GUIDE TO THE STUDY OF THE COLLECTIONS IN THE SECTION OF APPLIED GEOLOGY.

BY

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PREFATORY NOTE.

The accompanying handbook and guide is an outgrowth of the work of installing and labeling the collections of the economic section of the Division of Physical and Chemical Geology. The term nonmetallic, as used, includes those minerals which, as here exhibited, are utilized in other than metallic forms. The collections, comprising as now arranged, some 2,500 specimens, include therefore some materials which—like the iron oxides—may be utilized as ores of metals. As such they have already been considered in Bulletin No. 42, under the title A Preliminary Descriptive Catalogue of the Systematic Collections in Economic Geology and Metallurgy, by F. P. Dewey. The collection of building and ornamental stones which might perhaps be included herewith has been also the subject of a special handbook published in the Annual Report of the National Museum for 1886, and entitled The Collection of Building and Ornamental Stones in the United States National Museum: A Handbook and Catalogue. By George P. Merrill.

It is scarcely necessary to remark that in the preparation of this work the curator has been hampered by a great dearth of information on certain subjects and burdened with a superabundance on others. Certain materials, such as the coals, phosphates, limes, and cements, would each require a volume, and necessarily must be very imperfectly treated here. In such cases the curator has aimed to give as brief and concise an abstract as the requirements of a handbook would permit, and make up for the deficiencies in the bibliography. In other cases the subjects are treated as fully as the knowledge at hand will allow. In describing occurrences the aim has been to give in detail one or two fairly typical deposits, referring to others more briefly. Naturally the preference has been given to American materials. Statements as to prices and annual production are quite unsatisfactory and of very temporary value at best. But little space has therefore been devoted to this branch of the subject. Technical, chemical, and crystallographic points have been but lightly touched upon, such being already covered by existing literature. Only such statements as to hardness, color, etc., are given as it is thought may be of value in rough preliminary determinations.

The satisfactory installation and classification of collections of this nature are matters of no inconsiderable difficulty. As the materials are utilized for industrial purposes, it might at first thought appear that they should be grouped according to the uses to which they are put, as is commonly done at expositions. Such a plan, however, involves a great amount of repetition, since many of the materials, as diatomaceous earths, the clays, steatite, etc., are used for a variety of purposes. On this account the method of installation, or grouping, adopted is somewhat loose, the materials being grouped (1) by kinds, and under kinds so far as possible (2) by uses. Further than this the character of the material has in many instances rendered it necessary to install those closely related and used, it may be, for quite similar purposes in cases of quite different type as is shown in the hydrocarbon series, the coals, asphalts, etc., being in the deep-wall cases while the petroleums, in bottles, are exhibited in the upright portion of the rail cases.

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GUIDE TO THE STUDY OF THE COLLECTIONS IN THE SECTION OF APPLIED GEOLOGY.

THE NONMETALLIC MINERALS.

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I. ELEMENTS.

1. Carbon.

The numerous compounds of which carbon forms the chief constituent are widely variable in their physical properties and origin. As occurring in nature few of its members possess a definite chemical composition such as would constitute a true mineral species, and they must for the most part be looked upon as indefinite admixtures in which carbon, hydrogen, and oxygen play the more important rôles. For present purposes the entire group may be best considered under the heads of (1) The Pure Carbon series; (2) The Coal series, and (3) The Bitumen series, the distinctions being based mainly on the gradually increasing amounts of volatile hydrocarbons, a change which is accompanied by a variation in physical condition from the hardest of known substances through plastic and liquid to gaseous forms. Here will be considered only the members of the pure carbon series, the others being discussed under the head of hydrocarbon compounds.

Diamond.—This mineral crystallizes in the isometric system, with a tendency toward octahedral forms, the crystals showing curved and striated surfaces. (Specimen No. 53558, U.S.N.M.) The hardness is great, 10 of Dana's scale; the specific gravity varies from 3.1 in the carbonados to 3.5 in good clear crystals. The luster is adamantine; the colors, white or colorless, through yellow, red, orange, green, brown to black. The transparent and highly refractive forms are of value as gems, and can best be discussed in works upon this subject. We have to do here rather with the rough, confused crystalline aggregates or rounded forms, translucent to opaque, which, though of no value as gems, are of the greatest utility in the arts. To such forms the name *black diamond*, *bort*, and *carbonado* are applied. (Specimens Nos. 53668–53671, U.S.N.M.)

Origin and Occurrence.—The origin of the diamond has long been a matter of discussion. A small proportion of the diamonds of the world are found in alluvial deposits of gravel or sand. In the South African fields they occur in a so-called blue gravel, formed, according to Lewis, along the line of contact between an eruptive rock (peridotite) and highly carbonaceous shales. They were regarded by Lewis as originating through the crystallization of the carbon of the shales by the heat of the molten rock. De Launay states, however, that there is no necessary connection between the shales and the diamond, and shows with apparent conclusiveness that the latter occur often in a broken and fragmental condition, such as to indicate beyond doubt that they originated at greater depths and were brought upward as phenocrysts in the molten magma at the time of its intrusion. The primary origin of the diamonds he regards as through the crystallization, under great pressure, of the carbon contained in the basic magma in the form of metallic carbides.

The diamond-bearing rock as above noted is a peridotite often brecciated and more or less serpentinized (Specimen No. 62108, U.S.N.M.). The blue and green gravel formed by the decomposition of this rock is shown in Specimen No. 73188, U.S.N.M. With these are others of the associated, eruptive, and metamorphic rocks, as melaphyr (Specimen No. 73184, U.S.N.M.), quartzite (Specimen No. 73185, U.S.N.M.), shale (Specimen No. 73186, U.S.N.M.), and basalt (Specimen No. 73187, U.S.N.M).

Whether or not a similar origin to that outlined above can be attributed to the Brazilian diamonds is as yet unproven. Their occurrence and association with detrital materials resulting from the breaking down of older rocks, with which they may or may not have been originally associated, renders the problem obscure and difficult of solution.

According to Kunz,[1] 95 per cent of all diamonds at present obtained come from the Kimberly Mines, Griqua Land, west South Africa; of these, some 47 per cent are bort. The remainder come from Brazil, India, and Borneo. A few have been found in North America, the Ural Mountains, and New South Wales, but these countries are not recognized as regular and constant sources of supply.

Uses.—The material, aside from its use as a gem, owes its chief value to its great hardness, and is used as an abrading and cutting medium in cutting diamonds and other gems, glass, and hard materials in general, such as can not be worked by softer and cheaper substances.

With the introduction of machinery into mining and quarrying there

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[1] Gems and Precious Stones. New York, 1890.

has arisen a constant and growing demand for black diamonds, or bort, for the cutting edges of diamond drills, and to a less extent for teeth to diamond saws. (Specimens Nos. 53668 to 53670, U.S.N.M.)

According to a writer in the Iron Age[1] the crystallized diamond is not suitable for these purposes owing to its cleavage property. The best bort or "carbonado" comes, it is said, from Bahia, Brazil, where it is found as small, black pebbles in river gravels. The ordinary sizes used for drills weigh but from one-half to 1 carat, but in special cases pieces weighing from 4 to 6 carats are used. It is stated that the crowns of large drills, 10 inches in diameter, armed with the best grade of carbonado, are sometimes valued as high as $10,000.

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Remarking on the occurrence of platinum associated with peridotites, he calls attention to the fact that Maskelyne had shown the diamonds of South Africa and Borneo to occur in a decomposed peridotite.

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The American Geologist, XI, 1893, p. 282. (Abstract of paper by H. Moissan, Comptes Rendus 1893, pp. 116 and 228.)

Henri Moissan. Study of the Diamantiferous Sands of Brazil.
Engineering and Mining Journal, LXII, 1896, p. 222.

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The Geological Magazine, IV, 1897, p. 366.

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[1] Volume XXXVI, December 24, 1885, p. 11.

L. de Launay. Les Diamants du Cap.
Paris, 1897.
Orville A. Derby. Brazilian Evidence on the Genesis of the Diamond.
The Journal of Geology, VI, 1898, p. 121.
H. W. Furniss. Carbons in Brazil. U. S. Consular Reports, 1898, p. 604. See also Engineering and Mining Journal, LXVI, 1898, p. 608.
M. J. Klincke. Gites Diamantifères de la République sud-Africaine.
Annales des Mines, XIV, 1898, p. 563.

Graphite.—Graphite, plumbago, or black lead, as it is variously called, is a dark steel gray to black lustrous mineral with a black streak; hardness of but 1.2, and a specific gravity of from 2.25 to 2.27. The prevailing form of the mineral is scaly or broadly foliated (Specimen No. 51007, U. S. N. M.), with a bright luster, but it is sometimes quite massive (Specimen No. 61138, U. S. N. M.) and columnar (Specimen No. 59976, U.S.N.M.) or earthy, with a dull coal-like luster (Specimens Nos. 64795 and 63133, U.S.N.M.).

Its most characteristic features are its softness, greasy feeling, and property of soiling everything with which it comes in contact. Molybdenite, the sulphide of molybdenum, is the only mineral with which it is likely to become confounded. This last, however, though very similar in general appearance, gives a streak with a slight greenish tinge, and when fused with soda before the blowpipe yields a sulphur reaction. Chemically, graphite is nearly pure carbon. The name black lead is therefore erroneous and misleading, but has become too firmly established to be easily eradicated.

The analyses given below show the composition of some of the purest natural graphites.

Locality.	Carbon.	Ash.	Volatile matter.
Ceylon	98.817	0.280	0.90
Do	99.792	.05	.158
Buckingham, Canada	97.626	1.78	.594
Do	99.815	.076	.109

As mined the material is almost invariably contaminated by mechanically admixed impurities. Thus the Canadian material (Specimens Nos. 59977, 62153, U.S.N.M.) as mined yields from 22.38 to 30.51 per cent of graphite; the best Bavarian, 53.80 per cent (Specimen No. 52050, U.S.N.M.). The grade of ore that can be economically worked naturally depends upon the character of the impurities and the extent and accessibility of the deposit. It is said[1] that deposits at Ticonderoga, New York, have been worked in which there was but 6 per cent of graphite (Specimen No. 37825, U. S. N. M.).

Occurrence and origin.—Graphite occurs mainly in the older crystal-

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[1] Engineering and Mining Journal, LXV, 1898, p. 256.

line metamorphic rocks, both siliceous and calcareous, sometimes in the form of disseminated scales, as in the crystalline limestone of Essex County, New York (Specimen No. 37825, U.S.N.M), or in embedded masses, streaks, and lumps, often of such dimensions that single blocks of several hundred pounds weight are obtainable. (Specimen No. 59976, U.S.N.M.) It is also found in the form of veins.

The fact that the mineral is carbon, one of the constituents of animal and vegetable life, has led many authorities to regard it, like coal, as of vegetable origin. While this view is very plausible it can not, however, be regarded as in all cases proven.

That graphite may be formed independently of organic life is shown by its presence in cast iron, where it has crystalized out, on cooling, in the form of bright metallic scales. See Specimens Nos. 51298 and 51312 in the metallurgical series of the manufacture of iron.

Carbon is also found in meteorites which are plainly of igneous origin, and which have thus far yielded no certain traces of either plant or animal organisms. It is, however, a well-known fact that coal—itself of organic origin—has in some cases been converted into graphite through metamorphic agencies, and intermediate stages like the graphitic anthracite of Newport, Rhode Island, afford good illustrations of such transitions. (Specimen No. 59099, U.S.N.M.) Certain European authorities[1] have shown that amorphous carbonaceous particles in clay slates have been converted into graphite by the metamorphosing influence of intruded igneous rocks. Prof. J. S. Newberry described an occurrence of this nature in the coal fields of Sonora, Mexico.[2] He says:

> All the western portion of this coal field seems to be much broken by trap dikes which have everywhere metamorphosed the coal and converted it into anthracite. At the locality examined the metamorphic action has been extreme, converting most of the coal into a brilliant but somewhat friable anthracite, containing 3 or 4 per cent of volatile matter. At an outcrop of one of the beds, however, the coal was found converted into graphite, which has a laminated structure, but is unctuous to the touch and marks paper like a lead pencil. The metamorphism is much more complete than at Newport (Rhode Island) [Specimen No. 59099, U.S.N.M.], furnishing the best example yet known to me of the conversion of a bed of coal into graphite.

In New York State, and in Canada, graphite occurs in Laurentian rocks, both in beds and in veins, a portion of the latter being apparently true fissure veins and others shrinkage cracks or segregation veins which traverse in countless numbers the containing rocks. It is said[3] that in the Canadian regions (Specimens Nos. 51007, 59976, U.S.N.M.), the deposits occur generally in limestone or in their immediate vicinity, and that granular varieties of the rock often contain large crystalline

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[1] Beck and Luzi, Berichte der Deutschen Chemischen Gesellschaft, 1891, p. 24.

[2] School of Mines Quarterly, VIII, 1887, p. 334.

[3] See On the Graphite of the Laurentian of Canada, by J. W. Dawson, Proceedings of the Geological Society of London, XXV, 1870, p. 112, and an article on Graphite by Prof. J. F. Kemp in The Mineral Industry, II, 1893, p. 335.

plates of plumbago. At other times the mineral is so finely disseminated as to give a bluish-gray color to the limestone, and the distribution of the bands thus colored seems to mark the stratification of the rock. Further, the plumbago is not confined to the limestones; large crystalline scales of it are occasionally disseminated in pyroxene rock or pyrallolite, and sometimes in quartzite and in feldspathic rocks, or even in magnetic oxide of iron. In addition to these bedded forms, there are also true veins in which graphite occurs associated with calcite, quartz, orthoclase, or pyroxene, and either in disseminated scales, in detached masses, or in bands or layers separated from each other and from the wall rock by feldspar, pyroxene, and quartz. Kemp describes[1] the graphite deposit near Ticonderoga, New York (Specimens Nos. 37825, 66759, U.S.N.M.), as in the form of a true fissure vein, cutting the lamination of the gneissic walls at nearly right angles. The wall rock is a garnetiferous gneiss, with an east and west strike, and the vein runs at the "big mine" north 12° west, and dips 55° west. The vein filling, he says, was evidently orthoclase (or microcline) with quartz and biotite and pockets of calcite. Besides graphite, it contained tourmaline, apatite, pyrite, and sphene.

Walcott[2] describes the graphite at the mines 4 miles west of Hague, on Lake George, New York, as occurring in Algonkian rocks, and as probably of organic origin.

> At the mines the alternating layers of graphite shale or schist form a bed varying from 3 to 13 feet in thickness. The outcrop may be traced for a mile or more. The garnetiferous sandstones form a strong ledge above and below the graphite bed. The appearance is that of a fossil coal bed, the alteration having changed the coal to graphite and the sandstone to indurated, garnetiferous, almost quartzitic sandstones. The character of the graphite bed is well shown in the accompanying plate, from a photograph taken by me in 1890. It is here a little over 9 feet in thickness and is formed of alternating layers of highly graphitic sandy shale and schist. [See Plate 3.]

According to J. Walther[3] the Ceylonese graphite (Specimens Nos. 66857, 62073, U.S.N.M.) occurs in coarsely foliated or stalky masses in veins in gneiss which, where mined, is decomposed to the condition of laterite. The veins are regarded as true fissures, and vary from 12 to 22 cm. (about 4¾ to 8¾ inches) in width.

The graphite of Northern Moravia occurs in gray to black crystalline granular Archæan limestone interbedded with amphibolites and muscovite gneiss, the limestone itself being often serpentinous, in this respect apparently resembling the graphitic portions of the ophicalcites of Essex County, New York. (Specimen No. 70084, U.S.N.M.). The material is quite impure, showing on the average but 53 per cent of carbon and 44 per cent of ash, the latter being made up largely of

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[1] Preliminary Report on the Geology of Essex County, Contributions from the Geological Department of Columbia College, 1893, pp. 452, 453.

[2] Bulletin of the Geological Society of America, X, 1898, p. 227.

[3] Records of the Geological Survey of India, XXIV, 1891, p. 42.

VIEWS IN GRAPHITE MINE NEAR HAGUE, WARREN COUNTY, NEW YORK.
From photographs by Charles D. Walcott.

silica and iron oxide, with a little sulphur, magnesia, and alumina. This graphite is regarded as originating through the metamorphism of vegetable matter included in the original sediments, the agencies of metamorphism being both igneous intrusions and the heat and pressure incidental to the folding of the beds.[1]

As to so much of the graphite as occurs in beds there seems, then, little doubt as to its origin from plant remains which may be imagined to have existed in the form of seaweeds or to have been derived from diffused bituminous matter. The origin of the vein material is not so evident, though it seems probable that it is due to the metamorphism of bituminous matter segregated into veins, like those of albertite in New Brunswick or of gilsonite, etc., in Utah. Kemp states that the Ticonderoga graphite must have reached the fissure as some volatile or liquid hydrocarbon, such as petroleum, and become metamorphosed in time to its present state. Walther believes the Ceylon material to have originated by the reduction of carburetted vapors. (See also under origin of diamonds, p. 166.)

The total quantity of carbon in the form of graphite in the Laurentian rocks of Canada has been estimated by Dawson as equal to that in any similar areas of the Carboniferous system of Pennsylvania.

Sources.—The chief sources of the graphite of commerce are Austria and Ceylon. Other sources of commercial importance are Germany, Italy, Siberia (Specimen No. 61138, U.S.N.M.), the United States, and Canada. The chief deposits of commercial value in the United States are at Ticonderoga, New York, where the graphite occurs in a granular quartz rock, or, according to J. F. Kemp, in "Elliptical Chimneys in Gneiss which are filled with Calcite and Graphite." An earthy, impure graphite, said to be suitable for foundry facings, is mined near Newport, Rhode Island (Specimen No. 53797, U.S.N.M.). About one hundred years ago the material was mined in Bucks County, Pennsylvania. Other American localities represented in the collections are Bloomingdale, New Jersey (Specimen No. 56272, U.S.N.M.); Clintonville, New York (Specimen No. 31597, U.S.N.M.); Hague, Warren County, New York (Specimen No. 63132, U.S.N.M.); Raleigh, Wake County, North Carolina (Specimen No. 63133, U.S.N.M.); Lehigh and Berks counties, Pennsylvania (Specimens Nos. 66952, 66953, U.S.N.M.); Salt Sulphur Springs, West Virginia (Specimen No. 63423, U.S.N.M.); St. Johns, Tooele County, Utah (Specimen No. 62721, U.S.N.M.).

Graphite is a very common mineral in the Laurentian rocks of Canada. The most important known localities are north of the Ottawa River, in the townships of Buckingham, Lochaber, and Grenville (Specimens Nos. 59976, 51007, U.S.N.M.). At Buckingham it is stated masses of graphite have been obtained weighing nearly 5,000 pounds.

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[1] Jahrbuch k. k. Geologische Reichsanstalt, 1897, XLVII, p. 21.

At Grenville the graphite occurs in a gangue consisting mainly of pyroxene, wollastonite, feldspar, and quartz, while the country rock is limestone. Blocks of graphite have been obtained weighing from 700 to 1,500 pounds.[1]

Graphite is also found in Japan (Specimen No. 34359, U.S.N.M.), Australia (Specimen No. 62177, U.S.N.M.), New Zealand (Specimens Nos. 17796 and 64795, U.S.N.M.), Greenland (Specimen No. 65374, U.S.N.M.), Guatemala (Specimen No. 33990, U.S.N.M.), Germany, and in almost all the Austrian provinces, the most important and best known deposits being those of Kaiserberg at St. Michel, where there are five parallel beds occurring in a grayish black graphite schist, the beds varying from a few inches to 6 yards. The only workable deposit in Germany is stated to be at Passau in Bavaria. The material occurs in a feldspathic gneiss, seeming to take the place of the mica (Specimen No. 52050, U.S.N.M.). The beds have been worked chiefly by peasants for centuries, and the output used mainly for crucibles.[2]

Uses.—Graphite is used in the manufacture of "lead" pencils, lubricants, stove blacking, paints, refractory crucibles, and for foundry facings. In the manufacture of pencils only the purest and best varieties are used, and high grades only can be utilized for lubricants (Specimens Nos. 51608–51619, U.S.N.M.). For the other purposes mentioned impure materials can be made to answer. In the manufacture of the Dixon crucibles (Specimens Nos. 51598–51600, U.S.N.M.) a mixture of 50 per cent graphite, 33 per cent of clay, and 17 per cent of sand is used.

Preparation.—In nature graphite is usually associated with harder and heavier materials, which it is necessary to get rid of before the material is of value. In New York it is the custom to crush the rock in a battery of stamps, such as are used in gold mining, and then separate the graphite by washing, its lighter specific gravity permitting it to be floated off on water, while the heavy, injurious constituents are left behind. Mica, owing to its scaly form, can not be separated in this manner, and hence micaceous ores of the mineral are of little if any value.

An improvement in the manufacture of plumbago or graphite has been described in a recent patent specification. Graphite, crushed and passed through a sieve of from 120 to 150 meshes per inch, is stirred into a saturated solution of alum or aluminum sulphate at a temperature of 212° F.; steatite is then added, and more water, if required. After mixing, excess of water is evaporated until a consistency suited to grinding in a chilled steel or other mixer is obtained. More graphite may here be added; then, after thorough grinding, the material may be compressed into cakes for household use, or is ready for the manu-

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[1] Descriptive Catalogue of Economic Minerals of Canada, 1876, p. 122.

[2] The Journal of the Iron and Steel Institute, 1890, p. 739.

facture of pencils or crucibles. The average formula of the mixture is: Graphite, 80 parts; steatite, soapstone, or talc, 14 parts; alum, 6 parts; but this varies with the purpose to which the material is to be applied. When several different kinds of graphite have to be employed, the richest in carbon is first mixed into the alum solution. By this process graphites previously regarded as incapable of being compacted are utilized, and are improved in polishing power. For pencils the material may be hard without being brittle, and black without being soft, while crucibles made from the treated graphite are at once harder, more durable, and lighter.[1]

Prices.—The value of the mineral varies with its quality. In 1899 the crude lump was reported as worth $8 a ton and the pulverized $30.

The annual output as given[2] for the principal countries is as follows:

World's production of graphite.

Year.	Austria.	Canada.	Ceylon.	Germany.	India.	Italy.	United States.
	Metric tons.	*Metric tons.*	*Metric tons.*	*Metric tons.*	*Metric tons.*	*Metric tons.*	*Metric tons.*
1892	20,978	151	21,300	4,036	(*a*)	1,645	707
1893	23,807	Nil.	21,900	3,140	(*a*)	1,465	634
1894	24,121	63	10,718	3,133	1,623	1,575	349
1895	28,443	199	13,711	3.751	(*a*)	2,657	171
1896	35,972	126	10,463	5,248	(*a*)	3,148	184
1897	38,504	396	*b* 19,275	3,861	61	5,650	450
1898	33,062	1,107	*b* 78,509	4,593	22	6,435	824

a Not reported in the Government statistics. *b* Exports.

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[1] Engineering and Mining Journal, LVIII, 1894, p. 440.

[2] The Mineral Industry, VI, 1897; VIII, 1899.

J. Postlethwaite. The Borrowdale Plumbago; its Mode of Occurrence and Probable Origin.

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American Journal of Science, XLII, 1891, p. 514. Review of article in Berichte der Deutschen chemischen Gesellschaft, XXIV, p. 1884, 1891.

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E. Weinschenk. Zur Kenntniss der Graphitlagerstätten. Chemisch-geologische Studien von Dr. Ernst Weinschenk.

1. Die Graphitlagerstätten des bayerischen Grenzgebirges. Habilitationsschrift zur Erlangung der venia legendi an der K. technischen Hochschule. München, 1897.

Franz Kretschmer. The Graphite Deposits of Northern Moravia.

Transactions of the North of England Institute of Mining and Mechanical Engineer, XLVII, 1898, p. 87.

2. Sulphur.

Color of the mineral when pure yellow, sometimes brownish, reddish, or gray through impurities. Hardness, 1.5 to 2.5. Specific gravity, 2.05. Insoluble in water or acids. Luster resinous. Occurs native in beautiful crystals (Specimens Nos. 53115, 53116, and 60669, U.S.N.M.) or in massive (Specimens Nos. 16092, 60849, U.S.N.M.), stalactitic and spheriodal forms (Specimens Nos. 57137 and 60864, U.S.N.M.). Once seen the mineral is as a rule readily recognized, and all possible doubts are set at rest by its ready inflammability, burning with a faint bluish flame and giving the irritating odors of sulphurous anhydride. In nature often impure through the presence of clay and bituminous matters; sometimes contains traces of selenium or tellurium (Specimens Nos. 60856 and 60864, U.S.N.M.).

Origin and mode of occurrence.—Sulphur deposits of such extent as to be of economic importance occur as a product of volcanic activity, or result from the alteration of beds of gypsum. On a smaller scale, and of interest from a purely mineralogical standpoint, are the occurrences of sulphur through the alteration of pyrite and other metallic sulphides.

As a product of volcanic action sulphur is formed through the oxidation of hydrogen disulphide (H_2S), which, together with steam and other vapors, is a common exhalation from volcanic vents and solfataras. Such deposits on a small scale may be seen incrusting fumaroles in the Roaring Mountain (Specimen No. 72872, U.S.N.M.) or associated with the sinter deposits of the Mammoth Hot Springs in the Yellowstone Park (Specimen No. 72877, U.S.N.M.). It may also be produced through the mutual reaction of hydrogen disulphide (H_2S) on sulphuric anhydride (SO_3), the product being sulphur (S) and water (H_2O) as before. To these types belong the sulphur deposits of Utah, California, Nevada, and Alaska in the United States, as well as those of Mexico, Japan, Iceland, and other volcanic regions. Sulphur is derived from the sulphate of lime (gypsum or anhydrite) through the reducing action of organic matter. The sulphate, through the loss of its oxygen, becomes converted into a sulphide, which, through the carbonic acid in the air and water, becomes finally reduced to hydrogen disulphide with the formation of calcium carbonate.

According to Fuchs and De Launay[1] there is formed at the same time with the hydrogen disulphide a polysulphide, which in its turn yields a precipitate of sulphur and carbonate of lime. The maximum amount of sulphur which would thus result from the decomposition of a given amount of gypsum is stated to be 24 per cent. This method of origin is illustrated in the celebrated deposit of Sicily, where we have the sulphur partially disseminated through and partly interbedded with a blue-gray limestone. (See Specimen No. 60932, U.S.N.M.). Beneath the sulphur beds as they now exist are found the older gypseous beds, which through decomposition have yielded the materials for the lime and sulphur beds now overlying.

With these Sicilian sulphurs occur a number of beautiful secondary minerals, as celestite (Specimens Nos. 60866, 60869, 60877, U.S.N.M.), calcite (Specimens Nos. 60854, 60865, 60871, U.S.N.M.), aragonite (Specimen No. 60859, U.S.N.M.), and selenite (Specimen No. 60857, U.S.N.M.).

Sulphur derived directly from metallic sulphides is of little economic interest. Kemp states[2] that masses of pyrite in the calciferous strata on Lake Champlain may yield crusts of sulphur an inch or so thick, and it is not uncommon to find small crystals of the mineral resulting from the alteration of galena, as described by George H. Williams[3] at the Mountain View (Maryland) lead mine.

The minute quantities of sulphur found in marine muds are regarded by J. Y. Buchanan[4] as due to the oxidation of metallic sulphides, which are themselves produced by the action of animal digestive secretions on preexisting sulphates, mainly of iron and manganese.

Localities.—The principal localities of sulphur known in the United States are, in alphabetical order: Alaska, California, Idaho, Louisiana, Nevada, Texas, Utah, and Wyoming. With the possible exception of those of Idaho and Texas, and that of Louisiana, these may all be traced to a solfataric origin. The Alaskan deposit,[5] according to Dall, are best developed on the islands of Kadiak and Akutan.

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[1] Traité des Gîtes Minéraux et Métallifères, I, p. 259.

[2] The Mineral Industry, II, 1893, p. 585.

[3] Johns Hopkins University Circulars, X, 1891, p. 74.

[4] Proceedings of the Royal Society of Edinburgh, XVIII, 1890–91, p. 17.

[5] Alaska and its Resources, Boston, 1870.

California deposits have in times past been worked at Clear Lake, in Modoc County, in Colusa County, in Tehama County (Specimen No. 30118, U.S.N.M.), and in Napa County (Specimen No. 67697, U.S.N.M.). The Louisiana deposits lie in strata of Quaternary age, and are derived from gypsum. The following facts relative to this deposit are from Professor Kemp's paper, already alluded to:

> Probably the richest and geographically the most accessible of the American localities is in southwestern Louisiana, 230 miles west of New Orleans and 12 miles from Lake Charles. The first hole which revealed this sulphur was sunk in search of petroleum, of which the presence of oil and tarry matter on the surface were regarded, quite justly, as an indication. While more or less of these bituminous substances were revealed by the drill, the great bed of sulphur is the main object of interest. A number of holes have since been put down with the results recorded below, and they leave no doubt that there is a very large body which awaits exploitation. The first explorations were made by the Louisiana Petroleum and Coal Oil Company. It was succeeded by the Calcasieu Sulphur and Mining Company. The Louisiana Sulphur Mining Company followed, and now the owners are the American Sulphur Company. The records of four holes are appended. Nos. 1 and 2 were the first sunk, and were about 150 feet apart. Nos. 2, 3, and 4 were put down in 1886. No. 3 is northwest of No. 1.

Records of several of the bore holes that have penetrated the sulphur bed.

Strata.	Original well No. 1.	Granet's Wells.			Van Slooten's well No. 5.	American Sulphur Company.		
		No. 2.	No. 3.	No. 4.		No. 6.	No. 7.	No. 8.
Clay, quicksand, and gravel	333	344	426	332	345	350	370	499
Soft rock	110	84	70	138	91	95	72	44
Sulphur bed, 70 to 80 per cent	108	112	119	45	110	125	126	52
Gypsum and sulphur	680	12	6	(*a*)	57	32	30	(*a*)
Depth of hole	1,231	552	621	525	603	602	598	596

a Stopped in sulphur.

Analyses from the large bed in holes No. 2 and No. 3 gave the following:

Depth.	Sulphur.	Depth.	Sulphur.
Hole No. 2.	*Per cent.*	*Hole No. 3.*	*Per cent.*
428 feet	62	503 feet	70
441 feet	70	533 feet	60
459 feet	80	549 feet	81
466 feet	83	552 feet	91
486 feet	90	604 feet	98
— feet	80		
— feet	75		
— feet	80		
540 feet	68		

The difficulties in development lie in the quicksands and gravel, which are wet and soft, and in the soft rock (hole 1), which yields sulphurous waters under a head, at the surface, of about 15 feet.

The Nevada deposits occupy the craters of extinct hot springs near Humboldt House. These craters are described by Russell[1] as situated on the open desert, above the surface of which they rise to a height of from 20 to 50 feet.

> Nearly all of the cones are weathered and broken down, and are all extinct, the water now rising to the surface for miles around. The outer surface of the cones is composed of calcareous tufa and siliceous sinter, forming irregular imbricated sheets that slope away at a low angle from the orifice at the top. The interiors of these structures are filled with crystalline gypsum, that in at least two instances is impregnated with sulphur. One of the cones has been opened by a cut from the side in such a manner as to expose a good section of the material filling the interior, and a few tons of the sulphur and gypsum removed. The percentage of sulphur is small, and the economic importance of the deposit, as shown by the excavation already made, will not warrant the further expenditure of capital. The cone that has been opened is surrounded on all sides by a large deposit of calcareous and siliceous material, thus forming a low dome or crater, with a base many times as great in diameter as the height of the deposit. These cones correspond in all their essential features with the structures that surround hot springs that are still active in various parts of the Great Basin, thus leaving no question as to their origin. They are situated within the basin of Lake Lahontan, and must have been formed and become extinct since the old lake evaporated away.

Sulphur is reported as occurring in the chemically formed deposits that surrounded Steamboat Springs, situated midway between Carson and Reno, Nevada. The conditions at these springs must be very similar to those that existed near Humboldt House at the time the cones containing the sulphur were formed. Sulphur is also said to occur in the Sweetwater Mountains, situated on the boundary between California and Nevada, in latitude 38° 30′. The extent and geological relations of these deposits are unknown.

Another illustration of sulphur deposits of the volcanic type is that furnished by the Rabbit-Hole Sulphur Mines (Specimen No. 16092, U.S.N.M.). These are located in northwestern Nevada, on the eastern border of the Black Rock Desert, and derive their name from the Rabbit-Hole Springs, a few miles to the southward. The hills bordering the Black Rock Desert on the east are mainly of rhyolite, with a narrow band of volcanic tufa along the immediate edge of the desert. These beds of tufa are stratified and evidently water-lain, and are identical with tufa deposits that occur over an immense area in Oregon and Nevada. At the sulphur mines the tufas contain angular fragments of volcanic rock, and have been cemented by opal and other siliceous infiltrations since their deposition, so that they now form brittle siliceous rocks, with pebbles and fragments of older rocks scattered through the mass.

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[1] Transactions of the New York Academy of Sciences, I, 1881–1882, p. 172.

In many places these porous tufas and breccias are richly charged with sulphur, which fills all the interstices of the rock and sometimes lines large cavities with layers of crystals 5 or 6 feet in thickness. In the Rabbit-Hole District sulphur has been found in paying quantities for a distance of several miles along the border of the desert, but the distribution is irregular and uncertain, and is always superficial, so far as can be judged by the present openings. The sulphur has undoubtedly been derived from a deeply seated source, from which it has been expelled by heat, and escaping upward along the lines of faulting has been deposited in the cooler and higher rocks in which it is now found, though whether the deposition took place by direct sublimation or through the decomposition of hydrogen disulphide can not now be told with certainty. Judging from the siliceous material that cements the tufas, it is evident that the porous rocks in which the sulphur is now found were penetrated by heated waters bearing silica in solution previous to the deposition of the sulphur. The mines occur in a narrow north-and-south belt along a line of ancient faulting which is one of the great structural features of the region. The association of faults with sulphur-bearing strata of tufa is here essentially the same as at the Cove Creek Mines, yet to be noted. At the Rabbit-Hole Mines, however, no very recent movement of the ancient fault could be determined. This absence of a recent fault-scarp, together with the fact that the mines are now cold and do not give off exhalations of gas or vapor, shows that the solfataric action at this locality has long been extinct, though at the Cove Creek Mines, mentioned below, the deposition is still in progress.

According to A. F. Du Faur[1] this Cove Creek (Utah) deposit is in Beaver County, near Millard County line. It was first discovered in 1869, but owing to lack of railroad communications remained undeveloped until 1883. The region is one of comparatively recent volcanic activity. The sulphur occurs impregnating limestone and slate to such a degree that very pure pieces as large as one foot in diameter are obtainable. It also occurs impregnating a decomposed andesite (Specimen No. 14921, U.S.N.M.). The Cove Creek mines are situated about 2 miles southeast of Cove Creek fort and to the east of the Beaver road in a small basin near the foot of the Sulphur Mountains, surrounded by low hills, with a narrow ravine opening in the west-northwest direction into the plain. The basin is about 6,000 feet above the level of the sea, while the Sulphur Mountains to the east rise about 2,000 feet higher. The hills surrounding the basin consist mainly of andesite, partly also of a very light white trachyte.

As far as explored, the sulphur bed extends at least 1,800 feet by 1,000 feet, and the quantity of sulphur contained therein was estimated

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[1] Transactions of the American Institute of Mining Engineers, XVI, 1888, p. 33.

by Professor vom Rath, at a time when the bed was not as fully exposed as it now is, to be at least 1,300,000 tons.

A curved cut has been made through the sulphur bed near the western end, exposing a vertical wall 34 feet high of rich yellow sulphur. The sulphur extends up to the surface over part of the basin, but is mostly covered with sand or rather decomposed andesite. The surface of the deposit is wavy, giving the impression of an agitated mass gradually cooled. The sulphur is partly mixed with sand or gypsum. Most of it is yellow color, while some of it is dark gray, and is called "black sulphur." The deposits of pure sulphur partly resemble the so-called "virgin rock," which is formed as a product of distillation in the sulphur-flower chambers, particularly when distillation goes on too rapidly. Some also resemble the delicate crystals formed on the walls of such chambers; others are like the crystals formed in slowly cooled masses of sulphur. Gases escape in many places in the cut and in the prospect holes, together with water holding salts in solution. At some points also a considerably elevated temperature is observed.

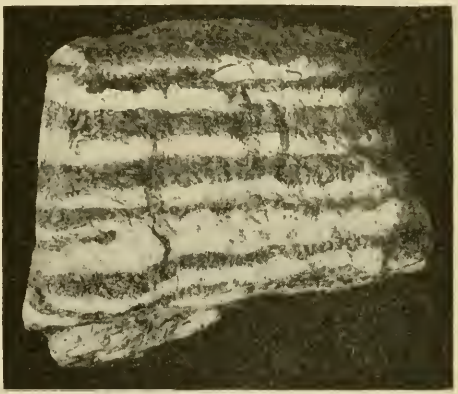

Fig. 1.
BLOCK OF LIMESTONE WITH ALTERNATING BANDS OF SULPHUR.
Sicily, Italy.
Specimen No. 60932, U.S.N.M.

Of the foreign localities of sulphur, the most noted at present are those of Sicily and Japan. The first-named deposits are described as occurring in Miocene strata involving, from below up, sandy marls with beds of salt, limey marls and lignite, gypsum and limestone impregnated with sulphur, black shales, and micaceous sands. Overlying all these is a white, marly Pleocene limestone, while below the Miocene is the Eocene nummulitic limestone. The sulphur is found in veinlets and sometimes in larger masses, which ramify through the cellular limestone, as shown in fig. 1 and Specimens Nos. 60932, 60862, 60852, U.S.N.M.

The yield in sulphur varies from 8 to 25 per cent, rarely running as high as 40 per cent. Below 8 per cent the rock can not be worked. More or less petroleum and bitumen are found in the mines. Barite and celestite sometimes accompany the sulphur.

The mining regions are in the southern central portion of the island Girgenti and Larcara are the chief centers. The mines are distributed over an area 160 to 170 kilometers (about 100 miles) from east to west, and 85 to 90 kilometers (55 miles) from north to south. They occur in groups around centers, partly because the sulphur-bearing stratum is not continuous, and partly because the sulphur indications are concealed by later deposits. The region, moreover, is much faulted.

According to Professor Kemp, the common methods of mining are of the crudest description. In most cases the deposits are reached by steep slopes or circular stairways ("scala"), with wide steps, up which boys laboriously bring the crude rock in baskets or sacks. No mine maps are made, and no precautions taken to work beds on a systematic scale. Timbering or any supports for the roof are not generally thought of. A feeling of distrust prevails between the owners of the land and the operators, and between the latter and the miners.

These objectionable features arise partly from the irregular nature and uncertainty of the deposits, partly from excessive subdivision of ownership and ill-adapted property laws, and partly from the local prejudices against innovations. Even in one case where an American and an Englishman in partnership secured the right to work a mine, and set about installing suitable hoisting machinery, they were hampered by a lawsuit with the owner because of this innovation, and had a long legal contention to establish their undoubted rights. It is a striking fact that in the new developments in Japan, on a remote island and against great natural difficulties, the most modern methods and management prevail, while in Sicily, in the center of the oldest civilization, these are to a great extent of the crudest.

The Japanese sulphur deposits are all of volcanic origin, and the Abosanobori mine (Specimen No. 61941, U.S.N.M.), in Kushiro village, Kawakami-gori, Kushiro Province, Hokkaido, may be taken as fairly typical. The mine is on a conical-shaped mountain of augite andesite which, on its northern side is open, and looks down upon a plain covered with lava and shut in by the walls of the old crater on the other sides. Sulphur is found in different parts of these walls in massive heaps and sulphur fumes still issue nearly everywhere about the mines. The ore as taken from the mines carries from 35 per cent to 90 per cent of sulphur, which is extracted by steam refining works at Hyocha, some 35 miles north of the mine.[1]

Other Japanese localities represented in the collection are the Aroya mines, at Onikobe village, Rikuzen Province (Specimen No. 61945, U.S.N.M.), refined sulphur from the Mitsui Production Company at Tokio (Specimen No. 61944, U.S.N.M.), and the active volcano of Icvo-San, in Yezo (Specimen No. 72801, U.S.N.M.).

In addition to these localities may be mentioned the following, in alphabetical order: Austria, Celebes, Egypt, France, Greece, Hawaii, Iceland, Italy, Mexico (Specimens Nos. 57136 and 57137 from Popocatepetl), New South Wales, New Zealand, Peru, Russia, Spain, and the West Indies (Specimen No. 33309, U.S.N.M.).

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[1] The Mining Industry of Japan, by Wada Tsunashiro, 1893.

Extraction and preparation.—Sulphur rarely occurs in nature in any quantity sufficiently pure for commercial purposes. In freeing it from its impurities three methods are employed: (1) Melting, (2) distillation, and (3) solution. In the first the ore is simply dry washed at a low temperature or treated with superheated steam until the sulphur melts and runs off. Specimen No. 60861 shows the rock after being subjected to this treatment. The first process is extremely wasteful; the second much more economical in the end, but demanding a more expensive plant. A process of fusion in a calcium chloride solution has come into use of late years, and bids fair to yield better results than either of the above. In the distillation process the ore is heated in iron retorts until the sulphur distills off and is condensed in chambers prepared for it. Specimen No. 60860 shows the rock after removal of the sulphur by this process. The product is mostly in the form of "flower of sulphur." The method is expensive, but the resultant sulphur very pure. In the third process mentioned the ore is treated with carbon disulphide, which dissolves out the sulphur and from which it is recovered by evaporation. This method, while giving good results, is expensive and somewhat dangerous, owing to the explosive nature of the gases formed.[1]

Uses.—Sulphur is used mainly for making of sulphuric acid—though small amounts are utilized in the manufacture of matches—for medicinal purposes, and in the making of gunpowder, fireworks, insecticides, for vulcanizing india rubber, etc. In the manufacture of sulphuric acid the sulphur is burned to sulphurous anhydride (SO_2) on a grate and then conducted with a slight excess of air into large lead-lined chambers and mixed with steam and nitrous fumes, where the SO_2 is oxidized to the condition of SO_3 (sulphuric anhydride) and takes up water from the steam forming H_2SO_4 (sulphuric acid). Ordinary roll sulphur is quoted in the current price lists at from 1½ to 2½ cents per pound. (See also under iron pyrites, p. 190.)

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[1] The Mineral Industry, II, 1893, p. 600.

3. ARSENIC.

This substance occurs native in the form of a brittle, tin-white metal, with a specific gravity of 5.6 to 5.7 and a hardness equal to 3.5 of the scale. On exposure it becomes dull black on the immediate surface. It is found, as a rule, in veins in the older crystalline rocks associated with antimony and ores of gold and silver. Some of the more celebrated localities for the mineral, as given by Dana, are the silver mines of Freiberg (Specimens Nos. 60924 and 67730, U.S.N.M.), Annaberg, Marienberg, and Schneeberg in Saxony; Joachimsthal in Bohemia; Andreasberg in the Harz; Kapnik and Orawitza in Hungary; Kongsberg in Norway; Zmeov in Siberia; St. Maria aux Mines, Alsace; Mount Corna dei Darden, Italy; Chañarcillo, Chili; San Augustin, Hidalgo, Mexico, and New Zealand. In the United States it has been found at Haverhill, New Hampshire; Greenwood, Maine; near Leadville, Colorado; and on Watson Creek, Frozen River in British Columbia.

The arsenic of commerce is, however, rarely obtained from the native mineral, but is prepared by the ignition of arsenical pyrites ($FeAs_2$) or arsenical iron pyrites ($FeS_2,FeAs_2$). The white arsenic of commerce (arsenious acid, As_2O_3), though occurring sometimes native as arsenolite in the form of botryoidal and stalactitic crusts of a white or yellowish color, is, as a rule, obtained as a by-product in the metallurgical operations of extracting certain metals, particularly cobalt and nickel, from their ores. Such ores as niccolite, a nickel arsenide ($NiAs$), gersdorffite ($NiAsS$), Rammelsbergite ($NiAs_2$), Smaltite ($CoAs_2$), Skutterudite ($CoAs_3$), Proustite (Ag_3AsS_3), and other arsenides and sulpharsenides on roasting give up their arsenic in the form of fumes, which are condensed in chambers prepared for this purpose.

Uses.—Arsenic is utilized in the form of arsenious acid (As_2O_3) in dyeing, calico printing, in the manufacture of various pigments, in arsenical soaps, in the preparation of other salts of arsenic, and as a preservative in museums, particularly for the skins of animals and birds.

4. ALLEMONTITE.

Allemontite, or arsenical antimony of the formula $SbAs_3$, =arsenic 65.2; antimony 34.8, occurs somewhat sparsely at Allemont in France, Pribram, Bohemia, and other European localities associated with sphalerite, antimony, etc. (Specimen No. 67728, U.S.N.M.). So far as the writer has information the mineral has not as yet been found in sufficient quantity to be of economic value.

II. SULPHIDES AND ARSENIDES.

1. Realgar.

This is a monosulphide of arsenic, AsS, = sulphur 29.9 per cent; arsenic, 70.1 per cent; hardness, 1.5 to 2; specific gravity, 3.55; color, aurora red or orange yellow, streak the same.

2. Orpiment; Auripigment.

A trisulphide of arsenic, of the formula As_2S_3, = sulphur 39 per cent, arsenic, 61; hardness, 1.5; specific gravity, 3.4 to 3.5. Color, lemon yellow. This mineral occurs usually associated with realgar at the localities mentioned below.

Occurrences.—Realgar and orpiment are very beautiful, though not abundant minerals which occur associated with ores of silver and lead in various European mining regions and also those of Japan (Specimen No. 11864, U.S.N.M.), Hungary (Specimen No. 66813, U.S.N.M.), Bohemia, Transylvania, and Saxony. They have been reported in the United States in beds of sandy clay beneath lava in Iron County, Utah, and form the so-called "Arsenical gold ore" of the Golden Gate Mine, Mercur, Tooele County, this same State (Specimen No. 53363, U.S.N.M.); also in San Bernardino County, California; Douglas County, Oregon (Specimen No. 62101, U.S.N.M.), and in minute quantities in the geyser waters of the Yellowstone National Park.

The realgar and orpiment of the Coyote mining district, Iron County, Utah, occur in a compact, sandy clay, occupying a horizontal seam or layer about 2 inches thick, not distinctly separated from the clay, but lying in its midst in lenticular and nodular masses. The bulk of the layer consists of realgar in divergent, bladed crystals, closely and confusedly aggregated, sometimes forming groups of brilliant crystalline facets in small cavities toward the center of the mass. The orpiment is closely associated with the realgar in the form of small and delicately fibrous crystalline rosettes, and small spherical aggregations made up of fine radial crystals, and also in bright yellow, amorphous crusts in and around the mass of the realgar. Fine parallel seams of gypsum occur both above and below the layer, and the strata of arenaceous clays above for 30 feet or more are charged with soluble salts which exude and effloresce upon the surface of the bank, forming hard crusts. The whole appearance and association of the minerals indicates that they have been formed by aqueous infiltration since the deposition of the beds.[1]

Orpiment is said[2] to occur at Tajowa, near Neusohl, Hungary, as nodular masses and isolated crystals in clay or calcareous marl.

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[1] W. P. Blake, American Journal of Science, XXI, 1881, p. 219.

[2] H. A. Miers, Mineralogical Magazine, July, 1892, p. 24.

Uses.—Realgar is used mainly in pyrotechny, yielding a very brilliant white light when mixed with saltpeter and ignited. It is now artificially prepared by fusing together sulphur and arsenious acid.[1] Orpiment is used in dyeing and in preparation of a paste for removing hair from skins. According to the British consular reports there were exported from Baghdan, in 1897, some 55,600 pounds of the mineral for use as a pigment. As with realgar, the mineral is now largely prepared artificially. The name "orpiment" is stated by Dana to be a corruption of *auripigment*, golden paint, in allusion to the color.

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3. Cobalt Minerals.

Several minerals contain cobalt as one of their essential constituents in sufficient quantity to make them of value as ores. In other cases the cobalt exists in too small quantities to pay for working for this substance alone, and it is obtained as a by-product during the process of extraction of other metals, notably of nickel. The common cobalt-bearing minerals, together with their chemical composition, mode of occurrence, and other characteristics are given below:

Cobaltite.—Cobaltine, or cobalt glance. (Specimens Nos. 60922, 34266, U.S.N.M.) This is a sulpharsenide of cobalt of the formula $Co AsS$, =Sulphur 19.3 per cent; arsenic, 45.2 per cent; cobalt, 35.5 per cent; hardness 5.5, and specific gravity 6 to 6.3. The luster is metallic and color silver white to reddish. When in crystals, commonly in cubes or pyritohedrons. Analysis of a massive variety from I, Siegen, Westphalia; II, Skutterud, Norway, and III and IV, Daschkessan, in the government of Elizavetpol, Caucasus, as given by various authorities, yielded results as below:

Constituents.	I.	II.	III.	IV.
Arsenic	45.31	43.46	35.97	31.73
Sulphur	19.35	20.08	....	....
Cobalt	33.71	33.10	17.90	17.55
Iron	1.63	3.23	1.44	9.85
Nickel	....	....	0.22	0.26
Undetermined	....	....	44.26	40.71

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[1] Wagner's Chemical Technology, p. 87.

In Saxony the mineral (Specimens Nos. 60922 and 67736, U.S.N.M.) occurs in lodes in gneiss and in which heavy spar (baryte) forms the characteristic gangue. It is associated with other metallic sulphides, notably those of lead and copper. At Skutterud and Snarum, Norway, the cobaltiferous fahlbands, according to Phillips[1]—

> Occur in crystalline rocks varying in character between gneiss and mica schists, but from the presence of hornblende they sometimes pass into hornblende schists; among the accessory minerals are garnet, tourmaline, and graphite. These schists, of which the strike is north and south, and which have an almost perpendicular dip, contain fahlbands very similar in character to those of Kongsberg. They differ from those of that locality, however, inasmuch as while here the fahlbands are often sufficiently impregnated with ore to pay for working, those of Kongsberg, although to some extent containing disseminated sulphides, are only of importance as zones of enrichment for ores occurring in veins. The ore zones usually follow the strike and dip of the surrounding rocks, and vary in breadth from 2½ to 6 fathoms. The distribution of the ores is by no means equal, since richer and poorer layers have received special names and are easily recognized. The Erzbander, or ore bands, are distinguished from the Reicherzbander, or rich ore bands, while the bands of unproductive rock are known as Felsbander. The predominant rock of the fahlbands is a quartzose granular mica schist, which gradually passes into quartzite, ordinary mica schist, or gneiss. The ores worked are cobalt glance, arsenical, and ordinary pyrites containing cobalt, skutterudite, magnetic iron pyrites, copper pyrites, molybdenite, and galena. It is remarkable that in these mines nickel ores do not accompany the ores of cobalt in any appreciable quantity. The principal fahlband is known to extend for a distance of about 6 miles, and is bounded on the east by a mass of diorite which protrudes into the fahlband, while extending from the diorite are small dikes or branches traversing it in a zigzag course. It is also intersected by dikes of coarse-grained granite which contain no ore, but which penetrate the diorite.
>
> The Skutterud mine in 1879 produced 7,700 tons of cobalt ore, which yielded 108 tons of cobalt schlich (concentrates), containing from 10 to 11 per cent of cobalt, and worth about £11,000.

At Daeshkessan the ore occurs under a sheet of diabase, the cobaltite being in the wall rock of this sheet, and which carries also garnets and copper pyrites. In 1887, 1,216 kilograms of the mineral were extracted; in 1888, 928 kilograms, and in 1889, 12,960 kilograms, besides some 3,000 kilograms of cobaltiferous matter obtained in treating the cobaltiferous copper ores.[2]

Smaltite.—(Specimen No. 66757, U.S.N.M.) This is essentially a cobalt diarsenide of the formula $CoAs_2$, = arsenic, 71.8 per cent; cobalt, 28.2 per cent; hardness, 5.5 to 6; specific gravity, 6.4 to 6.6. Color, white to steel gray. Through the assumption of nickel the mineral passes by gradations into chloanthite.

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[1] Ore Deposits, by J. A. Phillips, p. 389.

[2] Annales des Mines, II, 1892, p. 503.

Analyses of samples from (I) Schneeberg, Saxony, and (II) Gunnison County, Colorado, as given by Dana, yielded results as below:

Constituents.	I.	II.
Arsenic	71.53	63.82
Sulphur	1.38	1.55
Cobalt	18.07	11.59
Iron	7.31	15.99
Nickel	1.02	Trace.
Copper	0.01	0.16

The mineral occurs like cobaltite in veins associated with other metallic arsenides and sulphides.

SKUTTERUDITE is the name given to a cobaltic arsenide of the formula $CoAs_3$, = arsenic, 79.3; cobalt, 20.7. It is of a tin-white color, varying to lead-gray, has a hardness of 6, and specific gravity of 6.72 to 6.86. It occurs associated with cobaltite, titanite, and hornblende in a vein in gneiss at Skutterud, Norway. The name *safflorite* is given to a cobalt diarsenide closely resembling smaltite but differing in being orthorhombic, rather than isometric in crystallization. The composition as given by Dana is quite variable, running from 61 per cent to 70 per cent arsenic, and 10 to 23 per cent cobalt, with 4 to 18 per cent of iron and smaller amounts of sulphur, copper, nickel, and bismuth. It is found associated with smaltite in various localities.

GLAUCODOT is a sulpharsenide of cobalt and iron of the formula (Co, Fe) AsS, = sulphur, 19.4 per cent; arsenic, 45.5 per cent; cobalt, 23.8 per cent; iron, 11.3 per cent. Color, grayish; hardness, 5; specific gravity, 5.9 to 6. Actual analysis of a Chilean variety yielded (according to Dana) As 43.2, S 20.21, Co 24.77, Fe 11.90. It is therefore essentially a ferriferous cobaltite, that is, a cobaltite in which a part of the cobalt has been replaced by iron. The mineral is found at Huasco, Chile, associated with cobaltite in a chloritic schist. The name *alloclasite* is given to a variety of glaucodot containing bismuth and answering to the formula Co (As, Bi) S. The composition as given is somewhat variable. Arsenic, 28 to 33 per cent; bismuth, 23 to 32 per cent; sulphur, 16 to 18 per cent; cobalt, 20 to 24 per cent; iron, 2.7 to 3.8 per cent. It is reported only from Orawitza, Hungary.

LINNÆITE (Specimens Nos. 56159, 65309, U.S.N.M.) is a sulphide of cobalt with the formula Co_3S_4, =sulphur, 42.1per cent; cobalt, 57.9 per cent; a part of its cobalt is commonly replaced by nickel, giving rise to its variety *siegenite*. The mineral is brittle, of a pale steel-gray color, tarnishing red. Hardness, 5.5 and specific gravity 4.8 to 5. When crystallized it is commonly in octahedrons. The following analyses of a nickel-bearing variety (*siegenite*) are quoted from Dana:

Constituents.	S.	CO.	Ni.	Fe.	Cu.
Müsen, Prussia	41.00	43.86	....	5.31	4.10
Mineral Hill, Maryland	39.70	25.69	29.56	1.96	2.23
Mine La Motte, Missouri	41.51	21.34	30.53	3.37	Trace.

The mineral occurs in gneiss in Sweden; with barite and siderite at Müsen; in limestone with galena and dolomite at Mine La Motte, Missouri, and with sulphides of iron and copper in chloritic schists in Maryland.

SYCHNODYMITE has the formula $(Co, Cu)_4 S_5$, and yields sulphur, 40.64 per cent; copper, 18.98 per cent; cobalt, 35.79 per cent; nickel, 3.66 per cent; iron, 0.93 per cent. It is of a steel-gray color, metallic luster, and has a specific gravity of 4.75.

ERYTHRITE or COBALT BLOOM (Specimens Nos. 17698, 51909, 56463, 53096, and 67759, U.S.N.M.) is the name given to a hydrous cobalt arsenate of the formula $Co_3As_2O_8+8H_2O$, =arsenic pentoxide, 38.4 per cent; cobalt protoxide, 37.5 per cent, and water, 24.1 per cent. It occurs in globular and reniform shapes and earthy masses of a crimson to peach-red color associated with the arsenides and sulpharsenides mentioned above and from which it is derived by a process of oxidation. In Churchill County, Nevada, it occurs as a decomposition product of a cobalt bearing niccolite. It is also found at the Kelsey mine, Compton, in Los Angeles County, California; associated with cobaltite at Tambillo and at Huasco, Chile, and under similar conditions in various parts of Europe.

ASBOLITE, or earthy cobalt (Specimen No. 60993, U.S.N.M.), is a black and earthy ore of manganese (wad) which sometimes carries as high as 30 per cent of cobaltic oxide. It takes its name from the Greek *ασβολαινω*, to soil like soot. ROSELITE is an arsenate of lime, magnesia and cobalt with the formula $(Ca, Co. Mg)_3As_2O_8, 2H_2 O$, =arsenic pentoxide, 51.4 per cent; lime, 28.1 per cent; cobalt protoxide, 12.5 per cent; water, 8 per cent. It is of a light to dark rose-red color, hardness 3.5; specific gravity 3.5 to 3.6, and vitreous luster. SPHÆROCOBALTITE is a cobalt protocarbonate of the formula $CoCO_3$, =carbon dioxide, 37.1 per cent; cobalt protoxide, 62.9 per cent. It is also of a rose-red color, varying to velvet black. Hardness 4, and specific gravity 4.02 to 4.13. It occurs but sparing, associated with roselite at Schneeberg in Saxony. REMINGTONITE is a hydrous carbonate the exact composition of which has not been ascertained. COBALTOMENITE is a supposed selenide of cobalt. BIEBERITE, or cobalt vitriol, is a sulphate of the formula $CoSO_4 + 7 H_2O$. The color is flesh to rose red. It is soluble in water, has an astringent taste, and occurs in secondary stalactitic form. Pateraite is a possible molybdate of cobalt.

Aside from the possible sources mentioned above, cobalt occurs very constantly associated with the ores of nickel (niccolite, millerite, chloanthite, etc.), and is obtained as a by-product in smelting. Considerable quantities have thus from time to time been obtained from the Gap mines of Pennsylvania, Mine La Motte, Missouri, and Lovelock, Nevada. (Specimen No. 61324, U.S.N.M.) The nickel mines of New Caledonia are perhaps the most productive. The ore here (a silicate), carries some 3 per cent of cobalt protoxide. (Specimen No. 61027, U.S.N.M.)

A vein of cobalt ore near Gothic, Gunnison County, Colorado, is described as lying in granite, the gangue material being mainly calcite, throughout which was disseminated the ore in the form of smaltite. With it were associated erythrite, a small amount of iron pyrites, and native silver. An analysis of this ore yielded as below:

Cobalt	11.59	Bismuth	1.13
Iron	11.99	Copper	0.16
Arsenic	63.82	Nickel	Trace.
Silica	2.60	Silver	Trace.
Lead	2.05		
Sulphur	1.55		94.89

A cobalt ore, consisting of a mixture of glaucodot and erythrite, occurring near Carcoar Railway Station, New South Wales, has the composition given below:

Constituents.	I.	II.
Moisture	.120	2.180
Metallic arsenic	51.810	29.010
Metallic cobalt	10.447	13.830
Metallic nickel	.590	.390
Metallic iron	11.860	15.78
Alumina	....	Trace.
Metallic manganese	Nil.	Nil.
Metallic calcium	Nil.	.71
Magnesium	1.480	.22
Gold	Trace.	....
Silver	Trace.	....
Sulphur	1.520	11.24
Gangue (insoluble in acids)	22.078	26.31
	99.905	99.67
Specific gravity	5.43	

According to the Annual Report, Department of Mines, for 1888, this ore occurs concentrated in irregular hollows and bunches, often intimately mixed with diorite in a line of fissure between an intrusive diorite and slate, the fissure running for some distance following the line of junction between the two rocks, and being presumably formed at the time of the extrusion of the diorite.

Other cobalt ores, carrying from 13 to 15 per cent of cobalt oxide, occur near Nina.[1]

Uses.—Cobalt is produced and sold in the form of oxide and used mainly as a coloring constituent in glass and earthen wares. Only some 200 tons are produced annually the world over. The market value of the material is variable, but averages about $2 a pound.

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4. ARSENOPYRITE; MISPICKEL; OR ARSENICAL PYRITES.

Composition.—Somewhat variable. Essentially a sulpharsenide of iron of the formula FeAsS, or FeS_2, $FeAs_2$, =arsenic, 46 per cent; sulphur, 19.7 per cent, and iron, 34.3 per cent. The name *danaite* is given to a cobaltiferous variety. The specific gravity of the mineral varies from 5.9 to 6.2. Hardness, 5.5 to 6. Colors, silver white to steel gray, streak dark gray to black; luster, metallic. Brittle.

Occurrence.—The mineral occurs principally in crystalline rocks, and is a common associate of ores of silver, gold, tin, and lead. It is at times highly auriferous, forming a valuable ore of gold, as in New South Wales and more rarely in California and Alaska. It is found in nearly all the States bordering along the Appalachian Mountain system, but in no instance is regularly mined excepting incidentally in the process of working other metals. Concerning its occurrence abroad Dana states that it is "abundant at Freiberg and Munzig, where it occurs in veins (Specimens Nos. 62803, 66809, 66810, 73104, U.S.N.M.); at Reichenstein in Silesia in serpentine; at Auerbach in Baden; in beds at Breitenbrunn and Raschau, Andreasberg and Joachimsthal; at Tunaberg in Sweden; at Skutterud in Norway; at Wheal Mawdlin and Unanimity, Cornwall, and at the Tamar mines in Devonshire, England (Specimens Nos. 67456, 67457, U.S.N.M.) and in Bolivia.

Uses.—The only use of the mineral is as an ore of arsenic.

5. LÖLLINGITE; LEUCOPYRITE.

The prismatic arsenical pyrites, or *leucopyrite*, is essentially a diarsenide of iron, with the formula $FeAs_2$, though usually contaminated with a little sulphur and not infrequently cobalt, bismuth, or antimony. It has a specific gravity of 7 to 7.4, hardness of 5 to 5.5, metallic luster and silver-white to steel-gray color.

The mineral has been found at Edenville, New York (Specimen No. 67744, U.S.N.M.); Roxbury, Connecticut, and other places in the United States and associated with other arsenides and sulpharsenides in the gold and silver mines of Europe.

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[1] Complete analyses of these are given in Catalogue of the New South Wales Exhibit, World's Columbian Exposition, Chicago, 1893, p. 330.

6. PYRITES.

Two forms of the disulphide of iron are common in nature. The first, known simply as pyrite or iron pyrites, occurs in sharply defined cubes and their crystallographic modifications (Specimen No. 51740, U.S.N.M.), or in granular masses of a brassy-yellow color (Specimen No. 62152, U.S.N.M.).

The second, identical in composition, crystallizes in the othorhombic system (Specimens Nos. 17124, 55206, and 73613, U.S.N.M.), but is more common in concretionary (Specimen No. 62976, U.S.N.M.), botryoidal (Specimen No. 30772, U.S.N.M.), and stalactitic (Specimens Nos. 62800 and 67761, U.S.N.M.) forms, which are of a dull grayish-yellow color. This form is known as the gray iron pyrites. Both forms have the chemical composition, FeS_2, = iron 46.6 per cent and sulphur 53.4 per cent.

The ore as mined is, however, never chemically pure, but contains admixtures of other metallic sulphides, besides, at times, considerable quantities of the precious metals. The following analyses[1] of materials from well-known sources will serve to show the general variation:

Constituents.	I.	II.	III.	IV.	V.	VI.	VII.
Sulphur	48.0	48.0	48.02	40.00	47.76	46.40	45.60
Iron	43.0	44.0	42.01	35.0	43.99	39.00	38.52
Copper	1.6	1.6	....	4.00	3.69	1.50	....
Zinc	1.5	1.5	....	....	0.24	....	6.00
Silica	5.0	3.7	7.60	20.00	1.99	9.25	8.70
Alumina	....	....	....	....	....	3.75	....
Arsenic	Trace.	....	....	Trace.	0.83	0.10	Trace.
Silver and gold	....	....	....	Trace.	Trace.	....	....
Lead	....	....	....	....	0.10	....	0.64

I. Milan, Coos County, New Hampshire; II. Rowe, Massachusetts; III. Louisa County, Virginia; IV. Sherbrooke, Canada; V. Rio Tinto, Spain; VI. near Lyons, France; VII. Westphalia, Germany.

Pyrite is sufficiently hard to scratch glass, and this, together with its color, crystalline form, and irregular fracture, is sufficient for its ready determination in most cases. Once known, it is thereafter readily recognized. Owing to its yellow color, the mineral has by ignorant persons been mistaken not infrequently for gold—which, however, it does not at all resemble—and has hence earned the not very flattering but quite appropriate name of "fool's gold." In certain cases, however, it carries the precious metals, and in many regions is sufficiently rich in gold to form a valuable ore.

Mode of occurrence.—Pyrite is one of the most widely disseminated of minerals, both geologically and geographically, occurring in rocks of all kinds and of all ages the world over. It is found in the form of

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[1] Mineral Resources of the United States, 1883–1884, p. 877.

disseminated grains throughout the mass of a rock, or along the line of contact between basic eruptives and sedimentaries; as irregular and sporadic and concretionary masses in sedimentary rocks and modern sands and gravels; in the form of true fissure veins, and as interbedded, often lenticular masses, sometimes of immense size, lying conformably with the stratification (or foliation) of the inclosing rock. On the immediate surface the mineral is in most cases considerably altered by oxidation and hydration, forming the caps of gossan or limonite.

The origin of the mineral in the older crystalline rocks, as that of the rocks themselves, is not infrequently somewhat obscure. In sedimentary rocks it is undoubtedly due to the precipitation of the included ferruginous matter by sulphureted and deoxidizing solutions from decomposing animal and vegetable matter.

Some of the pyritiferous deposits, as those of Louisa County, Virginia (Specimens Nos. 54239, 54241, and 54242, U.S.N.M.), and Huelva, Spain, are of enormous proportions. The first named is described[1] as over 2 miles in length, and to have been exploited to upwards of 600 feet in depth and in width, from foot to hanging rock, as high as 60 feet of pure ore (see large Specimen No. 54242, U.S.N.M.). The average width of the two worked beds is upward of 18 feet. The rocks inclosing the deposits consist principally of talcose and hydromica slates. At Rio Tinto the ore is described[2] as occurring in immense masses several thousand feet in length and from 300 to 800 feet in width, extending in depth to an unknown distance. The ore (Specimen No. 11427, U.S.N.M.) is very clean and massive, containing besides sulphur and iron only some 2 to 4 per cent of copper and traces of silver and gold. The material is mined wholly from open cuts and to a depth of some 400 feet. The country rock is described as of Silurian and Devonian schists near contact with diorites.

Uses.—With the exception of the small amount utilized in the preparation of vermilion paints and the still smaller amount used for jewelry, almost the sole value of the mineral is for the manufacture of sulphuric acid and the sulphate of iron, known as green vitriol or copperas. In the process of making sulphuric acid the ore is roasted or burnt in specially designed ovens and furnaces until the mineral is decomposed, the sulphur fumes being caught and condensed in chambers prepared for the purpose. By the Glover and Gay-Lussac method from 280 to 290 parts of sulphuric acid of a density of 66° Baumé may be obtained for each 100 parts of sulphur in the ore or about 2,565 pounds of acid to 1 ton (2,000 pounds) of average ore.

In the manufacture of copperas the ore is broken into small pieces and thrown into piles over which water is allowed to drip slowly. A

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[1] Origin of the Iron Pyrites Deposits in Louisa County, Virginia, by F. L. Nason, Engineering and Mining Journal, LVII, 1894, p. 414.

[2] A Visit to the Pyrite Mines of Spain, Eng. and Min. Jour., LVI, 1893, p. 498.

natural oxidation takes place, whereby the sulphide is transformed into a hydrated sulphate. The latter being soluble runs off in solution in the water, which must be collected and evaporated in order to obtain the salt. Thus prepared the sulphate is used in dyeing, in the manufacture of writing ink, as a preservative for wood, and as a disinfectant. It has also been used in the manufacture of certain brands of fertilizers. The method of manufacture as formerly carried on at Strafford, Vermont, is given below:

> The process consists in first raising the ore from the bed, which is principally done with the help of gunpowder. The blocks of ore are then broken up into small pieces, to facilitate the decomposition, by suffering the oxygen contained in water and the atmosphere to come more directly in contact with the material composing the ore. Large heaps of these pieces, called leaches, are made upon a tight plank bottom or upon a sloping ledge of solid rock, where the liquor or lye that subsequently runs from them may be saved.
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> In dry weather a small stream of water is made to flow upon and penetrate these leaches in order to produce a spontaneous combustion, which in warm weather commences in a few days, and if properly managed will continue several weeks. When combustion is taking place great care is requisite in order to have the work go on successfully, for if too much water is suffered to penetrate the leach or heap the decomposition is checked by the reduction of temperature and the lye or liquor issuing from it is too weak to be valuable, and if there is not water enough put on the leach the decomposition is also arrested by the absence of the oxygen found in the water, which is necessary to convert the sulphurous acid into the sulphuric, that sulphate of iron or copperas may be produced.
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> The liquor that runs from the leaches is collected in reservoirs, from which it can be taken at pleasure. Below the reservoirs upon the hillside buildings are erected, called evaporators, to which liquor is conducted in troughs from the reservoirs in small streams that are divided and subdivided by means of perforated troughs, brush, etc. Several tiers of brush are arranged in the building, through which the liquor is made to pass to facilitate the process of evaporation. In dry, windy weather the evaporation is oftentimes so rapid that the brush and other substances with which the liquor comes in contact during the latter part of its journey often have an incrustation of copperas formed upon them; but upon the return of rainy weather the humid atmosphere checks the evaporation, and the crust of copperas is dissolved and passes with the liquor into reservoirs prepared to receive it.
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> The liquor, which is now very strongly impregnated with copperas, is conducted into leaden boilers, where heat is applied and the liquor reduced to a strength indicated by the acidimeter to be right for the production of copperas. The liquor is then placed in vats of lead or of brick and water cement, called crystallizers, and after remaining from eight to ten days a crust of copperas is formed upon the bottom and sides of the vats, composed of nicely formed crystals. The water remaining in the crystallizers is then pumped back into the boilers, the crust of copperas removed, and, after being sufficiently drained, it is packed in casks ready for market.[1] [See also under Alum shale and vitriol stone, p. 421.]

The analyses given below show (1) the composition of fresh pyrite from the Coal Measures of Mercer County, Pennsylvania, and (2) and (3) that of two varieties of paint produced from it by calcination.[2]

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[1] Geology of Vermont, II, 1861, p. 830.

[2] Report M. M. Second Report of Progress in the Laboratory of the Survey at Harrisburg, Second Geological Survey of Pennsylvania, 1879, p. 374.

Constituents.	1.	2.	3.
Bisulphide of iron	96.161	0.415	0.405
Bisulphide of copper	Trace.		
Sesquioxide of iron		66.143	77.143
Alumina	.653	.697	.543
Protoxide of iron		6.300	5.142
Lime	.450	.160	.160
Magnesia	.140	.100	.100
Silica	.680	3.880	3.980
Sulphuric acid		13.110	7.334
Water and carbonaceous matter		9.195	5.194
Undetermined	1.916		
Total	100,000	100,000	100,000

Pyrite on decomposing in the presence of moisture in the ground sometimes gives rise to an acid sulphate of iron. This may attack aluminous minerals when such are present, giving rise thus to solutions of sulphate of iron and alumina, which come to the surface as "alum springs," or, if no alumina is present, merely as iron or chalybeate springs, which are of more or less medicinal value. The presence of such sulphates in a soil is readily detected by the well-known astringent taste of green vitriol and alum, even where the quantity is not sufficient to appear as a distinct efflorescence. Impregnation of these salts in soils are by ignorant persons sometimes assumed to be of great medicinal value, and the writer has in mind a case in one of the Southern States, in which the aqueous leachings of such a soil were regularly bottled and sold as a specific for nearly all the ills to which the flesh is heir, though prescribed especially for flux, wounds, and ulcers. (See also under Alum, p. 416.)

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7. Molybdenite.

A disulphide of molybdenum having the formula MoS_2, = sulphur 40 per cent, molybdenum 60 per cent.

