rocks are not the definite and unchangeable mineral compounds they were once considered, but are rather ever varying aggregates of minerals, which even in themselves undergo structural and chemical changes almost without number. It is a common matter to find rock masses which may have had originally the mineral composition and structure of diabase, but which now are mere aggregates of secondary products such as chlorite, epidote, iron oxides, and kaolin, with perhaps scarcely a trace of the unaltered original constituents, yet the rock mass retains its geological identity, and to the naked eye shows little, if any, sign of the changes that have gone on. These and other changes are in part chemical and in part structural or molecular. A very common mineral transformation in basic rocks is that from augite to hornblende. This takes place merely through a molecular readjustment of the particles whereby the augite with its gray or brown colors and rectangular cleavages passes by uralitic stages over into a green hornblende, a mineral of the same chemical composition, but of different chrystallographic form. This transformation in its incompleted state is shown in the accompanying figure, in which the central nearly colorless portion with rectangular cleavage represents the original augite, while the outer dotted portion with cleavage lines cutting at sharp and obtuse angles, is the hornblende. This change is due to slow and gradual pressure exerted through unknown periods of time upon the rock masses, and the final result is the production of a rock of entirely different type and structure from that which originally cooled from the molten magma. The change such as above described is well shown in the two specimens of gabbro and gabbro-diorite from near Mount Hope, in Baltimore, Nos. 36754 and 36755. These are both portions of the same rock mass, but one is a plagioclase hypersthene rock, while the other is a plagioclase hornblende rock; in other words, one is a gabbro while the other is now a diorite, although both are chemically identical and were once mineralogically and structurally identical as well. Another and very common change shown by this method is that from olivine, pyroxene, or other magnesian silicate minerals to serpentine. This change will be dwelt upon more fully in the collection showing the origin of serpentinous rocks.

Fig. 90.
AUGITE ALTERING INTO HORNBLENDE.
(After Hawes.)

This science of microscopic petrography, as it is technically called, has also been productive of equally important results in other lines. As an instance of this may be mentioned the discovery that the structural features of a rock are dependent not upon its chemical composition or geological age, but upon the conditions under which it cooled from a molten magma, portions of the same rock varying all the way from holocrystalline granular through porphyritic to glassy forms. To this fact allusion has already been made.

The thin sections from which these transparencies were prepared are shown in the case. The actual portions of the rock shown in each transparency is that surrounded by the dark ring in the section.

The transparencies are as follows:

(1) Crystalline Limestone, or marble, from West Rutland, Vermont. Transparency No. 39074.

The transparency shows the stone to be made up wholly of calcite crystals. Observe that, owing to their crowded condition, none of the crystals have perfect crystallographic outlines, but have mutually interfered with one another's growth, giving rise to rounded and angular granules only. The striations, cutting at various angles across the granules, are cleavage lines and twin lammellæ. (See also Fig. 93, p. 545.)

(2) Granite, Sullivan, Maine. Transparency No. 39075. Composition, quartz, feldspars, and mica.

The clear colorless and the brilliant blue portions are quartz; the clouded portions sometimes bounded by longitudinal parallel striations are the feldspars, while the faintly yellowish almost opaque forms in small shreds near the center are black mica.

Observe that in this case as in that of the limestone the rock is fully crystalline, but that none of the minerals possess perfect crystalline outlines, owing to a mutual interference during the process of their formation. Such a structure is called crystalline granular, or more technically hypidiomorphic. It is a structure characteristic of plutonic or deep-seated rocks. (See Fig. 1, Pl. CXX.)

(3) Diabase, Weehawken, New Jersey. Transparency No. 39076.

This rock is composed mainly of the mineral augite and a triclinic variety of feldspar. The clear, colorless elongated forms often showing a parallel banding are the feldspars, and the large irregular forms of a bronze yellow and green color are augite.

Observe here that while the rock, as in the case of the granite, is wholly crystalline, the various minerals have interfered less in process of growth, giving in part very perfect crystalline forms. Such a structure is technically called panidiomorphic. (See also Fig. 96, p. 562.)

(4) Serpentine, Chester, Pennsylvania. Transparency No. 39077.

Serpentine is not known in crystals, but occurs as an amorphous product of alteration after other minerals. The section shows the characteristic reticulated structure. The interspaces in this case were filled with calcite and frequent grains of chrome iron. (See also Fig. 6, Pl. CXX.)

(5) Quartz porphyry, Fairfield, Adams County, Pennsylvania. Transparency No. 39078. Section No. 26377.

This rock has essentially the same composition as granite, but is of a markedly different structure owing to the different conditions under which it cooled from a molten mass. The large crystals just below the center and to the left of the top are of quartz, the one on the extreme right feldspar, while the main body of the rock is made up of an intimate mixture of these two minerals in the form known as felsitic. This porphyritic structure is characteristic of a large class of what are known as effusive rocks, and represents two distinct stages of crystallization. The large porphyritic crystals were formed during or prior to the period of eruption, the intratellurial period, while the very fine grained groundmass is due to a more rapid crystallization after the flow had ceased. (See also Fig. 3, Pl. CXX.)

(6) Rhyolite, High Rock Cañon, Nevada. Transparency No. 39079. Section No. 35441.

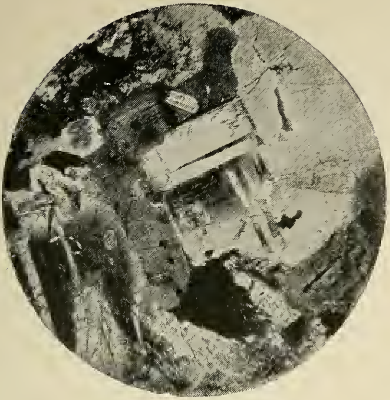
This rock, like the last, shows porphyritic crystals of quartz in a felsitic groundmass, the quartz being brilliant blue in the transparency. The felsitic groundmass, it will be observed, has a spherulitic structure and also a flow of fluxion structure, giving rise to the nearly parallel banding extending from top to bottom and which is due to the onward flowing of the molten lava while cooling and crystallizing.

(7) Hornblende Andesite, near Mono Lake, California. Transparency No. 39080. Section No. 35491.

This rock is composed essentially of the minerals hornblende and plagioclase, the former showing in opaque red and yellow crystals with a dark border, while the plagioclase appears colorless or faintly clouded in large irregular and prismatic forms, often showing a banded or zonal structure somewhat resembling the lines of growth upon the trunk of a tree. The extremely fine grained brownish portion is composed of minute imperfectly formed crystals of both hornblende and feldspar in the form called microlites; hence such a groundmass is called microlitic.

(8) Basalt, Bridgeport, California. Transparency No. 39081. Section No. 25663.

This rock has essentially the same mineral composition as the diabase already decribed, with the addition of olivine. Geologically it is different in having been a surface lava flow and of more recent origin. Observe that the rock is porphyritic and that the groundmass is composed of innumerable small lath-shaped crystals of plagioclase with a small quantity of glassy matter in the interstices. This, as in the quartz porphyries and liparites, denotes two distinct phases of crystallization. Structures of this kind, produced by porphyritic crystals imbedded in a groundmass in part crystalline and in part glassy, are technically known as hypocrystalline porphyritic.



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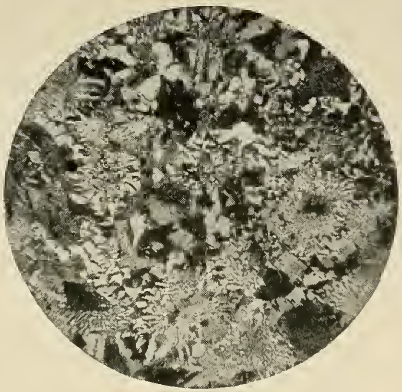

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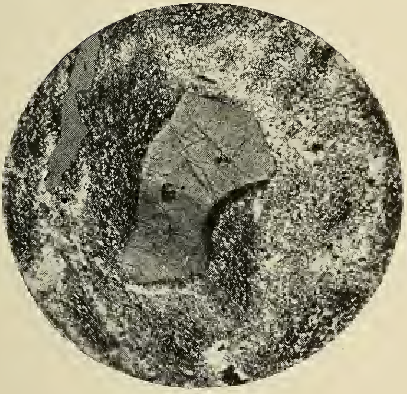

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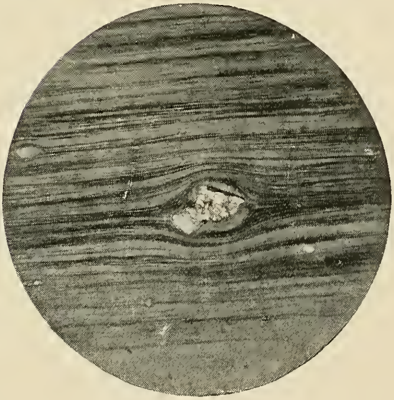

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FIG. 1. Microstructure of granite.
FIG. 2. Microstructure of micropegmatite.
FIG. 3. Microstructure of quartz porphyry.
FIG. 4. Microstructure of porphyritic obsidian.
FIG. 5. Microstructure of trachyte.
FIG. 6. Microstructure of serpentine.

The large cluster of blue, scarlet, and yellowish crystals at the left is augite, the scattering green, crimson, and brownish ones are olivine, while the abundant smaller lath-shaped forms are of feldspar (plagioclase.) Observe that the olivines and augites, being among the first minerals to solidify, have formed, as it were, little islands, around which flowed the still molten magma bearing the lath-shaped feldspars like logs in a millstream.

(9) Gneiss, West Andover, Massachusetts. Transparency No. 39082. Section No. 26595.

This rock has the same composition as granite, but differs in that its constituents are arranged in more or less parallel bands; that is, it has a foliated or schistose structure. This structure was formerly supposed to be due to the fact that such rocks were metamorphic; that they originated from the crystallization of sediments and were not forced up in a molten state, as was the case with granite. While it is very probable that certain of the gneisses may have been formed in this manner, there is little doubt that the foliation in this particular rock is due to dynamic agencies, rather than to original bedding. (See also Plate CXXIV and Fig. 94, p. 547.)

(10) Mica schist, Washington, District of Columbia. Transparency No. 39083.

This rock differs from the last only in the absence of feldspar, being composed wholly of quartz and mica. Like the gneiss it is regarded as a metamorphic rock and possesses a banded structure, which does not show in the transparency, owing to the extremely small part of the rock included.

(11) Sandstone, Portland, Connecticut. Transparency No. 39084. Section No. 26077.

The mineral composition of this stone is quite complex, but the ingredients are essentially those of granite or the gneisses. The colorless portions are quartz or feldspars, the bright iridescent shreds are white mica, the brownish and opaque, black mica, while the opaque material in the interstices is the ferruginous cement.

Observe that instead of a mass of interlocking crystals, as in the cases already described, we have here a confused aggregate of crystalline fragments cemented to form a rock of secondary origin. Such are called classic or fragmental rocks. (See also Fig. 92, p. 536.)

(12) Quartzite or quartz schist. Berks County, Pennsylvania. Transparency No. 39085. Section No. 26478.

Quartzites result from the induration of siliceous sandstones. In some cases the granules are elongated and arranged in nearly parallel layers, giving rise to a schistose structure, as here shown. Composition nearly pure quartz.

II.—SPECIFIC GRAVITY.

The term specific gravity is used to designate the weight of any substance when compared with an equal volume of distilled water at a temperature of 4° C. This property is therefore dependent upon the specific gravity of its various constituents and their relative proportions. The exact or true specific gravity of a rock may be obscured by its structure. Thus an obsidian pumice will float upon water, buoyed up by the air contained in its innumerable vesicles, while a compact obsidian of precisely the same chemical composition will sink almost instantly. This property of any subject is spoken of as its apparent specific gravity in distinction from the actual comparative weight bulk for bulk of its constituents parts, which could in the case of a pumice be obtained only by finely pulverizing so as to admit the water into all its pores. This difference between the apparent and true specific gravities is illustrated in the three specimens of obsidian pumice, pulverized obsidian pumice, and compact obsidian Nos. 39348 and 39348*a*. The first, it will be observed, floats readily owing to the buoyancy of the air included in its vesicles; the second glass contains the same rock pulverized so that all the air-chambers are broken open and the air escapes. The rock fragments consequently sink to the bottom, as does the third of the series (No. 29631), a compact, nonvesicular mass of the same obsidian. Inasmuch as the structural peculiarities of any igneous rock—as will be noted later—are dependent upon the condition under which it cooled, it is instructive to notice that the crystalline aggregates have a higher specific gravity, *i. e.* a greater weight, bulk for bulk, than does a glassy, noncrystalline rock of the same chemical composition. The property is therefore dependent upon chemical (and consequently mineral) composition and structure, and as a very general rule it may be said that among the siliceous rocks those which contain the largest amount of silica are the lightest, while those with a comparatively small amount, but are correspondingly rich in iron, lime, and magnesian constituents, are proportionately heavy.

III.—THE CHEMICAL COMPOSITION OF ROCKS.

This varies naturally with their mineral composition. It is customary to speak of rocks as calcareous, siliceous, ferruginous, or argillaceous, accordingly as lime, silica, iron oxides or clayey matter are prominent constituents. Among eruptive rocks it is customary to speak of those showing on analysis upwards of 60 per cent. silica as acidic and those showing less than 50 per cent., but rich in iron, lime, and magnesian constituents, as basic. The extremes as will be noted are represented by the rocks of the granite and peridotite groups.

The series illustrating the above-mentioned properties are arranged as below. With the eruptive rocks only the silica percentages are here given. The results of the complete chemical analysis of each variety are given further on, in the pages devoted to their description.

STRATIFIED ROCKS.

Kind.	Specific gravity.	Composition.
Calcareous:		
Compact limestone	2. 6 to 2. 8	Carbonate of lime.
Crystalline limestone		
Compact dolomite	2. 8 to 2. 95	Carbonate of lime and magnesia.
Crystalline dolomite		
Siliceous:		
Gneiss	2. 6 to 2. 7	Same as granite.
Siliceous sandstone	2. 6	Mainly silica.
Schist	2. 6 to 2. 8	60 to 80 per cent. silica.
Argillaceous:		
Clay slate (argillite)	2. 5	Mainly silicate of alumina.

ERUPTIVE ROCKS.

Acidic group:	*Specific Gravity.*	*Per cent. silica.*
Granite	2. 58 to 2. 73	77. 65 to 62. 90
Liparite	2. 53 to 2. 70	76. 06 to 67. 61
Obsidian	2. 26 to 2. 41	82. 80 to 71. 19
Obsidian pumice	Floats on water.	82. 80 to 71. 19
Intermediate group:		
Syenite	2. 73 to 2. 86	72. 20 to 54. 65
Trachyte	2. 70 to 2. 80	64. 00 to 60. 00
Hyalotrachyte	2. 4 to 2. 5	64. 00 to 60. 00
Andesite	2. 54 to 2. 79	66. 75 to 54. 73
Basic group:		
Diabase	2. 66 to 2. 88	50. 00 to 48. 00
Basalt	2. 90 to 3. 10	50. 59 to 40. 74
Peridotite	3. 22 to 3. 29	42. 65 to 33. 73
Peridotite (iron rich)	3. 86	23. 00
Peridotite (meteorite)	3. 51	37. 70

IV.—THE COLOR OF ROCKS.

The color of a rock is dependent upon a variety of circumstances, but which may here all be generalized under the heads of mineral and chemical composition and physical condition. Iron and carbon, in some of their forms, are the common coloring substances and the only ones that need be considered here. The yellow, brown, and red colors, common to fragmental rocks, are due almost wholly to free oxides of iron. The gray, green, dull brown, and even black colors of crystalline rocks are due to the presence of free iron oxides or to the prevalence of silicate minerals rich in iron, as augite, hornblende, or black mica. Rarely copper and other metallic oxides than those of iron are present in sufficient abundance to impart their characteristic hues. As a rule, a white or light-gray color denotes an absence of an appreciable amount of iron in any of its forms. The bluish and black colors of many rocks, particularly the limestones and slates, is due to the prevalence of carbonaceous matter.

In still other cases, and particularly the feldspar-bearing rocks, the color may be due in part to the physical condition of the feldspar. Thus, in many rocks, like the norite, from Keeseville, New York (specimen No. 38744), the dark color is due in part to the fact that the feldspar is clear and glassy, allowing the light rays to penetrate it and become absorbed. When such rocks are exposed for a long period to the weather the feldspars frequently undergo a physical change, become soft and porous and no longer absorb the light, but reflect it, giving the stone a white color. These white feldspars, as has been very neatly expressed by the late Dr. Hawes, bear the same relation to the glassy forms as does the foam of the sea to the water itself, the difference in color being in both cases due to the changed physical condition.

The color of rocks, as may be imagined, is not constant, but liable to change under varying conditions, particularly those of exposure. Rocks black with carbonaceous matter will fade to almost whiteness on prolonged exposure, owing to the bleaching out of the coloring materials. Rocks rich in magnetite or free iron oxides, protoxide carbonates, or sulphides, or in highly ferruginous silicate minerals, are likewise liable to a change of color, becoming yellowish, red, or brown, through oxidation of the ferruginous constituents.

In the series shown an endeavor has been made to arrange the rocks in five groups, showing (1) rocks colored by carbonaceous matter; (2) rocks colored by free oxides of iron; (3) rocks colored by the prevalence of iron rich silicates; (4) rocks, the color of which is due in part at least to structural features, and the transparency of the feldspathic constituent; and (5) rocks, the color of which is also in part due to the physical condition of the various constituents, but more particularly to a lack of carbonaceous matter, iron, or other metallic oxides. To this series is appended another, showing the changes in color due (1) to the bleaching of the carbonaceous matter; (2) to the leaching out of the ferruginous oxides by organic acids; (3) to the oxidation of iron protoxide carbonates or sulphides; (4) to a like change in the iron rich silicates; and (5) to a change in the physical condition of the constituent minerals, mainly the feldspars.

I. Colors due to carbonaceous matter:	
(1) Black. Black marble, Glens Falls, New York.	26163
(2) Dark gray. Limestone, Schoharie County, New York.	25909
(3) Blue. Limestone, Murphy, North Carolina.	27655
(4) Dark gray. Carbonaceous shale, Isere, France.	38176
(5) Dark gray. Slate, Savoy.	38194
II. Colors due to free iron oxides:	
(1) Dull brown. Sandstone, Washington County, Kansas.	56963
(2) Reddish brown. Sandstone, Rusk, Texas.	35574
(3) Red. Sandstone, Seneca Creek, Maryland.	69283
(4) Red. Quartzite, Rock County, Minnesota.	37407
(5) Light red. Volcanic Tuff, Nevada.	35381
(6) Yellow. Limestone, Wilson, Kansas.	26482

III. Colors due to iron-rich silicate minerals:
- (1) Black. Basalt, coast of Ireland. 37610
- (2) Dark gray. Diabase, York, Pennsylvania. 37020
- (3) Red. Granite (color due to red feldspar), Otter Creek, Mount Desert, Maine. 35923
- (4) Pink, green spotted. Granite (color due to pink feldspar and green epidote), Dedham, Massachusetts. 26386
- (5) Black. Amphibolite (color due to dark hornblende), Baltimore County, Maryland. 26857
- (6) Dark green. Serpentine, Easton, Pennsylvania. 70109
- (7) Yellow. Serpentine, Montville, New Jersey. 69198

IV. Color due in part to transparency of mineral constituents, principally feldspars:
- Dark greenish black. Norite, Keeseville, New York. 38744

V. Colors due mainly to the physical condition of the various constituents and a lack of metallic oxides or other coloring material.
- (1) White. Chalk. England.
- (2) White. Crystalline limestone, Loudoun County, Virginia. 38568

VI. Change in colors due to causes above enumerated.
- (1) From black to dull red-brown caused by oxidation of magnetite and iron rich silicates. Diabase. Lewiston, Maine. Two samples. 70661
- (2) From pure white to dull red, caused by oxidation of ferrous carbonates. White limestone. Newbury, Massachusetts. 73037
- (3) From dark gray to buff, caused by oxidation of pyrite and iron protoxide.
- (4) From pink to dirty white, caused by a bleaching out and change in the physical condition of the feldspathic constituent (commencement of kaolinization). Granite. Washington County, Maine. 25873
- (5) From reddish brown to gray, caused by a removal of coloring matter (iron oxide) by decomposing organic matter. Sandstone. Marquette, Michigan. 70659

Luster as a property of rocks does not, owing to their complex character, possess the same value, as a characteristic, as among minerals. Nevertheless, as there are certain of the more compact and homogeneous varieties which possess characteristic lusters, these may perhaps be well shown here. The exhibit is arranged as follows:

- (1) Vitreous luster..........Quartzite; Obsidian.
- (2) Greasy luster...........Serpentine.
- (3) Pearly luster...........Steatite.
- (4) Metallic luster..........Hematite.
- (5) Iridescent luster........Coal.
- (6) Dull, no luster..........Chalk.

The fracture or manner of breaking of any rock is dependent more upon structure than chemical or mineralogical composition. Many fine, even-grained crystalline or fragmental rocks break with a smooth, even surface and are spoken of as having a straight or even fracture; others, and particularly the very compact fine-grained varieties, break with shell-like concave and convex surfaces, and are said to have a conchoidal fracture. Still others have splintery, hackly, shaly, friable, or pulverulent fractures. These characteristics, being of value in determining the working properties of the stones, are dwelt upon more fully in the hand-book relating to the collection of building and ornamental stones.

(4) THE KINDS OF ROCKS.

In the present transitional state of our knowledge regarding the chemical and mineralogical composition of rocks, their structural features, and methods of origin, no scheme of classification can be advanced that will prove satisfactory in all its details. The older systems which were made to answer before the introduction of the microscope into geological science are now found to be founded upon what were in part false, and what have proven to be wholly inadequate data. This is especially true in regard to eruptive rocks. The time that has elapsed since this introduction has been too short for the evolution of a perfectly satisfactory system; many have been proposed, but all have been found lacking in some essential particular. To enter upon a discussion of the merits and demerits of the various schemes would obviously be out of place here, and the student is referred to the published writings of Naumann, Senft, Von Cotta, Richtofen, Vogelsang, Zirkel, Rosenbusch, and Geikie, as well as those of the American geologists Dana* and Wadsworth.† In the scheme here presented the Curator has aimed to simplify matters as much as possible, and has not hesitated to adopt or reject any such portions of systems proposed by others as have seemed desirable.

All the rocks forming any essential part of the earth's crust are here grouped under four main heads, the distinctions being based upon their origin and structure. Each of the main divisions is again divided into groups or families, the distinctions being based mainly upon mineral and chemical composition, structure, and mode of occurrence. We thus have:

I. *Aqueous rocks.*—Rocks formed mainly through the agency of water as (A) chemical precipitates or as (B) sedimentary beds. Having one or many essential constituents; in structure laminated or bedded; crystalline, colloidal or fragmental, never glassy.

II. *Æolian rocks.*—Rocks formed from wind-drifted materials. In structure irregularly bedded; fragmental.

III. *Metamorphic rocks.*—Rocks changed from their original condition through dynamic or chemical agencies, and which may have been in part of aqueous and in part of igneous origin. Having one or many essential constituents. In structure bedded, schistose, or foliated.

IV. *Igneous rocks. Eruptive.*—Rocks which have been brought up from below in a molten condition, and which owe their present structural peculiarities to variations in conditions of solidification and com-

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* On some points in Lithology, Am. Jour. Sci., vol. XVI, 1878, pp. 335 and 431.

† On the classification of rocks. Bull. Mus. Comp. Zool. Howard College, No. 13, vol. V.; also Lithological Studies.

position. Having as a rule two or more essential constituents. In structure massive, crystalline, felsitic or glassy, or in certain altered forms, colloidal.

The following shows the types of labels used in this collection:

HORNBLENDE-BIOTITE GRANITE.

Near Salt Lake City, Utah. 39,095.
Gift of G. K. Gilbert, 1887.

PERIDOTITE: Dunite.

Near Webster, Jackson County, North Carolina. 39,131.
Gift of W. A. H. Schreiber, 1887.

QUARTZITE [Novaculite].

Leigh River, Victoria, Australia. 28,321.
Australian Centennial Commissioners, 1876.

The inclosing a name in brackets, as [Novaculite] in the last form, indicates that it has gone out of use, or is a local or popular name of little value and not generally accepted.

I.—AQUEOUS ROCKS.

A.—ROCKS FORMED AS CHEMICAL PRECIPITATES.

This comparatively small though by no means unimportant group of rocks comprises those substances which, having once been in a condition of vapor or aqueous solution, have been deposited as rock masses either by cooling, evaporation, by a diminution of pressure, or by direct chemical precipitation. It also includes the simpler forms of those produced by chemical changes in preëxisting rocks. Water, when pure or charged with more or less acid or alkaline material, and particularly when acting under great pressure, is an almost universal solvent. Thus heated alkaline waters permeating the rocks of the earth's crust at great depths below the surface are enabled to dissolve from them various mineral matters with which they come in contact. On coming to the surface or flowing into crevices the pressure is diminished or evaporation takes place and the water, no longer able to carry its load, deposits it wholly or in part as vein material or a surface coating. In other cases alkaline or acid water bearing mineral matters may in course of their percolations be brought in contact with neutralizing solutions and these dissolved materials be thus deposited by direct precipitation. In still other instances a substance wholly or in part volatile may, when buried at considerable depths below the surface, be subjected to such temperature as shall cause it to assume a gaseous state and pass upwards until a cooler stratum is reached where it is again deposited. In these various ways were formed the rocks here shown.

This group can not, however, be separated by any sharp lines from that which is to follow, inasmuch as many rocks are not the product of a single agency acting alone, but are rather the result of two or more combined processes. This is especially the case with the limestones. It is safe to assume that few of these are due wholly to accumulations of calcareous organic remains, but are in part, at least, chemical precipitates, as is well illustrated by the oolitic varieties.

According to their chemical nature the group is divided into (1) Oxides, (2) Carbonates, (3) Silicates, (4) Sulphur, Sulphides, and Sulphates, (5) Phosphates, (6) Chlorides, and (7) the Hydrocarbon Compounds.

(1) OXIDES.—Here are shown those rocks consisting essentially of oxygen combined with a base, though usually other constituents are present as impurities.

(*a*) Red hematite. Specular iron ore. Iron sesquioxide $Fe_2 O_3$=iron 70 per cent., oxygen 30 per cent. This is a fibrous, scaly, or massive rock of a black, brownish, or blood-red color, and which consists essentially of iron oxide, but often carries more or less clayey and siliceous matter. It occurs in extensive beds among the older formations of the earth's crust and forms a valuable ore of iron. It is represented in the series by but a few characteristic specimens. The visitor is referred to the ore collections for a more complete series of these and of the limonites which follow.

(*b*) Limonite. Brown hematite. Iron sesquioxide plus water. ($Fe_2 O_3$ + aq.): An earthy or compact dark brown, black, or ocherous-yellow rock, containing, when pure, about two-thirds its weight of pure iron. It occurs in beds, veins, and concretionary forms, associated with rocks of all ages, and forms a valuabl ore of iron. (See Fig. 1, Pl. CXXII.) On the bottoms of lakes, bogs, and marshes it oftens forms in extensive deposits, where it is known as bog iron ore. The formation of these deposits, as described by Dr. Hunt,* is as follows: Iron is widely diffused in rocks of all ages, chiefly in the form of (1) the protoxide which is readily soluble in waters impregnated with carbonic or other feeble acids, or (2) the peroxide which is insoluble in the same liquids. Water percolating through the soils becomes impregnated with these acids from the decomposing organic matter, and then dissolves the iron protoxide with which it comes in contact. On coming to the surface and being exposed to the air as in a stagnant lake or marsh, this dissolved oxide absorbs more oxygen, becoming converted into the insoluble sesquioxide and floats on the surface as an oil-like iridescent scum. Finally it sinks to the bottom, where it gradually becomes aggregated as a massive iron ore. This same ore may also form through the oxidation of pyrite or beds of ferrous carbonate. At the Katahdin Iron Works in Piscataquis County, Maine, the pyrite as it oxides is brought to the surface by water and deposited as a coating over the leaves and twigs

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* Chemical and Geological Essays.