This mineral, like graphite, occurs, as a rule, in small, black, shining scales, sometimes hexagonal in outline and with a bright metallic luster. It is soft enough to be readily impressed with the thumb nail, and leaves a bluish-gray trace on paper. On porcelain it leaves a lead gray, slightly greenish streak. This faint greenish tinge, together with its property of giving a sulphur reaction when fused with soda, furnish a ready means of distinguishing it from graphite, which it so closely resembles. Through alteration it sometimes passes over into molybdite or molybdic ocher, a straw-yellow to white ocherous mineral of the formula MoO_3, = oxygen 33.3 per cent, molybdenum 66.7 per cent.

Occurrence.—The mineral has a wide distribution, occurring in embedded masses and disseminated scales in granite (Specimen No. 62169, U.S.N.M.), gneiss, syenite, crystalline schists, quartz (Specimen No. 60995, U.S.N.M.), and granular limestone. It is found in Norway, Sweden, Russia, Saxony, Bohemia, Austria, France, Peru, Brazil, England, and Scotland, throughout the Appalachian region in the United States and Canada (Specimen No. 53046, U.S.N.M.), and in various parts of the Rocky and Sierra Nevada mountains. In Okanogan County, Washington, the mineral occurs in beautiful large flakes in an auriferous quartz vein traversing slates. (Specimen No. 53126, U.S.N.M.)

On Quetachoo-Manicouagan Bay, on the north side of the Gulf of St. Lawrence, the mineral is reported[1] as occurring disseminated in a bed of quartz 6 inches thick, in the form of nodules from 1 to 3 inches in diameter and in flakes which are sometimes 12 inches broad by ¼ inch in thickness.

Molybdenite is also found in the form of finely disseminated scales or small bunches among the iron ores of the Hude mine at Stanhope, New Jersey, sometimes constituting as high as 2 per cent of the ore.

Molybdenum is also a constituent of the mineral wulfenite, or molybdate of lead.

Uses.—The principal use to which molybdenite has as yet been put is in the preparation of molybdates for the chemical laboratory. It is stated that a fine blue pigment can be prepared from it, which it has been proposed to use as a substitute for indigo in dyeing silk, cotton, and linen. The metal molybdenum is produced but rarely and only as a curiosity, and has a purely fictitious value. Up to the present time there has been no constant demand for the mineral nor regular source of supply.

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[1] Geology of Canada, 1863, p. 754.

III. HALIDES.

1. Halite; Sodium Chloride; or Common Salt.

Composition Na Cl,=sodium 60.6 per cent; chlorine 39.4 per cent. The natural substance is nearly always more or less impure, as noted later. Hardness, 2.5; specific gravity, 2.1 to 2.6 per cent. Colorless or white when pure, but often yellowish or red or purplish by the presence of metallic oxides and organic matter. Readily soluble in cold water, and has a saline taste. Crystallizes in the isometric system, usually in cubes (fig. 2, Specimen No. 40222, U.S.N.M.), but sometimes in octahedrons, the faces of the crystals (particularly when prepared artificially) being often cavernous or hopper shaped. Sometimes occurs in fibrous forms, which it has been suggested are pseudomorphous after fibrous gypsum (Specimen No. 64733, U.S.N.M.). Often found in the form of massive, crystalline granular aggregates commonly known as rock salt (Specimens Nos. 67558, 64736, 62946, U.S.N.M.).

Fig. 2.

CLUSTER OF HALITE CRYSTALS.

Stassfurt, Germany.

Specimen No. 40222, U.S.N.M.

Sylvite, the chloride of potassium, sometimes occurs associated with halite, where it has formed under similar conditions. From halite it can be distinguished by its crystalline form, that of a combination of cube and octahedron (Specimen No. 40223, U.S.N.M. See fig. 4, p. 203), and more biting taste. Owing to its ready solubility it is rarely found in a state of nature. Bischofite, the chloride of magnesium (Specimen No. 62428, U.S.N.M.) is still more soluble and practically unknown except in crystals artificially produced.

Origin and occurrences.—Sodium in the form of chloride, to which is commonly given the simple name of salt, is one of the most widely disseminated of natural substances, and not infrequently occurs in large masses interstratified with other rocks of the earth's crust in such a manner as to constitute a true rock mass.

The geological history of these beds of rock salt is as follows:

No terrestrial waters are absolutely pure, but all hold in solution more or less mineral matter which has been taken up from the rocks and soils with which they have come in contact. The nature of these impurities depends on the nature of the formations permeated and their relative solubility. Numerous analyses of river waters have shown that the substances mentioned below, though sometimes existing as mere traces, are almost invariably present; these are sodium, potassium, magnesium, silicon, aluminum, and iron, which exist mostly in the form of carbonates, oxides, sulphates, and chlorides.

When a stream bearing these substances in solution flows into a lake with no outlet, as the Great Salt Lake or the Dead Sea, the water is returned to the atmosphere by evaporation, while the impurities remain. In this way the water gradually becomes charged more and more heavily with mineral matter, until the point of saturation is reached and further concentration is impossible without precipitation. When such precipitation of mineral matters takes place, it is in the inverse order of their solubilities; that is, those substances which are least soluble will, under like conditions of temperature, be first precipitated. Hence a water containing the ingredients before mentioned on being subjected to complete evaporation would deposit its load in the following order: (1) Carbonates of lime and magnesia in the form of limestones, marls, and dolomites; (2) sulphate of lime in the form of anhydrite and gypsum; (3) chloride of sodium, or common salt; and these followed in regular order by the sulphates of magnesia and soda (Epsom salt and Glauber's salt) and the chlorides of potassium and magnesium. These last are, however, so readily deliquescent that they are rarely found crystallized out in a state of nature as above noted.

It rarely happens, however, that nature's processes are sufficiently regular and uninterrupted to allow a complete precipitation of the pure salts as above outlined. During periods of flood suspended silt may be poured into the inclosed basin to finally settle, forming thus alternating beds of saliferous clay or marl.

Such having been the method of formation, it is scarcely necessary to state that salt beds are not confined to strata of any one geological horizon, but are to be found wherever suitable circumstances have existed for their formation and preservation. The beds of New York State and of Canada and a part of those of Michigan lie among rocks of the Upper Silurian Age. They are regarded by Professor Newberry as the deposits of a great salt lake that formerly occupied central and western New York, northern Pennsylvania, northeastern Ohio, and southern Ontario, and which he assumes to have been as large as Lake Huron, or possibly Lake Superior. A part of the Michigan beds, on the other hand, were laid down near the base of the Carboniferous series, as were also those of the Ohio Valley, and presumably those of Virginia, while those of Petite Anse, Louisiana, are of Cretaceous, or possibly Tertiary Age. The beds of the Western States and Territories are likewise of recent origin, many of them being still in process of formation.

The English beds at Cheshire, the source of the so-called "Liverpool" salt, are of Triassic Age, as are also those of Vic and Dieuze in France, Wurtemburg in Germany, and Salzburg in Austria, while those of Wieliczka in Austrian Poland, and of Parajd in Transylvania are Tertiary.

Salt is now manufactured from brines or mined as rock salt in fifteen States of the American Union. These, in the order of their apparent importance, are Michigan, New York, Kansas, California, Louisiana, Illinois, Utah, Ohio, West Virginia, Nevada, Pennsylvania, Virginia, Kentucky, Texas, and Wyoming. At one time Massachusetts was an important producer of salt from sea waters. The industry has, however, been gradually languishing and may ere now be wholly extinct. In California salt is obtained largely from sea water, but also from salt lakes and salines. In Michigan, Ohio, the Virginias, Pennsylvania, and Kentucky salt is obtained from brines obtained from springs or by sinking wells into the salt-bearing strata, while in New York, Kansas, Louisiana, and the remaining States it is obtained both from brines and by mining as rock salt.

Of the foreign sources of rock salt the following districts are the most important: (1) The Carpathian Mountains, (2) the Austrian and Bavarian Alps, (3) western Germany, (4) the Vosges, (5) Jura, (6) Spain, (7) the Pyrenees and the Celtiberian Mountains, and (8) Great Britain, while sea salt is an important product of Turks Island in the Bahamas, of the island of Sicily, and of Cadiz, Spain.

We have space here for details concerning but a few of these beds, preference naturally being given to those of the United States.

The beds of New York State, of Ontario, northern Pennsylvania, northeastern Ohio, and eastern Michigan all belong to the same geologic group—are the product of similar agencies. They have been penetrated in many places by wells, and from the results obtained we are enabled to form some idea of their extent and thickness. Below is given a summary of results obtained in boring one of these wells to a depth of 1,517 feet at Goderich, Canada. Beginning at the top, the rocks were passed through in the following order:

		Ft.	In.
I.	Clay, gravel, marls, limestone, dolomite, and gypsum variously interstratified	997	0
II.	First bed of rock salt	30	11
III.	Dolomite with marls	32	1
IV.	Second bed of rock salt	25	4
V.	Dolomite	6	10
VI.	Third bed of rock salt	34	10
VII.	Marl, dolomite, and anhydrite	80	7
VIII.	Fourth bed of rock salt	15	5
IX.	Dolomite and anhydrite	7	0
X.	Fifth bed of rock salt	13	6
XI.	Marl and anhydrite	135	6
XII.	Sixth bed of rock salt	6	0
XIII.	Marl, dolomite and anhydrite	132	0
	Total thickness of formations passed through	1,517 feet.	
	Total thickness of beds of salt	126 feet.	

The above section shows that the ancient sea or lagoon underwent at least six successive periods of desiccation, and especial attention is called to the remarkable regularity of the deposits. On the oldest sea bottom (XIII) the carbonates and sulphates of lime and magnesia were deposited first, being least soluble. Then followed the salt, and this order is repeated invariably. The other constituents mentioned as occurring in the waters of lakes and seas are not sufficiently abundant to show in the section, or owing to their ready solubility they have been in large part removed since the beds were laid down. Chemical tests, however, reveal their presence.

Although salt was manufactured from the brine of springs, near Onondaga Lake, in New York, as early as 1788, and has been regularly manufactured from the brine of wells since 1798, it was not until subsequent to the discovery of extensive beds of rock salt in the Wyoming Valley, while boring for petroleum, that the mining of the material in this form became an established industry. In June, 1878, a bed of rock salt 70 feet in thickness was found in the valley above mentioned, at a depth of 1,270 feet. Subsequently other borings in Wyoming, Genesee, and Livingston counties disclosed beds at varying depths. In 1885 the first shaft was sunk at Pifford by the Retsof Mining Company, the salt bed being found at a depth of 1,018 feet. Three other shafts have since been sunk, the first about a mile west of the Retsof, the second about 2 miles south of Leroy, and the third at Livonia, in Livingston County. The salt when taken from the bed is stated to be of a gray color, due to the presence of clay, which renders solution and recrystallization necessary when designed for culinary purposes. The thickness of the salt beds and their depth are somewhat variable. The following figures are quoted from

Dr. Engelhardt's report.[1] At Morrisville, in Madison County, it is 12 feet thick and at a depth of 1,259 feet; at Tully, in Onondaga County, it varies from 25 to 318 feet, at depths of from 974 to 1,465 feet. The seven beds found at Ithaca have a total thickness of 248 feet, the uppermost lying at a depth of 2,244 feet. In the Genesee Valley the beds vary in depth from 750 to 2,100 feet and in thickness from 40 to 93 feet. In the Wyoming Valley the depth varies from 610 to 2,370 feet below the surface and in thickness from 12 to 85 feet.[2]

Michigan.—The salt-producing areas of this State are, so far as now known, limited to the counties of Iosco, Bay, Midland, Gratiot, Saginaw, Huron, St. Clair, Manistee, and Mason, the beds of the Saginaw Valley lying in the so-called Napoleon sandstone, at the base of the Carboniferous. Professor Winchell has estimated this formation to cover an area of some 17,000 square miles within the State limits. The beds of the St. Clair Valley, on the other hand, are in Upper Silurian strata, being presumably continuous with those of Canada. The manufacture of salt from brines procured from these beds began in the Saginaw Valley in 1860 and has since extended to the other regions mentioned. According to F. E. Engelhardt the rock salt deposits in the Upper Silurian beds, with a thickness of 115 feet, were reached at Marine City, in St. Clair County, at a depth of 1,633 feet; at St. Clair, St. Clair County, at a depth of 1,635 feet and with a thickness of 35 feet. At Caseville, in Huron County, the beds lie at a depth of 1,164 feet, and at Bay City, Saginaw Bay, at 2,085 feet, the salt beds being 115 feet in thickness. At Manistee the bed is 34 feet thick, lying 2,000 feet below the surface, while at Muskegon, in the Mason well, it was 50 feet thick at a depth of 2,200 feet. Although of so recent development, Michigan is rapidly becoming one of the leading salt-producing regions of the world, the estimated manufacturing capacity being now upward of 5,000,000 barrels annually. The total product of all the years since 1868 is given as 60,614,464 barrels of 280 pounds each.

In Kansas the rock salt occurs in beds regarded as of Permian age, and has been reached by means of shafts in several counties in the southern and central part of the State. The following is a section of a shaft sunk at Kingman in 1888–89:

	Feet.
"Red-beds," red arenaceous, limestones, ferruginous clays, and clay shales with thin streaks of gray shales and bands of gypsum as satin spar	450
Gray or bluish "slate," with 2 feet of limestone at 500 feet	140
Red clay shale	4
Gray "slate," with occasional streaks of limestone, 2 to 8 inches thick, and some salt partings and satin spar with ferruginous stain	78

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[1] The Mineral Industry, its Statistics and Trade for 1892, by R. P. Rothwell.

[2] For a very complete historical and geological account of these salt beds and the method of manufacture, see Bulletin No. 11, of the New York State Museum, 1893, by F. J. H. Merrill.

	Feet.
First rock salt, pure white	2
Shale and "slate," bluish, with vertical and other seams of salt, from 1 to 3 inches thick	26
Rock salt	4
Shales, with salt	11
Rock salt	7
Shale	3
Rock salt	3
Salt and shale, alternate thin seams	62
Rock salt	11
Shale	$1\frac{2}{12}$
Rock salt	5
Shales and limestone	8
Rock salt, bottom of it not reached	5
Total	820

Borings and shafts have also proven the existence of beds of salt in other parts of the State, as at Kanopolis, Lyons, Caldwell, Rago, Pratt, and Wilson. According to Dr. Robert Hays[1] it is safe to assume that beds of rock salt from 50 to 150 feet in thickness underlie fully half the area from the south line of the State to north of the Smoky River, an area from 20 to 50 miles in width. Although the mining of rock salt began in this region only in 1888, the annual output has already reached over 1,000,000 barrels.

Louisiana.—Salt in this State is derived from Petite Anse, a small island rising from the marshes on the southern coast and connected with the mainland by a causeway some 2 miles in length. According to E. W. Hilgard[2] the deposit is probably of Cretaceous age, and is presumably but a comparatively small residual mass of beds once extending over a much larger area, but now lost through erosion. (See fig. 3.) Exploration has shown the area occupied by the beds to be some 150 acres, but the full thickness, though known to be upward of 165 feet, has never been fully determined.

Salt in Kentucky is obtained from the brine of springs and wells in Carboniferous limestone. In Meade County brine accompanies the natural gas, the latter in some cases being utilized as fuel for its evaporation. Springs in Webster County furnished salt for Indians long anterior to the occupancy of the county by whites, and fragments of their clay kettles and other utensils used in the work of evaporation are still occasionally found.

Texas.—The occurrences of salt are numerous and widespread. Along the coast are many lagoons and salt lakes, from which considerable quantities are taken annually. "Besides the lakes along the shores many others occur through western Texas, reaching to the New Mexico

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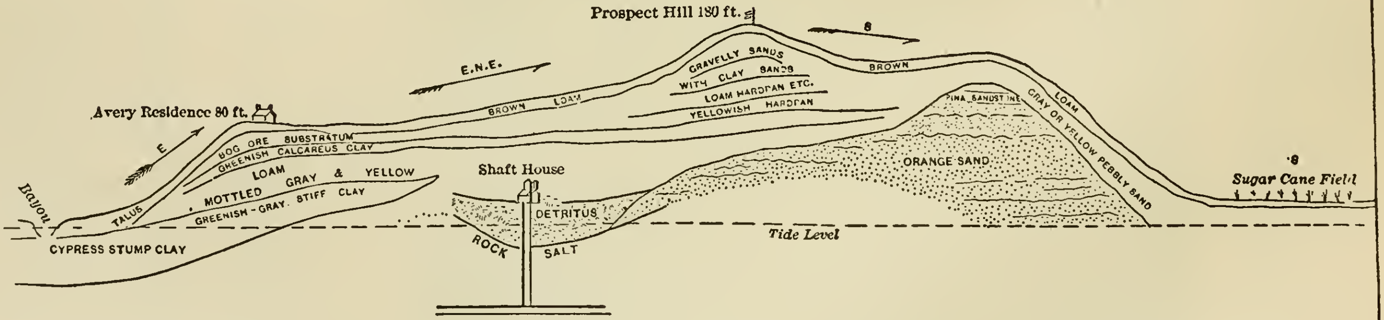
[1] Geological and Mineral Resources of Kansas, 1893, p. 44.

[2] Smithsonian Contributions to Knowledge, XXIII. On the Geology of Lower Louisiana and the Salt Deposit on Petite Anse Island.



GEOLOGICAL SECTION OF PETITE ANSE ISLAND, LOUISIANA.

(*Copied from Prof. E. W. Hilgard's Map.*)

Fig. 3.

line, while northeast of these, in the Permian region, the constant recurrence of such names as Salt Fork, Salt Creek, etc., tell of the prevalence of similar conditions." In addition to the brines there are extensive beds of rock salt. That which is at present best developed is located in the vicinity of Colorado City, in Mitchell County. The bed of salt was found at a depth of 850 feet, with a thickness of 140 feet. In eastern Texas there are many low pieces of ground called salines, where salt has been manufactured by evaporation of the brines obtained from shallow wells. At the "Grand Saline," in Van Zandt County, a bed of rock salt over 300 feet in thickness was found at a depth of 225 feet.

In England the salt occurs at Cheshire in two beds interstratified with marls and clays. The upper, with a thickness varying from 80 to 90 feet, lies at a depth of some 120 feet below the surface, and the second at a depth of 226 feet has a thickness varying between 96 and 117 feet. The accompanying general sections are from Davies' Earthy and Other Economic Minerals.

Detailed section of strata sunk through at Witton, near Northwich, to the lower bed of salt.

	Ft.	In.
1. Calcareous marl	15	0
2. Indurated red clay	4	6
3. Indurated blue clay and marl	7	0
4. Argillaceous marl	1	0
5. Indurated blue clay	1	0
6. Red clay with sulphate of lime in irregular branches	4	0
7. Indurated red clay with grains of sulphate of lime interspersed	4	0
8. Indurated brown clay with sulphate of lime crystallized in irregular masses and in large proportions	12	0
9. Indurated blue clay with laminæ of sulphate of lime	4	6
10. Argillaceous marl	4	0
11. Indurated brown clay laminated with sulphate of lime	3	0
12. Indurated blue clay laminated with sulphate of lime	3	0
13. Indurated red and blue clay	12	0
14. Indurated brown clay with sand and sulphate of lime irregularly interspersed through it. The fresh water, at the rate of 360 gallons a minute, forced its way through this stratum	13	0
15. Argillaceous marl	5	0
16. Indurated blue clay with sand and grains of sulphate of lime	3	9
17. Indurated brown clay as next above	15	0
18. Blue clay as strata next above	1	6
19. Brown clay as strata next above	7	0
20. The top bed of rock salt	75	0
21. Layers of indurated clay with veins of rock salt running through them	31	6
22. Lower bed of rock salt	115	0
Total	341	9

At Wieliczka, in Austrian Poland, the salt occurs in massive beds stated to extend over an area some 20 by 500 miles, with a maximum thickness of 1,200 feet. At Parajd, in Transylvania, beds belonging to the same geological horizon are estimated to contain upward of 10,000,000,000,000 cubic feet of salt.

One of the most remarkable deposits of the world, remarkable for its extent as well as for the variety of its products, is that of Stassfurt, in Prussian Saxony. On account of its unique character, as well as its commercial importance, being to-day the chief source of natural potash salts of the world, a little space may well be given here to a detailed description.[1]

Fig. 4.
CLUSTER OF SYLVITE CRYSTALS.
Stassfurt, Germany.
Specimen No. 40223, U.S.N.M.

Stassfurt is a small town of some 12,000 inhabitants, about 25 miles southwest of the city and fortress of Magdeburg, in Prussia. It lies in a plain, and the river Bode, which takes its rise in the Harz Mountains, flows through it. The history of the salt industry in Stassfurt is a very old one, and dates back as far as the year 806. Previous to the year 1839 the salt was produced from brine pumped from wells sunk about 200 feet into the rock. The brine, in the course of time, became so weak,

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[1] Journal of the Society of Chemical Industry, II, 1883, pp. 146, 147.

as regards the common salt it contained, that it was impossible to carry on the manufacture from this source without loss. In 1839 the Prussian Government, who were the owners of these saline springs, commenced boring with the object of discovering the whereabouts of the bed of rock salt from which the brine had been obtained, and in the year 1843, seven years after the commencement of the borings, the top of the rock salt was reached at a depth of 256 metres. The boring was continued through another 325 metres into the rock salt without reaching the bottom of the layer. At this total depth of 581 metres the boring was suspended. On analysing the brine obtained from the bore-hole, it was found to consist, in 100 parts by weight, of—

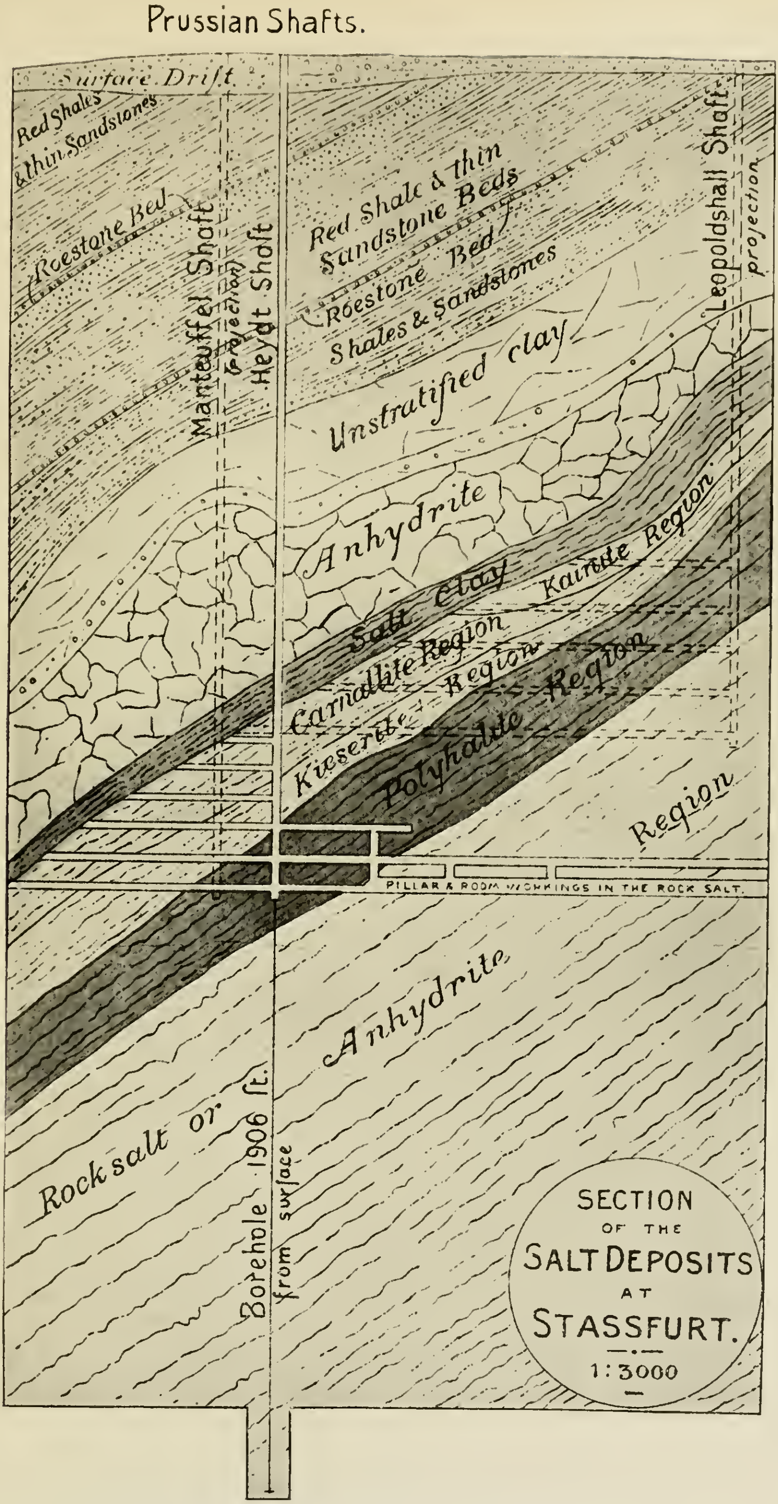
Sulphate of calcium	4.01
Chloride of potassium	2.24
Chloride of magnesium	19.43
Chloride of sodium	5.61

A result not only unexpected but disappointing, since the presence of chloride of magnesium in such quantities dispelled for the time all hopes of striking on the pure rock salt. The Government, however, guided by the opinions expressed by Dr. Karsten and Professor Marchand, namely, that the presence of chloride of magnesium in such quantities was probably due to a deposit lying above the rock salt, determined to further investigate the matter, and in the year 1852 the first shaft was commenced, which after five years had penetrated, at a depth of 330 metres, into a bed of rock salt, passing on its way, at a depth of 256 metres, a bed of potash and magnesia salts of a thickness of 25 metres.

On referring to the section of the mines [Plate 4], it will be seen that the lowest deposit of all consists of rock salt. The bore-hole was driven 381 metres into it without reaching the bottom of the layer. Its depth is therefore unknown. The black lines drawn across the rock salt deposit represent thin layers of sulphate of calcium 7 millimetres thick, and almost equidistant. The lines at the top of the rock salt represent thin layers of the trisulphate of potash, magnesia, and lime as the mineral Polyhallite [Specimen No. 67754, U.S.N.M.]. The deposit lying immediately on the bed of rock salt consists chiefly of sulphate of magnesia as the mineral Kieserite [Specimen No. 62417, U.S.N.M.]. Still farther toward the surface the deposit consists of the double chloride of potassium and magnesium, known as the mineral Carnallite, [Specimens Nos. 40225, 62416, U.S.N.M.] mixed with sulphate of magnesia and rock salt. The deposit to the right, on the rise of the strata, consists of the double sulphate of potash and magnesia combined with one equivalent of chloride of magnesium, and intermingled with common salt to the extent of 40 per cent. This double sulphate is known as the mineral Kainite [Specimen No. 64735, U.S.N.M.] and is a secondary formation, resulting from the action of a limited quantity of water on a mixture of sulphate of magnesia and the double chloride of potassium and magnesium, as contained in the uppermost deposit previously spoken of.

The upper bed of the rock salt, resting on a thick bank of Anhydrite [Specimen No. 64740, U.S.N.M.], is also a later formation. Almost imperceptible layers of Polyhallite are present in this deposit and at greater intervals than in the lower and older deposit. It has therefore probably originated from the action of water on the older deposit. This upper bed of rock salt varies in thickness from 40 to 90 metres, and its extent is comparatively limited. It is worked in preference to the older deposit, where both exist in the same mine, it being of much purer quality, averaging about 98 per cent in the mines of the New Stassfurt Mining Company and in the Royal Prussian mines.

Sixteen different minerals have as yet been discovered in the Stassfurt deposits. They may be divided into primary and secondary formations. Those of primary formation are rock salt, Anhydrite [Specimen No. 64740, U.S.N.M.], Polyhallite (K_2SO_4, $MgSO_4$, $2CaSO_4$, $2H_2O$) [Specimen No. 67754, U.S.N.M.], Kieserite ($MgSO_4$,



Section of the Salt Deposits at Stassfurt.
From the Transactions of the Edinburgh Geological Society, V, 1884, p. 111.

$H_2O)$ [Specimen No. 62417, U.S.N.M.], Carnallite $(KCl, MgCl_2, 6H_2O)$ [Specimen No. 40225, U.S.N.M.], Boracite $(2(Mg_3B_8O_{15}), MgCl_2)$ [Specimen No. 64742, U.S.N.M.], and Douglasite $(2KCl, FeCl_2, 2H_2O)$. Those of secondary formation, resulting from the decomposition of the primary minerals are, nine in number, namely: Kainite $(K_2SO_4, MgSO_4, MgCl_2, 6H_2O)$; Sylvin (KCl) [Specimen No. 62419, U.S.N.M.]; Tachydrite $(CaCl_2, 2MgCl_2 + 12H_2O)$ [Specimen No. 40230, U.S.N.M.]; Bischofite $(MgCl_2, 6H_2O)$ [Specimen No. 62428, U.S.N.M.]; Krugite $(K_2SO_4, MgSO_4, 4CaSO_4, 2H_2O)$ [Specimen No. 62426, U.S.N.M.]; Reichardtite $(MgSO_4, 7H_2O)$; Glauberite $(CaSO_4, Na_2SO_4)$ [Specimen No. 40229, U.S.N.M.]; Schönite $(K_2SO_4, MgSO_4, 6H_2O)$ [Specimen No. 62418, U.S.N.M.], and Astrakanite $(MgSO_4, 4H_2O)$ [Specimen No. 64734, U.S.N.M.]. Only four of these minerals have any commercial value, namely: Carnallite, Kainite, Kieserite, and rock salt. The yield of boracite, which is found in nests in the carnallite region of the mine, is too insignificant to be classed among those just mentioned.

The mine may be divided chemically into four regions: (1) The rock salt, (2) the Kieserite, (3) the Carnallite, (4) the Kainite region.

The rock salt region has almost the same composition throughout. Its character is crystalline, though in this region well-defined crystals are never met with. In other parts of the mine, especially in the Carnallite region, it is found crystallised in the form of the cube [Specimen No. 40222, U.S.N.M.] and the octahedron, sometimes coloured different shades of red and blue [Specimen No. 64731, U.S.N.M.]. Specimens have also been found of varied structure, laminated, granular, and fibrous [Specimen No. 64733, U.S.N.M.].

The deposit lying on the top of the rock constitutes the so-called Kieserite region. The thickness of this deposit is about 56 metres, and its average composition as follows:

	Per cent.
Kieserite	17
Rock salt	66
Carnallite	13
Tachydrite	3
Anhydrite	2
	100

In the pure state Kieserite is amorphous and translucent, possessing a specific gravity of 2.517. It contains 87.1 per cent sulphate of magnesia and 12.9 per cent water, corresponding to the formula $MgSO_4, H_2O$. Exposed to the air it becomes opaque from the absorption of moisture, and is converted into Epsom salts; 100 parts of water dissolve 40.9 parts of this mineral at 18° C. The solution, however, takes place very slowly at this temperature.

This deposit has not been worked to any great extent. Its composition is interesting as showing the gradual decrease of the proportion of common salt and the commencement of the separation of the more soluble salts.

Each of the two divisions of the mine just described contains only one mineral of importance. The third division, called the Carnallite region, contains a variety of minerals, and to this deposit Stassfurt owes its world-wide fame. The average thickness of this deposit is about 25 metres, and its composition is as follows:

	Per cent.
Carnallite	60
Kieserite	16
Rock salt	20
Tachydrite	4

besides small quantities of magnesium bromide. These minerals are deposited in the order given above, in successive layers, varying in thickness from $\frac{1}{100}$ to 1 metre, the different colours of these minerals giving the deposit a remarkable appearance.

The predominating mineral in this region is Carnallite [Specimen No. 40225, U.S.N.M.], a double chloride of potassium and magnesium, containing 26.76 per cent chloride of potassium, 34.50 per cent chloride of magnesium, and 38.74 per cent water, corresponding to the formula $KCl, MgCl_2, 6H_2O$. In the pure state it is colorless and transparent, and possesses a specific gravity of 1.618. It is very hygroscopic, and is easily soluble in water, 100 parts of which dissolve 64.5 parts of the mineral. It may be artificially formed from a solution of chloride of potassium, containing not less than 26 per cent of chloride of magnesium. The deposit which figures to the right of the Carnallite region is, as before mentioned, a secondary formation, and consists principally of the mineral Kainite [Specimen No. 64735, U.S.N.M.]. This deposit, though limited as compared to the other salt deposits, is yet of vast extent. The average composition of this deposit is:

Sulphate of potash	23.0
Sulphate of magnesia	15.6
Chloride of magnesium	13.0
Chloride of sodium	34.8
Water	13.6
	100.0

In the pure state it is colorless and almost transparent, and possesses a specific gravity of 2.13; 100 parts of water dissolve 79.5 parts of it. Cold water does not decompose it, but from its saturated hot solution the double sulphate of potash and magnesia separates, and chloride of magnesium remains in solution.

Methods of mining and manufacture.—In the manufacture of salt three principal methods are employed. The first, if, indeed, it can be called manufacture, consists in mining the dry salt from an open quarry, as in the Rio Virgen and Barcelona deposits, or by means of subterranean galleries, the methods employed at Petite Anse and in Galicia.

At Petite Anse the method of mining and preparation, as given by Mr. R. A. Pomeroy,[1] is as follows:

Mining is done by means of galleries on two levels. There are 16 to 25 feet of earth above the salt deposit. The contour of the latter conforms nearly with that of the surface. The working shaft is 168 feet deep. The depth to the first level or floor is 90 feet; to the second, 70 feet farther. The remaining 8 feet are used for a dump. The galleries of the first level were run, on an average, 40 feet in width and 25 feet and upwards in height, leaving supporting pillars 40 feet in diameter.

The galleries of the second level are run 80 feet in width and 45 feet in height, leaving supporting pillars 60 feet in diameter. The lower pillars are so left that the weight of the upper ones rests upon them in part, if not wholly, with a thickness of at least 25 feet of salt rock between.

Galleries aggregating nearly 1 mile in length have been run on the upper level and some 700 feet on the lower.

In running a gallery the first work is the "undercutting" on the level of the floor, of sufficient height to enable the miners to work

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[1] Transactions of the American Institute Mining Engineers, XVII, 1888–89, pp. 111.

with ease. The salt is then blasted down from the overhanging body. The yearly output is about 50,000 tons.

The salt as it comes from the mine is dumped into corrugated cast-iron rolls, which crush it. Next it goes into revolving screens, which take out the coarser lumps for "crushed salt" and let the fine stuff pass to the buhrstones. These grind the salt, and from them it goes to the pneumatic separators, which take out the dust and separate the market salt into various grades. Taking the dust out is essential to the production of a salt that will not harden, since the fine particles of dust deliquesce readily and on drying cement the coarse particles together. The drill used in the mine is what is known as the "Russian auger." It is turned by hand and forced by a screw of 12 threads per inch. The holes take cartridges 1½ inches diameter. Two men will bore 75 feet of hole each working-day of eight hours. Three-quarters of a pound of 18 per cent dynamite is used to the ton of salt mined.

On the Colorado Desert the salt occurs in the form of a crust a foot or more in thickness, resting on a lake of shallow brine. This crust, which is covered with a thin layer of dust and sand blown over it from the surrounding desert, is cut away longitudinally, much as ice is cut in the North. When loosened, the block, falling into the water beneath, is cleaned of its impurities, and is then thrown out on a platform to dry, after which it is ground and packed for market. In many parts of the arid West the salt is obtained merely by shoveling up the impure material deposited by the evaporation of salt lakes and marshes during seasons of drought. In this way is obtained a large share of the material used in chloridizing ores.

In the preparation of salt from sea water, solar evaporation alone is relied upon nearly altogether. This method, like the next to be mentioned, depends for its efficiency upon the fact already noted—that sea water holds in solution besides salt various other ingredients, which, owing to their varying degrees of solubility, are deposited at different stages of the concentration. In Barnstable County, Massachusetts, it was as follows: A series of wooden vats or tanks, with nearly vertical sides and about a foot in depth, is made from planks. These are set upon posts at different levels above the ground, and so arranged that the brine can be drawn from one to another by means of pipes. Into the first and highest of these tanks, known as the "long water room," the water is pumped directly from the bay or artificial pond by means of windmills, and there allowed to stand for a period of about ten days, or until all the sediment it may carry is deposited. Thence it is run through pipes to the second tank, or "short water room," where it remains exposed to evaporation for two or three days longer, when it is drawn off into the third vat, or "pickle room," where it stands until concentration has gone so far that the lime is deposited and a thin pellicle of salt begins to form on the surface. It is then run into the fourth and last vat, where the final evaporation takes place and the salt itself crystallizes out. Care must be exercised, however, lest the evaporation proceed too far, in which case sulphate of soda (Glauber's salt) and other injurious substances will also be deposited, and the quality of the sodium chloride thereby be greatly deteriorated.

As to the capabilities of works constructed as above, it may be said that during a dry season vats covering an area of 3,000 square feet would evaporate about 32,500 gallons of water, thus producing some 100 bushels of salt and 400 pounds of Glauber's salt. The moist climate of the Atlantic States, however, necessitates the roofing of the vats in such a manner that they can be protected or exposed as desired, thereby greatly increasing the cost of the plant. Sundry parts of the Pacific coast, on the other hand, owing to their almost entire freedom from rains during a large part of the year, are peculiarly adapted for the manufacture by solar evaporation. Hence, while the works on the Atlantic coast have nearly all been discontinued, there has been a corresponding growth in the West, and particularly in the region about San Francisco Bay.

The methods of procedure in the California works do not differ materially from that already given, excepting that no roofs are required over the vats, which are therefore made much larger. One of the principal establishments in Alameda County may be described as follows: The works are situated upon a low marsh, naturally covered by high tides. This has been divided, by means of piles driven into the mud and by earth embankments, into a series of seven vats or reservoirs, all but the last of which are upon the natural surface of the ground—that is, without wooden or other artificial bottoms. The entire area inclosed in the seven vats is about 600 acres, necessitating some 15 miles of levees. The season of manufacture lasts from May to October. At the beginning of the spring tides, which rise some 12 to 15 inches above the marsh level, the fifteen gates of reservoir No. 1, comprising some 300 acres, are opened and the waters of the bay allowed to flow in. In this great artifical salt lake the water is allowed to stand until all the mud and filth has become precipitated, which usually requires some two weeks. Then, by means of pumps driven by windmills, the water is driven from reservoir to reservoir as concentration continues, till finally the salt crystallizes out in No. 7, and the bittern is pumped back into the bay. The annual product of the works above described is about 2,000 tons.

A somewhat similar process is pursued in the manufacture of salt from inland lakes as the Great Salt Lake, Utah. The following account of the method here employed is by Dr. J. E. Talmage:

> The Inland Salt Company's gardens are situated near Garfield Beach, the most popular pleasure resort on the lake. In the method employed the water is pumped

from the lake into ponds prepared for its reception and situated above the level of the lake surface. The mother liquors flow off—are returned to the lake, in fact—when the evaporation has reached the proper stage. From the establishment of the works until 1883 the lake was close to the ponds; but, owing to the unusually high rate of evaporation attending the dry seasons of the immediate past, the water has receded, so that at present it has to be conveyed over 2,500 feet to the evaporating receptacles. This is effected by the aid of two centrifugal pumps, raising together 14,000 gallons of water per minute. The pumps throw the water to a height of 14 feet into a flume, through which it flows to the ponds. These are nine in number, and are arranged in series. In the first pond the mechanically suspended matters are left as sediment or scum, and the water passes into the second in a clear condition. The ponds cover upward of a thousand acres, and the drain channels leading from them aggregate 9 miles in length. The pumping continues through May, June, and July. A fair idea of the rate of evaporation in the thirsty atmosphere of the Great Basin may be gained from contemplating the fact that to supply the volume of water disappearing from the ponds by evaporation requires the action of the pumps ten hours daily in June and July. This is equal to the carrying away of 8,400,000 gallons per day from the surface of the ponds.

The "salt harvest" begins in August, soon after the cessation of pumping, and continues till all is gathered, frequently extending into the spring months of the succeeding year. An average season yields a layer of salt 7 inches deep, which amount would be deposited from 49 inches of lake water. The density at which salt begins to deposit, as observed at the ponds and confirmed by laboratory experiments, is 1.2121, and that of the escaping mother liquors is 1.2345. The yield of salt is at the rate of 150 tons per inch depth per acre. The crop is gathered on horse cars, which run on movable tracks into the ponds. At the works the operations are simple and effective. A link-belt conveyor carries the coarse salt to the crusher; thence to the dryer, after which a sifting process is employed by which the salt is separated into table salt and dairy salt.[1] [See Specimens Nos. 53630–53634, U.S.N.M.]

Owing to the depth below the surface of the salt beds in Ohio, Michigan, and other inland States, the material is never mined as in the cases first mentioned, but is pumped to the surface as a brine and there evaporated by artificial heat. In the Warsaw Valley region the beds lie from 800 to 2,500 feet below the surface, and are reached by wells. These are bored from 5½ to 8 inches in diameter and are cased with iron pipes down to the salt. Inside the first pipe is then introduced a second, 2 inches in diameter, with perforations for a few feet at its lower end, and which extends nearly if not quite to the bottom. Fresh water is then allowed to run from the surface down between the two pipes. This dissolves the salt, and forms a strong brine which, being heavier, sinks to the bottom of the well and is pumped up through the smaller or inner tube. At Syracuse the wells are not sunk into the salt bed itself, but into an ancient gravel deposit which is saturated with the brine. Here the introduction of water from the surface is done away with. In those cases, not at all uncommon, where the brine flows naturally to the surface in the form of a spring, pumping is of course dispensed with.

The methods of evaporation vary somewhat in detail. In New

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[1] Science, XIV, 1889, p. 445.

York the brine is run in a continuous stream in large pans some 130 feet long by 20 feet wide and 18 inches deep. As it evaporates the salt is deposited on the bottom and, by means of long-handled scrapers, is drawn on the sloping sides of the pan. Here it is allowed to drain, and is afterwards taken to the storage bins for packing or grinding.[1] Salt thus produced, it should be noticed, is never so coarse as the so-called rock salt, or that which has formed by natural evaporation. In Michigan the brine from the wells is first stored in cisterns, whence it is drawn off into large shallow pans, known technically as "settlers," where it is heated by means of steam pipes to a temperature of 175°, until the point of saturation is reached. It is then drawn into a second series of pans, called "grainers," where it is heated to a temperature of 185°, until crystallization takes place.

The strength of brines, and therefore the quantity of water that must be evaporated to produce a given quantity of salt, varies greatly in different localities. At Syracuse the brine contains 15.35 per cent of salt; at the Saginaw Valley, 17.91 per cent; at Saltville, Virginia, 25.97 per cent; while Salt Lake contains 11.86 per cent, and the waters of San Francisco Bay but 2.37 cent. The amount of impurities depends on the care exercised in process of manufacture, rapid boiling giving less satisfactory results than slower methods. The Syracuse salt has been found to contain 98.52 per cent sodium chloride; California Bay salt 98.43 per cent and 99.44 per cent; and Petite Anse 99.88 per cent. The impurities in these cases are nearly altogether chlorides and sulphates of lime and magnesia.

The Cheshire (England) salt beds are worked both by mining as rock salt and by pumping the brine. Formerly both upper and lower beds were mined, but flooding and falling in of the roofs caused the work to be discontinued on the upper beds. That now mined as rock salt comes wholly from the lower bed, and being impure is used mainly for agricultural purposes.

At Wieliczka the salt is likewise mined from galleries resembling in a general way those of a coal mine. These, according to Brehm,[2] begin at a depth of about 95 meters, forming several levels connected by stairways, the lowermost gallery being at a depth of 312 meters, or some 50 meters below sea level. These galleries have a total length of some 680 kilometers. They are connected with one another by means of "onze puits," of which seven are utilized for hoisting purposes. The work goes on continually night and day the year through. The salt is cut out in the form of blocks, leaving huge chambers, the roof being sustained by means of large columns of salt left standing. The

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[1] For details, see Salt and Gypsum Industries of New York, by Dr. F. J. H. Merrill, Bulletin No. 11, New York State Museum, 1893.

[2] Merveilles De La Nature. La Terre, etc., p. 315.

VIEWS OF BRINE-EVAPORATING TANKS AT SYRACUSE, NEW YORK.

From photographs by I. P. Bishop.

temperature within these chambers is very uniform, varying only between 10° and 15° C. The air is dry and healthful. The miners hew out of the salt statues of the saints, pyramids, and chandeliers, where they can place 300 lights. One chamber, called the Chapel of St. Antoine, with its altar, statues, columns, etc., is still in a condition of perfect preservation after a lapse of two centuries. The statements to the effect that the workmen, and indeed entire families, pass a good share of their lives in these mines, almost never coming to the surface, is stated by Brehm to be wholly erroneous. In reality, all the workers leave daily, only the horse remaining below.

The following statistics relative to the salt industry in the United States, are taken from Rothwell's Mineral Industry, 1892, page 419:

State.	1890.		1891.		1892.	
	Barrels.	Value.	Barrels.	Value.	Barrels.	Value.
Michigan	3,837,632	$2,302,579	3,927,671	$2,136,653	3,812,054	$1,906,027
New York	2,532,036	1,266,018	3,532,600	1,942,930	4,400,000	2,200,000
Ohio	231,303	136,617	397,000	264,000	460,000	276,000
West Virginia	229,938	134,688	275,000	192,500	278,000	166,800
Louisiana	273,553	132,000	221,430	93,000	192,850	81,000
California	62,363	57,085	200,000	100,000	250,000	125,000
Utah	427,500	126,100	465,000	150,000	700,000	295,000
Nevada	....	....	15,000	10,000	10,000	6,000
Kansas	882.666	397,199	1,000,000	650,000	1,232,850	698,395
All other	300,000	200,000	200,000	100,000	250,000	125,000
Total barrels	8,776,991	4,752,286	10,233,701	5,639,083	11,585,754	5,879,222
Total tons	1,228,779	....	1,432,718	....	1,622,006	....

The total production of salt in the United States for 1899 amounted to 19,861,948 barrels, or 2,780,677 short tons.

Uses.—The principal uses of salt have always been for culinary and preservative purposes. Aside from these, it is also used in certain metallurgical processes and in chemical manufacture, as in the preparation of the so-called soda ash (sodium carbonate), used in glass making, soap making, bleaching, etc., and in the preparation of sodium salts in general. Clear, transparent salt has been utilized in a few instances in optical and other research work. Secretary S. P. Langley of the Smithsonian Institution, in his astrophysical work made use of a salt prism some 19 centimetres in length and with faces 15 centimetres in breadth.

Composition of salt from various localities.

Varieties of salt.	Chloride of sodium.	Chloride of potassium.	Chloride of calcium.	Chloride of magnesium.	Sulphate of potash.	Sulphate of calcium.	Sulphates of magnesia and soda.	Carbonates of magnesia and lime.	Alumina and iron.	Residue.	Water.	Percentage of saline residue.	Authorities.
Rock salt.													
Wieliczka, white	100	....	....	Tr.	....	....	....	....	....	....	....	....	Bischof.
Berchtesgaden, yellow	99.928	....	....	0.07	....	....	....	....	....	....	....	....	Do.
Hall, in Tyrol	99.43	....	0.25	0.12	....	0.20	....	....	....	....	....	....	Do.
Schwäbire, Hall	99.63	....	0.09	0.28	....	....	....	....	....	....	....	....	
Stassfurt	94.57	....	....	0.97	....	0.89	....	....	1.12	2.23	0.22	....	Heine.
Hallstadt in Up. Austria.	98.14	Tr.	....	....	....	1.86	....	....	....	....	....	....	Bischof.
Wilhelmsglück	98.36	....	....	....	....	0.55	0.03	0.65	0.53	....	....	....	
Vic in German Loraine.	99.30	....	....	....	....	0.50	....	....	0.20	....	....	....	Berthier.
Jeb-el-Melah, Algeria	97	....	....	....	....	3.00	....	....	....	....	....	....	Fournet. (?)
Ouled Kebbah, Algeria	98.53	....	0.93	0.57	....	....	....	....	....	....	....	....	Do.
Cheshire, England	99.32	....	....	0.02	....	0.46	....	....	....	....	....	....	G. H. Cook.
Carrickfergus, Ireland.	96.28	....	....	....	....	3.50	0.08	....	....	....	0.14	....	Do.
Holston, Virginia	99.55	....	Tr.	....	....	....	....	0.45	....	....	....	....	C. B. Hayden.
Petite Anse, Louisiana.	98.88	....	Tr.	Tr.	....	0.79	....	....	....	....	0.33	....	Goessman.
Santo Domingo	98.33	....	....	0.04	....	1.48	....	....	....	0.01	0.07	....	Do.
Cardona, Spain	98.55	....	0.99	0.02	....	0.44	....	....	....	....	....	....	
Sea salt.													
Turks Island	96.76	....	....	0.14	....	1.56	0.64	....	....	....	0.90	....	G. H. Cook.
St. Martins	97.21	....	....	0.26	....	0.54	0.24	....	....	....	1.75	....	Do.
St. Kitts	99.77	....	....	0.01	....	0.08	....	....	....	....	0.14	....	Do.
Curaçoa	99.85	....	....	0.03	....	0.12	....	....	....	....	....	....	Do.
Cadiz	95.76	....	....	0.57	....	0.75	0.48	....	....	....	2.44	....	Do.
Lisbon	94.17	....	....	1.11	....	0.49	1.39	....	....	....	2.84	....	Do.
Trapani, Sicily	96.78	....	....	0.49	....	0.41	0.68	....	....	....	1.64	....	Do.
Marthas Vineyard	94.91	....	....	0.24	....	1.42	0.19	....	....	....	3.24	....	Do.
Texas	99.46	....	....	....	....	0.10	0.30	....	....	....	0.14	....	Do.
Pacific coast (Union Pacific Salt Co.).	98.435	....	....	....	....	....	0.365	....	....	....	1.20	....	Falkenan & Reese.
Salt from springs and lakes.													
Cheshire, England	96.36	....	0.01	0.02	....	1.17	....	....	....	....	2.44	....	Do.
Dienze, German Loraine.	97.39	....	....	....	....	1.02	0.89	....	....	....	0.50	....	Do.
Droitwich, England	96.93	....	....	0.02	....	3.05	....	....	....	....	....	....	Do.
Goderich, Ontario	97.03	....	0.01	0.03	....	1.43	....	....	....	....	1.50	....	Goessman.
Onondaga, New York	97.41	....	0.15	0.18	....	1.26	....	....	....	....	1.00	....	G. H. Cook.
Pittsburg, Pennsylvania.	96.70	....	0.33	0.07	....	....	....	....	....	....	2.70	....	Do.
Kanawha, West Virginia.	91.31	....	1.26	0.43	....	....	....	....	....	....	7.00	....	Do.
Holston, Virginia	99.11	....	....	....	....	0.68	0.11	....	....	....	0.10	....	Do.
Saginaw, Michigan	92.97	....	1.09	0.50	....	0.33	....	....	....	0.01	5.10	....	Do.
Hocking Valley, Ohio.	93.07	....	0.61	0.04	....	0.10	....	....	....	....	3.40	....	Goessman.
Pomeroy, Ohio	96.42	....	0.53	0.18	....	....	....	....	0.05	0.16	2.66	....	E. S. Wayne.
Nebraska	98.12	....	....	0.07	....	0.24	0.89	....	....	....	0.80	....	Goessman.
Kansas	93.06	....	....	0.24	....	1.12	0.18	....	....	....	4.80	....	Do.

Composition of salt from various localities—Continued.

Varieties of salt.	Chloride of sodium.	Chloride of potassium.	Chloride of calcium.	Chloride of magnesium.	Sulphate of potash.	Sulphates of calcium.	Sulphates of magnesia and soda.	Carbonates of magnesia and lime.	Alumina and iron.	Residue.	Water.	Percentage of saline residue.	Authorities.
Salt from springs and lakes.—Cont'd.													
Onondaga "factory filled."	98.28	....	....	....	....	0.91	0.09	....	....	0.12	0.60	......	Goessman.
Great Salt Lake	97.61	....	....	....	....	1.03	0.08	....	....	....	1.28	......	G. H. Cook.
Elton Lake, Russia	98.95	....	....	0.19	....	0.51	0.35	....	....	....	....	......	Göbel.
Solid residue of brines and sea water.													
Halle, in Prussia and Saxony.	94.43	0.21	1.03	1.69	....	2.23	......	0.39	....	....	....	12.28	Meissner.
Stassfurt	94.49	....	....	0.99	0.34	2.80	1.20	0.18	....	Tr.	....	17.16	Heine.
Schönebeck	95.71	0.08	....	1.09	0.08	1.61	1.37	0.06	....	....	....	2.00	Herman.
Do	93.72	....	....	0.67	1.34	2.55	1.18	0.49	0.03	....	....	11.10	Watts Dict. of Chem., Vol. V, p. 334.
Artern, from bore in rock salt.	95.35	0.45	....	1.59	1.10	1.51	......	....	....	....	....	26.50	Heine.
Dunenberg	89.88	....	....	1.49	0.99	0.04	0.63	0.17	6.77	0.02	....	8.39	Do.
Manheim	82.23	1.83	6.74	1.18	....	0.18	......	7.63	....	0.07	....	2.87	Bromeis.
Soden	86.01	1.81	....	2.24	....	0.65	......	8.79	....	0.50	....	1.27	Figuer and Mialho.
Cheshire	97.40	....	0.25	0.25	....	1.90	......	....	0.20	....	....	26.00	Wm. Henry.
Dieuze	84.87	....	....	....	....	1.83	3.30	....	....	....	....	15.20	G. H. Cook.
China	75.47	....	17.92	5.97	....	....	......	....	....	....	....	21.20	Boussingault.
Onondaga	95.42	....	0.84	0.64	....	3.09	......	....	0.01	....	....	18.54	G. H. Cook.
Pittsburg	81.27	....	13.93	4.80	....	....	......	....	Tr.	....	....	2.80	Do.
Kanawha	79.45	....	16.48	4.07	....	....	......	....	Tr.	....	....	9.20	Do.
Holston	98.39	....	....	....	....	1.22	0.39	....	Tr.	....	....	26.40	Do.
Salt Lake, Texas	97.08	....	....	....	....	0.82	2.10	....	....	....	....	24.90	Do.
Sea water	78.61	1.34	....	8.56	....	3.47	6.42	0.27	....	....	....	3.74	Usiglio.
Elton Lake	13.15	0.79	....	67.80	....	....	18.26	....	....	....	....	29.13	Rose.
Dead Sea	29.86	2.51	11.81	55.45	....	0.37	......	....	....	....	....	26.42	Booth and Muckle.
Great Salt Lake	90.07	....	....	1.12	....	....	8.18	....	....	....	....	22.42	L. D. Gale.
Sea water (San Francisco Bay).	......	....	....	....	....	....	......	....	....	....	....	3.033	F. Gutzkow.

2. FLUORITE.

This is a calcium fluoride, CaF_2 = fluorine 48.9 per cent, calcium 51.1 per cent. The most striking features of this mineral are its cubic crystallization (Specimens Nos. 51226, 66831, 66832, U.S.N.M.), octahedral cleavage (Specimen No. 48270, U.S.N.M.), and fine green (Specimen No. 48270, U.S.N.M.), yellow (Specimen No. 49160, U.S.N.M.), purple (Specimen No. 51226, U.S.N.M.), violet, and sky blue colors. White (Specimen No. 36091, U.S.N.M.) and red-brown varieties are also known. The mineral is translucent to transparent, and of a hardness somewhat greater than calcite (4 of Dana's scale).

Occurrence.—The mineral occurs as a rule in veins, though sometimes in beds in gneiss, the schists, limestones, and sandstones. It is also a common gangue of metallic ores, particularly those of lead and tin.

At Rosiclare, in southern Illinois, the fluorspar veins, according to Emmons,[1] are true fissure veins, varying from 4 to 20 feet in width in limestones immediately underlying the coal measures. He regards the original crevice as formed by dynamic action, as probably comparatively small and subsequently enlarged by solution by percolating waters. The source of the fluorspar of the veins would seem to be the surrounding limestones.

The associated minerals are galena and calcite, with smaller quantities of sphalerite and iron and copper pyrites.

Uses.—The material is used mainly as a flux for iron, in the manufacture of opalescent glass and for the production of hydrofluoric acid. The chief source of supply in the United States is Rosiclare, Illinois, the annual output being some 6,000 to 10,000 tons, valued at about $5 a ton.

3. CRYOLITE.

Composition.—Na_3AlF_6,=aluminum 12.8 per cent; sodium 32.8 per cent; fluorine 54.4 per cent. The mineral is as a rule of snow-white color, though sometimes reddish or brownish, rarely black, and coarsely crystalline granular, translucent to subtransparent. It has a hardness of 2.5; specific gravity of 2.9 to 3, and in thin splinters may be melted in the flame of a candle.

The name is from the Greek word *κρυος*, ice, in allusion to its translucency and ice-like appearance (Specimen No. 17571, U.S.N.M.).

Mode of occurrence.—Cryolite occurs, as a secondary product, in the form of veins. It is rarely found in sufficient abundance to be of commercial value, the supply at present coming almost wholly from Evigtok in South Greenland. The country rock here is said to be granite and the vein as described in 1866[2] was 150 feet in greatest breadth and was exposed for a distance of 600 feet. The principal mineral of the vein was cryolite, but quartz, siderite, galena, and chalcopyrite were constant accompaniments, irregularly distributed through the mass. In 1890 the mine as worked was described as a hole in the ground elliptical in shape, 450 feet long by 150 feet wide, the pit being some 100 feet deep. The drills had penetrated 150 feet

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[1] Transactions of the American Institute of Mining Engineers, XXI, 1893, p. 31.

[2] Paul Quale, Report of Smithsonian Institution, 1866, p. 398.

deeper and found cryolite all the way. Johnstrup, as quoted by Dana,[1] describes the cryolite as:

> Limited to the granite; he distinguishes a central and a peripheral part; the former has an extent of 500 feet in length and 1,000 feet in breadth and consists of cryolite chiefly, with quartz, siderite, galena, sphalerite, pyrite, chalcopyrite, and wolframite irregularly scattered through it. The peripheral portion forms a zone about the central mass of cryolite; the chief minerals are quartz, feldspar, and ivigtite, also fluorite, cassiterite, molybdenite, arsenopyrite, columbite. Its inner limit is rather sharply defined, though there intervenes a breccia-like portion consisting of the minerals of the outer zone enclosed in cryolite; beyond this it passes into the surrounding granite without distinct boundary.

Cryolite in limited quantity occurs at the southern base of Pike's Peak, in Colorado, and north and west of St. Peter's Dome (Specimen No. 48220, U.S.N.M.). It is found in vein-like masses of quartz and microcline embedded in granite.

Uses.—Until within a few years the material has been utilized only in the manufacture of soda, and sodium and aluminum salts, and to a small extent in the manufacture of glass and porcelain ware. It is also used in the electrolytic processes of extracting aluminum from its ores, as now practiced.

The principal works utilizing the Greenland cryolite in chemical manufacture are, at time of writing, those of the Pennsylvania Salt Manufacturing Company at Natrona, Pennsylvania (see series of crude and manufactured products Nos. 63327 to 63334, U.S.N.M).

IV. OXIDES.

1. Silica.

Quartz.—The mineral quartz, easily recognized by its insolubility in acids, glassy appearance (Specimen No. 67985, U.S.N.M.), lack of cleavage, and hardness, which is such that it readily scratches glass, is one of the most common and widely disseminated of minerals. Chemically it is pure silica, of the formula SiO_2. It crystallizes in the hexagonal system with beautiful terminations, and is one of the most attractive of minerals for the amateur collector (Specimen No. 61768, U.S.N.M.). The common form is, however, massive, occurring in veins in the older crystalline rocks (Specimen No. 55244, U.S.N.M.). Common sand is usually composed mainly of quartzose grains which, owing to their hardness and resistance to atmospheric chemical agencies, have withstood disintegration to the very last.

The terms *rose*, *milky* (Specimen No. 62381, U.S.N.M.), and *smoky* (Specimen No. 67986, U.S.N.M.) are applied to quartzes which differ from the ordinary type only in tint, as indicated. Chalcedony is the name given to a somewhat hornlike, translucent or transparent form of silica occurring only as a secondary constituent in veins, or isolated concretionary masses, and in cavities in other rocks. Agate is a banded

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[1] System of Mineralogy, 1892, p. 167.

variety of chalcedony. The true onyx is similar to agate, except that the bands or layers of different colors lie in even planes. Jasper is a ferruginous, opaque chalcedony, sometimes used for ornamental purposes. Opal is an amorphous form of silica, containing somewhat variable amounts of water.

Quartz occurs as an essential constituent of granite, gneiss, mica schist, quartz porphyry, and liparite, and also as a secondary constituent in the form of veins, filling joints and cavities in rocks of all kinds and all ages.

Uses.—The finer clear grades of quartz are used to some extent for spectacle lenses and optical work, as well as in cheap jewelry (Specimen No. 11893, U.S.N.M.). Its main value is, however, for abrading purposes, either as quartz sand or as sandpaper (Series Nos. 55877–55884, U.S.N.M.), and in the manufacture of pottery (Specimens Nos. 62123, 63035–63038, U.S.N.M.). For abrading purposes it is crushed and bolted, like emery and corundum, and brings a price barely sufficient to cover cost of handling and transportation. Pure quartz sand is also of value for glass making (Specimens Nos. 53188, 60683, 63128, 63123, 63122, U.S.N.M.), and ground quartz to some extent as a "filler" in paints (Specimen No. 63119, U.S.N.M.), and as a scouring material in soaps. The following analyses show the composition of some glass sands from (I) Clearfield and (II) Lewistown, Pennsylvania:

Constituents.	I.	II.
Silica	99.79	98.84
Alumina	0.12	0.17
Iron oxides	0.014	0.34
Lime	0.8	Traces.
Ignition	....	0.23
	100.724	99.58

FLINT is a chalcedonic variety of silica found in irregular nodular forms in beds of Cretaceous chalk. These nodules break with a conchoidal fracture and interiorly are brownish to black in color (Specimen No. 62120, U.S.N.M.). By the aboriginal races the flints were utilized for the manufacture of knives and general cutting implements. Later they were used in the manufacture of gun flints and the "flint and steel" for producing fire. At present they are used to some extent in the manufacture of porcelain, being calcined (Specimen No. 62061, U.S.N.M.) and ground (Specimen No. 62122, U.S.N.M.) to mix with the clay and give body to the ware. In this country the same purpose is accomplished by the use of quartz. Small round nodules of flint from Dieppe, France, are said to be used in the Trenton (New Jersey) pottery works for grinding clay by being placed in revolving vats of water and kaolin. All the flint now used in this country is imported either as ballast or as an accidental constituent of chalk.

As the material is worth but from $1 to $2 a ton delivered at Trenton, it may be readily understood that transportation is a rather serious item to be considered in developing home resources.

According to Mr. R. T. Hill, nodules of black flint occur in enormous quantities in the chalky limestones—the Caprina limestones—of Texas. Numerous localities are mentioned, the most accessible being near Austin, on the banks of the Colorado River.

BUHRSTONE, or burrstone, is the name given to a variety of chalcedonic silica, quite cavernous, and of a white to gray or slightly yellowish color. The cavernous structure is frequently due to the dissolving out of calcareous fossils. The rock is of chemical origin—that is, results from the precipitation of silica from solution, and presumably through the action of organic matter. In France the material occurs alternating with other unaltered Tertiary strata in the Paris basin (Specimen No. 36140, U.S.N.M.). It is also reported in Eocene strata in South America, and in Burke and Screven counties along the Savannah River in southern Georgia in the United States (Specimen No. 36051, U.S.N.M.). The toughness of the rock, together with the numerous cavities, impart a sharp cutting power such as renders them admirably adapted for millstones, and in years past material for this purpose has been sent out from French sources all over the civilized world.

TRIPOLI is the commercial name given to a peculiar porous rock regarded as a decomposed chert associated with the Lower Carboniferous limestones of southwest Missouri (Specimen No. 55028, U.S.N.M.). The rock is of a white cream or slight pink cast, fine grained and homogeneous, with a distinct gritty feel, and, though soft, sufficiently tenacious to permit of its being used in the form of thin disks of considerable size for filtering purposes (Specimen No. 62044, U.S.N.M.). According to Hovey[1] the deposit is known to underlie between 80 and 100 acres of land, in the form of a rude ellipse, with its longer diameter approximately north and south. From numerous prospect holes and borings it has been shown to have an average thickness of 15 feet, the main quarry of the present company showing a thickness of 8 feet. The following section is given from a well sunk in the northern part of the area:

	Feet.	
Earth	0	to 4
Tripoli	4	20
Stiff red clay	20	21½
Mixed chert, clay, and ochre	21½	40
Cherty limestone	40	93
Cherty limestone bearing galena	93	103
Limestone	103	128
Limestone bearing sphalerite and galena	128	136
Soft magnesian limestone	136	173

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[1] Scientific American Supplement, July 28, 1894, p. 15487.

The tripoli is everywhere underlain by a relatively thin bed of stiff red clay, and also traversed in every direction by seams of the same material from 1 to 2 inches thick. These seams and other joints divide the rock into masses which vary in size up to 30 inches or more in diameter. Microscopic examinations as given by Hovey show the rock to contain no traces of organic remains, but to be made up of faintly doubly refracting chalcedonic particles from 0.01 to 0.03 millimetre in diameter. The chemical composition, as shown from analysis by Prof. W. H. Seaman, is as follows:

Silica (SiO_2)	98.100
Alumina (Al_2O_3)	0.240
Iron oxide (FeO and Fe_2O_3)	0.270
Lime (CaO)	0.184
Soda (Na_2O)	0.230
Water (ignition)	1.160
Organic matter	0.008
	100.192

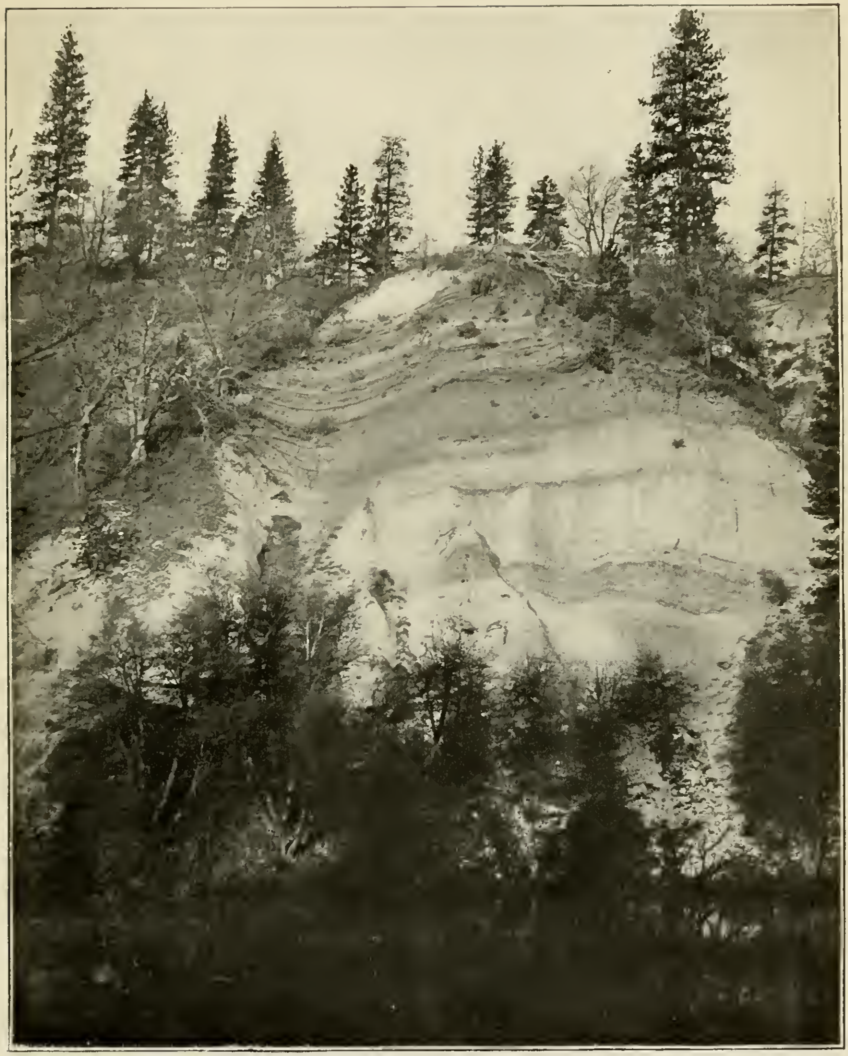
Silica soluble in a 10 per cent solution of caustic soda on boiling three hours, 7.28 per cent.

Aside from its use as a filter (Specimens Nos. 62044 and 62045, U.S.N.M.) the rock is crushed between burr stones, bolted, and used as a polishing powder (Specimens Nos. 51231 and 55029, U.S.N.M.). To a small extent it has been used in the form of thin slabs for blotting purposes, for which it answers admirably owing to its high absorptive property, but is somewhat objectionable on account of its dusty character. The view (Plate 6) shows the character of a quarry of this material as now worked by the American Tripoli Company at Seneca, in Newton County.

DIATOMACEOUS OR INFUSORIAL EARTH, as it is sometimes called, is, when pure, a soft, pulverulent material, somewhat resembling chalk or kaolin in its physical properties, and of a white or yellowish or gray color. Chemically it is a variety of opal (see analyses on page 220).

Origin and occurrence of deposits.—Certain aquatic forms of plant life known as diatoms, which are of microscopic dimensions only, have the power of secreting silica, in the same manner as mollusks secrete carbonate of lime, forming thus their tests or shells. On the death of the plant the siliceous tests are left to accumulate on the bottom of the lakes, ponds, and pools in which they lived, forming in time beds of very considerable thickness, which, however, when compared with other rocks of the earth's crust are really of very insignificant proportions. Like many other low organisms the diatoms can adapt themselves to a wide range of conditions. They are wholly aquatic, but live in salt and fresh water and under widely varying conditions of

View of Tripoli Mines in Carthage, Missouri.



DEPOSIT OF DIATOMACEOUS EARTH, GREAT BEND OF PITT RIVER, SHASTA COUNTY, CALIFORNIA.

From a photograph by J. S. Diller.

depth and temperature. They may be found in living forms in almost any body of comparatively quiet water in the United States. The exploring steamer *Challenger* dredged them up in the Atlantic from depths varying from 1,260 to 1,975 fathoms and from latitudes well toward the Antarctic Circle. Mr. Walter Weed, of the U. S. Geological Survey, has recently reported them as living in abundance in the warm marshes of the Yellowstone National Park, while Dr. Blake reported finding over 50 species in a spring in the Pueblo Valley, Nevada, which showed a temperature of 163° F.

Although beds of diatomaceous earth are still in process of formation, and in times past have been formed at various epochs, the Tertiary period appears for some reason to have been peculiarly fitted for the growth of these organisms, and all of the known beds of any importance, both in America and foreign countries, are of Tertiary age. The best known of the foreign deposits is that of Bilin, in Bohemia. This is some 14 feet in thickness. When it is borne in mind that, according to the calculations of Ehrenberg, every cubic inch of this contains not less than 40,000,000 independent shells, one stands aghast at the mere thought of the myriads of these little forms which such a bed represents. . Some of the deposits in the United States are, however, considerably larger than this. What is commonly known as the Richmond bed extends from Herring Bay, on the Chesapeake, Maryland, to Petersburg, Virginia, and perhaps beyond. This is in some places not less than 30 feet thick in thickness, though very impure (Specimen No. 67984, U.S.N.M., from Calvert County, Maryland, is fairly representative). Near Drakesville, in New Jersey, there occurs a smaller deposit, covering only some 3 acres of territory to a depth of from 1 to 3 feet. Some of the largest deposits known are in the West. Near Socorro, in New Mexico, there is stated to be a deposit of fine quality which crops out in a single section for a distance of 1,500 feet and some 6 feet in thickness.