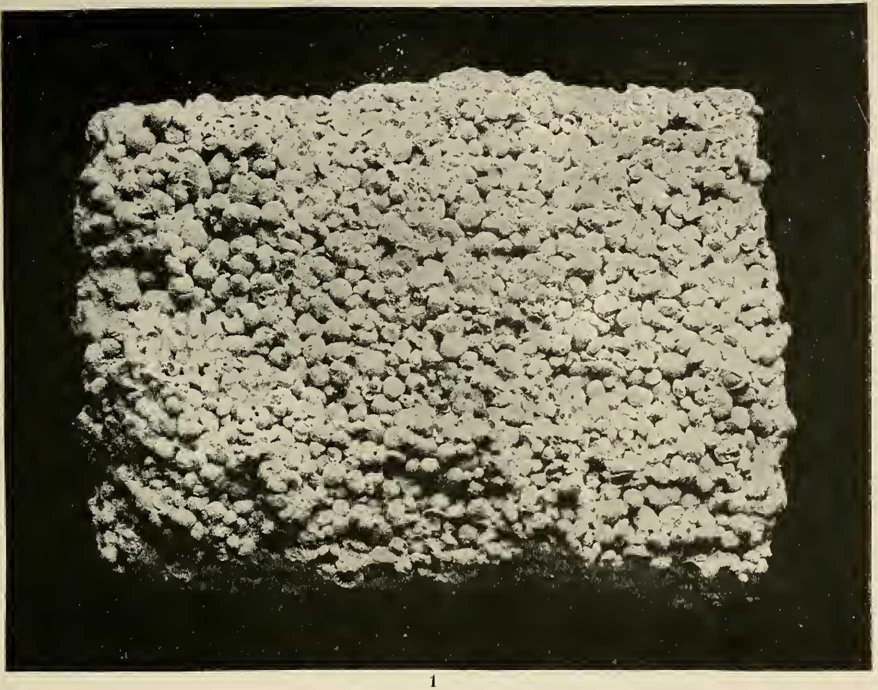

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FIG. 1. Pisolitic limestone. (Cat. No. 35306, U. S. N. M.)
FIG. 2. Oolitic limestone. (Cat. No. 18708, U. S. N. M.)

scattered about, forming thus beautifully perfect casts or fossils, as shown in specimen No. 35969.

(*c*) Pyrolusite, psilomelane, and wad: These are names given to the anhydrous and more or less hydrated forms of maganese oxides, and which, though wide in their distribution, are found in such abundance as to constitute rock masses in comparative rarity. As with the iron oxides, but a few forms are exhibited here, and the visitor is referred to the economic section for a more complete display.

(*d*) Beauxite (so called from Beaux, near Arles, France), is the name given to a somewhat indefinite mixture of alumina and iron oxides, and occurring in the form of compact concretionary grains of a dull red, brown or nearly white color. The origin of the rock is at present somewhat obscure, but it is considered by M. Ange * as a deposit from hot springs and geysers. The following analyses given by this authority show the variations in composition:

	Per cent.	Per cent.
Alumina	69.30	76.90
Iron oxides	22.90	0.10
Titanium oxide	3.40	4.00
Silica	0.30	2.20
Water	14.10	15.80

The rock is at present represented by specimens from Thoronet, France (10739), and Floyd County, Georgia (66576 and 66578).

(*c*) Silica: Silica, as has already been noted under the head of rock-forming minerals, is one of the most abundant constituents of the earth's crust. In its various forms, which are sufficiently extensive to constitute rock masses, it is always of chemical origin; that is, results by deposition from solution, by precipitation, or evaporation, as noted above. Varietal names are given to the deposits, dependent upon their structure, method of formation, color, and degree of purity. Siliceous Sinter, or "Geyserite," is the name given to the nearly white, often soft and friable hydrated varieties formed on the evaporation of the siliceous waters of hot springs and geysers, or through the eliminating action of algous vegetation, as described by W. H. Weed. The specimens from Yellowstone National Park (Nos. 12876, 12888, 17848, 18965, 28945, 28946, 28948, 28981, 28982, 35521, 36782, 72844, 72845, and 72882). Iceland (2548), and New Zealand (70338, 70340, and 70341), are characteristic.

Opal and semi-opal are also hydrous forms of silica occurring in veins and pockets in a variety of rocks. These varieties are shown in specimens from the Yellowstone National Park (36150); Buffalo Peaks, Colorado (69185); Rapides Parish, Louisiana (38612); Mexico (37985), and Hungary (6963). The variety known as wood opal, formed by the silicification of wood, is shown in No. 37042 from Wyoming, and in the two pieces from the Pliocene beds on the Madison River, Gallatin County, Montana (38567).

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* Bulletin Geological Society of France, 3d, XVI, 1888, No. 5, p. 345.

Jasper is a dull or bright red or yellow variety of silica containing alumina, and owing its color to iron oxides. Characteristic forms are shown in specimens from Colorado and Montana (10374, 10397, and 38572).

Chalcedony is a translucent, massive variety occurring mainly in cavities in older rocks where it has been deposited by infiltration. The specimens from Montana (38605) and Cuba (36146) are common forms. No. 70064 from Webster, Jackson County, North Carolina, is a cellular variety formed in seams in dunite rocks during the decomposition of the olivine; No. 36051 and 36140 are somewhat similar varieties from Sebastopol, Georgia, and Jonarre, France, used for buhrstones in grinding grain. Specimens 35599 and 36010 from Wyoming and Colorado are silicified woods partaking of the character of chalcedony rather than opal, as in the cases above mentioned.

Flint is a variety of chalcedony formed by segregation in chalky limestones, and composed in part of the broken and partially dissolved spicules of sponges and the remains of infusoria. Chert is an impure flint containing frequently fossil nummulitic remains (26581), and with sometimes an oölitic structure; oölitic varieties, such as that from Centre County, Pennsylvania (70606) are not common. The variety flint is shown by a characteristic sample from the English chalk beds (36012). The cherts are illustrated by specimens from Kansas (26581); Missouri (17598); Texas (70429); Nevada (21762), and Pennsylvania (70127).

The name novaculite is frequently given to very fine grained and compact quartz rocks, such as are suitable for hones. As commonly used the name is made to include rocks of widely different origin, some of which are evidently chemical precipitates, while others are indurated clastic or schistose rocks. Here are placed the well known "novaculites" of Arkansas, which are considered by authorities to be altered cherts (specimens 4307, 27833, and 39109).

Quartz is a massive form of crystalline silica occurring in veins, disseminated granules, and pockets in rocks of all kinds and all ages. It is often colored pink or reddish by iron oxides. Many other varieties of silica occur, but are not sufficiently abundant to constitute rock masses, and are to be found in the collection of the mineral department. It is represented here by specimens from Auburn, Maine (37613); Bedford, New York (36058); Lake Superior, Michigan (4260); Sawatch Mountains, Colorado (35896); Godhaven, Greenland (34947); Brazil (4092), and Freiberg, Saxony (3836).

Lydian stone is an exceedingly hard impure quartz rock of a black color and splintery fracture. It was formerly much used in testing the purity of precious metals. (Specimen 3820 from Frankenberg, Saxony.)

(2) CARBONATES.—Water carrying small amounts of carbonic acid readily dissolves the calcium carbonate of rocks with which it comes in contact, taking it up in the form of bicarbonate; on evaporation this

is again deposited as carbonate. In this way are formed numerous and at times extensive deposits, to which are given varietal names dependent upon their structure and the special conditions under which they originated. Calc sinter or tufa is a loose friable deposit made by springs and streams either by evaporation or through intervention of algous vegetation.* Such are often beautifully arborescent and of a snow-white color, as seen in specimens 12882, 72871, and 72876, from the Mammoth Hot Springs of the Yellowstone National Park. Somewhat similar deposits are shown from springs in Virginia (35759); California (29637); Mexico (37787), and New Zealand (70335). Others, like those from Niagara Falls, New York, and Soda Springs, Idaho (36107, 39136), were formed by the deposition of the lime on leaves and twigs, forming beautifully perfect casts of these objects.

Tufa deposits of peculiar imitative shapes have been described by Mr. I. C. Russell of the U. S. Geological Survey, as formed by the evaporation of the waters of Pyramid Lake, Nevada (35260). See, also, collection from Lake Lahanton, Nevada, in floor upright case). Oolitic and pisolitic limestones are so called on account of their rounded fish-egg-like structure, the word oolite being from the Greek word ωον, an egg. (See Pl. CXXI.) These are in part chemical and in part mechanical deposits. The water in the lakes and seas in which they were formed became so saturated that the lime was deposited in concentric coatings about the grains of calcareous sand on the bottom, and finally the little granules thus formed became cemented into firm rock by the further deposition of lime in the interstices. This structure will be best understood by reference to Fig. 91. Samples are shown such as are now forming in Pyramid Lake, Nevada (No. 35378); Cache Valley, Utah (35305 and and 35306); Great Salt Lake, Utah (35379), and Key West, Florida (18708), and from other geological formations of America and Europe (Nos. 36115 and 36960). Only those which are largely chemical are here shown; others are to be found in the group of stratified rocks.

Fig. 91.

MICRO-STRUCTURE OF OOLITIC LIMESTONE.

(Princeton, Kentucky.)

Travertine is a compact and usually crystalline deposit formed, like the tufas, by waters of springs and streams. The travertines are often

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* See Mr. Weed's paper on the Formation of Travertine and Siliceous Sinter, Annual Report United States Geological Survey for 1887–'88.

beautifully veined and colored by metallic oxides and form some of the finest marbles (Specimen 39071 from Mexico; 38445 from Suisin City, California; 37269, Idaho; and 38811, Tivoli, Rome, Italy. See, also, collection of building and ornamental stones).

Stalactite and stalagmite are the names given to the deposits formed from the roofs and on the floors of caves; shown by specimens from the rock of Gibralter (36769 and 38444) and from the Luray Caves in Virginia (35549). See also floor upright case on north side of hall.

Magnesite, a carbonate of magnesia, occurs frequently as a secondary mineral in the form of veins in serpentinous rocks (specimens 70158 from Lancaster County, Penn sylvania; 70678, Wells Island, New York; and 28464, Victoria, Australia).

Rhodochrosite, a carbonate of manganese, sometimes occurs in rock masses, but is found most commonly in the form of veins associated with ores of silver, lead, or copper (specimen 26745 from Walkerville, Montana). Another carbonate, less common than that of lime, but which sometimes occurs in such quantities as to constitute true rock masses, is siderite, or carbonate of iron. A common form of this is dull brownish or nearly black in color, very compact and impure, containing varying amounts of calcareous, clayey and organic matter. In this condition it is found in stratified beds and in the shape of rounded and oval nodules, or concretions, which are called "clay-iron-stone" nodules, "septaria," and "sphærosiderite" (specimen 12840 from Wakonda, Kansas; see, also, Fig. 2, Pl. CXXII). These septarian nodules are often beautifully veined with calcite (see concretion collection). Other forms of siderite, like those from Connecticut (36105) and Saxony (3810 and 39073), are massive, coarsely crystalline, and of a nearly white or yellowish color, becoming brownish on exposure. Pure siderite yields about 48 per cent. metallic iron, and is a valuable ore. As with the other ores of iron, but a few characteristic specimens are here exhibited, and the visitor is referred, as before, to the ore series for a more complete display.

(3) SILICATES.—Silica (oxide of silicon) combined with magnesia and water gives rise to an interesting group of serpentinous and talcose substances, which are often sufficiently abundant to constitute rock masses. Pure serpentine consists of about equal parts of silica and magnesia, with from 12 to 13 per cent. of water. It is a compact, amorphous or colloidal rock, soft enough to be cut with a knife, of a slight greasy feeling and luster, and of a color varying from dull greenish and almost black, through all shades of yellow, brownish, and red. It also occurs in fibrous and silky forms, filling narrow veins in the massive rocks, and is known as amianthus, or chrysolite. These fibers, when sufficiently long, are used for the manufacture of fireproof material, and the mineral is commercially confounded with asbestus, a fibrous variety of hornblende (specimen 37645 from Canada). It is very doubtful if serpentine is ever an original rock, but is always derived from the alteration of other and less stable magnesian minerals. Here are exhibited

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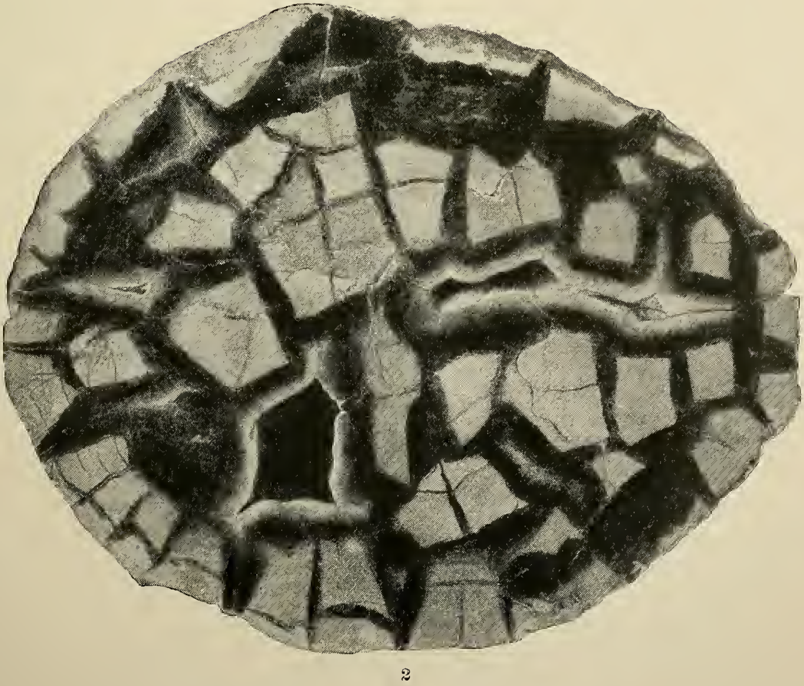

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FIG. 1. Botryoidal hematite. (Cat. No. 36085, U. S. N. M.)
FIG. 2. Clay-iron stone septarian nodule. (Cat. No. 12840, U. S. N. M.)

only those which have originated by a series of chemical changes known as metasomatosis, a process of indefinite substitution and replacement, in simple mineral aggregates occurring associated with the older metamorphic rocks. Such are the serpentines derived from nonaluminous pyroxenes, like those of Montville, New Jersey (39038), and Moriah, New York (70084), and those from Easton, Pennsylvania, derived from a massive tremolite rock (70109).

Several varieties of serpentine are popularly recognized. *Precious* or *noble* serpentine is simply a very pure compact variety of a deep oil-yellow or green color (39038). *Amianthus*, or *chrysolite*, as noted above, is the name given to the fibrous variety(37645). *Williamsite* is a deep bright green, translucent, and somewhat scaly granular variety, occurring associated with the chrome iron deposits in Fulton Township, Lancaster County, Pennsylvania (36041). *Deweylite* is a hard, translucent variety occurring in veins in altered dunite beds. *Bowenite* is a pale green variety forming veins in limestone at Smithfield, Rhode Island (36763). *Picrolite*, *Marmolite*, and *Retinolite*, are varieties of minor importance, and may be found in the mineral collections. Serpentine alone, or associated with .calcite and dolomite, forms a beautiful marble, to which the names verdantique, ophite, and ophiolite are given. (See Building and Ornamental stones.) The name serpentine is from the Latin *serpentinus*, a serpent, in allusion to its green color and often mottled appearance. The so-called "Eozoon Canadense," a supposed fossil rhizopod, is a mixture of serpentine and calcite or dolomite (specimen 70434 from Cote St. Pierre, Canada). Those serpentines which were derived from basic eruptives or complex metamorphic rocks are exhibited with those rocks with which, in their unaltered state, they would naturally be grouped.

The mineral steatite or talc, when pure, differs from serpentine in containing 63.5 per cent. of silica to 31.7 per cent. magnesia and 4.8 per cent. of water. Its common form is that of white or greenish inelastic scales, forming an essential constituent of the talcose schists. As is the case with serpentine it sometimes results from the alteration of eruptive magnesian rocks such as the pyroxenites.

Here are exhibited but a few forms occurring in veins or masses indicative of an origin by chemical deposition. Specimen 39088 is a compact variety occurring in the form of veins in the limestones of Thomaston and Rockland, Maine. Nos. 36135 and 27654 are schistose forms from New York and North Carolina. Rensselaerite is a related variety from St. Lawrence County, New York (specimen 36117). Pyrophyllite or agalmatolite is a hydrous silicate of alumina, somewhat harder than talc, and extensively used in making slate pencils and small images (specimen 37812 from Mexico and 27562 from Japan).

Kaolin, also a hydrous silicate of alumina, is a chemical product in that it is a residue left by the chemical decomposition of the feldspars. These minerals, as explained elsewhere, consist of silicates of alumina, lime, and magnesia with more or less of the alkalies, potash, and soda, and iron oxides. In the process of decomposition these soluble portions are leached out leaving the less soluble silicate, or kaolin, behind in a condition of more or less purity. The mineral is of great value for fictile purposes, and a larger number of localities are represented in the economic series in the southwest court. Other and more impure varieties in the form of clay are to be found with the fragmental rocks. But a few samples from North and South Carolina (39028 and 70172) and the Yellowstone National Park are here shown. That from the Yellowstone is thrown up in the form of a thick mud by hot springs (specimen 12879).

(4) SULPHUR, SULPHIDES, AND SULPHATES.—The mineral sulphur sometimes occurs in nature in such masses as to be fairly entitled to consideration as a rock. Its mode of occurrence has been already described under the head of chemical elements constituting rocks. In combination with iron, copper, lead, zinc, and other metals forming sulphides, it is an important rock constituent, and often occurs in beds or veins of such dimensions as to constitute a valuable ore. In combination with oxygen and the metals it forms sulphates. Gypsum, the hydrous sulphate of calcium, is a soft, white, yellowish, or pink rock, resulting mainly as a chemical deposit from the evaporation of sea water, although, as stated by Geikie (see p. 121), it may originate through the decomposition of sulphides and the action of the resultant sulphuric acid upon limestone; through the mutual decomposition of the carbonate of lime and sulphates of iron, copper, etc.; through the hydration of anhydrate, or through the action of sulphurous vapors and solutions from volcanoes acting upon the rocks with which they come in contact. It occurs in beds belonging to various geological horizons, and is usually associated with clay, rock salt, and anhydrate.

Alabaster is a fine white variety of gypsum used in smaller works of art. (Specimens 36872 and 38817.)

Anhydrite is an anhydrous variety of calcium sulphate, somewhat less common than gypsum. Barite or "Heavy Spar," the sulphate of barium, also occurs in nature, but less abundantly than the calcium sulphates.

The following localities and varieties are represented:

Sulphur:

Tehama County, California, 30118; Rabbit Hole Sulphur Mines, Humboldt County, Nevada, 35511 and 35512; Cove Creek, Utah, 35513 (7 specimens); Hell Roaring Mountain, Yellowstone National Park (72877); Murcia Province, Spain, 4246; Volcano of Popocatepetl, Mexico, 64773.

Sulphides:

Sulphide of iron. Deer Isle, Maine, 36021.

Sulphide of zinc. Deer Isle, Maine, 36016; Madison County, New Hampshire, 70094; Joplin, Missouri, 65262.

Sulphides of copper and iron. Gilpin County, Colorado, 15983; Ascension Island, 72950.

Sulphide of lead. Missouri, 39072; Brittany 6825.

The sulphides although of minor importance as rock masses are of the very greatest importance as ores, in which collections the visitor will find a very full series.

Sulphates:

Anhydrite. Isere, France, 38197; Boisset, France, (with gypsum) 38214; Volpino, Bergamo, Italy, 36733; La Graz, Mt. Blanc, 36114; Nova Scotia, 36102.

Gypsum:

Grand Rapids, Michigan, 35590; North Ogden Cañon, Colorado, 36771; Windsor, Nova Scotia, 13690 and 37624; State of Pueblo, Mexico (Satin Spar), 37815; Argentine Republic, 35531; Galica, Austria, 38817.

Barite or sulphate of barium. Vangueray, France, 38198. Alunite, or sulphate of aluminum and potash. Hungary, 36084.

(5) PHOSPHATES.—The mineral apatite, a phosphate of lime as already noted is a common accessory in the form of small crystals in crystalline rocks of all ages. It also sometimes occurs in the form of crystalline granular aggregates constituting true rock masses associated mainly with the older rocks of the earth's crust. It is therefore given a limited space here. The following localities are represented: Apatite mines of Bamle, Norway, 18873; Burgess, Ontario, Canada, 36128; France, 38143. (See also mineral fertilizers in economic series.)

(6) CHLORIDES.—Sodium chloride, or common salt is one of the most common constituents of the earth's crust. From an economic standpoint it is also a most important constituent. It occurs in greater or less abundance in all natural waters, and as a product of evaporation of ancient seas and lakes it occurs in beds of varying extent and thickness among rocks of all ages wherever suitable circumstances have existed for their formation and preservation. Salt beds from upwards of a few inches to 30 feet in thickness occur in New York State and Canada, while others abound in Pennsylvania, Virginia, Ohio, Michigan, and Louisiana. There are also numerous surface deposits of great extent in the arid regions of the West. The chlorides are here illustrated only by specimens from Lincoln County, Nevada (15501); New Iberia, Louisiana (38461).

(7) THE HYDROCARBON COMPOUNDS.—Here are brought together a small series of rocks consisting as do the mineral coals of carbon in combination with hydrogen and sometimes oxygen, and which are regarded as products of distillation or chemical alteration of buried organic matter, both plant and animal. Many compounds of the series are of a gaseous nature (natural gas, etc.,) and hence not applicable for exhibition purposes. Several members of this group are of great importance from an economic standpoint and a more complete display is given in the room devoted to economic geology (southwest court).

Petroleum is a mixture of natural hydrocarbons, liquid at ordinary temperatures and with a specific gravity somewhat less than that of water. In color it varies from nearly colorless through greenish to black. (See color series in southwest court.) But two samples are here exhibited, one (59867) from Washington, Pennsylvania, and the second (59853) from Aurelius, Ohio.*

The name paraffine is given to a wax-like hydrocarbon obtained by a process of distillation from petroleum, and occurring sparingly native.

Ozokerite is also a wax-like hydrocarbon compound occurring sparingly in seams in rocks and sometimes associated with beds of coal or other bituminous products. It is used mainly as a substitute for beeswax and as an insulator. But two localities are here represented. Utah (No. 67265) and Galicia, Austria (No. 12908). Asphaltum or bitumen is an amorphous mixture of hydrocarbons, derived presumably from decomposing organic matter, but belonging to rocks of no particular geological horizon. It has been found in gneissic rocks in Sweden. Specimen No. 27832 is from the Niagara limestones underlying Chicago, Illinois. No. 10678 is from the so-called Pitch Lake on the island of Trinidad, No. 66590 from Cuba, and No. 59345 from Scotland.

Albertite and grahamite are names given to closely related, coal-like, hydrocarbons occurring in pockets and veins, and which are supposed to have originated by the distillation of carbonaceous matter in the underlying shales. (Specimens Nos. 36138 and 59924 from Nova Scotia and West Virginia.)

Amber and gum copal are vegetable resins altered by fossilization. They are used for jewelry (see gem collection southwest range) and in the manufacture of varnishes.

B.—ROCKS FORMED AS SEDIMENTARY DEPOSITS AND FRAGMENTAL IN STRUCTURE.

The rocks of this group differ from those just described in that they are composed mainly of fragmental materials derived from the breaking down of older rocks, or are but the more or less consolidated accumulations of organic and inorganic débris from plant and animal life. The group shows transitional forms into the last as will be illustrated by certain of the limestones and the quartzites. They are water deposits, and as a rule are eminently stratified or bedded, although this structure is not always apparent in the hand specimen owing to its small size.

This great group of nonmetamorphic sedimentary rocks is one of the most important in geological science, since it is by means of the still unchanged organic forms (fossils) they contain that the paleontologist has been enabled to study the past history of the globe, to discover the multitudinous changes which have taken place in the climate, charac-

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* Under the title of "The Trenton Limestones as a source of petroleum and natural gas in Ohio and Indiana" (Ann. Rep. U. S. Geol. Survey, 1886–87, part II, pp. 483–662), Prof. Edward Orton gives a most instructive summary of our knowledge on these subjects, and to this paper those desiring further information are referred.

ter of life on land and sea, and the changes in the surface of the land itself from the earliest time down to the most recent. (See Geikie, pp. 158–176.)

As will be readily comprehended when we consider from what a multitude of materials the fragmental rocks have been derived, the amount of assorting, admixture with other substances, solution, and transportation by streams these materials have undergone, they can not be classified by any hard and fast lines, but one variety may grade into another, both in texture and structure as well as chemical composition, almost indefinitely. Indeed many of them can scarcely be considered as more than indurated mud, and only very general names can be given them.

Accordingly as these rocks consist of mechanically formed inorganic particles of varying composition and texture, or of the more or less fragmental débris from plant and animal life, they are here divided into two main groups, each of which is subdivided as below:

(A) Rocks formed by mechanical agencies and mainly of inorganic materials.

1. *The arenaceous group—Psammites.*—Sand, gravel, sandstone, conglomerate, and breccia.

2. *The argillaceous group—Pelites.*—Kaolin, clay, wacke, shale, clayey marl, argillite.

3. *The calcareous group.*—Arenaceous and brecciated limestones. The rocks of this group are often in part organic and in part chemical deposits. Only those are placed here in which the fragmental nature is the most pronounced characteristic.

4. *The volcanic group.*—Fragmental rocks composed mainly of ejected volcanic material. Tuffs, lapilli, sand and ashes, pumice dust, trass, peperino, pozzulano, etc.

5. *The ferruginous group.*—Fragmental iron ores, hematites, limonites, etc.

(B) Rocks formed largely or only in part by mechanical agencies and composed mainly of the débris from plant and animal life. Organagenous.

1. *The siliceous group.*—Infusorial earth.

2. *The calcareous group.*—Fossiliferous and oolitic limestone, marl, shell sand, shell rock.

3. *The carbonaceous group.*—Peat, lignite, coals, bitumen, oil shale, etc.

4. *The phosphatic group.*—Phosphatic sandstone, guano, coprolite nodules.

A.—ROCKS COMPOSED MAINLY OF INORGANIC MATERIALS.

1. *The arenaceous group—Psammites.*—Arenaceous from the Latin *arenaceus*, sandy or sand-like. Psammite from the Greek *Ψαμμιτης* sandy.

These rocks are composed mainly of the siliceous materials derived from the disintegration of older crystalline rocks and which have been rearranged in beds of varying thickness through the mechanical agency of water. They are, in short, consolidated beds of sand and gravel. In composition and texture they vary almost indefinitely. Many of them having suffered little during the process of disintegration and transportation, are composed of essentially the same materials as the rocks from which they were derived. This is the case with the arkose shown in specimens 39052 and 38135 from Rhode Island and France, and the red Triassic sandstone shown in specimen No. 70067 from Colorado. All of these were derived from granitic rocks and like them consist of quartz, feldspar, and mica. Others, in which the fragmental materials suffered more prior to their final consolidation, have had the softer and more soluble minerals removed, leaving the sand composed mainly of the hard, almost indestructible mineral quartz.

Fig. 92.

MICRO-STRUCTURE OF SANDSTONE.

(Portland, Connecticut.)

In structure the sandstones also vary greatly, in some the grains being rounded, while in others they are sharply angular. Fig. 92 shows the microscopic structure of a brown Triassic sandstone from Portland, Connecticut.

The material by which the individual grains of a sandstone are bound together is as a rule of a calcareous, ferruginous or siliceous nature; sometimes argillaceous. The substance has been deposited between the granules by percolating water and forms a natural cement. It frequently happens that the siliceous cement is deposited about the rounded grains of quartz in the form of a new crystalline growth converting the stone into quartzite; such are here classed with the crystaline rocks. (See p. 549.)

The colors of sandstone are dependent upon a variety of circumstances. The red, brown, and yellowish colors are due to iron oxides in the cementing constituent. In very light gray varieties the color is that of the minerals themselves composing the stone. Some of the dark colors are due to carbonaceous matter; others to iron protoxide carbonates or clayey matter. (See color series.)

Many varieties of sandstone are popularly recognized. Calcareous, ferruginous, siliceous, or argillaceous sandstones are those in which the cementing materials are of a calcareous, ferruginous, siliceous, or argillaceous nature. The name arkose is given to a coarse feldspathic sandstone derived frome granitic rocks. (Specimens No. 38135 from France and 39052 from Rhode Island.)

Conglomerate or puddingstone is merely a coarse sandstone; it differs from sandstone only as gravel differs from sand. (See specimens 25647 and 38199, which are but loosely consolidated gravels; also 38512, from Nantasket, Massachusetts.) The beautiful sample No. 70645 from Devonshire (?), England, is composed of rounded pebbles of jasper cemented by siliceous matter. In No. 28744, from near Point of Rocks, Maryland, is shown a Triassic conglomerate composed of both calcareous and siliceous pebbles, some of which are angular and some rounded, the rock thus presenting a form intermediate between conglomerates and the breccias. Sample No. 72795, from the Siskiyou Mountains, is perhaps rather a pebbly sandstone than a true conglomerate, being composed of large rounded pebbles in a finer grained or sandstone matrix.

Specimens 73080 and 73081, from Gallatin County, Montana, will illustrate the fragmental nature and origin of these rocks. Such were formed near the shore line of a now extinct lake, and show the irregular admixture of fine sand and rounded pebbles of quartz, feldspar, and other minerals, such as may not infrequently be seen on the margins of lakes and rivers of the present day.

Greywacke or Grauwacke is an old German name for brecciated fragmental rocks made up of argillaceous particles (Specimen No. 38156). The name is now little used. Other names, as flagstone, brownstone, and freestone, are applied to such of these rocks as are used for economic purposes, but which need not be referred to here. Shale is a somewhat loosely defined term, indicating structural rather than chemical or mineralogical peculiarities. The word is perhaps best used in its adjective sense, as a shaley sandstone or limestone. By many authors it is used with reference more particularly to thinly stratified or laminated clayey rocks (Specimen No. 36040). Itacolumite or flexible sandstone is a feldspathic quartzite from which the interstitial feldspathic portions have been removed by decomposition leaving the interlocking quartz grains with a small amount of play between them. The rock is in no sense elastic but merely loose jointed (Specimen No. 11951). (See also larger samples in special exhibit.)

Breccia is a fragmental rock differing from conglomerate in that the individual particles, having suffered but little attrition, are sharply angular instead of rounded. Specimen No. 37924, from the Yellowstone National Park, is a good type of these rocks. (See also Fig. 1, Plate CXIX.) No. 72794 is a chert breccia, the cementing material of which is sphalerite.

2. *The argillaceous group—Pelites.*—The rocks of this group are composed essentially of a hydrous silicate of alumina, which is the basis of common clay. In nature they are almost universally more or less impure through the presence of siliceous sand, calcareous or carbonaceous matter. They have originated in situ from the decomposition of feldspathic rocks or as deposits of fine mud or silt on the bottom of an ocean, or more rarely a lake or river. The older formations of argilla-

ceous rocks often display a pronounced fissile structure which is due as a rule to pressure, and in no way dependent upon the original bedding. Such, when splitting with sufficient ease into thin smooth slabs, are used for roofing and other purposes and known simply as slates. The cause of this slaty cleavage will be explained more fully under the head of dynamical geology. These cleavable rocks have been actually metamorphised by the pressure to which they have been subjected, and are therefore mainly exhibited with others of the metamorphic group. A few specimens are here placed to show the easy transitions from true fragmental rocks to the crystalline schists.

Kaolin is a very pure form of the hydrous silicate of alumina, formed from the decomposition of feldspathic rocks. It is, in its purest state, as has already been explained, a chemically formed rock, a residual product formed by the decay of feldspars and the removal of the soluble portions, the alkalies and iron oxides, by percolating water. It is used in the manufacture of porcelain ware. (Specimens 34441, 37240, 2879, 36029, etc.)

Kaolin, mixed with more or less siliceous matter, iron oxides, and other impurities, forms the well known common clay used by potters, pipe makers, for tile and for brick making. (Specimens 38162, 27394, 36783, 36042, 37278, 27407, etc.) The names clayey marl and shale are applied to indefinite admixtures of clay with calcareous and siliceous matters. Catlinite or "Indian pipe-stone" is an indurated clay rock formerly used by the Dakota Indians for pipe material. (Specimen 38373.) The name porcellainite has been given to a compact porcelain-like rock consisting of clay indurated by igneous agencies. (Specimens 36101 and 3809.) The name Wacke is sometimes used to designate an earthy or compact dark colored clayey rock resulting from the decomposition in situ of basaltic rocks. (See specimen No. 73102, with coating of hyalite, from Bohemia.)

3. *The calcareous group.*—Here are brought together a small series of fragmental rocks composed mainly of calcareous material, but of which the organic nature, if such it had, is not apparent. These rocks form at times beautifully brecciated marble. (See building and ornamental stone collection.) Their structure may be best comprehended by remembering that the original beds, whether crystalline or amorphous, whether fossiliferous or originating as chemical precipitates, have by geological agencies been crushed and shattered into a million fragments, and then, by infiltration of lime and iron-bearing solutions been slowly cemented once more into solid rock. The actual amount of movement of the various particles has in many cases been but slight, as will be noted by reference to the collections. Specimen 72868 from the Sphinx, Montana, furnishes a good example of the coarser varieties of these rocks.

4. *The volcanic group—Tuffs.*—Here are brought together a great variety of fragmental rocks, composed of the more or less finely commi-

nuted materials ejected from volcanoes as ashes, dust, and sand. Some of them, like the pumice dust from near Orleans, Nebraska (specimen No. 37023), are made up of minute shreds of pumiceous glass. These are the dust-like materials which, when blown from volcanic vents, are carried by atmospheric currents many miles and deposited so far from their original source that their true nature was never recognized until they came to be examined microscopically. (See under Æolian rocks.) Others, like the lapilli from the now extinct craters at Ice Spring Butte (specimen 35538), are irregular fragments of basaltic lava which when thrown into the air fell again into the immediate vicinity, forming beds of loose gravel and the cone of the crater itself. The character of the materials, therefore, varies almost indefinitely, and only very general names are given them in the majority of cases. The name tuff or tuffa is given to the entire group of volcanic materials formed in this way, and also by some authorities to fragmental rocks resulting from the breaking down and reconsolidation of older volcanic lavas. It would seem advisable to designate these last, as has F. Löwinson-Lessing,* as pseudotuffs or tuffoids. Characteristic forms of the tuffs are shown in the collections, and need not be especially enumerated here. The names volcanic ashes, sand, and dust are applied to the finer materials ejected and lapilli or rapilli to the coarser fragments like those from the extinct volcanoes of Ice Springs Butte, Utah (35538); Mono craters, California (29633); Pompeii and Monte Vultura, Italy (36603, 38794, and 38797). The finer dusts and sand, such as shown from Nebraska (37023 and 37024), Utah (37261), Montana (38584 and 38585), are of interest as being composed of minute shreds of volcanic glass which were blown from the volcanic vents and carried unknown distances to be ultimately deposited as stratified beds in comparatively shallow water. (See collections illustrating the transporting power of atmospheric currents.) The term trass is used to designate a compact or earthy fragmental rock composed of pumice dust, in which are imbedded fragments of trachytic and basaltic rock, carbonized wood, etc., and which occupies some of the valleys of the Eifel (specimen 36355 from Brohlthal, Prussia). Peperino is a tufaceous rock composed of fragments of basalt, leucite lava, and limestone, with abundant crystals of augite, mica, leucite, and magnetite. It occurs among the Alban Hills, near Rome, Italy. Palagonite tuff is composed of dust and fragments of basaltic lava with pieces of a pale yellow, green, reddish, or brownish glass called palagonite, as shown in specimens 36504 and 34739 from Nassau, Germany, or 36507 from Sicily. The general name of volcanic mud is given to such materials as that from Paterno, Sicily (73024).

The tuffs are as a rule more or less distinctly stratified, of very uneven texture, and with rarely a pisolitic structure as shown in the specimen from Nevada (35406) and Pompeii (73025). They are found associated with volcanic rocks of all ages and at times so highly meta-

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*Min. u. Pet. Mittheilungen, vol. 9, 1889, p. 530.

morphosed as to render the original nature a matter of some doubt. In the series exhibited a large share are of Tertiary or post-Tertiary origin. Among the older and more altered forms attention may be called to those of Needham and Nantasket, Massachusetts (39050 and 38528); Scotland (70388), and Brazil (69977, 69980, and 69984).

5. *Ferruginous group.*—This is a small and comparatively unimportant group, comprising only those fragmental rocks, the individual particles of which are composed mainly of ferruginous oxides. Such result from the breaking up of the iron ores, hematite and limonite, described under the head of rocks formed by chemical agencies.

B.—ROCKS COMPOSED MAINLY OF DÉBRIS FROM PLANT AND ANIMAL LIFE.

1. *Siliceous group.*—Infusorial or diatomaceous earth. This is a fine white or pulverulent rock composed mainly of the minute shells, or tests, of diatoms, and often so soft and friable as to crumble readily between the thumb and fingers. It occurs in beds which, when compared with other rocks of the earth's crust, are of comparatively insignificant proportions, but which are nevertheless of considerable geological importance. Though deposits of this material are still forming,* and have been formed in times past at various periods of the earth's history, they appear most abundantly associated with rocks belonging to the Tertiary formations.

The celebrated Bohemian deposit is some 14 feet in thickness, and is estimated by Ehrenberg to contain 40,000,000 shell to every cubic inch. The Australian specimen exhibited (No. 28473) is from a deposit 4 feet in thickness. In the United States beds are known at Lake Umbagog, New Hampshire (specimen No. 29322); Morris County, New Jersey; near Richmond, Virginia (specimen No. 70689); Calvert and Charles Counties, Maryland (specimen 70689); in New Mexico; Graham County, Arizona (specimen No. 72912); Nevada (22346); California, and Oregon. The New Jersey deposit covers about 3 acres, and varies from 1 to 3 feet in thickness; the Richmond bed extends from Herring Bay, on the Chesapeake, to Petersburgh, Virginia, and is in some places 30 feet in thickness; the New Mexico deposit is some 6 feet in thickness and has been traced some 1,500 feet; Professor Leconte states that near Monterey, in California, is a bed some 50 feet in thickness, while the geologists of the Fortieth Parallel Survey report beds not less than 300 feet in thickness, of a pure white, pale buff or canary-yellow color as occurring near Hunter's Station, west of Reno, Nevada. (See specimen No. 22346.)

The earth is used mainly as a polishing powder, and is sometimes designated as *tripolite*. It has also been used to some extent to mix with nitroglycerine in the manufacture of dynamite. Chemically the rock is impure opal, as will be seen from the following analyses made

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* *E. g.*, in the marshes of the Yellowstone Park. See on the Diatom Marshes and Diatom Beds of the Yellowstone National Park, by W. H. Weed, Botanical Gazette, vol. XIV, No. 5, p. 117.

on samples from (1), Lake Umbagog, (2), Morris County, New Jersey, and (3), Paper Creek, Maryland:

	Per cent.	Per cent.	Per cent.
Silica	80.53	80.60	81.53
Iron oxides	1.03	.....	3.33
Alumina	5.89	3.84	3.43
Lime	0.35	0.58	2.61
Water	11.05	14.00	6.04
Organic matter	0.98	.....	.....

Number 3 showed also small amounts of potash and soda.

2. *Calcareous group.*—These rocks are made up of the more or less fragmental remains of mollusks, corals, and other marine and fresh-water animals. Many of them are but consolidated beds of calcareous mud full of more or less fragmentary shells or casts of shells as in specimen No. 70169 from near Cincinnati, Ohio, and No. 36139, from Rochester, New York. Others are composed wholly of quite perfect shells as the well known "coquina" from near St. Augustine, Florida, (specimen No. 26023. See Pl. CXXIII). From such forms as these we have all possible gradations to compact crystalline limestone. Such gradations may readily be traced among the specimens exhibited.

Special names are often given these calcareous rocks designating the character of materials from which they are derived. Coral and shell limestones, as the names denote, are composed mainly of the debris from these organisms (specimens 70169, 36139, 35907, 70036, 38591, 25197, and 35530). In the shell limestone (Lumachelle) from the Tyrol (No. 38783) the pearly lining of the shells still retains its original beauty. Shell marl is a loose, pulverulent earthy rock containing remains of shells (specimen No. 36043 from Drayton Island, Florida, and No. 70034 from Australia). Shell sand is a loose aggregate of shell fragments formed on sea beaches by the action of wind and waves (see specimen Nos. 20256 from Bermuda, and 35811 from the Hawaiian Islands). Crinoidal limestone is composed mainly of fragmental remains of crinoids (specimens Nos. 35791 from Onondago County, New York, and 35801 from the Isle of Gotland). Chalk is a fine white rock composed of finely broken shells of mollusks and other marine animals associated abundantly with the minute shells of foraminifera (specimen No. 36013 from England). Nummulitic limestone carries fossil nummulites as shown in the specimens from the pyramid of Cheops, Egypt (Nos. 39165 and 26816).

3. *Carbonaceous group.*—Peat, Lignite, Coals, etc. The rocks of this group are made up of the more or less fragmental remains of plants. In many of them, as the peats and lignites (specimens Nos. 70097 and 6962) the traces of plant structure are still apparent. In others, as the anthracite coals, these structures have become wholly obliterated by metamorphisms, or, if observable at all, are to be seen only with a microscope of high power. Such belong properly in the group of metamorphic rocks.

Plants when decomposing upon the surface of the ground give off their carbon to the atmosphere in the shape of carbonic acid gas, leaving only the strictly inorganic or mineral matter behind. When, however, protected from the oxidizing influence of the air by water, or other plant growth, decomposition is greatly retarded, a large portion of the carbonaceous and volatile matters are retained, and by this means, together with pressure from the overlying mass, the material becomes slowly converted into coal. According to the amount of change that has taken place in the carbonaceous matter, the amount of gaseous matter still contained by it, its hardness and burning qualities, several varieties are recognized.

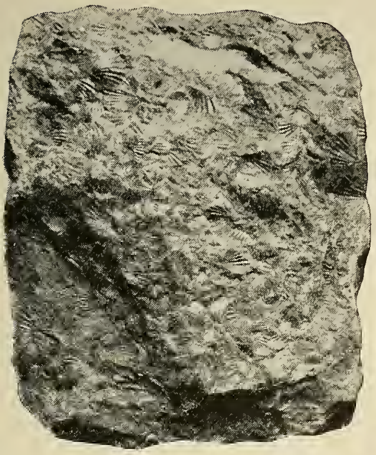
Peat is the matter in its least changed condition as it is found in bogs, and in which the plant remains are still plainly visible (specimens 70097 from New Hampshire, 36137 from Bavaria, and 59320 from Bering Island). Lignite is a form in which the woody structure is less apparent though often still recognizable as in specimen 6962 from France, and less distinctly in No. 35743 from the District of Columbia. Bituminous coal is a soft coal containing from 25 to 35 per cent. of volatile matter, and burning readily with a yellowish flame (specimens 36047, 36826, and 38224). Cannel coal is a variety of bituminous coal of a fine texture and almost no luster (specimen 59376). Anthracite is the hard, compact, highly lustrous metamorphic variety containing only traces of gaseous hydrocarbons, but with from 85 to 95 per cent. of carbon (specimen 36046). Graphite is pure crystallized carbon found in the older rocks and supposed by many to be of organic origin (specimen 36750).

4. *Phosphatic group.*—Phosphatic Sandstone; Bone breccia; Guano; Coprolite nodules. This is a group of rocks limited in extent, but nevertheless of considerable economic importance, owing to the high values of certain varieties for fertilizing purposes.

Guano consists mainly of the excrements of sea fowls, and is to be found in beds of any importance only in rainless regions like those of the western coast of South America and southern Africa (specimen 69281). The most noted deposits are on small islands off the coast of Peru. Immense flocks of sea fowls have, in the course of centuries, covered the ground with an accumulation of their droppings to a depth of sometimes 30 to 80 feet, or even more.

An analysis of American guano gave combustible organic matter and acids 11.3 per cent.; ammonia (carbonate, etc.) 31.7 per cent.; fixed alkaline salts, sulphates, phosphates, chlorides, etc., 8.1 per cent.; phosphates of lime and magnesia, 22.5 per cent.; oxalate of lime, 2.6 per cent.; sand and earthy matter, 1.6 per cent.; water, 22.2 per cent. (Geikie).

Coprolite nodules are likewise the excrements of vertebrate animals; those among the carboniferous shales of the basin of the Firth of Forth are regarded as accumulated excretions of ganoid fishes (specimen 36045).



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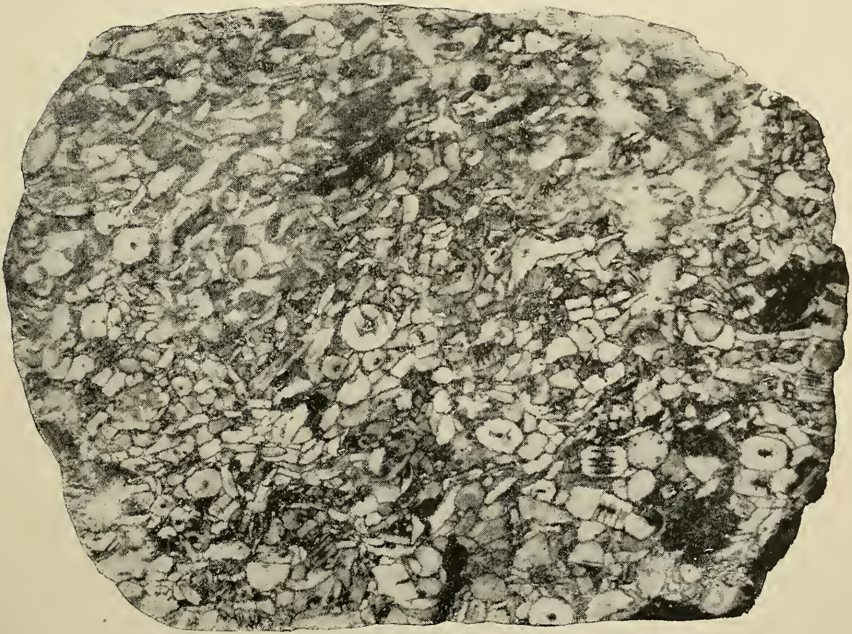

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FIGS. 1 and 2. Shell limestones. (Cat. Nos. 36139 and 26023, U. S. N. M.)
FIG. 3. Coral limestone. (Cat. No. 70036, U. S. N. M.)

Phosphatic sandstones, as the name indicates, are arenaceous rocks. Those from the Carolinas are dredged up in the form of rounded nodular masses from river bottoms, and consist of siliceous and calcareous sand with imbedded bones, fossil teeth of sharks, and other animal remains. These rocks are often of value as fertilizers, and a more complete display is to be found in the systematic collections of the South West Court.

Bone breccia consists mainly of fragmentary bones of living or extinct mammals. These are often cemented compactly by stalagmatic deposits.

II—AEOLIAN ROCKS.

This group comprises a small and comparatively insignificant class of rocks formed from materials drifted by the winds, and more or less compacted into rock masses. They are, as a rule, of a loose and friable texture and of a fragmental nature. Many of the volcanic fragmental rocks (tuffs) are grouped here, their materials having been thrown from the volcanic vent in small fragments and drifted long distances by wind prior to falling upon the surface of the ground or into the water for their final consolidation.

The group will be more fully described under the head of processes of rock formation and the transporting power of atmospheric currents. The volcanic members of the series are represented by the fine pumiceous dust drifted from Iceland to the coast of Norway. (Specimen No. 35800); by the beautifully fine white dust from Orleans, Nebraska, (37023); Gallatin Valley, Montana, (38588); Lake Lahontan, California, (37208), and other sources in Montana, Colorado and Nevada.

In specimen No. 20255 we have an example of the fine calcareous sand formed on the beaches of Bermuda and drifted inland by the winds, often forming high hills or dunes which overwhelm vegetation and dwellings. Specimen No. 25197 shows the same sand consolidated by the solvent action of percolating water. (See collection illustrating the geology of Bermuda, and also the transporting power of atmospheric currents.)

III—METAMORPHIC ROCKS.

Under this head is grouped a large series of rocks which have been changed from their original condition through dynamic and chemical agencies, and which may have been in part aqueous and in part of eruptive origin. Were it possible it would have been better to classify the rocks of this group under those of the other groups from which they were derived by this process of change, or metamorphism as it is called. In only too many cases, however, this change has been so complete as to quite obliterate all such traces of the original character as would lead to safe and satisfactory conclusions. In some instances it is nevertheless possible to trace the various stages of these changes through less and less altered forms to the original fragmental or eruptive rock. This is especially true with the calcareous rocks, and in the specimens exhibited such transitions are sometimes apparent. In the siliceous rocks these transitional forms are less readily traced. In specimen No. 36018, from Deer Isle, Maine, the conglomerate character of the rock is made apparent by the presence of pebbles, more or less changed and distorted, it is true, but still unmistakable indications of the former fragmental character of the beds. The finer grained portions, the material which formed the cementing or binding matter to hold the larger pebbles, yielded, as a matter of course, most readily to the metamorphosing influences, and gave rise to a fine aggregate of mica scales and other minerals, while the larger pebbles of quartz and feldspars offering greater resistance, have in some instances retained enough of their pebbly characteristics to still be recognizable. Accordingly as they vary in structure, we may divide these metamorphic rocks into two general groups, as below: A, stratified or bedded; B, foliated or schistose.

A.—STRATIFIED OR BEDDED.

The Crystalline Limestones and Dolomites.

Mineral composition.—The essential constituent of the crystalline limestones is the mineral calcite. The common accessories are minerals of the mica, amphibole, or pyroxene group, and frequently sphene, tourmaline, garnets, vesuvianite, apatite, pyrite, graphite, etc.

Chemical composition.—As may be inferred from the mineral composition these rocks, when pure, consist only of calcium carbonate. They are, however, rarely if ever found in a state of absolute purity, but show more or less magnesia, alumina and other constituents of the accessory minerals.

Structure.—The limestones are eminently straified rocks, though this peculiarity is not always sufficiently marked to be seen in the hand specimen. The purest and finest crystalline varieties often show a granular texture like that of loaf sugar, and hence are spoken of as saccharoidal limestones. Statuary marble is a good illustration of this type. (Specimen 17345, from Rutland, Vermont.) Under the microscope the stone is shown to be made up of small grains, which, having mutually interfered in process of growth, do not possess perfect crystal outlines, but are rounded and irregular in outline as shown in the transparency in the window (No. 39074) and in Fig. 93. All grades of texture are common, the coarser forms sometimes showing individual crystals an inch in length.

Colors.—The color of pure limestone is snow-white as seen in statuary marble. Other common colors are pink or reddish, greenish, blue, through all shades of gray to black. The pink and red colors are due to iron oxides, the greenish as a rule to micaceous minerals. (See color series.)

Geological age and mode of occurrence.—The limestones are metamorphosed chemical deposits or sedimentary beds occurring associated with rocks of all ages, from the earliest to the most recent. They are considered in large part as rocks composed of the metamorphosed débris of mollusks, corals, and other lime-secreting animals. In the process of metamorphism these remains may have been completely obliterated as in the Vermont marbles (specimen 17345), or may still be in part preserved though the entire mass has taken on a crystalline structure, as in numbers 35804, 35805, 35907, 69253, etc. To the paleontologist this group of rocks is one of very great importance, owing to their fossil remains. From an economic standpoint they are also of value, furnishing quantities of material for general building as well as beds of finest marble for ornamental work. (See building and ornamental stone collections.)

Fig. 93.

MICRO-STRUCTURE OF CRYSTALLINE LIMESTONE.

(West Rutland, Vermont.)

Classification and nomenclature.—It is common to speak of this entire group of rocks as simply limestones, though many varietal names are often rather indefinitely applied. The name *marble* is applied to any calcareous or magnesian rock sufficiently beautiful to be utilized in decorative work. *Argillaceous* and *siliceous* limestones carry clayey matter and sand. *Hydraulic limestones* contain varying proportions of magnesia, alumina, silica and iron oxides. Such furnish, when burned, a lime with the property of setting under water and known as hydraulic cement. (Specimens 39809 from Rosendale, Ulster County, New York.) *Dolomite* (so named after the French geologist Dolomieu) is a rock consisting of 45.50 per cent. carbonate of magnesia and 54.50 carbonate of lime. (Specimens 37662, 35906, 38820, 36854, 36729, etc.) In its typical form this is distinguishable from limestone by its greater hardness and by being less readily soluble in acids. In many cases chemical tests are rendered necessary to distinguish between them, and all gradations are common from limestone with a mere trace of magnesia to those which show the full amount characteristic of dolomite. The intermediate varieties are spoken of as magnesian or dolomitic limestones. (Specimens 37715, 70171, 26559, 26209, etc.) The snow-white coarsely crystalline rock from Pleasantville, West Chester County, New York (25046), and Lee, Massachusetts (37662), are good illustrations of dolomites. A chemical analysis of the Pleasantville dolomite as quoted in the circular of the Snowflake Marble Company yielded results as follows:

	Per cent.
Carbonate of lime	54.62
Carbonate of magnesia	45.04
Carbonate of iron	0.16
Alumina	0.07
Silica	0.10
	99.99

B.—FOLIATED OR SCHISTOSE.

1. THE GNEISSES

Gneiss from the German *gneis*, a term used by the miners of Saxony to designate the country rock in which occur the ore deposits of the Erzgebirge (Teall). The word is pronounced as though spelled *nīce* not *nees*.

Mineral and chemical composition.—The composition of the gneisses is essentially the same as that of the granites from which they differ only in structure and origin. They, however, present a greater variety and abundance of accessory minerals, chief among which may be mentioned (besides those of the mica, hornblende or pyroxene group) garnet, tourmaline, beryl, sphene, apatite, zircon, cordierite, pyrite, and graphite.

Structure.—Structurally the gneisses are holo-crystalline granular rocks as are the granites, but differ in that the various constituents are arranged in approximately parallel bands or layers as in specimens 72862 and 72863, from Madison County, Montana, and 36180 from Brazil. In width and texture these bands vary indefinitely. It is common to find bands of coarsely crystalline quartz several inches in width, alternating with others of feldspar, or feldspar, quartz and mica or hornblende (see specimen 72862). A lenticular structure is common, produced by lens-shaped aggregates of quartz or feldspar, about and around which are bent the hornblendes or mica laminæ, as in specimen 26547 from Massachusetts, in the structural series. The rocks vary from finely and evenly fissile through all grades of coarseness and become at times so massive as to be indistinguishable from granites in the hand specimens. The causes of the foliated structure are mentioned below.

Colors.—Like the granites they are all shades of gray, greenish, pink or red.