Geologists of the fortieth parallel survey reported abundant deposits in Nevada, one of which showed in the railroad cutting west of Reno a thickness not less than 300 feet, and of a pure white, pale buff, or canary yellow color (Specimen No. 67916, U.S.N.M.). Along the Pitt River, in California, there is stated to be a bed extending not less than 16 miles and in some places over 300 feet thick (see Plate 7). Near Linkville, Klamath County, Oregon (Specimens Nos. 53402, 53093, U.S.N.M.), there occurs a deposit which has been traced for a distance of 10 miles, and shows along the Lost River a thickness of 40 feet. Beds are known also to occur in Idaho (Specimens Nos. 63843, 66950, U.S.N.M.), near Seattle, in Washington (Specimen No. 53200, U.S.N.M.), and doubtless many more yet remain to be discovered. A deposit of unknown extent, pure white color, and almost pulp-like consistency has been worked in South Beddington, Maine (Specimens

Nos. 73253, 73254, U.S.N.M.). Others of less purity occur near South Framingham, Massachusetts (Specimens Nos. 62767, 62768, U.S.N.M.), Lake Umbagog, New Hampshire (Specimen No. 29322, U.S.N.M.), at White Head Lake, Herkimer County, New York (Specimen No. 62913, U.S.N.M.), and at Grand Manan, New Brunswick (Specimen No. 57339, U.S.N.M.).

Chemical Composition.—As already intimated, this earth is of a siliceous nature, and samples from widely separated localities show remarkable uniformity in composition. Of the following analyses, No. I is from Lake Umbagog, New Hampshire, No. II, from Morris County, New Jersey, and No. III, from Popes Creek, in Maryland. As will be noted, the silica percentage is nearly the same in all.

Constituents.	I	II	III
Silica	80.53	80.66	81.53
Alumina	5.89	3.84	3.43
Iron oxides	1.03	....	3.34
Lime	0.35	0.58	2.61
Soda	....	....	1.43
Potash	....	....	1.16
Water and organic matter	12.03	14.01	6.04

The substance may therefore be regarded as a variety of opal.

Uses.—The main use of infusorial earth is for a polishing powder. It is, however, an excellent absorbent, and has been utilized to mix with nitroglycerine in the manufacture of dynamite. It has also been used to some extent in the preparation of the soluble silicate known as water glass. The demand for the material is therefore quite small, not nearly equal to the supply. The Maryland and Nevada deposits are said to be the principal ones now worked. During the year 1897 the entire output was about 3,000 tons, valued at some $30,400.

2. CORUNDUM AND EMERY.

CORUNDUM.—Composition, sesquioxide of aluminum Al_2O_3, = oxygen, 47.1 per cent; aluminum, 52.9 per cent. In crystals often quite pure, but frequently occurring associated in crystalline granular masses with magnetic iron, and often more or less altered into a series of hydrated aluminous compounds, as damourite (Specimen No. 82492, U.S.N.M.). The crystalline form of the mineral is hexagonal, or sixsided in outline, and often with curved sides and square terminations, giving rise to roughly barrel-shaped forms, as shown in specimen No. 81450 from Bengal, India.

A prominent basal cleavage causes the crystals to break readily with smooth flat surfaces at right angles with the axis of elongation. The massive forms often show a nearly rectangular parting or pseudocleavage (Specimen No. 63480, U.S.N.M., from Pine Mountain, Georgia).

The most striking physical property of the mineral is its hardness, which is 9 of Dana's scale. In this respect it ranks then next to the diamond. The color of the mineral varies from white through gray (Specimen No. 46283, U.S.N.M), brown, yellow, blue (Specimens Nos. 73531 and 48182, U.S.N.M.), pink (Specimen No. 81922, U.S.N.M.), and red; luster adamantine to vitreous; specific gravity, 3.95 to 4.1. The highly colored transparent red and blue forms are valuable as gems, and are known under the names of ruby and sapphire. The consideration of these forms is beyond the limits of this work. (See Mineral and Gem Collections.)

Occurrences.—Athough widespread as a mineral, corundum, unmixed with a large proportion of magnetite (forming emery), has been found in but few localities in sufficient abundance to be of commercial value. The most important deposits in the United States are in southwestern North Carolina and in the Laurel Creek region of northern Georgia. The country rock in both these regions is hornblendic gneiss, through which has been intruded a basic eruptive (dunite, Specimen No. 70069, U.S.N.M.), and it is mainly along the decomposed lines of contact between the two that the corundum is found. According to Dr. T. M. Chatard, the Corundum Hill Mine is situated on a ridge which runs in the northeast and southwest direction characteristic of this section, the dunite outcrops being on the crest, and apparently surrounded on all sides except toward the east by hornblende gneiss. On the east side mica schist (probably damourite schist) takes the place of the gneiss, and it is on the eastern side of the dunite that the so-called "sand vein" is found. This is a vein-like mass of brown vermiculite in small scales containing an abundance of small crystals of corundum which are usually brown in color and often broken into fragments (Specimen No. 73529, U.S.N.M.). The easterly wall of this vein is the mica schist very much decomposed, while on the western side is found enstatite (Specimen No. 70070, U.S.N.M.), next vermiculite mixed with chlorite, then talc (Specimen No. 70071, U.S.N.M.), which in turn gives place to nodules of more or less altered dunite.

The specimens of corundum crystals for which this locality is so celebrated (Specimen No. 73530, U.S.N.M.) have been found mainly, if not wholly, on the westerly side of the dunite, and on or near the line of contact between the gneiss and dunite.

State Geologist Yeates has stated[1] that in the Laurel Creek region the corundum is not confined to the vermiculite and chlorite bands, but is abundant in the lime soda feldspar as well. The same authority states that in this region the dunite is not inclosed by the hornblendic

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[1] Bulletin No. 2, Geological Survey of Georgia, 1894.

gneisses, but intruded between these and other gneiss or mica schist; also that the corundum-bearing veins lie in the dunite close to the contact and in the vicinity of the hornblendic gneiss. It should be said before leaving the subject that certain micaceous minerals, as margarite and chloritoid (Specimen No. 63107, U.S.N.M., from Chester, Massachusetts) are almost invariable accompaniments of corundum and emery deposits, and that it was the finding of these minerals that led to the discovery of the emery beds at Chester. Chatard reports that in the North Carolina mines chlorite or vermiculite is considered a "corundum sign," and in mining such indications are followed so long as they hold out (Specimen No. 63153, U.S.N.M.).

The geographical distribution of corundum-bearing rocks in the eastern United States has been worked out in detail by J. V. Lewis of the North Carolina Geological Survey, from whose report[1] the accompanying map (Plate 8) is taken. According to this authority the corundum occurring in such quantities as to be of commercial value is almost universally found in connection with basic eruptive rocks, as peridotites or their varietal forms pyroxenite and amphibolite, which are themselves intruded into gneisses.

At Yogo Gulch, Montana, corundum in the form of sapphire (see Gem Collections) occurs as a constituent of a basic eruptive rock near the line of contact with aluminous shales (Specimen No. 53519, U.S.N.M.). In Gallatin County the mineral is found in well-defined crystals of all sizes up to an inch or more in length abundantly disseminated throughout a granite (Specimen No. 83838,U.S.N.M.). In the Russian Urals it occurs in disseminated crystals and large cleavage masses in feldspar (Specimens Nos. 40323, 40315, 40334, 73532, U.S.N.M.). In India it occurs as an original constituent associated with both acid and basic rocks, but in most cases where the mineral is in the basic rocks there have been found intrusions of pegmatite (an acid rock) in the near vicinity. In the celebrated Mogok Ruby Mines the corundum is found in a crystalline limestone and the detritus resulting from its decay, the limestone itself being regarded by Professor Judd as an extreme form of alteration of rocks of igneous origin (see further under Emery).

Corundum has recently been reported as a constituent of both nepheline syenites and ordinary syenites in the counties of Renfrew, Hastings, and Peterborough, in Eastern Ontario, Canada. According to W. G. Miller[2] these syenites are dike rocks, consisting essentially of feldspar, nepheline, and black mica or hornblende, the corundum occurring more abundantly in the ordinary syenite than in that which carries nepheline. The dikes are from a few inches to some feet in diameter, and the corundum is distributed in a somewhat capricious

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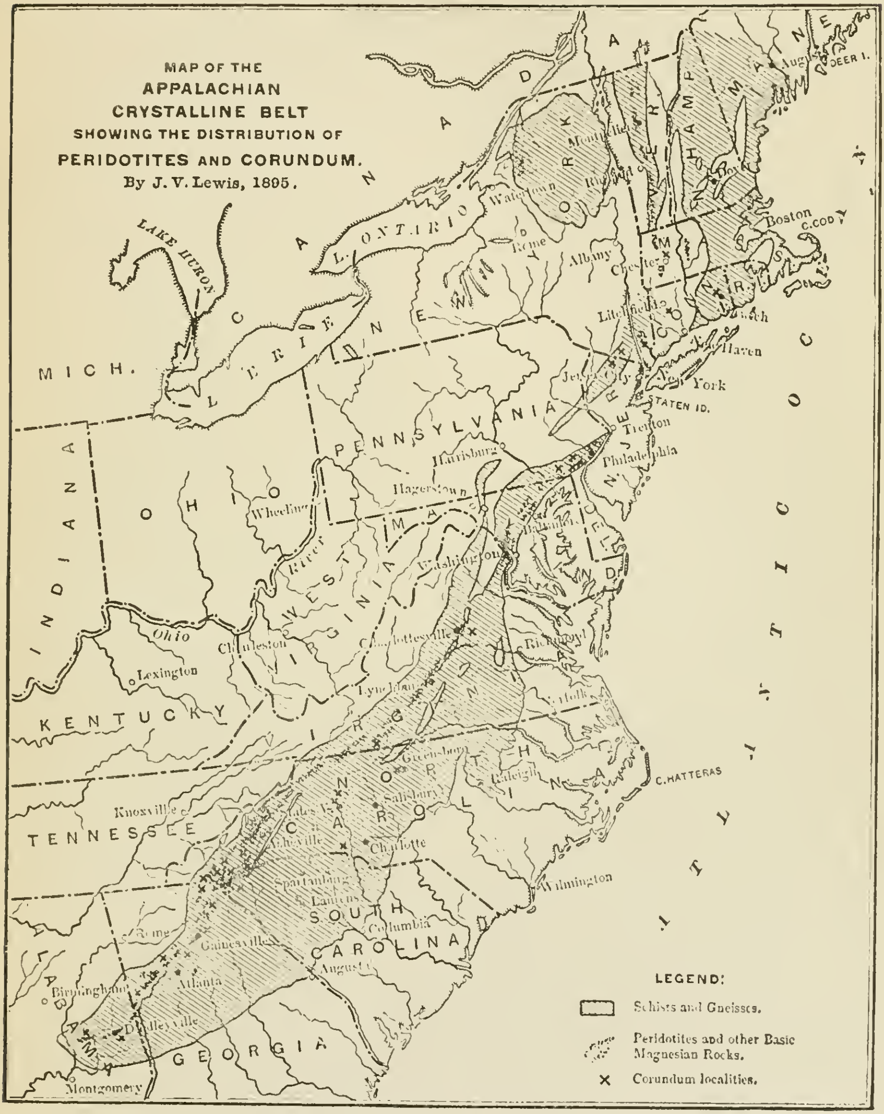
[1] Bulletin No. 11. Corundum and the Basic Magnesian Rocks of Western North Carolina, by J. V. Lewis, 1896.

[2] Report of the Canadian Bureau of Mines, VII, Pt. 3, 1898, p. 207.



Map showing Distribution of Corundum and Peridotite in the Eastern United States.

After J. V. Lewis, Bulletin 11, North Carolina Geological Survey.

manner, being quite uniformly distributed in some of the smaller dikes, or segregated irregularly along certain lines or patches. In some of the dikes the mineral is quite lacking. The total area covered by the corundum-bearing rocks, in the three counties mentioned, is 100 square miles (Specimen No. 53538, U.S.N.M.).

Origin.—Dr. Chatard, as a result of his observations already quoted, regards the corundum of Franklin County, North Carolina, and the Laurel Creek region of Georgia as a secondary mineral produced by a mutual reaction between the various elements of the dunite and gneiss during decomposition, the solutions formed during such decomposition giving rise to such reactions as are productive of chlorite and vermiculites, and, where the necessary conditions of proportion are reached, to corundum.

On the other hand, Dr. J. H. Pratt,[1] who has made a detailed study of the North Carolina region, regards the corundum as an original constituent of the peridotite—as having been held in solution in the molten magma at the time of its intrusion into the country rock, and having been one of the first minerals to crystallize on its cooling. This view is most in accord with recent synthetic work done by Morozewicz and others.

Pirsson, who has described[2] the occurrence of sapphires in a basic eruptive rock from Yogo Gulch, Montana, regards them as of pyrogenetic origin—that is, they result from the direct crystallization of the oxide, but which has been derived from aluminous material dissolved from shales by the molten rock during its intrusion. The sharp outlines of the crystals in the granite from Gallatin County, Montana (Specimen No. 83838, U.S.N.M.), is also indicative of a direct crystallization from a molten magma containing an excess of aluminum. A like origin must also be recognized for the Canadian mineral, and a part at least of that of India.

Emery.—The rock emery takes its name from Cape *Emeri*, on the island of Naxos, where it occurs in great abundance. Mineralogically it has been regarded by various authorities as either a mechanical admixture of corundum and magnetic iron ore or as simply a massive iron spinel—hercynite. So far as the Naxos emery is concerned. the first view is undoubtedly correct. Physically emery is a massive, nearly opaque, dark gray to blue-black or black material, with a specific gravity of 4 and hardness of 8, Dana's scale, breaking with a tolerably regular fracture, and always more or less magnetic.

Chemically the material is quite variable in composition, a fact which gives support to the opinions of those who hold it to be a mixture rather than a true chemical compound. Below are the results of

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[1] American Journal of Science, VI, 1898, pp. 49–65.

[2] Idem, IV, 1897, p. 421.

analyses by Dr. J. Lawrence Smith, from whose papers on the subject these notes are partially compiled:

Localities.	Alumina.	Iron.	Lime.	Silica.	Water.
Kulah	61.05	27.15	1.30	9.63	2.00
	63.50	33.25	0.92	1.61	1.90
Samos	70.10	22.21	0.62	4.00	2.10
Gumuch	60.10	33.20	0.48	1.80	5.62
	77.82	8.62	1.80	8.13	3.11
Nicaria	71.06	20.32	1.40	4.12	2.53
	75.12	13.06	0.72	6.88	3.10
Ephesus	60.10	33.20	0.48	1.80	5.62
Chester, Massachusetts	44.01	50.21	....	3.13	....
	50.02	44.11	....	3.25	....
	51.92	42.25	....	5.46	....
	74.22	19.31	....	5.48	....
	84.02	9.63	....	4.81	....

Geologically emery, like corundum, belongs mainly to the older crystalline rocks. In Asia Minor it occurs in angular or rounded masses from the size of a pea to those of several tons weight, embedded in a blue-gray or white crystalline limestone, which overlies micaceous or hornblendic schists, gneisses, and granites. Superficial decomposition has, as a rule, removed more or less of the more soluble portions of the limestone, leaving the emery nodules in a red ferruginous soil. With the emery are associated other aluminous minerals as mentioned below.

According to Tschermak[1] the Naxos emery (Specimen No. 60465, U.S.N.M.) occurs mostly in the form of an iron-gray, scaly to schistose, rarely massive, aggregate consisting essentially of magnetite and corundum, the latter mineral being in excess. In addition to these two minerals occur hematite and limonite, as alteration products of the magnetite; margarite, muscovite, biotite, tourmaline, chloritoid, diaspore, disthene, staurolite, and rutile occur as common accessories; rarely are found spinel, vesuvianite, and pyrite. Under the microscope he finds the emery rock to show the corundum in rounded granules and sometimes well-defined crystals with hexagonal outlines, particularly in cases where single individuals are embedded in the iron ores. (Plate 9, fig. 2.) In many cases, as in the emery of Krenino and Pesulas, the granules are partially colored blue by a pigment sometimes irregularly and sometimes zonally distributed. The corundum grains, which vary in size between 0.05 mm. and 0.52 mm. (averaging about 0.22 mm.), are very rich in inclosures of the iron ores, largely magnetite in the form of small, rounded granules. The quantity of these is so great as at times to render the mineral quite opaque, though at times of such dust-like fineness as to be translucent and of a brownish

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[1] Mineralogische und Petrographische Mittheilungen, XIV, 1894, p. 313.

MICROSTRUCTURE OF EMERY.

After Tschermak, Mineralogische und Petrographische Mittheilungen, XIV, Part 4.

color. The larger corundums are often injected with elongated, parallel-lying clusters or groups of the iron ores, as shown in fig. 3, Tschermak's paper. The corundums in turn are often surrounded by borders of very minute zircons. The iron ore, as noted above, is principally magnetite, but which, by hydration and oxidation, has given rise to abundant limonite. The magnetites are in the form of rounded granules and dust-like particles, and also at times in well-defined octahedrons. In their turn the magnetites also inclose particles of corundum very much as the metallic iron of meteorites of the pallosite group inclose the olivines and as shown in Plate 9, fig. 4. The iron ores, as a rule, occur in parallel layers and lenticular masses or nests.

The following account of these deposits and the method of working is by A. Gobantz:[1]

> Naxos, the largest of the Cyclades Islands, is remarkable as being one of the few localities in the world producing emery on a large scale; the deposits, which are of an irregularly bedded or lenticular form, being mostly concentrated on the mountains at the northern end of the island, the most important ones being in the immediate vicinity of the village of Bothris. The island is principally made up of archæan rocks, divisible into gneiss and schist formations, the latter consisting of mica schists alternating with crystalline limestones. The lenticular masses of emery, which are very variable in size, ranging in length from a few feet to upward of 100 yards and in maximum thickness from 5 to 50 yards, are closely associated with the limestones, and, as they follow their undulations, they vary very much in position, lying at all kinds of slope, from horizontal to nearly vertical. Seventeen different deposits have been discovered and worked at different times. These range over considerable heights from 180 to 700 meters above sea-level, the largest working, that of Malia, being one of the lowest. This important deposit covers an area of more than 30,000 square metres, extending for about 500 metres in length with a height of more than 50 metres. This was worked during the Turkish occupation, and it has supplied fully one-half of all the emery exported since the formation of the Greek Kingdom. The highest quality of mineral is obtained from two comparatively thin but extensive deposits at Aspalanthropo and Kakoryakos, which are 435 metres above the sea level. The mineral is stratified in thin bands from 1 to 2 feet in thickness, crossed by two other systems of divisional planes so that it breaks into nearly cubical blocks in the working. The floor of the deposit is invariably crystalline limestone, and the roof a loosely crystalline dolomite covered by mica schist. The underlying limestones are often penetrated by dykes of tourmaline granite, which probably have some intimate connection with the origin of the emery beds above them.
>
> Mineralogically emery is a compact mixture of blue corundum and magnetic iron ore, its value as an abrasive material increasing with the proportion of the former constituent. This proportion has, however, been usually much overestimated. Seven samples collected by the author have been examined at the Technical High School in Vienna, and found to contain from 60 to 66 per cent of alumina. The average composition may be considered to be $\frac{2}{3}$ corundum, the remainder being magnetite and silica in the proportion of about 2 to 1, with some carbonate of lime.
>
> The working of the deposits is conducted in an extremely primitive fashion.

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[1] Oesterreichische Zeitschrift für Berg- und Hüttenwesen, XLII, p. 143. Abstract in the Minutes and Proceedings of the Institute of Civil Engineers, CXVII, pp. 466–468.

During the period of Turkish rule the exclusive right of emery mining was given to two villages, and this rule has prevailed up to the present time; no Greek Government having ventured to break down the monopoly. These privileged workmen are about 600 in number, and have the right of working the mineral wherever and in what manner they may think best. The produce is taken over by the Government official at the rate of about £3 12s. for 50 cwts. The rock is exclusively broken by fire-setting. A piece of ground, about 5 feet broad and the same height, is cleared from loose material, and a pile of brushwood heaped against it and lighted. This burns out in about twenty-four or thirty hours, when water is thrown upon the heated rock to chill it and develop fractures along the secondary divisional planes in the mass of emery, and so facilitate the breaking up and removal of the material. Sometimes a crack is opened out by inserting a dynamite cartridge, but the regular use of explosives is impossible, owing to the hardness of the mineral which can not be bored with steel tools. Only the larger lumps are carried down to the shipping place, the smaller sizes, up to pieces as large as the fist, being left on the ground.

As most of the suitable places for fire-setting at the surface have been worked out, attempts have been made to follow the deposits underground, but none of these have been carried to any depth, partly on account of the suffocating smoke of the fires, rendering continuous work difficult; but more particularly from the dangerous character of the loose dolomite roof, which is responsible for many fatal accidents from falls annually. These might, of course, be prevented by the judicious use of timber or masonry to support the roof, but this appears to be beyond the skill of the native miners.

The rapid exhaustion of the forests in the neighbourhood of the mines, owing to the heavy consumption of fuel in fire-setting, has been a cause of anxiety to the Government for some years past, and competent experts have been employed to suggest new methods of working. These have been tolerably unanimous in recommending the institution of systematic quarry workings, using diamond boring machines and powerful explosives for winning the mineral, and the construction of wire-rope ways and jetties for improving the methods of conveyance and shipping; but as funds for these improvements, owing to the disastrous condition of the national finances, are not obtainable, the primitive method of working still continues. Meanwhile the competition of the mines in Asia Minor has become so intense that the export of emery from Naxos has almost entirely ceased for a year past.

According to Jackson, the principal emery deposit at Chester, Massachusetts, in the United States, occurs at South Mountain, in the form of a bed from 4 to 10 feet in width, with a nearly N. 20° E., S. 20° W., course, and dipping to the eastward at an angle of 70°. The bed widens rapidly as it rises in the mountain, and is in one place, where it is associated with a bed of iron ore (magnetite), 17 feet wide, the emery itself being not less than 10 feet in the clear. The highest point of outcrop is 750 feet above the immediate base of the mountain. The bed cuts through both the South and North Mountains, and has been traced in length 4 miles. Frequently large globular masses of the emery are found in a state of great purity, separated from the principal masses of the bed and surrounded by a thin layer of bright green chloritoid and a thicker layer of interwoven laminated crystals of delicate lilac-colored margarite (Specimen No. 63107, U.S.N.M.), sometimes 2 or more inches in thickness. Some of these balls of emery are 3 or more feet in diameter and extremely difficult to break.

(Specimens Nos. 63102, 63103, 63104, 63105, 63106, U.S.N.M.), show the character of the ore as mined and the character of the wall or country rock.

The chief commercial sources of emery are those of Gumuch-dagh, between Ephesus and the ancient Tralles; Kulah, and near the river Hermes in Asia Minor, and the island of Naxos, whence it is quarried and shipped from Smyrna, in part as ballast, to all parts of the world. The only commercial source of importance in the United States, or indeed, in North America, is Chester, Massachusetts, as above noted. The island of Naxos is stated to have for several centuries furnished almost exclusively the emery used in the arts, the material being chiefly obtained from loose masses in the soil. The mining at Kulah and Gumuch-dagh was begun about 1847 and at Nicaria in 1850. The emery vein at Chester, Massachusetts, was discovered by Dr. H. S. Lucas in 1863, and described by Dr. C. T. Jackson in 1864.

In preparing for use the mineral, after being dug from the soil or blasted from the parent ledge, is pulverized and bolted in various grades, from the finest flour to a coarse sand (Specimens Nos. 59844 to 59864, U.S.N.M., inclusive). The commercial prices vary according to grade from 3 to 10 cents a pound. At the end of the last century the price of the Eastern emery is given at from $40 to $50 a ton. About 1835 an English monopoly controlled the right of mining and the price rose in 1847 to as high as $140 a ton.

The chief uses of emery and corundum, as is well known, are in the form of powder by plate-glass manufacturers, lapidaries, and stone workers; as emery paper, or in the form of solid disks made from the crushed and bolted mineral and cement, known commercially as emery wheels. The great toughness and superior cutting power of these wheels renders them of service in grinding glass, metals, and other hard substances, where the natural stone is quite inefficient.

(See further under Grind and Whet Stones, p. 463.)

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Fig. 5.
PISOLITIC BAUXITE.
Bartow County, Georgia.
Specimen No. 63335, U.S.N.M.

3. Bauxite.

Composition $Al_2O_3.2H_2O$,=alumina, 73.9 per cent; water, 26.1 per cent. Commonly impure through the presence of iron oxides, silica, lime, and magnesia. Color, white or gray when pure, but yellowish, brown, or red through impurities. Specific gravity, 2.55; structure, massive, or earthy and clay like. According to Hayes[1] the

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[1] The Geological Relations of the Southern Appalachian Bauxite Deposits. Transactions of the American Institute of Mining Engineers, XXIV, 1894, pp. 250–251.

bauxites of the Southern United States show considerable variety in physical appearance, though generally having a pronounced pisolitic structure. (See Specimens Nos. 63335, 66576, 66577, and 66578, U.S.N.M., from Floyd and Bartow counties, Georgia; also fig. 5, p. 229.)

The individual pisolites vary in size from a fraction of a millimeter to 3 or 4 centimeters in diameter, although most commonly the diameter is from 3 to 5 millimeters. The matrix in which they are embedded is generally more compact and also lighter in color. The larger pisolites are composed of numerous concentric shells, separated by less compact substance or even open cavities, and their interior portions readily crumble to a soft powder.

In thin sections the ore is seen to be made up of amorphous flocculent grains, and the various structures which it exhibits are produced by the arrangement and degree of compactness of these grains. The matrix in which the pisolites are imbedded may be composed of this flocculent material segregated in an irregularly globular form or in compact oölites, with sharply-defined outlines. Or both forms may be present, the compact oölites being embedded in a matrix composed of the less definite bodies. In some cases the interstices between the oölites are filled either wholly or in part with silica, apparently a secondary deposition.

The pisolites also show considerable diversity in structure. In some cases they are composed of exactly the same flocculent grains as the surrounding matrix, from which they are separated by a thin shell of slightly denser material. This sometimes shows a number of sharply-defined concentric rings, and is then distinctly separated from the matrix and the interior portion of the pisolite. The latter is also sometimes composed of imperfectly defined globular masses, and in other cases of compact, uniform, and but slightly granular substance. It is always filled with cracks, which are regularly radial and concentric, in proportion as the interior substance has a uniform texture. Branching from the larger cracks, which, as a rule, are partially filled with quartz, very minute cracks penetrate the intervening portions. Thus the pisolites appear to have lost a portion of their substance, so that it no longer fills the space within the outer shell, but has shrunk and formed the radial cracks. No analyses have been made of the different portions of the pisolites or of the pisolites and matrix separately, and it is impossible to say whether any differences in chemical composition exist. It may be that some soluble constituent has been removed from the interior of the pisolites, but it is more probable that the shrinking observed is due wholly to desiccation.

Scattered throughout the ground-mass are occasional fragments of pisolites, whose irregular outlines have been covered to varying depths by a deposit of the same material as forms the concentric shells, and thus have been restored to spherical or oval forms.

Composition.—The following tables will serve to show the wide range of composition of bauxites from various sources:

Composition of bauxites from various localities.

	SiO_2.	TiO_2.	Al_2O_3.	Fe_2O_3.	(ign) H_2O.	(100°) H_2O.	P_2O_5.	Analyst.
Baux, France:								
1. Compact variety	2.8	3.1	57.6	25.3	10.8		......	Deville.
2. Pisiform	4.8	3.2	55.4	24.8	11.6		......	Do.
3. Hard and compact calcareous paste.	......	......	30.3	34.9	22.1		......	Do.
4. Calabres, France	2.0	1.6	33.2	48.8	8.6		......	Do.
5. Thoronet, France, red variety	0.30	3.40	69.30	22.90	14.10		......	

Composition of bauxites from various localities—Continued.

	SiO_2.	TiO_2.	Al_2O_3.	Fe_2O_3.	(ign) H_2O.	(100°) H_2O.	P_2O_5.	Analyst.
6. Villeveyrac, Hérault, France, white variety	2.20	1.00	76.90	.10	15.80		......	
7. Wochein, Germany	6.29	......	61.21	2.40	25.74		.46	Lill.
Langsdorf, Germany:								
8. Brownish red	5.14	......	50.85	14.36	27.03	1.35	.48	Lang.
9. Light red	10.27	......	49.02	12.90	25.88	.93	.38	Do.
10. Vogelsberg, Germany	1.10	3.20	50.92	15.70	27.75	.85	......	Liebreich.
11. Cherokee County, Alabama	37.87	......	39.44	2.27	12.80	9.20	......	Dr. Wm. B. Phillips.
12. Jacksonville, Calhoun County, Alabama.	18.67	......	45.94	11.86	21.20	1.40	......	Do.
13. Red	7.73	......	47.52	19.95	23.57		......	Do.
14. White	23.72	......	41.38	.85	23.72		......	Do.
15. Red	10.25	2.53	41.00	25.25	20.43	.65	trace	W. F. Hillebrand.
16. White	21.08	2.52	48.92	2.14	23.41	.45	trace	Do.
17. Floyd County, Georgia	2.80	3.52	52.21	13.50	27.72		......	Nichols.
18. Do	......	3.60	57.25	3.21	......	......	......	Do.
19. Do	2.30	3.55	56.88	1.49	......	......	.07	Do.
Georgia:								
20. No. 1	19.56	2.08	52.13	1.12	24.21		......	Prof. H. C. White.
21. No. 2	41.47	......	39.75	1.62	16.14		......	Do.
22. No. 3	2.56	......	56.10	10.64	30.10		......	Do.
23. No. 4	8.29	3.15	58.61	2.63	27.42		......	Do.
24. No. 5	6.62	......	59.82	2.16	31.10		......	Do.
25. No. 6	35.88	......	45.21	0.52	17.13		......	Do.
26. Barnsley estate, Dinwood Station, Georgia, No. 7.	1.98	2.38	61.25	1.82	31.43		......	Do.
Pulaski County, Arkansas:								
27. Black	10.13	......	55.59	6.08	28.99		......	
28. Do	11.48	......	57.62	1.83	28.63		......	
29. Do	2.00	3.50	62.05	1.66	30.31	......	......	
30. Red	4.89	......	46.40	22.15	26.68		......	
31. Do	3.34	......	58.60	9.11	28.63		......	
32. Do	10.38	3.50	55.64	1.95	27.62	......	......	
33. Do	16.76	3.50	51.90	3.16	24.86	......	......	

No. 1.—Contains also 0.4 $CaCO_3$. No. 2.—0.2 $CaCO_3$. No. 3.—12.7 $CaCO_3$. No. 5.—22.90 FeO + Fe_2O_3. No. 6—0.10 FeO + Fe_2O_3. No. 7.—0.85 CaO, 0.38 MgO, 0.20 SO_3. No. 8.—0.35 FeO, 0.41 CaO, 0.11 MgO, 0.09 K_2O, 0.17 Na_2O, trace CO_2. No. 9.—FeO not det., 0.62 CaO, trace MgO, 0.11 K_2O, 0.20 Na_2O, 0.26 CO_2. No. 10.—0.80 CaO, 0.16 MgO.

Origin and mode of occurrence.—The mineral received its name from the village of Baux, in southern France, where a highly ferriferous, pisolitic variety was first found and described by Berthier in 1821. The origin of the mineral, both here and elsewhere, has been a matter of considerable discussion. The following notes relative to the foreign occurrences are from a paper by R. L. Packard:[1]

The geological occurrence of the bauxite of Baux was studied by H. Coquand [Bulletin de la Société Geologique de France, XXVIII, 1871, p. 98], who describes

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[1] Mineral Resources of the United States, 1891, p. 148.

the mineral as of three varieties, pisolitic, compact, and earthy. The pisolitic variety does not differ in structure from the iron ores of Franche Comté and Berry, although the color and composition are different. It occurs in highly tilted beds alternating with limestones, sandstones, and clays, belonging to the upper cretaceous period, and in pockets or cavities in the limestone. The limestone containing the bauxite and that adjacent thereto is also pisolitic, some nodules being as large as the fist, and the pisolitic bauxite has sometimes a calcareous cement, and at others is included in a paste of the compact mineral. M. Coquand supposed that the alumina and iron oxide composing the bauxite were brought to the ancient lake bed in which the lacustrine limestone was formed by mineral springs, which, discharging in the bottom of the lake, allowed the alumina and iron oxide to be distributed with the other sediment. In some cases the discharge occurred on land, and the deposit then formed isolated patches. He refers to other similar deposits of bauxite of the same period in France. Sometimes the highly ferriferous mineral predominates over the aluminous (white), at others diaspose is found enveloping the red mineral, while in other cases it is mixed with it, predominating largely, and sometimes manganese peroxide replaces ferric oxide. In some places the ground was strewed with fragments of tuberous menilite, very light and white.

M. Angé [Bull. Soc. Geolog. de France, XVI, 1888, p. 345] describes the bauxite of Var and Hérault and gives analyses of it. Over 20,000 tons were being mined in this region annually at the time of writing his report [1888]. In the red mineral of Var druses occur with white bauxite running as high as 85 per cent. Al_2O_3, and 15 per cent. H_2O, corresponding to the formula $Al_2O_3+H_2O$. He refers to the prevailing theory of the formation of bauxite, according to which solutions of the chlorides of aluminum and iron in contact with carbonate of lime undergo double decomposition, forming alumina, iron oxide, and calcium chloride. Other deposits in the south of France, in Ireland, Austria, and Italy, he says, confirm this view, because they also rest upon or are associated with limestone. The bauxite deposit in Puy de Dome which he studied could not, however, be explained by this theory because it was not associated with limestone, but rested directly upon gneiss and was partly covered by basalt. The geological sketch map of the deposit near Madriat, Puy de Dome, which he gives shows gneiss, basalt, with uncovered bauxite largely predominating, and patches of miocene clay, while a geological section of the deposit near Villeveyrac, Hérault, shows the bed of bauxite conformably following the flexures of the limestone formation when covered by more recent beds, and when exposed and denuded occupying cavities and pockets in the limestone. This occurrence is substantially the same as that of the neighboring Baux. M. Angé agrees with M. Coquand in attributing the bauxite to geyserian origin. He uses as an illustration of the contemporaneous formation of bauxite the deposits from the geysers of the Yellowstone Park, which is evidently due to a misunderstanding. He made no petrographical examination of the bauxite of Puy de Dome, nor did he attempt to trace any genetic relation between the latter and the accompanying basalt. The occurrence is, however, noteworthy, and an examination might show that it is another instance of the direct derivation of bauxite from basalt, which is maintained in the two following instances, somewhat imperfectly in the first to be sure, but with greater detail in the second.

The first is a paper by Lang [in the Berichte der Deutschen Chemischen Gesellschaft, XVII, 1884, p. 2892]. He describes the bauxite in Ober-Hessen, which is found in the fields in round masses up to the size of a man's head, embedded in a clay which is colored with iron oxide. The composition varies very widely. The petrographical examination showed silica, iron oxide, magnetite, and augite. The chemical composition and petrographical examination shows the bauxite to be a decomposition product of basalt. By the weathering of the plagioclase feldspars, augite, and olivine, nearly all the silica had been removed, together with the greater part of the lime and magnesia; the iron had been oxidized and hydrate of alumina formed as shown by its easy solubility in hydrochloric acid. The residue of the silica had crystallized as quartz in the pores of the mineral.

The more detailed account of the derivation of bauxite from basalt is given in an inaugural dissertation by A. Liebreich, abstracted in the Chemisches Centralblatt, 1892, p. 94. This writer says that the well-known localities of bauxite in Germany are the southern slope of the Westerwald near Mühlbach, Hadamar, in the neighborhood of Lesser Steinheim, near Hanau, and especially the western slope of the Vogelsberg. Chemical analyses show certain differences in the composition of bauxite from different places, the smaller amount of water in the French bauxite referring it to diaspore, while the Vogelsberg mineral is probably Gibbsite (hydrargillite). The bauxites of Ireland, of the Westerwald, and the Vogelsberg, show by certain external indications their derivation from basalt. The bauxite of the Vogelsberg occurs in scattered lumps or small masses, partly on the surface and partly imbedded in a grayish white to reddish brown clay, which contains also similar masses of basaltic iron ore and fragments of more or less weathered basalt itself. Although the latter was associated intimately with the bauxite, a direct and close connection of the two could not be found, but an examination of thin sections of the Vogelsberg bauxite showed that most specimens still possessed a basaltic (anamesite) structure, which enabled the author to determine the former constituents with more or less certainty. The clays from different points in the district carrying basalt, basaltic iron ore, and bauxite were examined, some of which showed clearly a sedimentary character. Some of the bauxite nodules were a foot and a half in diameter and possessed no characteristic form. They were of an uneven surface, light to dark brown, white, yellowish, and gray in color, speckled and pitted, sometimes finely porous and full of small colorless or yellowish crystals of hydrargillite. The thin sections showed distinct medium-granular anamesitic structure. Lath-shaped portions filled with a yellowish substance preponderated (the former plagioclases) and filling the spaces between these were cloudy, yellow, brown, and black transparent masses which had evidently taken the place of the former augite. Laths and plates of titanic iron, often fractured, were commonly present and the contours of altered olivine could be clearly made out. The anamesitic basalt of the neighborhood showed a structure fully corresponding with the bauxite. Olivine and titanic iron oxide were found in the clay by washing. The basaltic iron ore also showed the anamesite structure.

But two localities in the United States have thus far yielded bauxite in commercial quantities. These are in Arkansas and the Coosa Valley of Georgia and Alabama.

According to Branner the Arkansas beds occur near the railway in the vicinity of Little Rock, Pulaski County, and near Benton, Saline County. "The exposures vary in size from an acre to 20 acres or more, and aggregate something over a square mile." This does not, in all probability, include the total area covered by bauxite in the counties mentioned, for the method of occurrence of the deposits leads to the supposition that there are others as yet undiscovered by the survey.

In thickness the beds vary from a few feet to over 40 feet, with the total thickness undetermined; the average thickness is at least 15 feet.

These Arkansas deposits occur only in Tertiary areas and in the neighborhood of eruptive syenites ("granites") to which they seem to be genetically related. In elevation they occur only at and below 300 feet above tide level, and most of them lie between 260 and 270 feet above tide. They have soft Tertiary beds both above and below them at a few places, and must, therefore, be of Tertiary age. As a rule, however, they have no covering, the overlying beds having been removed by erosion, and are high enough above the drainage of the country to be readily quarried. Erosive action has removed a part of the bauxite in some cases, but there are, in all probability, many places at which it has not yet been even uncovered.

It is pisolitic in structure, and, like all bauxite, varies more or less in color and in chemical composition. (Specimen No. 67600 from Pulaski County.) At a few places it is so charged with iron that attempts have been made to mine it for iron ore. Some of the samples from these pits assay over 50 per cent of metallic iron. This ferruginous kind is exceptional, however. From the dark red varieties it grades through the browns and yellows to pearl gray, cream colored, and milky white, the pinks, browns, and grays being the more abundant. Some of the white varieties have the chemical composition of kaolin, while the red, brown, and gray have but little silica and iron, and a high percentage of alumina. The analyses given on page 231 show that this bauxite compares favorably with that of France, Austria, and Ireland, and is apparently well adapted for the manufacture of chemical products, for refractory material, and for the manufacture of aluminum by the Deville process.

The Georgia and Alabama deposits have been the subject of exhaustive study by Willard Hayes, to whose paper reference has already been made.

According to this authority the ore is found irregularly distributed within a narrow belt of country extending from Adairsville, Georgia, southwestward, a distance of 60 miles, to the vicinity of Jacksonville, Alabama. The only points at which it has been worked on a commercial scale are at Hermitage furnace, 5 miles north of Rome, Georgia, near Six Mile Station, south of Rome, and in the dike district near Rock Run, Alabama. (See fig. 6.) The oldest rocks of the region are of Cambrian age and are subdivided on lithologic grounds into two formations, the Rome sandstone below and the Connasauga shale above. The former consists of 700 to 1,000 feet of thin-bedded purple, yellow, and white sandstones and sandy shales. In the southern portion of the region the Rome sandstone is replaced by the Weisner quartzite, which consists of a series of interbedded lenticular masses of conglomerate, quartzite, and sandy shale. It apparently represents delta deposits contemporaneous with a part or the whole of the Rome sandstone. These rocks form Weisner and Indian mountains, and in the latter they attain a thickness of 10,000 feet or more.

The Connasauga is between 2,000 and 3,000 feet in thickness. It consists at the base of fine aluminous shales; the upper portion is more calcareous, and locally passes into heavy beds of blue seamy limestone.

Above Connasauga shale is the Knox dolomite, the most uniform and persistent formation of the southern Appalachian region. It consists of from 3,000 to 4,000 feet of gray, semicrystalline, siliceous dolomite. The silica is usually segregated in nodules and beds of chert. These remain upon the surface, and with the other insoluble constituents form a heavy residual mantle covering all the outcrops of the formation. It is associated with these residual materials that the extensive deposits of limonite and bauxite are found. The geological structure of the region is complicated and for its details the present reader is referred to Dr. Hayes's original paper.

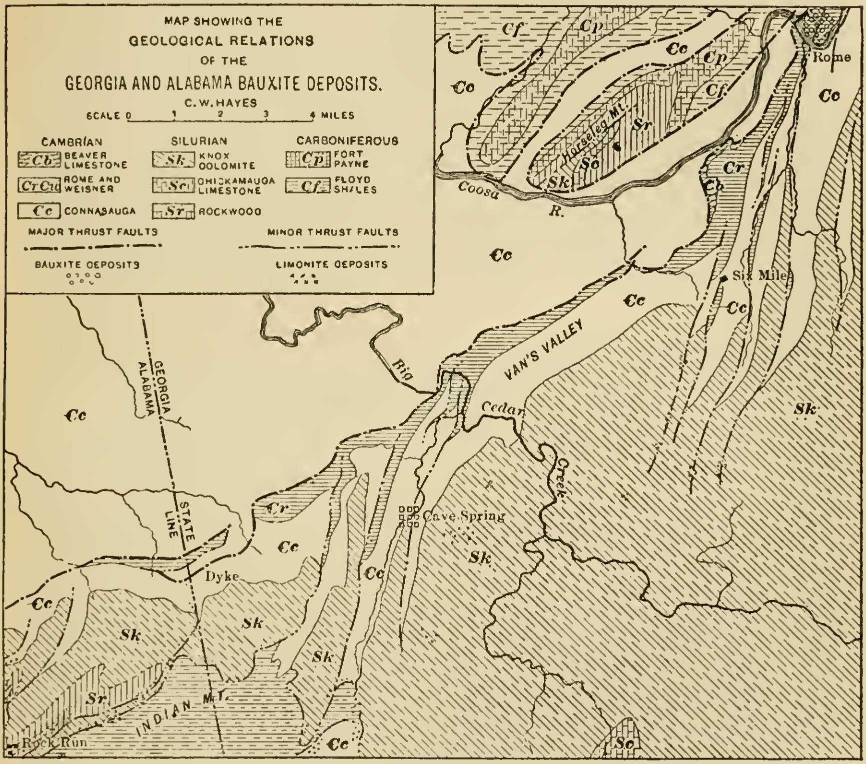

Fig. 6.

MAP SHOWING THE GEOLOGICAL RELATIONS OF GEORGIA AND ALABAMA BAUXITE DEPOSITS.

After C. W. Hayes.

Subaerial decomposition has progressed for a long period, and the surface is deeply covered with a mantle of residual material, consisting of the more insoluble portions of the original rock masses. This residual material consists mainly of ferruginous clay with large amounts of chert, and reaches a thickness of 100 feet or more. The bauxite deposits in the Rock Run district are regarded as typical for the entire region, and are described as follows:

Four bodies of the ore were being worked in 1893 on a considerable scale, and all show practically the same form. The southernmost of the four, called the Taylor bank, is located 3½ miles northeast of Rock Run, near the western base of Indian Mountain. Although the heavy mantle of residual material effectually conceals the underlying rocks, the ore appears to be exactly upon the faulted contact between the narrow belt of Knox dolomite on the northwest and the sandy shales and quartzites of Indian Mountain on the southeast. The ore is covered by 3 or 4 feet of red sandy clay in which numerous fragments of quartzite are imbedded. The ore-body is an irregularly oval mass, about 40 by 80 feet in size. Its contact with the surrounding residual clay, wherever it could be observed, appeared to be sharp and distinct, and, about the greater portion of its circumference, very nearly vertical. A certain amount of bedding is observable in the ore-body, although no trace of bedding can be detected in the surrounding residual material. Upon the northwestern or down-hill side of the ore-body, this bedding is very distinct. Layers of differently colored and differently textured ore alternate in regular beds, a few inches in thickness, and above these are thinner beds of chocolate and red material, probably containing considerable kaolin. These beds have a steep dip, somewhat greater than the slope of the hill-side, but in the same direction. They are not simply inclined planes, however, but are curved, so as to form a steeply-pitching trough. With increasing distance from the ore-body, the lamination becomes less distinct, and the beds pass gradually into a homogeneous mottled clay. The accompanying section, fig. 7, shows these relations of the ore and residual mantle.

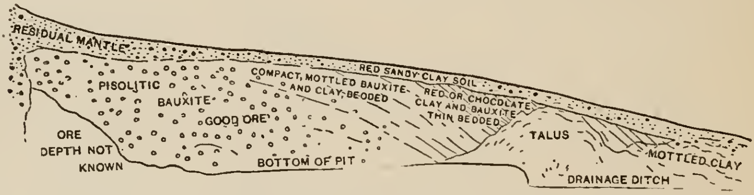

Fig. 7.

SECTION SHOWING RELATION OF BAUXITE TO MANTLE OF RESIDUAL CLAY IN GEORGIA.

After C. W. Hayes.

At the Dike bank [see Fig. 6], about a mile northeast of the one above described, the stratification is well shown in portions of the deposit. Beds of yellow and gray, fine-grained material, alternate with others of pisolitic ore. The beds dip at an angle of about 40°, and are curved so as to form a steep trough. The compact material also shows distinct cross-bedding; both primary and secondary planes dipping in the same direction.

In the Gain's Hill bank, about 250 yards north of the Dike bank, the ore-body shows a more regularly oval form than in most of the other deposits, and is also somewhat dome-shaped, swelling out laterally from the surface downward, as far as the working has progressed.

Although some of the workings have gone to a considerable depth (in a few cases 50 feet or more), the bottom of the ore-body has not been reached in any case. The ore varies in composition with depth, but not in a uniform manner, nor more than do different portions at the same depth. The deepest pits have not gone below the base of the surrounding residual mantle, so that no observations have yet been made with regard to the relations between the ore and the country-rock; and nothing has yet been observed which warrants the conclusion that the ore if followed to sufficient depth, will be found inter-bedded with the underlying formations, or even that it will be found occupying cavities in the limestone—although the latter is quite possible.

Concerning the origin of these deposits the author says:

No eruptive rocks, either ancient or modern, are found in the vicinity of the latter, nor are there any rocks in this region which, by weathering, could yield bauxite as a residual product. Hence, any satisfactory explanation of the origin of these deposits must give the source from which the material was derived, the means by which it was transported, and the process of its local accumulation.

As already stated in describing the stratigraphy of the region, the ore is associated with the Knox dolomite or with calcareous sandy shales immediately overlying the dolomite. The Connasauga, consisting of 2,000 feet or more of aluminous shales, invariably underlies the dolomite at greater or less distance beneath the ore-bearing regions, and is probably the source from which the alumina was derived.

The faults of the region have been briefly described. Undoubtedly such enormous dislocations of the strata generated a large amount of heat. The fractures facilitated the circulation of water, and for considerable periods the region was probably the seat of many thermal springs. These heated waters appear to have been the agent by which the bauxite was brought to the surface in some soluble form and there precipitated.

The chemical reactions by which the precipitation was effected are not well understood, and the conditions were not such as can be readily reproduced in the laboratory. Of the few soluble compounds of aluminum which occur in nature, only the sulphate and the double sulphate of potash and alumina need be considered.

The oxygen contained in the meteoric waters percolating at great depths through the fractured strata would readily oxidize the sulphides disseminated in the aluminous shales. Sulphates would thus be formed by a process strictly analogous to that commonly employed in the manufacture of alum. Probably the most abundant product of the process in nature was ferrous sulphate. Some sulphate of aluminum must also have been formed together with the double sulphate of potassium and aluminum, especially in the absence of sufficient potash to form alum with the whole.

In its passage from the underlying shales through several thousand feet of dolomite the heated water must have become highly charged with lime, in addition to the ferrous and aluminous salts already in solution. But calcium carbonate reacts upon aluminum sulphate and to some extent also on alum, forming a gelatinous or flocculent precipitate which consists of aluminum hydroxide and the basic sulphate. This reaction may have taken place at great depth and the resulting flocculent precipitate may have been brought to the surface in suspension. From analogy with pisolitic sinter and travertine now forming, such conditions would appear to be highly favorable for the production of the structures actually found in the bauxite. The precipitate was apparently collected in globular masses by the motion of the ascending water, and constant changes in position permitted these to be coated with successive layers of more compact material. Finally, after having received many such coatings, the pisolites were deposited on the borders of the basin, and the interstices were filled by minute oölites formed in a similar manner or by the flocculent precipitate itself. Slight differences in the conditions prevailing in the several springs, such as concentration and relative proportion of the various salts in solution, also temperature and flow of the water, would produce the variation in the character of the ore observed at different points.

The bedding observed in the bauxite-deposits may have been produced by the successive layers deposited on the steeply inclined outlet of the basin. After the cessation of the spring-action, surface-creep of the residual mantle from the higher portions of the ridges covered the deposits to varying depths, as they are found at present.

A small portion of the ferrous sulphate was oxidized and precipitated along with the bauxite, but the greater part was carried some distance from the springs and slowly oxidized, forming the widespread deposits of limonite in this region.

Uses.—The better known use of bauxite is as an ore of aluminum, for which purpose it lies beyond the scope of the present work. It may, however, be well to state that before the aluminum can be satisfactorily extracted the ore is purified by chemical processes. The principal use is for the manufacture of alums and other aluminum salts such as are used in the manufacture of baking powders and dyes. It is believed that the mineral, owing to its highly refractive qualities, will in the near future be utilized in the manufacture of fire brick and crucibles. An alumino-ferric cake, a by-product obtained in the purifying process, is claimed as of value for sanitary and deodorizing purposes. The price of the crude ore varies greatly, according to purity. The average price for the past few years has been about $5 a ton.

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4. DIASPORE.

This is a hydrous oxide of aluminum corresponding to the formula Al_2O_3,H_2O,=alumina, 85 per cent; water, 15 per cent; hardness, 6.5 to 7. It is a whitish, grayish, sometimes brownish or yellowish mineral, occurring in the form of thin flattened or acicular crystals and also foliated, massive and in thin plates or rarely stalactitic. (Specimen No. 53573, U. S. N. M.) It is transparent to subtranslucent, and sometimes shows violet-blue colors when looked at in one direction, or reddish-blue or asparagus-green in others. Luster, vitreous or pearly.

Occurrence.—The mineral commonly occurs with corundum and emery in dolomite and granular limestone or crystalline schists. In the United States it occurs in large plates in connection with the emery rock at Chester, Massachusetts.

Uses.—See under Gibbsite.

5. GIBBSITE; HYDRARGILLITE.

This is also, like diaspore, a hydrous oxide of aluminum, corresponding to the formula $Al_2O_3.3H_2O$=alumina 65.4 per cent, water 34.6 per cent. The mineral is of a whitish, grayish, or greenish color, sometimes reddish through impurities, and occurs in flattened, hexagonal crystals, or in stalactitic and mammillary and incrusting surfaces. (Specimen No. 4602, U.S.N.M.). Its occurrence is similar to that of diaspore.

Uses.—Neither diaspore nor gibbsite have as yet been found in sufficient quantities to be of economic importance. Should they be so found, their value as a source of alumina is easily apparent.

6. OCHER.

The term ocher as commonly used applies to earthy and pulverulent forms of the minerals hematite and limonite, but which are almost invariably more or less impure through the presence of other metallic oxides and argillaceous matter. In nature the material rarely occurs in a suitable condition for immediate use, but needs first to be prepared by washing and grinding and perhaps roasting.

Various varietal names are applied to the ochers, according to their natural colors or sources. The original "Indian red" was a red argillaceous ocher, with a purplish tinge, found on the island of Ormuz, in the Persian Gulf. A large part of the pigment of this name is now prepared artificially from iron pyrites. Umber is a gray, brown, or reddish variety containing manganese oxides and clay. It derives its name from Umbria, in Italy, where material of this nature was first utilized. Sienna is a highly argillaceous variety, also from Italy, near Sienna.

The natural colors of the ochers is dependent on the degree of hydration and oxidation of material and the kind and amount of impurities. In a general way the hematites are of a deep-red color (Specimen No. 56075, U.S.N.M.), while the limonites are yellow or brown (Specimen No. 61101, U.S.N.M.). Either color is liable to shade variations, according to amount and kind of impurities. The colors are intensified or otherwise varied by roasting (Specimens Nos. 63056 and 63057, U.S.N.M.).

Artificial ochers are produced by roasting iron pyrites (sulphide of iron) or an artificial sulphate (green vitriol) (Specimen No. 61122, U.S.N.M.). (See under Pyrite.) The materials known commercially as rouge, crocus, and Indian red are quite pure ferric oxide, prepared by roasting pyrite or by other artificial means.

Composition of ochers in their natural condition.

Natural color.	Locality.	Fe_2O_3.	Al_2O_3.	SiO_2.	H_2O.	Alks.
	Marksville, Page County, Virginia	39.0	1.50	33.0	11.5	0.5
	Rawlins, Wyoming	90.2	......	Insol. 7.2	......	1.2
Yellow brown	Hancock, Berks County, Pennsylvania (Specimen No. 62787, U.S.N.M.).	[a] 36.67	50.00		10.60	......
Deep brown	Anne Arundel County, Maryland (Specimen No. 60843, U.S.N.M.).	19.67	76.57		2.60	......
Deep red brown	Northampton County, Pennsylvania (Specimen No. 61103, U.S.N.M.).	[b] 42.45	30.58		11.85	......
Gray	Northampton County, Pennsylvania (Specimen No. 61098, U.S.N.M.).	[c] 12.20	74.10		5.23	......
Dark brown	Brandon, Vermont (Specimen No. 66732, U.S.N.M.)	[d] 52.92	2.88		14.62	......
	Montgomery County, Alabama (Specimen No. 63339, U.S.N.M.).	[a] 10.57	69.30		7.40	......
	Cartersville, Georgia (Specimen No. 63340, U.S.N.M.).	[b] 55.84	32.20		12.00	......

[a] A part of the iron in a ferrous condition.

[b] Contains also some manganese.

[c] Iron exists mainly in a ferrous condition.

[d] Contains much manganese.

Composition of manufactured mineral paints.

Variety.	Fe_2O_3	Al_2O_3	SiO_2	H_2O	P_2O_3, MnO, CaO.
Lowe's metallic paint [a]	78.87	3.29	11.96	5.07	0.80
Rossie red paint [b]	60.50	5.63	18.00	0.33	$CaCo_3$ 15 66
Light-brown paint [c]	77.26	7.00	13.84	0.06	1.84
Brown-purple paint [d]	93.68	3.06	3.20	S. and loss. 0.06	....

[a] Made from red fossiliferous ores mined at Atalla, Alabama, and Ooltewah, Tennessee.

[b] Made by Iron Clad Paint Company, of Cleveland, Ohio, from ore mined in Wayne County, New York.

[c] From ore mined at Lake Superior, Michigan.

[d] Ore from Jackson mine, Michigan.

A "blue ocher," formed by the decomposition of the Utica shales in Lehigh County, Pennsylvania, has the following composition:

Ignition (water and carbon)	9.10
Quartz	44.50
Combined silica	26.25
Alumina with traces of ferric oxide	17.95
Magnesia	.94
Alkalies, etc	1.26
	100.00

A second variety, from 1½ miles northwest of Breinigsville, and which was sold as a yellow ochre, yielded:

Silica, 60.53; alumina, 17.40; ferric oxide, 9.27; lime, 0.08; magnesia, 1.92; water, 5.51; alkalies, 5.27.

Origin and mode of occurrence.—These vary greatly. In some cases deposits of this nature are formed by springs. Such result from the leaching out from the rocks, by carbonated waters, of iron in the protoxide condition and its subsequent deposition as a hydrated sesquioxide. In other cases they are residual products formed by the removal by solution, of the lime carbonates of calcareous rocks, leaving their insoluble residues—the clay and iron oxides—in the form of a red, yellow, or brown ocherous clay. Again, they may result from the decomposition (oxidation) of beds of pyrite (iron disulphide) and from the decomposition of beds of hematite, and by the disintegration and perhaps partial hydration of the more compact forms of limonite. Still, again, they may result from the decomposition of schists and other rocks rich in iron-bearing silicate minerals. The yellow ochers of the Little Catoctin Mountains, near Leesburg, Virginia, are thus stated to be residual products from the decomposition of hydro-mica or damourite schists.

A paint ore found near Lehigh Gap, Carbon County, Pennsylvania (Specimens Nos. 61115, 63481, 63482, U.S.N.M.), though not properly an ocher, may be described here for want of a better place. The raw material is a dull shaly or slaty rock, of a dark gray color, sandy texture, and quite hard, and if descriptions are correct is probably an arenaceous siderite, or carbonate of iron.

According to C. E. Hesse[1] the "paint bed" is of unknown extent except so far as indicated by outcrops along the southern border of Carbon County, about 27 miles north of Bethlehem, where it occurs in a well-defined ridge of Oriskany sandstone. Along the outcrop the beds are covered by a cap of clay and by the decomposed portion of the Marcellus slate. Beginning with this slate the measures occur in the following descending order:

a. Hydraulic cement (probably Upper Helderberg), very hard and compact.

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[1] Transactions of the American Institute of Mining Engineers, XIX, 1891, p. 321.

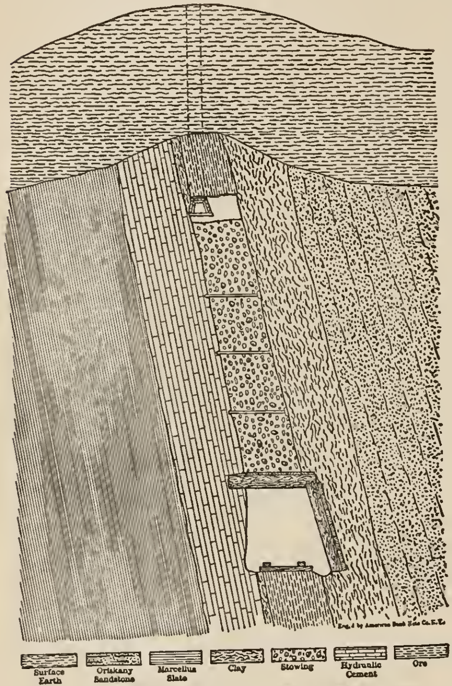
b. Blue clay, about 6 inches thick.

c. Paint ore, varying from 6 inches to 6 feet in thickness.

d. Yellow clay, 6 feet thick;

e. Oriskany sandstone, forming the crest and southern side of the ridge. It is extremely friable, and disintegrates so readily that it is worked for sand at many points. (See fig. 8.)

The paint bed is not continuous throughout its extent. It is faulted at several places; sometimes it is pinched out to a few inches, and again increases in width to 6 feet. The ore is bluish-gray, resembling limestone, and is very hard and compact. The bed is of a lighter tint, however, in the upper than in the lower part, and this is probably due to its containing more hydraulic cement in the upper strata. The paint ore contains partings of clay and slate at various places. At the Rutherford shaft there are fine bands of ore alternating with clay and slate, as follows: Sandstone (hanging wall), clay, ore, slate, ore, clay, ore, slate, ore, cement, slate (foot wall). These partings, however, are not continuous, but pinch out, leaving the ore without the admixture of clay and slate. Near the outcrop the bed becomes brown hematite, due to the leaching out of the lime and to complete oxidation. Occasionally streaks of hematite are interleaved with the paint ore. In driving up the breasts toward the outcrop the ore is found at the top in rounded, partially oxidized, and weathered masses, called "bombshells," covered with iron oxide and surrounded by a bluish clay. In large pieces the ore shows a decided cleavage.



SECTION ACROSS THE BED, RUTHERFORD AND BARCLAY MINE.

Fig. 8.

SECTION ACROSS PAINT MINE AT LEHIGH GAP, PA.

After C. E. Hesse.

Preparation.—As already intimated, only a small portion of the ocher is used in its natural condition, it being first roasted and then ground, the grinding being either "dry" or in oil. The roasting deepens the color to a degree dependent upon the length of time the ore is exposed. Yellows are converted into browns and reds, and the ocher rendered less hydrous at the same time. The crude ore as mined is not infrequently separated from the coarser or heavier impurities by a process of washing in running water, whereby the ochre, in a state of suspension, is drawn off into vats, where it is allowed to settle, the water decanted, and the sediment made up into bricks and dried, when it is ready for grinding.

The following description of the occurrence of umber and its preparation at the Caldbeck Fells, in Cumberland, England, is taken from the Journal of the Society of Chemical Industry for October, 1890, p. 953:

> The vein of umber contains crystals of quartz, and lies in a granitic rock largely decomposed. The method of working is as follows: The umber is brought down by an overhead tramway and passed through a hopper into a wash barrel consisting of a cylinder formed of parallel bars one-eighth of an inch apart, having a perforated pipe conveying water, for its axis. By this means the umber is washed through, the quartz being retained; the former then passes to an edge-runner, the casing of which is of sufficient depth to allow of the submersion of the rollers. The rate of revolution is about 14 to the minute, and the finer floating particles flow into the drag mill. The bed of this mill is a single block of granite and over it the four burrstone blocks are dragged; the finer "floating" particles of umber pass to a second mill of the same kind, then through a brass wire sieve (to remove particles of peat and heather that have been floating throughout the process) to settling tanks, composed of brickwork lined with cement. After settling for four hours four-fifths of the water are drawn off, and the umber, now of the consistency of slurry, filter-pressed and dried. It has the following composition:

Ferric oxide	47.14
Manganese dioxide	11.17
Cupric oxide	3.23
Alumina	7.66
Lime	Trace.
Magnesia	Trace.
Silica	24.70
Combined water	6.18
	100.08

> In this condition it may be put on the market, serving for colouring coarse brown paper (that being the chief use to which umber is put), or it may be re-ground in a conical burrstone mill and sold to paint and oil-cloth manufacturers and the makers of the finer kinds of brown paper. The fine state of division to which it is reduced may be judged from the facts that the workman in charge of the mill is compelled to wear a respirator, and the stain is not easily removed from the hands.

At the Lehigh Gap mines the ore, as it comes from the mines, is free from refuse, great care having been taken to separate slate and clay from it in the working places. It is hauled in wagons to kilns, which are situated on a hillside for convenience in charging. The platform upon which the ore is dumped is built from the top of the kiln to the side of the hill. The ore is first spalled to fist size and freed from slate, and is then carried in buggies to the charging hole of the kiln.

The kiln works continuously, calcined ore being withdrawn and fresh charges made without interruption. The ore is subjected for forty-eight hours to the heat, which expels the moisture, sulphur, and carbon dioxide. About 1½ tons of calcined ore are withdrawn every three hours during the day. The outside of the lumps of calcined ore has a light-brown color, while the interior shows upon fracture a darker brown. Great care is necessary to regulute the heat so that the ore is not overburnt. When this happens the product has a black, scoriaceous appearance, and is unfit for the manufacture of metallic paint, as it is extremely hard to grind.

The calcined ore is carried from the kiln in wagons to the mill, where it is broken to the size of grains of corn in a rotating crusher. The broken ore is carried by elevators to the stock bins at the top of the building, and thence by shutes to the hopper of the mills, which grind it to the necessary degree of fineness. Elevators again carry it to the packing machine by a spout, and it is packed into barrels holding 500, 300, or 100 pounds each.

A "mineral paint" mined on Porter Creek, near Healdsburg, Sonoma County, California, is said[1] to consist of hematite and silicate of iron in the form of a compact mass lying between hornblendic rock, actinolite and mica schist on the one side and rotten serpentine on the other. The vein has a north of east course, and is some 60 feet in width. The material is mined from a tunnel, crushed, ground between buhrstones, and bolted, making a paint fit for mixing with oils or japan.

Uses.—The ochers are among the most widespread and readily accessible of coloring materials, and have been used by savage and civilized people both ancient and modern. The war paint of the American Indian was not infrequently an ocher mixed with oil or grease.

According to William J. Russell,[2] the pigments used by the Egyptians and others since the earliest times were of hematite, and mostly of an oölitic variety, apparently closely corresponding to the Clinton hematites of New York State. As tested, such were found to contain from 79.11 to 81.34 per cent ferrio oxide.

Yellow ocherous pigments, presumably limonite, are also described by the same authority. These yield only about 33 per cent ferric oxide and some 7 to 10 per cent of water, together with clay. The ochers are now used mainly in the manufacture of paints for exteriors, as of buildings, the rolling stock of railways, bridges, and metal roofing. They are also used as a pigment for coloring mortars, and in the manufacture of linoleums and oilcloths. Mixed with a certain proportion of oxide of manganese, the ochers have been used to produce desirable colors in earthenware.

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[1] Twelfth Annual Report of the State Mineralogist, 1894, p. 406.

[2] Nature, XLIX, 1894, p. 374.

The raw ocher (that is, ocher not roasted), of a light-yellow color, was at one time in great demand, particularly throughout New England, for painting floors.

The value of the prepared material is but a few cents a pound.

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This is an important paper, giving position of ore beds, methods of mining and manufacture.

CONRAD E. HESSE. The Paint Ore Mines at Lehigh Gap. Transactions of the American Institute of Mining Engineers, XIX, 1890, p. 321.

7. ILMENITE; MENACCANITE; OR TITANIC IRON.

Composition $FeTiO_3$,=oxygen, 31.6; titanium, 31.6; iron, 36.8; hardness, 5 to 6; specific gravity, 4.5 to 5; color, iron black with a submetallic luster and streak; opaque. Differs from magnetite, which it somewhat resembles, by its crystalline form and by its influencing but slightly the magnetic needle.

Mode of occurrence.—Its common form is massive, or in thin plates or laminæ, or as small granules, sometimes disseminated through the mass of rock or loose in the sand. In microscopic forms it is a common constituent of eruptive rocks, both acid and basic. Not infrequently it occurs in large masses, closely resembling magnetic iron ore (Specimen No. 63861, U.S.N.M.). In the parish of St. Urbian, Bay St. Paul, Province of Quebec, Canada, is such a bed, stated to be 90 feet in thickness and to have been traced, with some interruptions, for a mile. The bed is in anorthite feldspar rock of Laurentian age. The ore is quite pure, and carries some 48.6 per cent titanic acid. At Kragerö, in Norway, the mineral occurs in the form of veins in diorite. In Virginia it is found in granular masses, containing apatite. (See Phosphate Series.)

Uses.—The mineral has as yet proved of little economic importance. It is stated that the presence of titanium has an important bearing upon the qualities of iron and steel, but as such it is beyond the scope of this work. As long ago as 1846 an attempt was made to use a ferrocyanide of titanium as a green paint in place of the poisonous arsenical greens. Later (1861) other patents were granted in England for titanium pigments. A deep-blue enamel, resembling the smalt prepared with the oxide of cobalt, has also been prepared from it, but as yet the mineral, though abundant and cheap, has practically no economic use.

8. RUTILE.

Composition and general properties.—This, like ilmenite, is a titanium oxide, having the formula TiO_2,=oxygen, 40 per cent, and titanium, 60 per cent. The hardness is 6 to 6.5; specific gravity, 4.18 to 4.25;

luster metallic-adamantine, opaque as a rule, rarely transparent; color, reddish brown to red, rarely yellowish, blue, or black; streak, pale brown. The mineral crystallizes in the tetragonal system, and is commonly found in prismatic forms longitudinally striated (Specimen No. 14410, U.S.N.M.) and often in geniculate or knee-shaped twins (Specimen No. 81904, U.S.N.M.). Not infrequently it occurs in the form of fine thread-like or acicular crystals penetrating quartz. It is insoluble in acids and infusible.

Mode of occurrence.—Rutile occurs mainly in the older crystalline granitic rocks, schists, and gneisses, but is also found in metamorphic limestones and dolomites, sometimes in the mass of the rock itself, or in the quartz of veins. Being so nearly indestructible under natural conditions, it gradually accumulates in the débris resulting from rock decomposition, and is hence not an uncommon constituent of auriferous sands.

Localities.—Some of the more noted localities are, according to authorities, the apatite deposits of Kragerö, in Norway; Yrieux, near Limoges, in France; the Ural Mountains; and the Appalachian regions of the United States. Graves Mountain, Georgia (Specimen No. 46081, U.S.N.M.); Randolph County, Alabama (Specimen No. 65354, U.S.N.M.); and the Magnet Cove region of Arkansas are celebrated localities.

Uses.—Like ilmenite, the mineral may serve as a source for titanium for a pigment for porcelain, but as yet it is little used.

Brookite (Specimen No. 45256, U.S.N.M.) and octahedrite have the same composition and essentially the same physical properties and mode of occurrence.

9. CHROMITE.

Chromite is a mineral of the spinel group, and of the theoretical formula FeO, Cr_2O_3. This equals a percentage of chromic oxide of 68 per cent, but the natural mineral has often alumina and ferric iron replacing a part of the chromium, so that 50 per cent chromic oxide more nearly represents the general average. The ordinary demand, it may be stated, is for an ore carrying 45 per cent and upward of chromic acid.

The analyses given below[1] will serve to show the varying character of the mineral:

Composition of chromite from various localities.

Location.	Constituents.								
	Al_2O_3.	MgO.	Cr_2O_3.	Fe_2O_3.	FeO.	SiO_2.	CaO.	Miscellaneous.	Total.
Kynouria, Greece	30.17	17.27	4.74	....	2.30	26.01	13.26	CO_2+H_2O=4.45	98.20
Near Athens, Greece	20.80	11.78	9.80	2.72	7.00	4.85	5.50	$FeCO_3$=37.75	100.20
Bare Hills, Baltimore, Maryland	13.002	....	39.514	36.004	....	10.596	....	....	99.116
Chester, Pennsylvania	....	....	41.55	62.02	....	1.25	....	....	104.82
Franklin, Macon County, North Carolina	22.41	15.67	44.15	5.78	11.76	....	....	....	99.77
Wilmington, Delaware	6.66	2.06	45.50	....	42.78	3.00	....	....	100.00
Bolton, Canada	3.20	15.03	45.90	....	35.68	....	....	....	99.81
Ekaterinburg, Russia	6.77	13.40	49.49	....	23.27	7.07	....	....	100.00
Chester County, Pennsylvania	9.723	....	51.562	35.14	....	2.901	....	MnO, trace.	99.326
Monterey County, California	2.18	12.29	52.12	15.24	....	12.12	5.65	....	+99.60
Lancaster County, Pennsylvania	5.75	9.39	55.14	....	28.88	....	....	....	99.16
Do	0.86	9.89	56.55	....	30.23	....	....	....	97.53
Chester County, Pennsylvania	....	....	63.39	38.66	....	....	....	NiO=2.28	104.33
		....	....	....	....	....	....	Al_2O_3+FeO	....
Urals	....	5.04	64.00	....	....	1.03	....	29.33	99.40
		6.15	62.25	....	....	0.95	....	30.05	99.40
		6.28	63.40	....	....	2.60	....	28.60	100.88

Chromite, like magnetic iron, is black in color and of a metallic luster, but differs in being less readily if at all attracted by the magnet. On a piece of ground glass or white unglazed porcelain it leaves a brown mark, and fused with borax before the blowpipe it gives a green bead.

Occurrence.—Chromite is a common constituent in the form of disseminated granules of basic eruptive rocks belonging to the peridotite and pyroxenite groups and in the serpentinous and talcose rocks which result from their alteration (Specimens Nos. 63032, 36845, U.S.N.M., from Maryland and North Carolina). It is never found in true veins or beds, though sometimes in segregated, nodular masses somewhat simulating veins on casual inspection. Masses of pure material, like Specimen No. 17288, U.S.N.M., from Lancaster, Pennsylvania (weight 1,000 pounds), are quite usual. The more common form, as noted above, is that of detached granules, which when freed from the inclosing rock form the ore known as chrome sand (Specimens Nos. 5179, 63032, 56310, U.S.N.M.), and small masses like Specimens Nos. 11681, 40320, 63032, U.S.N.M.

Deposits of chromite are now being worked near Black Lake Station,

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[1] As compiled from various sources in Wadsworth's Lithological Studies. Memoirs of the Museum of Comparative Zoology, XI, Part I, 1884, Cambridge, Massachusetts.

on the Quebec Central Railway, in close proximity to the asbestos mines. The ore here occurs in a series of pockets extending in an east and west direction. Some of the pockets are found lying in a dike of fine-grained granulite, but the possible relationship between the two has not been made out. While other deposits occur not associated with the granulite, it is to be noticed that the largest pockets of high-grade ore are thus associated. From one such pocket on the Lambly property over 500 tons of ore were taken, yielding 54 per cent to 56 per cent sesquioxide of chromium.

Aside from the localities above mentioned, chromic iron is found in pocket masses in the Cambrian and serpentinous rocks lying between the Vermont line and the Gaspe peninsula, but has never been successfully mined owing to the great uncertainty attending its occurrence.

It is rarely found in beds or veins, but in detached pockets which yield from a few pounds to hundreds of tons, the larger pockets being comparatively rare.

Chrome ore is also found in Newfoundland; the Russian Urals (Specimen No. 40322, U.S.N.M.); in Asia Minor (Specimen No. 40156, U.S.N.M.) and European Turkey (Specimen No. 4674, U.S.N.M.) and in Macedonia; in Australia (Specimens Nos. 62532, 60999, U.S.N.M.) and New Zealand (Specimen No. 70346, U.S.N.M.). In all cases so far as known the deposits occurring in peridotite or serpentine.

The principal domestic sources of chromite are at present Del Norte (Specimen No. 65349, U.S.N.M.); San Luis Obispo, Shasta (Specimen No. 66498, U.S.N.M.), and Placer (Specimen No. 65351, U.S.N.M.) counties in California, though formerly mines in Lancaster County, Pennsylvania (Specimens Nos. 11681, 5179, U.S.N.M.), and at the Bare Hills, near Baltimore, Maryland (Specimen No. 63032, U.S.N.M.) were very productive.

Uses.—Chromium is used in the production of the pigments chrome yellow, orange, and green, and in the manufacture of bichromate of potash for calico printing, and which is also used in certain forms of electric batteries. A small amount is also used in the production of what is known as chrome steel.

According to P. Speier, chrome ore linings for reverberatory furnaces have been successfully adopted in French, German, and Russian steel works. The bottom and walls of the furnace are lined with chrome ore in large blocks, united by a cement formed by two parts of chrome ore finely ground, and one part of lime as free from silica as possible.

The introduction of chromium from the lining into the bath of molten steel only takes place to a very limited extent. From 660 to 1,100 pounds of limestone is charged into the furnace, and, according to the percentage of sulphur, from 220 to 440 pounds of manganese ore, for a charge of 1.5 to 1.7 ton of pig iron and 1,100 to 1,300 pounds of cast-iron scrap. About one-third, including steel scrap, is introduced into the furnace; and to this quantity is afterwards added from 660 to 1,100 pounds of wrought-iron scrap as soon as the melting is complete. When a suitable temperature is attained the slag is run off, and the next charge is introduced into the furnace when the bath is quiescent. A sample is then taken and tested by bending, and if it be found that the percentage of phosphorus is too high, more lime, or lime and iron scale, are added, as much being introduced as the bath will take, and the addition of ferro-manganese is also made.

The iron chromate is decomposed only under the influence exerted by the reagents and oxidizing alkaline substances. Heat alone is insufficient to decompose chromate of iron, which may float in a bath of molten steel covered with basic slag without dissolving. One of the principal conditions of success in the employment of the chrome ore lining consists in carefully picking the pieces of ore used, which should be of uniform composition; and the best composition of ore used for lining reverberatory furnaces is found to be from 36 to 40 per cent of chromic oxide, 18 to 22 per cent of clay, 9 to 10 per cent of magnesia, and at most 5 per cent of silica.[1]

The total annual product of American mines does not exceed between 3,000 and 4,000 tons, valued at the mines in California at not more than $8 a ton for 50 per cent ore. Delivered in Baltimore its value is from $20 to $25 a ton.

Some 4,000 tons are annually imported. The chief foreign sources are Russia, New Zealand, New Caledonia, and Australia.

The following notes relative to the chrome industry in America are of sufficient interest to warrant reprinting here:[2]

> The chrome industry is one of the most unique and characteristic in Baltimore. It originated in the early discovery of chrome ore in the serpentine of Maryland, and has ever since maintained its prestige as one of the sources of the world's supply of the chromates of potassium and sodium, which have many applications in the arts. The following is the substance of an historical account of the Maryland chrome industry, kindly prepared by Mr. William Glenn:
>
> In 1827 chrome ore was first discovered in America on land belonging to Mr. Isaac Tyson, in what are known as the Bare Hills, 6 miles north of Baltimore. Mr. Tyson's son, Isaac Tyson, jr., then in business with his father, was persuaded by an English workman to attempt the manufacture of "chrome yellow" from this material, and this was done in a factory on what is now Columbia avenue, in Baltimore, in 1828. In the year of the discovery of the Bare Hill ore, Mr. Isaac Tyson, jr., who seems to have possessed a very keen power of observation, as well as a considerable knowledge of chemistry, recognized in a dull black stone, which he saw supporting a cider barrel in Belair market, more of the same valuable material. Inquiry disclosed the fact that this had been brought from near Jarrettsville, in Harford County, where much more like it was to be found. Mr. Tyson at once examined the locality, and finding it covered with boulders worth $100 a ton in Liverpool, purchased a considerable area.

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[1] Journal of the Iron and Steel Institute, 1895, pp. 506, 507. Abstract from L'Echo des Mines, XXI, p. 584.

[2] From Maryland, Its Resources, Industries, and Institutions, Baltimore, 1892, pp. 120–122.

Finding that the chrome ore was always confined to serpentine, Mr. Tyson began a systematic examination of the serpentine areas of Maryland, which could be easily traced by the barren character of the soil which they produce. A narrow belt of serpentine extends across Montgomery County, and while chrome ore is occasionally found in it (as, for instance, at Etchison post-office), nothing of economic importance has ever been discovered in Maryland south of the areas known as "Soldiers Delight" and "Bare Hills." Northeastward, however, the deposits become much richer. The region near Jarrettsville was productive, and thence the serpentine was traced to the State line in Cecil County. Near Rock Springs the serpentine turns and follows the State line eastward for 15 miles. On the Wood farm, half a mile north of the State line and 5 miles north of Rising Sun, in Cecil County, Mr. Tyson discovered in 1833 a chromite deposit, which proved to be the richest ever found in America. This property was at once purchased by Mr. Tyson and the mine opened. At the surface it was 30 feet long and 6 feet wide, and the ore so pure that each 10 cubic feet produced a ton of chrome ore averaging 54 per cent of chrome oxide. The ore was hauled 12 miles by wagon to Port Deposit, and shipped thence by water to Baltimore and Liverpool. At a depth of 20 feet the vein narrowed somewhat, but immediately broadened out again to a length of 120 feet and a width of from 10 to 30 feet. The Wood mine was worked almost continuously from 1828 to 1881, except between the years 1868 and 1873. During that time it produced over 100,000 tons of ore and reached a depth of 600 feet. It is not yet exhausted, but the policy of its owners is to reserve their ores while they can be elsewhere purchased at a cheap rate. Another well-known chrome mine in this region is exactly on the State boundary at Rock Springs, and is called the Line pit. So much of this deposit as lay within the limits of Maryland was owned by Mr. Tyson, while he worked the Pennsylvania portion on a royalty.

Other chrome openings near the Line pit were known as the "Jenkins mine," "Low mine," "Wet pit," and "Brown mine." This region has proved one of the best in the country for fine specimens of rare minerals. As a mineral locality it is usually given as "Texas, Pennsylvania,"[1]

During his exploration of the serpentine belt Mr. Tyson also noticed deposits of chromite sand, and to control the entire supply of this ore he either bought or leased these also, and worked them to some extent with his mines.

Between 1828 and 1850 Baltimore supplied most of the chrome ore consumed by the world; the remainder came from the serpentine deposits and platinum washings of the Urals. The ore was at first shipped to England, the principal consumers being J. and J. White, of Glasgow, whose descendents are still the chief manufacturers of chromic acid salts. In 1844 Mr. Tyson established the Baltimore Chrome Works, which are still successfully operated by his sons.

After 1850 the foreign demand for Baltimore ore declined gradually till 1860, since which time almost none has been shipped abroad. The reason for this was the discovery in 1848 of great deposits of chromite near Brusa, 57 miles southwest of Constantinople, by Prof. J. Lawrence Smith, who was employed by the Turkish Government to examine the mineral resources of that country. Other deposits were also discovered by him 15 miles farther south, and near Antioch. These regions now supply the world's demand.

After the discovery of the magnitude of Wood pit, and of the bountiful supply of

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[1] P. Frazer, Second Geological Survey of Pennsylvania, CCC, Lancaster County, 1880, pp. 176, 192.

sand chrome to be found within the Baltimore region, Isaac Tyson, jr., began to fear that the sources of supply could not much longer be restricted to his ownership. In such an event he realized that he would be compelled to manufacture his ores or to sacrifice them in competition.

The method of manufacture previously in use was to heat a mixture of chrome ore and potassium nitrate upon the working hearth of a reverberatory furnace. The potash salt yielded oxygen to the chromic oxide present, forming chromic acid, which, in turn, united with the base, producing potash chromate. The process was wasteful and exceedingly costly. Afterwards the process was somewhat cheapened by substitution of potassium carbonate for the more costly nitrate; oxygen was taken from heated air in the furnace. But not until 1845, when Stromeyer introduced his process, was the manufacture of chromic acid placed upon a safe mercantile basis. In this process pulverized chromic iron is mixed with potassium carbonate and freshly slaked lime, and the mixture is heated in a reverberatory furnace. After chromic oxide is set free in the charge it is freely oxidized because of the spongy conditions of the lime-laden charge.

Among the first steps of Isaac Tyson, jr., was to apply, in 1846, to Yale College for a chemist for his chrome works. In response a young man named W. P. Blake, who was then a student in the chemical laboratory, was sent. For a while Mr. Blake did excellent service in the new factory, but he was not willing to remain.

Mr. (now Professor) Blake was the first chemist to be employed in technology upon this continent, while the Baltimore works were the first to appreciate the value of chemistry. After the departure of Mr. Blake another chemist was secured from the first laboratory ever instituted for the teaching of chemistry, that founded at Giessen by Liebig. In succession came another chemist from the same laboratory, and this gentleman is yet employed in the works.

Between 1880 and 1890 the American production of chrome ore has varied between 1,500 and 3,000 tons. The total eastern product in 1886 was 100 tons only. Chrome ore was discovered in California in 1873, and since 1886 this State has been the only one to produce this mineral. From 2,000 to 4,000 tons of Turkish chrome ore are now annually imported into the United States, most of which is utilized in Baltimore.

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10. Manganese Oxides.

The element manganese exists in nature under many different forms, of which those in combination as oxides, carbonates, and silicates alone need concern us in this work. The principal known oxides are manganosite (MnO); Hausmanite ($MnO.Mn_2O_3$); Braunite ($3\,Mn_2O_3, MnSiO_3$); Polianite (MnO_2); Pyrolusite (MnO_2); Manganite (Mn_2O_3,H_2O); Psilomelane (H_4MnO_5); and Wad, the last being, perhaps, an earthy impure form of psilomelane. To this list should be added the mineral franklinite, a manganiferous oxide of iron and zinc. Of these the first named, manganosite, is rare, having thus far been reported only in small quantities associated with other oxides in Wermland, Sweden. The other forms are described somewhat in detail as below. It should be stated, however, that with the exception of the well-crystallized forms it is often difficult to discriminate between them, as they occur admixed in all proportions, and, moreover, one variety, as pyrolusite, may result from the alteration of another (manganite). The better defined species may be separated from one another by their comparative hardness, streak, and hydrous or anhydrous properties, as shown in the accompanying table.

IDEAL SECTIONS SHOWING THE FORMATION OF MANGANESE-BEARING CLAY FROM THE DECAY OF THE ST. CLAIR LIMESTONE.

▨ BOONE CHERT ▭ MANGANESE-BEARING CLAY ▦ IZARD LIMESTONE

▦ ST. CLAIR LIMESTONE ⬚ SACCHAROIDAL SANDSTONE

FIG. 1. ORIGINAL CONDITION OF THE ROCKS.

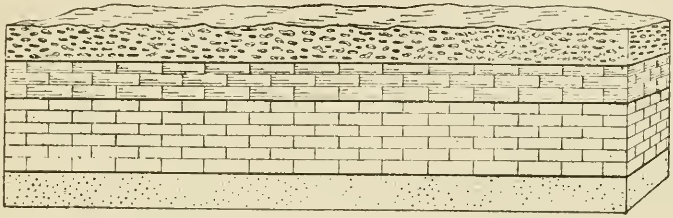


FIG. 2. FIRST STAGE OF DECOMPOSITION.

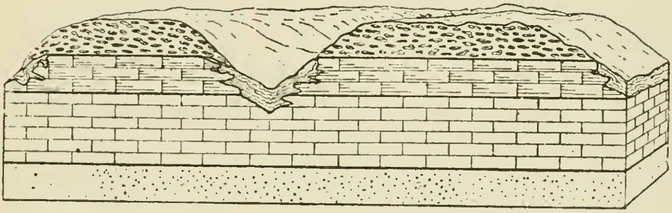


FIG. 3. SECOND STAGE OF DECOMPOSITION.

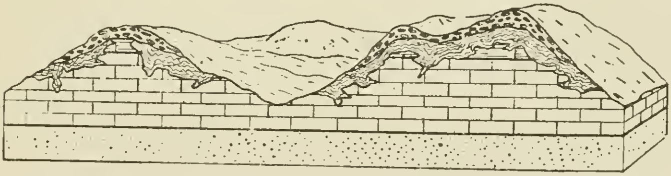
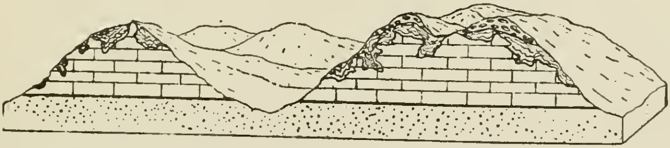


FIG. 4. THIRD STAGE OF DECOMPOSITION.



SECTION SHOWING THE FORMATION OF MANGANESE DEPOSITS FROM DECAY OF LIMESTONE.

After Penrose, Annual Report Geological Survey of Arkansas, I, 1890.

Variety.	Hardness.	Specific gravity.	Color.	Streak.	Anhydrous or hydrous.
Franklinite	5.5 to 6.5	5 to 5.22	Iron black	Reddish brown to black.	Anhydrous.
Hausmannite	5 5.5	4.7 4.85	Brown black	Chestnut brown	Do.
Braunite	6 6.5	4.7 4.85	Brown black to steel gray.	Brown black	Do.
Polianite	6 6.5	4.8 4.9	Light steel gray	Black	Do.
Pyrolusite	2 2.5	4.8	Iron black to steel gray or bluish.	Black or blue black	[a] Do.
Manganite	4	4.2 4.4	Dark steel gray to iron black.	Red brown to black	Hydrous.
Psilomelane	5.6 3.7	4.7	Iron black to steel gray.	Brown black	Do.

[a] Usually yields water in closed tube.

The chemical relationship of the ores as found in nature is thus set forth by Penrose:[1]

Chemical composition.	Anhydrous form.	Hydrous form.
Protoxide (MnO)	Manganosite (MnO)	Pyrochroite ($MnO.H_2O$).
Proto-sesquioxide (Mn_3O_4)	Hausmannite (Mn_3O_4)	
Sesquioxide (Mn_2O_3)	Braunite (Mn_2O_3)	Manganite (Mn_2O_3,H_2O).
Peroxide (MnO_2)	Pyrolusite, Polianite (MnO_2)	Psilomelane. Wad.

Manganese oxides frequently occur admixed in indefinite proportions with the hydrous oxides of iron limonite, giving rise to the manganiferous limonites as shown in Specimens Nos. 66090, 10867, U.S.N.M. from Spain.

Franklinite.—This may be termed rather as a manganiferous ore of iron and zinc than a true ore of manganese. Nevertheless, as the residue after the extraction of the zinc is used in the manufacture of spiegeleisen, we may briefly refer to it here. The mineral occurs in rounded granules or octahedral crystals of a metallic luster and iron black color, associated with zinc oxides and silicates in crystalline limestones, at Franklin Furnace, New Jersey. (Specimen No. 83941, U.S.N.M.) It bears a general resemblance to the mineral magnetite, but is less readily attracted by the magnet and gives a strong manganese reaction. Its average content of manganese oxides Mn_2O_3 and MnO is but from 15 to 20 per cent.

Hausmannite.—This form of the ore when crystallized usually takes the form of the octahedron, and may be readily mistaken for franklinite, from which, however, it differs in its inferior hardness, lower specific gravity, and in being unacted upon by the magnet. (Specimen No. 64241, U.S.N.M.) It occurs in porphyry, associated with other

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[1] Annual Report of the Geological Survey of Arkansas, I, 1890, p. 541.

manganese ores, in Thuringia; is also found in the Harz Mountains; Wermland, Sweden, and various other European localities. In the United States it is reported as occurring only in Iron County, Missouri. The mineral in its ideal purity consists of sesquioxide and protoxide of manganese in the proportion of 69 parts of the former to 31 of the latter. Analyses of the commercial article as mined are not at hand.

Braunite.—This, like hausmannite, crystallizes in the form of the octahedron, but is a trifle harder. Chemically it differs, in that analyses show almost invariably from 7 to 10 per cent of silica, though as to whether or no this is to be considered an essential constituent it is as yet difficult to say. Analyses 1 and 2, on p. 256, show the composition of the mineral as found. The ore is reported as occurring both crystallized and massive in veins traversing porphyry at Oehrenstock in Ilmenau, in Thuringia, near Ilefeld in the Harz; Schneeberg, Saxony (Specimen No. 68136, U.S.N.M.), and various other European localities. Also at Vizianagram in India; in New South Wales, Australia, and in the Batesville region, Arkansas.

Polianite.—Like pyrolusite, yet to be noted, this form of the ore is chemically a pure manganese binoxide, carrying some 63.1 per cent metallic manganese combined with 36.9 per cent oxygen. From pyrolusite it is distinguished by its anhydrous character and increased hardness. So far as reported, it is a rather rare form of manganese, though possibly much that has been set down as pyrolusite may be in reality polianite.

Pyrolusite occurs in the form of iron black to steel gray, sometimes bluish opaque masses, granular, or commonly in divergent columnar aggregates sufficiently soft to soil the fingers, and in this respect easily separated from the other common forms excepting wad. Not known in crystals except as pseudomorphs after manganite. Its composition is quite variable, usually containing traces of iron, silica, and lime and sometimes barium and the alkalies. Analyses III and IV, on p. 256, as given by Penrose, will serve to show the general average. This is a common ore of manganese, and is extensively mined in Thuringia, Moravia, Bohemia, Westphalia, Transylvania, Australia, Japan (Specimen No. 61936, U.S.N.M.), India, New Brunswick (Specimen No. 36825, U.S.N.M.), Nova Scotia, and various parts of the United States (Specimens Nos. 42011, Tennessee, 56354, Georgia, etc.).

Manganite differs and is readily distinguishable from the other ores thus far described, in carrying from 3 to 10 per cent of combined water, which can readily be detected when the powdered mineral is heated in a closed tube. From either psilomelane or pyrolusite it is distinguished by its hardness. When in crystals it takes prismatic forms with the prism faces deeply striated longitudinally (Specimen No. 67922, U.S.N.M., from Thuringia). Its occurrence is essentially

BOTRYOIDAL PSILOMELANE, CRIMORA, VIRGINIA.

Weight, 37½ pounds.

Specimen No. 66722, U.S.N.M.

the same as that of braunite. The composition of the commercial ore is given in the analyses on p. 256.

Psilomelane.—This is, with the possible exception of pyrolusite, the commonest of the manganese minerals. The usual form of occurrence is that of irregular nodular or botryoidal masses embedded in residual clays. It is readily distinguished from manganite or wad by its hardness, and from hausmannite, braunite, or polianite by yielding an abundance of water when heated in a closed tube. The sample (Specimen No. 66722, U.S.N.M.), from the Crimora mines in Virginia, is characteristic. See Plate 11. The composition of the commercial ore is given in analyses V, VI, and VII on p. 256.

Wad or bog manganese (Specimen No. 66602, U.S.N.M., from Cuba) is a soft and highly hydrated form of the ore, as a rule of little value, owing to impurities (analysis VIII). Asbolite is the name given to a variety of wad containing cobalt (see p. 187). See further Rhodonite and Rhodochrosite, pp. 280, 314.

Origin.—The deposits of manganese oxides which are of sufficient extent to be of commercial importance are believed to be in all cases of secondary origin; that is, to have resulted from the decomposition of preexisting manganiferous silicate constituents of the older crystalline rocks and the subsequent deposition of the oxides in secondary strata. Indeed, in many instances the ore has undergone a natural segregation, owing to the decomposition of the parent rock and the accumulate of the manganese oxide, together with other difficult soluble constituents in the residual clay. Thus Penrose has shown[1] that the deposits of the Batesville (Arkansas) region result from the decay of the St. Clair limestone, the various stages of which are shown in the accompanying Plate 10. The fresh limestone, as shown by analysis, contains but 4.30 per cent manganese oxide (MnO), while the residual clay left through its decomposition contains 14.98 per cent of the same constituent.

Occurrence.—As above noted, the ore is found in secondary rocks, and as a rule in greatest quantities in the clays and residual deposits resulting from their breaking down. The usual form of the ore is that of lenticular masses or nodules distributed along the bedding planes, or heterogeneously throughout the clay. Penrose describes the Batesville ores as sometimes evenly distributed throughout a large body of clay, but in most places as being in pockets surrounded by clay itself barren of ore. These pockets vary greatly in character, being sometimes comparatively solid bodies separated by thin films of clay, and containing from 50 to 500 tons of ore; sometimes they consist of large and small masses of ore embedded together, and again at other times of small grains, disseminated throughout the clay. In the Crimora

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[1] Annual Report of the Geological Survey of Arkansas, I, 1890.

(Virginia) deposits the ore (psilomelane) is found in nodular masses in a clay resulting from the decomposition of a shale which has been preserved from erosion through sharp synclinal folds.

Bog manganese is described as occurring in an extensive deposit near Dawson settlement, Albert County, New Brunswick, on a branch of Weldon Creek, covering an area of about 25 acres. In the center it was found to be 26 feet deep, thinning out toward the margin of the bed. The ore is a loose, amorphous mass, which could be readily shoveled without the aid of a pick, and contained more or less iron pyrites disseminated in streaks and layers, though large portions of the deposit have merely a trace. The bed lies in a valley at the northern base of a hill, and its accumulation at this particular locality appears to be due to springs. These springs are still trickling down the hillside, and doubtless the process of producing bog manganese is still going on.[1] A bed of manganese ore in the government of Kutais, in the Caucasus, is described as occurring in nearly horizontally lying Miocene sandstones. The ore is pyrolusite and the bed stated as being 6 to 7 feet in thickness.

Composition of manganese oxides.

Constituents.	Braunite.		Pyrolusite.		Psilomelane.			Wad.
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
MnO	87.47	86.95	90.15	88.98	84.99	80.27	63.46	25.42
O	9.62	9.85	....	....	10.48	14.10	....	....
Fe_2O_3	....	....	2.55	0.21	....	....	1.75	....
CaO	0.31	....	....	....	....	0.51	....	....
BaO	0.48	2.25	1.12	....	....	4.35 K_2O	....	....
SiO_2	0.18	....	2.80	....	....	2.84	9.80	....
H_2O	....	0.95	2.05	....	....	....	6.00	33.52

I. Batesville region, Arkansas.
II. Elgersburg, Germany.
III. Cheverie, Nova Scotia.
IV. Cape Breton.
V. Batesville region, Arkansas.
VI. Schneeberg, Saxony.
VII. Crimora, Virginia.
VIII. Big Harbor, Cape Breton.

Uses.—According to Professor Penrose,[2] the various uses to which manganese and its compound are put, may be divided into three classes: Alloys, oxidizers, and coloring materials. Each of these classes includes the application of manganese in sundry manufactured products, or as a reagent in carrying on different metallurgical and chemical processes. The most important of these sources of consumption may be summarized as follows:

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[1] Annual Report of the Geological Survey of Canada, VII, 1894, p. 146 M.

[2] Annual Report of the Geological Survey of Arkansas, I, 1890.

Alloys	Spiegeleisen Ferromanganese	Alloys of manganese and iron.
	Manganese bronze	Alloys of manganese and copper, with or without iron.
	Silver bronze	An alloy of manganese, aluminum, zinc, and copper, with a certain quantity of silicon.
	Alloys of manganese with aluminum, zinc, tin, lead, magnesium, etc.	
Oxidizers	Manufacture of chlorine.	
	Manufacture of bromine.	
	As a decolorizer of glass (also for coloring glass, see coloring materials).	
	As a dryer in varnishes and paints.	
	LeClanché's battery.	
	Preparation of oxygen on a small scale.	
	Manufacture of disinfectants (manganates and permanganates).	
Coloring materials	Calico printing and dyeing.	
	Coloring glass, pottery, and brick.	
	Paints	Green. Violet.

Besides these main uses a certain amount is utilized as a flux in smelting silver ores, and, in the form of its various salts, is employed in chemical manufacture and for medicinal purposes. Pyrolusite and some forms of psilomelane are utilized in the manufacture of chlorine, and for bleaching, deodorizing, and disinfecting purposes. For this purpose the ore must be very pure and free from iron, lime carbonates, and alkalies. It is also utilized in the manufacture of bromine.

In glass manufacture the manganese is used to accomplish two different results: First, to remove the green color caused by the presence of iron, and second, to impart violet, amber, and black colors.

According to Mr. J. D. Weeks[1] the amount of manganese actually used for other than strictly metallurgical purposes in the United States is small.

The value of a manganese ore depends somewhat upon the uses to which it is to be applied.

Pyrolusite and psilomelane only are of value in the production of chlorine as above noted. These are rated, as stated by Penrose, according to their percentages of peroxide of manganese (MnO_2). The standard for the German ores is given at 57 per cent MnO_2 and 70 per cent for Spanish. For the manufacture of spiegeleisen the prices are based on ores containing not more than 8 per cent silica and 0.10 per cent phosphorus, and are subject to deductions as follows: For each 1 per cent silica in excess of 8 per cent, 15 cents a ton; for each 0.02 per cent phosphorus in excess of 0.10 per cent, 1 cent per

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[1] Mineral Resources of the United States, 1892, p. 178.

unit of manganese. Settlements are based on analysis made on samples dried at 212°, the percentage of moisture in samples as taken being deducted from the weight. The prices paid at Bessemer, Pennsylvania in 1894, based on these percentages, were as below:

Manganese.	Prices per unit.	
	Iron.	Manganese.
	Cents.	*Cents.*
Ore containing above 49 per cent	6	28
Ore containing 46 to 49 per cent	6	27
Ore containing 43 to 46 per cent	6	26
Ore containing 40 to 43 per cent	6	25

Otherwise expressed, the value ranges from $5 to $12 a ton, according to quality and condition of the market.

It is probable that the total consumption in pottery and glass manufacture does not exceed 500 tons a year, of which about two-thirds is used in glass making. The amount used in bromine manufacture and the other uses enumerated probably amounts to another 500 tons. The remainder is used in connection with iron and steel manufacture, chiefly in the production of steel and a pig iron containing considerable manganese for use in cast-iron car wheels. In the crucible process of steel manufacture manganese is charged into the pots, either as an ore at the time of charging the pots or it is added as spiegeleisen or ferromanganese at the time of charging or during the melting, usually toward the close of the melting, so as to prevent too great a loss of manganese by oxidation. In the bessemer and open-hearth process the manganese is added as spiegeleisen or ferromanganese at or near the close of the process, just before the casting of the metal into ingots.

It has been found in recent years that a chilled cast-iron car wheel containing a percentage of manganese is much tougher, stronger, and wears better than when manganese is absent. For this reason large amounts of manganiferous iron ores are used in the manufacture of Lake Superior pig iron intended for casting into chilled cast-iron car wheels. (See also The Mineral Industry, VIII, p. 419.)

V. CARBONATES.

1. CALCIUM CARBONATE.

CALCITE, CALC SPAR, ICELAND SPAR.—These are the names given to the variety of calcium carbonate crystallizing in the rhombohedral division of the hexagonal system. The mineral occurs under a great variety of crystalline forms, which are often extremely perplexing to any but an expert mineralogist. The chief distinguishing characteristics of the mineral are (1) its pronounced cleavage, whereby it splits

Fig. 1.

Fig. 2.

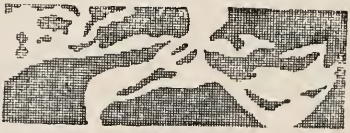
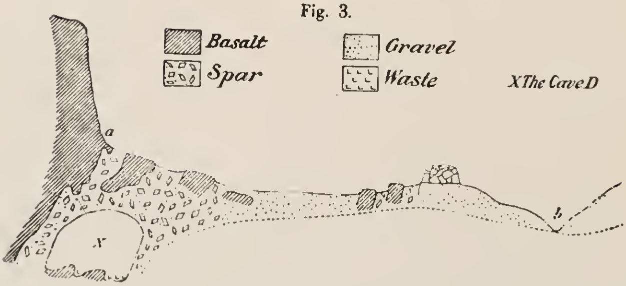


Fig. 3.



VIEWS SHOWING OCCURRENCE OF CALCITE IN ICELAND.
After Thoroddsen.

up into rhombohedral forms, with smooth, lustrous faces, and (2) its doubly refracting property, which is such that when looked through in the direction of either cleavage surfaces it gives a double image. (Specimen No. 53673, U.S.N.M.) It is to this property, accompanied with its transparency, that the mineral, as a crystallized compound, owes its chief value, though as a constituent of the rock limestone it is applied to a great variety of industrial purposes. When not sufficiently transparent for observing its doubly refracting properties the mineral is readily distinguished by its hardness (3 of Dana's Scale) and its easy solubility, with brisk effervescence, in cold dilute acid. This last is likewise a characteristic of aragonite, from which it can be distinguished by its lower specific gravity (2.65 to 2.75) and its cleavage. Calcium carbonate, owing to its ready solubility in terrestrial waters, is one of the most common and widely disseminated of compounds. Only the form known as double spar, or Iceland spar, need here be considered.

Origin and mode of occurrence.—Calc spar is invariably a secondary mineral occurring as a deposit from solution in cracks, pockets, and crevices in rocks of all kinds and all ages. The variety used for optical purposes differs from the rhombohedral cleavage masses found in innumerable localities only in its transparency and freedom from flaws and impurities (Specimen No. 53673, U.S.N.M.). The chief commercial source of the mineral has for many years been Iceland, whence has arisen the term Iceland spar, so often applied. For the account of the occurrences of the mineral at this locality, as given below, we are indebted mainly to Th. Thoroddsen.[1] The quarry is described as situated on an evenly sloping mountain side at Reydarfjorden, about 100 meters above the level of the ocean and a little east of the Helgustadir farm. (See Plate 12.)

The veins of spar are in basalt and at this spot have been laid bare through the erosive action of a small stream called the "Silfurlakur," the Icelandic name of the spar being "Silfurberg." The quarry opening is on the western side of this brook, and at date of writing was some 72 feet long by 36 feet wide (see fig. 1). In the bottom and sides of this opening the calc-spar is to be seen in the form of numerous interlocking veins, ramifying through the basalt in every direction and of very irregular length and width, the veins pinching out or opening up very abruptly. In fig. 2 of plate is shown an area of some 40 square feet of the basaltic wall rock, illustrating this feature of the occurrence. Fig. 3 of the same plate shows the largest and most conspicuous vein, the smaller having been omitted in the sketch. The high cliffs on the north side of the quarry are poorer in calc-spar veins, the largest dipping underneath at an angle of about 40°.

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[1] Geologiska Foreningens I, Stockholm Forhandlingar, XII, 1890, pp. 247–254.

A comparatively small proportion of the calc-spar as found is fit for optical purposes. That on the immediate surface is, as a rule, lacking in transparency. Many of the masses, owing presumably to the development of incipient fractures along cleavage lines, show internal, iridescent, rainbow hues, such are known locally as "litsteinar" (lightstones). Others are penetrated by fine, tube-like cavities, either empty or filled with clay, and still others contain cavities, sometimes sufficiently large to be visible to the unaided eye, filled with water and a moving bubble. The most desirable material occurs in comparatively small masses imbedded in a red-gray clay, filling the veinlike interspaces in the bottom of the pit. The nontransparent variety, always greatly in excess, occurs in cleavable masses and imperfectly developed rhombohedral, sometimes 1 to 2 feet in diameter, associated with stilbite.

Calc-spar has been exported in small quantities from Iceland since the middle of the seventeenth century, though the business was not conducted with any degree of regularity before the middle of the present century, prior to that time everyone taking what he liked or could obtain, asking no one's permission. About the time Bartholin discovered the valuable optical properties of the mineral (in 1669), the royal parliament under Frederick III granted the necessary permission for its extraction.[1] It was not, however, until 1850 that systematic work was begun, when a merchant by name of T. F. Thomsen, at Seydisfjord, obtained permission of the owner of some three-fourths the property (the pastor Th. Erlendsson) to work the same. The quarried material was then transported on horseback to the Northfjord, and thence to Seydisfjord by water. In 1854 the factor H. H. Svendsen, from Eskifjord, leased the pastor's three-fourths right for 10 rigsdalers a year, and the remaining fourth, belonging to the Government, for 5 rigsdalers. Svendsen worked the mine successfully up to 1862, when one Tullinius, at Eskifjord, purchased the pastor's three-fourths and leased the Government's share for five years, paying therefor the sum of 100 rigsdalers [about $14 or $15]. This lease was renewed for four years longer at the rate of 5 rigsdalers per year and for the year 1872 at the rate of 100 rigsdalers, when the entire property passed into the hands of the Government in consideration of the payment of 16,000 kroner [about $3,800]. From that time until 1882 the mine remained idle, when operations were once more renewed, though not on an extensive scale, owing, presumably in part, to the fact that Tullinius, the last year he rented the mine, had taken out a sufficient quantity to meet all the needs of the market. Over 300 tons of the ordinary type of the spar is stated to have been sent to England and sold to "factory owners" (Fabrikanter) at about 30 kroner a ton, though to what use it was put is not stated.

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[1] Laws of Iceland, I, 1668, pp. 321, 322.

Aside from the locality at Helgustadir, calc-spar in quantity and quality for optical purposes is known to occur only at Djupifjördur, in West Iceland.

The Reydharfjördhr locality was also visited by Mr. J. L. Hoskyns-Abrahall in the summer and autumn of 1889, and whose account[1] is reproduced in part below.

Sudhrmúla Sysla, of which Reydharfjördhr, the largest, bisects the east coast of Iceland, are cut out of an immense plateau, formed of horizontal sheets of volcanic rock, chiefly trachyte, between 3,000 and 4,000 feet high. This has been subsequently eroded into sharp, bare ridges with immense cliffs or steep slopes falling from them, parted by torrent valleys and fjords, the greater part of the district not reaching the present snow line. It is on one of these slopes, which slants down at an angle of forty degrees into Reydharfjördhr, that the unique quarry of Iceland spar is found. It consists of a cavity in the rock about 12 by 5 yards and some 10 feet high, originally filled almost entirely, but now only lined, with immense crystals, which are fitted so closely together as to form a compact mass, like a lump of sugar, with grains averaging 10 inches across.

The Syslumadhur,[2] Jón Asmundarson Johnsen, had given me leave to examine the cave and take as many specimens as I liked, but the permission was not of very much use, there being about 5 feet of water nearly all over the bottom; and such specimens as I did get involved doing severe penance in walking barefoot over sharp crystals. The floor is covered with a thin layer of very fine chocolate-brown mud, which sticks as tenaciously to one's feet as to the crystals. I had to resort to tooth powder to get the latter clean, though the great heaps of spar which lie on the path side and in front of the mouth of the cave were all washed by the rain till they were as bright and transparent as ice. The water now running through the cave is incapable of forming calc-spar. It appears, like the surrounding rocks, to contain an excess of silicic acid, and either etches the surface of the spar wherever it comes in contact with it, or covers it with stilbite, the characteristic zeolite of the doleritic and basaltic rocks in Iceland. The rock in which the cave is formed is a dolerite, and darker in color than the surrounding phonolite, which is traversed by veins of black and green pitchstone. In the neighborhood of the spar it is disintegrated, colored slightly with green earth, and full of microscopic crystals of stilbite and calcite.

The quarry was worked till 1872 by Herra Tulinius, a Danish merchant of Eskifjördhr. The trading station is an hour and a half's ride from Helgastadhir, the nearest farm to the quarry. (In Iceland all distances are measured in terms of the hour's ride, *tima*, and the day's

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[1] Mineralogical Magazine, IX, 1890, p. 179.

[2] Magistrate, public notary, receiver of taxes, liquidator, auctioneer, etc.

journey, *leidh.*) The Icelandic government in that year bought a quarter share of the quarry, and stopped the work, so that Tulinius was glad to sell them the rest. Five years ago an attempt was made to reopen it. One man was employed, and after spending about a week in the cave he succeeded in pumping out the water and extracting a fine block of clear spar, which was sold at a high price in London. Here, however, the work dropped, and in consequence Tulinius remains the proprietor of the whole of the calc spar that is available for physical work, and naturally sells it at a price that is calculated to make his very moderate stock last for a considerable time.[1] The reason of the Icelandic government is not very clear, but as the working of the quarry is, perhaps from patriotic motives, delegated to Herr Gunnarsson, an Icelandic merchant, whose nearest warehouse is at Seydhisfjördhr, a good day's ride from Eskifjördhr, it is hardly to be expected that the buried treasure will soon see the light. Perhaps, too, the specimens of the best quality have been already removed. Certainly clear pieces do not constitute the great mass of the spar, and if M. Labonne, who visited the cave in May, 1877 (the water being at that time frozen), could extract it "en assez grande abondance"[2] he did not leave much exposed for me to take two years later. M. Labonne speaks in his note of ramifications into the environing rock which have never been worked and suggests that this investigation might increase the importance of the quarry. Such ramifications as I could see were on a very small scale. On the other hand, the thickness of the deposit has not yet been ascertained, but it is said that the best pieces occurred near the surface. For the most part the calcite is rendered semiopaque by innumerable cracks, generally following the gliding and cleavage planes (— ½ R and R), and apparently produced by the pressure of the spar itself, but sometimes following the conchoidal fracture. Remarkable examples of the latter kind are in the British Museum.

CHALK.—This is the name given to a white, somewhat loosely coherent variety of limestone composed of the finely comminuted shells of marine mollusks, among which microscopic forms known as foraminifera are abundant. The older text-books gave one to understand that foraminiferal remains constituted the main mass of the rock, but the researches of Sorby[3] showed that fully one-half the material was finely comminuted shallow-water forms, such as inoceramus, pecten, ostrea, sponge spicules, and echinoderms.

Chalk belongs to the Cretaceous era, occurring in beds of varying thickness, alternating with shales, sands, and clays, and often including numerous nodules of a dark chalcedonic silica to which the name

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[1] It is sold by Thor E. Tulinius, Slotsholmsgade 16, Copenhagen K.

[2] Comptes Rendus, CV., 1887, p. 1144.

[3] Address to Geological Society of London, February, 1879.

flint is given. Though a common rock in many parts of Europe, it is known to American readers mainly for its occurrence in the form of high cliffs along the English coast, as near Dover. Until within a few years little true chalk was known to exist within the limits of the United States. According to Mr. R. T. Hill[1] there are, however, extensive beds, sometimes 500 feet in thickness, extending throughout the entire length of Texas, from the Red River to the Rio Grande, and northward into New Mexico, Kansas, and Arkansas. These chalks in many instances so closely simulate the English product, both in physical properties and chemical composition, as to be adaptable to the same economic purposes. The following analyses from the report above alluded to serve to show the comparative composition:

Constituents.	Lower Cretaceous chalk, Burnet County, Texas.	Upper Cretaceous chalk, Rocky Comfort, Arkansas.	White Cliff chalk, Little River, Arkansas.	White chalk of Shoreham, Sussex, England.	Gray chalk, Folkstone, England.
Carbonate of lime	92.42	88.48	94.18	98.40	94.09
Carbonate of magnesia	1.38	Trace.	1.37	.08	.31
Silica and insoluble silicates	1.59	9.77	3.49	1.10	3.61
Ferric oxide and alumina	.41	1.25	1.41	....	....
Phosphoric acid, alumina, and loss	....	....	....	.42	Trace.
Chloride of sodium	....	....	....	....	1.29
Water	.18	....	.55	....	.70
	99.98	99.50	101	100	100

Chalk is used as a fertilizer, either in its crude form or burnt, in the manufacture of whiting (Specimen No. 26499, from Trego County, Kansas), in the form of hard lumps by carpenters and other mechanics, and in the manufacture of crayons (Specimen No. 62063, U.S.N.M.). Washed. chalk (Specimen No. 62085, U.S.N.M.) is used to give body to wall paper; as a whitewash for ceilings; as a thin coating on wood designed for gilding, being for this purpose mixed with glue; to vary the shades of gray in water-color paints, and as a polishing powder for metals.

Concerning the importation and uses of chalk, Williams states:[2]

> Paris white is the name given to the white coloring substance prepared by grinding cliffstone, a variety of chalk or limestone which is as hard as some building stones and has a greater specific gravity than the ordinary chalk. It is imported from Hull, England, and sells at from \$2 to \$4 per ton ex vessel, according to freight rates from Hull. During the calendar year 1884 3,905½ tons of cliffstone were imported at New York.
>
> The paris white made in this country is sold at from \$1.10 to \$1.25 per hundredweight, in casks, according to make and quality. The paris white made in England, of which 508,185 pounds were imported at New York during the calendar year 1884,

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[1] Annual Report of the Arkansas Geological Survey, II, 1888.

[2] Mineral Resources of the United States, 1883–84, p. 930.

sells at from $1.25 to $1.30 per hundredweight. There is apparently no difference in quality between the cliffstone ground in this country and the imported paris white. Its principal use is in the preparation of kalsomine. It is also employed in the manufacture of rubber, oilcloth, wall papers, and fancy glazed papers. * * *

Until recently all of the whiting used in this country was ground from chalk imported from Hull, England. [See Specimen No. 36013, U.S.N.M.] The annual production of whiting is about 300,000 barrels. The price varies, according to the quality, from 35 to 90 cents per hundredweight. There are four grades made, as follows: Common whiting, worth from 35 to 40 cents; gilders' whiting, 60 to 65 cents; extra gilders' whiting, 70 to 75 cents; American paris white, 80 to 85 cents. The uses of whiting are about the same as paris white, which it closely resembles.

The material, as should be stated, is brought mainly as ballast from England and France.

LIMESTONES; MORTARS; AND CEMENTS.—Pure limestone or calcium carbonate is a compound of calcium oxide and carbonic acid in the proportion of 56 parts of lime (CaO) to 44 parts of the acid (CO_2). In its crystalline form as exemplified in some of our white marbles the rock is therefore but an aggregate of imperfectly outlined calcite crystals, or, otherwise expressed, is a crystalline granular aggregate of calcite. In this form the rock is white or colorless, sufficiently soft to be cut with a knife, and dissolves with brisk effervescence when treated with dilute hydrochloric or nitric acid. Sulphuric acid will not dissolve it except in small proportions, since the exteriors of the granules become converted shortly into insoluble calcium sulphate (gypsum), which protects them from further attack.

As a constituent of the earth's crust, however, absolutely pure limestone is practically unknown, all being contaminated with more or less foreign material, either in the form of chemically combined or mechanically admixed impurities. Of the chemically combined impurities the most common is magnesia (MgO), which replaces the lime (CaO) in all proportions up to 21.7 per cent, when the rock becomes a dolomite. This in its pure state can readily be distinguished from limestone by its greater hardness and in its not effervescing when treated with cold dilute acid. (See p. 274.) It dissolves with effervescence in hot acids, as does limestone. As above noted, all stages of replacement exist, the name magnesian or dolomitic limestone being applied to those in which the magnesia exists in smaller proportions than that above given (21.7 per cent). Iron in the form of protoxide (FeO) may also replace a part of the lime. Of the mechanically admixed impurities silica in the form of quartz sand or various more or less decomposed silicate minerals, clayey and carbonaceous matter, together with iron oxides, are the more abundant. These exist in all proportions, giving rise to what are known as siliceous, aluminous or clayey, carbonaceous, and ferruginous limestones. Phosphatic material may exist in varying proportions, forming gradations from phosphatic limestones to true phosphates.

Limestones are sedimentary rocks formed mainly through the deposition of calcareous sediments on sea bottoms; many beds, however, as the oölitic limestones, show unmistakable evidences of true chemical precipitation. They are in all cases eminently stratified rocks, though the evidences of stratification may not be evident in the small specimen exhibited in museum collections. Varietal names other than those mentioned above are given and which are dependent upon structural features or other peculiarities. A shaly limestone is one partaking of the nature of shale. Chalk is a fine pulverulent limestone composed of shells in a finely comminuted condition and very many minute foraminifera. (See p. 262.) The name chalky limestone is frequently given to an earthy limestone resembling chalk. Marl is an impure earthy form, often containing many shells, hence called shell marl. An oölitic limestone is one made up of small rounded pellets like the roe of a fish. The name marble is given to any calcareous or even serpentinous rock possessing sufficient beauty to be utilized for ornamental purposes.

Uses.—Aside from their uses as building materials, lithographic purposes, etc., as described elsewhere, limestones are utilized for a considerable variety of purposes, the more important being that of the manufacture of mortars and cements. Their adaptability to this purpose is due to the fact that when heated to a temperature of 1,000° F. they gradually lose the carbonic acid, becoming converted into anhydrous calcium oxide (CaO), or quicklime, as it is popularly called; and further, that this quicklime when brought in contact with water and atmospheric air greedily combines with, first, the water, forming hydrous calcium oxide ($CaOH_2O$), and on drying once more with the carbonic acid of the air, forming a more or less hydrated calcium carbonate. In the process of combining with water the burnt lime (CaO) gives off a large amount of heat, swells to nearly twice its former bulk, and falls away to a loose, white powder. This when mixed with siliceous sand forms the common mortar of the bricklayers, or, if with sand and hair, the plaster for the interior walls of houses. (Specimens Nos. 63144, 63145, U.S.N.M., from Vermont; No. 53195, U.S.N.M., from Maine, and No. 53168, from Pennsylvania, show the character of the rocks commonly used for these purposes.) Quicklime formed from fairly pure calcium carbonate sets or hardens after but a few days' exposure, the induration, it is stated, being due in part to crystallization. The less pure forms of limestone, notably those which contain upwards of 10 per cent of aluminous silicates (clayey matter), furnish, when burned, a quicklime which slakes much more slowly—so slowly, in fact, that it is not infrequently necessary to crush to powder after burning. These same quicklimes when slaked are further differentiated from those already described by their property of setting (as the process of induration is called) under water. Hence they are known as hydraulic limes, and the rocks from which they are made as hydraulic limestones.

Their property of induration out of contact with the air is assumed to be due to the formation of calcium and aluminum silicates. Inasmuch as these silicates are practically insoluble in water, it follows that quite aside from their greater strength and tenacity they are also more durable; indeed, there seems no practical limit to the endurance of a good hydraulic cement, its hardness increasing almost constantly in connection with its antiquity. Certain stones contain the desired admixture of lime and clayey matter in just the right proportion for making hydraulic cement. In the majority of cases, however, it has been found that a higher grade, stronger and more enduring material, can be made by mixing in definite proportions, determined by experiment, the necessary constituents obtained, it may be, from widely separated localities. The exact relationship existing between composition and adaptability to lime making does not seem as yet to be fully worked out. As is well known, the pure white crystalline varieties yield a quicklime inferior to the softer blue-gray, less metamorphosed varieties. Nevertheless there are certain distinctive qualities, due to the presence and character of impurities, which led Gen. Q. A. Gillmore to adopt the following classification:

(1) The common or fat limes, containing, as a rule, less than 10 per cent of impurities.
(2) The poor or meager limes, containing free silica (sand) and other impurities in amounts varying between 10 per cent and 25 per cent.
(3) The hydraulic limes, which contain from 30 to 35 per cent of various impurities.
(4) The hydraulic cements, which may contain as much as 60 per cent of impurities of various kinds.

As above noted most cements are manufactured from a variety of materials, and their consideration belongs therefore more properly to technology. Nevertheless it has been thought worth the while here to give in brief the matter below relative to a few of the more important and well-known varieties now manufactured.

Portland cement.—This takes its name from a resemblance of the hardened material to the well-known oölitic limestone of the island of Portland in the English Channel. As originally made on the banks of the Thames and Medway it consists of admixtures of chalk and clay dredged from the river bottoms, in the proportions of three volumes of the former to one of the latter, though these proportions may vary according to the purity of the chalk. These materials are mixed with water, compressed into cakes, dried and calcined, after which it is ground to a fine powder and is ready for use. The following analyses from Heath's Manual of Lime and Cement will serve to show the varying composition of the chalk and clay from the English deposits.

Constituents.	Upper chalk.		Gray chalk.		Clay.	
Calcium carbonate ....about..	97.90 to	98.60	87.35 to	96.52	....	
Silica ....do....	.66	1.59	1.67	6.84	55 to 70	
Magnesium carbonate ......do....	.10	.21	.10	.50	....	
Iron oxide ....do....	.35	.74	.38	.46	3	15
Alumina ....do....	....		1.14	.93	11	24
Potash and soda ....do....	....		.42	4.29	3	4
Lime..........................do....	....		....		4	8
Magnesia ....do....	....		....		1	2
Carbonic acid...............do....	....		....		4	5

It is stated that the presence of more than very small quantities of sand, iron oxides, or vegetable matter in the clay is detrimental. A good cement mud before burning may contain from 68 to 78 per cent of calcium carbonate, 21 to 15 per cent of silica, and from 10 to 7 per cent of alumina.

The following analyses from the same source as the above serve to show (I) the composition of the clay; (II) the mixed clay and chalk or "slurry," as it is called, and (III) the cement powder prepared from the same:

Constituents.	I. Clay.	II. Slurry.	III. Cement.
Lime	....	....	62.13
Calcium sulphate	....	....	2.13
Calcium carbonate........................	2.01	69.97	....
Silica (soluble)............................	54.14	11.77	20.45
Alumina	14.68	4.45	8.05
Magnesium carbonate	4.48	2.87	....
Magnesia....................................	....	....	1.48
Iron oxide	7.76	2.13	4.37
Sand	.87	1.24	.98
Water	15.03	7.59	....

Several brands of Portland cement are manufactured in America, usually from a mixture of materials, the proportions of which have been worked out by experiment. At the Coplay Cement Works, in Lehigh County, Pennsylvania, a blue-gray crystalline limestone and dark gray more siliceous variety are ground and mixed into the desired proportions, molded into a brick, and burnt to the condition of a slag. The material is then ground to a powder and forms the cement. Through the courtesy of the manager, the Museum collections contain samples of the crude and manufactured materials, as follows: Limestone (Specimen No. 53541, U.S.N.M.); cement rock (No. 53542, U.S.N.M.). Composition formed by admixing the two rocks (No. 53543, U.S.N.M.); and the clinker (No. 53544, U.S.N.M.) obtained by burning the composition. The chemical composition of the samples as given are as follows:

Constituents.	Limestone.	Cement rock.	Compound of the two.	Clinker.
Silica (SiO_2)	2.10	15.22	13.22	22.74
Alumina (Al_2O_3)	.84	4.24	5.20	10.50
Iron oxide (Fe_2O_3)				
Calcium carbonate ($CaCO_3$)	96.17	69.88	77.00	CaO 61.82
Magnesian carbonate ($MgCO_3$)	Trace.	4.60	4.20	MgO 2.05

An impure limestone, forming a portion of the water-lime group of the Upper Silurian formations at Buffalo, New York, forms a "natural cement" rock which is utilized in the manufacture of the so-called Buffalo Portland cement.[1]

The so-called *Rosendale cement* is made from the tentaculite or water limestones of the Lower Helderburg group as developed in the township of Rosendale, Ulster County, New York. According to Darton[2] there are two cement beds in the Rosendale-Whiteport region, at Rosendale the lower bed or dark cement averaging some 21 feet in thickness and the upper or light cement 11 feet, with 14 to 15 feet of water-lime intervening. In the region just south of Whiteport the upper white cement beds have a thickness of 12 feet and the lower or gray cement of 18 feet, with 19 to 20 feet of water-lime beds between them. The underlying formation is quartzite. The method of mining the material from the two beds, as well as their inclination to the horizon, is shown in Plate 13. (See Specimens, Nos. 63062–63086, U. S. N. M., from Ulster, Onondaga, and Erie Counties, New York; Nos. 63090–63099, U.S.N.M., Cumberland and Hancock, Maryland; No. 53173, from Lisbon, Ohio, and No. 53193, from Sandusky, Ohio).

ROMAN CEMENT.—The original Roman cement appears to have been made from an admixture of volcanic ash or sand (pozzuolana, peperino, trass, etc.) and lime, the proportions varying almost indefinitely according to the character of the ash. The English Roman cement is made by calcining septarian nodules dredged up from the bottoms of Chichester Harbor and off the coast of Hampshire, and from similar nodules obtained from the Whitby shale beds of the Lias formations in Yorkshire and elsewhere. The following analysis of the cement stone from Sheppey, near South End, will serve to show the character of the material:

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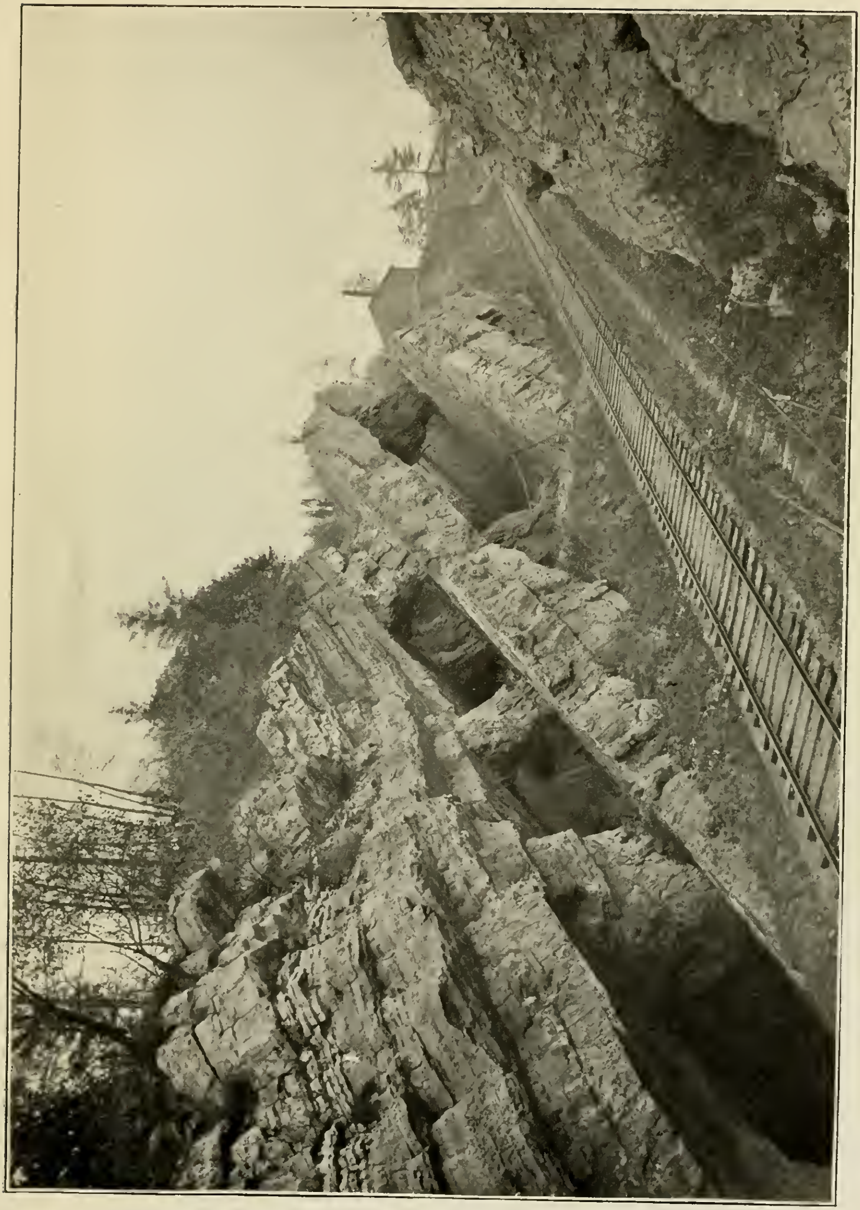
[1] Cement Rock and Gypsum Deposits in Buffalo. J. Pohlman. Transactions of the American Institute of Mining Engineers, XVII, 1889, p. 250.

[2] Report of the State Geologist of New York, I, 1893.



VIEW IN A CEMENT QUARRY NEAR WHITEHALL, ULSTER COUNTY, NEW YORK.

From a photograph by N. H. Darton.

Carbonate of lime	64.00
Silica	17.75
Alumina	6.75
Magnesia	.50
Oxide of iron	6.00
Oxide of manganese	1.00
Water	3.00
Loss	1.00
	100.00

The names concrete and beton are applied to admixtures of mortar, hydraulic or otherwise, and such coarse materials as sand, gravel, fragments of shells, tiles, bricks, or stone. According to Gillmore the matrix of the beton proper is a hydraulic cement, while that of the concrete is nonhydraulic. The terms are, however, now used almost synonymously.

Aside from their uses as above indicated limestones are used in the preparation of lime for fertilizing purposes. For this purpose, as before, the lime carbonate is reduced to the condition of oxide by burning, and then allowed to become air slaked, when it remains in the condition of a fine powder suitable for direct application to the land as is the plaster made from gypsum. A lime prepared by burning oyster shells is utilized in a similar manner.

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Boston, 1898, 299, pp.
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New York, 1898, 192 pp.
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(Reprinted from Journal of the Association of Engineering Societies. XX, June, 1898).

Playing marbles.—At Oberstein on the Nahe, Saxony, playing marbles are made in great quantities from limestone. The stone is broken into square blocks, each of such size as to make a sphere the size of the desired marble. These cubes are then thrown into a mill consisting of a flat, horizontally revolving stone with numerous concentric grooves or furrows on its surface. A block of oak of the same diameter as the stone and resting on the cubes is then made to revolve over them in a current of water, the cubes being thus reduced to the spherical form. The process requires but about fifteen minutes.

Lithographic limestone.—For the purpose of lithography there is used a fine-grained homogeneous limestone, breaking with an imperfect, shell-like or conchoidal fracture, and as a rule of a gray, drab, or yellowish color. A good stone must be sufficiently porous to absorb the greasy compound which holds the ink and soft enough to work readily under the engraver's tool, yet not too soft. It must be uniform in texture throughout and be free from all veins and inequalities of any kind, in order that the various reagents used may act upon all exposed parts alike. It is evident, therefore, that the suitability of this stone for practical purposes depends more upon its physical than chemical qualities. An actual test of the material by a practical lithographer is the only test of real value for stones of this nature. Nevertheless the analyses given below are not without interest as showing the variation in composition even in samples from the same locality.

Composition of lithographic stones.

Localities.	$CaCo_3$.	$MgCo_3$.	Al_2O_3.	Fe_2O_3.	Soluble silica.	Insoluble silica.	Organic matter.	FeO.	H_2O.	Specific gravity.	Authority.
Solenhofen, Bavaria	81.47	13.83	0.25		4.45		....	....	....	....	J. Lewis Howe.
Solenhofen, Bavaria (dark)	90.934	3.571	0.584	0.236	0.520	2.00	0.720	0.13	0.40	2.95	C. W. Volney.
Solenhofen, Bavaria (yellow)	89.589	4.380	0.101	0.321	0.02	1.893	0.132	0.003	1.379	2.84	Do.
Solenhofen, Bavaria	96.24	0.21	2.02				....	....	....	....	Gmelin.
Kentucky (light gray)	73.241	12.431		1.141		11.50	0.40	....	0.935	2.99	C. W. Volney.
Iowa (blue gray)	82.20	4.327		1.076		6.795	3.30	....	0.24	2.82	Do.
Missouri (light gray)	77.03	14.27		2.143		4.30	1.83	....	0.341	2.75	Do.
Missouri, Ralls County	81.77	15.10	0.06		3.12		....	....	....	....	
Overton, Tennessee	77.62	17.32	0.66		4.10		....	....	....	....	
Canada (light-blue gray)	89.989	2.789	....	0.884	....	3.712	0.409	0.104	1.25	2.84	
Canada (dark-blue gray)	88.034	2.50	0.577	0.359	0.49	3.60	1.29	0.41	1.360	2.89	

Localities.—Stones possessing in a greater or less degree the proper qualities for lithographic purposes have from time to time been reported in various parts of the United States; from near Bath and Stony Stratford, England; Ireland; Department of Indre, France, and also Silesia, India, and the British American possessions. By far the best stone, and indeed the only stone which has as yet been found to satisfactorily fill all the requirements of the lithographer's art, and which is the one in general use to-day wherever the art is practiced, is found at Solenhofen, near Pappenheim, on the Danube, in Bavaria. (Specimens Nos. 35888 and 35706, U.S.N.M.) These beds are of Upper Jurassic or Kimmeridgian age and form a mass some 80 feet in thickness, though naturally not all portions are equally good, or adapted for the same kind of work. The stone varies both in texture and color in different parts of the quarry, but the prevailing tints are yellowish or drab. In the United States materials partaking of the nature of lithographic stone have been reported from Yavapai County, Arizona (Specimens Nos. 62798 and 68162, U.S.N.M.); Talladega County, Alabama; Arkansas; Lawrence County, Indiana (Specimen No. 25030, U.S.N.M.); near Thebes and Anna, Illinois (Specimens Nos. 61344 and 62570, U.S.N.M.); James and Van Buren counties, Iowa; Hardin, Estelle, Kenton, Clinton, Rowan, Wayne, and Simpson counties, Kentucky (Specimen No. 36897, U.S.N.M., from Simpson County); near Saverton, Ralls County, Missouri (Specimen No. 28498, U.S.N.M.); Clay and Overton counties, Tennessee; Burnet and San Saba counties, Texas (Specimens Nos. 38624 and 70671, U.S.N.M.); near Salt Lake City, Utah, and at Fincastle, Virginia. While, however, from nearly, if not quite every one of these localities, it was possible to get small pieces which served well for trial purposes, each and every one has failed as a constant source of supply of the commercial article, and this for reasons mainly inherent in the stone itself. It is very possible that ignorance as to proper methods of quarrying may have been a cause of failure in some cases.

The Arizona stone is one of the most recent discoveries, and according to first reports seems also the most promising. Samples of the stone submitted to the writer, as well as samples of work done upon it, seemed all that could be desired (Specimens Nos. 62798 and 68162, U.S.N.M.). It is stated by Mr. W. F. Blandy that the quarries are situated on the east slope of the Verdi Range, about 2 miles south of Squaw Peak and at an elevation of about 1,200 feet above the Verdi Valley, 40 miles by wagon road east of Prescott. Two quarries have thus far been opened in the same strata, about 1,000 feet apart, the one showing two layers or beds 384 feet in thickness, and the other three beds 3,188 feet in thickness. As at present exposed the beds, which are of Carboniferous age, are broken by nearly vertical fissures into blocks rarely 4 or 5 feet in length. Owing to the massive form of the beds and this conchoidal fracture the stone can not be split into thin slabs, but must be sawn. No satisfactory road yet exists for its transportation in blocks of any size, and such material as has thus far been produced is in small slabs such as can be "packed." Those who have inspected the properties express themselves as satisfied that blocks of good size and satisfactory quality can be had in quantity.

The Alabama stone as examined by the writer is finely granular and too friable for satisfactory work. Qualitative tests showed it to be a siliceous magnesian limestone. It is of course possible that the single sample shown does not fairly represent the product. The Arkansas deposit is situated in Township 14° N., R. 15° W. of the 5th p. m., sections 14, 23, and 24, Searcy County. The color is darker than that of the Bavarian stone. The reports of those who have tested it are represented as being uniformly favorable.

The Illinois stone is darker, but to judge from the display made in the Illinois building at the World's Columbian Exposition, 1893, is capable of doing excellent work and can be had in slabs of good size (Specimens Nos. 61344 and 62570, U.S.N.M.). The Kentucky stone is hard and brittle, though that from Rowan County is stated to have received a medal at the exposition of 1876. It is fine grained and homogeneous and very pure, only a small flocculent residue of organic matter remaining insoluble in dilute hydrochloric acid.

The Indiana stone is harder than the Bavarian, and samples examined were found not infrequently traversed by fine, hard veins of calcite. (Specimen No. 25030, U.S.N.M.)

The stone from Saverton, Missouri, is compact and fine grained, with, however, fine streaks of calcite running through it. (Specimen No. 28498, U.S.N.M.) It leaves only a small brownish residue when dissolved in dilute acid. This stone has been worked quite successfully on a small scale. The State geologist, in writing on the subject, says:[1]

> Some of the beds of the St. Louis limestone (Subcarboniferous) have been successfully used for lithographic work. No bed is, however, uniformly of the requisite quality, and the cost of selection of available material would seem to preclude the development of an industry for the production of lithographic stone. From the deposit at Overton, Tennessee, it is stated slabs 40 by 60 inches by 3½ inches thick were obtained, though little, if anything, is now being done. An analysis of this stone is given in the table. Other promising finds are reported from McMinn County, in the same State. According to the State geological reports, the stone lies between two beds of variegated marble. The stratum is thought to run entirely through the county, but some of the stone is too hard for lithographic purposes. The best is found 8 miles east of Athens on the farm of Robert Cochrane, and a quarry has been opened by a Cincinnati company, which only pays a royalty of $250 per annum. It is sold for nearly the same price as the Bavarian stone. It is a calcareous and argillaceous stone, formed of the finest sediment, of uniform texture, and possesses a pearl-gray tint. The best variety of this stone has a conchoidal fracture and is free from spots of all kinds.

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[1] Bulletin No. 3, Geological Survey of Missouri, 1890, p. 38.

A lithographic stone is described in the State survey reports of Texas as occurring at the base of the Carboniferous formations near Sulphur Springs, west of Lampasas, on the Colorado River, and to be traceable by its outcrops for a distance of several miles, the most favorable showing being near San Saba. The texture of the stone is good; but as it is filled with fine reticulating veins of calcite (Specimen No. 70671, U.S.N.M.), and as moreover the lithographic layer itself is only some 6 or 8 inches in thickness, it is obvious that little can be expected from this source. The Texas Lithographic Stone Company, with headquarters at Burnet, have used the stone, it is said, in considerable quantities. A stone claiming many points of excellence has for some years been known to exist in the Wasatch range within a few miles of Salt Lake City, and several companies are or have been engaged in its exploitation.

Very encouraging reports of beds examined by men whose opinions should be conservative, come from Canadian sources, and it is possible a considerable industry may yet be here developed, though little is being done at present. The descriptions as given in the geological reports are as follows:[1]

> The lithographic stones of the townships of Madoc and Marmora and of the counties of Peterboro and Bruce have been examined and practically tested by lithographers, and in several cases pronounced of good quality; they have also obtained medals at various exhibitions. They were obtained from the surface in small quarries, and possibly when the quarries are more developed better stones, free from "specks" of quartz and calcite, will be available in large slabs.

It should be stated that in actual use the principal demand is for stones some 22 or 28 by 40 inches; the largest ones practically used are some 40 by 60 inches and 3 to 3½ inches thick. As the better grades bring as high as 22 cents a pound, it will be readily perceived that the field for exploration is one offering considerable inducement.

2. DOLOMITE.

This is a carbonate of calcium and magnesium (Ca, Mg), CO_3,= calcium carbonate 54.35 per cent, magnesium carbonate 45.65 per cent. Hardness 3.5 to 4; specific gravity, 2.8 to 2.9; colors when pure, white, but often red, green, brown, gray, or black from impurities. (Specimen No. 82167, attached crystals on limestone from Joplin, Missouri.) Dolomite, like calcite, occurs in massive beds or strata either compact (Specimen No. 37795, U.S.N.M.) or coarsely crystalline, and is to the eye alone often indistinguishable from that mineral. Like limestone, the dolomites occur in massive forms suitable for building purposes, or in some cases as marble. (Specimen No. 25075, U.S.N.M.) From the limestone they may be distinguished by their increased hardness and being insoluble in cold dilute hydrochloric acids. The dolomites, like the limestones, are sedimentary rocks, though it is doubtful

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[1] Geology of Canada, 1863.

if the original sediments contained sufficient magnesium carbonate to constitute a true dolomite. They are regarded rather as having resulted from the alteration of limestone strata by the replacement of a part of the calcium carbonate by carbonate of magnesium.

Uses.—Aside from its use as a building material, dolomite has of late come into use as a source of magnesia for the manufacture of highly refractory materials for the linings of converters in the basic processes of steel manufacture. According to a writer in the Industrial World[1] the magnesia is obtained by mixing the calcined dolomite with chloride of magnesia, whereby there is formed a soluble calcic chloride which is readily removed by solution, leaving the insoluble magnesia behind. According to another process the calcined dolomite is treated with dissolved sugar, leading to the formation of sugar of lime and deposition of the magnesia; the solution of sugar of lime is then exposed to carbonic acid gas, which separates the lime as carbonate, leaving the sugar as refuse. Recently it has been proposed to use magnesia as a substitute for plaster of paris for casts, etc.

The snow-white coarsely crystalline Archean dolomite commercially known as snowflake marble, and which occurs at Pleasantville, in Westchester County, New York (Specimen No. 30863, U.S.N.M.), is finely ground and used as a source of carbonic acid in the manufacture of the so-called soda and other carbonated waters. (Specimen No. 30864, U.S.N.M.)

3. MAGNESITE.

This is a carbonate of magnesium, $MgCO_3$, = carbon dioxide 52.4 per cent, magnesia 47.6 per cent. Usually contaminated with carbonates of iron and free silica.

The following analysis will serve to show the average run of the material, both in the crude state and after calcining:

Constituents.	Styria.	Greece.
Crude magnesite.		
Carbonate of magnesia	90.0 to 96.0	94.46
Carbonate of lime	0.5 to 2.0	4.40
Carbonate of iron	3.0 to 6.0	FeO 0.08
Silica	1.0	0.52
Manganous oxide	0.5	Water 0.54
Burnt magnesite.		
Magnesia	77.6	82.46 to 95.36
Lime	7.3	0.83 to 10.92
Alumina and ferric oxide	13.0	0.56 to 3.54
Silica	1.2	0.73 to 7.98

The mineral occurs rarely in the form of crystals, but is commonly in a compact finely granular condition of white or yellowish color some-

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[1] June 1, 1893.

what resembling unglazed porcelain (Specimen No. 16070, from Gilroy, California), and more rarely crystalline granular, like limestone or dolomite (Specimen No. 48273, U.S.N.M., from Wells Island).

It is hard (3.5 to 4.5) and brittle, with a vitreous luster, and is unacted upon by cold, but dissolves with brisk effervescence in hot hydrochloric acid.

Localities and mode of occurrence.—Most commonly the mineral is found in the form of irregular veins in serpentinous and other magnesian rocks, being a decomposition product either of the serpentine itself or of the original rock from which the serpentine is derived. It is also found in granular aggregates disseminated throughout serpentinous rocks. It is stated by Dana to occur associated with gypsum.

Prof. W. P. Blake has described[1] immense beds of very pure magnesite as occurring in the foothills of the Sierra Nevadas, between Four and Moore creeks, in what is now Tulare County. The beds are from 1 to 6 feet in thickness and are interstratified with talcose and chloritic schists and serpentine. Mr. H. G. Hanks, who has since inspected these deposits, reports them as existing in several hills or low mountains, the mineral cropping out boldly in distinct and clearly marked veins, varying from 2 inches to 4 feet, and of a maximum length, as exposed, of 500 feet. In section 5, T. 15 S., R. 24 E., Fresno County, California, there is stated[2] to be a large vein of the material averaging 10 feet in width, incased in hornblendic and micaceous shales. A white marble-like crystalline granular variety has been found in the form of drift bowlders on an island in the St. Lawrence River near the Thousand Islands Park. (Specimen No. 48273, U.S.N.M.) According to Canadian geologists magnesite forming rock masses occurs associated with the dolomites, serpentines, and steatites of the eastern townships of Quebec. In Bolton it occurs in an enormous bed resembling crystalline limestone in appearance. An analysis of this yielded: Carbonate of magnesia, 59.13 per cent; carbonate of iron, 8.72 per cent; silica, 32.20 per cent. In the township of Sutton a slaty variety yielding as high as 80 per cent of carbonate of magnesium occurs admixed with feldspar and green chromiferous mica. In Styria the material lies in Silurian beds consisting of argillaceous shales, quartzites, dolomites, and limestones, resting upon gneiss. The extensive deposit of magnesite occurring associated with Subcarboniferous limestones in the Swiss Tyrol is regarded by M. Koch[3] as due to a decomposition of the original limestone through percolating magnesia-bearing solutions. Magnesia being the stronger base replaces the lime, which is carried away in solution.