Geological age and mode of occurrence.—The true gneisses are among the oldest crystalline rocks, and are considered by many geologists as representing "portions of the primeval crust of the globe, traces of the surface that first congealed upon the molten nucleus." By others they are regarded as metamorphosed sedimentary deposits resulting from breaking down of still older rocks, and may not in themselves therefore be confined to any one geological horizon. (See specimen conglomerate gneiss from Maine, No. 36018). They are in large part, however, indis-

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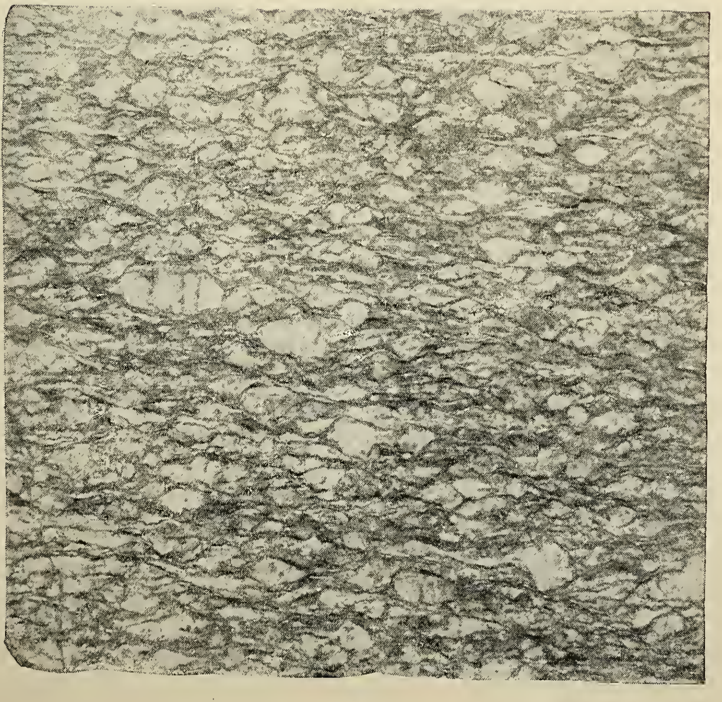

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FIG. 1. Banded gneisses. (Cat. No. 72862, U. S. N. M.)
FIG. 2. Foliated gneisses. (Cat. No. 26547, U. S. N. M.)

putably the oldest known rocks, lying beneath or being cut by all rocks of later formation or injection.

The origin of the gneisses as above suggested is in many cases somewhat obscure, the banded or foliated structure being considered by some as representing the original bedding of the sediments, the different bands representing layers of varying composition. In many schistose rocks this structure is now, however, considered to be due to mechanical uses, and in no way dependent upon original stratification (see Geikie's Textbook, pp. 123 and 298). The name as commonly used is made to include rocks of widely different structure, and which are beyond doubt in part sedimentary and in part eruptive, but in all cases altered from their original conditions. Figs. 1 and 2 on Pl. CXXIV show two rather extreme types of these rocks. Fig. 1 is that of a banded gneiss from Madison County, Montana (specimen 72862), and which, so far as we know, may be an altered sedimentary rock. In fig. 2 of the same plate (made from specimen No. 26547 in the building stone collection) is shown a foliated rather than a banded rock, and whatever may have been its origin it undoubtedly owes its foliated structure to dynamic agencies. The effect of the shearing force whereby the foliation was produced is evident in the figure, even to the unaided eye, to the left and just above the center, where an elongated feldspar is seen broken transversely into four pieces. The same features are shown even more plainly in fig. 94, which shows the structure of this same gneiss as seen under the microscope.

Fig. 94.

MICROSTRUCTURE OF GNEISS.

(West Andover, Massachusetts.)

(Drawn from section No. 26595. At *a a* are shown plagioclase crystals broken and rounded by the compressive force producing the foliation.)

As in the present state of our knowledge it is in most cases impossible to separate what may be true metamorphosed sedimentary rocks from those in which the foliated or banded structure is in no way connected with bedding and which may or may not be altered eruptives, all are grouped together here.

Classification and nomenclature.—The varietal distinctions are based upon the character of the prevailing accessory mineral as in the granites, forming a parallel series. We thus have *biotite-gneiss*, *muscovite-gneiss*, *biotite-muscovite-gneiss*, *hornblende-gneiss*, etc. Rarely the mineral cordierite occurs in sufficient abundance to become a characterizing accessory, as in specimens 73097 and 73178 from Saxony and Connecticut.

The term *syenite-gneiss* is used to designate a rock of the composition of syenite, but with a gneissoid structure. The name *granulite* is applied to a banded quartz-feldspar rock the constituents of which occur in the form of small grains and show under the microscope a mosaic structure. The Saxon granulites shown (specimens numbered 36126, 36658 to 36668, etc.) are regarded by Lehman as eruptive rocks altered by pressure. *Halleflinta* is a Swedish name for a rock resembling in most respects the eruptive felsites or quartz porphyries already described. Such, however, show a banded structure and are as a rule regarded as metamorphic rocks (see specimens 35673, 36676, 36677, and 38459 from Dannemora and Kopparberg, Sweden). *Porphyroid* is also a felsitic rock with a more or less schistose structure and with porphyritic feldspar or quartzes (specimens 36721, 36722, and 36723 from the Ardennes, France).

2. THE CRYSTALINE SCHISTS.

Under this head are grouped a large and extremely variable class of rocks differing from the gneisses mainly in the lack of feldspar as an essential constituent. They consist therefore essentially of granular quartz, with one or more minerals of the mica, chlorite, talc, amphibole, or pyroxene group. In accessory minerals the schists are particularly rich. The more common of these are feldspar, garnet (specimen 36112), cyanite, staurolite (specimen 36764), tourmaline (specimen 28574), epidote, rutile, magnetite, menacannite, and pyrite. Through an increase in the proportional amount of feldspar the schists pass into the gneisses and through a decrease in mica, hornblende, or whatever may be the characterizing mineral, into the quartz schists in which quartz alone is the essential constituent. Occasional forms are met with quite lacking in quartz and other accessory minerals and consisting only of schitose aggregates of minerals of a single species, as is the case with the pyrophyllite schists (or more properly schistose pyrophyllites) from North Carolina (specimen 27665), talcose schists from Michigan (specimen 35799) and St. Lawrence County, New York (specimen 36131), and with the more massive "soapstones" from Maryland (specimen 27331) and Vermont (specimen 25288).

The rocks of this group are characterized as a whole by a pronounced schistose structure, due to the parallel arrangement of the various constituents, this structure being most pronounced in those varieties in which mica is the predominating mineral. They are ordinarily considered as having originated from the crystallization of sediments, and in many cases the microscope still reveals existing "traces of the original grains of quartz sand and other sedimentary particles of which the rocks at first consisted." Like the gneisses they are in part, however, mechanically deformed massive rocks and their schistosity in no way relates to true bedding.

The varietal names given are dependent mainly upon the character of the prevailing ferro-magnesian silicate. We thus have *mica-schists*, *chlorite-schists, talc-shists, hornblende, actinolite, glaucophane schists*, etc. The term *slate* was originally applied to these and other types of rock of schistose or fissile character. In the arrangement here adopted this term is restricted to the argillaceous fragmental or semi-crystalline and foliated rocks next to the described.

The first of the above mentioned varieties—the mica schists—are represented by some 40 specimens from widely separated localities, principally American and European, the mica being in some cases biotite, in others muscovite, or perhaps a mixture of the two. The principal accessories sufficiently developed to be conspicuous are staurolites (specimens 29358, 29359, 36764 and 36822); chiastolites (29361 and 36209); garnets (36122, 36881 and 36882); and tourmalines (28574). In the sericite schists the hydrous mica sericite prevails (specimens 36715, 36716, and 36718, from Germany); *Paragonite schist* carries the hydrous sodium-mica paragonite (specimen 36720, from St. Gotthard, Switzerland); *Ottrelite schist* carries the accessory mineral ottrelite (specimens 36724, from Ottrey, Belgium, and 37659, from Massachusetts).

The name *phyllite* is used by German petrographers to designate a micaceous semicrystalline rock standing intermediate between the true schists and clay slates. (Specimens 36697, 36699, 36701, 36704, and 36706, from various European localities.) *Quartzite* is a more or less schistose or banded rock consisting essentially of crystalline granules of quartz. Such originate from the induration of siliceous sandstones. This induration is brought about through a deposition of crystalline silica in the form of a binding material or cement around each of the sand particles of which the stone is composed. Each of these granules then forms the nucleus of a more or less perfectly outlined quartz crystal. This structure is shown in Fig. 95, drawn from a thin section of a Potsdam quartzite from St. Lawrence County, New York. The rounded more or less shaded portions represent the original grains of quartz sand, and the clear colorless interstitial portions the secondary silica.

Fig. 95.

MICRO-STRUCTURE OF QUARTZITE.

(Potsdam, New York.)

The quartzites consist, as a rule, only of silica, or silica colored brown and red by iron oxides, as shown in specimens 37680, from Sioux Falls, Dakota, and 73078, from Madison County, Montana. At times a greenish tinge is imparted through the development of chloritic minerals (specimen 73079); accessory minerals are not, as a rule, abundant, and specimens like those from Clip, Arizona (72942), which are actually blue from the abundance of the mineral dumortierite, are quite exceptional. In specimens 70612 and 70613, from Pigeon Point, Minnesota, are shown quartzites somewhat altered by the action of intrusive rocks forced up through them. Specimens 70674, from McDowell County, North Carolina, carries abundant small indistinct garnets, and also white mica, giving it a schistose structure, and affording thus a form intermediate between the quartzites and mica schists.

Among the hornblende schists there are but few needing especial attention. It will be noticed that these are, as a rule, less finely schistose than are the mica-bearing schists, owing to the fact that the mineral hornblende is itself less finely fissile. The specimens from Woodbury, Connecticut (36121); Canaan, New Hampshire (29295); and Bavaria (36660) may be regarded as the more typical forms. No. 29300 from Hanover, New Hampshire, carries, it will be noticed, abundant small red garnets.

The *glaucophane schists* are perhaps the least abundant of the hornblendic varieties. They are represented in the collections by samples from the Isle of Syra in the Mediterranean (38626); Zermatt, Switzerland (70177); the Anglesey Monument, Wales, England (70421); Pegli, Riviera, Italy (73060) and the more massive form, perhaps an altered eruptive, from near the mouth of Sulphur Creek, Sonoma County, California (39103).

Amphibolite is the name given to an extremely tough and often massive rock of obscure origin, and consisting essentially of the mineral amphibole or hornblende. Specimens 37655, from Chester, Massachusetts; 36692 and 38220, from Ardennes and Isere, France; 36690 and 36691, from the Erzgebirge, and 36671 and 36672, from Saxony, may be considered as sufficiently typical, the last two as will be noticed carrying many garnets. In specimen 70408, from near Bamle, Norway, and 37437, from Maryland, the allied mineral anthophyllite takes the place of the ordinary hornblende. No. 38383, from Brandford, Massachusetts, and 70114, from Easton, Pennsylvania, differ from the ordinary amphibolite in that the varieties of amphibole *actinolite* and *tremolite* take the place of the common hornblende. The tremolite rock, it will be noticed, undergoes alteration into serpentine as shown by the adjoining specimen (70123).

Eclogite is a tough, massive or slightly schistose rock consisting of the grass-green variety of pyroxene omphacite and small red garnets, with which are frequently associated bluish kyanite, green hornblende (*smaragdite*), and white mica (See specimen 34670 and 35876) from Bavaria and California. *Garnet* rock or *garnetite* is a crystalline granular aggregate of garnets with black mica, hornblende, and magnetite (Specimen 36851, from North Carolina). *Kinzigkite* is a somewhat similar, though fine grained, and compact, rock consisting of garnets, plagioclase, feldspar, and black mica, and which is found in Kinzig and the Odenwald (specimen 36657).

3. The Argillaceous schists. Clay slates.

Clay slate, or roofing slate, differs from the argillaceous rocks already described (p. 537), in that it has undergone a certain amount of dynamic metamorphism which has developed in it its fissile character, and at the same time more or less obliterated its fragmental nature and converted it in many cases into an extremely fine-grained mica schist. The slates as a whole may perhaps be considered as standing intermediate between the true fragmental rocks and the crystalline schists, though a constant gradation is readily traced from the unaltered argillites through the cleavable slates to the so-called argillitic mica schists. The nature and structure of the rocks here included may be best understood by reference to Professor Geikie's text book, pp. 125 and 228. A more instructive series than is here shown is displayed in the exhibits devoted to dynamic geology.

IV.—Rocks formed through igneous agencies. Eruptive.*

This group includes all those rocks which having once been in a state of igneous fusion owe their present structural and other peculiarities to (1) The chemical composition of their original molten magmas, and (2) the conditions under which these magmas cooled. As a matter of general principle it may be stated that the greater the pressure under which a rock solidifies and the slower and more gradual the cooling the more perfect will be the crystalline structure. Hence it follows that the older and deep-seated rocks which were forced up in the form of dikes, bosses, or intrustive sheets into the overlying masses, and which have become exposed only through erosion, are the more highly crystalline, while those which like the modern lavas have flowed out upon the surface are more or less felsitic or glassy. (See Figs. 1, 2, 3, and 4, Pl. cxx. The rocks from which these sections were prepared are of essentially the same composition, the variations in structure being due to conditions of cooling.) Intermediate structures have been produced through a beginning of crystallization at certain depths below the surface, after which and while a portion of the magma was still fluid it was pushed upwards towards the surface where cooling progressed more rapidly, the result being a glassy or felsitic rock with scattering or porphyritic crystals, as shown in the structural series. It is customary to speak of this noncrystalline or unindividualized material as the groundmass or base. Rocks which are crystalline throughout are said to be *holocrystalline;* those which are without crystalline development, but consist

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*Advantage has been taken of the opportunity here offered for bringing together as large a series as the present facilities will allow of such rocks as have been the subject of the close methods of scrutiny adopted in modern petrography. It therefore happens that certain groups, and perhaps the eruptive rocks as a whole, are represented in greater profusion than their geological importance seemingly warrants. The system of installation is, however, by no means inelastic, and when these other groups shall in their turn receive the attention they merit a place can readily be made for them by substitution, or, better yet, by an expansion of the entire series.

of a structureless mass are *amorphous*. Intermediate varieties, in part crystalline and in part amorphous, those carrying crystals imbedded in a glassy or felsitic base, are called *hypocrystalline*.

According to their mode of occurrence the eruptive rocks are divided here into two main groups. (1) The intrusive or plutonic rocks, and (2) the effusive, or volcanic rocks.[*] These two groups are then subdivided according to their mineral and chemical composition.

A.—INTRUSIVE OR PLUTONIC ROCKS.

This group includes those rocks which, while in a molten condition, were forced up or intruded between the older and overlying rocks in the form of dikes, bosses, or intrusive sheets, and which never reached the surface, but cooled and crystallized at such depths and under such pressure as to become holocrystalline. They are found as a rule only among the older rocks, since it is only here that the erosion has been sufficient for their exposure. It is to be noticed that they are, as a rule, even to the unaided eye, distinctly crystalline; that they are never amygdaloidal or vesicular, and very rarely show flow structure; all of which are features common to the effusive rocks next to be described.

According to their mineral and chemical composition the rocks of this group are divided into nine subgroups, or families, as follows: (1) The granites, (2) the syenites, (3) the nepheline syenites, (4) the diorites, (5) the gabbros, (6) the diabases, (7) the theralites, (8) the peridotites, and (9) the pyroxenites.

1. THE GRANITES.

Granite, from the Latin *granum*, a grain in allusion to the granular structure.

Mineral composition.—The essential constituents of granite are quartz and a potash, feldspar (either orthoclase or microcline), and plagioclase. Nearly always one or more minerals of the mica, hornblende, or pyroxene group are present, and in small, usually microscopic forms, the accessories magnetite, apatite, and zircon; more rarely occur sphene, beryl, topaz, tourmaline, garnet, epidote, allanite, fluorite, and pyrite. Delesse[*] has made the following determination of the relative proportion of the various constituents in two well-known granites:

Egyptian red granite.	Parts.	Porphyritic granite, Vosges.	Parts.
Red orthoclase	43	White orthoclase	28
White albite	9	Reddish oligoclase	7
Gray quartz	44	Gray quartz	59
Black mica	4	Mica	6
Total	100	Total	100

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[*] Rosenbusch's group of dike rocks or gangesteine is here included with the plutonics.

[†] Prestwich Chemical and Physical Geology, vol. I, p. 42.

Chemical composition.—The average chemical composition as given by Geikie is as follows: Silica, 72.07; alumina, 14.81; potash, 5.11; soda, 2.79; lime, 1.63; magnesia, 0.33; iron protoxide, 2.22; loss by ignition, 1.09. Total, 100.05 per cent. Specific gravity, 2.66.

Structure.—The granites are holocrystalline granular rocks without trace of amorphous interstitial matter. As a rule none of the essential constituents show perfect crystal outlines, though the feldspathic minerals are often quite perfectly formed. The quartz has always been the last mineral to solidify, and hence occurs only as irregular granules occupying the interspaces. It is remarkable from its carrying innumerable cavities filled with liquid and gaseous carbonic acid or with saline matter. So minute are these cavities that it has been estimated by Sorby that from one to ten thousand millions could be contained in a single cubic inch of space. The microscopic structure of a mica granite from Maine is shown in transparency No. 39075 and in Fig. 1, Pl. CXX.

The rocks vary in texture almost indefinitely, presenting all gradations from fine evenly granular rocks to coarsely porphyritic forms in which the feldspars, which are the only constituents porphyritically developed, are several inches or feet in length. Compare specimens 36751 and 26815 from Maryland and Egypt, with 26386 and 38763 from Massachusetts and California. Concretionary forms are rare. Specimen No. 38546 (see Fig. 2, Pl. CXXVI) is of a granite concretion from Fonni, Sardina, cut in halves. Specimen 70098 from Craftsburg, Vermont, is unique on account of the numerous concretionary masses of black mica it carries.

Colors.—The prevailing color is some shade of gray, though greenish, yellowish, pink, to deep red, are not uncommon, as may be seen by reference to the collection. The various hues are due to the color of the prevailing feldspar and the abundance and kind of the accessory minerals. Granites, in which muscovite is the prevailing mica, are nearly always very light gray in color: (Specimen 36164 from the Vosges Mountains). The dark gray varieties are due largely to abundant black mica or hornblende (specimens 36186 and 38762 from Germany and California); the greenish and pink or red colors to the prevailing greenish, pink or red feldspars (specimens 29527, 26386, and 37667 from New Hampshire, Massachusetts, and New Brunswick).

Classification and nomenclature.—Several varieties are commonly recognized and designated by names dependent upon the predominating accessory mineral. We thus have (1) muscovite granite, (2) biotite granite or granitite, (3) biotite muscovite granite, (4) hornblende granite, (5) hornblende biotite granite, and more rarely (6) pyroxene, (7) tourmaline, and (8) epidote granite. The name *protogine* has been given to a granite in which the mica is in part or wholly replaced by talc (specimen No. 36127 from Mount Blanc). *Graphic granite* or pegmatite is a granitic rock consisting essentially of quartz and orthoclase so crystalized together in long parallel columns or shells that a cross section bears a crude resemblance to Hebrew writing (see specimens 10771, 3857, 69548, 4081, 35121, 39100, and 37927, and Fig. 4, Pl. CXXV. *Aplit* is a name used by the Germans for a granite very poor in mica and consisting essentially of quartz and feldspar only (specimen No. 36151 from Schemnitz, Hungary). The names *granitell* and *binary* granite have also been used to designate rocks of this class (specimen 25115 from Missouri). *Greisen* is a name applied to a quartz mica rock with accessory topaz occurring associated with the tin ores of Saxony and regarded as a granite metamorphosed by exhalations of fluoric acid (specimens 3364, 36165, and 36166). *Luxullianite* and *Trowlesworthite* are local names given to tourmaline or tourmaline-fluorite granitic rocks occurring at Luxullian and Trowlesworth, in Cornwall, England (specimens 36113 and 39002). The name *Unakite* has been given to an epidotic granite with pink feldspars and occurring in the Unaka Mountains in western North Carolina and eastern Tennessee (specimen 36784).

The name *granite porphyry* is made to include a class of rocks placed by Professor Rosenbusch under the head of "*gangesteine*," or dike rocks, and differing from the true granites mainly in structural features. They consist in their typical forms of orthoclase feldspars and quartzes porphyritically developed in a finer holocrystalline aggregate of the minerals common to the granite group. The characteristic features of the rocks so far as revealed by hand specimens may be best understood by referring to the collections (specimens 3873, 36219, 36220, and 36221, from Saxony, Germany, Silesia, and England).

The following localities and varieties are represented:

Muscovite granite: Hansdorf, Silesia, 36152; Schmenitz, Hungary, 36151; Raymond, Maine (with garnets), 12251; Barrington, New Hampshire, 29515.

Pegmatite: Auburn, Maine (polished slab), 39100; Minot, Maine (with tourmalines), 35966; Stowe, Maine, 10771; Portland, Connecticut, 35121; New Bedford, Massachusetts, 4081; Jefferson, Clear Creek County, Colorado, 69548; Limbach, near Penig, Saxony, 3857.

Muscovite biotite granite: Musquito Gulch, Park County, Colorado, 68813; Georgetown, Clear Creek County, Colorado, 36163; Musquito Gulch, Park County, Colorado, 36882; Canton Haag, in the Vosges Mountains, Germany, 36164; Vosges Mountains, Germany, 36156; Ochsenkopf, in the Fichtelgebirge, Germany, 36159; Gefrecs, in the Fichtelbirge, Germany, 36157; The Erzgebirge, Germany, 36161; Greffenstein, Saxony, 36158; Isle of Elba, Italy, 36160; Mount Pleasant, Camborn, Cornwall, England, 36162.

Biotite muscovite granite: Manchester, Hillsborough County, New Hampshire, 36168; Concord, Merrimack County, New Hampshire, 27081; Salem, New Hampshire, 27895; northwest from Crawford House, New Hampshire, 27868.

Biotite granite: Near Calais, Maine (pink), 70146; Auburn, Maine, 28539; Brunswick, Maine (with molybdenite) 28815; Millbridge, Washington County, Maine, 25966; Craftsburg, Vermont (orbicular granite), 70098; Lyme Station, New London, Connecticut, 26079; Baltimore, Maryland, 38355; Jones Falls, Baltimore, Maryland (with microline), 36751; Ilchester, Maryland (with allanite), 69550; Davidson College, Mecklenburgh County, North Carolina, 27644; Buckhorn Falls, Harnett County, North Carolina, 27653; Burnet, Texas, 38824; Buffalo, Jefferson County, Colorado, 36883; Iron Mass Mountains, Gunnison County, Colorado,


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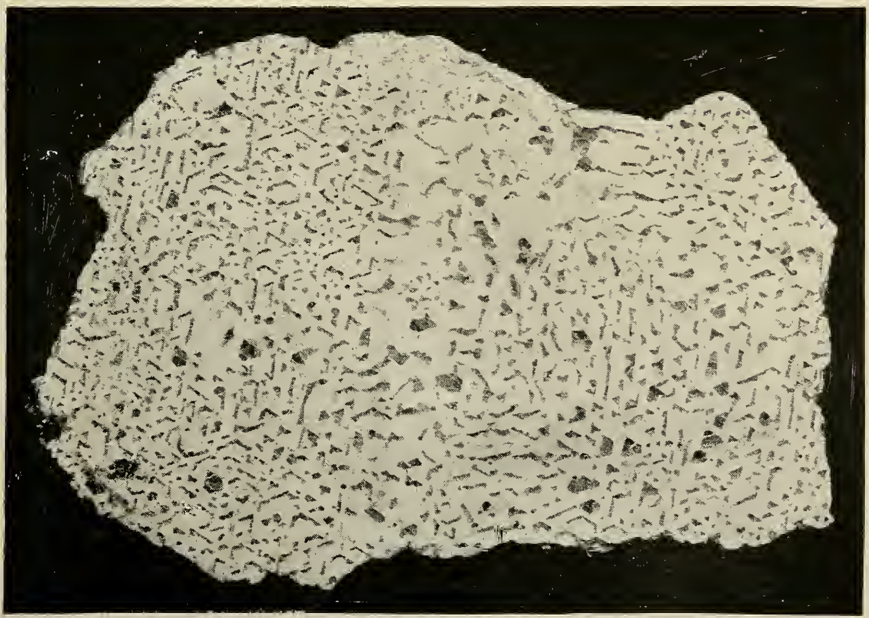
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FIGS. 1 and 2. Concretionary pebbles of siliceous sinter. (Cat. No. 12888, U. S. N. M.)
FIG. 3. Concretionary aragonite. (Cat. No. 36097, U. S. N. M.)
FIG. 4. Pegmatite. (Cat. No. 10771, U. S. N. M.)

28651. Gold Cañon, of Red Jacket Mine, Nevada, 24066. Between Los Angeles and Cocamonga, Los Angeles County, California, 38763; Peter-Head, Scotland, 36177; Korostyesor, South Russia (with garnets), 38816; Rhone, France, 38262; La Bresse Vosges, France, 38203; Roken, Christiania, Norway, 36178; Ockerthal, in the Harz Mountains, 36172; Brocken, in the Harz Mountains, 36171; Kirneckthal Barr, in the Vosges Mountains, Germany, 36170; Vosges Mountains, Germany, 36179; near Chemnitz, Saxony, 3854; near Bautzen, Saxony, 3852; Dresden, Saxony, 3850; Altenberg, Saxony, 3851; near Freiberg, Saxony, 3855 and 3853; near Pirna, Saxony, 3856; Kleesberg, Schneeberg, Saxony, 36180; Zeheen, Saxony, 36174; Aue, Schneeberg, Saxony, 36181; Silesia, 36168; Triberg, in the Black Forrest, Germany, 36169; Predazzo, Tyrol, 36167; Baveno, Lake Maggiore, Italy, 36176; Schrisheim, Baden, 36173; Japan, 11737.

Hornblende biotite granite: Meissen, Saxony, 36187; Reichenberg, Saxony, 36197; Markirch, Alsace, Germany, 36185; Kirneckthal, Vosges Mountains, Germany, 36184; Vosges Mountains, Germany, 36182; Hohwald, Vosges Mountains, Germany, 36183; Odenwald, Hesse, Germany, 36186; Loch Etive, Argyleshire, Scotland, 36191; Mount Sorrel, Leicestershire, England, 36189; Ilha de Pafueta Bay, Province de Rio Janeiro, Brazil, 69840; Alexandria, Egypt, 26815; Egypt, 70168; Lightning Mountain, Stratford, New Hampshire, 29527; Saw Pit Cañon, Los Angeles County, California, 38762; Buffalo Creek, Platte Cañon, Jefferson County, Colorado, 36192; near Salt Lake City, Utah, 39095.

Hornblende granite: Otter Creek, Mount Desert, Maine, 35923; Bemis Station, New Hampshire, 29524; Quincy, Massachusetts, 28556; Jimtown, Elysian Park, Colorado, 29264; top of Mount Lyell, California, 37201; St. George, New Brunswick, Canada, 37667; Groby, Leicestershire, England, 36196; Freiberg, Saxony, 3881; Elfdalen, Sweden, 36194; Upsala, Sweden, 36193; Meissen, Saxony, 3858; Romaniche, Saone et Loire, France, 38227; Haute Saone, France, 38260, 38263, and 36198; St. Maurice, Vosges Mountains, France, 36195.

Augite granite: Lavelline, Vosges Mountains, France, 38353.

Tourmaline granite: Heidelberg, Prussia, 70176; Luxullian, St. Anstell, Cornwall, England (Luxullianite), 36113; Trowlesworth, England (Trowlesworthite), 39002; Govaranno, Tuscany, Italy, 38334; Predazzo, Tyrol, 39176.

Greisen: Zinwald, near Altenberg, Saxony, 3864 and 36165; Geyer, Saxony (with much topaz), 36166.

Epidote granite: Dedham, Norfolk County, Massachusetts, 36386; Milans Gap, Madison County, Virginia (Unakite), 36784.

Biotite epidote granite: Grand River, Colorado, 36027.

Lithia granite: Near Perus Station, Sao Paulo Railroad, Province de Sao Paulo, Brazil, 69819.

Protogine: Mount Blanc, 36127.

Binary granite: Middleboro, Missouri (without mica or hornblende), 25115.

Granite porphyry: Altenberg, Germany, 36219; near Freiberg, Saxony, 3973; Wheal Tremayne, Cornwall, England, 36221; Erdmansdorf, Silesia, 36220.

2. THE SYENITES.

The name Syenite, from Syene, a tower of Egypt.*

Mineral composition.—The syenites differ from the granites only in the absence of the mineral quartz, consisting essentially of orthoclase feldspar in combination with biotite, or one or more minerals of the

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*The word syenite was first used by Pliny to designate the coarse red granite from quarries at Syene (see specimen 26185 in hornblende-biotite granite series), and used by the Egyptians in their obelisks and pyramids. Afterwards (in 1787) Werner introduced the word into geological nomenclature to designate a class of granuamphibole or pyroxene group. A soda-lime feldspar is nearly always present and frequently microcline; other common accessories are apatite, zircon, and the iron ores.

Chemical composition.—In column I below is given the composition of a hornblende syenite from near Dresden, Saxony, and in II that of a mica syenite (minette) from the Odenwald.

	I.	II.
	Per cent.	*Per cent.*
Silica	60.02	57.37
Alumina	16.66	13.84
Ferric iron	7.21	2.44
Ferrous iron		3.44
Magnesia	2.51	6.05
Lime	3.59	5.53
Soda	2.41	1.53
Potash	6.50	4.47
Ignition	1.10	3.17

Structure.—The structure of the syenites is wholly analogous to that of the granites and need not be further described here. In process of crystallization the apatite, zircon, and iron ores were the first to separate out from the molten magma, and hence are found in more or less perfect forms inclosed by the feldspars and later formed minerals. These were followed in order by the mica, hornblende, or augite, and lastly the feldspars, the soda-lime feldspars, when such occur, forming subsequent to the orthoclase.

Color.—The prevailing colors, as shown by the collection, are various shades of gray, through pink to reddish.

Classification and nomenclature.—According as one or the other of the accessory minerals of the bisilicate group predominates we have (1) hornblende syenite, (2) mica syenite, or minette, and augite syenite.

Other varietal names have from time to time been given by various authors. The name *Minette*, first introduced into geological nomenclature by Voltz in 1828 (Teall), is applied to a fine-grained mica orthoclase rock, occurring only in the form of dikes and further differing from the typical syenites in having a porphyritic rather than granitic structure. (See specimens 36290 to 36299 inclusive, from Baden, Saxony, and various parts of Germany.) *Vogesite* (specimen 70025 from

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lar rocks consisting of feldspar and hornblende, either with or without quartz. Later, when a more precise classification became necessary, the German geologists reserved the name syenite to designate only the quartzless varieties of these rocks, while the quartz-bearing varieties were referred to the hornblendic granites. This is the classification now followed by all the leading petrologists and is therefore adopted here. Much confusion has arisen from the fact that the French geologist Roziere insisted upon designating the quartz-bearing rock as syenite, a practice which has been followed to a considerable extent both in this country and England.

Brazil) is the name applied to a similar rock in which hornblende or augite prevails in place of mica. These rocks are placed by Prof. Rosenbusch in his latest work in the group of syenitic lamprophyrs. *Monzonite* is a varietal name for the augite syenite of Monzoni in the Tyrol (specimens 36300 and 73112).

The distribution of the syenites is much more limited than is that of the granites. The following localities and varieties are now represented in the exhibition series:

Hornblende syenite: Marblehead Neck, Massachusetts, 35962; Red Hill, Moultonborough, New Hampshire, 29580; Blue Hills, Custer County, Colorado, 36881; Cluro Hills, Cortes Range, Nevada, 21288; Serra de Stinba, province of Bahia, Brazil, 69857 and 69858; Vosges Mountains, Germany, 36289; Biella, Piedmont, Italy, 36287; Oslö, Christiana, Norway, 36288; Ise, Japan, 11727; near Dresden, Moritzberg, Zischenwitz, and Meissen, Saxony, 3861, 3863, 36285 and 36286.

Augite syenite: Jackson, New Hampshire (Uralitic), 27909 and 29587; Monzoni, Tyrol (Monzonite), 36300 and 73112; Ilha do Cabo Frio, Rio de Janeiro, Brazil, 69934 and 69936; Serra do Hilario, province of Sao Paulo, Brazil (Vogesite), 70025.

Mica syenite: Schriesheim, Odenwald, Germany (Minette), 36293; Mittershausen, Odenwald, Germany, 36290; Nassau, Germany, 36296; Weinheim, Baden (Minette), 36291; Cleurz, in the Vosges Mountains, 36292; Spessburg, near Barr in the Vosges Mountains, 36225; Andlanthal, in the Vosges, 36294; Scharpenstein and St. Michaels, Saxony (Minette), 36297 and 36298; Schnappenhaussuer, in the Fitchtelgebirge (Lamprophyr of Gumbel), 36299; Gallatin and Jefferson Counties, Montana, 38600, 73168, and 73169.

Syenite porphyry: Near Altenberg, Saxony, 3871; St. Nabord, in the Vogesen, 73120.

3. THE NEPHELINE (ELÆOLITE) SYENITES. FOYAITS.

Nepheline from the Greek νεφελη, a cloud, since the mineral becomes cloudy on immersion in acid. Elæolite from ελαίον, oil, in allusion to its greasy luster. Syenite from Syene in Egypt.

Mineral composition.—The essential constituents of this group are nepheline (elæolite) and orthoclase, with nearly always a pyroxenic mineral and a plagioclase, feldspar. The common accessory minerals are sphene, sodalite, cancrinite, zircon, apatite, black mica, and the iron ores (ilmenite and magnetite) with occasional eucolite, melinophane (specimens 36339 and 36340), and also tourmalines, perowskite, and olivine. Calcite, epidote, chlorite, analcite, and sundry minerals of the zeolite group occur as secondary products.

Chemical composition.—The composition of the elæolite syenite from province of Algrave, Portugal, as given by A. Meriau, is as follows: Silica 54.61, alumina 22.07, sesquioxide of iron 2.33, protoxide of iron 2.50, magnesia 0.88, lime 2.51, soda 7.58, potash 5.46, water 1.13, titanic oxide 0.09, phosphoric acid 0.15 per cent.

Color.—The colors are light to dark gray and sometimes reddish.

Structure.—These, like the syenites and granites, are massive holocrystalline granular rocks, and as a rule sufficiently coarse in texture to allow a partial determination of the constituent parts by the unaided eye. In the Litchfield (Maine) syenite the elæolite often occurs in crystals upwards of 5 centimetres in length, and zircons 2 centimetres in length are not rare (specimens 26418 and 72884). Neither of the essential constituents occur in the form of perfect crystals, while the apatite, zircon, black mica, and pyroxenic constituents often present very perfect forms. The cancrinite occurs both as secondary after the elæolite and as a primary constituent in the form of long needle-like yellow crystals with a hexagonal outline. This last form is especially characteristic of the Litchfield rock (see specimens Nos. 72884, 72885, and 72886). The sodalite occurs both as crystals and in irregular massive forms, coating the walls of crevices, as shown in specimens 36342, 38845, 72884 and 72885, from Maine, and from Ditro, Transylvania.

Classification and nomenclature.—Several varietal names have been given to the rocks of this group as described by various authors. *Miascite* was the name given by G. Rose to the syenite occurring at Miask in the Urals; *Ditroite* to that occurring at Ditro, in Transylvania (specimens 36342, 38813, 38814, 38815 and 73110), and *Foyaite* by Blum to that from Mount Foya in the province of Algrave in Portugal (specimens 34817 and 34820). The name *Zircon syenite* has been quite appropriately given to the variety from Laurvig (specimen No. 36341), in southern Norway, which is rich in this mineral. *Tinguaite* is the name proposed for a varietal form from Serra de Tingua, province of Rio Janeiro, Brazil (specimens 69953, 70234, 70235, 70236 and 70240).

Like the syenites proper, these are rocks of comparative rarity. The following varieties and localities are represented:

Near Hot Springs, Saline County, Arkansas, 27519 and 39188; Fourche Cove, Pulaski County, Arkansas, 4874 and 4885; Litchfield, Kennebec County, Maine, 26418 and 35935; *Ibid*, with much cancrinite, 72884; *Ibid*, showing large patches of sodalite (blue) and cancrinite (yellow), together with zircons, 72885; Marblehead, Massachusetts, 37664; near Libertyville, New Jersey, 36776. Serra de Tingua, Brazil (Tinguaite), 69953, 70234, 70235, 70236, and 70240; Ilha do Cabo Frio, Rio Janeiro, Brazil, 69944; Aroen, Langsundsfjord, Norway (with eukolit and melinophane), 36340; *Ibid* (zirkon syenite), 36341; Little Aro, Barkevig and Laven, Aroen, Langsundsfjord, Norway, 70405, 36336, 36337, and 36338; Laurvik, Norway, 70400; Ditro, Transylvania (Ditroite), 38815 (with sodalite), 38813, 38814, 36342; Predazzo, Tyrol, 36340, 39184; Foya, Portugal (Foyaite), 34819 and 34820; Picota, Portugal, 34817.

Elæolite syenite porphyry (Liebnerite) near Predazzo, Tyrol, 36343; Viezena, Fassa Thal, Tyrol, 73113.

4.—THE DIORITES (GREENSTONE IN PART).

Diorite, from the Greek word διοριζειν, to distinguish. Term first used by the mineralogist Hauy.

Mineral composition.—The essential constituents of diorite are plagioclase feldspar, either labradorite or oligoclase, and hornblende or black mica. The common accessories are magnetite, titanic iron, orthoclase, apatite, epidote, quartz, augite, black mica, and pyrite, more rarely garnets. Calcite and chlorite occur as alteration products.

Chemical composition.—According to Zirkel, the average chemical composition is silica, 52.66; alumina, 18.92; iron protoxide, 9.09; lime, 6.73; magnesia, 5.12; potash, 2.42; soda, 3.71; water, 1.35 per cent.

Structure.—Diorites are holocrystalline granular rocks, and are, as a rule, massive, though schistose forms occur. The individual crystals composing the rock are sometimes grouped in globular aggregates, thus forming the so-called *Orbicular diorite*, *Kugel diorite*, or Napoleonite, shown in specimen No. 6722 from Corsica (see also Pl. CXXVI). The texture is, as a rule, fine, compact, and homogeneous, and its true nature discernible only with the aid of a microscope; more rarely porphyritic forms occur.

Colors.—The colors vary from green and dark gray to almost black.

Classification.—Accordingly as they vary in mineral composition the diorites are classified as (1) diorite, in which hornblende alone is the predominating accessory; (2) mica diorite, in which black mica replaces the hornblende, and (3) augite diorite, in which the hornblende is partially replaced by augite. The presence of quartz gives rise to the varieties, *quartz*, *quartz augite*, and *quartz micadiorites.* The name *tonalite* has been given by Vom Rath to a quartz diorite containing the feldspar andesine and very rich in black mica (specimen 36361, from Monte Tonale, in the Tyrol). *Kersantite* is a dioritic rock occurring, so far as known, only in dikes, and consisting essentially of black mica and plagioclase, with accessory apatite and augite, or more rarely hornblende, quartz, and orthoclase (specimens 36356, 36357, 36360, 70206, 36358, 36359 and 39039). It differs from the true mica diorite in being, as a rule, of a porphyritic rather than granitic structure. Professor Rosenbusch, in his latest work, has placed the kersantites, together with the porphyritic diorites (Camptonites), under the head of dioritic lamprophyrs in the class of dike rocks or "gangesteine." The name, it should be stated, is from Kersanton, a small hamlet in the Brest Roads, department of Finistere, France.

The diorites were formerly, before their exact mineralogical nature was well understood, included with the diabases and melaphyrs under the general name greenstone (Ger. Grunstein). They are rocks of wide geographic distribution, but apparently less abundant in the United States than are the diabases. The lamprophyr varieties are still less abundant, so far as now known, and are represented in the collection, as will be noticed, by specimens from but five localities.

The following localities and varieties are at present represented:

Diorites proper: Near Reading, Berks County, Pennsylvania, 26474; Comstock Lode, Nevada, 24151, 24154, 24005, 24007, 24042; Agate Pass, Cortes Range, Nevada, 21312; Virginia Range, Washoe County, Nevada, 22616; Jamestown, Boulder County, Colorado, 26876; Howland, Lake County, Colorado, 68963; Buckskin Gulch, Park County, Colorado, 68967; Madison County, Montana, 73171, 73172, and 73173; Rio San Francisco, Brazil, 69870; Hesse, Germany, 36365; Redwitz, in the Fitchelgebirge, Bavaria, 36366; Weinheim and Schriesheim, Baden, 36367 and 3669; Frieberg, Saxony, 36368; La Fiesse, Vosges, France, 36372; Grisselham, Upland Sweden, 35635.

Orbicular diorite, kugel diorite, or napoleonite, Corsica, 67222, 36054 (polished slab).

Mica diorite: Stewartstown, New Hampshire, 27860; near Croton, New York, 72957; Comstock Lode, Nevada, 24124; Stony Point, Rockland County, New York, 38342; Lippinhof, near Freiberg, Black Forest, Baden, 38345.

Quartz diorite: Schwarzenberg, Saxony, 36362; Monte Tonale, in the Tyrol (tonalite), 36361; Mount Blanc, 3619; Schemenitz, Hungary, 26371; Neuntestein in the Vosges, 36363; Weinheim, Baden, 70207.

Augite diorite: Schemnitz, Hungary, 36373 and 36374; Cziclova Band, Hungary (with quartz), 70208.

Of the *dioritic,* lamprophyrs, are exhibited: *Camptonite,* Campton Falls, New Hampshire, 29424 and 29425; Livermore Falls, New Hampshire, 29452; North Lisbon, New Hampshire, 38042; Dixville Notch, New Hampshire, 29422; Forest of Dean Iron mines, Orange County, New York, 39399.

Kersantite: Kersanton, Finistere, France, 36356; Nassau, Germany, 36357 and 36360; Michælstein, Hartz Mountains, Germany, 70206; Wilischthal in the Erz-Gebirge, Saxony, 36358; Markish in the Vosges Mountains, 36359; Franklin Furnace, New Jersey, 39039.

5. The gabbros.

Gabbro, an old Italian name originally applied to serpentinous rocks containing diallage.

Mineral composition.—The gabbros consist essentially of a basic soda lime feldspar, either labradorite, bytownite or anorthite, and dillage or a closely related monoclinic pyroxene, a rhombic pyroxene (enstatite or hypersthene), and more rarely olivine. Apatite and the iron ores are almost universally present and often picotite, chromite, pyrrhotite, more rarely common pyrites, and a green spinell. Secondary brown mica and hornblende are common. Quartz occurs but rarely.

Chemical composition.—The average of seven analyses as given by Professor Zirkel is as follows: Silica 50.17, alumina 16.39, oxide of iron 11.91, lime 9.49, magnesia 6.06, potash .93, soda 2.67, ignition 1.84 per cent. Specific gravity, 2.85 to 3.10.

Structure.—The gabbro structure is quite variable. Like the other plutonic rocks mentioned they are crystalline granular, the essential constituents rarely showing perfect crystal outlines. As a rule the pyroxenic constituent occurs in broad and very irregularly outlined plates, filling the interstices of the feldspars which are themselves in short and stout forms quite at variance with the elongated lath-shaped forms seen in diabases. This rule is, however, in some cases reversed, and the feldspars occur in broad irregular forms surrounding the more perfectly formed pyroxenes. (See very coarse gabbro from Monte Ferrato, near Prato, Italy, No. 73056.) Transitions into diabase structure are not uncommon. In rare instances the pyroxenic constituents occur in concretionary aggregates or kugels as in the peculiar gabbro from Smaalanene in Norway (see large specimen No. 38429). Through a molecular change of the pyroxenic constitutent the gabbros pass into diorites as do also the diabases. A beautiful illustration of this is given in the gabbro about Baltimore, Maryland, described by Dr. George H. Williams, and represented in the collections by specimens 36754 and 36755. Both are from the same rock mass, but one is a typical gabbro while the other would be classed as a diorite if judged by its mineral composition alone.

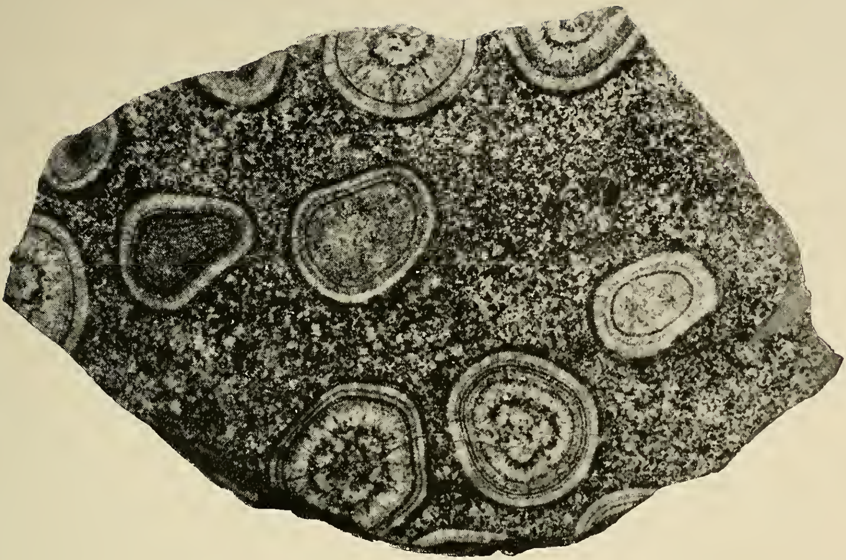

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FIG. 1. Orbicular diorite. (Cat. No. 36054, U. S. N. M.)
FIG. 2. Granite spheroid. (Cat. No. 38596, U. S. N. M.)

Colors.—The prevailing colors are gray to nearly black; sometimes greenish through decomposition.

Classification.—The rocks of this group are divided into (1) the true gabbros—that is, plagioclase diallage rocks—and (2) norites or plagioclase bronzite and hypersthene rocks. Both varieties are further subdivided according to the presence or absence of olivine. We then have:

True gabbro = Plagioclase + diallage.
Olivine gabbro = Plagioclase + diallage and olivine.
Norite = Plagioclase + hypersthene or bronzite.
Olivine norte = Plagioclase + hypersthene and olivine.

Nearly all gabbros contain more or less rhombic pyroxene, and hence pass by gradual transitions into the norites. (Illustrated in specimens 38429, 39016 and 36754.) Through a diminution in the proportion of feldspar they pass into the peridotites, and a like diminution in the proportion of pyroxene gives rise to the so-called *forellenstein.* (Specimens 36522 and 36523, from Volpersdorf, Silesia.) *Hyperite* is the name given by Tornebohm to a rock intermediate between normal gabbro and norite. (Specimen 70416, from Norway.)

The following are the principal localities and varieties now represented:

Gabbro: Gilford and Waterville, New Hampshire, 37048, 37047, and 27856; Beaver Bay, Lake County, Minnesota, 26571 and 26632; Washingtonville, Orange County, New York, 36129; Coverack, Lizard District, England (the diallage rock of De la Beche), 39003; Bamle, Norway, 70410; Volpersdorf, Silesia, 36510 to 36514 inclusive; Schmalenberg, Prussia, 36515 and 36516; Monte Ferrato, near Prato, Italy, 73056; near Porretta, Province of Bologne, Italy, 36517, 36518, and 73059; Monte Cavaloro, Bologne, Italy (oligoklasit), 36519 and 73058; Kijor, South Russia, 38,809.

Olivine gabbro: Pigeon Point, Minnesota, 70611; Pikesville, Maryland, 69556; Gwynn's Falls, Maryland, 36753; Volpersdorf, Silesia, 36520 to 36523, inclusive; Elfdalen, Sweden, 36524; Snarum, Norway, 36525; Bamle, Norway, 36526; Anson, North Carolina, 39016; Ilchester, Maryland, 69552; near Baltimore, Maryland, 36754 and 36755; the last a gabbro diorite resulting from the molecular alteration of the gabbro No. 36754, both samples being broken from the same rock mass.

Norite: Keeseville, Essex County, New York, 38744, 38748, and 29346, the last with garnets; Port Kent, New York (hyperite), 36125; Kragero, Norway (hyperite), 70416; Ebersdorf, Saxony (hypersthenite), 34680; Radanthal, Harz Mountains, Germany (hypersthenite and bronzite anorthite rock), 36527 and 73045; Barro do Pratorio, Rio Tubaras, Province of Sta. Catharina, Brazil (olivine norite), 69876; Baste Harz (bastite), 36528.

Hypersthene gabbro: West side of Ramsas Mountain, about 35 kilos southeast of Christiana, Norway. (Large mass on special pedestal, 38429). This rock is a peculiar variety of gabbro and has been called "Potato Rock" on account of its fancied resemblance to a mass of potatoes imbedded in a matrix. It consists, according to Prof. Meinich, of "kugels,' or concretionary nodules of greenish-brown labradorite, greenish oligoclase, scales of brown and green mica, and abundant magnetite. It occurs associated with the nickel ores of Smalenene.

6. The diabases.

Diabase, from the Greek word διαβασις, a passing over; so called by Brongniart because the rock passes by insensible gradations into diorite.

Mineral composition.—The essential constituents of diabase are plagioclase feldspar and augite, with nearly always magnetite and apatite in microscopic proportions. The common accessories are hornblende, black mica, olivine, enstatite, hypersthene, orthoclase, quartz, and titanic iron. Calcite, chlorite, hornblende, and serpentine are common as products of alteration. Through a molecular change known as uralitization the augite not infrequently becomes converted into hornblende, as already described (page 516), and the rock thus passes over into diorite. The plagioclase may be labradorite, oligoclase, or anorthite.

Chemical composition.—The average chemical composition as given by Zirkel is as follows: Silica, 49.54; alumina, 15.50; iron protoxide, 14.27; lime, 8.20; magnesia, 5.29; potash, 1.16; soda, 3.38; loss by ignition 2.29 per cent. Specific gravity, 2.8.

Fig. 96.

Micro-structure of Diabase.

(Weehawken, New Jersey.)

Structure.—In structure these rocks are holo-crystalline granular, very rarely showing any trace of amorphous or glassy base.* Rarely do the constituents possess perfect crystal outlines, but are more or less imperfect and distorted, owing to mutual interference in process of formation, the granular hypidiomorphic structure of Prof. Rosenbusch. The augite in the typical forms occurs in broad and sharply angular plates inclosing the elongated or lath-shaped crystal of plagioclase, giving rise to a structure known as ophitic (see Fig. 96). The rocks are, as a rule, compact, fine, and homogeneous, though sometimes porphyritic and rarely amygdaloidal.

Colors.—The colors are somber, varying from greenish through dark-gray to nearly black, the green color being due to a disseminated chloritic or serpentinous product resulting from the alteration of the augite or olivine.

Classification.—Two principal varieties are recognized, the distinction being based upon the presence or absence of the mineral olivine. We thus have: (1) Olivine diabase, or diabase containing olivine, and (2) diabase proper, or diabase without olivine.

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* Iddings discovered the presence of a glass base in the diabase of Orange Mountain, New Jersey. American Journal of Science, May, 1888.

Many varietal names have been given from time to time by different authors. Gumbel gave the name of *leucophyr* to a very chloritic diabase-like rock consisting of pale green augite and a saussurite-like plagioclase. (Specimens 36439 and 36440, from Bavaria and the Vosges.) The same authority gave the name *epidiorite* to an altered diabase rock occurring in small dikes between the Cambrian and Silurian formations in the Fichtelgebirge, and in which the augite had become changed to hornblende. (Specimens 36370 and 70209, from Champ St. Veron, Belgium.) He also designated by the term *proterobase* a Silurian diabase consisting of a green or brown somewhat fibrous hornblende, reddish augite, two varieties of plagioclase, chlorite, ilmenite, a little magnetite, and usually a magnesian mica. (Specimens 36435 to 36438, inclusive, from Bavaria, Saxony, and the Vogesen.) The name *ophite* has been used by Pallarson to designate an augite plagioclase eruptive rock rich in hornblende and epidote and occurring in the Pyrenees. The researches of M.Levy Kuhn (Untersuchungen über pyrenäische Ophite, Inaug. Dissertation) and others have, however, shown that both these constituents are secondary, resulting from the augite alteration and that the rock must be regarded as belonging to the diabases. (Specimens 36477 to 36480, from France.)

The Swedish geologist Törnebohm gave the name *sahlite diabase* to a class of diabasic rocks containing the pyroxene sahlite, and which occurred in dykes cutting the granite, gneiss, and Cambrian sandstones in the province of Smaaland and in other localities. (Specimen 36441, from Scotland). The name *teschenite* was for many years applied to a class of rocks occurring in Moravia, and which, until the recent researches of Rohrbach, were supposed to contain nepheline, but are now regarded as merely varietal forms of diabase. (Specimens 36529, 36530, 36531, and 36533.) *Variolite* is a compact often spherulitic variety occurring in some instances as marginal facies of ordinary diabase. (Specimens 73124 and 73125, from the headwaters of the Durance, on the Franco-Italian frontier.) The name *eukrite* or *eucrite* was first used by G. Rose to designate a rock consisting of white anorthite and grayish green augite occurring in the form of a dike cutting the carboniferous limestone of Carlingford district, Ireland. These rocks were included by Prof. Zirkell under the head of "anorthitgesteine." The name is now little used, and rocks of this type are here included with the diabases. (Specimens 35736 and 34828, from Finmark, Norway.)

The diabases are among the most abundant and widespread of our so-called trap rocks occurring in the form of dikes, intrusive sheets and bosses. They are especially characteristic of the Triassic formations of the Eastern United States.

The following are the principal varieties and localities now represented:

Diabase: Near Calais, Maine, 70147; Waterville, New Hampshire (mica diabase), 27879; Ossipee, New Hampshire (labradorite porphyry), 27853; Medford, Massachusetts, 26423; Hingham, Massachusetts, 38377; Greenfield, Massachusetts, 38385; Rocky Hill, Somerset County, New Jersey, 26843; York County, Pennsylvania, 37020; Goose Creek, Loudoun County, Red House, Charlotte County, and Brandy Station, Culpeper County, Virginia, 28116, 73208, and 73215; Lookville, North Carolina, 73210; Forder Saltash, Cornwall, England, 39007; Gove Saltash, Cornwall, England, 39008; Craig Park, Glasgow, Scotland, 70382 and 70384; Magdesprung, Wolfshagen, Bodenthal, Blankenburg, Altenbrak, etc., Hartz Mountains, Germany, 36426, 36427, 36428, 36429, 36430, 36431; Nassau, Germany, 36420, 36422. 36424, and 36425; Anhalt, Germany, 36432; Ehrenbreitstein, Prussia, 36419; Nahe, Prussia, 36418, and 36426; Steinbach and Berneck, in the Fichtel Gebirge, 36433 and 36434; Boguschowitz, Moravia (teschenite), 36529 to 36531 inclusive, and 36533; Koditz, in the Fichtel Gebirge (leukophyr), 36439; Breitenbach, in the Voges Mountains, 36440; Hartz Mountains (ophite), 6723; Haute Goronne, France (ophite), 36477 and 36478; Beziers, Heranet, France (ophite), 36479; Garraux, Pyrenees, France (ophite), 36480; Champ St. Veron, Brabant, Belgium (Epidiorite), 36370 and 70209; Edinburgh, Scotland (sahlitdiabase), 36441; Hof, in the Fichtel Gebirge (proterobase), 36435; Bantzen, Saxony (proterobase), 36436 and 36437; Sperberbach, Hohwald, in the Vosges Mountains (proterobase), 36438. Hammerfest, Province of Finmark, Norway (Eukrite), 34828 and 35736.