The chief localities of magnesite, native and foreign, are as fol-

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[1] Pacific Railroad Reports, V, p. 308

[2] Tenth Annual Report of the State Mineralogist of California, 1890, p. 185.

[3] Zeitschrift der Deutschen Geologischen Gesellschaft, XLV, Pt. 2, 1893, p. 294.

lows: Maryland, Bare Hills, Baltimore County. New Jersey, Hoboken. Massachusetts, Roxbury. New York, near Rye, Westchester County; Warwick, Orange County; Stony Point, Rockland County; New Rochelle, Westchester County; Serpentine Hills, Staten Island. North Carolina, Webster, Jackson County; Hamptons, Yancey County, McMakins Mine, Cabarrus County. Pennsylvania, Goat Hill, West Nottingham, Chester County; Scotts Mine, Chester County; Low's Chrome Mine, Lancaster County (Specimen No. 53101, U.S.N.M.). California, Coyote Creek, near Madison Station, Southern Pacific Railroad, Santa Clara County (Specimen No. 16070, U.S.N.M.); Gold Run, Iowa Hill, and Damascus, Placer County; Arroyo Sero, Monterey County; Mariposa and Tuolumne counties; Diablo Range, Alameda County; between Four Creek and Moores Creek, near Visalia, Tulare County (Specimen No. 63842, U.S.N.M.); Alameda County; Napa County (Specimen No. 62594, U.S.N.M.); Millcreek, Fresno County. Washington, Spokane County (Specimen No. 53235, U.S.N.M.). Sutton, Quebec, lot 12, range 7; Bolton, Quebec. Regla, near Havana, Cuba. Köngsberg, Norway. Piedmont, Italy. Bingera Diamond Fields, New South Wales. Victoria, South Australia (Specimens Nos. 28466 and 28472, U.S.N.M.). Kosewitz and Frankenstein, Silesia. Styria, in Austria-Hungary. Greece (Specimens Nos. 62895 and 67983, U.S.N.M.).

Uses.—Magnesite is used in the preparation of magnesian salts (Epsom salts, magnesia, etc.), in the manufacture of paint, paper, and fire brick. For the last-named purpose it is said to answer admirably, particularly where a highly refractive material is needed, as in the so-called basic process of iron smelting.

> Magnesia made from the carbonate [magnesite] by driving off the carbonic acid is very refractory, if pure. It is made into any shape that is required, and is one of the most refractory of substances. It was formerly very difficult to get the carbonate of magnesia, but large quantities of it have been found on the island of Eubœa, so that it can now be had for $15 to $25 per ton, instead of $60 to $70 as formerly. It can be calcined at a less cost than ordinary lime, losing half of its weight, so that if calcined before it is transported the cost may be still further reduced. It contains a little lime, silicates of iron, and some serpentine and silica. After calcination, the serpentine and silica can be separated, as it is easily crushed, but the most of the work can be done by hand-picking beforehand. Before moulding, it must be submitted to about the temperature it is to undergo in the furnace, otherwise it would contract. It is then mixed with a certain portion of less calcined material, which is one-sixth for steel fusion, and 10 to 15 per cent. water by weight, and pressed in iron moulds. If for any reason—either because there was too much or too little water, or because the material was not properly mixed, or contains silica—the crucible is not strong enough, it has only to be dipped in water, which has been saturated with boracic acid, and then heated.[1]

Twenty or more years ago the mineral was mined from serpentinous

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[1] T. Egleston, Transactions of the American Institute of Mining Engineers, IV, 1876, p. 261.

rocks in Lancaster County, Pennsylvania, by McKim, Sines and Company, of Baltimore, by whom it was used for the manufacture of Epsom salts (sulphate of magnesia).

Although it is said[1] that these gentlemen made a pure salt at less price than it could be imported, and thereby excluded the foreign material almost exclusively, the mines are now wholly abandoned. Isaac Tyson & Co., of this same city, also operated mines in Lancaster County.

Early in the fall of 1886 a small force of men was set to work on the deposits of magnesite discovered on Cedar mountain, Alameda county, California. Since that time several carloads of the mineral have been gotten out and shipped by rail to New York, these deposits being only a few miles from the line of the Central Pacific Railroad. The mineral occurs here in a decomposed serpentine rock and in a yellow clay in which are embedded large bowlders. It lies in pockets and small veins, the latter running in every direction. The richest spots are found under the bowlders, where the mineral is quite pure. A machine is used to sift out the small stones from the powdered magnesite, a good deal of which is met with. A number of veins of this mineral has been exposed by the occurrence of landslides on the side of the mountain where they are situated; only a few of them, however, contain good mineral, nor is there any certainty as to how long these will last. The claims are being opened by tunnels, of which two have been started. The process of gathering this mineral is slow, as every piece has to be cleaned by hand and the whole has to be carefully assorted according to purity. Having been divided into three classes, it is put up in sacks weighing from 80 to 100 pounds each. This sacking is preliminary not only to shipping but to getting it down from the mountains, which can be done only on the backs of animals. While carbonate of magnesia occurs at a great many places in California and elsewhere on the Pacific coast, the above is the only deposit of this mineral that is being worked. An artificial article of this kind is obtained as a by-product in the manufacture of salt by the Union Pacific Salt Company of California.[2]

Th. Schlossing has proposed[3] to utilize magnesian hydrate obtained by precipitation from sea water by lime, for the preparation of fire brick, the hydrate being first dehydrated by calcination at a white heat, after which it is made up into brick form.

According to the Industrial World[4] magnesite as a substitute for barite in the manufacture of paint is likely to prove of importance. The color, weight, and opacity of powder add to its value for this purpose. In Europe it is stated the material is used as an adulterant for the cheaper grades of soap.

Prices.—During 1892 the material, 96 to 98 per cent pure, was quoted as worth $9 to $15 a ton in New York City. Material containing as high as 15 to 30 per cent silica and 8 to 10 per cent of iron is said to be practically worthless. In 1899 crude California magnesite was quoted as worth $3 a ton at the mines.

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[1] Report C. C. C. Second Geological Survey of Pennsylvania, p. 178.

[2] Mineral Resources of the United States, 1886, p. 696.

[3] Comptes Rendus, 1885, p. 137.

[4] Industrial World, XXXVI, No. 20, 1891.

4. WITHERITE.

This is a carbonate of barium of the formula $BaCO_3$, = baryta 77.7 per cent, carbon dioxide 22.3 per cent. Color, white to yellow or gray, streak white; translucent. Hardness, 3 to 3.75; specific gravity, 4.29 to 4.35. When crystallized, usually in form of hexagonal prisms, with faces rough and longitudinally striated. Common in globular and botryoidal forms, amorphous, columnar, or granular in structure. The powdered mineral dissolves readily in hydrochloric acid, like calcite, but is easily distinguished from this mineral by its great weight and increased hardness, as well as by its vitreous luster and lack of rhomboidal cleavage, which is so pronounced a feature in calcite. From barite, the sulphate of barium, with which it might become confused on account of its high specific gravity, it is readily distinguished by its solubility in acids as above noted. From strontianite it can be distinguished by the green color it imparts to the blowpipe flame.

Localities and mode of occurrence.—The mineral occurs apparently altogether as a secondary product filling veins and clefts in older rocks and often forming a portion of the gangue material of metalliferous deposits. The principal localities as given by Dana are Alston Moor, Cumberland (Specimen No. 67923, U.S.N.M.), where it is associated with galena. In large quantities at Fallowfield near Hexam in Northumberland; at Anglezarke in Lancashire; at Arkendale in Yorkshire, and near St. Asaph in Flintshire, England. Tarnowitz, Silesia; Szlana, Hungary; Leogang in Salzburg; the mine of Arqueros near Coquimbo, Chile; L. Etang Island; near Lexington, Kentucky, and in a silver-bearing vein near Rabbit Mountain, Thunder Bay, Lake Superior.

Uses.—The mineral has been used to but a slight extent in the arts. As a substitute for lime it has met with a limited application in making plate glass, and is also said to have been used in the manufacture of beet sugar, but is now being superseded by magnesite.

5. STRONTIANITE.

This is a carbonate of strontium, $SrCO_3$, = Carbon dioxide 29.9 per cent; strontia 70.1 per cent. Often impure through the presence of carbonates and sulphates of barium and calcium. Colors, white to gray, pale green, and yellowish. Hardness 3.5 to 4. Specific gravity 3.6 to 3.7. Transparent to translucent. When crystallized often in acute spear-shaped forms. Also in granular, fibrous, and columnar globular forms. Soluble like calcite in hydrochloric acid, with effervescence, but readily distinguished by its cleavage and greater density. The powdered mineral when moistened with hydrochloric acid and held on a platinum wire in the flame of a lamp imparts to the flame a very characteristic red color.

Occurrence.—According to Dana the mineral occurs at Strontian in Argyllshire, in veins traversing gneiss, along with galena and barite; in Yorkshire, England; at the Giants Causeway, Ireland; Clausthal, in the Harz; Bräunsdorf, Saxony; Leogang, in Salzburg; near Brixlegg, Tyrol; near Hamm and Münster, Westphalia. In the United States, at Schoharie, New York, in the form of granular and columnar masses and also in crystals, forming nests and geodes in the hydraulic limestone; at Clinton, Oneida County; Chaumont Bay and Theresa, Jefferson County; and Mifflin County, Pennsylvania.

Uses.—Strontianite, so far as the writer has information, has but a limited application in the arts. It is stated[1] that "basic bricks" are prepared from it by mixing the raw or burnt strontianite with clay or argillaceous ironstone in such proportions that the brick shall contain about 10 per cent of silica, and then working into a plastic mass with tar or some heavy hydrocarbon. After molding, the bricks are dusted with fine clay or ironstone, dried, and burned. The effect of the dusting is to form a glaze on the surface, which protects the brick from the moisture of the air. Like celestite, it is also used in the production of the red fire of fireworks. The demand for the material is small, and the price but from $2.50 to $4 a ton.

6. RHODOCHROSITE; DIALOGITE.

This is a pure manganese carbonate of the formula $MnCO_3$, =carbon dioxide, 38.3 per cent; manganese protoxide, 61.7 per cent. The color is much like that of rhodonite (see p. 314), from which, however, it is readily distinguishable by its rhombohedral form, inferior hardness (3.5 to 4.5), and property of dissolving with effervescence in hot hydrochloric acid, while rhodonite is scarcely at all attacked. The mineral is a common constituent of the gangue of gold and silver ores, as at Butte, Montana; Austin, Nevada, etc. (Specimen No. 26745, U.S.N.M.) So far as known the mineral has as yet no commercial value.

7. NATRON, THE NITRUM OF THE ANCIENTS.

This is a hydrous sodium carbonate; $Na_2CO_3+10H_2O$, =carbon dioxide, 15.4 per cent; soda, 21.7 per cent; water, 62.9 per cent. Occurs in nature, according to Dana, only in solution, as in the soda lakes of Egypt and elsewhere, or mixed with other sodium carbonates. The artificially crystallized material is of white color when pure, soft and brittle, and with an alkaline taste. Crystals, thin, tabular, monoclinic. Thermonatrite, also a hydrous sodium carbonate of the formula $Na_2CO_3+H_2O$=carbon dioxide, 35.5 per cent; soda, 50 per cent, and water 14.5 per cent, occurs under similar conditions, and is considered as derived from natron as a product of efflorescence. (See further under Sodium sulphates, p. 405.)

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[1] Journal of the Society of Chemical Industry, III, 1884, p. 33.

8. Trona; Urao.

This is a hydrous sodium carbonate, corresponding to the formula $Na_2CO_3.HNaCO_3+2H_2O$, =carbon dioxide, 38.9 per cent; soda, 41.2 per cent; water, 19.9 per cent.

Found in nature as an efflorescence or incrustation from the evaporation of lakes, particularly those of arid regions. W. P. Blake has recently described[1] crude carbonate of soda (Trona) occurring in the central portion of a basin-shaped depression or dry lake in southern Arizona, near the head of the Gulf of California. The deposit covers an area of some 60 acres to a depth of from 1 to 3 feet, the lower portion being saturated with water from a solution so strong that when exposed to the air soda is deposited at the rate of an inch in thickness for every ten days. In its native condition the soda is naturally somewhat impure, from silt blown in from the surrounding land. The analysis given below shows the general average:

Sand, silt, etc	13.00
Iron oxides and alumina	2.80
Lime	1.14
Salt (NaCl.?)	4.70
Sulphate of soda	4.70
Carbonate of soda	73.66
	100.00

See further under Thernardite, p. 415.

VI. SILICATES.

1. Feldspars.

The name feldspar is given to a group of minerals resembling each other in being, chemically, silicates of aluminum with varying amounts of lime and the alkalies potash and soda. All members of the group have in common two easy cleavages whereby they split with even, smooth, and shining surfaces along planes inclined to one another at angles of nearly if not quite 90°. (Specimen No. 67361, U.S.N.M.) They vary from transparent through translucent to opaque, the opaque form being the more frequent. In colors they range from clear and colorless through white and all shades of gray to yellowish, pink and red, more rarely greenish.

On prolonged exposures to the weather they become whitish and opaque, gradually decomposing into soluble carbonates of lime and the alkalies, and soluble silica, any one of which may be wholly or in part removed by percolating waters, leaving behind a residual product, consisting essentially of hydrous silicates of alumina, to which the names kaolin and clay are given (see p. 325). The hardness of the feldspars varies from 5 to 7 of Dana's scale; specific gravity 2.5 to 2.8.

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[1] Engineering and Mining Journal, LXV, 1898, p. 188.

They are fusible only with difficulty, and with the exception of the mineral quartz are the hardest of the common light-colored minerals. From quartz they are readily distinguished by their cleavage characteristics noted above. Geologically the feldspars belong to the gneisses and eruptive rocks of all ages, certain varieties being characteristic of certain rocks and furnishing important data for schemes of rock classification. Nine principal varieties are recognized, which on crystallographic grounds are divided into two groups. The first, crystallizing in the monoclinic system, including only the varieties orthoclase and hyalophane; the second, crystallizing in the triclinic system, including microclinic, anorthoclase, and the albite-anorthite series, albite, oligoclase, andesine, labradorite, and anorthite. The above-mentioned properties are set forth in the accompanying table.

Constituents.	Orthoclase.	Hyalophane.	Microcline.	Anorthoclase.	Albite.	Oligoclase.	Andesine.	Labradorite.	Anorthite.
Silica SiO_2	64.7	51.6	64.7	66.0	68.0	62.0	60.0	53.0	43.0
Alumina Al_2O_3	18.4	21.9	18.4	20.0	20.0	24.0	26.0	30.0	37.0
Potash K_2O	16.9	10.1	16.9	5.0	....	....	....	....	....
Soda Na_2O	....	....	....	8.0	12.0	9.0	8.0	4.0	....
Barite BaO	....	16.4	....	....	....	....	....	....	....
Lime CaO	....	....	....	....	....	5.0	7.0	13.0	20.0
Specific gravity	2.4–2.6	2.8	2.4–2.6	2.0–5.8	2.5–2.6	2.56–2.7	2.6–2.7	2.6–2.7	2.6–2.8
Hardness	6.0–6.5	6.0–6.5	6.0–6.5	....	6.0–7.0	6.0–7.0	5.0–6.0	6.0	6.0–7.0
Crystalline system	Monoclinic.		Triclinic.						

Of the above those which most concern us here are the potash feldspars orthoclase and microcline, two varieties which for our purposes are esssentially identical, both as regards composition and general physical properties as well as mode of occurrence. Indeed, although crystallizing in different systems they are as a rule indistinguishable but by microscopic means or by careful crystallographic measurements.

Occurrence.—The feldspars are common and abundant constituents of the acid rocks—such as the granites, gneisses, syenites—the orthoclase and quartzose porphyries, and the tertiary and modern lavas—such as trachyte, phonolite, and the liparites.

Among the older rocks they not infrequently occur in large veins or dike-like masses of coarse pegmatitic crystallization, the individual crystals being in some cases a foot or more in diameter. The associated minerals are quartz and white mica, with beryl, tourmaline, garnet, and a great variety of rarer minerals. The ordinary white mica of commerce comes from deposits of this nature and often the two minerals are mined contemporaneously. Such of our feldspars as have yet been worked for economic purposes occur associated only with the older rocks—the granites and gneisses of the Archean and Lower Paleozoic formations.

Near Topsham, Maine, is one of these pegmatitic veins, running parallel with the strike of the gneissoid schists in which it lies, i. e. northeast and southwest. The vein material is quartz, feldspar, and mica. The quarry, as described by R. L. Packard, is in the form of an open cut in the hillside, being some 300 feet long by 100 feet wide, and of very irregular contours. The present floor and the sides of the cut are of feldspar (Specimen No. 61086, U.S.N.M.), containing irregular bodies of quartz and mica, the first named occurring in large masses entirely free from other minerals, though a second grade is taken out which is in reality an intimate mixture of quartz and feldspar.

The quartz occurs, besides as mentioned above, in the form of irregular bodies, sometimes 6 or 8 feet across and 15 feet or more long. It also occurs in cavities, or geodes, in the form of flattened crystals (Specimen No. 61085, U.S.N.M.). The mica is here of little economic importance, being found in the mass of the feldspar and along the seams in the form of narrow, lanceolate masses, often arranged in small radiating conical forms with their apexes outward.

The principal feldspar quarries thus far worked are in the Eastern United States, from Maine to New Jersey. The material is mined from open cuts, being blasted out with powder and separated from adhering quartz, mica, and other minerals by hand, after which it is shipped in the rough to the potteries, or in some cases ground and bolted in the near vicinity. In Connecticut the material has in times past been ground by huge granite disks mounted like the wheels of a cart on an axle through the center of which extended a vertical shaft. By the slow revolution of this shaft the wheels traveled around in a limited circle over a large horizontal granite slab. The pieces of spar being placed upon the horizontal slab were thus slowly ground to powder, after which it was bolted and sacked. The modern method of pulverizing is by means of the so-called "Cyclone" crusher. The value of the uncrushed material delivered at the potteries is but a few dollars a ton. Hence, while there are unlimited quantities of the material in different parts of the Appalachian region, but few are so situated as to be profitably worked.

Uses.—The feldspars are used mainly for pottery, being mixed in a finely pulverized condition with the kaolin or clay. When subjected to a high temperature the feldspar fuses, forming a glaze and at the same time a cementing constituent. There are other substances more readily fusible which are utilized for this purpose in the cheaper kinds of ware, but it is stated that in the highest grades of porcelain, as those of Sevres, feldspar is the material used. The proportions used vary with different manufacturers, each having adopted a formula best adapted for his own workings.

2. Micas.

Under this head are comprised a number of distinct mineral species, alike in crystallizing in the monoclinic system and having a highly perfect basal cleavage, whereby they split readily into thin, translucent to transparent, more or less elastic sheets. Chemically they are in most cases orthosilicates of aluminum with potassium and hydrogen, and in some varieties magnesium, ferrous, and ferric iron, sodium, lithium, and more rarely barium, manganese, titanium, and chromium. Seven species of mica are commonly recognized, of which but three have any commercial value, though a fourth form, lepidolite, may perhaps be utilized as a source of lithia salts. Of these three forms, the white mica, muscovite, and the pearl gray, phlogopite, are of greatest importance, the black variety, biotite, being but little used. Muscovite, or potassium mica, is essentially a silicate of aluminum and potassium, with small amounts of iron, soda, magnesia, and water. Its color is white to colorless, often tinted with brown, green, and violet shades. When crystallized it takes on hexagonal or diamond-shaped forms, as do also phlogopite and biotite as shown in samples (Specimens Nos. 62377 and 30763, U.S.N.M.). Its industrial value lies in its great power of resistance to heat and acids, its transparency, and its wonderful fissile property, in virtue of which it may be split into extremely thin, flexible sheets. It has been stated, though I know not how correctly, that sheets but one two hundred and fifty thousandths (1/250000) of an inch in thickness have been obtained. Phlogopite, or magnesian mica, differs from muscovite in being of a darker, deep pearl gray, sometimes smoky, often yellowish, brownish red, or greenish color. Biotite, or magnesia iron mica, differs in being often deep, almost coal black and opaque in thick masses, though translucent and of a dark brown, yellow, green, or red color in thin folia. It further differs from the preceding in that its folia are less elastic, and the sheets of smaller size. Lepidolite, a lithia mica, is much more rare than either of the above, is of a pale rose or pink color, folia usually of small size, commonly occurring in scaly granular forms without crystal outlines. The following table will serve to show the varying composition of the four varieties mentioned:

Variety.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	K_2O	Na_2O	F.	H_2O
Muscovite..........	45.71	36.57	1.19	1.07	0.71	0.46	9.22	0.79	0.12	4.83
	44.48	35.70	1.09	1.07	Trace.	0.10	9.77	2.41	0.72	5.50
	45.40	33.66	2.36	....	1.86	....	8.33	1.41	0.69	5.46
Phlogopite.........	39.66	17.00	0.27	0.20	26.49	....	9.97	0.60	2.24	2.99
	43.00	13.27	1.71	....	27.70	....	10.32	0.30	5.67	0.78
	40.64	14.11	2.28	0.69	27.97	....	8.16	1.16	0.82	3.21
Biotite.............	44.94	31.69	4.75	3.90	....	....	8.00	0.59	0.93	3.85
	34.67	30.09	2.42	16.99	1.98	....	7.55	1.57	0.28	4.64
	39.30	16.95	0.48	8.45	21.89	0.82	7.79	0.49	0.89	4.02
	40.16	15.79	2.53	4.12	26.15	....	7.64	0.37	....	3.58
Lepidolite..........	50.39	28.19	....	....	5.08	Li_2O	12.34	....	5.15	2.36
	49.62	27.30	0.31	0.07	4.34	Li_2O	11.19	2.17	5.45	1.52

Although the basal cleavage which permits of the ready splitting of the mica into thin sheets is the only one sufficiently developed to be of economic importance, the mica as found is often traversed by sharp lines of separation, called gliding planes, which may, by their abundance, be disastrous to the interests of the miner. Such partings, or gliding planes, supposed to be induced by pressure, are developed at angles of about 66½° with the cleavage, and may cut entirely through a block or extend inward from the margin only a short distance and come to an abrupt stop. In many cases the mica is divided up into long narrow strips, from the breadth of a line to several inches in thickness, with sides parallel, and as sharply cut as though done with shears. (Specimens Nos. 62517, 63134, U.S.N.M.)

The imperfections in mica are due to inclosures of foreign minerals, as flattened garnets, to the presence of free iron oxides, often with a most beautiful dendritic structure, to the partings or gliding planes noted above, and to crumplings and V-like striations which destroy its homogenity. (Specimens Nos. 63139, 44450, U.S.N.M.)

Occurrence.—Mica in quantity and sizes to be of economic importance is found only among the older rocks of the earth's crust, particularly those of the granite and gneissoid groups. Muscovite and biotite are among the commonest constituents of siliceous rocks of all kinds and ages, while phlogopite is more characteristic of calcareous rocks. It is, however, only when developed in crystals of considerable size in pegmatitic and coarsely feldspathic veins, or, in the case of phlogopite, in gneissic and calcareous rocks associated with eruptive pyroxenites, that it becomes available for economic purposes. The associated minerals are almost too numerous to mention. The more common for muscovite are quartz and potash feldspar, which form the chief gangue materials in crystals and crystalline masses, sometimes a foot or more in diameter. With these are almost invariably associated garnets, beryls, and tourmalines, with more rarely cassiterite, columbite, apatite, fluorite, topaz, spodumene, etc. Indeed, so abundant are, at times, the accessory minerals in the granitic veins, and so perfect their crystalline development, that they furnish by far the richest collecting grounds for the mineralogists. Of these minerals the quartz and feldspars are not infrequently contemporaneously with the mica and utilized in the manufacture of pottery and abrasives.

The origin of these pegmatitic veins is a matter of considerable doubt. The finer grained pegmatites are, in certain cases, undoubted intrusives, though to some authorities it seems scarcely possible that the extremely coarse aggregates of quartz, feldspar, and mica, with large garnets, beryls, and tourmalines, can be a direct result of cooling from an igneous magma. To such it seems more probable that they are portions of an original rock mass altered by exhalations of fluorhydric acids, like the Saxon "greisen." Others regard them as resulting from the very slow cooling of granitic material injected in a pasty condition, brought about by aqueo-igneous agencies, into rifts of the preexisting rocks. It must be remembered that the high degree of dynamic metamorphism which these older rocks have undergone render the problems relating to their origin extremely difficult.

Localities.—From what has been said regarding occurrences, it is evident that mica deposits are to be looked for only in regions occupied by the older crystalline rocks. In the United States, therefore, we need only look for them in the States bordering immediately along the Appalachian range and in the Granitic areas west of the front range of the Rocky Mountains.[1] In the Appalachian region south of Canada mica mines, worked either for mica alone or for quartz and feldspar in addition, have from time to time been opened in various parts of Maine, New Hampshire, Connecticut, Maryland, Virginia, North Carolina, and perhaps other States, but in none of them, with the exception of New Hampshire and North Carolina, has the business proven sufficiently lucrative to warrant continuous and systematic working. Indeed, were it not for the increased demand lately arising for the use of mica in electrical machines it is doubtful if any but the most favorably situated mines would remain longer in operation in the United States. This for the reason not so much that foreign mica is better as that it is cheaper.

In Maine muscovite has been mined in an intermittent manner along with quartz and feldspar at the well-known mineral localities at Paris Hill and Rumford, Oxford County; Auburn, Androscoggin County; Topsham, Sagadahoc County; Edgecomb, Lincoln County, and other counties in the southeastern part of the State. In New Hampshire the industry has assumed greater importance. The mica-bearing belt is described by Prof. C. H. Hitchcock as usually about 2 miles in width, and extending from Easton, in Grafton County, to Surry, in Cheshire County; being best developed about the towns of Rumney and Hebron. The mica occurs in immense coarse granite veins in a fibrolitic mica schist (Specimen No. 63029, U.S.N.M.) of Montalban age, and is found in sheets sometimes a yard in length, but the more common sizes are but 10 or 12 inches in length. Immense beryls, sometimes a yard in diameter, and beautiful large tourmalines occur among the accessory minerals. Mines for mica were opened at Grafton as early as 1840, and as many as six or eight mines have been worked at one time, though by no means continually. Other mines have been worked in Groton, Alexandria, Grafton, and Alstead, in Grafton Country; Acworth and Springfield, Sullivan County; Marlboro, Cheshire County; New Hampton, Belknap County, and Wilmot, Merrimack County, though only those of Groton are in operation at date of writing (1894).

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[1] The region of the Black Hills of South Dakota is an important exception.

As seen by the writer, the veins at the latter place cut sharply across the fibrolitic schist, and though the vein materials adhere closely to the wall rock on either side, without either selvage or slickensides, still the line of demarcation is perfectly sharp. There seems no room for doubt but that the vein material was derived by injection from below, though from their extremely irregular and universally coarsely crystalline condition we must infer that the condition of the injected magma was more in the nature of solution than fusion, as the word is ordinarily used, and also that the rate of cooling and consequent crystallization was very slow. The feldspars not infrequently occur in huge crystalline masses several feet in diameter, though sometimes more finely intercrystallized with quartz in the form known as pegmatite. [Specimen No. 62519, U.S.N.M.] The mica is by no means disseminated uniformly throughout the vein, but on the contrary is very sporadic, and the process of mining consists merely in following up the mineral wherever indications as shown in the face of the quarry are sufficiently promising. Most of the mines are in the form of open cuts and trenches, though in a few instances underground cuts have been made for a distance of a hundred feet or more. The mica blocks as removed are of a beautifully smoky-brown color, and often show a distinct zonal structure, indicating several periods of growth. The associated feldspar is not in all cases orthoclase, but, as at the Alexandria mines, sometimes a faintly greenish triclinic variety.

Samples of the New Hampshire micas, with the accompanying gangue and wall rocks, are shown in Specimens Nos. 62515 to 62519 and 63028 to 63030, U.S.N.M.

In Connecticut some mica (muscovite) has been obtained in connection with the work of mining feldspar and quartz in and about the towns of Haddam, Glastonbury, and Middletown, but the business has never assumed any importance. Mica mines have also been worked in Montgomery County, Maryland. South of the glacial limit mica mining has proven more successful from the reason that the gangue minerals (feldspar and quartz) were in a state of less compact aggregation, due to weathering, the feldspar being often reduced to the state of kaolin, and hence readily removed by pick and shovel. The following account of the deposits of North Carolina is given by Prof. W. C. Kerr:[1]

I have stated elsewhere, several years ago, that these veins were wrought on a large scale and for many ages by some ancient peoples, most probably the so-called Mound Builders; although they built no mounds here, and have left no signs of any permanent habitation. They opened and worked a great many veins down to or near water-level; that is, as far as the action of atmospheric chemistry had softened the rock so that it was workable without metal tools, of the use of which no signs are apparent. Many of the largest and most profitable of the mines of the present day are simply the ancient Mound Builders' mines reopened and pushed into the hard undecomposed granite by powder and steel. Blocks of mica have often been found half imbedded in the face of the vein, with the tool-marks about it, showing the exact limit of the efficiency of those prehistoric mechanical appliances. As to the geological relations of these veins, they are found in the gneisses and schists of the Archæan horizons. * * * These rocks are of very extensive occurrence in North Carolina, constituting in fact the great body of the rocks throughout the whole length of the State,—some 400 miles east and west,—being partially covered

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[1] Transactions of the American Institute of Mining Engineers, VIII, 1880, p. 457.

up, and interrupted here and there by belts of later formation. Mica veins are found here, in fact may be said to characterize this horizon everywhere, from its eastern outcrop, near the seaboard, to and quite under the flanks of the Smoky Mountains. It is, however, in the great plateau of the west, between the Blue Ridge and the Smoky, that the mica veins reach their greatest development, and have given rise to a very new and profitable industry,—new and at the same time very old.

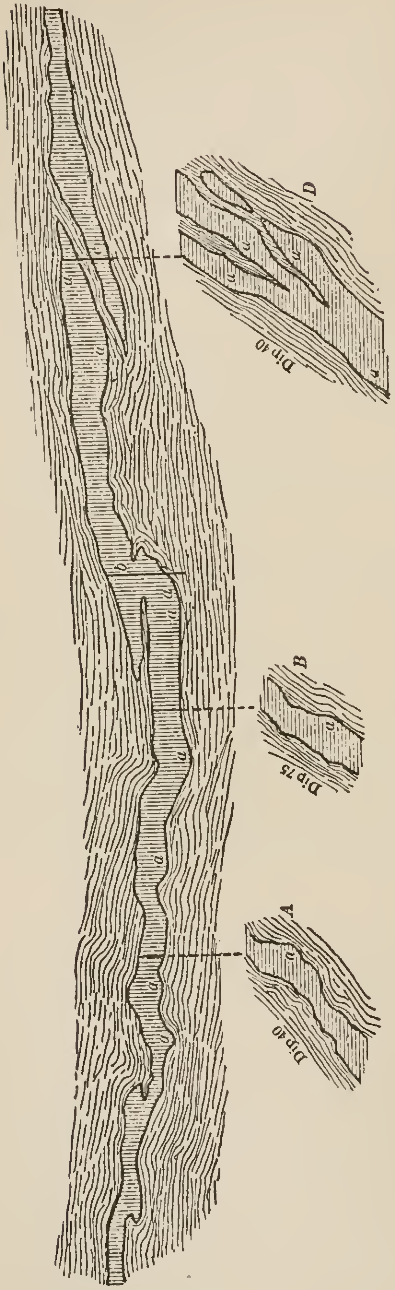

Fig. 9.
SECTION OF MICA VEINS IN YANCEY COUNTY, NORTH CAROLINA.
After W. C. Kerr.

It may be stated as a very general, almost universal, fact, that the mica vein is a *bedded* vein. Its position (as to strike and dip) is dependent on and controlled by, and quite nearly conformable to, that of the rocks in which it occurs, and hence, as well as on account of their great size, some observers, accustomed to the study of veins and dikes and the characters of intrusive rocks in other regions, have been disposed to question the vein character of these masses at first. But a good exposure of a single one of them is generally sufficient to remove all doubt on this score. The mica vein is simply and always a dike of *very coarse granite*. It is of any size and shape, from a few inches—generally a few feet—to many rods (in some cases several hundred feet) in thickness, and in length from a few rods to many hundred yards, extending in some cases to half a mile or more. The strike, like that of the inclosing rocks, is generally northeast, and the dip southeast, at a pretty high angle; but they are subject, in these respects, to many and great local variations, all the conditions being occasionally changed, or even reversed. An idea may be formed of the coarseness of these veins from this statement, that the masses of cleavable feldspar and of quartz (limpid, pale yellow, brown, or, more generally, slightly smoky), and of mica, are often found to measure several yards in two or three of their dimensions, and weighing several tons. I have a feldspar *crystal* from one of these mines of nearly a thousand pounds weight, and I have known a single block of mica to make two full two-horse wagon-loads, and sheets of mica are sometimes obtained that measure three and four feet in diameter.

There are many peculiarities about these veins. Among the most important, in a practical sense, is the arrangement of the different constituents of the vein *inter se.* Sometimes the mica, for example, will be found hugging the hanging-wall; sometimes it is found against both walls; again it may be distributed pretty equally through the whole mass of the vein; sometimes, again, it will be found collected in the middle of the vein; in other cases, where the vein varies in thickness along its course, the mica will be found in bunches in the ampullations, or bellies, of the vein; in still other cases, where the vein has many vertical embranchments, the mica will be found accumulated in nests along the upper faces of these processes or offshoots. Those features of structure will be best understood from a few representative diagrams.

Figure 9 is a horizontal section, with several transverse vertical sections, of a typical vein in Yancey County, at the Presnel Mine. The length of the section, i. e., of the portion of the vein that has been stripped, is 125 feet; the thickness varies from 3 to 10 feet, except at a few points, as *b c* where it is nearly 20 feet.

The crystals of mica are found in this mine generally near the foot wall, in the recesses or pouches; at *c*, however, as seen in section D, it is found next the hanging-wall.

The inclosing rock in this case is a hard, gray slaty to schistose gneiss. * * *

The feldspar, which constitutes the larger part of the mass of these veins, is often found converted into beds of the finest kaolin; and, curiously enough, this was one of the first and most valuable exports to England in the early part of the seventeenth century, "packed" by the Indians out of the Unaka (Smoky) Mountains, and sold under the name "unakeh" (white). This kaolin, like the mica, will doubtless soon come again into demand, after lying forgotten for generations.

Characteristic samples of the micas of the region are shown in Specimens Nos. 18205, 18207, 62962, and 62964, U.S.N.M.

In Alabama, along a line stretching from Chilton County, northeast, through Coosa, Clay, and Cleburne counties, there are numerous evidences of prehistoric mica mining. Many pits are met with around which pieces of mica are still to be seen. In some places, just as in Mitchell County, North Carolina, large pine trees have grown up on the débris, so that a considerable time must have elapsed since the mines were worked. About ten years ago, Col. James George, of Clanton, Chilton County, prospected for mica, and some fairly good specimens were obtained, but the investigations were not continued. It is not thought that any mica has been marketed from Alabama. The indications of good mica along the line mentioned are, however, sufficient to warrant additional and more extended examinations. Little mica is reported from other Southern States, though some mines have been opened in South Carolina, Georgia (Specimens Nos. 63139 to 63141, U.S.N.M.), Virginia, and West Virginia. In 1881, a mica mine was opened in Anderson County, South Carolina, and some miners from Mitchell County, North Carolina, employed. The enterprise was not successful, and the miners returned home shortly afterwards. Good mica has been found in South Carolina, notably in Anderson, Oconee, and Pickens counties. The mica-bearing rocks of western North Carolina do not protrude into Tennessee, except at intervals, and then only for short distances. Some prospecting has been done in Tennessee near Roan Mountain, but the results were not considered satisfactory.[1]

In Colorado mica has long been known to be widely disseminated and to occur in many places in bodies of workable size, but mining has until lately always proved the mica to be "plumose" and unfit for cutting into sheets. Many mines have been located, but the product has always proved worthless, until in the summer of 1884 the Denver Mica Company opened a mine near Turkey Creek, about 35 miles from Denver. This mica is of fair quality, and quite a considerable quantity of it has been mined. It is slightly brown and the largest plates which have yet been cut are not more than 2¾ by 6 inches in size. Only an extremely small percentage of the gross weight is available for cutting into sheets. An effort is being made to put it upon the market, and at present four workmen are employed in trimming the sheets. Mica of good quality and in large plates has also been recently reported from the neighborhood of Fort Collins.

In Wyoming, mica has been found in workable quantities near Diamond Park and in the Wind River country, as well as at many points along the mountain ranges in Laramie County. It has recently been mined to some extent at Whalen cañon, 20 miles north of Fort Laramie, and some of the product has been shipped to the Eastern market.

In New Mexico mica occurs near Las Vegas, and reports of shipments have been published. At Petaca, the Cribbenville mica mines are being worked at present by sixteen men. Work was commenced at these mines July 2, 1884, and the amount of excavation at present is 13,160 cubic feet. The plates cut range from 2 by 2 inches to 5 by 8 inches in size. Some specimen plates have been cut 10 by 12 inches, but the general average is about 3½ by 4½ inches. Some 12 tons of mica have been handled, but the amount sold and the average price obtained are not reported. Other localities in New Mexico also yield mica, but none have been developed, except the two above mentioned. (Specimen No. 61335, U.S.N.M.).

In California many deposits of mica have been noted, especially at Gold lake, Plumas county; in Eldorado county; Ivanpah district, San Bernardino county; near Susanville, Lassen county, and at Tehachapi pass, Kern county. In 1883 a large deposit was discovered in the Salmon mountains, in the northwestern part of the State, and some prospecting was done.[2]

The mica-bearing deposits of the Black Hills of South Dakota have been variously regarded by different observers as intrusive granites or true segregation veins lying parallel to the apparent bedding. New-

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[1] Mineral Resources of the United States, 1887, p. 671.

[2] Idem, 1883–84, p. 911.

ton and Jenny,[1] Blake,[2] and Vincent regard them as intrusive, while Carpenter[3] and Crosby[4] hold the opposite view.

According to Blake the mica occurs in granitic masses, remarkable for the coarseness of their crystallization, the constituent minerals being usually large and separately segregated. "Large masses of pure quartz are found in one place and masses of feldspar in another, and the mica is often accumulated together instead of being regularly disseminated through the mass. It also occurs in large masses or crystals, affording sheets broad enough for cutting into commercial sizes." Associated with the mica at this point are the minerals quartz and feldspar, mainly a lamellar albite (Clevelandite), which form the gangue, and irregularly disseminated cassiterite (tinstone), gigantic spodumenes, black tourmalines, and, in small quantities, block mica, beryls, garnets, columbite, and a variety of phosphatic minerals, such as apatite, triphylite, etc.

In Nevada mines have been worked in the St. Thomas mining district, Lincoln County, the mica occurring in hard, glassy quartz rock forming an outcrop some 200 feet wide by 600 feet long in gneiss and schists. At the Czarina Mine, located in May, 1891, near Rioville, the mica occurs under similar conditions. The mineral seems to follow the division plane of the stratification, along the line or axis of fold. This line runs north and south, slightly east of north of the main trend of the range, thus running into Arizona a few miles north of Rioville. In fact, the mica belt forms the boundary line between Nevada and Arizona for 50 miles The mica, mostly small, is abundant, but marketable sizes are rare, and not to be had without a great deal of hard work.[5]

Merchantable mica has been reported on the Payette River and Bear Creek, in the Cœur d'Alene region of Idaho, and also in Oregon and Alaska.

According to Mr. R. W. Ells[6] the Canadian micas of commercial importance occur associated with eruptive dikes of pyroxenite and pegmatite cutting the Laurentian gneisses. More rarely, as in the Gatineau area, they are found where dikes of the pyroxenite cut the limestone. This authority gives the condition of occurrence as below:

1. In pyroxene intrusive rocks which either cut directly across the strike of greyish or other colored gneisses or are intruded along the line of stratification. Some of these deposits have been worked downward along the contact with the gneiss, where the mica is most generally found, for 250 feet, as at the Lake Girard Mine, and irregular masses of pink calcite are abundant. In certain places apatite crystals

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[1] Geology of the Black Hills of Dakota, Monograph, U. S. Geological Survey, 1880.

[2] Engineering and Mining Journal, XXXVI, 1883, p. 145.

[3] Transactions of the American Institute Mining Engineers, XVII, 1889, p. 570.

[4] Proceedings of the Boston Society of Natural History, XXIII, 1884–1888, p. 488.

[5] Mineral Resources of the United States, 1893, p. 754.

[6] Bulletin of the Geological Society of America, V, 1894, p. 484.

occur associated with the mica, but at other times these are apparently wanting. As in the case of apatite deposits, mica occurring in this condition would apparently be found at almost any workable depth.

2. In pyroxene rocks near the contact of cross-dikes of diorite or feldspar, the action of which on the pyroxene has led to the formation of both mica and apatite. Numerous instances of this mode of occurrence are found, both in the mines of apatite and mica, the deposits of the latter in certain areas being quite extensive and the crystals of large size.

3. In pyroxene rock itself distinct from the contact with the gneiss. In these cases the mica crystals, often of large size but frequently crushed or broken, apparently follow certain lines of faults or fracture. Some of these deposits can be traced for several yards, but for the most part are pockety. Some of these pyroxene masses are very extensive, as in the case of the Cascade mine on the Gatineau river and elsewhere in the vicinity. In these cases calcite is rarely seen and apatite is almost entirely absent. When cut by cross-dikes conditions for the occurrence of mica or apatite should be very favorable.

4. Dikes of pyroxene, often large, cutting limestone through which subsequent dikes of diorite or feldspar have intruded as in Hincks township. The crystals occurring in the pyroxene near to the feldspar dikes are often of large size and of dark color, resembling in this respect a biotite mica.

The mica found under the conditions stated above, in one, two, three, and four is all amber-colored and of the variety known as phlogopite, or magnesia mica. [Specimens Nos. 30763, 62149, U.S.N.M.]

5. In feldspathic-quartzose rocks which constitute dikes often of very large size, cutting red and greyish gneiss, as at Villeneuve and Venosta. These are distinct from the smaller veins of pegmatite which occur frequently in the gneiss as the anorthosite areas are approached. In this case the mica is muscovite or potash mica and is invariably found in that portion of the dike near the contact with the gneiss. The crystals frequently are of large size and white in color, associated with crystals of tourmaline, garnet, et cetera, but with no apatite, unless pyroxene is also present.

6. In quartz-feldspar dikes cutting crystalline limestone, in which case the crystals are generally of small size, mostly of dark color and of but little value.

In the case of the amber micas this peculiarity was noted that when the pyroxene was of a light shade of greenish gray and comparatively soft, the mica was correspondingly light colored and clear, and in some places almost approached the muscovite in general appearance. As the pyroxene became darker in color and harder in texture, the mica assumed a correspondingly darker tint and a brittle or harder character, and in certain cases where dikes of blackish hornblendic diorite were present the mica also assumes a black color as well.

The chief Canadian localities, as given by the authority quoted, are as below:

Along the Ottawa River it is found from a point nearly 100 miles west of Ottawa to the township of Greenville, 60 miles east of that city, while on the Gatineau River, which flows into the Ottawa at the city of Ottawa, mines have been located and worked for 80 miles north from its mouth, and the mineral is reported from points many miles farther north along that stream. To the east of Quebec it is known on the branch of the Saguenay called the Manouan and in the townships of Escoumains, Bergeronnes, and Tadoussac, situated east of the mouth of that river, as well as at several other places along the river St. Lawrence. The mica found in this last district is chiefly muscovite.

The principal areas where mica is at present worked are in the belt which extends from North Burgess, in the Province of Ontario, approximately along the strike of the gneiss, into the territory adjacent to the Gatineau and Lievre. Over much of this area south of the Ottawa River the Laurentian is concealed by the mantle of Cambro-Silurian rocks belonging to the Ottawa River basin, but it may be said that the geologic conditions and the stratigraphic sequence in the area south of the Ottawa and in the rear of Kingston are the same as those found in the mineral-bearing belts north of the Ottawa, and that the most favorable conditions under which the deposits of mica and apatite may be looked for where traces of igneous agency are visible in the presence of dikes of pyroxene and quartz feldspar, though it should be stated that the mere occurrence of these in the gneiss does not warrant the presence of either of these minerals.

The India mica mines occur in coarse intrusive pegmatitic-granite dikes, cutting what is known as the "newer gneiss" of Singrauli. At Inikurti the crystals (of mica) are as much as 10 feet in diameter. Sheets 4 or 5 feet across have been obtained free from adventitious inclusions which would spoil their commercial value.[1]

Black mica (biotite, lepidomelane, etc.,) is a much more common and widely distributed variety than the white, but unlike the latter is found not so much in veins as an original constituent disseminated in small flakes throughout the mass of eruptive and metamorphosed sedimentary rocks. The small sizes of the sheets, their color, and lack of transparency render the material as a rule of little value. In Renfrew County, Canada, the mineral occurs in large cleavable masses, which yield beautiful smoky-black and greenish sheets sufficiently elastic for industrial purposes (Specimens Nos. 62735, 62709, U.S.N.M.).

Lepidolite.—This variety of mica is much more rare than any of the others described. While in a few instances it has been reported as accompanying muscovite in certain granites, as those of Elba and Schaistausk, its common form of occurrence is in the coarse pegmatitic veins already described, where it is associated with muscovite, tourmalines, and other minerals of similar habit. As a rule it is readily distinguished from other micas by its beautiful peach-blossom red color, though sometimes colorless and to be distinguished only by the lithia reaction.[2] The folia are thicker than those of muscovite and of small size, the usual form being that of a scaly granular aggregate. At Auburn, Maine, it is found both in this form (Specimen No. 61079, U.S.N.M.) and forming a border a half inch, more or less, in width about the muscovite folia (Specimen No. 13810, U.S.N.M.). The more noted localities in the United States are Auburn, Androscoggin County; Hebron, Paris, Rumford (Specimen No. 63003, U.S.N.M.), and Norway, Oxford County, Maine, where it is associated with beautiful red and green tourmalines and other interesting minerals; Chesterfield, Massachusetts; Haddam, Connecticut (Specimen No. 53540, U.S.N.M.), and near San Diego, California (Specimen No. 62593, U.S.N.M.). The most noted foreign locality is Zinnwald, Saxony,

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[1] Geology of India, 2d ed., 1893, p. 34.

[2] The pulverized mineral when moistened with hydrochloric acid and held on a wire in the flame of a lamp imparts to the flame a brilliant lithia red color.

where the mineral occurs in large foliated masses together with quartz forming the gangue minerals of the tin veins. Also found in Moravia (Specimen No. 62580, U.S.N.M.).

Uses.—Until within a few years almost the only commercial use of mica was in the doors or windows of stoves and furnaces, the peepholes of furnaces and similar situations where transparency and resistance to heat were essential qualities. To a less extent it was used in lanterns, and it is said, in the portholes of naval vessels, where the vibrations would demolish the less elastic glass. In early days it was used to some extent for window panes, and is, in isolated cases, still so used to some extent. For all these purposes the white variety muscovite is most suited. For use in stoves and furnaces "the mica is generally split into plates varying from about one-eighth to one sixty-fourth of an inch in thickness. In preparing these plates for market the first step is to cut them into suitable sizes. Women are frequently employed in this work, and do it as well as, if not better, than the men. The cutter sits on a special bench which is provided with a huge pair of shears, one leg of which is firmly fixed to the bench itself, while the movable leg is within convenient grasp.

The patterns according to which the mica is cut are arranged in a case near at hand. They are made of tin, wood, or pasteboard, according to the preference of the establishment. Generally they are simple rectangles, varying in size from about four square inches to eighty.

The cutter selects the pattern which will cut to the best advantage, lays it on the sheet of mica, and then, holding the two firmly together, trims off the edges of the mica to make it correspond to the pattern.

The cleaning process comes next. The cleaner sits directly in front of a window and must examine each sheet of cut mica by holding it up between her eyes and the light. If there be any imperfections, and there nearly always are, they must be removed by stripping off the offending layers of mica until a clear sheet remains.

Finally, the cut and cleaned mica is put up in pound packages and is ready for the market. There is an enormous waste in the processes of preparation. One hundred pounds of block mica will scarcely yield more than about fifteen pounds of cut mica, and sometimes it is even less. The proportion varies, of course, with different localities.[1] Professor Kerr states with reference to the North Carolina mines that there is a waste of from nine-tenths to nineteen-twentieths of the material, even in a good mine.

Mica being a nonconductor is of value for insulating purposes, and since the introduction of the present system of generating electricity there has arisen a considerable demand for it in the construction of dynamos and electric motors. For these purposes the mica must be

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[1] Engineering and Mining Journal, LV, 1893, p. 4.

smooth and flexible, as well as free from spots or inequalities of any kind. It is stated that it should be sufficiently fissile to split into sheets not above three one-hundredths inch in thickness, and which may be bent without cracking into a circle of 3 inches diameter. Strips of various dimensions are used in building up the armatures, the more common sizes being about 1 inch wide by 6 or 8 inches long. Muscovite serves the purposes well, but is less used than phlogopite, the latter serving equally well, and being less desirable for stoves and furnaces. Black mica would doubtless serve for electrical purposes, could it be procured in sheets of sufficient size.

Mica scraps such as until within a few years have been thrown away as worthless are now utilized by grinding, the product being used for a variety of purposes, noted below. The material is as a rule ground to five sizes, such as will pass through sieves of 80, 100, 140, 160, and 200 meshes to the inch, respectively. The prices of this ground material vary from 5 to 10 cents a pound according to sizes. Large quantities of this ground material are used in the manufacture of wall paper, in producing the frost effects on Christmas cards, in stage scenery, and as a powder for the hair, being sold for the latter purposes under the name of diamond powder. The so-called French "silver molding" is said to be made from ground mica. It is also used as a lubricant, and as a nonconductor for steam and water heating; in the manufacture of door knobs and buttons. It is stated further that owing to its elasticity it can be used as an absorbent for nitroglycerin, rendering explosion by percussion much less likely to occur. Small amounts of inferior qualities are also mixed with fertilizers where it is claimed to be efficacious in retaining moisture. A brilliant and unalterable mica paint is said to be prepared by first lightly igniting the ground mica and then boiling in hydrochloric acid, after which it is dried and mixed with collodion, and applied with a brush. Owing to the unalterable nature of the material under all ordinary conditions, and the fact that it can be readily colored and still retain its brilliancy and transparency, the ground mica is peculiarly fitted for many forms of decoration. Much of the ground material now produced is stated to be sent to France.

The chief and indeed only use for lepidolite thus far developed is in the manufacture of the metal lithium and lithia salts.

Prices.—The total value of the cut mica produced annually in the United States during the past ten years has varied from $50,000 to over $360,000, while the value of the imports has varied between $5,000 and $100,000. The price of the cut mica, it should be stated, varies with the size of the sheets, the larger naturally bringing the higher price. The average price of the cut mica, all sizes, is not far from $1 a pound, while the scrap mica is worth perhaps half a cent a pound. The dealers' lists, as published, include 193 sizes, varying from 1½ by 2 inches up to 8 by 10 inches, the prices ranging from 40 cents to $13 a pound. For electrical work upward of 400 patterns are called for, the prices varying from 10 cents to $2.50 a pound.

3. Asbestos.

The name asbestos in its original sense includes only a fibrous variety of the mineral amphibole; hence is a normal metasilicate of calcium and magnesium with usually varying amounts of iron and manganese and not infrequently smaller quantities of the alkalies. As is well known, the amphiboles crystallize in the monoclinic system in forms varying from short, stout crystals, like common hornblende, to long columnar or even fibrous forms, to which the names actinolite, tremolite, and asbestos are applied. The word asbestos is derived from the Greek *ασβεστος*, signifying incombustible, in allusion to its fireproof qualities. The name "amianthus" was given it by the Greeks and Romans, the word signifying undefiled, and was applied in allusion to the fact that cloth made from it could be readily cleansed by throwing it into the fire. As now used, this term is properly limited to fibrous varieties of serpentine. Owing to careless usage, and in part to ignorance, the name asbestos[1] is now applied to at least four distinct minerals, having in common only a fibrous structure and more or less fire and acid proof properties. These four minerals are: First, true asbestos; second, anthophyllite; third, fibrous serpentine (chrysotile), and, fourth, crocidolite. The true asbestos is of a white or gray color, sometimes greenish or stained yellowish by iron oxide. Its fibrous structure is, however, its most marked characteristic, the entire mass of material as taken from the ledge or mine being susceptible of being shredded up into fine fibers sometimes several feet in length. In the better varieties the fibers are sufficiently elastic to permit of their being woven into cloth. Often, however, through the effect of weathering or other agencies, the fibers are brittle and suitable only for felts and other nonconducting materials. The shape of an asbestos fiber is as a rule polygonal in outline and of a quite uniform diameter, as shown in the illustration (fig. 10); often, however, the fibers are splinter like, running into fine, needle-like points at the extremity. The diameters of these fibers is quite variable, and, indeed, in many instances there seems no practical limit to the shredding. Down to a diameter of 0.002 mm. and sometimes to even 0.001 mm. the fibers retain their uniform diameter and polygonal outlines. Beyond this, however, they become splinter like and irregular as above noted.

The mineral anthophyllite like amphibole occurs in both massive, platy, and fibrous forms, the fibrous form being to the unaided eye indistinguishable from the true asbestos.

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[1] Also spelled asbestus. The termination *os* seems most desirable when the derivation of the word is considered.

Chemically this is a normal metasilicate of magnesia of the formula (Mg.Fe) SiO_3, differing, it will be observed, from asbestos proper in containing no appreciable amount of lime. It further differs in crystallizing in the orthorhombic rather than the monoclinic system, a feature which is determinable only with the aid of a microscope. The shape and size of the fibers is essentially the same as true asbestos. The fibrous variety of serpentine to which the name asbestos is commercially given is a hydrated metasilicate of magnesia of the formula $H_4Mg_3Si_2O_9$ with usually a part of the magnesia replaced by ferrous iron. It differs, it will be observed, from asbestos and anthophyllite in carrying nearly 14 per cent of combined water and from the first named in containing no lime. This mineral is in most cases readily distinguished from either of the others by its soft, silk-like fibers and further by the fact that it is more or less decomposed by acids. As found in nature the material is of a lively oil yellow or greenish color, compact and quite hard, but may be readily reduced to the fluffy, fibrous state by beating, handpicking, or running between rollers. The length of the fiber is quite variable, rarely exceeding 6 inches, but of very smooth uniform diameter and great flexibility.

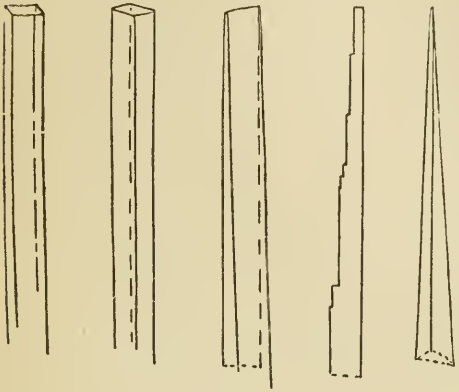

Fig. 10.

ASBESTOS FIBERS.

After G. P. Merrill.

The mineral crocidolite, although resembling somewhat fibrous serpentine, belongs properly to the amphibole group. Chemically it is anhydrous silicate of iron and soda, the iron existing in both the sesquioxide and protoxide states. More or less lime and magnesia may be present as combined impurities. The color varies from lavender blue to greenish, the fibers being silky like serpentine, but with a slightly harsh feeling. The composition of representative specimens of these minerals from various sources is given in the accompanying table.[1]

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[1] From Notes on Asbestos and Asbestiform Minerals by George P. Merrill. Proceedings of the U. S. National Museum, XVIII, 1895, pp. 281–292.

Analyses of asbestiform minerals.

No.	Locality.	Mineralogical nature.	Extinction angle.	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	MnO	K_2O	Na_2O	Ign.	Totals.	Authority.
1	Salls Mountain, Georgia (61357).	Anthophyllite....	0°	57.12	0.75	....	6.36	....	29.44	....	(*a*)	(*a*)	5.47	99.14	R. L. Packard.
2	Nacoochee, Ga. (60842)	.....do	0	57.73	0.72	....	8.61	0.08	28.77	....	0.14	0.57	2.52	....	Do.
3	Rabun County, Ga. (56351) ...	.....do	0	56.52	3.57	....	10.08	Trace.	27.13	....	(*a*)	(*a*)	2.96	100.26	Geo. P. Merrill.
4	Tallapoosa County (?), Ala...	.....do	0	55.92	3.69	11.00		0.60	26.33	....	(*a*)	(*a*)	2.40	99.94	Do.
5	Lenoir, Caldwell County, N. C.	.....do	0	56.21	2.78	....	8.58	0.82	28.95	Trace.	(*a*)	(*a*)	2.23	99.31	Do.
6	Warrenton, Warren County, N. C. (62748).	.....do	0	57.00	....	10.32	....	Trace.	29.98	....	(*a*)	(*a*)	2.29	99.59	Do.
7	Franklin, N. C. (44232)	.....do	0	54.79	....	13.65	....	....	28.52	....	(*a*)	(*a*)	2.55	99.51	Do.
8	Mitchell County, N. C. (50876).	.....do	0	59.00	0.91	....	6.09	0.45	29.90	....	0.43	0.68	2.35	99.81	R. L. Packard.
9	Alberton, Md. (62604)	.....do	0	56.75	1.54	....	10.76	0.10	27.46	Trace.	(*a*)	(*a*)	2.88	99.49	Do.
10	Carbon County, Wyo. (62090).	.....do	0	54.56	1.47	....	12.39	1.86	25.28	....	(*a*)	(*a*)	2.95	99.51	Geo. P. Merrill.
11	San Diego, Cal. (67001)	.....do	0	57.31	1.57	....	7.06	....	30.24	....	(*a*)	(*a*)	2.73	98.91	R. L. Packard.
12	Albemarle County, Va. (62550).	Amphibole, var. asbestos.	0–16	56.26	1.81	....	6.40	11.98	20.85	Traces.	(*a*)	(*a*)	2.65	99.95	Do.
13	Parkton, Md. (8536)	.....do	0–15	56.96	0.52	....	1.12	13.84	23.90	....	(*a*)	(*a*)	2.37	98.71	Geo. P. Merrill.
14	Roanoke, Va. (5694)	.....do	0–15	55.81	1.66	....	6.81	12.74	21.09	....	....	....	1.81	99.92	R. L. Packard.
15	Chester, S. C. (73462)	.....do	0–15	54.66	3.72	....	6.83	12.81	19.87	Traces.	(*a*)	(*a*)	2.28	100.17	Geo. P. Merrill.
16	Pylesville, Harford County, Md.	.....do	0–15	56.76	....	....	3.10	12.75	23.85	....	(*a*)	(*a*)	2.68	98.94	Do.
17	Aston, Delaware County, Pa. (62754).	.....do	....	53.42	....	....	....	13.42	22.85	....	(*a*)	(*a*)	4.36	98.05	Do.
18	Staten Island, New York.....	.....do	....	52.50	....	....	11.82	....	30.73	....	....	....	2.25	100.0	Hintze, p. 1241.
19	Zillerthal, Tyrol............	.....do	0–15	55.08	1.64	....	4.57	14.65	22.56	0.81	....	....	2.39	100.4	Hintze, p. 1235 (av. of 4 dets.).
20	Cow Flats, Bathurst, New South Wales (62450).	.....do	0–15	54.75	1.21	....	2.79	13.99	22.93	Traces.	(*a*)	(*a*)	2.58	98.25	Geo. P. Merrill.
21	Corsica (82259)	.....do	0–17	56.72	0.545	....	1.73	14.72	23.63	Traces.	(*a*)	(*a*)	2.33	99.67	Do.

22	Zillerthal	Amphibole, var. mountain cork.	....	57.20	....	....	4.37	13.39	22.85	....	....	....	2.43	100.24	Dana, p. 395.
23	Frankenstein, Silesia	Amphibole, var. asbestos.	....	57.69	....	....	2.46	13.39	23.68	0.13	....	3.14	0.17	100.66	Do.
24	Cunsdorf, Saxony	....do	....	57.98	0.58	....	6.32	12.95	22.38	....	....	....	....	100.21	Hintze, p. 1234.
25	Taberg, Sweden	....do	....	59.75	....	....	3.95	14.25	21.10	0.31	Fl.1.16	....	....	100.52	Hintze, p. 1238.
26	Cow Flats, New South Wales.	....do	....	49.45	9.69	16.33	5.15	11.97	Trace.	4.39	....	....	3.03	100.01	Hintze, p. 1240.
27	Bolton, Mass	....do	....	58.80	....	....	3.05	16.47	22.23	....	....	....	....	100.55	Hintze, p. 1242.
28	Malden, Mass	....	0–17	48.60	6.64	....	18.23	12.55	9.52	....	....	....	2.85	98.39	Geo. P. Merrill.
29	Nahant, Mass	....	0–17	51.58	1.88	....	14.99	9.72	16.65	....	....	....	4.98	99.8	R. L. Packard.
30	Mexico	....	0–20	55.48	2.01	12.32	....	10.35	17.23	....	....	1.54	1.47	100.40	Bauer, Neues Jahrbuch. I, 1882, p. 159.
31	South Africa (50877)	Crocidolite	0	52.11	1.01	20.62	16.75	....	1.77	....	....	6.16	1.58	99.00	Dana, p. 400.
32	Idaho (49521)	....	....	53.28	....	....	....	None.	22.87	....	....	....	19.53	98.97	Geo. P. Merrill.
33	Glen Urquhart, Scotland	Amphibole, var. asbestos.	....	47.721	3.837	0.176	5.741	5.64	28.745	0.159	0.186	0.264	7.648	100.117	M. F. Heddle.
34	The Balta, Scotland	....do	....	56.153	1.539	0.388	3.111	11.716	22.461	0.769	0.188	0.692	2.5	99.517	Do.
35	Shinness, Sutherland, Scotland.	....do	....	56.864	0.232	0.484	2.124	12.535	23.923	0.23	0.437	0.538	2.325	99.866	Do.
36	Portsoy, Scotland	....do	....	56.307	0.77	0.527	2.323	12.578	23.307	0.153	0.439	0.633	2.941	99.978	Do.
37	Italy	Fibrous serpentine, amianthus.	0	40.30	....	2.27	0.87	....	43.37	....	....	....	12.72	100.53	J. T. Donald.
38	Canada	....do	0	40.57	....	0.90	2.81	....	41.50	....	....	....	13.55	99.33	Do.
39	Victoria, British Columbia	....do	0	41.95	....	....	2.81	....	41.62	....	....	....	14.85	100.23	Geo. P. Merrill.
40	Alberton, Md. (62778)	Hydrous anthophyllite. (?)	0	51.84	....	1.51	....	....	24.54	(a)	0.25	0.45	b20.18	98.77	Do.

a Not determined.

b H_2O at 110°, 10.55 per cent; at bright, red heat, an additional loss of 9.63 per cent.

Mode of occurrence and origin.—Concerning the associations, occurrence, and origin of the fibrous structure of these minerals existing literature is strangely silent. It is known that all occur only in regions occupied by the older eruptive and metamorphic rocks. It is probable that in the fibrous forms the mineral is always secondary, and the fibrous structure due in part, at least, to shearing agencies; that is, to movements in the mass of a rock whereby a mineral undergoing crystallization would be compressed laterally and drawn out along a line of least resistance. This is, however, not the case with the fibrous varieties of serpentine, which undoubtedly result from the crystallization in preexisting fractures, or gash veins, of the serpentinous material. The process is evidently the same as that which is seen in studying, under the microscope, thin sections of olivine-bearing rocks which have undergone hydration. The asbestos in Alberene, in Albemarle County, Virginia (Specimen No. 62550, U.S.N.M.), occurs in thin, platy masses along slickensided zones in the so-called soapstone (altered pyroxenite) of the region, the fibers always running parallel with the direction of the movement which has taken place. At Alberton, Maryland, the fibrous anthophyllite (Specimen No. 62604, U.S.N.M.) occurs along a slickensided zone between a schistose actinolite rock and a more massive serpentinous or talcose rock, which is also presumably an eruptive peridotite or pyroxenite. The fibration here runs also parallel with the direction of movement as indicated by the slickensided surfaces.

Localities.—As already stated true hornblende asbestos occurs only in regions of eruptive and metamorphic rocks belonging to the paleozoic formations. The same is true of anthophyllite. Fibrous serpentine occurs sporadically with the massive forms of the same rock which is, so far as known, almost invariably an altered eruptive. The three forms are therefore likely to occur in greater or less abundance in any of the States bordering along the Appalachian system, but are necessarily lacking in the great Interior Plains regions, reoccurring once more among the crystalline rocks of the Rocky Mountains and the Pacific coast. The principal States from which either the true asbestos or anthophyllite has been obtained in anything like commercial quantities are Massachusetts, Connecticut, New York, Maryland, Virginia, North Carolina, South Carolina, Georgia, and Alabama, though it has been reported from other Eastern as well as several of the Western States. Fibrous serpentine (chrysotile, or amianthus) occurs in small amounts at Deer Isle, Maine; in northern Vermont; at Easton, Pennsylvania; Montville, New Jersey; in the Casper Mountains of Wyoming, and in Washington. It is known also to occur in Newfoundland. The chief commercial sources of the material are, however, Canada and Italy. The Canadian source is in a belt of serpentinous rocks extending more or less interruptedly from the Vermont line northeastward to some distance beyond the Chaudière

River. The geological horizon is that subdivision of the Lower Silurian known as the Quebec Group. The material has also been found in the Laurentian rocks of this region.

Among the principal areas of serpentine which are found at so many widely scattered points, the most easterly yet known is at a point called Mount Serpentine, about 10 miles up the Dartmouth River from its outlet in Gaspé Basin. The serpentine is here associated with limestone and surrounded by strata of Devonian age. Small veins of asbestos are found in the rock, but not yet in quantity sufficient to be economically valuable. West of this the next observed is the great mass of Mount Albert, whence it extends west in a great ridge for some miles. This mass is known to contain veins of chromic-iron, and traces of asbestos have also been observed, but the area has never yet been carefully explored with a view to ascertain the presence of the mineral in quantity, owing largely to the present difficulty of access.

In Cranbourne and Ware, to the north of the Chaudière River and in the vicinity of that stream between the villages of St. Joseph and St. Francis, several small knolls are seen, in all of which small and irregular veins are visible, but apparently not in quantity sufficient to render them economically important, at least in so far as yet examined. Further to the southwest, in Broughton, Thetford, Coleraine, Wolfestow and Ham, a very great development of these rocks is observed, forming at times mountain-masses from 600 to 900 feet above the surrounding country level, and presenting very peculiar and boldly marked features in the landscape by their rugged outlines and curiously weathered surfaces. The large areas of this division terminate southward at a point termed Ham Mountain, a very prominent peak of diorite which marks the extremity of the ridge. In this great area, which we may style the central area, asbestos can be found at many points in small quantity, but at a comparatively few does it occur in quantity and quality sufficient to warrant the expenditure of much capital in its extraction.

The third area, regarding that of the Shickshocks as the first, begins near the village of Danville, and may be styled the southwestern area. Thence it extends through Melbourne, Brompton, Orford, Bolton, and Potton, in a series of disconnected hills, to the American boundary, beyond which the continuation of the serpentines can be traced into Vermont. In these areas, with the exception of the peculiar isolated knoll near Danville, the asbestos has, as yet, been observed in small quantity only, and generally of inferior quality. Large areas of soapstone are found at points throughout the area, and the associated diorites have a large development. It must, however, be said of this section, that considerable areas, whose outcrops can be seen along the roads which traverse the district, are concealed by a dense forest growth, and the true value of such portions must, for some considerable time, be largely conjectural. In fact, until the forest and soil are completely removed by the action of forest fires, as was the case at Black Lake and Thetford, the search for asbestos is likely to prove difficult and unsatisfactory. It is, however, very evident from the studies already made on this interesting group of rocks in Canada, that all serpentines are not equally productive—a fact very evident even in the heart of the great mining centers themselves, where large areas of the belt are made up of what is known as barren serpentine. As a general rule, however, the rock likely to prove asbestos-producing can be determined by certain peculiarities of texture, color or weathering.

At the Thetford mines, and in that portion of Coleraine lying to the northeast of Black Lake, certain conditions favorable to the production of asbestos appear to have prevailed, and have led to the formation of numerous veins, often of large size, which, in places, interlace the rock in all directions. These veins range in size from small threads to a width of 3 to 4 inches [fig. 11], and in rare cases even reach a thickness of over 6 inches. [See large Specimens Nos. 72836 and 61348, U.S.N.M.]. The quality of the fiber, however, varies even in these localities, and while much of it is soft, fine and silky, other portions are characterized by a harshness or stiffness which detracts greatly from its commercial value.

The veins while not disturbed by faulting generally improve so far as quality of material is concerned as the depth below the surface increases. They are, however, very irregular in their distribution, and are rarely persistent for any great distance.

A small vein at the surface, of half an inch in thickness, may quickly enlarge to one of three inches or more, and, continuing, may die out entirely, while others come in on either side. They have much the aspect of the gash veins in slaty rocks, though there are many instances seen where the fiber maintains a tolerably uniform size for considerable distances. [See large Specimen No. 61348, U.S.N.M.].

Fig. 11.

SERPENTINE ASBESTOS IN MASSIVE SERPENTINE.

Specimen No. 72836.

The containing rocks show the presence of numerous faults, as in other mineral localities, but possibly in the serpentine these are often more plainly marked. These faults throw the veins from side to side, and frequently are of sufficient extent to cut off entirely the working face of a highly productive area, the rock on the other side of the fissure being often entirely barren. The sides of the fault, in such cases, show extensive slickensides, and frequently have great sheets of coarse or woody-fibered or imperfect asbestos, along the planes of fracture. Occasionally, pockets or small veins of chromic iron are found in close proximity to the asbestos.[1]

Specimens Nos. 62135, 62150, U.S.N.M. from Marmora and Thetford show the characteristic manner of the occurrence of the mineral on a small scale, while No. 62151, U.S.N.M., shows the material as freed from the wall rock, before shredding. See also Specimens Nos. 53682 to 53690 from Danville, Province of Quebec.

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[1] R. W. Ells, Transactions of the American Institute of Mining Engineers, XVIII, 890, p. 322.

The Italian asbestos which finds it way to the American markets is both of the amphibolic and serpentinous varieties, both being remarkable for the beautiful long fibers they yield. The amphibolic variety, the true asbestos, from Mont Cenis, is shown in Specimen No. 53164, U.S.N.M., and the serpentinous variety, from Aosta, in the sample, No. 53161, U.S.N.M. Both are in the form of fibrous aggregates over a metre in length.

Methods of mining and preparation.—The mining of asbestos is carried on almost wholly from open cuts and shallow tunnels. Rarely does it pay to follow the material to any great depth. In the United States the mines are worked very irregularly, and in most cases abandoned at the end of a short season.

The mining of the Canadian material is carried on by means of open cuts, much as a farmer cuts down a stack of hay or straw, or by open quarry on a level. The rock is blasted out and the asbestos separated from the inclosing rock by a process known as "cobbing," and which consists in breaking away the fibrous material from the walls of the vein or from other foreign ingredients by means of hammers.

The cobbed material is separated into grades, according to quality, which depends upon the length, fineness, and flexibility of the fiber. During 1888 the finest grades brought prices varying from $80 to $110 a ton. In 1899 the price had fallen to about $26 a ton.