Olivine diabase: Addison, Washington County, Maine, 37019 and 36843; Tenant's Harbor, Knox County, Maine, 39043; Auburn, Maine, 28533; Lewiston, Maine (very rich in olivine), 37618; near Mine La Motte Station, Missouri, 70129; Thetford Hill, Vermont (drift), 35062; Rio Janeiro, Brazil, 69904.

7. THE THERALITES.

Theralite from the Greek word ϑηραν, to seek eagerly.

This is the name given by Professor Rosenbusch to a class of intrusive rocks consisting essentially of plagioclase feldspar and nepheline, and which are apparently the plutonic equivalents of the tephrites and basanites. Rocks of this group are, so far as now known, of very limited distribution.

The group is founded by Professor Rosenbusch upon certain rocks occurring in dikes and laccolites in the Cretaceous sandstones of the Crazy Mountains of Montana, and described by Prof. J. E. Wolff,* of Harvard University.

Mineral composition.—The essential constituents as above noted are nepheline and plagioclase with accessory augite, olivine, sodalite, biotite, magnetite, apatite and secondary hornblende, and zeolitic minerals.

Chemical composition.—The chemical composition as given by Mr. Wolff of a sample from near Martinsdale is as follows: Silica, 43.175; alumina, 15.236; ferrous oxide, 7.607; ferric oxide, 2.668; lime, 10.633; magnesia, 5.810; potash, 4.070; soda, 5.68; water, 3.571; sulphuric anhydride, 0.94 per cent.

Structure.—The rocks are holocrystalline granular throughout.

Colors.—These are dark gray to nearly black.

The theralites so far as known have an extremely limited distribution. The group is represented in the collection only by samples from Gordon's Butte, and Upper Shields River basin in the Crazy Moun-

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* Notes on the Petrography of the Crazy Mountains and other localities in Montana, by J. E. Wolff. Also Neues Jahrb., 1885, I, p. 69.

tains, Montana, 70599 and 73138; and Jaguecy, Xirinca, Rio Riberia, Province of Sao Paulo, Brazil, 70023.

8. THE PERIDOTITES.

Peridotite, so called because the mineral peridot (olivine) is the chief constituent.

Mineral composition.—The essential constituent is olivine associated nearly always with chromite or picotite and the iron ores. The common accessories are one or more of the ferro-magnesian silicate minerals augite, hornblende, enstatite and black mica; feldspar is also present in certain varieties and more rarely apatite, garnet, sillimanite, perowskite and pyrite.

Chemical composition.—The chemical composition varies somewhat with the character and abundance of the prevailing accessory. The following table shows the composition of several typical varieties:

	I.	II.	III.	IV.	V.	VI.
Silica	41.58	43.84	39.103	42.94	38.01	45.68
Alumina	0.14	1.14	4.94	10.87	5.32	6.28
Magnesia	49.28	41.33	29.176	16.32	23.29	34.76
Lime	0.11	1.71	3.951	9.07	4.11	2.15
Iron sesquioxide	....	8.76	4.315	3.47	6.70	9.12
Iron protoxide	7.49	....	11.441	10.14	4.92	....
Chrome oxide	....	0.42	0.446	....	....	0.26
Manganese	....	0.12	0.276	Trace.	....	....
Potash	....	....	Trace.	0.15	0.22	....
Soda	....	....	....	0.90	4.15	....
Nickel oxide	0.34	....	....	....	....	....
Water and ignition	1.72	1.06	5.669	6.09	10.60	1.21
Specific gravity	....	3.287	2.93	2.88	2.83	3.269

(I) Dunite: Macon county, North Carolina. (II) Saxonite: St. Paul's Rocks, Atlantic Ocean. (III) Picrite: Nassau, Germany. (IV) Hornblende Picrite: Ty Cross, Anglesia. (V) Picrite: Little Deer Isle, Maine. (VI) Lherzolite: Monte Rossi, Piedmont.

Structure.—The structure as displayed in the different varieties is somewhat variable. In the dunite it is as a rule even crystalline granular, none of the olivines showing perfect crystal outlines. (Specimen 36845 from North Carolina.) In the picrites the augite or hornblende often occurs in the form of broad plates occupying the interstices of the olivines and wholly or partially inclosing them, as in the hornblende picrite of Stony Point, New York, No. 38339. The saxonites and lherzolites often show a marked porphyritic structure produced by the development of large pyroxene crystals in the fine and evenly granular ground mass of olivines. (Specimen 35758 from Norway. See also Fig. 97, as drawn by Dr. G. H. Williams.) The rocks belong to the class designated as hypidiomorphic granular by Professor Rosenbusch, that is rocks composed only in part of minerals showing crystal faces peculiar to their species.

Colors.—The prevailing colors are green, greenish-gray, yellowish-green, dark green to black.

Nomenclature and classification.—Mineralogically and geologically it will be observed the peridotites bear a close resemblance to the olivine diabases and gabbros, from which they differ only in the absence of feldspars. Indeed, Prof. Judd has shown that the gabbros and diabase both in places pass by insensible gradations into peridotites through a gradual diminution in the amount of their feldspathic constituents. Dr. Wadsworth would extend the term peridotite to include rocks of the same composition, but of meteoric as well as terrestrial origin, the condition of the included iron, whether metallic or as an oxide being considered by him as nonessential, since native iron is also found occasionally in terrestrial rocks, as the Greenland basalts and some diabases.

In classifying the peridotites the varietal distinctions are based upon the prevailing accessory mineral. We thus have:

Dunite, consisting essentially of olivine only.

Saxonite, consisting essentially of olivine and enstatite.

Picrite, consisting essentially of olivine and augite.

Hornblende picrite, consisting essentially of olivine and hornblende.

Wehrlite (or eulysite), consisting essentially of olivine and diallage.

Lherzolite, consisting essentially of olivine, enstatite, and augite.

The name Dunite was first used by Hochstetter and applied to the olivine rock of Mount Dun, New Zealand. (Specimen 70346.) Saxonite was given by Wadsworth, rocks of this type being prevalent in Saxony. The same rock has since been named Harzburgite by Rosenbusch. The name Lherzolite is from Lake Lherz in the Pyrenees.

The peridotites are, as a rule, highly altered rocks, the older forms showing a more or less complete transformation of their original constituents into a variety of secondary minerals, the olivine going over into serpentine or talc and the augite or hornblende into chlorite. The more common result of the alteration of peridotitic rocks is the conversion into serpentine, which takes place through the hydration of the olivine and the liberation of free iron oxides and chalcedony. (See Fig. 97.) Recent investigations have shown that a large share of the serpentinous rocks were thus originated. Hence a part of the serpentines are here exhibited.

Fig. 97.

Micro-structure of Porphyritic Lherzolite.

(See specimens 39014, 70137, and 70556, from California, England, New York State.) Those resulting from the hydration of other magnesian silicate minerals are to be found grouped with the unaltered rocks of the same nature. (See also exhibit illustrating the origin of serpentine.)

It is, perhaps, as yet too early to state definitely that all peridotites are eruptive. In many instances their eruptive nature is beyond dispute. Others are found in connection with the crystalline schists, so situated as to suggest that they may themselves be metamorphic.* Owing to their basic nature and low fusing points the peridotites have not, as a rule, been productive of pronounced contact metamorphism. They have of late excited considerable interest from their supposed connection with the origin of the diamond. (See under head of picrite porphyrites, p. 585.)

The peridotites are rocks of wide distribution, but covering comparatively limited areas. The following are the principal varieties and localities represented:

Dunite: Near Webster, North Carolina, 39131 and 29004; Corundum Hill, Macon County, North Carolina, 36845; Wake County, North Carolina (serpentine), 39030; Red Hill, Plumas County, California, 38361; Cumberland, Rhode Island (Cumberlandite), 39034; Dun Mountain, New Zealand, 70346.

Saxonite: San Francisco, California, 39014; Riddle, Oregon, 70600; Lizard district, Cornwall, England (serpentine), 39011; Cadgwith district, Cornwall, England (serpentine), 70137; near Tromsoe, Norway, 35758.

Picrite: Ilchester, Maryland, 69551; Little Deer Isle, Maine, 39044; Clickerton, Cornwall, England, 39010; Biedenkoff, Hesse Nassau, Prussia, 36578, (Palæopikrite) 36579; Tringenstein, Nassua, 36580.

Hornblende Picrite: Stony Point, New York, 38339. Madison County, Montana.

Wherlite (*Eulysite*): Near Red Bluff, Madison County, Montana, 70675; Volpersdorf, Silesia, 34766; Schriesheim, Baden, 36581; Terra di Zanschetta, Bologna, Italy, 36584 and 36585; Monte Ferrato, near Prato, Florence, Italy, 73057.

Lherzolite: Lherz, France, 38240; Areige, France, 6731; Argnenos, Haute Garonne, France, 36582; Fauraft, Markirch, in the Vosages Mountains, 36585.

The following are so much altered that they can be designated simply *serpentines:*

Deer Isle, Maine, 39047; Lynnfield, Massachusetts, 70140; Hoosac, Berkshire County, Massachusetts, 27205; Russell, Massachusetts, 38403; Blandford, Massachusetts, 38405; Bare Hills, near Baltimore, Maryland, 37435; Saliwick Lake, Alaska, 37027; Kupperberg, in the Fichtelgebirge, Bavaria, 36583; Greipendorf, Saxony, 36673; Waldheim, Saxony, 36675; Ranenthal, Vosges Mountains, 36587; Grumberg, Silesia, 34765; Japan, 27136.

9. THE PYROXENITES.

Pyroxenite, a term applied by Dr. Hunt † to certain rocks consisting essentially of minerals of the pyroxene group, and which occurred both as intrusive and as beds or nests intercallated with stratified rocks. The curator here follows the nomenclature and classification adopted by Dr. G. H. Williams.‡

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* See Kalkowsky's Elemente der Lithologie, p. 242.

† Geology of Canada, 1863, p. 667.

‡ American Geologist, vol. I, July, 1890, pp. 35–49.

Mineral composition.—The essential constituents are one or more minerals of the pyroxene group, either orthorhombic or monoclinic. Accessory minerals are not abundant and limited mainly to the iron ores and minerals of the hornblende or mica groups.

Chemical composition.—The following analyses serve to show the variations which are due mainly to the varying character of the pyroxenic constituents:

	I.	II.	III.
Silica	50.80	53.98	55.14
Alumina	3.40	1.32	0.66
Chrome oxide	0.32	0.53	0.25
Ferric oxide	1.39	1.41	3.48
Ferrous oxide	8.11	3.90	4.73
Manganese	0.17	0.21	0.03
Lime	12.31	15.47	8.39
Manganesia	22.77	22.59	26.66
Soda	Trace	....	0.30
Potash	Trace	....	....
Water	0.52	0.83	0.38
Chlorine	0.24	....	0.23
Total	100.03	100.24	100.25

(I) Hypersthene diallage rock, Johnny Cake road, Baltimore County, Maryland; (II) hypersthene diallage rock, Hebbville post-office, Baltimore County, Maryland, and (III) bronzite diopside rock, from near Webster, North Carolina.

Structure.—The pyroxenites are holocrystalline granular rocks, at times evenly granular and saccharoidal, or again porphyritic, as in the websterite from North Carolina (specimens 38832 and 17927). The microscopic structure of this rock is shown in Fig. 98 from the original drawing by Dr. Williams.

Fig. 98.
MICRO-STRUCTURE OF PYROXENITE.

Colors.—The colors are, as a rule, greenish or bronze.

Classification and nomenclature.—The pyroxenites, it will be observed, differ from the peridotites only in the lack of olivine. Following Dr. Williams's nomenclature, we have the varieties Dillagite, Bronzitite, and Hypersthenite, according as the mineral dillage, bronzite, or hypersthene forms the essential constituent. Websterite is the name for the enstatite-dillage variety, such as occurs near Webster, North Carolina (specimens 38832, 39132, and 70060), and hornblendite that of the hornblende augite variety. Through hydration and other chemical changes the pyroxenites give rise to serpentinous, hornblendic, and steatitic masses, as shown in specimens from Chester, Pennsylvania, and Russdorf, Saxony. The rocks appear to rank in geological importance next to the peridotites.

The following localities are represented:

Chester County, Pennsylvania (these rocks all more or less altered into impure serpentine), 25669, 38467, 38470, 38471, 38473, 38491, 38498, 38484, 70160 (williamsite), and 70154; near Webster, Jackson County, North Carolina, 70060, 38832, 39132; Russdorf and Kuhschnappel, Saxony, 36674 and 70191, Madison County, Montana, 73175.

B.—EFFUSIVE OR VOLCANIC ROCKS.

This group includes those igneous rocks which, like the plutonics, have been forced up through the overlying rocks, but which in this case came nearly or quite to the surface and flowed out as lavas. They therefore in many cases represent merely the upper portions of plutonic rocks, from which they differ structurally, having become less perfectly crystalline, owing to their more rapid cooling and solidification. The characteristic structure of the group is porphyritic, and represents two distinct phases of cooling and crystallization; (1) an intratellurial period marked by the crystallization of certain constituents while the magma, still buried in the depth of the earth, was cooling very gradually, and (2) an effusive period marked by the final consolidation of the rock on the surface. As this final cooling was much the more rapid the ultimate product is a glassy, felsitic, or sometimes holocrystalline groundmass inclosing the porphyritic minerals formed during the first or intratellurial stage. (See structural series and Figs. 3 and 4, Pl. CXX.) Those portions which have cooled wholly on the surface often show not merely a vitreous form, but are vesicular or pumiceous as well from the expansion of the included aqueous vapor. When the groundmass is holocrystalline the rock is said to have a *holocrystalline porphyritic* structure; when glassy, a *vitrophyric* structure. An intermediate form in which the groundmass is in part crystalline and in part glassy is called *hypocrystalline porphyritic.* As would naturally be expected, the rocks of this group form a series in part parallel with those of the plutonic group, though as a matter of fact, as noted below, effusive forms occur of which no plutonic equivalents have as yet been found.

According to the geologic period of their extravasation, whether pre-Tertiary or Tertiary and post-Tertiary, many authorities have found it convenient to divide the rocks of this group into (1) the older or *paleovolcanic* effusives, and (2) the younger or *neovolcanic* effusives. This distinction is, however, not well marked and can be of little permanent value. It is nevertheless recognized to a certain extent here, inasmuch as it is upheld in the leading text-book on the subject, and, moreover, in most instances the names which have been applied to the Tertiary and post-Tertiary effusives differ from those applied to rocks of the Paleozoic ages, of which they may be otherwise almost exact equivalents.* The following table shows the relationship such as exists between the plutonics and the effusives so far as now known:

Plutonics.	Effusives.	
	Paleovolcanic.	Neovolcanic.
Granites	Quartz porphyries	Liparites.
Syenites	Quartz- -free porphyries	Trachytes.
Nepheline Syenites	(Not known)	Nepheline Phonolites.
Diorites	Porphyrites	Andesites.
Gabbros, Norites, Diabases	Melaphyrs and Augite porphyrites.	Basalts.
Theralites	(Not known)	Tephrites and Basanites (in part).
Peridotites	Picrite porphyrites	Limburgites.
Pyroxenites	(Not known)	Augitites (?).
(Not known)	....do	Leucite Rocks.
Do	....do	Nepheline Rocks.
Do	....do	Melilite Rocks.

In the collections the effusives are arranged in the order given below: (1) Quartz porphyries, (2) Liparites, (3) Quartz-free porphyries, (4) Trachytes, (5) Phonolites, (6) Porphyrites, (7) Andesites, (8) Melaphyrs and Augite porphyrites, (9) Basalts, (10) Tephrites and Basanites, (11) Picrite porphyrites, (12) Limburgites and Augitites, (13) Leucite Rocks, (14) Nepheline Rocks, and (15) Melilite Rocks.

1. THE QUARTZ PORPHYRIES.

Composition.—The mineral and chemical composition of the quartz porphyries is essentially the same as that of the granites, from which they differ mainly in structure. Their essential constituents are quartz and feldspar, with accessory black mica or hornblende in very small quantities; other accessories present, as a rule, only in microscopic quantities, are magnetite, pyrite, hematite, and epidote.

Structure.—The prevailing structure is porphyritic. To the unaided eye they present a very dense and compact groundmass of uniform reddish, brown, black, gray, or yellowish color, through which are scattered clear glassy crystals of quartz alone, or of quartz and feldspar together. The quartz differs from the quartz of granites in that here it was the first mineral to separate out on cooling, and hence has taken on a more perfect crystalline form; the crystal outlines of the feldspar are also well defined. Under the microscope the groundmass in the typical porphyry is found to consist of a dense felt-like or felsitic irresolvable

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* The Curator has not felt it incumbent upon himself here to substitute other names for those now commonly accepted by the best authorities. Such a proceeding would only increase the confusion now existing.

substance, which chemical analysis shows to be also a mixture of quartzose and feldspathic material. The porphyritic quartzes show frequently a marked corrosive action from the molten magma, the mineral having again been partially dissolved after its first crystallization. (Fig. 3, Pl. CXX.) This difference in structure in rocks of the same chemical composition is believed to be due wholly to the different circumstances under which the two rocks have solidified from a molten magma. The structure of the groundmass is not always felsitic, but may vary from a glass, as in the pitchstones of Meissen, Isle of Arran, and the Lake Lugano region, through spherulitic, micropegmatitic, and porphyritic to perfectly microcrystalline forms as in the microgranites. This difference in structure may be best understood by reference to transparencies Nos. 39075 and 39078 in the windows and to Pl. CXX, which show the microscopic structure of (1) granite from Sullivan, Hancock County, Maine, (2) micropegmatite from Mount Desert, Maine (specimen 70041), and (3) a quartz porphyry from Fairfield, Pennsylvania.

Marked fluidal structure is common as shown by the specimens in the structural series Nos. 35946 and 35959, and also in specimens 35959 and 26570, from Massachusetts and Minnesota. (See Pl. CXXVII.)

Colors.—The colors of the groundmass, as above noted, vary through reddish, brownish gray to black and sometimes yellowish or green. The porphyritic feldspars vary from red, pink, and yellow to snow-white and often present a beautiful contrast with the groundmass, forming a desirable stone for ornamental purposes. (Specimens 36244 and 36245, from Elfdalen, Sweden.)

Classification and nomenclature.—Owing to the very slight development of the accessory minerals mica, hornblende, etc., it has been found impossible to adopt the system of classification and nomenclature used with the granites and other rocks. Vogelsang's classification as modified by Rosenbusch is based upon the structure of the groundmass as revealed by the microscope. It is as follows:

Groundmass holocrystalline granular	Micro-granite.
Groundmass holocrystalline, but formed of quartz and feldspar, aggregates rather than district crystals	Granophyr.
Groundmass felsitic	Felsophyr.
Groundmass glassy	Vitrophyr.

Intermediate forms are designated by a combination of the names as *granofelsophyr*, *felsovitrophyr*, etc. The name felsite is often given to rocks of this group in which the porphyritic constituents are wholly lacking, as in specimens No. 38031 and 69571, from Saugus and Nahant, Massachusetts. The names *felstone* and *petrosilex* are also common, though gradually going out of use. *Elvanite* is a Cornish miners' term and too indefinite to be of great value. (Specimen 36188, from Cornwall, England). *Eurite*, now little used, applies to felsitic forms such as specimens 38245, 38254, and 38259, from Jura, France. The name *felsite-pitchstone* or *retinite* has been given to a glassy form with pitch-like luster such as occurs in dikes, cutting the old red sandstone on the Isle of Arran. *Kugel porphyry* is a name given by German writers to varieties showing spheroids with a radiating or concentric structure. (Specimen 36235, from Baden.) *Micropegmatite* is the term not infrequently applied to such as show under the microscope a pegmatitic structure. (Specimen 70041, from Mount Desert, Maine, and Fig. 2, Pl. CXX.) Various popular names as *leopardite* and *toadstone* are sometimes applied to such as Nos. 27587 and 35722, from near Charlotte, North Carolina, and the peculiar spherlitic form, from Newbury, Massachusetts, No. 70138.

The following localities and varieties are represented:

Microgranite: Friedrichsrode, Germany, 70234, 70744, and 70251; Muhlenthal, Poppenberg and Auersberg. In the Harz Mountains, Germany 36223, 36222, and 36224; Nassau, Saxony 36225; Norway 70250; Elfdahlen, Sweden 36232; Catalonia, Spain, 36233; Liskeard, Wheal Busy and Penhall Moor, Cornwall, England, 36228, 36229, and 36231.

Granophyr: Kirneckthal and Barr Alsace, in the Voges Mountains, Germany, 36234 to 36239 inclusive; Lake Lugano (Lago di Lugano) Switzerland, 36606, 36608, 36609, and 36611; Mount Desert, Maine (micropegmatite) 70038, 70041, 70042.

Felsophyr: Albany, Mount Kearsarge, Waterville, New Hampshire, 27973, 29599, 29591, 29601, 29605; Marblehead, Massachusetts, 35953, 35955, 35956, 35959, 35961; Nahant, Massachusetts, 69671; Saugus, Massachusetts, 38031; Newbury, Massachusetts, 70138; Hyde Park, Massachusetts, 35942; Hingham, Massachusetts, 35943; Charlotte, North Carolina, 35722 and 27587; St. Francois, Iron and Stone Counties, Missouri, 26406, 26341, 26593; Lake County, Minnesota, 26570 and 26630; Bradon, Wisconsin, 28503; Park County, Colorado, 68943 and 68921; Lake County, Colorado, 68861 and 68901; Washoe District, Nevada, 24052 and 24071; St. Catharine, Brazil, 69860; Cornwall, England, 36188; Isle of Arran, Scotland, 70375 and 70378; Freiberg, Adorf, Werdau, Grimma, Erdmansdorf, and Schoeneck, Saxony, 38351, 3867 to 3870, inclusive, 36227, 36248, and 73109; Dossenheim, Handschuhsheim, and Weinham, Baden, 36242, 36246, and 36255; Odenwald, Germany, 36241 and 36243; Jura, France, 38259, 38245, and 38254; Poeplitz, Bohemia, 34808; Danemora and Elfdalen, Sweden, 36250, 36244, 36245, and 36247; Isle of Hogland, Russia, 27550.

Vitrophyr: Meissen and vicinity, Saxony, 3631, 3642, 3872, 3876 to 3880 inclusive, 4115, 34678, 36252, 36258, 36259; Auer and Recoaro, in the Tyrol, 36253, 38879; Lake Lugano region, Switzerland, 73121; Isle of Arran, Scotland, 36200 and 70374.

2. THE LIPARITES.

Mineral composition.—These rocks may be regarded as the younger equivalents of the quartz porphyries, or the volcanic equivalents of the granites, having essentially the same mineral and chemical composition. The prevailing feldspar is the clear glassy variety of orthoclase known as sanidin; quartz occurs in quite perfect crystal forms often more or less corroded by the molten magmas, as in the porphyries, and in the minute, six-sided, thin platy forms known as tridymite. The accessory minerals are the same as those of the granites and quartz porphyries.

Chemical composition.—Below is given the composition (I) nevadite, from the northeastern part of Chalk Mountain, Colorado, as given by Cross.* (II) That of a rhyolitic form, from the Montezuma Range,

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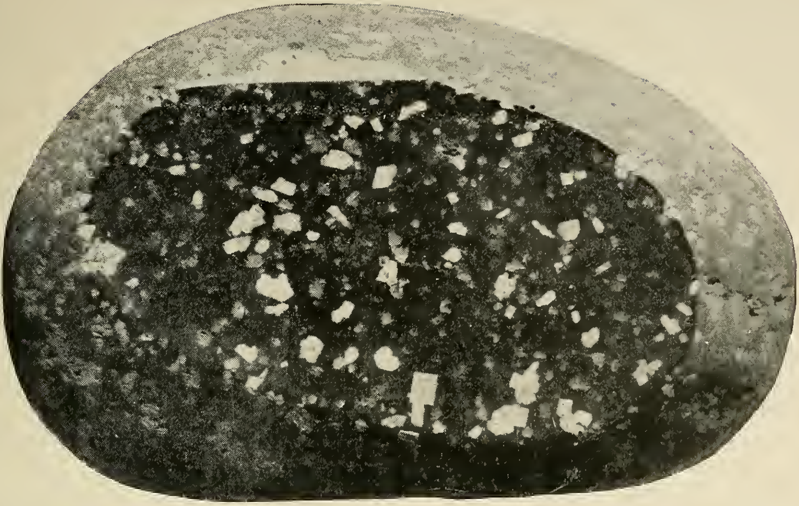
* Geology and Mining Industry of Leadville, Monograph XII, U. S. Geological Survey, p. 349.



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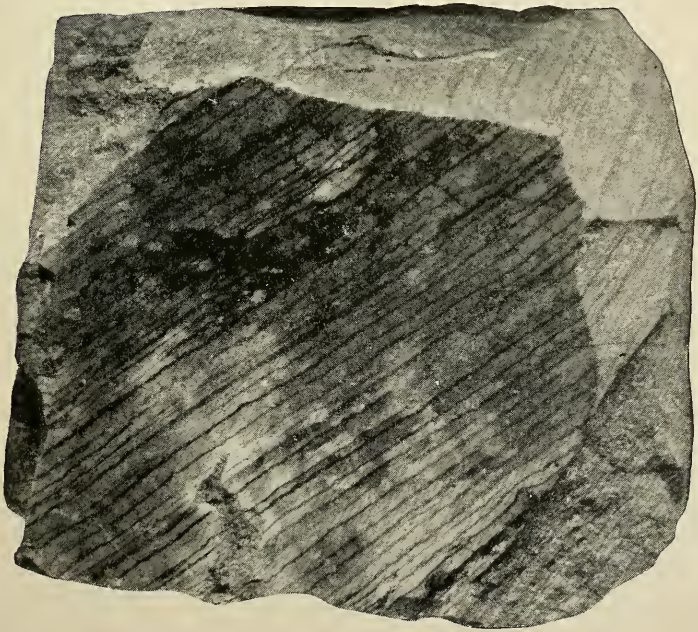

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FIG. 1. Quartz porphyry showing porphyritic structure. (Cat No. 35953, U. S. N. M.)
FIG. 2. Quartz porphyry showing flow structure. (Cat. No. 35946, U. S. N. M.)

Nevada, as given by King,* and (III) that of a black obsidian from the Yellowstone National Park, Wyoming, as given by Iddings.†

	I.	II.	III.
	Per cent.	*Per cent.*	*Per cent.*
Silica	74 45	74.62	74.70
Alumina	14.72	11.96	13.72
Ferric oxide	None ...	1.20	1.01
Ferrous oxide	0.56	0.10	0.62
Ferric sulphide	....	....	0.40
Manganese	0.28	....	Trace.
Lime	0.83	0.36	0.78
Magnesia	0.37	....	0.14
Soda	3.97	2.26	3.90
Potash	4.53	7.76	4.02
Phosphoric anhydride	0.01	....	....
Ignition	0.66	1.02	0.62
	100.38	99.28	99.91
Specific gravity	....	2.2	2.3447

Colors.—These are fully as variable as in the quartz porphyries; white, though all shades of gray, green, brown, yellow, pink, and red are common. Black is the more common color for the glassy varieties of obsidian, though they are often beautifully spotted and streaked with red or reddish-brown as shown in samples 72855 and 72856 from the Yellowstone Park, in 35268 from Glass Buttes, Oregon, 70252 from Mararatio, Mexico, 16248 from the Caucasus, and 11894 from Japan.