Uses.—The uses of asbestos are manifold, and ever on the increase. Among the ancient Greeks it was customary to wrap the bodies of those to be burned in asbestos cloth, that their ashes might be kept intact. In the eighth century Charlemagne is said to have used an asbestos tablecloth, which, when the feast was over, he would throw into the fire, after a time withdrawing it cleaned but unharmed, greatly to the entertainment of his guests. The most striking use to which the material is put is the manufacture of fireproof cloths for theater curtains, for suits of firemen and others liable to exposure to great heat. It is also used for packing pistons, closing joints in cylinder heads, and other fittings where heat, either dry or from steam and hot water, would shortly destroy a less durable substance. For this purpose it is used in the form of a yarn, or as millboard. The lower grades, in which the fibers are short or brittle, are made into a felt which, on account of its nonconducting powers, is utilized in covering steam boilers. It is also ground and made into cements and paints, the cement being used as a nonconductor on boilers, and the paint to render wooden structures less susceptible to fire. In the chemical laboratory the finely fibered, thoroughly purified asbestos forms an indispensable filtering medium. For this purpose the true asbestos is preferable to the fibrous serpentine.[1] Examples of the manufactured products mentioned are exhibited with the crude products.

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[1] Prof. A. H. Chester: Some Misconceptions Concerning Asbestos. Engineering and Mining Journal, LV, 1893, p. 531.

The chief commercial use of the material is based upon its highly refractory or noncombustible nature. The popular impression that it is a nonconductor of heat is, according to Professor Donald, erroneous, the nonconducting character of the prepared material being due rather to its porous nature than to the physical properties of the mineral itself.[1] Owing to the comparative high price of asbestos, it is, in the manufacture of the so-called nonconducting materials, largely admixed with plaster of paris, powdered limestone, dolomite, magnesite, diatomaceous earth, or carbonaceous matter, as hair, paper, sawdust, etc. With the possible exception of the magnesite (carbonate of magnesia) these are all less effective than the asbestos, and deteriorate as well as cheapen the manufactured article. The following table will serve to convey some idea of the relative portions of the various materials used as nonconducting pipe coverings, etc.:

	Parts.
Asbestos sponge, molded:	
Plaster of paris	95.80
Fibrous asbestos	4.20
	100.00
Fire felt sectional covering:	
Asbestos	82.00
Carbonaceous matter (hair, paper, sawdust, etc.)	18.00
	100.00
Magnesia sectional covering:	
Carbonate of magnesia	92.20
Fibrous asbestos	7.80
	100.00
Magnesia plastic:	
Carbonate of magnesia	92.20
Fibrous asbestos	7.80
	100.00
Asbestos cement felting:	
Powdered limestone	64.50
Plaster of paris	3.50
Asbestos	32.00
	100.00
Asbestos sponge cement felting:	
Powdered limestone	59.00
Plaster of paris	10.00
Asbestos	31.00
	100.00
Fossil meal:	
Insoluble silicate	75.00
Carbonaceous matter (hair, paper, sawdust, etc.)	11.00
Soluble mineral matter	8.00
Moisture	6.00
	100.00

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[1] The Mineral Industry, II, 1893, p. 4.

The following catalogue shows the mineral nature and localities represented in the Asbestos collection of the Museum:

Fibrous anthophyllite. Tallapoosa County, Alabama. 62763.

Fibrous anthophyllite. San Diego County, California. 67001.

Fibrous amphibole. California. 50899.

Fibrous amphibole. Colorado. 50878, 50879, and 50880.

Fibrous amphibole. Connecticut. 50912.

Fibrous amphibole. Black Hills, South Dakota. 50916, 50917.

Fibrous amphibole. Lawrence County, South Dakota. 63487.

Fibrous anthophyllite. Salls Mountain, Georgia. 61305, 61357.

Fibrous anthophyllite. Cleveland, White County, Georgia. 62749.

Fibrous anthophyllite. Near Nacoochee, White County, Georgia. 60842, 63155.

Fibrous anthophyllite. Fulton County, Georgia. 63156.

Fibrous anthophyllite. Alberton, Howard County, Maryland. 62604, 62605.

Fibrous amphibole. Maryland. 50891 and 50892.

Asbestos in limestone. West end of lower bridge, Baltimore and Ohio Railroad, over Patapsco River, just west of Alberton, Maryland. 62778.

Fibrous amphibole. Parkton, Baltimore County, Maryland. 8536.

Fibrous amphibole. Jefferson, Frederick County, Maryland. 63479.

Fibrous amphibole. Harford County, Maryland. 63033.

Fibrous amphibole. Massachusetts. 50909, 50910.

Fibrous amphibole. Gallatin County, Montana. 53341.

Fibrous anthophyllite. Warrenton, Warren County, North Carolina. 62748.

Fibrous anthophyllite. Mitchell County, North Carolina. 50876, 63158, 63159.

Fibrous amphibole. Nevada. 50885.

Fibrous serpentine, chrysotile. New Hampshire. 50914.

Fibrous amphibole. New York. 50867–50871 and 63160.

Fibrous amphibole. Delaware County, Pennsylvania. 62754.

Fibrous amphibole. Pennsylvania. 50895, 50896, 73507.

Fibrous amphibole. Chester, Chester County, South Carolina. 73462.

Fibrous anthophyllite. South Carolina. 50874, 50875.

Fibrous amphibole. Tennessee. 50905.

Mountain leather, amphibole. Minersville, Beaver County, Utah. 67266, 55379.

Fibrous amphibole. Utah. 50907, 50908.

Fibrous serpentine, chrysotile. Vermont. 50898, 63161.

Fibrous amphibole in calcite. Alberene, Albemarle County, Virginia. 62550, 62551.

Fibrous amphibole, near Roanoke, Roanoke County, Virginia. 5694.

Fibrous amphibole. Virginia. 50872.

Fibrous amphibole. Washington. 63206.

Fibrous amphibole. Wisconsin. 50906.

Fibrous anthophyllite. Carbon County, Wyoming. 62090.

Fibrous serpentine, chrysotile. Casper Mountain. 12 miles south of Casper, Wyoming. 67377, 62091.

Fibrous amphibole. Wyoming. 66674.

Fibrous crocidolite. Weinthal, Cape of Good Hope, South Africa. 62107.

Fibrous amphibole. Transvaal, South Africa. 50877.

Fibrous crocidolite. Orange River, Mount Hopetown, Africa. 73128.

Fibrous amphibole. Gundagai, New South Wales, Australia. 62450.

Fibrous amphibole. Australia. 50893.

Fibrous serpentine, chrysotile. Victoria, British Columbia. 50902.

Fibrous serpentine in ophicalcite. Canada. 72836.

Fibrous amphibole, variety of mountain cork. Buckingham, Canada. 68138.

Fibrous serpentine, chrysotile. Black Lake, Quebec, Canada. 62151.
Fibrous serpentine, chrysotile. Thetford, Quebec, Canada. 62150.
Veins of chrysotile. Marmora, Ontario, Canada. 62135.
Fibrous serpentine, chrysotile. Algoma District, Ontario, Canada. 62134.
Fibrous serpentine, chrysotile. Danville, Quebec, Canada. 53682–53684.
Fibrous amphibole. Canada. 50889.
Fibrous serpentine, chrysotile. Manitoba. 50904.
Fibrous amphibole. Canada. 50888.
Fibrous amphibole. Canada. 50890.
Fibrous amphibole. Canada. 50887.
Fibrous serpentine, chrysotile. Canada. 50886.
Fibrous amphibole. China. 50900.
Fibrous amphibole. Corsica. 73000.
Fibrous amphibole. Corsica. 82359.
Fibrous amphibole. France. 50883.
Fibrous amphibole. France. 50882.
Fibrous amphibole. France. 50881.
Fibrous serpentine, chrysotile. Erese, about 20 miles east of Aosta, Italy. 53161.
Fibrous amphibole. Monte Lunella, spur of Monte Cenis, 5 miles from Usseglio, Italy. 53164.
Fibrous amphibole. Italy. 50894.
Fibrous amphibole. Zillerthal, Tyrol. 66838.
Fibrous serpentine, chrysotile. Piedmont, Italy. 73539.
Fibrous amphibole. Caterce, San Luis Potosi, Mexico. 57168.
Fibrous amphibole. Goldenstein, Moravia. 66837.
Fibrous amphibole. Newfoundland. 50919.
Fibrous amphibole. Nova Scotia. 50911.
Fibrous amphibole. Spain. 50913.
Fibrous amphibole. Tasmania. 50918.
Fibrous amphibole, mountain cork. Venezuela. 50884.
Fibrous amphibole. Argentine Republic. 63416.
Fibrous amphibole. Bohemia. 73538.
Fibrous amphibole. Smyrna. 50901.

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4. GARNET.

The chemical composition of the various minerals of the garnet group is somewhat variable, though all are essentially silicates of alumina, lime, iron, or magnesia. The more common types are the lime-alumina garnet *grossularite*, and the iron alumina garnet *alamandite*. Other varieties of value as minerals or as gems are *pyrope*, *spessartite*, *andradite*, *bredbergite*, and *uvarovite*.

The ordinary form of the garnet is the regular 12 or 24 sided solid, the dodecahedron and trapezodedron, as shown in Specimen No. 53241, U.S.N.M., from Roxbury Falls, Connecticut. The color is dull red or brown, though in the rarer forms yellow, green, and white. Hardness from 6.5 to 7.5 of the scale.

Occurrence.—Garnets occur mainly in metamorphic siliceous rocks, such as the mica schists and gneisses, and though sometimes found in limestones and in eruptive rocks, are rarely sufficiently abundant to be of economic importance. In the gneisses and schists, however, they not infrequently preponderate over every other constituent, varying from sizes smaller than a pin's head to masses of 100 pounds weight, or more.

The most important garnet-producing regions of the United States are Warren County, New York, and Delaware County, Pennsylvania. At the first-named locality, the garnets occur in laminated pockets scattered through beds of a very compact hornblende feldspar rock, the size of the pockets ranging from 5 or 6 inches in diameter to such as will yield 1,000 pounds or more (Specimen No. 53228, U.S.N.M.). In the Delaware County localities the garnets occur in aggregates of small crystals in a quartzose gneiss[1] (Specimens Nos. 53221, 66710, U.S.N.M.).

One of the most noted garnet regions of the world is that near Prague, Bohemia. According to G. F. Kunz,[2] the garnets of the pyrope variety are indigenous to an eruptive rock now changed to serpentine, and the mineral is found "loose in the soil or in the lower part of the diluvium, or embedded in a serpentine rock. * * In mining for garnets the earth is cut down in banks and only the lower layer removed, and the garnets are separated by washing. The earth is first dry sifted and then washed in a small jig consisting of a sieve moved back and forth in a tank of water."

Uses.—Aside from their use in the cheaper forms of jewelry garnets

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[1] The Mineral Industry, V, 1896.

[2] Transactions of the American Institute Mining Engineers, XXI, 1892, p. 241.

are used mainly for abrading purposes and mainly as a sand for sawing and grinding stone or for making sandpaper. The material is of less value than corundum or emery, owing to its inferior hardness. The commercial value is variable, but as prepared for market it is worth about 2 cents a pound.

5. ZIRCON.

This is a silicate of zirconium, $ZrSiO_4$, = silica 32.8 per cent; zirconia 67.2 per cent; specific gravity 4.68 to 4.7; hardness 7.5; colorless, grayish, pale yellow to brown or reddish brown. Ordinarily in the form of square prisms. Specimens Nos. 61133 and 62581, U.S.N.M., are characteristic.

Zircon is a common constituent of the older eruptives like granite and syenite, and also occurs in granular limestone, gneiss, and the schists. It is so abundant in the elæolite syenites of southern Norway as to have given rise to the varietal name Zircon syenite. Although widespread as a rock constituent it has been reported in but few instances in sufficient abundance to make it of commercial value. Being hard and very durable it resists to the last ordinary atmospheric agencies, and hence is to be found in beds of sand, gravel, and other débris resulting from the decomposition of rocks in which it primarily occurs. It has thus been reported as found in the alluvial sands in Ceylon, in the gold sands of the Ural Mountains, Australia, and other places. In the United States it occurs in considerable abundance in the elæolite syenite of Litchfield, Maine, and is also found in other States bordering along the Appalachian Mountains. The most noted localities are in Henderson and Buncombe counties in North Carolina, whence several tons have been mined during the past few years from granite débris. (Specimen No. 61133, U.S.N.M.)

Uses.—See under monazite, p. 383.

6. SPODUMENE AND PETALITE.

This is an aluminum lithium silicate of the formula $LiAl\,(SiO_3)_2$, = silica, 64.5 per cent; alumina, 27.4 per cent; lithia, 8.4 per cent; in nature more or less impure through the presence of small amounts of ferrous oxide, lime, magnesia, potash, and soda. Luster vitreous to pearly; colors white, gray, greenish, yellow, and amethystine purple. Transparent to translucent. Usual form that of flattened prismatic crystals, with easy cleavages parallel with the faces of the prism. Also in massive forms. Crystals sometimes of enormous size, as noted below.

Mode of occurrence.—Spodumene occurs commonly in the coarse granitic veins associated with other lithia minerals, together with tourmaline, beryls, quartz, feldspar, and mica. The chief localities as given by Dana are as below:

In the United States, in granite at Goshen, Massachusetts, associated at one locality with blue tourmaline and beryl; also at Chesterfield, Chester, Huntington (formerly

Norwich) [Specimen No. 62579, U.S.N.M.], and Sterling, Massachusetts; at Windham, Maine, with garnet and staurolite; at Peru with beryl, triphylite, petalite; at Paris, in Oxford County [Specimen No. 62578, U.S.N.M.]; at Winchester, New Hampshire; at Brookfield, Connecticut, a few rods north of Tomlinson's tavern, in small grayish or greenish white individuals looking like feldspar; at Branchville, Connecticut, in a vein of pegmatite, with lithiophilite, uraninite, several manganesian phosphates, etc.; the crystals are often of immense size, embedded in quartz; near Stony Point, Alexander County, North Carolina, the variety hiddenite in cavities in a gneissoid rock with beryl (emerald), monazite, rutile, allanite, quartz, mica, etc.; near Ballground, Cherokee County, Georgia; in South Dakota at the Etta tin mine in Pennington County, in immense crystals. [Specimen No. 73,642, U.S.N.M.]. At Huntington, Massachusetts, it is associated with triphylite, mica, beryl, and albite; one crystal from this locality was 16½ inches long and 10 inches in girth.

At the Etta tin mine, in the Black Hills of South Dakota, the mineral occurs, according to W. P. Blake, in sizes the magnitude of which exceeds all records. Crystalline masses extend across the face of the open cut from 2 to 6 feet in length and from a few inches to 12 and 18 inches in diameter. Blocks too large to lift have been freely tumbled over the dump with the waste of the feldspar, quartz, and mica. The gigantic crystals preserve the cleavage characteristics and show the common prismatic planes. The color is lighter and is without the delicate creamy pink hue of the specimens from Massachusetts. It is very hard, compact, and tough, and is difficult to break across the grain. Some of the fragments are translucent.

The chief foreign localities of spodumene are Utö in Södermanland, Sweden, where it is associated with magnetic iron ore, tourmalines, quartz, and feldspar; near Sterzing and Lisens, in Tyrol; embedded in granite at Killiney Bay near Dublin, and at Peterhead, Scotland.

Uses.—So far as the writer is aware, the mineral has as yet been put to no economic use. There seems no reason for its not being utilized as a source of lithia salts as well as amblygonite and lepidolite.

PETALITE, another lithium aluminum silicate containing 2.5 to 5 per cent lithia occurs associated with lepidolite, tourmaline, and spodumene in an iron mine at Utö, Sweden (Specimen No. 62582, U.S.N.M.), with spodumene and albite at Peru, Maine, and with scapolite at Bolton, Massachusetts.

7. LAZURITE; LAPIS LAZULI; OR NATIVE ULTRAMARINE.

Composition essentially $Na_4 (NaS_3.Al) Al_2Si_3O_{12}$, = silica, 31.7 per cent; alumina, 26.9 per cent; soda, 27.3 per cent; sulphur, 16.9 per cent; hardness, 5.5; specific gravity, 2.38 to 2.45. Color, rich azure-violet or greenish blue, translucent to opaque. The ordinary lapis lazuli is not a simple mineral as given above, but a mixture of lazurite, hauynite, and various other minerals.

The following analyses quoted from Dana serve to show the heterogeneous character of the material as found:

Localities.	Silica, SiO_2.	Alumina, Al_2O_3.	Ferric iron, Fe_2O_3.	Lime, CaO.	Soda, Na_2O.	Water, H_2O.	Sulphur, SO_3.
Orient	45.33	12.33	2.12	23.56	11.45	0.35	3.22
Ditró	40.54	43.00	0.86	1.14	12.54	1.92	....
Andes	45.70	25.34	1.30	7.48	10.55	....	4.32

Occurrence.—The localities are mostly foreign. The ultramarine reported not long since as occurring near Silver City, New Mexico, has been shown by R. L. Packard to be a magnesian silicate.

Mexico, Chile, Siberia, India, and Persia are the chief sources. The following regarding the Indian localities is taken from Ball's Geology of India, Part III.

According to Captain Hutton, the lapis lazuli sold in Kandahar is brought from Sadmoneir and Bijour, where it is said to occur in masses and nodules embedded in other rocks. He obtained a small specimen from Major Lynch, which was said to have been brought from Hazara, and he heard that it occurred in Khelat. Several writers speak of its occurrence in Biluchistan, but possibly this may be due to some confusion in names. Beyond a question of doubt it does exist in Badakshan, the mines south of Firgamu, in the Kokcha valleys, having been described by Wood in the narrative of his journey to the Oxus.

The entrance to the mines is on the face of the mountain at an elevation of about 1,500 feet above the level of the stream. The rocks are veined, black and white limestones. The principal mine, as represented in elevation, pursues a somewhat serpentine direction. The shaft by which you descend to the gallery is about 10 feet square, and is not so perpendicular as to prevent your walking down. The gallery is 30 paces long, with a gentle descent, but it terminates in a hole 20 feet in diameter and as many deep. The gallery is 12 feet in diameter, and as it is unsupported by pillars accidents sometimes occur. Fires are used to soften the rock and cause it to crack; on being hammered it comes off in flakes, and when the precious stone is disclosed a groove is picked round it, and together with a portion of the matrix it is prised out by means of crowbars. Three varieties are distinguished by the miners, the *nili*, or indigo colored, the *asmani*, or sky-blue, and the *sabzi*, or green. The labour was compulsory; and mining was only practised in the winter. According to Wood, these mines and also those for rubies had not been worked for four years as they had ceased to be profitable. Possibly this may have been partly due to the fall in value; according to Mr. Baden-Powell, recent returns represent the exports as amounting to only 2 seers; but Colonel Yule, in his book of Marco Polo, states that the produce was 30 to 60 poods (36 lbs. each) annually, the best qualities selling at prices ranging from £12 to £24 a pood. Mr. Powell's figures perhaps only refer to the exports to India. Formerly the produce from these mines, which must have been considerable, was exported principally to Bokhara and China, whence a portion found its way to Europe.

Marco Polo says that the *azure* found here was the finest in the world, and that it occurred in a vein like silver. The Yamgan tract, in which the mines were situated, contained many other mines, and doubtless Tavernier referred to it when he spoke of the territory of a Raja beyond Kashmir and toward Thibet, where there were three mountains close to one another, one of which produced gold, another *granats* (garnets, or rather balas rubies), and the third lapis lazuli.

A small quantity of *lajward* is said to be imported into the Punjab from Kashgar, and a mine is reported to exist near the source of the Koultouk, a river which falls into Lake Baikal.

Uses.—Ultramarine for coloring purposes has in modern times lost much of its value, owing to the discovery by M. Guimet in 1828 of an artificial substitute. Formerly it was much used as a pigment, being preferred by artists in consequence of its possessing greater purity and clearness of tint. According to Ball,[1] the artificial substitute is now commonly sold in the bazars of India under the same name, lajward, for about 4 rupees a seer, while at Kandahar in the year 1841, according to Captain Hutton, the true lajward, which was used for house painting and book illuminating, was sold, when purified, at from 80 to 100 rupees a seer. Mr. Emanuel states that the value of the stone itself, when of good color, varies, according to size, from 10 to 50 shillings an ounce. In Europe the refuse in the manufacture is calcined, and affords delicate gray pigments, which are known as ultramarine ash.

Lajward is prescribed as a medicine internally by native physicians; it has been applied externally to ulcers. That it possesses any real therapeutic powers is of course doubtful.

Although no longer a source of any considerable amount of the ultramarine of commerce, the compact varieties of the mineral, such as that from Persia, are highly esteemed for the manufacture of mosaics, vases, and other small ornaments.

8. ALLANITE; ORTHITE.

This is a cerium epidote of the formula $HR^{II}R^{III}_3Si_3O_{13}$, in which R^{II} may be either calcium or iron (or both) and R^{III} aluminum, iron, cerium, didymium, or lanthanum. The following analyses are selected

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[1] Geology of India, III, p. 528.

from Dana's Mineralogy as showing variation in the composition sufficiently for present purposes:

Constituents.	I.	II.	III.
Silica (SiO_2)	31.63	33.03	30.04
Thorina (ThO_2)	0.87	1.12	None.
Alumina (Al_2O_3)	13.21	17.63	16.10
Iron sesquioxide (Fe_2O_3)	8.39	5.26	5.06
Cerium sesquioxide (Ce_2O_3)	8.67	2.84	11.61
Didymium sesquioxide (Di_2O_3)	5.60	7.68	5.39
Lanthanum sesquioxide (La_2O_3)	5.46	None.	4.11
Yttrium sesquioxide (Y_2O_3)	0.87	2.92	None.
Erbinum sesquioxide (Er_2O_3)	0.52	None.	None.
Iron protoxide (FeO)	7.86	7.01	9.89
Manganese (MnO)	1.66	0.64	Trace.
Lime (CaO)	10.48	12.78	13.02
Magnesia (MgO)	0.08	0.11	1.11
Potash (K_2O)	0.28	0.40	0.02
Soda (Na_2O)	None.	None.	0.28
Water (H_2O)	3.49	9.37	2.56
	99.07	100.79	99.19

(I) Hitterö, Norway; (II) Ytterby, Sweden; (III) Nelson County, Virginia.

When in crystals often in long slender nail-like forms (orthite); also massive and in embedded granules. Color pitch black, brownish, and yellow. Brittle. Hardness 5.5 to 6. Specific gravity 3.5 to 4.2. Before the blowpipe fuses and swells up to a dark, slaggy, magnetic glass.

Localities and mode of occurrence.—The more common occurrence is in the form of small acicular crystals as an original constituent in granitic rocks. It also occurs in white limestone, associated with magnetic iron ore, and in igneous rocks as andesite, diorite, and rhyolite. At the Cook Iron Mines, near Port Henry, New York, it is reported as occurring in great abundance and in crystals of extraordinary size, in a gangue of quartz and orthoclase.

The variety orthite occurs in forms closely simulating rusty nails in the granitic rock about Brunswick, Maine. In Arendal, Norway, it is found in massive forms (Specimen No. 66853, U.S.N.M.). At Finbo, near Falun, Sweden, in acicular crystals a foot or more in length. In Amherst and Fauquier counties, Virginia, it occurs in large masses (Specimen No. 68661, U.S.N.M.) from Fauquier County, as it also does near Bethany Church, Iredell County, North Carolina, and Llano County, Texas (Specimen No. 62756, U.S.N.M.). At Balsam Gap, Buncombe County, North Carolina, it occurs in slender crystals 6 to 12 inches long and in crystalline masses, in a granitic vein and under similar conditions at the Buchanan and Wiseman mines in Mitchell County.

Uses.—See under Monazite, p. 383.

9. GADOLINITE.

This is a basic orthosilicate of yttrium, iron, and glucinum, though with frequently varying amounts of didymium, lanthanum, etc. The formula as given by Dana is $Gl_2FeY_2Si_2O_{10}$,=silica 23.9 per cent, yttrium oxides 51.8 per cent, iron protoxide 14.3 per cent, and glucina 10 per cent. Actual analyses yielded results as below:

Constituents.	I.	II.
Silica (SiO_2)	24.35	23.79
Thorina (ThO_2)	0.30	0.58
Yttrium sesquioxide (Y_2O_3)	45.96	41.55
Cerium sesquioxide (Ce_2O_3)	1.65	2.62
Didymium sesquioxide (Di_2O_3) Lanthanum sesquioxide (La_2O_3)	3.06	5.22
Iron sesquioxide (Fe_2O_3)	2.03	0.96
Iron protoxide (FeO)	11.39	12.42
Berylium (Glucina) protoxide (BeO)	10.17	11.33
Lime (CaO)	0.30	0.74
Soda (Na_2O)	0.17	Trace.
Water (H_2O)	0.52	1.03
	99.90	100.24

(I) Ytterby, near Stockholm, Sweden; (II) Llano County, Texas.

The mineral is sometimes found in form of rough and coarse crystals, but more commonly in amorphous, glassy forms. Hardness 6.5 to 7; specific gravity 4 to 4.47. Color brown, black and greenish black, usually translucent in thin splinters and of a grass green to olive green color by transmitted light. No true cleavage; fracture conchoidal or splintery like glass, and with a vitreous or somewhat greasy luster. Through oxidation and hydration the mineral becomes opaque, brown, and earthy. Hence masses are not infrequently found consisting of the normal glassy gadolinite enveloped in a brown red crust of oxidation products. (Specimen No. 62780, U.S.N.M.) On casual inspection the mineral closely resembles samarskite and the dark, opaque varieties of orthite, but is easily distinguished from the fact that before the blowpipe it glows brightly for a moment and then swells up, cracks open, and becomes greenish without fusing. Some varieties (the normal anisotropic forms) swell up into cauliflower-like forms and fuse to a whitish mass. Like orthite, it gives a jelly when the powdered mineral is boiled in hydrochloric acid.

Localities and mode of occurrence.—The mineral occurs mainly in coarse pegmatitic veins associated with allanite, and other allied minerals. The principal locality in the United States thus far described is some five miles south of Bluffton on the west bank of the Colorado River, in Llano County, Texas (Specimen No. 62780, U.S.N.M). The region is described[1] as occupied by Archæan rocks with granite, and occasional cappings of limestone.

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[1] American Journal of Science, XXXVIII, 1889, p. 474.

A coarse deep red granite is the most abundant, and is cut by numerous extensive veins of quartz and feldspar which carry the gadolinite, in pockety masses, and the other minerals mentioned. Most of the mineral thus far found is altered into the brown-red waxy material noted above and occurs in the form of masses weighing half a pound and upward. One "huge pointed mass, in reality a crystal, weighed fully 60 pounds;" another 42 pounds. One of the earliest opened pockets yielded some 500 kilos (227 pounds) of the mineral.

Of the foreign localities those of Kårarfvet, Broddbo and Finbo, near Falun, Sweden, and at Ytterby, near Stockholm (Specimen No. 62793, U.S.N.M.), are important, the mineral here occurring in the form of rounded masses embedded in a coarse granite. On the island of Hitterö, in the Flecke fiord, southern Norway, crystals sometimes four inches across have been obtained.

Uses.—See under monazite, p. 383.

10. CERITE.

This is a silicate of the metals of the cerium group; of a complex and doubtful formula. The analyses below, taken from Dana's System of Mineralogy, will serve to show the varying character of the mineral.

Constituents.	I.	II.	III.
Silica (SiO_2)	19.18	22.79	18.18
Cerium oxide (Ce_2O_3)	64.55	24.06	33.25
Didynium oxide (Di_2O_3) Lanthanum (La_2O_3)	7.28	35.37	34.60
Iron oxide (FeO)	1.54	3.92	3.18
Alumina (Al_2O_3)	....	1.26	....
Lime (CaO)	1.35	4.35	1.69
Water (H_2O)	5.71	3.44	5.18

The mineral occurs in gneiss and mica schist, and is of a prevailing pink to gray color. Specimen No. 62794, U.S.N.M., from Bastnäss, Westmanland, Sweden, is characteristic,

Uses.—See under monazite, p. 383.

11. RHODONITE.

This is a metasilicate of manganese of the formula $MnSiO_3$, = Silica 45.9 per cent; manganese protoxide 54.1. As a rule, iron, calcium, or zinc replaces a part of the manganese. The prevailing form of the mineral when in crystals is that of rough, tabular, or elongated prisms with rounded edges (Specimen No. 83927, U.S.N.M., from Franklin, New Jersey). It is also common in massive highly cleavable forms, and in disseminated granules (Specimens Nos. 83927 and 83929, U.S.N.M.). Rarely, as in the Ekaterinburg district of Russia, it occurs in massive forms suitable for ornamental work. (See Collection Building and Ornamental Stones.) Color brownish red, flesh red, and pink; sometimes rose red. Hardness, 5.5 to 6.5. Specific gravity, 3.4 to 3.68.

On exposure the mineral undergoes oxidation, becoming coated with a black film and giving rise thus to indefinite admixtures of silicate, oxides, and carbonates of manganese.

The mineral occurs in abundance associated with the iron ores of Wermland, Sweden, and at other localities in Europe; in Ekaterinburg, Russia, as above noted. The zinciferous variety commonly associated with the zinc ores in granular limestones of Sussex County, New Jersey, is known as fowlerite. (Specimen No. 67405, U.S.N.M.)

So far as the writer has information, rhodonite has as yet little commercial value, excepting as an ornamental stone. To some extent it has been utilized in glazing pottery and as a flux in smelting furnaces.

12. Steatite; Talc; and Soapstone.

The mineral steatite, or talc, is a soft micaceous mineral, consisting when pure of 63.5 per cent of silica, 31.7 per cent of magnesia, and 4.8 per cent of water. Its most striking characteristics are its softness, which is such that it can be readily cut with a knife or even with the thumb nail, and soapy feeling, there being an entire absence of anything like grit. The prevailing colors are white or gray and apple green. Several varietal forms are recognized; the name *talc* as a rule being applied to the distinctly foliaceous or micaceous variety (Specimen No. 72838, U.S.N.M.), while that of *steatite* is reserved for the compact cryptocrystalline to coarsely granular forms (Specimens Nos. 26137 and 63448, U.S.N.M.).

Pyrallolite and rensselaerite are names given to varied forms of talc resulting from the alteration of hornblende or pyroxene. Such forms are found in various portions of northern New York, Canada, and Finland.

According to Dana, a part of the so-called agalmatolite used by the Chinese is steatite.

The name soapstone is given to dark gray and greenish talcose rocks, which are soft enough to be readily cut with a knife, and which have a pronounced soapy or greasy feeling; hence the name. Such rocks are commonly stated in text-books to be compact forms of steatite, or talc, but as the writer has elsewhere pointed out, and as shown by the analyses here given, few of them are even approximately pure forms of this mineral, but all contain varying proportions of chlorite, mica, and tremolite, together with perhaps unaltered residuals of pyroxene, granules of iron ore, iron pyrites, quartz, and in seams and veins calcite and magnesian carbonates.[1]

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[1] Rocks, Rockweathering, and Soils, p. 101.

Composition.—The varying composition of talc is shown in the series of analyses given below.

Analyses of talc.

Locality.	SiO_2.	Al_2O_3.	FeO.	MgO.	CaO.	MnO.	Na_2O.	K_2O.	H_2O.	Totals.
St. Lawrence County, New York	60.59	0.13	0.21	34.72	....	1.16	....	......	3.77	100.58
Do	62.10	....	1.30	32.40	....	2.15	....	......	2.05	100.00
Luzenach, France	61.85	2.61	0.25	34.52	Trace.	......	0.17		0.60	100.00
Valley of Pignerolles, Italy	60.60	0.30	0.60	35.30	0.40	......	2.80	......	Not determined.	100.00

The following analyses of soapstone have been made in the laboratory of the department:

Analyses of soapstone.

Locality.	SiO_2.	Al_2O_3.	FeO.	MgO.	CaO.	MnO.	Na_2O.	K_2O.	H_2O.	Totals.
Francestown, New Hampshire (Specimen No. 63166, U.S.N.M.)	42.43	6.08	13.07	25.71	3.27	Trace	0.16	0.32	8.45	99.49
Grafton, Vermont (Specimen No. 17569, U.S.N.M.)	51.20	5.22	8.45	26.79	1.17	0.32	....	......	6.90	100.05
Dana, Massachusetts (Specimen No. 26439, U.S.N.M.)	38.37	5.64	8.86	28.62	3.90	Trace	....	......	14.49	99.88
Baltimore County, Maryland (Specimen No. 26628, U.S.N.M.)	52.70	5.57	7.63	26.88	1.77	......	....	......	5.48	100.03
Guilford County, North Carolina (Specimen No. 27662, U.S.N.M.)	40.03	10.86	9.59	26.97	1.70	......	....	......	10.78	99.93
Lafayette, Pennsylvania (Specimen No. 63168, U.S.N.M.)	33.47	0.45	7.38	33.72	1.34	0.21	....	......	23.00	99.57

Occurrence and origin.—Talc in all its forms is presumably always a secondary mineral, a product of alteration of other magnesian silicates.

Smyth has shown[1] that the talc beds of St. Lawrence County, New York (Specimen No. 63173), are alteration products from schistose aggregates of enstatite or tremolite, principally the former. According to this author, the talc occurs, not as has been stated, in the form of a well-defined vein with walls of granite or gneiss, but in the beds lying wholly within the schistose portions of the prevailing limestone.

The following account of these deposits as occurring near Gouverneur is by A. Sahlin:[2]

The village of Gouverneur is situated near the northwest edge of a geological island of Azoic rocks; granite, gneiss, limestone, and marble

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[1] School of Mining and Forestry, XVII, No. 4, 1896. Also Fifteenth Annual Report of the State Geologist of New York, 1895, pp. 665–671.

[2] Mining and Scientific Press, May 11, 1893.

being the representative features of the formation. To the west of Gouverneur, extending to and beyond the St. Lawrence River, the Potsdam sandstone is encountered; to the southeast, the Trenton limestones extend toward the Adirondack Mountains. The talc belt is found in the towns of Fowler and Edwards, from 7 to 14 miles southeast of Gouverneur. It has a length of about 8 miles, a width of 1 mile, more or less, and crosses the above-named Azoic island in the general direction of WNW. to ESE. The "veins" generally dip from 45° to 75° toward the northeast. Their width varies from a few inches to 20 feet or more. Surface out croppings are frequent, and local experts contend that there is no use in looking for talc where it does not appear on the surface. The abrupt change of formation precludes the probability of discovering new deposits beyond the small, and now most thoroughly explored, belt already known. Within this narrow territory, "veins" of talc minerals, separated by layers of granite and gneiss, are found and worked. They are principally made up of the hydrated silicates of magnesia, known as agalite and rensselaerite, the former of a smooth, fibrous texture, the latter scaly and lamellar, and both beautifully white or bluish-white. In the agalite veins are found nodules of handsome pink to purple, columnar crystals of hexagonite, and also large "horses" of yellowish-white hornblende. The occurrence of the two latter minerals, representing the anhydrous silicates of magnesia, has given rise to the theory that the talc deposits originally occurred as hornblende, which has gradually become hydrated.

Since 1879, ten distinct mines have been opened, and some of these have reached a depth of 400 feet or more on the slope. The present output from these ten mines amounts, according to a close estimate, to 51,000 tons a year, which figure, however, could be readily doubled if the reducing mills had the capacity to handle the larger quantity. (Specimens Nos. 53590 to 53592, U.S.N.M., from Gouverneur are characteristic.)

In western North Carolina and northern Georgia, particularly in Cherokee, Moore, Guilford, and Murphy counties in the first-named State, and in the Cohutta Mountains of Murray County in the last, are numerous beds of very clean white or greenish fibrous talc occurring in part, at least, in connection with the marble beds. Some of the material is soft, white, and almost translucent (Specimens Nos. 26137, 27654, 63448, U.S.N.M.), while other is tough and semitranslucent, hornlike. The beds are mostly very irregular in extent as well as in quality of material.

In Stockbridge, Windsor County, Vermont, talc is mined from veins from 3 to 12 feet in width in soapstone. (Specimen No. 53206, U.S.N.M.) A greenish schistose talc is also mined in Murray County, Georgia. (Specimen No. 53226, U.S.N.M.)

Soapstone occurs mainly associated with the older crystalline rocks, and in some cases is undoubtedly an altered eruptive; in others there is a possibility of its being a product of metamorphism of magnesian sediments. The principal beds now known lie in the Appalachian regions of the eastern United States, though others have recently been found in California, and there is no reason for supposing that many more may not exist in the Rocky Mountain regions. The beds, if such they can be called, are not extensive as a rule, but occur in lenticular masses of uncertain age intercalated with other magnesian and hornblendic or micaceous rocks frequently more or less admixed with serpentine. The rock, like serpentine, is, as a rule, traversed by bad seams and joints, and the opening of any new deposit is always attended with more or less risk, as there is in many cases no guarantee that sound blocks of sufficient size to be of value will ever be obtainable. The following facts relative to the occurrence of soapstone in the United States are taken mainly from a handbook by the writer on Stones for Building and Decoration, issued by Messrs. Wiley & Co., of New York.

An extensive bed of fine quality soapstone was discovered as early as 1794 at Francestown, New Hampshire (Specimen No. 10774, U.S.N.M.). This was worked as early as 1802, and up to 1867 some 5,500 tons had been quarried and sold. In this latter year some 3,700 stoves were manufactured by one company alone. The business has been conducted on a large scale ever since, and the bed has been followed some 400 feet, the present opening being 40 feet wide 80 feet long and 80 feet deep. Other beds, constituting a part of the same formation, occur in Weare, Warner, Canterbury, and Richmond, in the same State, and all of which have been operated to a greater or less extent.

Fine beds of the stone also occur in the town of Orford, and an important quarry was opened as early as 1855 in Haverhill, but it has not been worked continuously.

At least sixty beds of soapstone are stated to occur in Vermont, mostly located along the east side of the Green Mountain range, and extending nearly the entire length of the State. The rock occurs associated with serpentine and hornblende, and the beds as a rule are not continuous for any distance, but have a great thickness in comparison with their length. It not infrequently happens that several isolated outcrops occur on the same line of strata, sometimes several miles apart, and in many cases alternating with beds of dolomitic limestone that are scattered along with them.

The sixty beds above mentioned occur mainly in the towns of Readsboro, Marlboro, New Fane, Windham (Specimen No. 26626, U.S.N.M.), Townsend, Athens, Grafton, Andover, Chester (Specimen No. 53244, U.S.N.M.), Cavendish, Baltimore, Ludlow, Plymouth, Bridgewater, Thetford, Bethel, Rochester, Warren, Braintree, Waitsfield, Moretown, Duxbury, Waterbury, Bolton, Stow, Cambridge, Waterville, Berkshire, Eden, Lowell, Belvidere, Johnson, Enosburg, Westfield, Rich-

View in a Soapstone Quarry, Lafayette, Pennsylvania.

ford. Troy, and Jay. Of these beds those of Grafton (Specimen No. 17569, U.S.N.M.) and Athens are stated to have been longest worked and to have produced the most stone. The beds lie in gneiss, and were profitably worked as early as 1820. Another important bed occurs in the town of Weatherfield. This, like that of Grafton, is situated in gneiss, but has no overlying rock, and the material can be had in inexhaustible quantities. It was first worked about 1847. The Rochester beds were also of great importance, the stone being peculiarly fine-grained and compact. It was formerly much used in the manufacture of refrigerators. The bed at New Fane occurs in connection with serpentine, and is some half mile in length by not less than 12 rods in width at its northern extremity. The soapstone and serpentine are strangely mixed, the general courses of the bed being like that of an irregular vein of granite in limestone.

In Massachusetts quarries of soapstone have been worked from time to time in Lynnfield and North Dana (Specimen No. 26439, U.S.N.M.). The Lynnfield stone occurs associated with serpentine. It has not been quarried of late, but was formerly used for stove backs, sills, and steps. In New York State soapstone and talc occur in abundance near Fowler and Edwards in St. Lawrence County. Some of this is very pure, nearly snow-white talc, and is quarried and pulverized for commercial purposes, as already noted.

In Pennsylvania, in the southern edge of Montgomery County, extending from the northern brow of Chestnut Hill between the two turnpikes across the Wissahickon Creek and the Schuylkill to a point about a mile west of Marion Square, there occurs a long, straight outcrop of steatite and serpentine. The eastern and central part of this belt on the southern side consists chiefly of steatite, while the northern side contains much serpentine, interspersed through it in lumps. Only in a few neighborhoods, as at Lafayette, does either the steatite or serpentine occur in a state of sufficient purity to be profitably quarried. On the east bank of the Schuylkill, about 2 miles below Spring Mill, a good quality of material occurs that has long been successfully worked (Specimen No. 63168, U.S.N.M.) The material is now used principally for stoves, fireplaces, and furnaces, though toward the end of the last century and during the early part of the present one, before the introduction of the Montgomery County marble, it was in considerable demand for doorsteps and sills. It proved poorly adapted for this purpose, owing to the unequal hardness of the different constituents, the soapstone wearing away rapidly, while the serpentine was left projecting like knots, or "hobnails in a plank."

Several small deposits of soapstone occur in Maryland and some of them have been worked on a small scale. The material is of good quality, but apparently to be had only in small pieces (Specimens Nos. 25010 and 26628) from Montgomery and Baltimore Counties.

In Virginia soapstone occurs in Fairfax (Specimens Nos. 25254, 28649, U.S.N.M.), Fluvanna and Buckingham, counties. There is also a bed at Alberene, Albemarle County, a little west of Green Mountain. This is the bed so extensively worked by the Albemarle Soapstone Company (Specimen No. 62547, U.S.N.M.) From these points the beds extend in a southwesterly direction through Nelson County, where they are associated with serpentine; thence across the James River above Lynchburg and present an outcrop about 2 miles west of the town on the road leading to Liberty; also one some 2½ miles west of New London. Continuing in the same direction the bed is seen at the meadows of Goose Creek, where it has been quarried to some extent. Parallel ranges of soapstone appear near the Pigg River in Franklin County. About 30 miles southwest from Richmond, at Chula, in Amelia County, there are outcrops of soapstone said to be of fine quality, and which in former times were quite extensively operated by the Indians. They have been reopened within a few years and the material is now on the market.

North Carolina contains, in addition to an abundance of the finest grades of talc and steatite as already noted, beds of the compact common soapstone. Deposits in Cherokee and Moore counties furnish especially desirable material for lubricating and other purposes. Murphy, Guilford, Ashe, and Alamance counties (Specimen No. 27664, U.S.N.M.) are also capable of affording good materials, but much of it is inaccessible at present on account of poor railroad facilities (Specimens Nos. 27662, 28118, U.S.N.M.) from Greensboro and Ball Mountain.

Beds of soapstone are stated to occur in Salina County, Arkansas (Specimen No. 39061, U.S.N.M.), and in Chester, Spartanburg, Union, Pickens, Oconee, Anderson, Abbeville, Kershaw, Fairfield, and Richland counties in South Carolina (Specimens Nos. 37590, 39019, U.S.N.M.). Texas is also stated to have an abundance of material and of good quality on the Hondo and Sandy creeks in Llano County. The District of Columbia contains a bed which is, however, probably too small to ever prove of value (Specimen No. 38510, U.S.N.M.).

Uses.—The use to which the material is put varies greatly according to its purity and physical characteristics. The white, fibrous variety of great purity from St. Lawrence County, New York, is used as a filler in paper manufacture, something like 30 per cent of the weight of printing paper being made up of this material. For the purpose it is run successively through coarse and finer crushers and then through buhrstones, after which it is placed into what is known as an Alsing cylinder, some 6 feet in diameter by about the same length. This cylinder is lined with porcelain brick and filled to one-third its volume with rounded pebbles or quartz, and when in motion revolves at about the rate of 20 revolutions a minute. At the end of some three to four hours the talc is reduced to the form of an impalpable powder. The so-called cyclone crusher has also been used to good advantage in this work. The pulverized material is also used as a lubricator, for which purposes it is remarkably well adapted. Rubbed between the thumb and finger the powder is smooth and oily without a particle of grit. It is also used in soap making, for which purpose it can, however, be considered only as an adulterant, increasing the weight but not the cleaning properties of the article. It is further used as a dressing for fine leathers. Small quantities are used by shoe and glove dealers also. The pure, creamy white talc, such as is obtained from North Carolina, is used for crayons and slate pencils, while the still finer, cryptocrystalline varieties, such as are at present obtained almost wholly from abroad, are used by tailors under the name of "French chalk" and for making the tips for gas burners. Fine compact grades of a somewhat similar rock (agalmatolite) are used extensively in China and Japan for small ornaments. The stone is readily carved in fine sharp lines, and is a general favorite for making the grotesque images for which these countries are noted, and which are often sold throughout the country under the name of jadestone.

The following account of the soapstone industry of China is taken from the Engineering and Mining Journal of September 30, 1893. The material referred to as soapstone is, however, very probably agalmatolite. (See p. 322.)

> The British consul at Wenchow, in his last report, gives some interesting details respecting the manufacture of steatite or soapstone ornaments in China. The mines are distant 42 miles from Whenchow, and are reached by a boat journey of 35 miles up the river, followed by a land journey of 7 miles over rough ground. The hills containing steatite are owned by 20 to 30 families, who in some cases work the mines themselves, in others engage miners to do it on their account. The galleries are driven into the sides of the hills, and are often nearly a mile in length. The composition of the hills is soft, and the shafts require to be propped up by supports of timber; for the same reason the floors are full of mire and clay, so that the miners wear special clothing, made principally of rhea fiber. They lead a hard life, living in straw huts on the hillside. The stone when first extracted is soft, hardening on exposure to the air. It is brought out of the mine in shovels, and is sold at the pit mouth to the carvers at a uniform price of about one-half a penny per pound. This would be when the purchaser buys it in gross, without first selecting it in any way. When picked over, the mineral varies very considerably in value—according to the size of the lump, its shape, and above all, its colors. The colors are given as purple, red, mottled red, black, dark blue, light blue, gray, white, eggshell white, "jade," beeswax, and "frozen." Of these "jade" (the white variety, not the green) and "frozen" are the most valuable. Indeed so valuable is the latter that good specimens of it are said to fetch more than real jade itself. The industry finds employment at the present time for some 2,000 miners and carvers. A great impetus was given to it by the opening of Wenchow to foreign trade. Previous to that event the chief purchasers of soapstone were officials and literary men, and the article most often carved was a stamp or seal. When it was discovered that foreigners admired the stone, articles were produced to meet what was supposed to be their taste. Such were landscapes in low or high relief, flower vases, plates, card trays, fruit dishes, cups, teapots, and pagodas. If left to his own devices, the native carver proceeds first to examine his stone, much as a cameo cutter would do, to discover how best he can take advantage of its shape and shades of color. (See further under Agalmatolite.)

The following quotation from an English writer will serve to show the advantages gained by a use of talc in paper making:

> There is a decided advantage in substituting agalite for China clay, because not only is there an increase of dry paper, but such is obtained by a saving of fiber, as well as a decrease of the waste in the actual loading material and a lessened amount of polluting matter to be dealt with. Moreover, the fibrous character of the agalite causes it to yield a paper of higher class quality than is the case with China clay. The extra gloss which it is possible to obtain with papers containing agalite is shown in various American journals and books.

The soapstones are suited for a considerable range of application. Although so soft, they are among the most indestructible and lasting of rocks, but are too slippery and perhaps of too sombre a color for general structural purposes. At present the chief use of the material in the United States is in the form of thin slabs for sinks and stationary washtubs. At one time it was quite extensively used throughout New England in the manufacture of stoves for heating purposes and to some extent for fire brick, the well-seasoned stone being thoroughly fireproof. The putting upon the market of unseasoned materials or of material with bad veins, which caused the stone to crack or perhaps fly to fragments when subjected to high temperature, aroused a prejudice against the employment of this material, and the manufacture is stated to have been to a considerable extent discontinued as a consequence. In the manufacture of either stoves or washtubs slabs of considerable size, free from segregation nodules of quartz, pyrite, or other minerals or from dry seams, are essential. As but few of the now known outcrops can furnish material of this nature, the main part of the business of the country is in the hands of but two or three companies. The waste material from the quarries, or the entire output in certain cases, is pulverized and used as a lubricant or white earth, as is the micaceous variety.

13. PYROPHYLLITE; AGALMATOLITE; AND PAGODITE (IN PART).

This is a hydrous silicate of aluminum corresponding to the formula $H_2O, Al_2O_3, 4SiO_2$. The analyses given below show the average composition of the material as it occurs in nature:

Locality.	Silica.	Aluminum.	Water.	Remarks.
Westanå, Sweden	65.61	26.09	7.08	With small amounts of iron, magnesia, and lime.
China	66.38	27.95	5.20	
Deep River, North Carolina	65.93	29.54	5.40	

The mineral is not known in distinct crystals, but occurs rather in foliated lamellar, massive and compact forms, closely resembling some forms of talc, for which its soapy or greasy feeling renders it very likely to be mistaken, though its hardness (2 to 2.5) is somewhat greater. The prevailing colors are white or greenish gray to dull red, often mottled.

Occurrence.—The material sometimes occurs, as in the Deep River region (Chatham, Moore, and Orange counties), North Carolina, in compact to schistose masses of beds of considerable extent and purity.

Uses.—The more compact varieties, like that of Deep River (Specimen No. 27665, U.S.N.M.), are used for making slate pencils and tailors' chalk, or French chalk, so called. The still more compact forms, known as agalmatolite (Specimens Nos. 37812, from Sonora, Mexico, and 27133 and 27134, Japan) and pagodite, are used extensively by the Chinese and Japanese for making small images and art objects of various kinds. Dana states, however, that a part of the so-called Chinese agalmatolite is in reality pinite and a part of steatite. The objects sold by Chinese dealers at the various expositions of late years under the name of jade stone are, however, of agalmatolite.

PINITE: Agalmatolite in part. Composition, a hydrous silicate of alumina and the alkalies. According to Dana,[1] the name is made to include a large number of alteration products of white spodumene, nepheline, feldspar, etc. Professor Heddle has described[2] a pinite (agalmatolite) occurring in large lumps of a sea-green color, surrounding crystalline masses of feldspar in the granites of Scotland, and which he regards as alteration products of oligoclase. The composition as given is: Silica, 48.72 per cent; alumina, 31.56 per cent; ferric oxide, 2.43 per cent; magnesia, 1.81 per cent; potash, 9.48 per cent; soda, 0.31 per cent; water, 5.75 per cent.

14. SEPIOLITE; MEERSCHAUM.

This mineral is a hydrous silicate of magnesia, having the composition indicated by the formula $H_4Mg_2 Si_3O_{10}$, =silica 60.8 per cent; magnesia, 27.1 per cent; water, 12.1 per cent. The prevailing colors are white or grayish, sometimes with a faint yellowish, reddish, or bluish green tinge. It is sufficiently soft to be impressed by the nail, opaque, with a compact structure, smooth feel, and somewhat clay-like aspect; rarely it shows a fibrous structure. Specimens Nos. 62545, 66861, and 67749 are characteristic. In nature it rarely occurs in a state of absolute purity. The following analyses are quoted from Dana's Mineralogy:

Locality.	SiO_2.	MgO.	FeO.	H_2O.	CO_2.
Turkey	61.17	28.43	0.06	9.83	0.67
Greece	61.30	28.39	0.08	9.74	0.56
Utah (fibrous)	52.97	22.50	CuO. 0.87	9.90	Hygroscopic H_2O 8.80

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[1] System of Mineralogy, 6th ed., p. 621.

[2] Mineralogical Magazine, IV, p. 215.

The name is from the German words *Meer*, sea, and *Schaum*, foam, in allusion to its appearance.

Mode of occurrence and origin.—According to J. Lawrence Smith,[1] the Asiatic material occurs in the form of nodular masses in alluvial deposits on the plain of Eski-Shehr, and is regarded by him as derived by a process of substitution from magnesium carbonate which is found in the serpentine of the neighboring mountains.

In an article by Dr. E. D. Clarke in the Cyclopedia of Arts and Sciences it is stated that the meerschaum of the Crimeria forms a stratum some 2 feet thick beneath a much thicker stratum of marl. Cleveland in his elementary treatise on minerals (1822) states that at Analotia, in Asia Minor, meerschaum occurs in the form of a vein more than 6 feet wide, in compact limestone. At Vallecas, Spain, a very impure form is stated to occur in the form of beds and in such abundance as to be utilized for building material. Aside from the localities above mentioned, sepiolite is known to occur in Greece, at Hrubschitz in Moravia, and in Morocco, in all cases being associated with serpentine, with which it is apparently genetically related.

Uses.—The mineral owes its chief value to its adaptability for smokers' use, being utilized in the manufacture of what are known as meerschaum pipes. At Vallecas, as above noted, the material is said to occur in such abundance as to be utilized as a building stone. In Algeria a soft variety is used in place of soap at the Moorish baths and for washing linen.

According to Kunz,[2] meerschaum has occasionally been met with in compact masses of smooth, earthy texture in the serpentine quarries of West Nottingham Township, Chester County, Pennsylvania. Only a few pieces were found, but they were of good quality. It also occurs in grayish and yellowish masses in the serpentine in Concord, Delaware County, Pennsylvania. Masses of pure white material, weighing a pound each, have been found in Middletown, in the same county, and of equally good quality at the Cheever Iron Mine, Richmond, Massachusetts, in pieces over an inch across; also in serpentine at New Rochelle, Westchester County, New York. A fibrous variety, in masses of considerable size, has within a few years been found in the Upper Gila River region, New Mexico (Specimen No. 67840, U.S.N.M.).

According to a writer in the Engineering and Mining Journal,[3] the Eski-Shehr mineral is mined from pits and horizontal galleries in much the same manner as coal. As first brought to the surface it is white, with a yellowish tint, and is covered with red clayey soil. In this condition it is sold to dealers on the spot. Before exporting the

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[1] American Journal of Science 1849, VIII, p. 285.

[2] Gems and Precious Stones, p. 189.

[3] Volume LIX, 1895, p. 464.

material is cleaned, dried, and assorted, the drying taking place in the open air, without artificial heat in summer, and requiring from five to six days. The bulk of the material is sent direct to Vienna and Paris.

15. CLAYS.

The term "clay," as commonly used comprises materials of widely diverse origin and mineral and chemical composition, but which have in common the property of plasticity when wet, and usually that of becoming indurated when dried either by natural or artificial means. Of so variable a nature is the material thus classed that no brief definition can be given that is at all satisfactory. One may perhaps describe the clays, as a whole, as heterogeneous aggregates of hydrous and anhydrous aluminous silicates, free quartz, and ever-varying quantities of free iron oxides and calcium and magnesian carbonates, all in a finely comminuted condition.

Origin and mode of occurrence.—The clays are invariably of secondary origin—that is, they result from the decomposition of preexisting rocks and the accumulation of their less soluble residues, either in place (as residual clays) or through the transporting power of ice and water (drift clays). The fact that silicate of aluminum is so characteristic a constituent of nearly all clays is due to the fact that this substance is one of the most insoluble of natural compounds, and hence when, under the action of atmospheric or subterranean agencies, rocks decompose and their more soluble constituents—as lime, magnesia, potash, soda, or even silica—are removed. the aluminous silicate remains.

The kaolins, which may perhaps be regarded as the simplest of clays, are the product, as a rule, of decomposition in place of feldspathic rocks, as gneisses, granites, and pegmatites. Those of Hockessin, Delaware (Specimens Nos. 63427 to 63430), are mainly of gneissic origin, though from some of the pits the material is in part at least derived from the decomposition of feldspathic conglomerate. In other cases the rock, as in the case of that from Blandford, Massachusetts (Specimens Nos. 68219 and 68221, U.S.N.M.), is a quite pure pegmatite, composed almost wholly of quartz and orthoclase. The samples show the material in various stages of decomposition. In all these cases the material as mined contains particles of free quartz and other substances detrimental to its use as a clay, and which must be removed by washing. It sometimes happens that the natural admixture of silica and undecomposed silicates is of just the right proportions to be utilized after merely grinding and bolting. The so-called "Cornwall stone" (Specimens Nos. 65136 and 62118, U.S.N.M.) is but a granite, very free from mica and ferruginous impurities, and in which the feldspar only has in part decomposed to the condition of kaolin. In some instances the natural conditions are such that running waters have assorted out the fine clay particles from the coarser impurities and deposited them by themselves, as in the case of that from Florida (Specimen No. 67256, U.S.N.M.). In the majority of cases, however, natural washing has but served to still further contaminate the materials, giving rise to the complex transported clays to be noted later. Many rocks, such as the aluminous limestones, are so impure that on decomposing and the losing of their soluble lime carbonates they leave only very inferior varieties of clay, suitable for brick and tile or pottery making. Such are often highly colored by iron oxides (Specimens Nos. 62564, 62673, 63463, and 63493, U.S.N.M., in Rockweathering series).

The assorting and transporting power of running waters rarely allow the beds of kaolin or of clay to remain in a condition of virgin purity or even in the place of their origin. The minute size and the shape of their constituent particles render them easily transported by rains and running streams, to be deposited again in regularly laminated beds (see Plate 18) when the streams lose their carrying power by flowing into lakes or seas. It is through such agencies that have in times passed been formed the so-called Leda clays (Specimen No. 73036, U.S.N.M.) and the loess. Such may contain a very large proportion of mechanically derived material and proportionately little kaolin.

Speaking of clays of this nature as they exist in Wisconsin, Chamberlain says:

> They owe their origin mainly to the mechanical grinding of glacial ice upon strata of limestone, sandstone, and shale, resulting in a comminuted product that now contains from 25 to 50 per cent of carbonates of lime and magnesia. This product of glacial grinding was separated from the mixed stony clays produced by the same action by water either immediately upon its formation or in the lacustrine epoch closely following. The process of separation must have been rapid and comparatively free from the agency of carbonated waters, otherwise the lime and magnesia would have been leached out.

The formation of beds of clay has been confined to no particular period of the earth's history, but has evidently gone on ever since the first rocks were formed and when rock decomposition began. The older beds are as a rule greatly indurated and otherwise altered, and in many instances no longer recognizable as clays at all. Throughout the Appalachian region clay beds of Cambrian and Silurian ages have, by the squeezing and sheering incident to the elevation of this mountain system, become converted into argillites and roofing slates.

Mineral and chemical composition.—Formed thus in a variety of ways, and consisting not infrequently of materials brought from diverse sources, it is easy to comprehend that the substances ordinarily grouped under the name of clays may vary widely in both mineral and chemical composition. It may be said at the outset that the statements so frequently made to the effect that kaolinite or even kaolin is the basis of of all clays is not yet well substantiated.

Kaolinite is in itself not properly a clay, nor is it plastic. Further, in many cases it is present only in nonessential quantities. More open to criticism yet, because more concise, is the statement sometimes made that clay is a hydrated silicate of alumina having the formula Al_2O_3, $2SiO_2+2H_2O$. It is doubtful if a clay was ever found which could be reduced to such a formula excepting by a liberal exercise of the imagination. There is scarcely one of the silicate minerals that will not when sufficiently finely comminuted yield a substance possessing those peculiar physical properties of unctuous feel, plasticity, and color, which are the only constant characteristics of the multitudinous and heterogeneous compounds known as clays. Even pure vitreous quartz when rubbed to the condition of an impalpable powder has when wet the plasticity and odor of clay.[1] Daubree so long ago as 1878[2] pointed out the fact that by the mechanical trituration of feldspars in a revolving cylinder with water an impalpable mud was obtained, which remained many days in suspension, and on drying formed masses so hard as to be broken only with a hammer, resembling the argillites of the coal measures.

The ever varying chemical nature of the materials classed as clays is brought out to some extent by a comparison of the analyses in the table (p. 349), but is even more evident in microscopic and mechanical examinations. Indeed, as stated by Chamberlain:[3]

> While it is convenient and customary to speak of the crude material of brick as clay, that which is really made use of is a mixture of clay and sand, or, in the cream-colored brick, of aluminous clay, calcareous clay or marl, and sand. The mixture is really a loam and but for the appropriation of that term as the designation of a soil, it would doubtless be more generally applied to such mixtures.

Professor Crosby, as noted elsewhere, has shown that the blue-gray brick clays of Cambridge contain only from one-fourth to one-third of their bulk of "true clay," the remainder being finely comminuted material to which he gives the name rock flour.

An examination of certain English fire clays has shown[4] that they can not properly be considered as mere hydrous silicates of alumina, but are very complex mineral admixtures, among which scales of hydrous micas, grains of feldspar, more rarely quartz and rutile needles greatly preponderate over the kaolin. The Leda clays of Maine, as the writer has noted elsewhere, contain a comparatively small amount

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[1] Referring to the odor of clay when a shower of rain first begins to wet a dry, clayey soil, Mr. C. Tomlinson has remarked that it is commonly attributed to alumina, and yet pure alumina gives off no odor when breathed upon or wetted. The fact is, the peculiar odor referred to belongs only to impure clays, and chiefly to those that contain oxide of iron. (Proceedings of the Geological Association, I, p. 242; quoted in Woodward's Geology of England and Wales, p. 439.)

[2] Geologie Expérimentale; 1879, p. 251.

[3] Geology of Wisconsin, I, p. 673.

[4] W. M. Hutchings, Geological Magazine, VII, 1890, p. 264, and VIII, 1891, p. 164.

of kaolin but much free quartz, scales of mica, bits of still fresh feldspar, and more rarely tourmalines and other of the less destructible silicates.

Iron in the hydrated sesquioxide state is found in nearly all clays, even the whitest varieties. More than 1 per cent was found in a siliceous clay from Ohio, although the clay itself was almost of snowy whiteness.

Iron also exists in the form of a silicate and protoxide carbonate, and sometimes as a sulphide in the form of disseminated pyrite. Lime and magnesia are also common constituents, either as free carbonates or as lime-magnesia silicates, and may exercise an important bearing upon the suitability of a clay for any particular purpose, as will be noted later. The clay from which the well-known Milwaukee cream-colored bricks are made contains sometimes as high as 23 per cent carbonate of lime and 17 per cent carbonate of magnesia, together with nearly 5 per cent of iron.

The alkalies, potash and soda, are common constituents in small proportions, and also lithia, the first named being most common as well as most detrimental. It is a fair assumption that these substances are constituent of still undecomposed fragments of feldspar and the micas. To the presence of rutile needles and particles of ilmenite are due the frequent traces of titanic acid revealed by chemical analysis. The presence of any quartz and undecomposed feldspathic material in a clay can as a rule be detected by the gritty feeling manifested when the material is rubbed between the thumb and fingers. Mica is, however, not readily detected by this means.

The above remarks will explain why a purely chemical analysis of a clay may be of little value for the purpose of ascertaining its suitability for any particular purpose. It is essential that we know not merely the presence or absence of certain elements but also how these elements are combined. Further than this few clays are used in their natural condition, being first purified by washing and usually mixed with other constituents to give them body or fire-resisting properties.

Kinds and classification.—From a geological standpoint the clays may be divided into two general classes, as above noted, (1) residual and (2) transported, the first class including a majority of the kaolin, halloysite, etc., and the second the ordinary brick and potter's clays, the loess, adobe, Leda, and the bedded, alluvial deposits of the Cretaceous, Carboniferous, and other geological periods. Special names, based upon such properties as render them peculiarly adapted to economic purposes, are common. We thus have (1) the kaolin and China clay, (2) potter's clay, (3) pipe clay, (4) fire clay, (5) brick, tile, and terra cotta clays, etc., (6) slip clays, (7) adobe, and (8) fuller's earth. These will be discussed in the order given, though they must necessarily be discussed but briefly, since the subject of clays alone could be made to far exceed the entire limits of the present volume. The names fat and lean clays are workmen's terms for clays relatively pure and plastic or carrying a large amount of mechanical admixtures, such as quartz sand.

In the Kaolin and China Clays are included a series of clays used in the manufacture of the finer grades of porcelain and china ware and which consist in large proportion of the material kaolin, the name being derived from the Chinese locality Kaoling, from whence have for ages been obtained the materials for the highest grades of Chinese porcelain.

According to Richthofen,[1] however, the material from which the porcelain of King-te-chin is made is not kaolin at all, but a hard greenish rock having somewhat the appearance of jade and which occurs intercalated between beds of clay slate. He says:

> This rock is reduced, by stamping, to a white powder, of which the finest portion is ingeniously and repeatedly separated. This is then moulded into small bricks. The Chinese distinguish chiefly two kinds of this material. Either of them is sold in King-te-chin in the shape of bricks, and as either is a white earth, they offer no visible differences. They are made at different places, in the manner described, by pounding hard rock, but the aspect of the rock is nearly alike in both cases. For one of these two kinds of material, the place Kaoling ("high ridge") was in ancient times in high repute; and, though it has lost its prestige since centuries, the Chinese still designate by the name "Kao-ling," the kind of earth which was formerly derived from there, but is now prepared in other places. The application of the name by Berzelius, to porcelain *earth* was made on the erroneous supposition, that the white earth which he received from a member of one of the embassies (I think, Lord Amherst) occurred naturally in this state. The second kind of material bears the name Pe-tun-tse ("white clay").

The following analyses will serve to show the average composition of (I) the natural material from King-te-Chin, such as is used in the manufacture of the finest porcelain; (II) that from the same locality used in the so-called blue Canton ware; (III) that of the English Cornish or Cornwall stone; (IV) washed kaolin from St. Yrieux, France, and (V) washed kaolin from Hockessin, Delaware.[2]

Constituents.	I.	II.	III.	IV.	V.
Silica	73.55	73.55	73.57	48.68	48.73
Alumina	21.09	18.98	16.47	36.92	37.02
Ferric oxide	....	....	.27	....	.79
Lime	2.55	1.58	1.17	....	.16
Magnesia	.15	1.08	.21	.52	.11
Potash	....	.46	5.84	.58	.41
Soda	....	2.09			.04
Combined water	2.62	1.96	2.45	13.13	12.83
Total	99.62	99.70	99.98	99.83	100.09

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[1] American Journal of Science, 1871, p. 180.

[2] Analyses I and II by J. E. Whitfield, Bulletin 27, U. S. Geological Survey; III from Langenbeck's Chemistry of Pottery; IV from Zirkel's Lehrbuch der Petrography, III, p. 758, and V by George Steiger, U. S. Geological Survey.

Plate 15, figs. 1 and 2, will serve to show the shape and kind of the particles in the mineral kaolinite and in a prepared sample of the Hockessin kaolin, as seen under the microscope.

The name halloysite is given to a white or yellowish material closely simulating kaolin in composition, but occurring in indurated masses, with a greasy feel and luster, and which adheres strongly to the tongue, a property due to its capacity for absorbing moisture.[1] As it is utilized for much the same purpose as is kaolin, it is included here.

Halloysite is described by Gibson[2] as occurring in a bed some 3 feet in thickness, lying near the base of the Lower Siliceous (L. Carboniferous) formation, a little above or close to the Black Shale (Devonian), in Murphrees Valley, Alabama. This bed has been worked with satisfactory results near Valley Head, in Dekalb County. The present writer has found the material in comparatively small quantities, associated with kaolin, in narrow veins in the decomposing gneissic rock near Stone Mountain, Georgia. A similar occurrence is described near Elgin, Scotland. (Analysis below.) Near Tüffer, Styria, halloysite is described[3] as occurring in extensive thick and veinlike agglomerations in porphyry. It is quite pure, and in the form of irregular nodules of various sizes, frequently with a pellucid, steatitelike central nucleus, passing outwardly into a pure white substance, greasy to the touch, in which are occasionally included minute pellucid granules. Outside it passes into an earthy, friable substance. The following analyses show the varying composition of halloysite from (I) Elgin, Scotland, (II) Steinbruck, Styria, and (III) Detroit Mine, Mono Lake, California.

Constituents.	I.	II.	III.
Silica	39.30	40.7	42.91
Alumina	38.52	38.40	38.4
Lime	0.75	0.60	0.6
Magnesia	0.83	1.50	1.5
Ferric oxide	1.42	....	Trace.
Manganese	0.25	....	....
Water	19.34	18.00	18.00
		99.20	

A white chalky halloysite from the pits of the Frio Kaolin Mining Company in Edwards County, Texas (Specimen No. 53253, U.S.N.M.),

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[1] This property is characteristic of nearly all clay compounds when they are dry. It is to this same property that many of the so-called "madstone" owe their imaginary virtues. Nearly all the stones of this type examined by the writer have proved to be of indurated clay, halloysite, or a closely related compound. When applied to a fresh wound, such adhere until they become saturated with moisture, when they fall away. Their curative powers are of course wholly imaginary.

[2] Geological Survey of Alabama. Report on Murphrees Valley, 1893, p. 121.

[3] Mineralogical Magazine, II, 1878, p. 264.

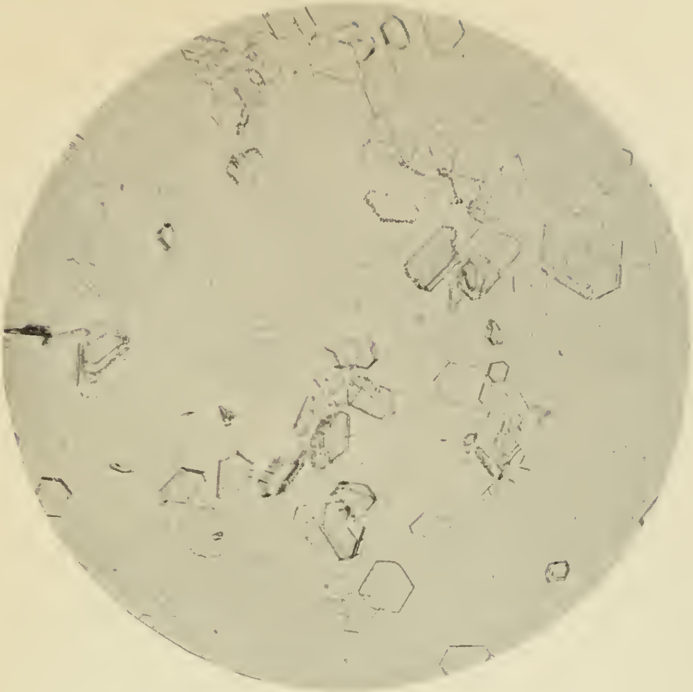

Fig. 1.

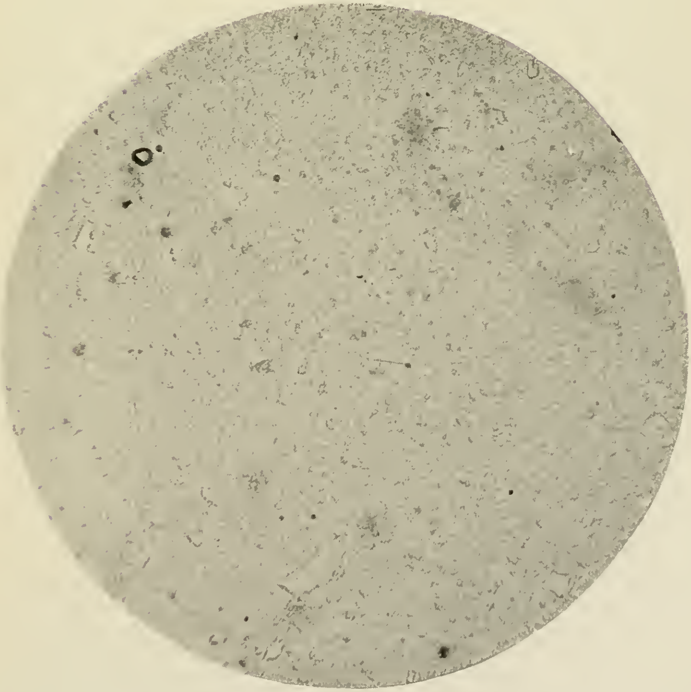

Fig. 2.

MICROSECTIONS SHOWING THE APPEARANCE OF (1) KAOLINITE AND (2) WASHED KAOLIN.

The enlargement is the same in both cases.

Fig. 1.

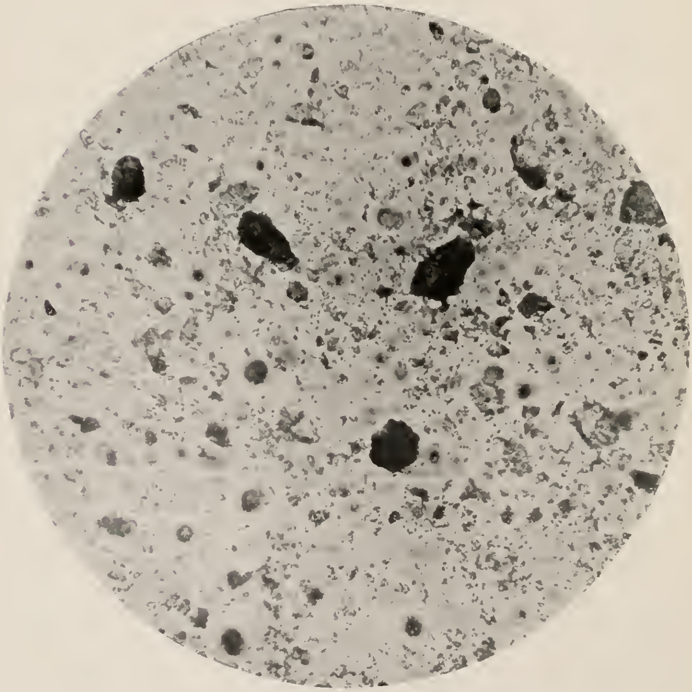

Fig. 2.