Structure.—The liparites present a great variety of structural features, varying from holocrystalline, through porphyritic and felsitic to clear, glassy forms. These varieties can be best understood by reference to the collections and Plates CXXVIII and CXXIX, prepared from photographs. Fig. 1, Pl. CXXVIII, is that of the coarsely crystalline variety nevadite from Chalk Mountains, Colorado; Fig. 2 is that of a common felsitic and porphyritic type; Fig. 3 is that of the clear, glassy form obsidian; Fig. 4 shows also an obsidian, but with a pumiceous structure; Figs. 1 and 2 on Pl. CXXIX show the hollow spherulites or lithophysæ, which have been studied and described by Mr. J. P. Iddings, of the U. S. Geological Survey.‡ Such forms are regarded by Mr. Iddings as resulting "from the action of absorbed vapors upon the molten glass from which they were liberated during the process of crystallization consequent upon cooling." A pronounced flow structure is quite characteristic of the rocks of this group as indicated by the name rhyolite. (See large sample of obsidian No. 72853, from Yellowstone National Park). The microscopic structure of a lip-

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* Geological Exploration 40th Parallel, vol. I, p. 652.

† Annual Report U. S. Geological Survey, 1885–'86, p. 282.

‡ Obsidian Cliff, Yellowstone National Park, Annual Report U. S. Geological Survey, 1885–'86.

arite from High Rock Cañon Nevada (35441), is shown in the colored transparency in the window (39079). Transitions from compact obsidian into pumiceous forms, due to expansion of included moisture, are common, as shown in the samples from the Mono Craters in California and those from the Lipari Islands.

Classification and nomenclature.—The following varieties are now generally recognized, the distinctions being based mainly on structural features, as with the quartz porphyries. We thus have the granitic-appearing variety *nevadite*. The less markedly granular and porphyritic variety *rhyolite*, and the glassy forms *hyaloliparite*, *hyaline rhyolite*, or *obsidian* as it is variously called. Hydrous varieties of the glassy rock with a dull pitch-like luster are sometimes called *rhyolite pitchstone.*

The name *rhyolite*, from the Greek word ῥεω, to flow, it may be stated, was applied by Richtofen as early as 1860 to this class of rocks as occurring on the southern slopes of the Carpathians. Subsequently Roth applied the name liparite to similar rocks occurring on the Lipari Islands. The first name, owing to its priority, is the more generally used for the group, though Professor Rosenbusch in his latest work has adopted the latter. The name *nevadite* is from the State of Nevada and was also proposed by Richtofen. The name obsidian as applied to the glassy variety is stated to have been given in honor of Obsidius, its discoverer, who brought fragments of the rock from Ethiopia to Rome. The name *pantellerite* has been given by Rosenbusch to a liparite in which the porphyritic constituent is anorthoclase.

The following localities and varieties are now represented:

Nevadite: Ten Mile District, Summit County, Colorado, 36872 and 36392; Chalk Mountain, Lake and Summit Counties, 73176; Apati, Hungary (Felso-Nevadite) 36269.

Rhyolite: Near Cortez, Nevada, 35361; Golanda Cañon, Sonoma Range, Nevada, 35327; south end of High Rock Cañon, Nevada, 35357; south end of Ha-wa-wa Mountains, Utah, 35308; Beaver Head Cañon, Montana, 36779; south of Cherry Creek, west side of Madison Valley, Madison County, Montana, 72945; Mount Sheridan, Wyoming, 38835; Yellowstone Cañon, Yellowstone Park, Wyoming, 28829; summit of Flat Mountain, Wyoming, 28843; Pima and Cochiel Counties, Arizona, 28578; Rattlesnake Hill and Querida, Custer County, Colorado, 36871, 36868, and 36870; Hidalgo, Santa Rosa, Zacatecas and Tezintlan, Mexico, 34995, 37734, 37689, 37730, and 37987; Bear Creek Falls, Shasta County, California, 70591; Schemnitz, Eisenbach, Hlinik, Glashutte, Nagy Tolesva, Kremnitz, Hungary, 34590, 36263, 36267, 36266, 36264, 36270, 36271, 36265, 36268, and 70122; Berkune and Kuckstein, in the Siebengebirge, Prussia, 36261, and 36262.

Hyalo-liparite; obsidian: Crater south side of Mono Lake, California, 22901 and 22899; *ibid.*(pumiceous forms), 22904 and 22907; Mono Lake, 8 specimens showing compact and pumiceous forms, 29630, 29631, 37210, 37211; same locality, showing spherulites, 35274; Upper Pit River, California, 1675; Deer Creek Meadows (spherulitic), 38364; Glass Buttes, Oregon, 35268 and 35267; Coyote Springs, Utah, 35265; Beaver Valley, Utah, 35269; obsidian cliffs in the Yellowstone National Park, 10569, 18969, 72855 and 72856; the same locality (spherulitic forms), 18969, 28921, 29106, 10574, 29107, 70676, and 28979; the same locality, with lithophysæ 72852; Obsidian cañon, Yellowstone National Park, 28922, 28923, and 10570; between Madison River and Shoshone Lake, Wyoming, 28914 and 28917; south

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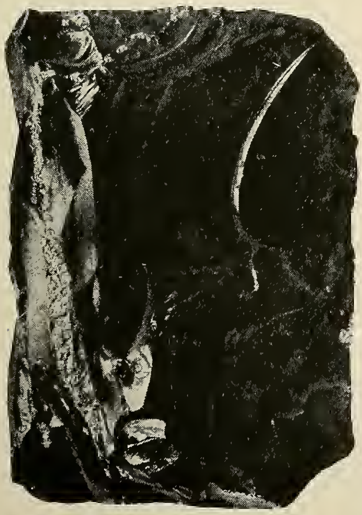

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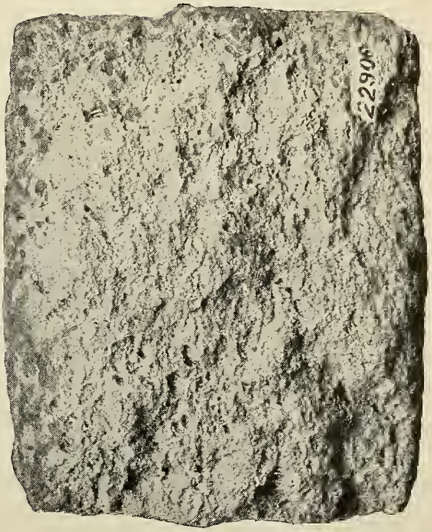

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FIG. 1. Liparite, pumiceous form. (Cat. No. 22906, U. S. N. M.)
FIG. 2. Liparite, obsidian form. (Cat. No. 28922, U. S. N. M.)
FIG. 3. Liparite, rhyolite form. (Cat. No. 72870, U. S. N. M.)
FIG. 4. Liparite, nevadite form. (Cat. No. 73176, U. S. N. M.)

base of Mount Washburn, Wyoming, 28975; east side of Snake River, Wyoming, 37273; Mararteo, Magdalena, Michoacan and Rio del Norte, Mexico, 70252, 35780, 19536, and 19,547; San Juan de los Llanos, Mexico (perlitic), 38130; Guatemala, 35587; Alaska, Beach near Nonikaket River, 6384; island of Lipari, 36184 and 36143; (8 specimens showing common types) *ibid.*, 36284; Ascension Island, 36281; New Zealand, 36110; Mayor Island, Bay of Plenty, New Zealand. 70345; Northeast Iceland, 72810; Mount Gokshi in the Caucasus, 16248; Tokaz, Hungary, 36280; Japan, 11894; Granada, Spain (perlitic), 35720.

Hyalo-liparite, pitchstone.—North slope of Salient Mountain, Nevada, 35402; Esmeralda district, Nevada, 15567 and 15562; south end of Carson Lake, Nevada, 35351; Clear Creek, Colorado, 36988; Rio Grande, Colorado, 5124; Sonora, Mexico, 7058; Grand Cañon Yellowstone River (porphyritic), 36830; Spring Valley, Utah (spherulitic), 1025; Mount Rotaro, Isle of Ischia, 36282; Gallatin Valley, Montana, 73116.

3. THE ORTHOCLASE OR QUARTZ-FREE PORPHYRIES.

Mineral composition.—The essential constituents are the same as those of syenite. They consist therefore of a compact porphyry groundmass with porphyritic feldspar (orthoclase) and accessory plagioclase, quartz, mica, hornblende, or minerals of the pyroxene group. More rarely occur zircon, apatite, magnetite, etc., as in the syenites.

Chemical composition.—Being poor in quartz these rocks are a trifle more basic than the quartz porphyries which they otherwise resemble. The following is the composition of an orthoclase porphyry from Predazzo as given by Kalkowski:* Silica, 64,45; alumina, 16.31; ferrous oxide, 6.49; magnesia, 0.30; lime, 1.10; soda, 5.00; potash, 5.45; water, 0.85 per cent.

Structure.—Excepting that orthoclase is the porphyritic constituent they are structurally identical with the quartz porphyries, and need not be further described here.

Colors.—These are the same as the quartz porphyries already described.

Classification and nomenclature.—The orthoclase or quartz-free porphyries bear the same relation to the syenites as do the quartz porphyries to granite, and the rocks are frequently designated as syenite porphyries. Like the quartz porphyries they occur in intrusive sheets, dikes and lava flows associated with the Paleozoic formations. Owing to the frequent absence of accessory minerals of the ferro-magnesia group the rocks can not in all cases be classified as are the syenites, and distinctive names based upon other features are often applied. The term orthophyr is applied to the normal orthoclase porphyries, and these are subdivided when possible into biotite, hornblende, or augite orthophyr according as either one of these minerals is the predominating accessory. The term *rhombporphyry* has been used to designate an orthoclase porphyry found in Southern Norway, and in which the porphyritic constituent appears in characteristic rhombic outlines, and which is further distinguished by a complete absence of quartz and rarity of hornblende. (Specimens 1660 and 34831.) The

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*Elemente der lithologie, p. 86.

name *keratophyr* has been given by Gümbel to a quartzose or quartz-free porphyry containing a sodium-rich alkaline feldspar. (Specimens 70609, Minnesota; 70194 and 70195, Bavaria; 70186, Hartz Mountains; and 70564, Bomelö, Norway.)

So far as can be at present judged, these rocks are much more restricted in their occurrence than are the quartz porphyries.

The following localities and varieties are represented:

Andlau, Vosges Mountains, Germany, 36304; Hohwald, Vosges Mountains, 36303; Katzenellnogen, Nassau, Germany, 36302; Oldenwald Hesse, Germany, 36301; Christiania Fjord, Norway, 1680; near Christiania, Norway (orthophyr), 70413; Tyvehomen, near Christiania, Norway (rhomb-porphyry), 1660, 34381, and 36456; Pigeon Point, Minnesota (Keratophyr), 70609; Torkel in the Fichtelgebirge, Bavaria (Keratophyr), 70194; Bavaria, 70195; Elbingerode, Hartz Mountains, Germany, 70186; Bammelo, Norway (Keratophyr), 70564.

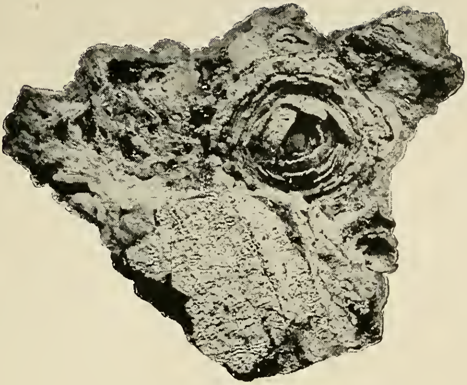
4. THE TRACHYTES.

Trachyte from the Greek word τραχυς, rough, in allusion to the characteristic roughness of the rock. The term was first used by Hauy to designate the well-known volcanic rocks of the Drachenfels on the Rhine.

Mineral composition.—Under the name of trachyte are comprehended by Professor Rosenbusch those massive Tertiary and post-Tertiary eruptive rocks, consisting essentially of sanidin with hornblende augite or black mica, and which may be regarded as the younger equivalents of the quartz-free porphyries. The common accessory minerals are plagioclase, tridymite, apatite, sphene, and magnetite, more rarely olivine (specimen 72988 from the Isle of Ischia); sodalite (specimens 36320, 36321, and 72994 from the Isle of Ischia, and specimens 73013, 73014, and 73017 from near Naples, Italy); humite (specimen 36331 from Monte Somma); hauyne (specimens 36315 to 36317 from the Laacher See), and mellilite (specimen 72997 from Isle of Ischia).

Chemical composition.—The following shows the range in chemical composition of these rocks (I) being that of the trachyte of Game Ridge, Colorado (see specimen 70605) and (II) that of the La Guardia stone. (See specimens 38788 and 73004).

	I.	II.
	Per cent.	*Per cent.*
Silica	66.03	56.09
Alumina	18.49	26.09
Ferric oxide	2.18	1.53
Ferrous oxide	0.22	....
Manganese oxide	Trace.	Trace.
Lime	0.96	3.41
Magnesia	0.39	2.70
Potash	5.86	6.49
Soda	5.22	3.38
Ignition	0.85	1.05
Phosphoric acid (P_2O_5)	0.04	....
Total	100.24	100.74



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2

Obsidian with lithophysæ. (Cat. No. 72851, U. S. N. M.)

Structure.—In structure the trachytes are rarely granular, but possess a fine, scaly or microfelsitic groundmass, rendered porphyritic through the development of scattering crystals of sanidin, hornblende, augite of black mica. The texture is porous, and the rock possesses a characteristic roughness to the touch; hence the derivation of the name as given above. Perlitic structure is common in the glassy forms. The microscopic structure of the trachyte of Monte Vetta is shown in Fig. 5, Plate CXX, as prepared from specimen 36332.

Colors.—The prevailing colors are grayish, yellowish, or reddish.

Classification and nomenclature.—They are divided into hornblende, augite or mica-trachytes, according as any one of these minerals predominates. The name *sanidin-oligoclase trachyte* is sometimes given to trachytes in which both these feldspars appear as prominent constituents. (See specimens from the Siebengebirge, Prussia.) The presence of quartz gives rise to the variety *quartz-trachytes*. (See under rhyolites.) The glassy form of trachyte is commonly known under the name of the *trachyte pitchstone* (specimens 36272, 36276, and 38786 and 72995 from Hungary, Isle of Ponza, and the Isle of Ischia), or if with a perlitic structure simply as perlite. (Specimens 36277, 36278 and 36279 from Hungary.) In his most recent work Professor Rosenbusch has included the glassy forms under the name of *hyalo-trachyte*.

The following localities and varieties are represented.

Trachyte: Game Ridge, near Rosita, Silver Cliff Region, Colorado, 70605; near Carbonate Camp, Black Hills, Dakota, 39097; Isle of Ischia, 36320 to 36326, inclusive, 38336, 35857, and 72,994 to 72998, inclusive; Euganaen Hills, Italy, 36318 and 36319; near Naples, Italy, 36314, 73013, 73014, and 73017; Monte Verginio, Rome, Italy, 36328; Astroni, Naples, Italy, 36327; Monte Bracalon, Italy, 34792; Monte Nuovo, Naples, Italy, 36329; Monte Somma, Italy, 36330 and 36331; Laacher See, Prussia, 36315, 36316, and 36317; Isle of Ponza, Italy, 38788 and 73004; Isle of St. Stefano, 73007; Visegrad, Apatkuter, Hungary, 34569; Moscar, Hungary (Biotite Hypersthene Trachyte), 70183; Hlinik, Hungary (pumiceous), 36312; the Siebengebirge, Prussia, 34644, 36305 to 36308, inclusive, and 36348; Hulsberg, Nassau, Germany (Sanidin-oligoclase-trachyte), 36310; Inselberg, Prussia (sanidin-oligoclase-trachyte), 36311.

Hyalo trachyte—trachyte pitchstone.—Hlinik, Hungary, 36272; Kozelnik, Hungary, 36376; Isle of Ponza, 38786; Pusti Hrad, Hlinik and Kremnitz, Hungary (Perlitic varieties), 36277, 36278, and 36379.

5. THE PHONOLITES.

Phonolite, from the Greek word φωνή, sound, and λίθος, stone, in allusion to the clear ringing or clinking sound which slabs of the stone emit when struck with a hammer; frequently called *clinkstone* for the same reasons.

Mineral composition.—The phonolites consist essentially of sanidin and nepheline or leucite, together with one or more minerals of the augite hornblende group, and generally hauyn or nosean. The common accessories are plagioclase, apatite, sphene, mica, and magnetite; more rarely occur tridymite, melanite, zircon, and olivine. The rock undergoes ready decomposition, and calcite, chlorite, limonite, and various minerals of the zeolite group occur as secondary products.

Chemical composition.—The average of six analyses given by Zirkel* is as follows: Silica, 58.02 per cent.; alumina, 20.03; iron oxides, 6.18; manganese oxide, 0.58; lime, 1.89; magnesia, 0.80; potash, 6.18; soda, 6.35; water, 1.88; specific gravity, 2.58.

Structure.—The phonolites present but little variety in structure, being usually porphyritic, seldom evenly granular. The porphyritic structure is due to the development of large crystals of sanidin, nepheline, leucite, or hauyn, and more rarely hornblende, augite, or sphene, in the fine-grained and compact groundmass, which is usually micro-crystalline, never glassy or amorphous.

Colors.—The prevailing colors are dark gray or greenish.

Classification and nomenclature.—Three varieties are recognized by Professor Rosenbusch, the distinction being founded upon the variation in proportional amounts of the three minerals sanidin, nepheline, or leucite. We thus have, 1st. *Nepheline-phonolite*, consisting essentially of nepheline and sanidin, and which may therefore be regarded as the volcanic equivalent of the nepheline syenite. 2d. *Leucite phonolite*, consisting essentially of leucite and sanidin, and 3d. *Leucitophyr*, which consists essentially of both nepheline and leucite in connection with sanidin, and nearly always melanite.

The following localities and varieties are represented:

Nepheline-phonolite: Black Buttes, Black Hills, Dakota, 39096 and 70608; Rio Janeiro, Brazil, 69974; Serra dos Pocos de Caldas, Prov. do S. Paulo, Brazil 69968; Serra de Tingua, Brazil, 69965 and 70237; Ilha de Fernando Poroula, Prov. de Pernambuco, Brazil, 69970 and 69971; Eifel, Rhenish Prussia, 36344; Ober Scheffhausen Kaiserstuhl, Switzerland, 36346; Schlofsberg, Bohemia, 36347; Kleine Priessen, Bohemia, 36350; Kletschner Berg, Bohemia, (Nosean-sanidin phonolite), 36348; Mileschauer, Mittelgebirge, Bohemia, (Nosean sanidin-phonolite), 36349; Hohen-Mahlberg, Nassau, Germany, 36345; Hohen Krahen, Baden, 38349 and 35371; Gemersbold, Baden, 38350.

Leucite-Phonolite: Civata Castellana, Viterbo, Rocca Monfina, and Bagnoria Cimin Mountains, Italy, 36541, 36540, 36562, and 38790.

Leucitophyr: Englenkopf, Eifel, Prussia, 38337; Burg Olbruck Eifel, Prussia, 35753 and 36351; Dachsbusch, Laacher See, Prussia, 36352; Rieden and Perlerkopf, Laacher See, Prussia, 36353 and 36354.

6. THE PORPHYRITES.

Mineral and chemical composition.—The essential constituents of the porphyrites are the same as of the diorites, from which they differ mainly in structure.

Structure.—The porphyrites, as a rule, show a felsitic or glassy groundmass, as do the quartz porphyries, in which are imbedded quite per-

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* Lehrbuch der petrographie, II, p. 193.

fectly developed porphyritic plagioclases with or without hornblende or black mica. At times, as in the well known "porfido rosso antico," or antique porphyries of Egypt, the groundmass is micro-crystalline, forming thus connecting links between the true diorites and diorite porphyrites. Indeed the rocks of the group may be said to bear the same relation to the diorites in the plagioclase series as do the quartz porphyries to the granites in the orthoclase series, or better yet, they may be compared with the hornblende andesites, of which they are apparently the Palæozoic equivalents.

Colors.—The prevailing colors are dark brown, gray, or greenish.

Classification.—According to the character of prevailing accessory mineral we have *hornblende porphyrite*, or *diorite porphyrite*, as it is sometimes called, and *mica porphyrite*. When, as is frequently the case, neither of the above minerals are developed in recognizable quantities, the rock is designated as simply *porphyrite*. The porphyrites are widespread rocks, very characteristic of the later Palæozoic formations, occurring as contemporaneous lava flows, intrusive sheets, dikes and bosses. The more important localities and varieties exhibited are given in the following list:

Elk Mountains, Colorado, head of Willow Creek, 39197; Mosquito Gulch, Park County, Colorado, 68976 and 68951; north slope Bartlett Mountains, Summit County, Colorado, 68972; Cedar Creek, Madison County, Montana, 72866 and 72880; Jefferson County, Montana, 73170; near Libertyville, New Jersey (mica porphyrite), 72830; Nantasket, Massachusetts, 38514; Terra del Fuego, South America, 1880; North Berwick, Law, England, 36386; Loch Fine, Argyleshire, Scotland, 70380 and 70381; Lake Lugano, 36622 and 36616, 36617 and 36618; Vallee du Lys, Pyrenees, 36375; Quenast, Belgium, 36377; Falkenstein, in the Fichtelgebirge, Bavaria, 36376; Hochwald and Gottesberg, Silesia, 36389 and 36390; Postchappel, Saxony, 36387; Gienberg, Theodorshall, Munster, Wertenberg, Gonnesweiler, Wolfstein, and Namborn (epidiorite porphyrite), Nahe, Prussia, 36379, 36380, 36381, 38384, 36388, 70242, 70185, 70205; Ilfeld, Hartz Mountains, 36385.

7. THE ANDESITES.

Andesite. The name was first used by L. V. Buch in 1835, to designate a type of volcanic rocks found in the Andes Mountains, South America.

Mineral composition.—The essential constituents are soda-lime feldspar, together with black mica, hornblende, augite, or a rhombic pyroxene, and in smaller, usually microscopic proportions, magnetite, ilmenite, hematite, and apatite. Common accessories are olivine, sphene, garnets, quartz, tridymite, orthite, pyrite, and sanidin.

Chemical composition.—The composition of the andesites varies very considerably, the quartz-bearing members naturally showing a much higher percentage of silica. The following table shows the composition of a few typical forms:

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O
1	66.32	14.33	5.53	0.25	2.45	4.64	3.90	1.61	1.13
2	69.51	15.75	3.34	....	2.09	1.71	3.89	3.34	....
3	61.12	11.61	11.64	....	0.61	4.33	3.85	3.52	4.35
4	56.07	19.06	5.39	0.92	2.12	7.70	4.52	1.24	0.99
5	56.19	16.12	4.92	4.43	4.60	7.00	2.96	2.37	1.03
6	58.33	18.17	....	6.03	2.40	6.19	3.20	3.02	0.76

1 Dacite from Kis Sibes Transylvania.
2 Dacite from Lassens Peak, California.
3 Hornblende andesite from hill north of Gold Peak, Nevada.
4 Hornblende andesite from Bogoslof Island, Alaska.
5 Hypersthene andesite, Buffalo Peaks, Colorado.
6 Augite andesite from north of American Flat, Washoe, Nevada.

Structure.—To the unaided eye the andesites present as a rule a compact, amorphous, often rough and porous groundmass carrying porphyritic feldspars and small scales of mica, hornblende, or whatever may be the prevailing accessory; pumiceous forms are not uncommon (specimens 35516 and 36979). Under the microscope the groundmass is found to vary from clear glassy through microlitic forms to almost holocrystalline. The minerals of the groundmass are feldspars in elongated microlites, specks of iron ore, apatite in very perfect forms, and one or more of the accessory ferro-magnesian minerals. The porphyritic constituents present well developed crystalline outlines, or having once been fully developed have suffered from the corrosive action of the molten magma, the feldspars being rounded, and the hornblendes displaying a characteristic black border. A pronounced flow structure is usually developed. The micro-structure as seen by a low power is well shown in the colored transparency in the window number (39080).

Colors.—The prevailing colors are some shade of gray, greenish or reddish.

Classification and nomenclature.—Specific names are given dependent upon the character of the prevailing accessory. We thus have:

Andesites with quartz=*Quartz andesites* or *dacites*
Andesites in which hornblende prevails=*Hornblende andesites.*
Andesites in which augite prevails=*Augite andesites.*
Andesites in which hypersthene prevails=*Hypersthene andesites.*
Andesites in which mica prevails=*Mica andesites.*

The glassy varieties are often known as *hyaline andesites.* The name *propylite* was given by Richthofen to a group of andesitic rocks prevalent in Hungary, Transylvania, and the western United States (specimens No. 36414 and 35323 from Colorado and Nevada and 36481 from Hungary), but these rocks have since been shown by Wadsworth and others to be but altered andesites, and the name has fallen into disuse.

The following varieties and localities are represented:

Quartz andesite: Dacite. Lassen's Peak, California, 70597; State of Mexico, Mexico, 37716; Nagy Ag, Transylvania, 34587 and 34575; Schemnitz, Hungary, 70180 and 70181; Kis Lebes, in the Siebengebirge, 36391.

Hornblende andesite: Pelican Peak, Wyoming, 28900 and 28901; north end of Mono Valley, Nevada, 35497; Mountain Pass, between Bodie and Mono Lake, 35469; Mullin's Ranch, west shore of Pyramid Lake, Nevada (propylite), 35323; Washoe District, Nevada, 24001, 24020, 24026, 24121; south slope Sepulchre Mountain, Yellowstone National Park, 72860; road from Ennis to Virginia City, Madison County, Montana, 72867; Mount Shasta, California, 38362 and 36977; Bogosloff Island, Alaska, 36855 and 37033; Buckskin Gulch, Colorado (propylite), 36414; Oaxaca, Mexico, 37752; Mexico, Mexico, 37770; Ixtapalapa, Mexico, 37711; the Siebengebirge, Prussia, 34579, 34580, 34581, 36400 to 36406 inclusive; Sengelberg, near Salz, Nassau, Germany, 36409; Dahlen, Nassau, Germany, 36407; Wolferding, Nassau, Germany, 36408; Gyalu, Transylvania, 36411; Com Neograd, Hungary, 34585.

Hypersthene andesite: Mount Shasta, California, 36978 and 38363; *ibid*, (pumiceous) 36979; Mono Craters, California, 37216; Zacatecas, Mexico, 37707; Mexico, Mexico, 37712; Volcano of Krakatoa (pumiceous), 35516.

Mica andesite: Geisberg in the Siebengebirge, Rhenish Prussia, 36393; Dilln, Repistye, Kremnitz, Tepla, and Schemnitz, Hungary, 36394, 36395, 36396, 36398, 36399, 70182, 70185; Monte di Capucini, near Viterbo, Italy (with hypersthene), 36397.

Augite andesite: Southeast side of Mono Lake, near Mono Springs Station, California, 35439; west side Humboldt Valley, 35465; Washoe District, Nevada, 24018; near Fort Ellis, Gallatin County, Montana, 38577; South Boulder Creek, Montana (with hypersthene), 73167; Kremnitz, Hungary, 34577, 36484 and 36486; Nagy Banya, Hungary, 36485; Schemnitz, Hungary, 36116, 36482, 34576, 34578; Tokaj, Hungary (with hypersthene), 36487; Bath, Hungary (spherulitic, with hypersthene), 36488; Bagonya, Hungary (with hypersthene), 36489; Kis Kapus, transylvania, 36483; Monte St. Croce, Roccamonfina, Italy (with mica), 73021.

8. THE MELAPHYRS AND AUGITE PORPHYRIES.

The term melaphyr is used by Rosenbusch to designate a volcanic rock occurring in the form of intrusive sheets and lava flows, and consisting essentially of a plagioclase feldspar, augite and olivine, with free iron oxides and an amorphous of porphyry base. The augite porphyrites differ in containing no olivine. The rocks of this group are therefore the porphyritic forms of the olivine bearing and olivine free diabases and gabbros, differing from these in structure, in mode of occurrence, and in belonging in great part to the Carboniferous and older Permian formations.

Structure.—As above noted they are porphyritic rocks with, in their typical forms, an amorphous base, are often amygdaloidal, and with a marked flow structure.

Colors.—In colors they vary through gray or brown to nearly black; often greenish through chloritic and epidotic decomposition, as shown in specimens No. 35940, from Brighton, Massachusetts.

Classification and nomenclature.—According as olivine is present or absent they are divided primarily into melaphyrs and augite porphyrites, the first bearing the same relation to the olivine diabases as do the quartz porphyries to the granites, or the hornblende porphyrites to the diorites, and the second a similar relation to the olivine free diabases. The augite porphyrites are further divided upon structural grounds into (1) *diabase porphyrite*, which include the varieties with holocrystalline diabase granular groundmass of augite, iron ores and feldspars, in which are embedded porphyritic lime-soda feldspars—mainly labradorite—idiomorphic augites, and at times accessory hornblende and black mica; (2) *spilite*, which includes the non-porphyritic compact, sometimes amygdaloidal and decomposed forms such as are known to German petrographers as *dichte diabase*, *diabase mandelstein*, (amygdaloid) *kalk-diabase*, *variolite*, etc.; (3) the true *augite porphyrite*, including the normal porphyritic forms with the amorphous base, and (4) the glassy variety *augite vitrophyrite.*

The following localities and varieties are represented:

Melaphyr: Hingham, Nantasket, and Brighton, Massachusetts, 38378, 38524, and 35940; Taylor's Falls, Minnesota, 26591; Berkshire Cañon, Virginia Range, Nevada, 22405; Ilfeld, in the Harz Mountains, 36474; Heimbach, Asweiler, Sotern and Erzweiler, Nahe, Prussia, 36472, 36469, 36471, and 36470; Berschweiler and Niederbrombach, Nahe, Prussia (Weiselbergite types), 70220 and 70233; Heisterberg, Reidscheid, Oberstein, and Hopstaten, Nahe, Prussia (navite types), 70219, 70221 to 70223 inclusive; Braunshausen, Nahe, Prussia (olivine tholeeit type), 70210; Gersdorf, Saxony, 36475; Neuhaus and Lahn, Silesia, 36473 and 36470.

Augite porphyrite: Barro de Oratorio, Rio Zubara, Province de Str. Catharina, Brazil, 69915; Durham, England, 36462; Christiania, Norway, 70398; Upsala, Sweden (uralite porphyrite), 70196; Bufaure and Fassathal, Tyrol, 36476, and 36461; Hof, in the Fichtelgebirge, Bavaria, 36459; Dillenburg, Baldwinstein, and Langenaubach, Nassau, Germany, 36457, 36460, and 36454; Rubeland, Harz Mountains, Germany, 36455; Elbingerode, Harz Mountains (diabase porphyrite, labradorite porphyrite), 36453; Rosenberg, Nahe, Prussia, 36458; Berneck, in the Fichtelgebirge, Bavaria (spilite type), 70174; Gebweiler, Alsace, Germany (labrodorite porphyrite), 36449, 36450, 36451, and 36452; Cottonwood Creek, Gallatin County, Montana, 38595; Cusel, Nahn, Prussia (cuselite type), 70192 and 70193.

9. The basalts.

Basalt—A very old term used by Pliny and Strabo to designate certain black rocks from Egypt, and which were employed in the arts in early times.*

Mineral composition.—The essential minerals are augite and plagioclase feldspar with olivine in the normal forms; accessory iron ores (magnetite and ilmenite), together with apatite, are always present, and more rarely a rhombic pyroxene, hornblende, black mica, quartz, perowskite, hauyn and nepheline, and minerals of the spinel group. Metallic iron has been found as a constituent of certain basaltic rocks on Disco Island, Greenland (specimen 73164).

Chemical composition.—The composition is quite variable. The following shows the common extremes of variation: Silica, 45 % to 55 %; alumina, 10 % to 18 %; lime, 7 % to 14 %; magnesia, 3 % to 10 %; oxide of iron and manganese, 9 % to 16 %; potash, 0.058 %; soda, 2 % to 5 %; loss by ignition, 1 % to 5 %; specific gravity, 2.85 to 3.10.

Structure.—Basalts vary all the way from clear glassy to holocrystalline forms. The common type is a compact and, to the unaided eye,

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* Teall. British Petrography, p. 136.

homogeneous rock, with a splintery or conchoidal fracture, and showing only porphyritic olivines in such size as to be recognizable. (See specimens Nos. 34752, 35852, and 36500.) Under the microscope they show a groundmass of small feldspar and augite microlites, with perhaps a sprinkling of porphyritic forms of feldspar, augite, and olivine, and a varying amount of interstitial brownish glass; the glass may be wholly or in part replaced by devitrification products, as minute hairs, needles, and granules. A marked flow structure is often developed, the feldspars of the groundmass having flowed around the olivine belonging to the earlier period of consolidation, giving rise to an appearance that may be compared to logs in a mill stream, the olivines representing small islands. (See transparencies No. 39081.) Pumiceous and amygdaloidal forms are common.

Colors.—The prevailing colors are dark, some shade of gray to perfectly black. Red and brown colors are also common. Mineralogically it will be observed the basalts resemble the olivine diabases and melaphyrs, of which they may be regarded as the younger equivalents. Indeed, in very many cases it has been found impossible to ascertain from a study of the specimen alone to which of the three groups it should be referred, so closely at times do they resemble one another.

Classification and nomenclature.—In classifying, the variations in crystalline structure are the controlling factors. As, however, these characteristics are such as may vary almost indefinitely in different portions of the same flow the rule has not been rigidly adhered to here. We thus have:

(1) *Dolerite*, including the coarse-grained almost holo-crystalline variety; (2) *Anamesite*, including the very compact fine-grained variety, the various constituents of which are not distinguishable by the unaided eye; (3) *Basalt* proper, which includes the compact homogeneous, often porphyritic variety, carrying a larger proportion of interstitial glass or devitrification products than either of the above varieties, and (4) *Tachylite*, *hyalomelan* or *hyalobasalt* which includes the vitreous or glassy varieties, the mass having cooled too rapidly to allow it to assume a crystalline structure. These varieties therefore bear the same relation to normal basalt as do the obsidians to the liparites. Other varieties, though less common, are recognizable and characterized by the presence or absence of some predominating accessory mineral. We have thus *quartz*, *hornblende*, and *hypersthene basalt*, etc. An olivine free variety is also recognized.

The basalts are among the most abundant and widespread of the younger eruptive rocks. In the United States they occur mainly in the regions west of the Mississippi River. They are eminently volcanic rocks and occur in the form of lava streams and sheets, often of great extent, and sometimes showing a characteristic columnar structure (see collections under head of structural geology). According to Richthofen the basalts are the latest products of volcanic activity. The quartz basalt from Snag Lake, near Lassen's Peak, California (No. 38604), is regarded by Mr. J. S. Diller as a product of the latest volcanic eruption in California, and perhaps in the United States (Alaska excepted). This lava field covered an area of only about 3 square miles, and trunks of trees killed at the time of the eruption are still standing.

The following localities and varieties are represented:

Olivine free basalt: Stoppelberg, near Wiensbach, Rhon Mountains, Prussia, 70254.

Olivine basalt: Beaver Head County, Montana, 38571; Valmont, Boulder County, Colorado, 36491; near Golden, Jefferson County, Colorado, 36874; Canadian Hills, New Mexico, 29173; Turkey Mountains, New Mexico, 29180; Washoe District, Nevada, 24054; Aurora, Nevada, 35477; Antelope Spur, Mt. Washburn, Wyoming, 29094; Madeline Valley, California, 25322; Ten-mile Creek, Quinn River Valley, Oregon, 35350; Gardiner's River, Yellowstone National Park, 72858; South of Eight-mile creek, west side of Madison Valley, Madison County, Montana, 72799; South branch Bear Creek, East side Madison Valley, Madison County, Montana (olivine rich variety), 72800; South of Cherry Creek, Madison County, Montana, 72944; Agate Pass, Cortez Range, Nevada, 21302; Basalt Hills, Kawsoh Mountains, Nevada, 21998; Unalashka, Alaska, 28076; Lehigh River, Victoria, Australia, 28193; Chatham Islands, Galapagos Archipelago, 70655; Finkenberg, near Bonn, Prussia, 36496; Lowenburg, Jungfernberg, Petersberg, and Oelberg in the Siebengebirge, 36490, 36492, 36493, and 36494; Unkel on the Rhein (Saulen basalt, near Limburgite), 36495; Limburg, Nassau, Germany, 36497; Alsfeld, Hesse, Germany, 36498; Tannenbergsthal in the Erzgeberge, 36499; Groditzberg, Silesia, 34752; Auvergne, France, 35858, San-Miguel, Azores Islands, 35522 and 35524; Zacatecas, Mexico, 37782 and 37786; Serena, Mexico, 37701; Disco Island, Greenland (with native iron), 12118; Thordarfell, Reykjavir, Iceland, 72807; Hawaiian Islands (rich in olivine) 35852.

Quartz basalt: Near Snag Lake, Lassen's Peak, California, 36604.

Hornblende basalt: Rossdorf, Rhon Mountains, Germany, 70264.

Hyalobasalt—Tachylite: Hilo, Hawaiian Islands, 70567; Kilauea, Hawaiian Islands, (Peles Hair), 72947; Gethurms, Vogelsberg, Prussia, 70261 and 70263; Rossdorf, Silesia, 70677.

10. THE TEPHRITES AND BASANITES.

Mineral composition.—The essential constituent of the rocks of this group as given by Rosenbusch are a lime-soda-feldspar and nepheline or leucite, either alone or accompanied by augite. Olivine is essential in basanite. Apatite, the iron ores, and rarely zircon occur in both varieties. Common accessories are sanidin, hornblende, biotite, hauyn (see specimen 34686 from Niedermendig), melanite, perowskite and a mineral of the spinel group.

Chemical composition.—The following is the composition of (I) a nepheline tephrite from Antao Pico da Cruz, Azores, and (II) a nepheline-basanite from San Antonio, Cape Verde Islands, as given by Roth.*

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*Abhandlungen der König. Akad. der Wissenschaften zu Berlin. 1884, p. LXIV.

	I.	II.
	Per ct.	Per ct.
Silica	47.44	43.09
Alumina	23.71	17.45
Iron sesquioxide	6.83	18.99
Iron protoxide	3.53	....
Magnesia	1.95	4.63
Lime	6.47	9.76
Soda	6.40	5.02
Potash	3.34	1.81
Water	1.73	0.33

Structure.—The rocks of this group are as a rule porphyritic with a holo-crystalline groundmass, though sometimes there is present a small amount of amorphous interstitial matter or base; at times amygdaloidal.

Colors.—The colors are dark, some shade of gray or brownish.

Classification and nomenclature.—According to their varying mineral composition Rosenbusch divides them into:

Leucite tephrite = Leucite, augite, plagioclase rocks.
Leucite basanite = Leucite, augite, plagioclase and olivine rocks.
Nepheline tephrite = Nepheline, plagioclase rocks.
Nepheline basanite = Nepheline, plagioclase and olivine rocks.

The rocks it will be observed stand intermediate between the true basalts and the nephelinites to be noted later. The distribution of these rocks is, so far as now known, quite limited.

The following localities and varieties are represented:

Leucite tephrite: Tovalato, near Rome, Italy, 35752.

Leucite basanite: Bosco Reale, Vesuvius, flow of 1751, 36542; Il Granatello, Vesuvius, flow of 1631, 36544; La Scala, Vesuvius, flow of 1631, 36547; Uncino, Vesuvius, flow of 1760, 36545; Cisterna, Monte Somma, 38738 and 38789; Vesuvius flow of 1855, 36546; do., flow of 1872, 36144; Vesuvius, 35724.

Nepheline tephrite: Kleine Priessen, Bohemia, 36534 and 36535; Kostal, Bohemia, 36536; Calvarienberg, Poppenhausen, Rhon Mountains, 36532, 70227, and 70228; Langenscheid, Nassau, Germany, 36537; Niedermendig, Prussia (with Hauyn), 34686; Tavolato, Rome, Italy, 36539; Rocco Monfina, Rome, Italy, 36540; Serra de Tingua, Brazil, 70255.

Nepheline basanite: Hundkoph, Salzungen, Germany, 70229; Stallberg, Rhon Mountains, Germany, 70230; near Rossdorf, Germany, 70231 and 70238; near Weiler, Baden, 35859; Loban, Saxony, 73116, 73117, and 73118.

11. THE PICRITE PORPHYRITES.

Under this head is placed, by Professor Rosenbusch, a small group of rocks so far as now known, very limited in their distribution, and which are regarded as the effusive forms of the plutonic picrites, as bearing the same relation to these rocks as do the melaphyrs to the olivine diabases. The essential constituents are therefore olivine and augite with accessory apatite, iron ores and other minerals mentioned as occurring in the true picrites. Structurally they differ from these rocks in presenting an amorphous base rather than being crystalline throughout. These rocks are supposed to have an important bearing on the origin of the diamond, the diamond bearing rocks of South Africa having been found to be picrite porphyrite (Kimberlite, see specimen No. 73190 from the De Beers mine) cutting highly carbonaceous shales. An examination of the Kentucky peridotite locality, where the rock occurs under quite similar conditions, failed to show that similar results had been there produced, a fact which is supposed to be due in part to the small amount of carbonaceous matter in the surrounding shales.

The group is very limited, and is represented in the collection only by samples from Elliott County, Kentucky (38603 and 38360); Pike County, Arkansas, (72792); Syracuse, Onondaga County, New York (35721 and 70556), and the De Beers diamond mine at Kimberly, South Africa (73190).

12. THE LIMBURGITE AND AUGITITE GROUP.

Limburgite, a name given by Rosenbusch in 1872 to designate this type of rocks as occurring at Limburg, on the Kaiserstuhl in the Rhine. The name Augitite given, since augite is the essential constituent.

These are small groups of eruptive rocks consisting essentially of the mineral augite, with iron ores, and having a glassy base. Olivine is present in the variety Limburgite. The common accessories are the same as those of the basalts. Structurally the rocks so far as known are never holocrystalline, but glassy and porphyritic. They are divided into the olivine-bearing variety limburgite, and the olivine-free variety augitite. The composition of (I), a limburgite from Rhenish Prussia, and (II), an augitite from the Cape Verde Islands, as given by Roth, is as follows:

	I.	II.
	Per cent.	*Per cent.*
Silica	42.24	41.83
Alumina	8.66	18.60
Iron sesquioxide	7.45	16.11
Magnesia	12.27	4.98
Lime	11.76	11.83
Soda	4.02	4.70
Potash	1.08	2,47
Water	3.71	0.91

These rocks are of very limited distribution and at present quite unknown within the limits of North America. The group is represented in the collections as follows:

Limburgites: Limburg ruin on the Kaiserstuhl, near Sasbach, Baden, 34718 and 36589; Hasenberg, Bohemia, 36588; near Xiririca, Prov. de Sao Paulo, Brazil, 69992; Nova Laraugerras, Prov. de Rio Janeiro, Brazil, 69991.

Augitite: Province de Rio Janeiro, Brazil, 69995; Paschkapole, Bohemia, 36590.

13. THE LEUCITE ROCKS.

Mineral composition.—The essential constituent is leucite and a basic augite. A variety of accessories occur, including biotite, hornblende, iron ores, apatite, olivine, plagioclase, nepheline, melilite, and more rarely garnets, hauyn, sphene, chromite, and perowskite. Feldspar as an essential fails entirely.

Chemical composition.—The average chemical composition as given by Blaas* is as follows: Silica, 48.9; alumina, 19.5; iron oxides, 9.2; lime, 8.9; magnesia, 1.9; potash, 6.5; soda, 4.4 per cent.

Structure.—The rocks of this group are, as a rule, fine-grained and often slightly vesicular, presenting to the unaided eye little to distinguish them from the finer grained varieties of ordinary basalt.

Colors.—The prevailing colors are some shades of gray, though sometimes yellowish or brownish.

Classification and nomenclature.—The varietal distinctions are based upon the presence or absence of the mineral olivine and upon structural grounds and various minor characteristics. We have the olivine free variety *Leucitite* and the olivine holding variety *Leucite basalt.*

These rocks have also a very limited distribution, and so far as known are found within the limits of the United States only at the Leucite Hills, Wyoming (specimens 36877 and 72846).

The localities now represented are as follows:

Leucitite: The following localities in the province of Rome, Italy: Capo di Bove, 36560; Aqua acetosa, via Laurentia, 36561; Bagnorea, 36562; Cava di Marino, 36673; Fontana di Papa, Strada d'Albano, 36564; Sta Maria di Galera Bracciano, 36565; Mte. Salumone, Mte. Compatri, 36566; Villa Lancellotti, Frascati, 36567; Colle del Eremita, Mte. Compatri, 36568; Cima del Tuscolo, 36569; Colle dei Cypressi, Mte. Compatri, 36570; Italy, 70232; near Conca, Roccamonfina, Italy, 73020; Serra des Pocos di Caldos, province de la Sao Paulo, Brazil, 69985; N. W. of Points of Rocks, Leucite Hills, Wyoming, 36877 and 72846.

Leucite basalt.—Laacher See, Prussia (with rubelan), 36571; Diefelderstein, Kungskopf, Bausenberg, and Veitskopf, Laacher See, Prussia, 36571 to 36575, inclusive; Pohleberg, near Annaberg in the Erz-Gebirge, Saxony, 36576.

14. THE NEPHELINE ROCKS.

Mineral composition.—These rocks consist essentially of nepheline with a basaltic augite and accessory sanidin, plagioclase, mica, olivine, leucite, minerals of the sodalite group, magnetite, apatite, perowskite, and melanite.

Chemical composition.—Below is given the composition of (I) a nephelinite from the Cape Verde Islands, and (II) a nepheline basalt from the Vogelsberg, Prussia.†

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* Katechismus der Petrographie, p. 117.

† Roth's Gesteine Analysen, 1884.

	I.	II.
	Per cent.	*Per cent.*
Silica	46.95	42.37
Alumina	21.59	8.88
Iron sesquioxide	8.09	11.26
Iron protoxide	....	7.80
Magnesia	2.49	13.01
Lime	7.97	10.93
Soda	8.93	4.51
Potash	2.04	1.21
Water	2.09	0.34
Specific gravity	....	3.103

Colors.—The prevailing colors are various shades of gray to nearly black.

Structure.—Structurally they are porphyritic with a holocrystalline or in part amorphous base, usually fine grained and compact, at times amygdaloidal.

Classification and nomenclature.—These rocks differ from the basalts, which they otherwise greatly resemble, in that they bear the mineral nepheline in place of feldspar. Based upon the presence or absence of olivine we have, first, *Nephaline basalt*, and second, *Nephelinite.* The name *Nepheline dolerite* has been given in some cases to the coarser holocrystalline olivine-bearing varieties.

Like the leucite rocks the rocks of this group are somewhat limited in their distribution. They are at present represented in the collection as follows:

Nephelinite: Herchenberg and Hahnenbacher Ley, Rhenish Prussia, 36550 and 36551; Monte Vulture, near Melfi, Italy (Hauynophyr, so called because rich in the mineral Hauyn), 56552, 73012, and 73010; Neudorf, Saxony (Hauynbasalt), 36548.

Nepheline basalt: Near Weiler, Baden, 35861; Katzenbuckel, in the Odenwald, Baden, 36557 and 73040; Eppstein, in the Taunus Mountains, Germany, 36555; Rossberg, near Rossdorf, Hesse, Germany, 36558; Hydrotachylite in same, 36502; Spechtshausen, Saxony (transitional variety, near Limburgite), Lobau, Saxony, 36553; Salzberg, near Schlan, Bohemia (noseanite of Boricky), 36549; Kletschner Berg, Bohemia, 36554; Scheibenberg, in the Erz-Geberge, 36559.

15. THE MELILITE ROCKS.

Professor Rosenbusch places under this head a small group of rocks heretofore known as melilite basalts, in which the mineral melilite is the chief constituent, with accessory augite, olivine, nepheline, biotite magnetite, perowskite, and spinell. The normal structure is holocrystalline porphyritic, in which the olivine, augite, mica, or occasionally the melilite, appear as porphyritic constituents.

These are rocks of very limited distribution, and at present represented in the Museum collections only by specimens from Wartenberg, Bohemia, and from near Owen, in Wurtemberg (35860 and 36577.)

APPENDIX.

Aside from the collections described above as forming the exhibition series, as illustrative of the mineral aggregates forming any appreciable proportions of the earth's crust, there are in the department, stored away in the table cases, many collections designed primarily for study. These are so arranged as to be accessible to the student on application to the Director of the Museum, and on presentation of proper credentials if such be deemed necessary. The collections thus stored are classed under the head of the study series. In preparing and arranging this series it may be well to state that it is made up largely of such materials as have somewhere and at some time been subject to investigation. Each specimen, after trimming to a size approximating 3 by 4 by 1 inch, has a number painted on it in oil colors, and which refers to a written catalogue in which is given whatever detailed information regarding its source and nature may be in possession of the department. The specimen is then placed in a pasteboard tray, accompanied by a written label containing the same information as given in the catalogue, and placed in the drawers of the table cases. Material which is designed for the study series is, if of a miscellaneous nature, distributed through the collections in a systematic manner, corresponding to that adopted for the exhibition series. Collections which like those from Leadville and the Eureka district, to be noted later, represent systematic work upon rocks of a definite area, or which have been studied as a group for the elucidation of some particular problem, are kept intact in order to best serve the purposes of the investigator. Characteristic rocks have in some cases been selected from these collections for exhibition purposes, but the individuality of the collection is in no case allowed to become destroyed.

The more important collections in this study series are mentioned below:

(1.) *Systematic study series.*—This collection comprises some 3,000 specimens miscellaneous rocks from all parts of the globe classified systematically as in the exhibition series.

(2.) *The Leadville collection.*—This comprises some 380 eruptive, sedimentary and metamorphic rocks and ores as collected and studied by Messrs. S. F. Emmons and C. Whitman Cross, of the U. S. Geological Survey, from the vicinity of Leadville, Colorado. It is a representative collection of the materials described by the above-named authorities in Monograph XII of the U. S. Geological Survey, J. W. Powell Director, and entitled "Geology and Mining Industries of Leadville." A characteristic series of the rocks and ores has been selected out and placed upon exhibition in the section devoted to economic geology (catalogue Nos. 68801–69540, inclusive).

(3.) *The Washoe collections.*—These collections represent the work done by G. F. Becker and colleagues in the Washoe district and Comstock

Lode, Nevada, the results of which were published in Monograph III of the U. S. Geological Survey, entitled "The Geology of the Comstock Lode." They have also been the subject of investigation by Messrs. Hague and Iddings, of the Geological Survey, whose results are embodied in Bulletin No. 7, U. S. Geological Survey, 1885, entitled "The Development of Crystallization in the Igneous Rocks of Washoe, Nevada."

The collection is in part duplicated. There is, first, a series of 198 specimens typical rocks of the region in sizes some 4 by 5 by 1 inches and which is in part upon exhibition. Besides this is the main study series in sizes about 1½ by 1 by ½ inches and comprising 2,064 specimens. (Catalogue Nos. 24001–24198 inclusive, and 70691–72754 inclusive).

(4) *The collections of the fortieth Parallel Survey.*—This comprises some 3,000 specimens eruptive and sedimentary rocks collected by members of the Fortieth Parallel Survey, under the direction of Clarence King in 1867–'73. The eruptive rocks of the series were described by Prof. F. Zirkel in vol. VI (microscopic petrography) of the reports of the U. S. Geological Explorations of the Fortieth Parallel. (Catalogue Nos. 20301 to 23388, inclusive.)

(5) *New Hampshire State Survey, C. H. Hitchcock in charge.*—A collection in the form of rough hand specimens, some 6 by 6 by 1½ inches in dimensions and representing the typical rocks of New Hampshire as described by Hitchcock and Hawes in the reports of the Geological Survey of New Hampshire.

(6) *The Hawes collections.*—These comprise some 350 specimens eruptive and altered rocks, representing in part the work done by Dr. Hawes in connection with the New Hampshire surveys as published in part IV, vol. III, of these reports. It also includes the small fragments described in his paper as the Albany granites and their contact phenomena (Am. Jour. of Science, 1881, XXI, p. 21–32), Cat. Nos. 29628–29290.

(7) *The Pacific Slope quicksilver collections.*—These comprise several hundred small specimens (mostly 4 x 6 cm) rocks and ores from the quicksilver regions of the locality above noted, as collected and described by G. F. Becker and colleagues in Monograph XIII, of the U. S. Geological Survey, entitled Geology of the Quicksilver Deposits of the Pacific Slope.

(8) *U. S. Geological Survey collections, F. V. Hayden in charge.*—The various collections made by the surveys under the direction of F. V. Hayden, mainly from Colorado, New Mexico, Utah, Montana, Wyoming, Idaho, and the Yellowstone National Park. These comprise some 1,200 hand specimens of eruptive and sedimentary rocks. Much valuable material is missing from these, having been lost or destroyed prior to 1880.

(9) *Collections from surveys west of the one hundredth meridian.*—The collections made in 1871–'79 under the direction of Lieut. G. M.

Wheeler, U. S. Engineer Department. These comprise some 680 specimens which, though but little studied by modern methods, are, together with those of the Hayden surveys, kept together for purpose of reference.

(10) *Canadian geological survey.*—A stratigraphic series comprising some 854 hand specimens of rocks from the various geological horizons of Ontario, Quebec, New Brunswick, and Nova Scotia, received from the Canadian authorities at the close of the Centennial Exposition at Philadelphia in 1876.

(11) *Pigeon Point collection.*—This comprises 400 specimens illustrating various contact phenomena, as occurring at Pigeon Point on the north shore of Lake Superior, and as described by Prof. W. S. Bailey in a forthcoming bulletin of the U. S. Geological Survey.

(12) *Menominee Valley and Marquette River collections.*—These comprise 254 specimens illustrative of the dynamic metamorphism of eruptive rocks as described by Dr. G. H. Williams in Bull. No. 62, U. S. Geological Survey.

(13) *Alaska collections.*—These comprise some 250 specimens miscellaneous rocks collected mainly by W. H. Dall in 1866–68.

(14) *Missouri.*—A series comprising 114 characteristic rocks from southwestern Missouri, as collected and described by Prof. E. Haworth. (Catalogue Nos. 38618–38741, inclusive.)

(15) *Bear Paw Mountains, Montana.*—A small series eruptive, metamorphic, and drift rocks from the Bear Paw Mountains, collected by Dr. A. C. White and J. B. Marcou in 1883. (Catalogue Nos. 28666–28743, inclusive.)

(16) *St. Gothard Tunnel.*—A series of metamorphic rocks, comprising some 81 specimens received from the Swiss Commissioner to the Centennial Exposition at Philadelphia in 1876. (Catalogue Nos. 37495-37574.)

(17) *Commander Islands, coast of Kamschatka.*—A small series of the characteristic rocks of these islands, collected by Dr. L. Stejniger in 1882–'83. (Catalogue Nos. 37937–37972.)

(18) *Australian collections.*—A series of some 355 rocks from Victoria, Australia, as received from the Australian centennial commissioners in 1876. (Catalogue Nos. 28121–28475, inclusive.)

(19) *Brazilian collections.*—An interesting series of 266 specimens eruptive and metamorphic rocks received from the governmental geologist, O. A. Derby. (Cat. Nos. 69759–70027.)

(20) *District of Columbia collections.*—This includes a series of several hundred specimens, collected mainly by Prof. Thomas Robinson at intervals of every fifty feet in the tunnel of the Washington Acqueduct extension.

To the extent that facilities have permitted, sections for microscopic study have been prepared from the rocks of both the exhibition and study collections. At the date of writing, the number of these slides amounts to some 4,000. Of these, 2,700 are of rocks in the building-stone collections, and which were prepared in large part under the direction of Dr. G. W. Hawes.