MICROSECTIONS SHOWING THE APPEARANCE OF (1) HALLOYSITE AND (2) LEDA CLAY.

The enlargement is the same in both cases.

has the composition given below as shown by analyses made in the laboratory of the department:

Silica	45.82
Alumina	39.77
Potash	.30
Ignition	13.38
	99.27

The material is somewhat variable, corresponding in part to the halloysite described by Dana, and being nonplastic, and in part being plastic to an extraordinary degree. The plastic portions are almost as gritless as starch paste. Its appearance under the microscope is shown in Plate 16, fig. 1, the interspaces of the visible angular particles being occupied by the pasty, almost amorphous material. The particles themselves act very faintly on polarized light, and it is not possible to determine their mineralogical nature.

The name Indianaite has been given by Cox to a variety of halloysite found in Lawrence County, Indiana, and which he regarded as resulting from the decomposition of Archimedes (Lower Carboniferous) limestone. It is represented as forming a stratum from 6 to 10 feet thick, underlying a massive bed of Coal Measure conglomerate 100 feet thick and overlying a bed of limonite 2 to 5 feet thick. The material like kaolin is used in the manufacture of porcelain ware. The composition of this material as given by Dana is as follows: Silica 39 per cent, alumina 36 per cent, water 23.50 per cent, lime and magnesia 0.63 per cent, alkalies 0.54 per cent; 99.67 per cent. (See Specimens, Nos. 29714, 34441, U.S.N.M.)

The potters' and pipe clays belong mainly to what are known geologically as bedded clays, and are as a rule very siliceous compounds, carrying in some instances as much as 50 per cent of free quartz and 6 to 10 per cent of iron oxides and other impurities. They are highly plastic and of a white to blue, gray, or brown color (See Specimens, Nos. 17245, 33975, 20286, 67796, to 67798, from the United States and England) and burn gray, brown, or red. The tables on page 349 will show the varying composition of materials thus classed. The fire clays, so called on account of the refractory nature, differ mainly in the small percentages of lime and the alkalies they carry, and to the absence of which they owe their refractory properties. (Specimens, Nos. 11629, New Jersey; 53179, Maryland; 59258, West Virginia; 68248, California; 53249–53251, South Dakoka, etc., are characteristic.)

The bedded clays of the United States reach their maximum development in strata of Cretaceous and Carboniferous ages. To the Cretaceous age belong the celebrated plastic clays of New Jersey and a very large proportion of the brick, tile, and terra cotta clays of Delaware,[1] Maryland, and Virginia. The New Jersey beds are very extensively utilized in Middlesex County and fully described in the State Geological Reports.[2]

As described, the entire plastic clay formation consists of several members as below, arranged in a descending series:

	Feet.
(1) Dark-colored clay (with beds and laminæ of lignite)	50
(2) Sandy clay, with sand in alternate layers	40
(3) Stoneware clay bed	30
(4) Sand and sandy clay (with lignite near the bottom)	50
(5) South Amboy fire-clay bed	20
(6) Sandy clay (generally red or yellow)	3
(7) Sand and kaolin	10
(8) Feldspar bed	5
(9) Micaceous sand bed	20
(10) Laminated clay and sand	30
(11) Pipe clay (top white)	10
(12) Sandy clay (including leaf bed)	5
(13) Woodbridge fire-clay bed	20
(14) Fire-sand bed	15
Raritan clay beds:	
(15) Fire clay	15
(16) Sandy clay	4
(17) Potters' clay	20
Total	347

The following section of the Coal Measure clays at St. Louis, as pubilshed in Bulletin No. 3 of the Geological Survey of Missouri, will serve to show the alternating character of these beds, and their varying qualities as indicated by the uses to which they are put.[3]

(1) Loess, 20 feet.

(2) Limestone (Coal Measure), 5 feet.

(3) Clay, white and yellow, used for sewer-pipe manufacture, called "bastard fire clay," 3 to 4 feet.

(4) Clay, yellow and red, sold for paint manufacture and for coloring plaster and mortar, called "ochre," 3 feet.

(5) Clay, gray to white, used for paint manufacture and filling, 1 foot 6 inches.

(6) Pipe clay, variegated, reddish brown and greenish, called "keel," 12 feet.

(7) Sandstone.

(8) Slaty shale.

(9) Coal.

(10) Fire clay, becoming sandy toward the base.

When first mined these Coal Measure clays are usually very hard, but on exposure to the weather slack and fall into powder. They are

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[1] This of course does not include the kaolin deposits of Hockessin, Newcastle County, and similar deposits.

[2] Report on Clay Deposits of Woodbridge, South Amboy, and other places in New Jersey, 1878.

[3] Bulletin No. 3, Geological Survey of Missouri, 1890.

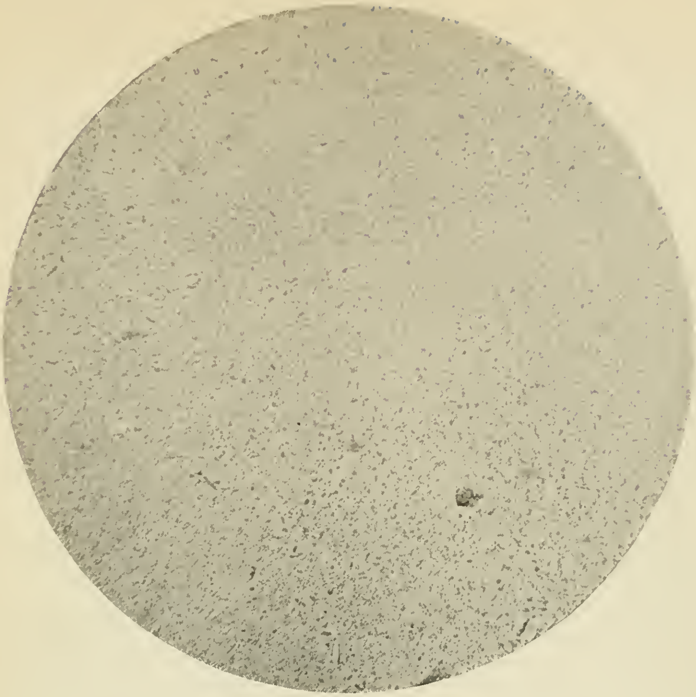

Fig. 1.

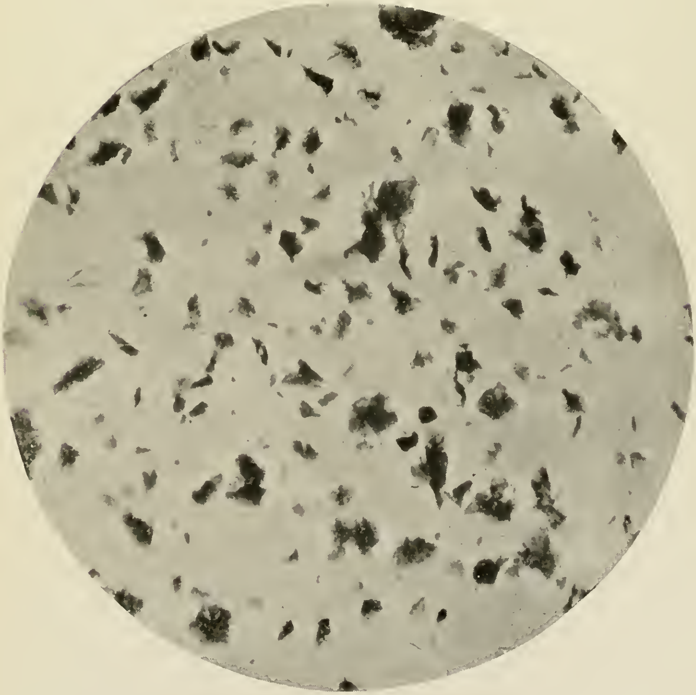

Fig. 2.

MICROSECTIONS SHOWING THE APPEARANCE OF (1) ALBANY COUNTY, WYOMING, CLAY AND (2) FULLER'S EARTH.

The enlargement is the same in both cases.

LEDA CLAYS, LEWISTON, MAINE.
From a photograph by L. H. Merrill.

as a rule much less fusible than are the glacial or stratified clays, and are used mainly in the manufacture of fire brick, sewer pipe, terra cotta stoneware, as crocks, fruit jars, jugs, etc., glass and gas retorts, smelting pots, etc. Some of these articles are made direct from the natural clays, while others are from a mixture of several clays or of a clay mixed with powdered quartz and feldspar.

For ordinary brick-making purposes a great variety of materials are employed; in some cases residuary deposits, and in others alluvial and sedimentary. Throughout the glacial regions of the United States a fine unctious blue-gray material, laid down in estuaries during the Champlain epoch, the so-called Leda clays, are the main materials used for this purpose. Such are also sometimes used in making the cheaper kinds of pottery. The bowlder clays of the glacial regions are also sometimes used when sufficiently homogeneous.

The prevailing colors of the Leda clays are blue-gray or yellowish. They all carry varying amounts of iron, lime, magnesia, and the alkalies, and when burned turn to red of varying tints. They fuse with comparative ease and are used mainly for brick and tile making and for the coarser forms of earthenware, such as flower pots, being as a rule mixed with siliceous sand to counteract shrinkage. The mining of such material is of the simplest kind, and consists merely of scraping away the overlying soil and sand, if such there be, and removing the clay in the form of sidehill cuts or open pits.

Plate 18, facing this page, shows a cut in one of the beds at Lewiston, Maine. The material here is fine and homogeneous, of a blue-gray color, and contains no appreciable grit. It is mixed with siliceous sand and used for making bricks, baking red. An analysis of the material in its air-dry state yielded results as below:

Silica (SiO_2)	56.17
Alumina (Al_2O_3)	24.25
Ferrous oxide (FeO)	3.54
Lime (CaO)	2.09
Magnesia (MgO)	2.57
Potash (K_2O)	4.06
Soda (Na_2O)	2.25
Ignition (H_2O)	4.69
	99.62

Under the microscope these clays are seen to be made up of beautifully fresh, angular bits of quartz, feldspar, mica, hornblende, and augite, with more rarely tourmalines, zircons, and other refractory minerals, with a basis of extremely fine undetermined material which may perhaps be kaolin, though the general structure of the clay is such as to suggest it owes its origin mainly to mechanical trituration, rather than chemical decomposition. The appearance of the Lewiston clay under the microscope is shown in Plate 16, fig. 1. (See Specimens

Nos. 73036, 61041, and 61042, of these clays in their natural, mixed, and baked condition.)

One of the most constant distinctions between the so-called clays of glacial and nonglacial origin, are the relatively large amounts, in the first mentioned, of lime carbonate and alkalies and the extremely finely comminuted siliceous material to which the name *rock flour* is commonly given. Prof. W. O. Crosby, has shown that the smooth and plastic bluish-gray brick clays of West Cambridge contain only from one-fourth to one-third their bulk of the clay kaolin, the remainder being largely *rock flour*. [Proceedings of the Boston Society of Natural History, XXV, 1890.]

Leda clays from Beaver County, Pennsylvania, used in the manufacture of terra cotta at New Brighton, are reported[1] as having the following composition:

Silica	46.160	67.780
Alumina	26.976	16.290
Sesquioxide of iron	7.214	4.570
Titanic acid	.740	.780
Lime	2.210	.600
Magnesia	1.520	.727
Alkalies	3.246	2.001
Water	11.220	6.340
	99.286	99.088

Vitrified brick for street pavements are made from fusible clays, sometimes in their natural condition and sometimes mixtures of ground shale and clay. (See Specimens, Nos. 61141, 61142, and 68049, from Evansville, Indiana.)

The following analyses of the materials used by the Onondaga Vitrified Pressed Brick Company show the character of the materials there used:[2]

Constituents.	Calcareous layer in shale bank.	A green brick; being a mixture of the different shales.	Red shale.	Blue shale.	Clay.
Silica	25.40	54.25	52.30	57.79	45.35
Alumina	9.46	16.89	18.85	16.15	12.19
Peroxide of iron	2.24	5.81	6.55	5.20	4.41
Lime	22.81	4.34	3.36	2.73	10.99
Magnesia	10.39	5.21	4.49	4.67	6.38
Carbonic acid	20.96	4.30	3.04	3.42	7.24
Potash	.95	2.95	4.65	4.11	3.26
Soda	....	.83	1.35	1.22	1.14
Water and organic matter	7.60	5.01	5.30	4.50	8.90
Oxide of manganese	....	....	Trace.	Trace.	....
Total	99.81	99.59	99.89	99.79	99.86

The name slip clay is given to a readily fusible, impalpably fine clay used for imparting a glaze to earthenware vessels. These clays carry

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[1] Second Geological Survey of Pennsylvania, Report of Chemical Analyses, p. 257.

[2] Bulletin of the New York State Museum, III, No. 12, March, 1895. Clay Industries of New York, p. 200.

iron oxides, potash and soda, together with lime and magnesia in such proportions that they vitrify readily, forming thus an impervious glass over those portions of the ware to which they are applied.

The following analyses show (I) the composition of a slip clay used in pottery works in Akron, Ohio, and (II) one from Albany, New York. (Specimen No. 53583, U.S.N.M.):

Constituents.	(I.)	(II.)
Silica	60.40	58.54
Alumina	10.42	15.41
Iron sesquioxide	5.36	3.19
Lime	9.88	6.30
Magnesia	4.28	3.40
Alkalies	0.87	4.45
Sulphuric acid	0.65	1.10
Phosphoric acid	0.09	....
Carbonic acid and water	8.05	8.08
Total	100.00	100.47

The Albany clay is stated by Nason[1] to glaze at comparatively low temperatures and to rarely crack or check. It occurs in a stratum 4 to 5 feet thick. It is used very extensively in the United States, and has even been shipped to Germany and France. (See also Specimens Nos. 53582, U.S.N.M., from Brimfield, Ohio; 53580, U.S.N.M., from Rowley, Michigan, and 52985, 52995, U.S.N.M., from Meissen, Saxony.)

The name *adobe* is given to a calcareous clay of a gray-brown or yellowish color, very fine grained and porous, which is sufficiently friable to crumble readily in the fingers, and yet has sufficient coherency to stand for many years in the form of vertical escarpments, without forming appreciable talus slopes. It is in common use throughout Arizona, New Mexico, and Mexico proper for building material, the dry adobe being first mixed with water, pressed in rough rectangular wooden molds some 10 by 18 or more inches and 3 or 4 inches deep, and then dried in the sun. In some cases chopped straw is mixed with it to increase its tenacity. Buildings formed of this material endure for generations and even centuries in these arid climates. The material of the adobe is derived from the waste of the surrounding mountain slopes, the disintegration being mainly mechanical. According to Prof. I. C. Russell it is assorted and spread out over the valley bottoms by ephemeral streams. It consists of a great variety of minerals, among which quartz is conspicuous. The chemical nature of the adobes vary widely, as would naturally be expected, and as is shown in the following analyses from Professor Russell's paper:[2]

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[1] Forty-seventh Annual Report of the State Geologist of New York, 1893, p. 468.

[2] Subaerial Deposits of North America, Geological Magazine, VI, 1889, pp. 289 and 342.

Analyses of adobe.

Constituents.	I, Santa Fe, New Mexico.	II, Fort Wingate, New Mexico.	III, Humboldt, Nevada.	IV, Salt Lake City, Utah.
SiO_2	66.69	26.67	44.64	19.24
Al_2O_3	14.16	0.91	13.19	3.26
Fe_2O_3	4.38	0.64	5.12	1.09
MnO	0.09	Trace.	0.13	Trace.
CaO	2.49	36.40	13.91	38.94
MgO	1.28	0.51	2.96	2.75
K_2O	1.21	Trace.	1.71	Trace.
Na_2O	0.67	Trace.	0.59	Trace.
CO_2	0.77	25.84	8.55	29.57
P_2O_5	0.29	0.75	0.94	0.23
SO_3	0.41	0.82	0.64	0.53
Cl	0.34	0.07	0.14	0.11
H_2O	4.94	2.26	3.84	1.67
Organic matter	2.00	5.10	3.43	2.96
Total	99.72	99.97	99.79	100.35

The name *loess* is given to certain quaternary surface deposits closely simulating adobe, but concerning the origin of which there is considerable dispute. Deposits in the United States are, according to the best authorities, of subaqueous origin. Clays of this nature are, as a rule, higher in silica than the adobes and correspondingly poorer in alumina. Loess is a common surface deposit throughout the Mississippi Valley, and is in many instances of such consistency as to be utilized for brickmaking.

The analyses given below are from Professor Russell's paper:

Analyses of the loess of the Mississippi Valley.

Constituents.	No. 1.	No. 2.	No. 3.	No. 4.
SiO_2	72.68	64.61	74.46	60.69
Al_2O_3	12.03	10.64	12.26	7.95
Fe_2O_3	3.53	2.61	3.25	2.61
FeO	0.96	0.51	0.12	0.67
TiO_2	0.72	0.40	0.14	0.52
P_2O_5	0.23	0.06	0.09	0.13
MnO	0.06	0.05	0.02	0.12
CaO	1.59	5.41	1.69	8.96
MgO	1.11	3.69	1.12	4.56
Na_2O	1.68	1.35	1.43	1.17
K_2O	2.13	2.06	1.83	1.08
H_2O	[a]2.50	[a]2.05	[a]2.70	[a]1.14
CO_2	0.39	6.31	0.49	9.63
SO_3	0.51	0.11	0.06	0.12
C	0.09	0.13	0.12	0.19
Total	100.21	99.99	99.78	99.54

[a] Contains H of organic matter, dried at 100° C.

The name fullers' earth (Walkerde, volaorde, terre à foulon, terra da purgatori, etc.) includes a variety of clay of a greenish white, greenish gray, olive and oil green or brownish color, very soft, with a greasy feeling. It falls into powder in water, imparts a milky hue to the liquid, and appears to melt on the tongue like butter. It was formerly used by fullers to take the grease out of cloth; hence the name.

The English beds, according to Geikie[1] occur in Jurassic and Cretaceous formations. Fullers' earth from beds at Nutfield, near Redhill, Surrey, England, is described[2] as a heavy blue or yellow clay, with a greasy feel and an earthy fracture.

When examined with a microscope it is found to consist of extremely irregular corroded particles ot a siliceous mineral which in its least altered state is colorless, but which in nearly every case has undergone a chloritic or talcose alteration whereby the particles are inverted into a faintly yellowish green product almost wholly on polarized light. The particles are of all sizes up to 0.07 mm. The larger portion of the material is made up of particles fairly uniform in size and about the dimensions mentioned. In addition to these are minute colorless fragments down to sizes 0.01 mm. and even smaller.

The minute size of these colorless particles renders a determination of their mineral nature practically impossible. But the outline of the cleavage flakes is evidently suggestive of a soda lime feldspar. The high percentage of silica in the insoluble residue would indicate the presence of a considerable amount of free quartz. This, however, the microscope only partially substantiates, very few of the particles showing the brilliant polarization colors characteristic of this mineral.

When the powder is treated with hydrofluorsilicic acid it yields abundant crystals of potassium and aluminum fluosilicate, together with radiating forms of calcium fluosilicate. The material differs from that last described in that its particles are much larger and more angular in outline and the various elements in a different state of combination. (See Plate 17, fig. 2.)

A substance recently put upon the American market as a fullers' earth (Specimen No. 62737, U.S.N.M., from Enid, Oklahoma), under the trade name of "glacialite," has the following chemical composition, the material being dried at 100° C. before analyzing:

Silica	50.36
Alumina	33.38
Ferric oxide	3.31
Sodium, lithium, potassium oxide	.88
Water	12.05
Organic matter	Trace.
Titanium	Trace.
	99.98

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[1] Text book of Geology. 3d. ed. p. 133.

[2] Geological Magazine, VI, 1889, p. 45

This material when placed in water falls away to a loose flocculent powder, which shows up under the microscope in the form of sharply angular colorless particles, very faintly doubly refracting, without crystal outlines or other physical properties, such as will determine their exact mineral nature. The particles are of all sizes, from the larger flocculent masses, some 0.25 mm. in greatest diameter, down to those too small for measurement. The greater number lie between 0.005 and 0.01 mm., though a very large proportion are even smaller, not exceeding 0.002 mm. These smaller particles are angular in outline and almost perfectly colorless. Their appearance under the microscope is somewhat that of decomposed cherts.

In addition to the faintly doubly refracting particles above mentioned, there are occasional clear, colorless, sharply angular particles of a doubly refracting mineral which can only be referred to quartz. A few yellowish iron-stained particles are suggestive of residual products from decomposition of iron magnesian silicates.

The Gadsden County, Florida, fullers' earth (Specimens Nos. 53254 and 53255, U.S.N.M.) is a light-gray material, often blackened by organic matter, and which shows under the microscope the same greenish, faintly doubly refracting particles as does the English, intermixed with numerous angular particles of quartz. This earth is quite plastic and sticky when wet. A section of the beds at the pits of the Cheesebrough Manufacturing Company, as given in The Mineral Resources for 1895–96, is as follows:

Soil	inches	18
Red clay	feet	3
Blue clay	do	3
Fullers' earth	do	5½
Sandy blue earth	do	3
Fullers' earth (second bed)		

PLATE 19.

VIEW IN KAOLIN PIT, DELAWARE COUNTY, PENNSYLVANIA.

The following table[1] as compiled by Dr. Ries shows the variable character of the material from different sources:

Constituents.	Smectite from Cilly.[a]	Fullers' earth from Reigate.[b]	Malthite from Steindörfel.[c]	Fullers' earth from England.[d]	Fullers' earth from England.[e]	Fullers' earth from Gadsden County, Florida.[f]	Fullers' earth from Decatur County, Georgia.[f]	Fullers' earth from Fairborn, South Dakota.[g]	Fullers' earth from southeast of River Junction, Florida.[h]	Fullers' earth from between Mount Pleasant and Norway, Florida.[i]	Fullers' earth from near Norway, Florida.[j]
SiO_2	51.21	53.00	50.17	44.00	44.00	62.83	67.46	58.72	50.70	58.30	54.60
Al_2O_3	12.25	10.00	10.66	11.00	23.06	10.35	10.08	16.90	21.07	10.63	10.99
Fe_2O_3	2.07	9.75	3.15	10.00	2.00	2.45	2.49	4.00	6.88	6.72	6.61
CaO	2.13	.50	.25	5.00	4.08	2.43	3.14	4.06	4.40	1.71	6.00
MgO	4.89	1.25	....	2.00	2.00	3.12	4.09	2.56	.30	3.15	3.00
H_2O	27.89	24.00	35.83	....	24.95	7.72	5.61	8.10	9.60	9.05	10.30
Na_2O	....	....	....	5.00	....	0.20	....	2.11	....	....	....
K_2O	....	....	....	....	....	0.74	....				
Moisture	....	....	....	....	....	6.41	6.28	2.30	7.90	9.55	7.45
Total	100.44	98.50	100.06	77.00	100.09	96.25	99.15	98.75	100.85	99.11	98.95

[a] Pogg. Ann., LXXVII, 1849, p. 591.
[b] Klaproth. Beitr., Vol. IV, 1807, p. 338.
[c] Dana, System of Min., 1893, p. 695.
[d] Geikie, 1893, p. 133.
[e] Penny Encyclopedia, XI, Dr. Thompson, analyst.
[f] P. Fireman, analyst.
[g] E. J. Riederer, analyst.
[h] Standard Oil Company's property, E. J. Riederer, analyst.
[i] Howell property, E. J. Riederer, analyst.
[j] Morgan property, E. J. Riederer, analyst.

Properties of clay.—To what the peculiar properties displayed by the clays are due can not as yet be said to have been fully determined. This is particularly the case with the property of plasticity and that of becoming indurated when dried. "Various explanations have been offered, but none are yet advanced which make clear all points. It has been ascribed to the impurities, to the alumina, to the combined water, and to other causes, against each of which, examples can be cited that seem to set it aside as inadequate. The impurities do not appear to cause the plasticity, for the sand acts unfavorably to it. The alumina is not responsible, or kaolins would be the most plastic of all, while the flint clays of Ohio are many of them approximately pure kaolins, and at the same time eminently non-plastic.[2] The combined water exerts some influence it is evident, as its expulsion entails permanent loss of plasticity, but it can not be the sole cause of plasticity, as clays equally hydrated are just as liable to differ in this respect as to agree. No theory is so well received at present as that advanced by Cook. He shows that the microscope reveals a crystalline structure which the eye does not detect, and that this structure varies greatly in degree of perfection in different samples. Some are composed of masses of

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[1] Seventeenth Annual Report of the U. S. Geological Survey, 1895–96, p. 880.

[2] As is also kaolinite, the theoretically pure hydrous silicate of aluminum corresponding to the formula $Al_2O_3.2SiO_2.2H_2O$.

hexagonal plates or scales piled up in long bundles or faces and masses of unattached scales nearly perfect. Such clays are always but little plastic, but may become so on mechanical treatment such as grinding and kneading; on re-examination the clay then shows the same elements of structure, but broken and confused, no bundles left intact, scales broken and a homogenous matrix of the crushed material derived from the still crystalline part. Clays are found in all states of this breaking up, from the highly crystalline mass to the homogenous matrix showing no plates at all; and on the degree in which the crystalline structure is retained, its plasticity depends. This theory is certainly plausible, and is supported by the fact that we always subject our clays to secure increased plasticity to mechanical disturbance which has the effect that the microscope reveals. This view harmonizes with more points than any other advanced as yet, and offers a fair solution of the different degrees of plasticity which plastic clays exhibit, but it does not explain, nor attempt to explain, the differences which exist between flint clays and plastic clays, as Professor Cook's examinations were entirely confined to the latter.[1]

According to Russian authorities quoted by Ries,[2] the plasticity is not only due to the interlocking of the clay particles, but varies with the fineness of the grain, the extremely coarse and fine varieties having less plasticity than those of intermediate texture. This view is also held by Drs. Ries and Wheeler.

So far as the compiler's own observations go, plasticity is not dependent wholly upon hydration nor size nor shape of the constituent particles. The glacial (Leda) clays are made up of fresh, sharply angular particles of various minerals and contain less than 5 per cent combined water; yet in their natural condition they are extremely plastic, and scarcely less so when mixed with two-fifths their bulk of ordinary siliceous sand, as is done in the process of brickmaking. The Albany County, Wyoming, clay (Specimen No. 53229, U.S.N.M.), on the other hand, equally or even more plastic and exceedingly pasty, is made up of extremely minute particles of fairly uniform size, scarcely angular, and apparently all of the same mineral nature throughout. This yields some 16 per cent of water, on ignition, as shown in analysis, p. 348. On the whole, the evidence seems to show that the plasticity is due to the manner in which the particles conduct themselves toward moisture, and this is apparently dependent upon the size and shape and the proportional admixture of varying sizes of the constituents rather than upon their chemical composition. The work now being done by Dr. Whitney, of the Agricultural Department, on the relationship of soils to moisture bids fair to throw important light upon this branch of the subject.

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[1] Geological Survey of Ohio, Economic Geology, V, pp. 651–652.

[2] Clay Deposits and Clay Industry in North Carolina, Bulletin No. 13, North Carolina Geological Survey, 1897.

The expulsion of the combined water in a clay is nearly always accompanied by a diminution in volume, which varies directly as the water, or the purity of the clay. Pure kaolin shrinks as much as one-fourth of its bulk, it is stated, sometimes even more. The sandy clays used in making sewer-pipe and stoneware shrink from the tempered state from one-ninth to one-sixteenth, usually about one-twelfth. The shrinkage of the raw clay would be very much less, probably not over 3 or 4 per cent.

A clay, when all the water of crystallization is expelled, will not shrink any more at red heat, but with increased heat will shrink more and more up to the moment of fusion. A pure kaolin apparently shrinks when heated a second time, even if the water is all expelled by the first heat, yet it is practically impossible to fuse it. But a good flint clay containing some sand will lose all shrinkage on being once calcined at white heat. Such clay is then used to counteract shrinkage in a body of green clay, as this effect is obtained by mixing in sand or some nonshrinking body. Many clays contain sand enough naturally to shrink little or none on heating, and some are so sandy as to actually expand, though usually at the expense of soundness of structure; for the particles of clay will shrink away from the grains of sand and this renders the structure very friable.

The qualifications of a clay for common pottery and building material are simple, viz., plasticity when wet, and solidity and hardness when burned, but those products involving the highest qualities of clay, refractoriness, require much sharper tests.

The first requisite is purity, at least purity within limits, and though the other points, density, plasticity, and non-shrinkage add greatly to the value of a pure clay, they can in no degree supply its place.

Infusibility in clays rests in the aluminous base and the quartz.

Long and intense heat applied to an intimate mixture of clay and silica is apt to result in a silicate of another ratio of base to acid, and which is likely to be fusible. But the great trouble with free silica in clay, in a fine state of division, is the fact that any fluxing agent readily unites with it, and makes a fluid slag; and in a refractory body the fusing of any one part is the beginning of the end.

The constituents tending to make a clay fusible are iron, the alkalies soda and potash, and lime and magnesia. It is hard to state which is of the most consequence. Of the first two, iron is not so powerful a flux as potash, which is the worst of all the common elements; but the iron is present in larger amounts than potash in most clays, and consequently does as much harm, if not more.

The effect of the iron is detrimental to the appearance of clay ware, and consequently has a direct bearing on the price of goods, while potash shows no more on the surface than on the inside, and when present in the usual small amounts it produces an incipient vitrification which makes the ware ring like a bell when struck, and is often a help in selling.

The extent to which iron may be present without detriment is a point on which authorities do not agree. The Stourbridge clay of England, acknowledged to be the most refractory clay known, has 2.25 per cent of iron on an average of 100 analyses, with extremes of 1.43 and 3.63. Gros Almerode clay, has 2.12, Coblentz, 2.03, New Castle, 2.32, and yet all these clays are famous. Test mixtures of iron and pure kaolin have been run higher than this and have stood well, but as a general rule it is unsafe to rely for fine qualities on a clay with over 2 per cent of iron, particularly if the other impurities are developed in any amount. It is a well-known principle in chemistry that mixtures of bases are much more active fluxes than an equal amount of any one base; so with iron, its effect shows worse when in presence of other fluxing agents.

The state in which the iron is present makes some difference; if as the sesquioxide, it takes more heat than when in the protoxide state to combine in the clay, for iron will only combine with silica in the protoxide state, and if that state is already developed, it is easier to combine the sand and iron than if in the other oxide.

Sulphide of iron has a bad effect on the clay since its decomposition gives rise to the lower oxide of iron, besides the effect which the sulphur may have.

Silicate of iron is also detrimental, since it melts at a comparatively low temperature. On a piece of ware, iron in the uncombined state imparts a buff or red color; when combination begins and progresses the ware is of a bluish-gray cast, deepening as the fusion of the iron proceeds, and running to glassy black if much iron is present.

Lime and magnesia act as fluxes on clays, but in any but the glacial clays the comparatively small amounts present makes them but little thought of as detrimental. They are probably present as silicates, and as these are readily fusible, their action is evidently unfavorable. When these bases are present as carbonates they combine at a higher temperature than iron or potash. The Milwaukee bricks, as already noted, are full of carbonates of lime and magnesia, and require a very hot burn, but when once the lime and silica combine they destroy the effect of 5 per cent of iron, enough to make the clay perfectly black. A brick of this kind presents an even, fine-grained, vitrified appearance on its fracture.[1]

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[1] They (lime and magnesia) have also the remarkable property of uniting with the iron ingredient to form a light-colored alumina-lime-magnesia-iron silicate, and thus the product is cream-colored instead of red. Mr. Sweet has shown by analysis that the Milwaukee light-colored brick contain even more iron than the Madison red brick. At numerous points in the Lake region and in the Fox River valley cream-

The amount of potash which a clay can contain and keep its fire properties is variously put by different authorities. As with iron, pure kaolin will stand a good deal when no other base is present, but a multiplicity of bases makes fusion easy. Titanic acid is regarded as neutral to fire qualities; the form in which it is present being infusible.

Testing clays.—The statement of the tendencies and comparative power of the dangerous impurities of clay would lead us to believe we could use predictions as to their result in a given clay with some confidence, but the best practice does not yet trust to analysis alone.

The most complete test of a clay now known would be obtained by use of such analysis as has been described, coupled with a fire test made especially to develop such points as the analysis indicates to be weak ones. Fire tests are of two kinds—one is subjecting the clay to absolute heat without the action of any accompaniments, and the other is in putting the clay through the course of treatment for which it is designed to be used. The former develops the absolute quality of the clay as good or bad, the latter proves or disproves the fitness of the clay for the work. The latter is better of course as a business test wherever it is practicable to use it. The former can be made only in a specially adapted furnace. The clay is cut into one-inch cubes with square edges, and is set in a covered crucible resting on a lump of clay of its own kind, so that it touches no foreign object. The heat is then applied, and its effect will vary from fusing the mass to a button to leaving it with edges sharp and not even glazed on the surface. Experience soon renders one proficient in judging of clays by this test.[1]

A method of testing the fusibility of clays by comparing them with samples of known composition and fusibility has of late years come into extensive use. These prepared samples, known from their inventor and their shape as Seger's pyramids, consist of mixtures in varying proportions of kaolin and certain fluxes, so prepared that there is a constant difference between their fusing points. When such pyramids, together with the samples to be tested, are placed in a furnace or kiln,

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colored brick are made from red clays. In nearly or quite all cases, whatever the original color of the clay, the brick are reddish when partially burned. The explanation seems to be that at a comparatively moderate temperature the iron constituent is deprived of its water and fully oxidized, and is therefore red, while it is only at a relatively high heat that the union with the lime and magnesia takes place, giving rise to the light color. The calcareous and magnesian clays are, therefore, a valuable substitute for true aluminous clays, for they not only bind the mass together more firmly, but give a color which is very generally admired. They have also this practical advantage, that the effects of inadequate burning are made evident in the imperfect development of the cream color, and hence a more carefully burned product is usually secured. It is possible to make a light-colored brick from a clay which usually burns red by adding lime. The amount of lime and magnesia in the Milwaukee brick is about 25 per cent. In the original clays in the form of carbonates they make up about 40 per cent. Geology of Wisconsin, I, 1873–79, p.669.)

[1] Geological Survey of Ohio, Economic Geology, V, pp. 652–655.

they begin to soften as the temperature is raised, and as it approaches their fusion point the cones bend over until the tip is as low as the base. When this occurs the temperature at which they fuse is considered to be reached.[1]

Uses.—Clay when moistened with water is plastic and sufficiently firm to be fashioned into any form desired. It can be shaped by the hands alone; by the hands applied to the clay as it turns with the potter's wheel, or it can be shaped by moulds, presses or tools. When shaped and dried, and then burned in an oven or kiln, it becomes firm and solid, like stone; water will not soften it, it has entirely lost its plastic property, and is permanently fixed in its new forms, and for its designed uses. These singular and interesting properties are possessed by clay alone, and it is to these it owes its chief uses. It is used (1) for making pottery; (2) for making refractory materials; (3) for making building materials; (4) for miscellaneous purposes.

Pottery.—Pure clay worked into shapes and burned, constitutes earthenware. The ware of itself is porous, and will allow water and soluble substances to soak through it. To make it hold liquids, the shaped clay before burning is covered with some substance that in the burning of the ware will melt and form a glass coating or glazing which will protect the ware in its after uses from absorbing liquids, and give it a clean smooth surface. The color of the ware depends on the purity of the clay. Clays containing oxide of iron burn red, the depth of color depending on the amount of the oxide, even a small fraction of 1 per cent being sufficient to give the clay a buff color.

Clay containing oxide of iron in sufficient quantity to make it partially fusible in the heat required to burn it, when made into forms and burned, is called stoneware clay. The heat is carried far enough to fuse the particles together so that the ware is solid and will not allow water to soak through it; and the fusion has not been carried so far as to alter the shapes of the articles burned. The oxide of iron by the fusion has been combined with the clay, and instead of its characteristic red, has given to the ware a bluish or grayish color. Stoneware may be glazed like earthenware, or by putting salt in the kiln, when its vapor comes in contact with the heated ware and makes with it a sufficient glaze.

Clay which is pure white in color and entirely free from oxide of iron, may be intimately mixed with ground feldspar or other minerals which contain potash enough to make them fusible, and the mixture still be plastic so as to be worked into forms for ware. When burned, such a composition retains its pure white color, while it undergoes

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[1] See Dr. Ries's paper on North Carolina clays, already quoted, and also his numerous contributions on their subject in the volumes of the United States Geological Survey relating to mineral statistics.

fusion sufficient to make a body that will not absorb water. And its surface can be made smooth and clean by a suitable plain or ornamented glaze. Ware of this kind is porcelain or china.

The analyses on page 349, compiled from works believed to be authoritative, show the varying character, so far as chemical composition is concerned, of the clays. In most of the analyses, it will be observed, the silica existing in the form of quartz is given in a separate column from the combined, while in column 4 is given the actual calculated percentage of kaolin which the analyses indicates each sample contains.

Refractory materials.—Modern improvements in metallurgy, and in furnaces for all purposes, are dependent to a great degree on having materials for construction which will stand intense heat without fusing, cracking, or yielding in any way. The two materials to which resort is had in almost all cases, are pure clay, and quartz in the form of sand or rock. They are both infusible at the highest furnace heats. The clay, however, is liable to have in it small quantities of impurities which are fusible, and it shrinks very much when heated to a high temperature. Quartz rocks are very liable to crack to pieces if heated too rapidly, and both the rocks and sand are rapidly melted when in contact with alkalies, earths or metallic oxides, at a high temperature. They do not shrink in heating. Sandstone, or quartz rock, is not as much used as a refractory material as it was formerly. Bricks to resist intense heat are made of clay, of sand, and of a mixture of clay and sand. The different kinds are specially adapted to different uses.

Fire bricks made of clay, or clay and sand, are the ones which have been generally made in the United States. To make these, the clay which stands an intense heat the best, is selected as the plastic material of the brick. This is tempered so that it may not shrink too much or unevenly in burning, by adding to the raw clay a portion of clay which has been burned till it has ceased to shrink and then ground, or a portion of coarse sand, or a quantity of so-called feldspar. These materials are added in the proportions which the experience of the manufacturer has found best. The formula for the mixture is the special property of each manufacturer, and is not made public. The materials, being mixed together and properly wet, are molded in the same way as common bricks are, and after they have dried a little, they are put into a metallic mould and subjected to powerful pressure. They are then taken out, dried, and burned in a kiln at an intense heat.

It does not appear which is the best for tempering, burned and ground clay, or coarse sand, or feldspar. Reputable manufacturers are found who use each of these materials, and make brick that stand fire well. It is of the utmost importance to select the materials carefully, and to allow no impurity to get in while handling the clay or working the components together.

Fire bricks intended, in addition to their refractory qualities, to retain their size and form under intense heat without shrinkage, have been made to some extent. The English Dinas bricks are of this kind, and the German and French "silica bricks." The Dinas bricks are of quartz sand or crushed rock, and contain very little alumina and about one per cent of lime. They stand fire remarkably well, the lime being just enough to make the grains of sand stick together when the bricks are intensely heated. In the other "silica bricks," fire clay to the amount of 5 or 10 per cent is mixed with the sand, and this plastic material makes the particles of the sand cohere sufficiently to allow of handling the bricks before burning. They have met the expectation of those who made them, and are extensively used.[1]

Under the head of "Miscellaneous uses of clay," p. 317, Cook gives the following, which may well be incorporated entire:

> *Paper clay.*—Clay which is pure white and that also which is discolored and has been washed to bring it to a uniform shade of color, is used by the manufacturers of paper hangings, to give the smooth satin surface to the finished paper. It is used by mixing it up with a thin size, applying it to the surface of the pieces of paper, and then polishing by means of brushes driven by machinery. The finest and most uniformly colored clays only are applicable to this use, and they are selected with great care. Clay is also used to some extent by paper manufacturers, to give body and weight to paper.

Heavy wrapping paper, such as is used by the United States Post-Office Department, must, according to specifications, contain 95 per cent of jute butts and 5 per cent of clay. The cheaper forms of confectionery, particularly such as is sold from carts upon the streets, is very heavily adulterated with this material.

> *Alum clay.*—A large quantity of clay is sold every year to the manufacturers of chemicals, for making alum. A rich clay is needed for this purpose, but those containing lignite or pyrite which renders them inapplicable for refractory materials, do not spoil them for this use. Alum is made by digesting the clay in sulphuric acid, which forms sulphate of alumina, then dissolving out the latter salt from the silica and other impurities, and forming it into alum by the addition of the necessary salt of potash, soda, or ammonia, and crystallizing out the alum.

The white clay of Gay Head and Chilmark, Marthas Vineyard, Massachusetts, was at one time used extensively for alum making, according to Edward Hitchcock.[2]

As a substitute for sand in making mortar and concrete clay is perhaps the best material to be found. For this purpose the clay is burnt so that it is produced in small irregular pieces that are very hard and durable. These pieces are then ground to a fairly fine powder, which is used to mix with the lime or cement just as sand would be. The

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[1] Geological Survey of New Jersey, Report on Clay Deposits, pp. 307–312.

[2] American Journal of Science, XXII, 1832, p. 37.

result is a very strong mortar, in some cases stronger than when sand is employed.[1]

The so-called gumbo clays, sticky, tough, and dark-colored clays of the Chariton River region, Missouri, are hard burned and used for railroad ballast and macadam.

Under the names of *Rock Soap* and *Mineral Soap* there have from time to time been described varieties of clay which, owing to their soapy feeling, are suggestive of soap, and which in a few instances have been actually used in the preparation of this material.

A rock soap from Ventura County, California, has been described by Prof. G. H. Koenig as a mixture of sandy and clayey or soapy material in the proportion of 45 per cent of the first and 55 per cent of the second. The chemical composition of the material and of the two portions is given below:

Constituents.	Crude material.	Sandy portion.	Soapy portion.
Silica	67.55	69.40	73.10
Alumina and iron	12.97	13.50	14.10
Lime	0.77	0.30	Not determined.
Magnesia	0.85	Trace.	
Potash	1.43	4.55	
Soda	3.63		
Water	13.67	12.25	6.70

Nearly all the silica is reported as being in a soluble or opalescent state and the alumina as either a hydrate or very basic silicate. It is said[2] that at one time the material was made into a variety of useful articles, as "salt water soap," scrubbing and toilet soap, tooth powder, etc.

A somewhat similar material from Elk County, Nevada, has been used for like purposes, and put upon the market under the name of San-too-gah-choi mineral soap. This clay is of a drab color, with a slight pinkish tint, a pronounced soapy feeling and slight alkaline reaction when moistened and placed upon test paper. An analysis by Packard in the laboratory of the U. S. National Museum yielded:

Silica	48.80
Alumina	18.57
Iron oxides	3.88
Lime	1.07
Magnesia	2.52
Soda	2.32
Potash	1.12
Ignition	21.13
Total	99.41

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[1] The Worlds Progress, February, 1893.

[2] Sixth Annual Report of the State Mineralogist of California, 1886, Pt. 1, p. 132.

Mention may be made here also of the material sold in the shops under the name of Bon Ami and used for cleansing glass and other like substances. This under the microscope shows abundant minute sharply angular particles, consisting of partially decomposed feldspar mixed with a completely amorphous mineral which may be opalescent silica or possibly a very finely comminuted pumice. An analysis by Packard in the laboratory of the Department yielded:

Silica	59.86
Alumina	18.74
Magnesia	0.34
Potash	10.70
Soda	3.51
Ignition	7.67
Total	100.82

Alcohol extracts 7.43 per cent, and water 0.244 per cent in addition, the extract having a soapy appearance and the odor of some essential oil.

A soapy clay occurring near Rock Creek station, in Albany County, Wyoming, has been shipped in considerable quantities during the past few years to New York, Philadelphia, and Chicago, but the use to which it was put remains a secret. It is stated[1] that at first the material was sold at the rate of $25 a ton, but that the price has now dropped to $5 a ton. Analyses are given as below. The chief physical characteristic of this clay, aside from its soapy feeling, is its enormous absorptive power, the absorption being attended naturally with an increase in bulk amounting to several times that of the original mass.[2] Plate 17, fig. 11 shows the extreme fineness and homogeneity of this clay as seen under the microscope.

Constituents.	I. Rock Creek.	II. Crook County.	III. Weston County.	IV. Natrona County.
SiO_2	59.78	61.08	63.25	65.24
Al_2O_3	15.10	17.12	12.62	15.88
Fe_2O_3	2.40	3.17	3.70	3.12
MgO	4.14	1.82	3.70	5.34
CaO	0.73	2.69	4.12	
Na_2O, K_2O	(*a*)	*b* 0.20		(*a*)
SO	(*a*)	0.88	1.53	(*a*)
H_2O	16.26			9.17
Specific gravity			2.132	

a No estimate. *b* NaO.

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[1] Engineering and Mining Journal, LXIII, 1897, p. 600; LXVI, 1898, p. 491.

[2] A small plug of this clay fitted to accurately occupy a space of 20 cubic centimeters in the bottom of a conical measuring flask, and kept saturated with water for two days, swelled to a bulk of 160 cubic centimeters. The absorption was so complete that none of the water ran off when the flask was inverted, and the condition of the clay resembled that of flour or starch paste.

Composition of clays.

Name of company and location.	Combined silica (SiO_2).	Alumina (Al_2O_3).	Combined water (H_2O).	Per cent of the kaolin base.	Quartz (free SiO_2).	Titanic acid (TiO_2).	Total sandy material.	Sesquioxide of iron (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Potash (K_2O).	Soda (Na_2O). Lithia (Li_2O).	Total deleterious impurity.	Moisture.	Sum total.	Authority.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	
China clays.																
Kaolin (washed), Hockessin, Newcastle County, Delaware.	40.72	34.10	12.35	87.17	6.50	......	......	2.49	......	0.39	1.64	0.27	4.79	1.35	99.81	
China clay, Redruth, Cornwall, England.	28.40	24.11	7.20	59.71	37.80	0.20	38.00	0.79	......	......	0.96	......	1.75	0.70	100.16	Report on Clay Deposits, Geological Survey of New Jersey.
China clay, from Huron, Lawrence County, Indiana.	40.10	36.35	22.60	99.05	0.40	0.00	0.40	0.15	......	0.13	0.14	......	0.42	....	99.87	Do.
China clay, St. Yrieux, France....	48.37	34.95	12.62	......	......	......	......	1.26	......	......	2.40		......	....	......	
Potters' clays.																
Brummage's stoneware clay, Roseville, Ohio.	25.60	19.08	5.57	50.25	43.73	0.29	44.02	1.26	0.60	0.63	2.14	0.02	4.65	0.94	99.86	Geol. Survey of Ohio, Vol. V.
Allen's stoneware clay, Roseville, Ohio.	28.61	23.01	8.03	59.65	34.79	0.35	35.14	1.50	0.41	0.62	1.26	Tr. Li_2O.	3.81	1.97	100.57	Do.
Walker's stoneware clay, Roseville, Ohio.	69.79	19.31	5.08	94.18	With clay.	......	......	......	......	......	....	......	By diff. 4.80.	0.94	100.00	Do.
Uniontown stoneware clay, Perry County, Ohio.	29.35	23.05	7.39	59.79	35.85	0.55	36.40	0.99	0.58	0.58	1.45	Tr. Li_2O.	3.60	1.11	100.90	Do.
Myers, Atchison & Co., North Springfield, Ohio, stoneware.	72.10	19.38	5.13	96.61	......	......	......	......	1.38	0.23	....	......	1.61	1.12	99.34	Do.
Do	68.2	22.61	5.56	96.41	......	......	......	......	0.99	0.11	....	......	1.10	1.00	98.51	Do.
Do	69.0	21.37	6.00	96.42	......	......	......	......	1.70	0.21	....	......	1.91	1.00	99.33	Do.
East Liverpool, Ohio (yellow-ware clay).	42.28	24.12	7.77	74.17	18.02	1.20	19.22	1.46	0.59	0.68	2.42	Tr.	5.15	0.86	99.40	Do.

Composition of clays—Continued.

Name of company and location.	Combined silica (SiO_2). 1.	Alumina (Al_2O_3). 2.	Combined water (H_2O). 3.	Per cent of the kaolin base. 4.	Quartz (free SiO_2). 5.	Titanic acid (TiO_2). 6.	Total sandy material. 7.	Sesquioxide of iron (Fe_2O_3). 8.	Lime (CaO). 9.	Magnesia (MgO). 10.	Potash (K_2O). 11.	Soda (Na_2O). Lithia (Li_2O). 12.	Total deleterious impurity. 13.	Moisture. 14.	Sum total. 15.	Authority.
Potters' clays—Continued.																
H. Cutter & Sons, Woodbridge, New Jersey.	43.90	38.24	14.10	96.24	1.10	1.30	2.40	0.96	0.00	0.11	0.15	0.00	1.22	0.70	100.56	Report on Clay Deposits, Geol. Survey of New Jersey.
Blue Ball clay, Pennsylvania......	44.55	39.00	13.66	97.21	....	1.70	......	1.44	0.02	0.07	0.53	....	2.06	....	100.98	Geol. Survey of Ohio, Vol. V.
Pipe clay.																
N. U. Walker, Walker's Station, Ohio (sewer pipe).	39.03	27.88	8.87	75.08	15.50	1.26	16.76	2.41	0.42	0.68	3.31	0.12	6.94	0.76	99.54	Geol. Survey of Ohio, Vol. V.
Bolivar clay, Island Siding, Ohio (fit for pipe).	35.73	28.69	9.67	74.09	16.07	0.72	16.79	2.77	0.77	1.41	2.57	0.25	7.77	1.72	100.37	Do.
W. H. Evans, Waynesburg, Ohio (drain pipe).	16.20	15.89	7.07	39.16	52.69	0.16	52.85	2.86	0.59	0.66	2.23	0.29	6.61	1.03	99.65	Do.
A. O. Jones, Columbus, Ohio (drain tile).	14.50	12.63	7.30	34.43	56.80	......	56.80	5.07	1.05	....	....	....	6.12	....	99.35	Do.
Whitmore, Robinson & Co., Akron, Ohio (kaolite slip clay).	60.40	10.42	H_2SO_4 0.65.	H_3PO_4 0.09.	CO_2+H_2O 8.05.		......	5.36	9.88	4.28	0.87		20.39	....	100.00	Do.
Fire clay.																
C. E. Holden, Mineral Point, Ohio.	35.39	31.84	11.68	78.91	17.13	1.68	18.81	0.67	0.50	0.19	0.59	0.00	1.95	0.69	100.36	Geol. Survey of Ohio, Vol. V.
Scioto Fire Brick Co., Sciotoville, Ohio.	43.78	40.82	13.77	97.97	....	......	......	With Al_2O_3.					....	0.82	98.79	Do.
Do	52.56	34.80	10.50	97.80	With clay.	......	......	1.00	1.20				2.20	....	100.00	Do.
Wassall Fire Clay Co., Columbus, Ohio.	60.77	25.74	9.46	95.97	With clay.	......	......	1.61	0.89	0.63	1.20	....	4.33	....	100.30	Do.

Island Fire Clay Co., near Steubenville, Ohio.	29.22	24.97	8.90	63.09	31.34	1.30	32.64	1.66	0.63	0.40	0.28	Tr.	2.97	1.69	100.39	Do.
Ballou clay, Zanesville, Ohio	31.07	26.47	9.96	67.50	27.71	0.94	28.65	1.22	0.59	0.32	0.99	Tr. Li.	3.12	1.04	100.31	Do.
Etna Fire Brick Co., Oakhill, Ohio.	63.12	26.20	10.72	100.05	With clay.	......	......		This is a plastic clay.						100.05	Do.
B. Ellison, south-southwest of Bonhamtown, New Jersey.	17.90	15.50	4.90	38.30	57.35	1.60	58.95	1.20	....	....	0.17	....	1.37	1.30	99.92	Do.
Brick clay																
Milwaukee brick clay, Wisconsin..	38.22	9.75	1.85	49.82	....	CaO 3.24	FeO 1.16	2.84	$CaCO_3$ 23.20	$MgCO_3$ 15.83	2.16	0.65	49.07	0.95	99.84	Geol. Survey of Ohio, Vol. V.
Mount Savage, Maryland..........	39.90	30.08	7.00	77.58	16.90	1.15	18.05	1.67	....	....	2.30	....	3.97	0.90	100.50	Report on Clay Deposits, Geol. Survey of New Jersey.
Newcastle, England	55.50	27.75	10.57	93.78	....	......	......	2.01	0.67	0.75	2.19	0.44	6.06	....	99.84	Geol. Survey of Ohio, Vol. V.
Sayre & Fisher, front brick clay, Sayreville, New Jersey.	28.30	27.42	6.60	62.32	27.80	1.00	28.80	2.68	....	0.18	2.71	....	5.57	2.90	99.59	Report on Clay Deposits, Geol. Survey of New Jersey.

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VII. NIOBATES AND TANTALATES.

1. Columbite and tantalite.

These are columbates and tantalates of iron and manganese, columbite representing the nearly pure columbate and tantalite the nearly pure tantalate. Both are likely to carry varying quantities of iron and manganese. The analyses given below will serve to show the varying composition, No. I being columbite from Greenland, No. II from Haddam, Connecticut, and Nos. III and IV from the Black Hills of South Dakota:

Constituents.	I.	II.	III.	IV.
Columbium pentoxide	77.97	51.53	54.09	29.78
Tantalium pentoxide	....	28.55	18.20	53.28
Iron protoxide	17.33	13.54	11.21	6.11
Manganese protoxide	3.28	4.55	7.07	10.40

With traces of tin, wolfram, lime, magnesia, etc.

The mineral is of an iron black, grayish or brownish color, opaque, often with a bluish iridescence, dark red to black streak, specific gravity varying from 5.3 to 7.3 and hardness of 6. Insoluble in acids.

Occurrence.—The mineral occurs in granitic and feldspathic veins in the form of crystals, crystalline granules, and cleavable masses. In the United States it has been found in greater or less abundance in nearly all the States bordering along the Appalachian Mountain system (Specimen No. 63478, from Portland, Connecticut), in the Black Hills of South Dakota, and also in California and Colorado. It has also been found in Italy, Bavaria, Finland, Greenland, and western South America.

Uses.—The material is used only in the preparation of salts of columbium and tantalium, and as but a small quantity of these salts are used, the mineral is in but little demand, except as mineralogical specimens.

2. YTTROTANTALITE.

This name is given to a mineral closely related to samarskite (see below), but carrying smaller percentages of uranium and lacking in didymium and lanthanum. It is essentially a tantalate of yttrium with small amounts of other of the rarer earths. (Specimen No. 60926, U.S.N.M.) In appearance it is distinguished from samarskite only with difficulty. Pyrochlore, fergusonite, æschynite, euxenite, etc., are closely related compounds, the commercial uses of which have not yet been demonstrated.

3. SAMARSKITE.

Composition as given below. When crystallized, in the form of rectangular prisms, but occurring more commonly massive and in flattened granules. Cleavage, imperfect; fracture conchoidal; brittle. Hardness, 5 to 6; specific gravity, 5.6 to 5.8. Luster, vitreous to resinous. Color, velvet black. (Specimen No. 62772, U.S.N.M.)

Constituents.	I.	II.	III.	IV.
Columbic oxide	54.81	54.96	55.13	37.20
Tantalic oxide				18.60
Tungstic and stannic oxides	....	0.16	0.31	0.08
Uranic oxide	17.03	9.91	10.96	12.46
Ferrous oxide	14.07	14.02	11.74	10.90
Manganous oxide	....	0.91	1.53	0.75
Cerous oxide, etc	3.95	5.17	4.24	4.25
Yttria	11.11	12.84	14.49	14.45
Magnesia	....	....	Trace.	....
Lime	....	0.52	....	0.55
Loss by ignition	0.24	0.66	0.72	1.12
Insoluble	....	1.25	....	....
	101.21	100.40	99.12	100.36

Localities and mode of occurrence.—The only localities of importance in the United States are the Wiseman Mica Mine and Grassy Creek Mine, in Mitchell (Specimen No. 62772, U.S.N.M.) and in McDowell counties, North Carolina. The mineral has also been found in the form of black grains and pebbles, sometimes weighing one-fourth of an ounce, in the gold-bearing sands of Rutherford County. At the Wiseman Mine large masses, one weighing upwards of 20 pounds, were found some years ago. The analyses quoted above were made from material from this mine.[1]

Uses.—See under Monazite, p. 383.

4. Wolframite and Hübnerite.

Composition, a tungstate of manganese, and iron. The proportion of the iron and manganese are quite variable, the tungsten remaining nearly constant. The name hübnerite is given to the variety containing very little iron, but consisting essentially of tungsten and manganese. The following table shows the range in composition:

Locality.	WO_3.	FeO.	MnO.	CaO.	MgO.
Wolframite:					
Adun-Chalon	75.55	21.31	2.37	0.26	0.51
Monroe, Connecticut	75.47	9.53	14.26	....	....
Hübnerite:					
Bonita, New Mexico	76.33	3.82	19.72	0.13	Trace.
Nye County, Nevada	74.88	0.56	23.87	0.14	0.08

Wolframite is dark reddish brown to black in color, with a resinous luster; has a hardness of about 5, a specific gravity of 7.55, and a pronounced tendency to cleave with flat, even surfaces. Its great weight, color, and cleavage tendencies are strongly marked characteristics, and the mineral once identified is as a rule easily recognized.

Occurrence.—The mineral is found in veins associated with tin ore (cassiterite), and also with quartz, pyrite, galena, sphalerite, etc. The chief known localities in the United States are Monroe and Trumbull, Connecticut; Blue Hill Bay, Maine; Rockbridge County, Virginia (Specimen No. 65206, U.S.N.M.); the Mammoth district, Nye and Lander counties, Nevada (Specimens Nos. 15755, 5653, U.S.N.M.); Black Hills, S. Dakota (Hübnerite) (Specimen No. 53461, U.S.N.M.); Bonita and White Oaks, Lincoln County, New Mexico; Falls County, Texas (Specimen No. 62766, U.S.N.M.); Russellville, Arizona (Specimen No. 53223, U.S.N.M.). The foreign localities are the tin regions of Bohemia, Saxony (Specimen No. 67752, U.S.N.M.), and Cornwall and Devonshire (Specimens Nos. 67460, 67753, 67787, and 67788, U.S.N.M.), England; also Australia (Specimens Nos. 60978, 60967, U.S.N.M.) and Bolivia and Peru, South America. For uses, see under Scheelite, p. 356.

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[1] See the Minerals of North Carolina, Bulletin 74, U. S. Geological Survey, 1891.

5. SCHEELITE.

This is calcium tungstate, consisting when pure of some 80.6 per cent tungsten trioxide (WO_3) and 19.4 per cent lime; usually, however, carrying from 1 to 8 per cent of molybdic oxide (MoO_3). The mineral is white and translucent, and yellow and brownish in color, with a hardness of 4.5–5, gravity 6, and a tendency to cleave into octahedral forms. The occurrence is similar to that of wolframite, but the mineral is less common.

Uses.—The tungstates have been used mainly in the manufacture of tungstic acid, but the metal tungsten is coming into use as an alloy in making steel. Recently attempts have been made in France to utilize the material in porcelain glazes, but thus far without much success. There is at present no regular source of supply in America.

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VIII. PHOSPHATES.

1. APATITE; ROCK PHOSPHATE; GUANO; ETC.

Phosphorus is one of the most widespread of the elements, and is apparently indispensable to both animal and vegetable life. In nature it occurs in various compounds, by far the more common being the phosphates of calcium and aluminum, such as are commercially used as fertilizers. These in various conditions of impurity occur under several forms, some distinct and well defined, others illy defined and passing by insensible gradations into one another, but all classed under the general term of phosphates. Their origin and general physical properties are quite variable, and any attempt at classifying must be more or less arbitrary. For our present purposes it is sufficient that we treat them under the heads of mineral phosphates and rock phosphates, as has been done by Dr. Penrose.[1] These two classes are then subdivided as below:

- (I) Mineral phosphates[2]
  - Apatites
    - Fluor apatites,
    - Chlor apatites.
  - Phosphorite.
- (II) Rock phosphates
  - Amorphous nodular phosphates loose or cemented into conglomerates.
  - Phosphatic limestones.
  - Guanos
    - Soluble guanos.
    - Leached guanos.
  - Bone beds.

Apatite.—Under the name of apatite is included a mineral composed essentially of phosphate of lime, though nearly always carrying small amounts of fluorine or chlorine, thereby giving rise to the varieties *fluor-apatite* and *chlor-apatite*. The mineral crystallizes in the hexagonal system, forming well-defined six-sided elongated prisms of a green, yellow, rose, or reddish color, or sometimes quite colorless. (Specimens, Nos. 62128, 62129, U.S.N.M., from Renfrew, Canada.) It also occurs as a crystalline granular rock mass. (Specimens, Nos. 62137, 62148, 65111, U.S.N.M.) The hardness is 4.5 to 5; specific gravity, 3.23; luster, vitreous. Apatite in the form of minute crystals is an almost universal constituent of eruptive rocks of all kinds and all ages. It is also found in sedimentary and metamorphic rocks as a constituent of veins of various kinds, and is a common accompaniment of beds of magnetic iron ore. It is only when occurring segregated in veins and pockets, either in distinct crystals or as massive

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[1] Bulletin No. 46 of the U. S. Geological Survey.

[2] Fuchs (Notes Sur la Constitution des Gites Phosphate de Chaux) divides the natural phosphates into three classes. In the first the phosphatic material is concentrated in sedimentary beds; in the second it is disseminated throughout eruptive rocks, and in the third it constitutes entirely or partially the material filling veins and pockets. That found in sedimentary beds occurs in rounded and concretionary masses called nodules. In eruptive and metamorphic rocks the phosphate occurs in the crystalline form of apatite, sometimes isolated or grouped in aggregates. In veins the phosphate occurs massive and in pockets, crystalline, but not in distinct crystals; rather as globular and radiating masses. To such the name phosphorite is given. The three varieties show a like variation in solubility, the amorphous phosphates being soluble in citrate or oxalate of ammonia to the extent of 30 to 50 per cent; the phosphorites to the extent of only 15 to 30 per cent, and the apatite scarcely at all. The amorphous phosphates alone have proven of value for direct application to soils, the other varieties needing previous treatment to render them soluble.

crystalline aggregates, as in Canada and Norway, that the material has any great economic value. The average composition of the apatites, as given in the latest edition of Dana's Mineralogy, is as follows:

Variety.	P_2O_5	CaO	F.	Cl.	
Chlor-apatite	41.0	53.8	....	6.8	or $Ca_3P_2O_8$ 89.4 + CaCl, 10.6.
Fluor-apatite	42.3	55.5	3.8	......	or $Ca_3P_2O_8$ 92.25 + CaF_2 7.75.

The name *phosphorite* covers a material of the same composition as apatite, but occurring in massive concretionary and mammilary forms. (Specimens No. 37147, U.S.N.M., from Spain and 66741, U.S.N.M., from Florida). The name was first used by Kirwan in describing the phosphates of Estremadura, Spain, which occur in veins and pockety masses in Silurian schists, as noted later.

Rock phosphate.—The general name of rock phosphate is given to deposits having no definite composition but consisting of amorphous mixtures of phosphatic and other mineral matter in indefinite proportions. Here would be included the amorphous nodular phosphates like those of our Southern Atlantic States (Specimens Nos. 34322, 44244, 66737, U.S.N.M.), phosphatic limestones and marls (Specimens Nos. 62718, U.S.N.M., Africa, and 62723 Utah), guano (Specimen No. 69281, U.S.N.M.), and bone bed deposits (Specimens Nos. 66581, 67332, U.S.N.M.). These are so variable in character that no satisfactory description of them as a whole can be given. The name *coprolite* is given to a nodular phosphate such as occurs among the Carboniferous beds of the Firth of Forth in Scotland, and which is regarded as the fossilized excrement of vertebrate animals. (Specimen No. 62731, U.S.N.M.) Phosphatic limestones and marl, as the names denote, are simply ordinary limestones and marls containing an appreciable amount of lime in the form of phosphate. Such are rarely sufficiently rich to be of value except in the immediate vicinity, owing to cost of transportation. Guano is the name given to the accumulations of sea-fowl excretions, such as occur in quantities only in rainless regions, as the western coast of South America. The most noted deposits are on small islands off the coast of Peru. The material is of a white-gray and yellowish color, friable, and contains some 20 or more per cent of phosphate of lime, 10 to 12 per cent of organic matter, 30 per cent ammonia salts, and 20 per cent of water. Through prolonged exposure to the leaching action of meteoric waters, like deposits in the West India Islands have lost all their ammonia salts and other soluble constituents and become converted into insoluble phosphates, or leached guanos like those of the Navassa Islands. (Specimen No. 73243, U.S.N.M., to be noted later; and also specimens from the Grand Connetables, French Guiana, Nos. 73069 to 73075, U.S.N.M., and Redonda Nos. 53147 to 53152, U.S.N.M.)

Origin and occurrence.—The origin of the various forms of phosphatic deposits has been a subject of much speculation. Their occurrence under diverse conditions renders it certain that not all can be traced to a common source, but are the result of different agencies acting under the same or different conditions. By many, all forms are regarded as being phosphatic materials from animal life, and owing their present diversity of form to the varying conditions to which they were at the time of formation or have since been subjected. This, however, as long since pointed out, is an uncalled-for hypothesis, since phosphatic matter must have existed prior to the introduction of animal life, and there is no reason to suppose it may not, under proper conditions, have been brought into combination as phosphate of lime without the intervention of life in any of its forms. The almost universal presence of apatite in small and widely disseminated forms in eruptive rocks of all kinds and all ages would seem to declare its independence of animal origin as completely as the pyroxenic, feldspathic, or quartzose constituents with which it is there associated. The occurrence of certain of the Canadian apatites as noted later, in veins and pockets, sometimes with a banded or concretionary structure and blending gradually into the country rock, is regarded by some as strongly suggestive of an origin by deposition from solution, that is, by a process of segregation of phosphates from the surrounding rock contemporaneously with their metamorphism and crystallization.

Dr. Ells, of the Canadian survey, would regard those occurring in close juxtaposition with eruptive pyroxenites as due to combination of the phosphoric acid brought up in vapors along the line of contact with the calcareous materials in the already softened gneisses. This explanation as well as others will perhaps be better understood in the part of this work relating to localities. On the other hand, the presence of apatite in crystalline form associated with beds of iron ore, as in northern New York, has been regarded by Prof. W. P. Blake and others as indicative of an organic and sedimentary origin for both minerals. The Norwegian apatite from its association with an eruptive rock (gabbro) has been regarded as itself of eruptive origin.

The phosphorites, like the apatites, occur in commercial quantities mainly among the older rocks, and in pockets and veins so situated as to lead to the conclusion that they are secondary products derived by a process of segregation from the inclosing material. Davies regards the Bordeaux phosphorites occurring in the Jurassic limestones of southern France as the result of phosphatic matter deposited on the rocky floor of an Eocene ocean, from water largely impregnated with it. Others have considered them as geyserine ejections, or due to infiltration of water charged with phosphatic matter derived from the bones in the overlying clays. Stanier, on the other hand, regards the phosphorites of Portugal as due to segregation of phosphatic matter from the surrounding granite, the solvent being meteoric waters. These deposits are regarded as superficial and limited to those portions of the rock affected by surface waters.

The origin of the amorphous, nodular, and massive rock phosphates can, as a rule, be traced more directly to organic agencies. All things considered, it seems most probable that the phosphatic matter itself was contained in the numerous animal remains, which, in the shape of phosphatic limestones, marls, and guanos, have accumulated under favorable conditions to form deposits of very considerable thickness. Throughout these beds the phosphatic matter would, in most cases, be disseminated in amounts too sparing to be of economic value, but it has since their deposition been concentrated by a leaching out by percolating waters of the more soluble carbonate of lime. Thus H. Lösne, in writing of the nodular phosphates occurring in pockety masses in clay near Doullens (France), argues that the nodules as well as the clay itself are due to the decalcification of preexisting chalk by percolating meteoric waters.

In this connection it is instructive to note that phosphatic nodules, in size rarely exceeding 4 to 6 cm., were dredged up during the *Challenger* expedition from depths of from 98 to 1,900 fathoms on the Agualhas Banks, south of the Cape of Good Hope. These are rounded and very irregular capricious forms, sometimes angular and have exteriorly a glazed appearance, due to a thin coating of oxides of iron and manganese. The nodules yield from 19.96 to 23.54 per cent P_2O_5. In those from deep water there are found an abundance of calcareous organic remains, especially of rhizopods. The phosphate penetrates the shell in every part, and replaces the original carbonate of lime.

The nodules are most abundant apparently where there are great and rapid changes of temperature due to alternating warm and cold oceanic currents, as off the Cape of Good Hope and eastern coast of North America. Under such conditions, together with perhaps altered degrees of salinity, marine organisms would be killed in great numbers, and by the accumulation of their remains would, it is believed, furnish the necessary phosphatic matter for these nodules. It seems probable that the Cretaceous and Tertiary deposits in various parts of the world may have formed under similar conditions.

Hughes has described[1] phosphatic coralline limestones on the islands of Barbuda and Aruba (West Indies), as having undoubtedly originated through a replacement of their original carbonic by phosphoric acid, the latter acid being derived from the overlying guano. The phosphatic guano has, however, now completely disappeared through the leaching and erosive action of water, leaving the coral rock itself containing 70 to 80 per cent phosphate of lime.

Hayes[2] regards the Tennessee black phosphates (Specimens Nos.

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[1] Quarterly Journal of the Geological Society of London, XLI, 1885, p. 80.

[2] Sixteenth Annual Report of the U. S. Geological Survey, 1894–95, Pt. 4, p. 620; Seventeenth Annual Report U. S. Geological Survey, 1895–96, Pt. 2, p. 22.

62574 and 62781, U.S.N.M.) as due to the slow accumulation on sea bottoms of phosphatic organisms (Lingulæ), from which the carbonate of lime was gradually removed by the leaching action of carbonated waters, leaving the less soluble phosphate behind. The white bedded phosphates of Perry County (Specimen No. 52060, U.S.N.M.), in the same State, are regarded as a product of secondary replacement—that is, as due to phosphate of lime in solution, replacing the carbonate of lime of preexisting limestones, as in the case noted above. The source of the phosphoric acid, whether from the overlying Carboniferous limestones or from the older Devonian and Silurian rocks, is not, however, in this case apparent.

Teall has shown[1] that some phosphatic rocks from Clipperton Atoll, in the northern Pacific, are trachytes in which phosphoric acid has replaced the original silica. The replacement he regards as having been effected through the agency of alkaline (principally ammonium) phosphate which has leached down from overlying guano. A microscopic examination of the rock in thin sections showed that the replacing process began with the interstitial matter, then extended to the feldspar microlites, and lastly the porphyritic sanidin crystals. The gradual change in the relative proportion of silica and phosphoric acid, as shown by analyses of more or less altered samples, is shown below, No. I being that of the unaltered rock and II and III of the altered forms:

Constituents.	I.	II.	III.
SiO_2	54.0	43.7	2.8
P_2O_5	8.4	17.0	38.5
Loss on ignition	3.8	12.3	23.0

From a comparison of these rocks with those of Redonda, in the Spanish West Indies, it is concluded that the latter phosphates have likewise resulted from a similar replacement in andesitic rocks. (Specimens Nos. 53148 to 53152, U.S.N.M.) In this connection reference is made to the work of M. A. Gautier,[2] in which he describes the formation of aluminous phosphates in caves through the action of the ammonium phosphate arising from decomposing organic matter on the clay of the floor of caverns. (See under Occurrences.)

The guanos, as noted elsewhere, owe their origin mainly to the accumulations of sea-fowl excretions. Such deposits when unleached, are relatively poor in phosphatic matter and rich in salts of ammonia. Where, however, subjected to the leaching action of rains the more soluble constituents are carried away, leaving the less soluble phosphates, together with impurities, in the shape of alumina, silica, and iron oxides to form the so-called leached guanos of the West India Islands. As stated in the descriptions of localities, guano deposits are

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[1] Quarterly Journal of the Geological Society of London, LIV, 1898, p. 230.

[2] Formation des Phosphates Naturels d'Alumina et de Fer, Comptes Rendus de l'Academie des Sciences, Paris, CXVI, 1893, p. 1491.

not infrequently of a thickness such as to cause their origin as above stated to seem well-nigh incredible were there not sufficient data acquired within historic times to demonstrate its accuracy beyond dispute. Thus it is said[1] that in the year 1840 a vessel loaded with guano on the island of Ichabo, on the east coast of Africa. During the excavations which were necessary the crew exhumed the dead body of a Portuguese sailor, who, according to the headboard on which his name and date of burial had been carved with a knife, had been interred fifty-two years previously. The top of this headboard projected 2 feet above the original surface, but had been covered by exactly 7 feet of subsequent deposit of guano. That is to say, the deposition was going on at the rate of a little over an inch and a half yearly.

LOCALITIES OF PHOSPHATES.

Canada.—According to Dr. Ells, of the Canadian Survey,[2] the discovery of apatite in the Laurentian rocks of eastern Canada was first made in the vicinity of the Lievre by Lieutenant Ingall in 1829, though it was not until early in 1860 that actual mining was begun. The mineral occurs in the form of well-defined crystals in a matrix of coarsely crystalline calcite (Specimen No. 67942, U.S.N.M.) and in vein-like and pockety granular masses along the line of contact between eruptive pyroxenites and Laurentian gneisses. The first form is the predominant one for Ontario only, the second for Quebec. From a series of openings made at the North Star Mine, in the region north of Ottawa, it appears that the massive coarsely crystalline granular apatite follows a somewhat regular course in the pyroxenite near the gneiss, but occurs principally in a series of large bunches or chimneys connected with each other by smaller strings or leaders. Sometimes these pockety bunches of ore are of irregular shape and yield hundreds of tons, but present none of the characteristics of veins, either in the presence of hanging or foot walls, while many of the masses of apatite appear to be completely isolated in the mass of pyroxene, though possibly there may have been a connection through small fissures with other deposits. The lack of any connection between these massive apatites and the regularly stratified gneiss is evident, and their occurrence in the pyroxene is further evidence in support of the view that these workable deposits are not of organic origin, but confined entirely to igneous rocks. In certain cases where a supposed true-vein structure has been found, such structure can be explained by noticing that the deposits of phosphates occur, for the most part at least, near the line of contact between the pyroxene and the gneiss.

By far the greater part of the Canadian apatite thus far mined has been from the Ottawa district of Quebec, where it is mined or quarried mainly from open cuts and shafts. The principal fields lie in

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[1] R. Ridgway, Science, XXI, 1893, p. 360.

[2] The Canadian Mining and Mechanical Review, March, 1893.

Ottawa County, Province of Quebec (Specimen No. 62157, U.S.N.M.) and Leeds, Lanark (Specimens Nos. 62136, 62137, U.S.N.M.), Frontenac (Specimen No. 62148, U.S.N.M.), Addington, and Renfrew (Specimen No. 62130, U.S.N.M.) counties, Province of Ontario. The first consists of a belt running from near the Ottawa River on the south for over 60 miles in a northerly direction through Buckingham, Portland, Templeton, Wakefield, Denholm, Bowman, Hincks, and other townships to the northward have an average width of 15 to 25 miles. The second belt runs from about 15 miles north of the St. Lawrence River in a northerly direction to the Ottawa River, a distance of about 100 miles, and varies from 50 to 75 miles in breadth.

Davies gives the following table as showing the average composition of the Canadian phosphates:

Constituents.	I.	II.	III.	IV.	V.	VI.
Moisture, water of combination, and loss on ignition.	0.62	0.10	0.11	1.09	0.89	1.83
Phosphoric acid	33.51	41.54	37.68	30.84	32.53	31.87
Lime	46.14	54.74	51.04	42.72	44.26	43.62
Oxide of iron, alumina, fluorine, etc	7.83	3.03	6.88	13.32	12.15	9.28
Insoluble siliceous matter	11.90	0.59	4.29	12.03	10.17	13.50
	100.00	100.00	100.00	100.00	100.00	100.10
Equal to tribasic phosphate of lime	73.15	90.68	82.25	67.32	71.01	69.35

Norway.—The principal apatite fields lie along the coast in the southern portion of the peninsula between Langesund and Arendal. The material occurs in crystals and crystalline granular aggregates of a white, yellow, greenish, or red color in veins and pockets embedded in the mass of an eruptive gabbro, near the line of contact of the gabbro and adjacent rocks, in the country rock itself in the immediate vicinity of the gabbro, and in coarse pegmatitic veins which are cut by the gabbro. The largest veins are in the mass of the gabbro itself or near the line of contact. Where the apatite occurs in the gabbro the latter is as a rule altered into a hornblende scapolite rock. The principal associated minerals are quartz, mica, tourmaline, scapolite, feldspars, rutile, and magnetic and titanic iron and sulphides of iron and copper. The country rock is gneiss, schist, and granite. The mineral belongs to the variety called fluor apatite, as shown by the following analysis from Dr. Penrose's Bulletin:

Apatite from Arendal.

Phosphoric acid (P_2O_5) (1)	42.229
Fluorine (2)	3.415
Chlorine (3)	0.512
Lime (CaO)	49.96
Calcium	3.884
	100.000

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[1] Equal 92.189 per cent tribasic phosphate.

[2] Equal 7.01 per cent fluoride of calcium.

[3] Equal 0.801 per cent chloride of calcium.

The Norway apatites have been mined according to Penrose since 1854, the earliest workings being at Kragerö. According to Davies, however, the discovery of deposits that could be profitably worked dates only from 1871. The distribution of the material is very uncertain and irregular, and the value of the deposits can not be foretold with any great approximation to accuracy. Specimen No. 65122, U.S.N.M., is characteristic. The large specimen on floor of hall, weighing nearly 2 tons, shows well the massive character of the material.

A second locality of phosphates but recently described, and which seems to occur under somewhat similar conditions, exists in the Gellivara Mountains, in Norrland.

Nodular phosphatic deposits are described by Penrose[1] as being found at intervals all along the Atlantic coast of the United States, from North Carolina down to the southern extremity of Florida. The North Carolina deposits occur principally in the counties of Sampson, Duplin, Pender, Onslow, Columbus, and New Hanover, all in the southeastern part of the State. The deposits are of two kinds, (1) a nodular form overlying the Eocene marls and consisting of phosphate nodules, sharks' teeth (Specimen No. 73643, U.S.N.M.), and bones as embedded in a sandy or marly matrix, and (2) as a conglomerate of phosphate pebbles, sharks' teeth, bones, and quartz pebbles, all well rounded and cemented together along with grains of green sand in a calcareous matrix. (Specimen No. 44244, U.S.N.M.)

The beds of the first variety usually overlie strata of shell marl, though this is sometimes replaced by a pale green indurated sand. The two following sections will serve to illustrate their mode of occurrence:

SAMPSON COUNTY.

(1) Soil, sand or clay, 5 to 10 feet.
(2) Shell marl, 5 to 10 feet.
(3) Bed with phosphate nodules, 1 to 3 feet.
(4) Sea green, sandy marl, 2 to 4 feet.
(5) Ferruginous hardpan, 6 to 12 inches.
(6) Interstratified lignites and sands as in (4).

DUPLIN COUNTY.

(1) Sandy soil, 1 to 10 feet.
(2) Nodule bed, 1 to 2 feet.
(3) Shell marl.

The nodules as described are of a lead gray color, varying in size from that of a man's fist to masses weighing several hundred pounds. In texture they vary from close compact and homogeneous masses to coarse-grained and highly siliceous rocks distinguished by considerable quantities of sand and quartz pebbles sometimes the size of a chestnut. Occasionally the nodules, which as a rule are of an oval flattened form,

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[1] Bulletin 46 of the U. S. Geological Survey, 1888.

contain Tertiary shells (Specimens Nos. 44244 and 34318, U.S.N.M.). The second or conglomerate variety occurs mainly in New Hanover and Pender counties, the beds in some instances being 6 feet in thickness, though usually much less. The following section, taken like those above from Dr. Penrose's Bulletin, shows their position and association as displayed at Castle Hayne, New Hanover County.

(1) White sand, 0 to 3 feet.
(2) Brown and red ferruginous sandy clay, or clayey sand, 1 to 3 feet.
(3) Green clay, 6 to 12 inches.
(4) Dark brown indurated peat, 3 to 12 inches.
(5) White calcareous marl, 0 to 2 feet.
(6) White shell rock, 0 to 14 inches.
(7) Phosphatic conglomerate, 1 to 3 feet.
(8) Gray marl containing smaller nodules than the overlying beds, 2½ to 4½ feet.
(9) Light-colored, calcareous marl, containing nodules which are smaller than those in the overlying beds, which grow fewer and smaller at a depth. Many shells.

The phosphatic nodules in this conglomerate are kidney and egg shaped as sometimes make up as much as three-fourths the contents of a bed; usually, however, the proportion is smaller, and sometimes there are none at all. The mass as a whole does not contain more than 10 to 20 per cent phosphate of lime, but it is said to have been successfully used as a fertilizer. The individual may be richer in phosphatic matter on the outer surface than toward the center.

Aside from the phosphatic layer as described above, phosphatic nodules are found in large quantities in the beds of rivers of these districts, where they have accumulated through the washing action of flowing water, the finer sand clay and gravel having been carried away. Such phosphates naturally do not differ materially from those on land except that they are darker in color and sometimes more siliceous.

The deposits of South Carolina, though of low grade compared with some others, are now more generally used than any other known phosphate. The output of the mines, which is yearly increasing, is shipped to the North, South, and East by sea and to the West by rail. This popularity is due not only to the cheapness of the phosphate ($5 to $6 a ton in 1886), but to the many good qualities of the low-grade acid phosphate made from it. The fact that the nodule bed extends, at an accessible depth, over many miles of country, the easy approach for large vessels up to the very mines, the abundance of water, fuel, and labor, and a climate that permits mining operations to be carried on throughout the whole year, all combine to make the South Carolina phosphates the cheapest and consequently the most productive source of supply of this material. Specimens Nos. 34317 and 34318, 34321 to 34324, and 34326 to 34328, U.S.N.M. are characteristic.

Phosphates in the form of nodules and phosphatic marls and greensands occur in Alabama in both the Tertiary and Cretaceous formations. Their geographical distribution is therefore limited to areas south of the outcrops of the lowest Cretaceous beds which stretch in a curve from the northwest corner of the State across near Fayette, Courthouse, Tuscaloosa, Centerville, and Wetumpka, to Columbus, Georgia. As all the Cretaceous and Tertiary beds have a dip toward the Gulf of from 25 to 40 feet to the mile, the phosphate-bearing strata appear at the surface only in a comparatively narrow belt along the line above indicated and are to be found only at gradually increasing depths below at points to the southward.

Phosphatic nodules and marls of the Tertiary occur in four different horizons: The Black Bluffs and Nantehala groups of the Lignitic; in the white limestone, and in eastern Alabama, at Ozark, in strata of the Claiborne group. Selected nodules run as high as 27 per cent of phosphoric acid, and marls as high as 6.7 per cent. The Tertiary is not, however, regarded by Professor Smith as a promising source of commercial phosphates in the State. In the Cretaceous the phosphates occur in the transition beds both above and below the so-called Rotten Limestone existing as nodules, shell casts, phosphatic limestones, marls, and greensands. The nodules have essentially the characteristics of those of South Carolina.

The principal phosphate region of Florida, as known to-day, comprises an area extending from west of the Apalachicola River eastward and southward to nearly 50 miles south of Caloosahatchee River, as shown on the accompanying map.[1] According to Mr. Eldridge, the deposits comprise four distinct and widely different classes of commercial phosphates, each having a peculiar genesis, a peculiar form of deposit, and chemical and physical properties such as readily distinguish it from any of the others.

According to their predominant characteristics or modes of occurrence, these classes have come to be known as hard-rock phosphates, soft phosphate, land pebble or matrix rock, and river pebble. With the exception of the soft phosphates, they underlie distinct regions, each class being separate or but slightly commingling with one another. The type of the hard-rock phosphate, as described by Mr. Eldridge, is a hard, massive, close-textured homogeneous, light-gray rock, showing large and small irregular cavities, which are usually lined with secondary mammillary incrustations of phosphate of lime (Specimens Nos. 66737, 66741, U.S.N.M.), the general appearance being that of the calcareous deposits of the preglacial hot springs of the Yellowstone National Park.

There are numerous variations in color and physical characteristics from this type, but which can best be comprehended by a study of the collection. This type carries some 36.65 per cent phosphoric anhydride (P_2O_5). The deposits of the hard-rock phosphate lie in Eocene and Miocene strata, occurring in the first named as a bowlder

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[1] Preliminary sketch of Phosphates of Florida, by George H. Eldridge.

MAP SHOWING PHOSPHATE REGIONS OF FLORIDA
After George H. Eldridge.

deposit in a soft matrix of phosphatic sands, clays, and other material, resulting from the disintegration of the hard rock and constituting the soft phosphates. The deposits underlie sands of from 10 to 20 feet in thickness, and have been penetrated to a depth of 60 feet. The phosphate deposit proper is white, the bowlders of rounded and irregular outline, varying in diameter from 2 or 3 inches to 10 feet. None of the hard-rock deposits of the Eocene originated in the positions they now occupy. The Miocene hard-rock phosphates, on the other hand, lie in regular bedded deposits in situ, as well as in bowlders. The beds lie horizontal but a few feet below the surface, being covered only by superficial sand. The beds as a rule are but from 4 feet to 5 feet thick. The name soft rock, or soft phosphate, as above indicated, is given to the softer material associated with the hard rock, which in part results from the disintegration of the last named. It is also applied somewhat loosely to any variety not distinctly hard. It therefore varies greatly in color, chemical and physical characteristics, and rarely carries more than 20 to 25 per cent of P_2O_5 (Specimens Nos. 67304, 67319, 67293, 67296, 67297, U.S.N.M.).

The name land-pebble phosphate includes pebble from deposits consisting of either earthy material carrying fossil remains, grains of quartz, and pisolitic grains of lime phosphate, or else of a material resembling in texture and other characteristics the hard-rock phosphate. The individual pebbles vary in size up to that of the English walnut, are normally white, but when subjected to percolating water become dark gray or nearly black. The exteriors are quite smooth and glossy, colors and textures uniform, and average some 30 to 35 per cent P_2O_5 (Specimen No. 61070, U.S.N.M.).

The river-pebble varieties differ from the last mainly in mode of occurrence, being found, as the name would indicate, in the beds of streams, where presumably they have accumulated through the washing away of finer and lighter materials. They are most abundant in the Peace, Caloosahatchee, Alafia, and other rivers entering the Gulf south of Tampa and Hillsborough bays, though the Withlacoochee, Aucilla, and rivers of the western part of the State, carry also a mixture of pebbles, hard-rock fragments, and bones derived from the various strata through which they have cut their channels. The pebbles of the Western rivers show a very uniform composition, and range from 25 to 30 per cent phosphoric anhydride (P_2O_5), or about 65 per cent of phosphate of lime, the impurities being mainly siliceous matter, carbonate of lime, alumina, and iron oxides (Specimens Nos. 67299, 67298, 67355, U.S.N.M.).

Phosphates the mineralogical nature of which does not seem to be as yet accurately made out occur in the Devonian Shales of Middle Tennessee. They are thus described by Professor Safford:[1]

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[1] Engineering and Mining Journal, LVII, April 21, 1894, p. 366.

There are two distinct beds of the phosphates, one above a stratum known as the black shale; the other below the shale. The one above is a bed or layer of concretionary masses, balls, and kidney and knee-shaped forms from the size of walnuts to that of a man's head (Specimen No. 52059 from Hickman County). These are sometimes loosely disposed in a greenish or bluish shale. and sometimes tightly packed together like so many cannon balls in a layer 8 or 10 inches thick. Ordinarily the layer has less thickness, often, in fact, being represented by only a few scattered concretions. But, thick or thin, it may be said to be universally present, its kidneys serving to indicate the place of the black shale and the underlying bed when these are concealed by débris or soil.

The other phosphate, that underlying the shale, and the more important of the two, is, in its best presentations, a well-defined, continuous stratum of dark-bluish or bluish-black—rarely grayish—rock, with fine or coarse grain. Its regularly stratified character and its dark color make it look like a bed of stone coal.

The geographical distribution and general geology of these phosphates has been worked out in considerable detail by C. W. Hayes, to whose papers reference has been already made (p. 360). According to this authority the phosphates occur in four distinct varieties: (1) Black nodular phosphate; (2) black bedded phosphate; (3) white breccia phosphate, and (4) white bedded phosphate. The first two of these are of Devonian age, the third is a secondary and comparatively recent deposit, while the fourth, perhaps also of secondary origin, is interbedded with rocks of Carboniferous age. The black nodular variety contains from 60 to 70 per cent of phosphate of lime, and is found in commercial quantities only in the region of the black bedded phosphate in western middle Tennessee. The black bedded variety, which is the only one that has thus far proved of commercial importance, is confined, so far as at present known, "to an oval area southwest of Nashville, having Centerville about in its center." It also covers portions of Hickman, Williamson, Maury, Lewis, Wayne, Perry, and Decatur counties.

Sections showing the relation of the phosphates to the adjacent formations are given in Dr. Hayes's paper. The beds vary in thickness from a fraction of 1 to 8 or 10 feet, the average run of the rock being about 50 per cent phosphate of lime. The white bedded and white breccia phosphates are limited to small areas in Perry County. Their contents of phosphoric acid (P_2O_5) is low, varying from 14 to 15 per cent, and as yet their value for other than local purposes is to be determined. (See especially Specimens Nos. 52058, 52060, 52061, U.S.N.M.)

England.—Deposits of phosphates sufficiently concentrated for commercial purposes lie near the upper limit of Cambro-Silurian strata in North Wales. According to Davies, the phosphatic material occurs in the form of nodular concretions of a size varying from that of an egg to a cocoanut, closely packed together and cemented by a black slaty matrix. The concretions have often a black highly polished appearance, due to the presence of graphite, but owing to the presence of oxidizing pyrite they sometimes become rusty brown. The concretions carry from 60 to 69 per cent of phosphate of lime; the matrix is also phosphatic. The phosphate beds are highly tilted and are overlaid by gray shales with fossilized echinoderms and underlaid by dark crystalline limestone, which also contains from 15 to 20 per cent of phosphatic material. Davies regards the deposit as an old sea bottom "on which the phosphatic matter of Cretaceous and Molluscan life was precipitated and stored during a long period, while certain marine plants may also have contributed their share of phosphatic matter. He thinks it also as possible that, as in the Laurentian deposits, the water of the sea may have contained phosphatic matter in solution, to be deposited independently of organic agencies.

These phosphated beds are mined at Berwin, where an average production over a space of 360 fathoms was 2 tons 10 hundredweight of phosphate per fathom, of an average strength of 46 per cent.

The nodules average from 45 to 55 per cent of phosphate of lime.

Amorphous nodular phosphates also occur in both the Upper and Lower Greensands of the Cretaceous and in Tertiary deposits. Those of the upper beds have been mined in Cambridgeshire and Bedfordshire. The phosphatic material occurs in the form of shell casts, fossils, and nodules, of a black or dark-brown color, of varying hardness, embedded in a sand consisting of siliceous and calcareous matter as well as phosphatic and glauconitic grains. The average composition shows from 40 to 50 per cent of phosphate of lime. The thickness of the nodule-bearing bed is rarely over a foot. The nodules of the Lower Greensands differ from those of the Upper in many details, the more important being their lower percentages of phosphate of lime (from 40 to 50 per cent). They occur in a bed of siliceous sand which itself is not phosphatic. The Tertiary phosphates reach their best development in the county of Suffolk, where they are found at the base of the Coralline and Red Crog groups and immediately overlying the London clays. The beds consist of a "mass of phosphatic nodules and shell casts, siliceous pebbles, teeth of cetaceans and sharks, and many mammal bones, besides occasional fragments of Lower Greensand chert, granite, and chalk flints." The nodules vary in both quality and quantity. They are at times of a compact and brittle nature, while at others they are tough and siliceous. They average about 53 per cent phosphate of lime and 13 per cent phosphate of iron.

France.—Phosphates of the nodular type occur in beds of Cretaceous age in the provinces of Ardennes and Meuse, and to a less extent in others in northern France; in the department of Cote d'Or, and along the Rhone at Bellegarde, Seyssel, and Grenoble. As in England, the phosphatic nodules of the northern area, such as are of commercial importance, occur in both the Upper and Lower Greensands. They resemble in a general way the English phosphates, but are described as soft and porous and easily disintegrating when exposed to the air. Those of the Upper Greensand average some 55 per cent of phosphate of lime.

More recently deposits have been described by M. J. Gosselet,[1] near Fresnoy-le-Grand, in the north of France. The phosphatic material occurs in a zone of gray chalk some 6 feet in thickness (1½ to 2 meters), and is in the form of concretionary nodules forming a sort of conglomerate in the lower part of the bed. A portion of the chalk is also phosphatic. Phosphatic material (of the type of phosphorites) is found in fissures and pockets in the upper portion of limestones of Middle Jurassic (Oxfordian) age, in the departments of Tarn-et-Garonne, Aveyron, and Zoti, France.

The deposits are of two kinds. The first occurring in irregular cavities or pockets never over a few yards long, and the second in the form of elongated leads with the sides nearly vertical. These are generally shallow, and thin out very rapidly at a short distance below the surface.

The nodules or concretions are of a white or gray color, waxy luster, and opal-like appearance, and occur in the form of tubercular or kidney shaped masses embedded in ferruginous clay in the clefts of the limestone, or in geodic, fibrous, and radiating forms.

The material of this region is known commercially as Bordeaux phosphate, being shipped mainly from Bordeaux. They average from 70 to 75 per cent phosphate of lime, the impurities being mainly iron oxides and siliceous matter.

Gautier[2] describes deposits of phosphates estimated to the amount of 120,000 to 300,000 tons on the floors of the Grotte de Minerve, near the village of Minerve on the northeast flank of the Pyrenees, in Aude, France. The cave proper is in nummulitic limestone of Eocene age, the floors being formed by Devonian rocks. The filling material consists of cave earth and bone breccia below which are the aggregates of concretionary phosphorites and other phosphatic compounds of lime and alumina, the more interesting being *Brushite*, a hydrous tribasic calcium phosphate hitherto known only as a secondary incrustation on guano from the West India islands, and *Minervite*, a new species having the formula Al_2O_3. P_2O_5, $7H_2O$, a hydrous aluminum phosphate, existing in the form of a white plastic clay-like mass filling a vein from a few inches to 2 or more feet in thickness.

Germany.—According to Davies, the principal phosphate regions of

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[1] Annales de la Société Géologique du Nord., XXI, 1893, p. 149.

[2] Annals des Mines, V, 1894, p. 5.

North Germany occupy an irregular area bounded on the northeast by the town of Weilburg, on the northwest by the Westerwald, on the east by the Taunus Mountains, and on the south by the town of Dietz. The phosphorite occurs in the form of irregular nodular masses of all sizes up to masses of several tons weight, embedded in clay which rests upon Devonian limestone and is overlaid by another stratum of clay. The phosphate-bearing clay varies in thickness from 6 inches to 10 feet. With the phosphate nodules are not infrequently associated deposits of manganese and hematite. Davies regards the deposits as of early Tertiary age. The color of the freshly mined material varies from pale buff to dark brown, varying in specific gravity from 1.9 to 2.8, the quality deteriorating with the increase in gravity. Selected samples of the staple nodules yielded as high as 92 per cent phosphate of lime; but the average is much lower, being but about 50 to 60 per cent phosphate of lime. (Specimens Nos. 66827, 66828, U.S.N.M., from Gleisenberg and Heckholzhausen.)

Belgium.—Nodular phosphates belonging to the Upper Cretaceous formations occur in the province of Hainaut, where they form the basis of an extensive industry. The nodules, which are generally of a brown color and vary in size from the fraction of 1 to 4 or 5 inches in diameter, lie in a coarse-grained, friable rock called the brown or gray chalk, which itself immediately underlies what is known as the Cipley conglomerate. The phosphate-bearing bed is sometimes nearly 100 feet in thickness, but is richest in the upper 10 feet, where it is estimated the phosphatic pebbles constitute some 75 per cent of its bulk. Below this the bed grows gradually poorer, passing by gradations into the white chalk below.

The overlying conglomerate also carries phosphate nodules, which carry from 25 to 50 per cent phosphate of lime. Owing to the hardness of the inclosing rock they are less mined than those in the beds beneath. The mining of phosphates is carried on extensively near the town of Mons, on the lands of the communes of Cuesmes, Ciply, Mesvin, Nouvelles, Spiennes, St. Symphorien, and Hyon. The annual output has gradually increased from between 3,000 and 4,000 tons in 1887 to 85,000 tons in 1894. Other phosphatic deposits are described[1] as occurring in the provinces of Antwerp and Liege.

Spain.—Important deposits of phosphorites occur between Logrosan and Cáceres, in Estremadura Province. The deposits are in the form of pockets and veins in slates and schists supposed to be of Silurian age; at times a vein is found at the line of contact between the slate and granite. The veins vary in thickness from 1 to several feet, the largest being some 20 feet and extending for over 2 miles. This is by

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[1] Annales de la Société Géologique de Belgique, XVII, 1890, p. 185.

far the largest of its kind known. As described by Penrose, the "Logrosan phosphate has a subcrystalline structure; some specimens are fibrous and radiating and often resemble feathers. [See Specimen No. 44277, U.S.N.M.]. It is soft and chalky to the touch, easily broken, but difficult to grind into a fine powder. An examination under the microscope exhibits conchoidal figures, interrupted with spherical grains, devoid of color and opaque. (Shepard.)

"The highest-grade material is rosy white or yellowish white in color, soft, concentric, often brilliantly radiated, with a mammillary or conchoidal surface. Red spots from iron and beautiful dendrites of manganese are not infrequent. The poorer qualities are milky white, vitreous, hard, and, though free from limestone, contain considerable silica."

In the Cáceres district the phosphorites occur not in veins but rather in pockety masses in veins of quartz and dark-colored limestone, which are found cutting both the granite and slate. (Specimens Nos. 37147, 63779, 63780, U.S.N.M.)

The following analyses from Dr. Penrose's paper show about the average composition of these phosphorites:

Logrosan, by Professor Daubeny.

Silica	1.70
Protoxide of iron	3.15
Fluoride of lime	14.00
Phosphate of lime	81.15

Cáceres, by Bobierre and Friedel.

Insoluble siliceous matter	21.05
Water expelled at a red heat	3.00
Tribasic phosphate of lime	72.10
Loss, iron oxides, etc	3.85

Portugal.—Phosphorites occur in Silurian and Devonian rocks under similar conditions to those of Spain in Estremadura, Alemetjo, and Beira provinces, and which need, therefore, no further notice here. Stanier,[1] however, describes a variety found in pockety and short veinlike masses which are worthy of a passing notice. These occur not in schists and sedimentary rocks but in massive granites. They are found mainly in the superficial portions, where the granite has weathered away to a coarse sand, and in short gashlike veins and pockets of slight width and extent. The phosphatic material is described as of a milk-white color, opaque, and showing when broken open a palmately radiating structure, like hoarfrost upon a window pane. As a rule the masses when found are enveloped in a thin coating of kaolinlike material supposed to be derived by decomposition from the feld-

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[1] Les Phosphorites du Portugal, Annales de la Société Géologique de Belgique, XVII, 1890, p. 223.

spar of the granites. They are mined only from open cuts and in the superficial more or less decomposed portions of the rock, to which they are believed to be mainly limited, having originated, as elsewhere indicated, through a segregation of the phosphatic material dissolved by meteoric waters from the surrounding granite and subsequently depositing it in preexisting fissures. The percentage of tricalcic phosphate is given as varying between 60 and 80 per cent.

Italy.—Phosphatic deposits consisting of coprolites, bones, etc., imbedded in a porous Tertiary limestone occur between Gallipoli and Otranto, Cape Leuca, west of the Gulf of Taranto, on the Italian coast. There are two beds having a thickness of 19½ and 31½ inches, respectively, and which have been traced for a distance of some 160 yards. Analyses show them to be of low grade, rarely carrying as high as 10 per cent P_2O_5.

Tunis.—Phosphatic nodules in the form of cylindrical coprolites and clustered aggregates have been found in Tertiary strata covering considerable areas in the region south of Tunis. The coprolite nodules are stated to carry as high as 70 per cent of calcium phosphate, and the clustered aggregate some 52 per cent.

Russia.—Rich phosphate deposits of Cretaceous age occur in the governments of Smolensk, Orlow, Koursk, and Vorouez, between the rivers Dnieper and the Don in European Russia. The deposits lie mostly in a sandy marl, underlying white chalk and overlying greensands, which also carry beds of from 6 to 12 inches thickness of phosphatic nodules. The nodules are dark, often nearly black, in color and are intermixed with gray, brown, and yellow sands. The depth of the beds below the surface is variable. Yermolow[1] divides the deposits into two groups, the first presenting the form of separate nodules, rounded or kidney-shaped, of variable size, and black, brown, gray, or green in color. The second is in form of an agglomeration of large nodules cemented together into a sort of flag, which used to be quarried for road purposes. The nodules in this agglomerate are richer in phosphoric acid when most dense and of a deep black color, the sandy varieties being comparatively poor. The cement carrying the nodules contains numerous fossil bones, shells, corals, etc., which are also phosphatic. The samples yield about 30 to 60 per cent phosphate of lime. Other deposits occur south of Saratov, on the Volga (Specimen No. 52067, U.S.N.M.); at Tambov and Spask, where the overlying rock is a greensand in place of the chalk; Moscow; east of Novgorod, on the Msta; at Kiev, on the Dnieper; Kamenetz, Podolsk, on the Dniester, and at Grodno, on the Niemen.

Maltese Islands.[2]—Nodular phosphates occur in Miocene beds on the

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[1] Recherches sur les Gisements de Phosphate de Chaux Fossil en Russie.

[2] J. H. Cooke, The Phosphate Beds of the Maltese Island. Engineering and Mining Journal, LIV, 1892, p. 200.

islands of Malta, Gozo, and Comino, of the Maltese group in the Mediterranean Sea. The bed containing the nodules is in what is known as the Globigerina limestone, which underlies an upper coralline limestone, greensands, and blue clays, and overlies the lower coralline limestone. Upper and lower beds all carry phosphoric acid in small amounts. There are four seams of nodules, the first varying in different localities from 9 to 15 inches in thickness. The second is more constant in character, averaging some 2 feet in thickness and consisting of an aggregate of irregularly shaped nodules, intermixed with which are considerable quantities of the phosphatized remains of mollusks, corallines, echinoderms, crustaceans, sharks, whales, etc., the whole being firmly bound together by an interstitial cement, composed of foraminiferal and other calcareous matter similar to that of which the overlying beds are made up. The third seam is the poorest of the lot and consists of two or more thin layers of nodules, none of which exceeds 3 inches in thickness. Between this and the fourth and lowest seam, which is the most important of all, is a bed of rock some 50 to 80 feet in thickness. The seam averages some 3½ feet in thickness. The nodules are of a dark-chocolate color embedded in a calcareous matrix, from which they are freed by calcination. The composition of I, the nodules, and II, the average composition of nodules and interstitial cement, is given below, from analyses by Drs. Murray and Blake:

Constituents.	I.	II.
Sulphate of lime	2.26	1.97
Carbonate of lime	47.14	51.12
Phosphate of lime	38.34	31.66
Alumina (Al_2O_3)	5.98	10.59
Oxide of iron (Fe_2O_3)	Trace.	*a* 3.83
Residue	6.08	*b* 0.87
Total	99.80	100.00

a Silica. *b* Moisture.

GUANO, SOLUBLE AND LEACHED.—The largest and best-known deposits of unleached guanos are found on the mainland and small islands off the coasts of Peru and Bolivia, where abundant animal life and lack of rainfall have contributed to their formation and preservation. These deposits are described as consisting mainly of the evacuations of sea fowl and marine animals, such as flamingoes, divers, penguins, and sea lions. Mixed with these deposits are naturally more or less bone and animal matter furnished by the dead bodies of both birds and mammals. The deposits vary indefinitely in extent and thickness, but have attained in places a depth of upward of 100 feet. As a rule they are more compact beneath than at the surface, but may be readily removed by pick and shovel. The first deposits to be worked are stated by Penrose to have been those of the Chincha Islands, off the Peruvian coast. These were practically exhausted as early as 1872. Other islands which have been worked and completely if not entirely stripped are those of Macabi, Guañape, Ballestas, Lobos, Foca, Pabellon de Pica, Tortuga, and Huanillos.

A mean of 21 analyses of Macabi Island guano, by Barral, as quoted by Penrose,[1] showed:

Nitrogen	10.90
Phosphates	27.60
Potash	2 to 3

Other analyses are given in the following table:

Constituents.	Angamos, coast of Bolivia, white guano.		Bolivian.	Los Patos.	Island of Elide, coast of California.	
Organic matter	70.21 to 52.92		23.00	32.45	27.37 to 34.50	
Containing nitrogen	20.09	14.38	3.38	5.92	1.34	6.98
Equivalent in ammonia	24.36	17.44	4.10	7.18	1.62	8.46
Total phosphates	13.30	20.95	48.60	34.81	[a] 28.00	31.00

Constituents.	Îlot de Pedro-Bey, coast of Cuba.	Mexican coast.		Galapagos, Ecuador.	Falkland Islands.	
Organic matter	6.16	13.05 to 18.00		....	17.35 to 28.68	
Containing nitrogen	0.28	0.21	3.45	0.7	0.56	2.26
Equivalent in ammonia	0.34	0.26	4.19	0.85	0.68	2.74
Total phosphates	48.52	8.00	25.00	60.30	[a] 21.46	25.62

[a] Containing sometimes very considerable quantities of phosphates of alumina and the oxide of iron.

Aside from on the islands, guano is found all along the coast of the Chilean province of Tarapaca, from Carmarones Bay to the mouth of the river Loa, there being scarcely a prominence or rock on the shore that does not contain some guano. According to the Journal of the Society of Chemical Industry,[2] the deposits have been known from a very early date. The aborigines of the valleys and gullies of Tarapaca, Mamina, Huatacondo, Camina, and Quisma were acquainted with the fertilizing qualities of guano, and they conveyed it from the coast to their farms on the backs of llamas.

The southern beds vary so much in aspect and color that it frequently requires an experienced eye to make them out. Many of the deposits are covered with immense layers of sand, while others are buried beneath a solid layer of conglomerate. Guano is also frequently found in the fissures and gullies which descend to the sea-

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[1] Bulletin No. 46 of the United States Geological Survey.

[2] Volume VI, 1887, p. 228.

shore. The richest and largest beds are at Pabellon de Pica, Punta de Lobos, Huanillos, and Chipana.

Aside from the localities above mentioned, guano is found on the islands Itschabo, Possession, Pamora, and Halifax, off the Namagua coast of South Africa. The material is described as forming a grayish brown powder, free from large lumps, and possessing a faint ammoniacal odor. It carries from 8 to 14 per cent of nitrogen and 8 to 12 per cent of phosphoric acid.[1]

The West India Islands.—Phosphates belonging to the class of leached guanos occur in considerable abundance on several of the islands of the West Indies group, the principal localities being Sombrero, Navassa, Turk, St. Martin, Aruba, Curaçao, Orchillas, Arenas, Roncador, Swan, Cat or Guanahani, Redonda, the Pedro and Morant Keys, and the reefs of Los Monges and Aves in Maracaibo Gulf. These, as would naturally be expected from their mode of origin, vary greatly, not merely in appearances, but in chemical composition as well. That of Sombrero is described[2] as occurring in two forms—one a granular, porous, and friable mass of a white, pink, green, blue, or yellow color (Specimen No. 44275, U.S.N.M.); the other as a dense, massive, and homogeneous deposit of a white or yellow color. Many bones occur. The phosphate carries from 70 to 75 per cent phosphate of lime. An analysis as given by Davies[3] is as follows:

Moisture and water of combination	8.92
Phosphoric acid[4]	31.73
Lime	45.69
Carbonic acid[5]	5.99
Oxide of iron and alumina	7.07
Insoluble siliceous matter	.60
	100.00

The Nevassa phosphate is described by D'Invilliers[6] as occurring (1) in the form of a gray phosphate confined to the lower levels of the island, and (2) a red variety occupying the oval flat of the interior. The gray is the better variety, as shown by the analyses below, though both are aluminous, and difficult of manipulation on that account. Both varieties occur in cavities and fissures in the surface of the hard gray, white, or blue limestone, of which the island is mainly composed. These cavities or pockets are rarely more than 4 or 5 yards wide on the surface, and frequently much smaller, and of depths varying from 5 to 25 feet. The deposits, so far as explored, are wholly superficial.

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[1] Journal of the Society of Chemical Industry, I, 1882, p. 29.

[2] R. F. Penrose, Bulletin No. 46 of the U. S. Geological Society.

[3] D. C. Davies, Earthy and Other Minerals, p. 178.

[4] Equal to tribasic phosphate of lime, 69.27 per cent.

[5] Equal to carbonate of lime, 13.61 per cent.

[6] Bulletin of the Geological Society of America, II, 1891, p. 75–89.

Experimental shafts sunk to a depth of 250 feet have failed to bring to light any deeper lying beds.

Analysis of gray Navassa phosphate.

Water, at 100 C	2.33
Organic matter and water of combination	7.63
Lime	34.22
Magnesia	.51
Sesquioxide of iron and alumina	15.77
Potash and soda	.86
Phosphoric acid	31.34
Sulphuric acid	.28
Chlorine	.15
Carbonic acid	1.84
Silica	4.53
Bone phosphate	68.46
Bone phosphate (dry basis)	70.09

Analysis of red Navassa phosphate.

Loss on ignition	14.223
Lime	23.090
Magnesia	Trace.
Sesquioxide of iron	9.796
Alumina	18.425
Phosphoric acid	29.779
Sulphuric acid	1.160
Carbonic acid (by difference)	3.527
Bone phosphate	65.037

Specimens Nos. 10247, 73245–73248, U.S.N.M., show the variable character of the phosphate rock, and Nos. 73242, 73243, U.S.N.M., the associated coral work.

The Aruba phosphate is described as a hard, massive variety of a white to dark-brown color. The underlying corals of this island are sometimes found phosphatized. An analysis given by Davies[1] is as follows:

	Per cent.
Moisture	8.50
Water of combination	4.15
Phosphoric acid[2]	28.47
Lime	34.07
Magnesia	.45
Carbonic acid[3]	2.30
Oxide of iron	4.49
Alumina	9.48
Sulphuric acid	1.81
Insoluble siliceous matter	6.28
	100.00

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[1] D. C. Davies, Earthy and Other Minerals, p. 177.

[2] Equal to tribasic phosphate of lime, 62.15 per cent.

[3] Equal to carbonate of lime, 5.22 per cent.

The Pedro Keys, Redonda, Alta Vela, and some others differ in carrying larger percentages of alumina and iron oxides, necessitating special methods of preparation.

Deposits of leached guano of considerable extent have existed on several islands of the Polynesian Archipelago, in the Pacific Ocean, the better known being those of Bakers, Howland, Jarvis, Malders, Birmie, Phœnix, and Enderbury islands. The deposits are described[1] as varying from 6 inches to several feet in thickness, of a whitish-brown or red color, pulverulent when dry, sometimes in the form of fine powder and again in coarse grains. Though closely compacted, the material can as a rule be readily removed by pick and shovel. The purest varieties are those lying on the unaltered coral limestones, of which the islands are mainly composed. Those lying upon gypsum have become contaminated with sulphate of lime. In places the deposits are covered with a thin crust due to the action of atmospheric agencies. On Jarvis Island a considerable share of the deposit is covered by material of this crust-like character. Such on analysis are found to contain less water and a corresponding higher percentage of lime and phosphoric acid than the loosely compacted material, being indeed, as shown by Mr. Hague, a nearly pure diphosphate of lime. The following analyses show the general character of these guanos from Bakers Island, No. I being freshly deposited and consisting of the dung of the frigate bird (*Pelicanus aquilus*). No. II is a light-colored variety from a deep part of the deposit, and No. III dark guano from a shallow part.

Analyses of guano.

Constituents.	I.	II.	III.
Moisture expelled at 212° F	10.40	2.92	1.82
Loss by ignition	36.88	8.32	8.50
Insoluble in HCl (unconsumed by ignition)	0.78	....	....
Lime	22.41	42.74	42.34
Magnesia	1.46	2.54	2.75
Sulphuric acid	2.36	1.30	1.24
Phosphoric acid	21.27	39.70	40.14
Carbonic acid, chlorine and alkalies, undetermined	4.44	2.48	3.21
Total	100.00	100.00	100.00
Soluble in water remaining after ignition	3.63	....	....

Bat guano.—The dry atmosphere of caves preserves indefinitely the fecal matter of bats and such other animals as may frequent them. Such under favorable conditions may accumulate in sufficient quantities to become of economic importance, being gathered and used as a fertilizer under the name of bat guano. The usual form of the

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[1] J. D. Hague, American Journal of Science, XXXIV, 1862, p. 224.

entrances to caves is, however, such as to make the process of removal tedious and expensive.

Bat guano is, as a rule, dark in color, of a glossy, almost mucilaginous appearance, and quite hard (Specimen No. 53358, U.S.N.M., from Goshen caves, Juab County, Utah). Its composition is shown in the following analysis of a sample from the Wyandotte caves[1] in southern Indiana:

Loss at red heat	44.10
Organic matter	4.90
Ammonia	4.25
Silica	6.13
Alumina	14.30
Ferric oxide	1.20
Lime	7.95
Magnesia	1.11
Sulphuric acid	5.21
Carbonic acid	3.77
Phosphoric acid	1.21
Chloride of alkalies and loss	5.82
	100.00

According to the reports of the State geologist, the caves in the Silurian strata in Burnet County, Texas, are in many instances enormously rich in bat guano. The following description of one of these caves is taken from the report for 1889:

> The bat cave in the northwest corner of Burnet County is worked by a Georgia company, and I learn from the men there that about 157 tons of the material had been shipped up to December 20, 1889. The shipments are made by wagon to Lampasas, Texas, and from there by rail to Georgia and other parts of the United States. The cave is situated about 8 miles from Bluffton, going north up Beaver Creek. Near Lacy Branch, a tributary of Beaver Creek, about 2 miles north of Silver Mine Creek, there is a fault on the west side of Beaver Creek, in a branch which is called "Bat Cave Hollow." Proceeding from this point in a northwest direction for about 2 miles we reach the bat cave, on top of a higher chert bed. The way from Beaver Creek to the cave is constantly ascending, first over Silurian limestone for about 1 mile, when the chert formation appears. On the top of a chert hill there is an opening of about 10 feet in diameter, extending perpendicularly downward for 30 feet, where, at the north side of this opening, there is an entrance to the cave. The cave has not been measured, but I estimate its length from north to south to be about 600 yards, with as much if not more space in the opposite direction. The top of the cave, as well as its sides, is solid chert, such as occurs in all the chert beds in San Saba and all the neighboring counties. The guano bed in the heart of the cave has been burned, leaving the ashes at places 26 feet deep, and not less than 18 feet at others. The ash is not brought up, and the supply of guano is taken from the surrounding portions and sides of the cave. As I understand, there are some leaders to the cave that have not yet been explored, there being plenty of material near the heart of the cave for all present requirements. Five men were employed in digging and bringing out the guano by means of a rail track to the surface, where it is deposited upon a large platform erected for that purpose.

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[1] Geology of Indiana, 1878, p. 163.

Muntz and Marcano[1] have called attention to the extensive deposits of guano, sometimes amounting to millions of tons, in caves in Venezuela and other parts of South America.

According to them the deposits consists not merely of the excreta of the birds and bats which frequent the caves, but also of the dead bodies of these and other animals. The excreta were found to consist almost wholly of the remains of insects. Through the agency of bacteria, nitrification takes place, whereby the organic nitrogen is converted in nitric acid which combines with the lime from the bones or the carbonate of lime in the soils to form nitrates, as described on page 391.

Uses.—The phosphates of the classes thus far described are used wholly for fertilizer purposes. In their natural condition they exist in the form known to chemists as tribasic phosphates—that is a compound in which three atoms of a base mineral, usually calcium, are combined with one of phosphoric anhydride (P_2O_5). Thus the common tribasic phosphate of lime has the formula $(CaO)_3\ P_2O_5$ (= 45.81 parts by weight P_2O_5 and 54.19 CaO). Other bases, as alumina, iron, or magnesia, may partially replace the lime, but the phosphate is always deteriorated thereby. This is particularly the case when aluminum and iron are the replacing constituents. Although when finely ground the tricalcic phosphates are of value for fertilizers, it is customary to first submit them to chemical treatment in order to render them more readily soluble.

This treatment consists, as a rule, in converting them into a superphosphate by treatment with sulphuric acid whereby a portion of the base becomes converted into sulphates and the anhydrous and insoluble tribasic phosphate into a hydrous and soluble monobasic form of the formula $CaO.\ (H_2O)_2.\ P_2O_5$. There are other reactions than those above given, but the process is one too complicated for discussion here, and the reader is referred to especial treatise on the subject.

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2. Monazite.

Composition, a phosphate of cerium metals of the general formula $(Ce, La, Di) PO_4$. Actual analyses as given by Dana yielded results as below:

Constituents.	I.	II.
Phosphoric anhydride (P_2O_5)	29.28	27.55
Cerium sesquioxide (Ce_2O_3)	31.38	29.20
Lanthanum sesquioxide (La_2O_3)	30.88	26.26
Didymium sesquioxide (Di_2O_3)		
Yttrium sesquioxide (Y_2O_3)	....	3.82
Iron sesquioxide (Fe_2O_3)	....	1.13
Silica (SiO_2)	1.40	1.86
Thorina (ThO_2)	6.49	9.57
Lime (CaO)	....	0.69
Ignition	0.20	0.52
Total	99.63	100.60

I Burke County, North Carolina. II Arendal, Norway.

The crystals are commonly minute, often flattened; not uncommonly in form of small cruciform twins. The mineral also occurs in coarse masses yielding angular fragments. Hardness, 5 to 5.5; specific gravity, 4.9 to 5.3. Color, hyacinth-red to brown and yellowish, subtransparent to translucent.

Localities and mode of occurrence.—The common form of occurrence of the mineral is that of minute crystals or crystalline granules disseminated throughout the mass of gneissoid rocks. Owing to their small size they have been very generally overlooked, and it is only where, through the decomposition of the inclosing rock and the concentration of these and the accompanying heavy minerals—as magnetite, garnet, etc.—in the form of sand, that it becomes sufficiently conspicuous to be evident. Prof. O. Derby was the first to point out the widespread occurrence of the mineral as a rock constituent, he having obtained it in numerous and hitherto unsuspected localities by washing the débris from decomposed gneisses of Brazil. Although widespread as a rock constituent and of interest from a mineralogical and petrographical standpoint, only the localities mentioned below have thus far yielded the mineral in commercial quantities.

North Carolina.—The mineral is found in considerable quantities in the form of small brown, greenish, or yellow-brown granules, often rounded by water action, in the gold-bearing sands of Rutherford, Polk, Alexander, Burke, and McDowell counties, and also in the neighborhood of Crowders Mountain, Gaston County, and at Todds Branch, in Mecklenburg County, where it occurs associated with zircons and an occasional diamond. Fine crystals over an inch in length have been found in Mitchell County, and large cleavable masses, sometimes 3 or

4 inches across and of a yellowish-brown color, at Mars Hill, in Madison County. From the gold-bearing sands at Brindleton, Burke County, some 15 tons of sand, containing from 60 to 92 per cent of small crystals, had been obtained prior to 1891.

According to Mr. H. B. Nitze[1] the commercially economical deposits of monazite are those occurring in the placer sands of the streams and adjoining bottoms and in the beach sands along the seashore. The geographical areas over which such workable deposits have been found up to the present time are quite limited in number and extent. In the United States the placer deposits of North and South Carolina stand alone. This area includes between 1,600 and 2,000 square miles, situated in Burke, McDowell, Rutherford, Cleveland, and Polk counties, North Carolina, and the northern part of Spartanburg County, South Carolina. The principal deposits of this region are found along the waters of Silver, South Muddy, and North Muddy creeks, and Henrys and Jacobs Forks of the Catawba River in McDowell and Burke counties; the Second Broad River in McDowell and Rutherford counties; and the First Broad River in Rutherford and Cleveland counties, North Carolina, and Spartanburg County, South Carolina. These streams have their sources in the South Mountains, an eastern outlier of the Blue Ridge. The country rock is granitic biotite gneiss and dioritic hornblende gneiss, intersected nearly at right angles to the schistosity by a parallel system of small auriferous quartz veins, striking about N. 70° E., and dipping steeply to the N.W. Most of the stream deposits of this region have been worked for placer gold. The existence of monazite in commercial quantities here was first established by Mr. W. E. Hidden, in 1879. The thickness of these stream gravel deposits is from 1 to 2 feet, and the width of the mountain streams in which they occur is seldom over 12 feet. The percentage of monazite in the original sand is very variable, from an infinitesimal quantity up to 1 or 2 per cent. The deposits are naturally richer near the headwaters of the streams.

Brazil.—As above noted, the original source of the Brazilian monazite were gneisses from which the mineral has been liberated by decomposition. The particular localities examined by Professor Derby are in the provinces of Minas Geraes, Rio de Janeiro, and São Paulo. The most extensive accumulation thus far reported is in the form of considerable patches on the sea beach near the little town of Alcobaca in the southern part of the province of Bahia, though it has been also found on other sea beaches and in river sands. Nitze writes that

> Sacks filled with this sand were shipped to New York in 1885, the deposit having been taken for tin ore. Its true character was, however, soon recognized, and since then a number of tons have been shipped in the natural state, without any further

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[1] Sixteenth Annual Report U. S. Geological Survey, 1894–95, pt. 4, p. 685.

concentration or treatment, as ballast, mainly to the European markets. It is reported to contain 3 to 4 per cent thoria. * * * Monazite has also been found in the gold and diamond placers of the provinces of Bahia (Salabro and Caravellas), Minas Geraes (Diamantia), Rio de Janeiro, and São Paulo. It has been found in the river sands of Buenos Ayres, Argentine Republic, and also in the gold placers of Rio Chico, at Antioquia, in the United States of Colombia.

In the Ural Mountains of Russia monazite is found in the Bakakui placers of the Sanarka River. The placer gold mines of Siberia are reported to be rich in monazite, which is rafted down the Lena and the Yenesei rivers to the Arctic Ocean, and thence to European ports.

Economic deposits of monazite are also reported to exist in the pegmatic dikes of Southern Norway. It is picked by the miners while sorting feldspar at the mines. It is not known to exist in placer deposits. The annual output is stated to be not more than 1 ton, which is shipped mainly to Germany.

Methods of extraction.—The monazite is won by washing the sand and gravel in sluice boxes exactly after the manner that placer gold is worked. The sluice boxes are about 8 feet long by 20 inches wide by 20 inches deep. Two men work at a box, the one charging the gravel on a perforated plate fixed in the upper end of the box, the other one working the contents up and down with a gravel fork or perforated shovel in order to float off the lighter sands. These boxes are cleaned out at the end of the day's work, the washed and concentrated monazite being collected and dried. Magnetite, if present, is eliminated from the dried sand by treatment with a large magnet. Many of the heavy minerals, such as zircon, menaccanite, rutile, brookite, corundum, garnet, etc., can not be completely eliminated. The commercially prepared sand, therefore, after washing thoroughly and treating with a magnet, is not *pure* monazite. A cleaned sand containing from 65 to 70 per cent monazite is considered of good quality. From 20 to 35 pounds of cleaned monazite sand per hand, that is, from 40 to 70 pounds to the box, is considered a good day's work. The price of labor is 75 cents per day.

But very few regular mining operations are carried on in the region. As a rule each farmer mines his own monazite deposit and sells the product to local buyers, often at some country store in exchange for merchandise.

At the present time the monazite in the stream beds has been practically exhausted, with few exceptions, and the majority of the workings are in the gravel deposits of the adjoining bottoms. These deposits are mined by sinking pits about 8 feet square to the bed rock and raising the gravel by hand labor to a sluice box at the mouth of the pit. The overlay is thrown away excepting in cases where it contains any sandy or gritty material. The pits are carried forward in parallel lines, separated by narrow belts of tailing dumps, similar to the methods pursued in placer gold mining.

At the Blanton and Lattimore mines on Hickory Creek, 2 miles northeast of Shelby, Cleveland County, North Carolina, the bottom is 300 to 400 feet wide, and has been partially worked for a distance of one-fourth of a mile along the creek. The overlay is from 3 to 4 feet and the gravel bed from 1 to 2 feet thick. The methods of mining and cleaning are much more systematic in Spartanburg County, South Carolina, than in North Carolina regions. Although the raw material contains on an average fully as much garnet, rutile, titanic iron ore, etc., as that in the North Carolina mines, a much better finished product is obtained, and more economically, by making several grades. Two boxes are used in washing the gravel, one below the other. The gravel is charged on a perforated plate at the head of the upper box, and the clean-up from this box is so thoroughly washed as to give a high grade sand, often up to 85 per cent pure. The tailings discharge directly into the lower box, where they are rewashed, giving a second grade sand. At times the material passes through as many as five washing treatments in the sluice boxes. Even after these grades are obtained as clear as possible by washing, the material, after being thoroughly dried, is further cleaned by pouring from a cup, or a small spout in a bin, in a fine, steady stream from a height of about 4 feet, on a level platform; the lighter quartz and black sand with the fine-grained monazite (tailings) falls on the periphery of the conical pile and is constantly brushed aside with hand brushes; these tailings are afterwards rewashed. Instead of pouring and brushing, the material is sometimes treated in a winnowing machine similar to that used in separating chaff from wheat.

Although the best grade of sand is as high as 85 per cent pure, its quantitative proportion is small as compared with the second and other inferior grades, and there is always considerable loss of monazite in the various tailings. It is impossible to conduct this washing process without loss of monazite, and equally impossible to make a perfect separation of the garnet, rutile, titanic iron ore, etc., even in the best grades. The additional cost of such rewashing and rehandling must also be taken into consideration.

If the material washed contains gold, the same will be collected with the monazite in concentrating. It may frequently pay to separate it, which can easily be accomplished by treating the whole mass over again in a riffle box with quicksilver.

It has been shown that the monazite occurs as an accessory constituent of the country rock. and that the latter is decomposed to considerable depths, sometimes as much as 100 feet. On account of the minute percentage of monazite in the mother rock, it is usually impracticable to economically work the same in place, by such a process as hydraulicking and sluicing, for instance. However, even hillside mining has been resorted to. Such is the case at the Phifer mine, in Cleveland County, North Carolina, 2 miles northeast of Shelby. The country rock is a coarse mica (muscovite and biotite) gneiss, and the small monazite crystals may at times be distinctly seen, unaided by a magnifying glass, in this rock. It is very little decomposed and still quite hard, and the material that is mined for monazite is the overlying soil and subsoil, which is from 4 to 6 feet thick. This is loaded on wheelbarrows and transported to the sluice boxes below the water race. The yield is fairly good, and the product very clean, though the cost of working * * * must be considerably in excess of that of bottom mining. Where the rock contains sufficient gold, as it sometimes does, to be operated as a gold mine, there is no reason why the monazite can not be saved as a valuable by-product.[1]

The following localities are represented in the Museum collections:

Specimen No. 53107, U.S.N.M. Prado, Bahia, Brazil. Monazite-bearing sand from the bed of a small stream near the beach.

Specimen No. 53108, U.S.N.M. Monazite sand, Prado, Bahia, Brazil. Natural concentrate of beach; represents the condition in which much of the material is shipped.

Specimen No. 53109, U.S.N.M. Monazite sand, Prado, Bahia, Brazil. The natural concentrate of the beach still further concentrated in the batea.

Specimen No. 53110, U.S.N.M. Monazite sandstone, Prado, Bahia, Brazil. A small bit of loosely coherent standstone, composed largely of monazite particles. Of Quaternary (?) age, and presumably the source of much of the sand on the beach.

Specimen No. 62568, U.S.N.M. Monazite sand, with magnetic iron and other impurities. Henderson County, North Carolina.

Specimen No. 63343, U.S.N.M. Monazite sand from near Shelby, Cleveland County, North Carolina.

Specimen No. 63496, U.S.N.M. Monazite sand, concentrated, from Abbeville, South Carolina.

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[1] Sixteenth Annual Report U. S. Geological Survey, 1894–95, Pt. 4, pp. 686–687.

Uses.—The rare elements cerium, zirconium, thorium, yttrium, lanthanium, etc., which are as a rule associated with each other in the minerals cerite, zircon, monazite, samarskite, etc., as described, find their commercial use not in the form of metals, but as oxides only; and it is only since the introduction of the Welsbach incandescent system of lighting that their use in this form has assumed any commercial importance.

This Welsbach light consists of a cap or hood to gas or other burners, to increase their illuminating powers. The cap is made of cotton or other suitable material, impregnated with the oxides in proportions 60 per cent zirconia, 20 per cent yttria, and 20 per cent lanthanum. The fabric is strengthened and supported with fine platinum wire and suspended in the flame. On igniting in the flame the fabric is quickly reduced to ash, the cotton being burnt away and the earthy matter still retaining the form of a cap or hood.[1]

The drawback to the use of these oxides has been, it is said,[2] the great difficulty in obtaining them in a pure condition. Several methods have been used, but usually with poor results, especially when the mineral contains iron.

The demand for the minerals of this group being so limited there is no regular market price. The Mineral Industry for 1893 quotes zircon at 10 cents a pound, monazite 25 cents, and samarskite 50 cents. It is stated that 1 ton of zircon will yield sufficient zirconia for half a million Welsbach burners.

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See paper on Monazite, by H. B. C. Nitze, in Mineral Resources of the United States, Part. 4, of the Sixteenth Annual Report U. S. Geological Survey, 1894–95, pp. 667–693. This contains a very satisfactory bibliography down to date of publication. Also see Les Terres Rares Mineralogie-Properties Analyse, by P. Truchot. Carré et Naud. Paris, 1898.

3. VANADINITE.

This is a vanadinate and chloride of lead of the formula (PbCl) $Pb_4V_3O_{12}$, = Vanadium pentoxide 19.4 per cent; lead protoxide 78.7 per cent; chlorine 2.5. In nature often more or less impure through the presence of arsenic and traces of iron, manganese, zinc, and lime. Color deep red to brown and straw-yellow, resinous luster; translucent to opaque. Hardness 2.75 to 3. Gravity 6.66 to 7.23. When a drop of nitric acid is applied to a particle of a crystal there is soon formed a yellow coating of vanadic oxide. This reaction is quite characteristic and furnishes an easy and convenient means of determination.

Localities and mode of occurrence.—Occurs in prismatic crystals with smooth faces and sharp edges; crystals sometimes cavernous at the top,

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[1] Journal of the Society of Chemical Industry, V, 1886, p. 522.

[2] Mineral Resources of the United States, 1885, p. 393.

as in Specimen No. 61135, U.S.N.M. Also common in parallel grouped and rounded forms and globular incrustations. Dana gives the following relative to the known localities:

> This mineral was first discovered at Zimapan in Mexico, by Del Rio. Later obtained among some of the old workings at Wanlockhead in Dumfriesshire, where it occurs in small globular masses, on calamine, and also in small hexagonal crystals; also at Berezov in the Ural, with pyromorphite; and near Kappel in Carinthia, in crystals; at Undenäs, Bölet, Sweden; in the Sierra de Córdoba, Argentine Republic; South Africa.
>
> In the United States it occurs sparingly with wulfenite and pyromorphite as a coating on limestone, near Sing Sing, New York. In Arizona it is found at the Hamburg, Melissa, and other mines in Yuma County, in brilliant deep red crystals; Vulture, Phœnix, and other mines in Maricopa County; at the Black Prince mine; also the Mammoth gold mine, near Oracle, Pinal County, and in brown barrel-shaped crystals in the Humbug district, Yavapai County. In New Mexico it is found at Lake Valley, Sierra County (endlichite); and the Mimbres mines near Georgetown [Specimen No. 67844, U.S.N.M.].

The characteristic mode of occurrence at the Mimbres Mine, above noted, is associated with descloizite in the form of small hopper-shaped crystals and drusy or botryoidal and globular masses coating the siliceous residues of the limestone in the irregular cavities with which the stone abounds. The color of these coatings varies from beautiful ruby red to light ocherous yellow. The mineral is here nearly always associated with descloizites as noted below.

Uses.—See under descloizite.

4. Descloizite.

This is a vanadinate of lead and zinc of the formula 4 (PbZn) O. V_2O_5, H_2O = vanadum pentoxide 22.7 per cent; lead protoxide 55.4 per cent; zinc oxide 19.7 per cent; water 2.2 per cent. The published analyses show also small amounts of arsenic, copper, iron, manganese and phosphorus. Color, red to brown; luster, greasy; no cleavage; fracture small conchoidal to uneven. Occurs in small prismatic or pyramidal crystals and in fibrous, mamillated or massive forms. Often associated with and pseudomorphous after vanadinite.

Localities and mode of occurrence.—Dana gives the following relative to occurrence:

> Occurs in small crystals, 1 to 2 millimeters thick, clustered on a siliceous and ferruginous gangue from South America, at the Venus Mine and other points in the Sierra de Córdoba, Argentine Republic, associated with acicular green pyromorphite, vanadinite, etc. At Kappel, in Carinthia, in small clove-brown rhombic octahedrons.
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> * * * * * * *
>
> Sparingly at the Wheatley Mine, Phœnixville, Pennsylvania, as a thin crystalline crust on wulfenite, quartz, and a ferruginous clay. Abundant at the Sierra Grande Mine, Lake Valley, Sierra County, New Mexico, in red to nearly black crystals, pyramidal and prismatic in habit, associated with vanadinite, iodryite, etc.; at the Mimbres and other mines, near Georgetown, New Mexico, in stalactitic crystalline

aggregates [Specimen No. 67844, U.S.N.M.]. In Arizona near Tombstone, in Yavapai County, in brownish olive-green crystals; at the Mammoth Gold Mine, near Oracle, Pinal County, in orange-red to brownish red crystals with vanadinite and wulfenite.

A vanadinite, probably identical with descloizite, occurs at the Mayflower Mine, Bald Mountain district, in Beaverhead County, Montana; it is in an impure earthy form of a dull yellow to pale orange color. See further under Carnotite, p. 404.

Vanadium is also found in small quantities in certain Swedish iron ores; in the cupriferous schists of Mansfeld, Saxony; in cupriferous sands of Cheshire, England, and Perm, Russia; in coals from various localities; in beauxite and in clay near Paris. As stated by Fuchs and De Launey,[1] vanadium has been shown to exist in extremely small proportions in primordial rocks, from which it became concentrated in the clays on their breaking up. Certain oölitic iron ores (limonites) at Mafenay, Saone et Loire, France, contain the substance in such proportions that the slag from their smelting have become commercial sources of supply, some 60,000 kilograms of vanadic acid being manufactured annually from them.

The following referring to the occurrence and value of vanadinates in the United States is of sufficient interest to bear reproduction here:

> The lead vanadates are frequently found in association with lead ores, as, for instance, in the deposits at Leadville, whence some very handsome specimens were formerly obtained. The most important occurrence of lead vanadates in the United States, however, is probably in Arizona, where it has been reported in the ores of several mines, among others those of the Castle Dome district, the Crowned King mine in the Bradshaw Mountains, and the Mammoth gold mines at Mammoth, in Pinal County. The last-mentioned mines are probably the only ones in the United States from which vanadium minerals have been won on an industrial scale. The vanadium minerals, of which nearly all the known varieties occurred, the dechenite and descloizite predominating, were found in the upper levels of the mine, forming about 1 per cent of the ore on the average, though within limited areas they formed from 3 to 4 per cent. In the lower levels they occurred less abundantly, only an occasional pocket and a small quantity of disseminated crystals being found. The red crystals, according to an analysis by the late Dr. F. A. Genth, contained chlorine, 2.43 per cent; lead, 7.08 per cent; lead oxide, 69.98 per cent; ferric oxide, 0.48 per cent; vanadic acid, 17.15 per cent; arsenic acid, 3.06 per cent, and phosphoric acid, 0.29 per cent. In milling the ore (gold) the vanadium minerals collected in riffles, placed about 18 inches apart in the sluices. The material thus obtained was worked over by hand in a sort of buddle, and the resulting concentrates were sold to the Kalion Chemical Company, of Gray's Ferry Road, Philadelphia. The total quantity of concentrates obtained in this manner did not exceed 6 tons. An average sample of the lot, analyzed by Dr. Genth, gave the following results: Vanadic acid, 15.40 per cent; molybdic acid, 3.35 per cent; arsenic acid, 1.50 per cent; carbonic acid, 0.90 per cent; chlorine, 0.48 per cent; oxide of lead, 56.80 per cent; oxide of zinc, 10.70 per cent; oxide of copper, 0.95 per cent; oxide of iron, 0.35 per cent; soluble silica, 0.60 per cent; insoluble matter, 5.29 per cent. The value of the gold and silver contents of the concentrates was about $140 per ton. The price realized on this first lot was 12.5 cents per pound, or $250 per ton, on board the cars at Tucson.
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> The vanadic salts manufactured from this lot of concentrates were said to have

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[1] Traité des Gites Mineraux, II, p. 95.

been the first produced on a commercial scale in the United States, and owing to the limited market for the same the price dropped over 50 per cent.

Frue vanners were then introduced into the mill, and the product obtained from them, amounting to about 1 ton per 100 tons of ore crushed, contained from 5 to 6 per cent vanadic acid and $40 to $80 per ton in gold and silver. The Kalion Chemical Company offered to buy this product according to the following sliding scale: With the market price of ammonium vanadate $5 per pound, $100 per ton for the concentrates; vanadate of ammonium $4.50 per pound, concentrates $92; vanadate of ammonium $4 per pound, concentrates $82; vanadate of ammonium $3.50 per pound, concentrates $72; vanadate of ammonium $3 per pound, concentrates $64. Only a few tons of these concentrates were shipped to Philadelphia, the remainder being sold to the Denver smelters for their gold, silver, and lead value.[1]

Uses.—The only uses thus far developed for the mineral are as a source for vanadium salts used as a pigment for porcelain; in the manufacture of ink and in textile dyeing and printing, both vanadate of ammonium and vanadic oxide being used for the latter purpose, producing an intense black color with a slight greenish cast.

5. AMBLYGONITE.

This is a fluo-phosphate of aluminum and lithium, of the formula $Li\ (Al\ F)\ P\ O_4$. Analysis of a sample from Paris, Maine, as given by Dana, shows: Phosphoric acid, 48.31 per cent; alumina, 33.68 per cent; lithia, 9.82 per cent; soda, 0.34 per cent; potash, 0.03 per cent; water, 4.89 per cent; fluorine, 4.82 per cent; hardness, 6; specific gravity, 3.01 to 3.09. Luster vitreous to greasy, color white to pale greenish, bluish, yellowish to brownish, streak white. On casual inspection the mineral somewhat resembles potash feldspar (orthoclase), but when finely pulverized is soluble in sulphuric acid, and less readily so in hydrochloric acid. The Hebron variety, when pulverized and moistened with sulphuric acid, gives the characteristic lithia red color to the flame.

Mode of occurrence.—Amblygonite occurs in the form of coarse crystals, or compact and columnar forms in pegmatic veins associated with lepidolite, tourmalines, and other minerals so characteristic of this class of veins. In the United States it occurs at Hebron (Specimen No. 62576, U.S.N.M.); Mount Mica, in Paris (Specimen No. 53694, U.S.N.M.); Auburn and Peru, Maine, at the latter place associated with spodumene, petalite, and lepidolite. In Saxony the mineral is found at Chursdorf and Arnsdorf, near Penig, and near Geier. Also found at Arendal, Norway, and at Montebras and Creuze, France.

Uses.—Since 1886 the mineral has been utilized as a source of lithia salts, in place of the lithia mica. The chief commercial source is at present Montebras, France, where it occurs in a coarse granitic vein yielding also cassiterite and kaolin in commercial quantities.

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[1] The Mineral Industry, II, 1893, p. 574.

6. TRIPHYLITE AND LITHIOPHILITE.

These are names given to phosphates of iron, manganese, and lithium, and which pass into one another by insensible gradations through variations in the proportional amounts of manganese protoxide, the triphylite containing from 10 to 20 per cent of this oxide, while the lithiophilite contains twice that amount. The comparative composition of extreme types is shown below:

Name.	P_2O_5.	FeO.	MnO.	Li_2O.	Na_2O.	H_2O.
Triphylite	43.18	36.21	8.96	8.15	0.26	0.87
Lithiophilite	44.67	4.02	40.86	8.63	0.14	0.82

Triphylite is a gray to blue-gray mineral in crystals and coarsely cleavable masses of a hardness of 4.5 to 5 of Dana's scale, and specific gravity of 3.42 to 3.56.

Lithiophilite differs mainly in color—aside from composition as above noted—being of a pink to clove-brown hue. Both minerals may undergo a darkening in color, becoming almost black through a higher oxidation and hydration of the manganese protoxide. This feature is best shown in the lithiophilite from Branchville, Connecticut. (Specimen No. 62583, U.S.N.M.)

Occurrence.—These minerals occur chiefly in granitic veins, associated with spodumene and other lithia bearing minerals, as at the localities above mentioned. Peru, Hebron, and Norway, Maine; Keityö, Finland, etc.

IX. NITRATES.

There are three compounds of nitric acid and a base occurring in nature in such quantities and of sufficient economic importance to merit attention here. These are (1) the true niter or potassium nitrate (KNO_3), (2) soda niter or sodium nitrate ($NaNO_3$), and (3) nitrocalcite, a calcium nitrate (CaN_2O_6). All are readily soluble in water, and hence found in any quantity only in arid regions or where protected, as in the dry parts of caves.

1. NITER, POTASSIUM NITRATE.

Composition KNO_3,=nitric anhydride, 53.5 per cent; potash, 46.5 per cent. Hardness, 2; specific gravity, 2.1; color, white, subtransparent. Readily soluble in water. Taste, saline and cooling. Deflagrates vividly when thrown on burning coals and colors the flame violet.

The mineral occurs in nature mainly in the form of acicular crystals and efflorescences on the surface or walls of rocks and scattered in the loose soil of limestone caves and similar dry and protected places.

It is also found in certain soils of tropical countries, as noted under origin. In the United States it has been found in caves of the Southern States, as those of Madison County, Kentucky, but never in commercial qualities. The chief commercial source of the salt has been the artificial nitrates of France, Germany, Sweden, and other European countries. It is also prepared artificially from soda niter.

2. Soda Niter.

Nitrate of sodium, $NaNO_3$. This in its pure state is a white or colorless salt, but in nature brown or bright lemon yellow (See Specimens in jar, No. 67278, U.S.N.M.), of a slight saline taste, but with a peculiar cooling sensation when placed upon the tongue. It is by far the most common of the nitrates, and indeed the only one of the natural salts of any great commercial value, owing to the comparative rarity of the others. Though found to a slight extent in caves and protected places, the commercial supply is drawn almost wholly from the desert regions of the Pacific coast of South America and particularly from Chile, the chief deposits being found in the provinces of Tarapaca and Antofagasta.

According to the Journal of the Society of Chemical Industry:[1]

> The total area of the province of Tarapaca is 16,789½ square miles, and it is divided naturally into five distinct and well-defined zones. The first of these zones commences on the shores of the Pacific and has an average width, west to east, of 18 miles. It is formed, in the first place, of the beach; and, in the second, of the coast range, which attains an altitude varying from 1,125 to 5,800 feet above the sea level. This zone may be denominated the guano and mining zone. * * * This belt as it advances eastward becomes more and more depressed and terminates in a series of pampas (open plains), having an elevation of 3,500 to 3,800 feet above the sea level. Nearly all these pampas contain vast beds of salts, sulphate of soda, and sulphate of lime. They are known locally by the name of "salares." In some parts of the desert of Atacama the beds of nitrate of soda are found under these salares deposits, but in Tarapaca the caliche (nitrate earth) is found only under a bed of conglomerate known as "costra." * * *
>
> The second zone—the nitrate zone—commences on the edge of the Camarones Gully and extends southward to the desert of Atacama. Up to 1858 it was believed that the nitrate beds did not extend southward beyond the Loa Gully, but in that year beds were discovered in what was then the Bolivian littoral. Explorations which were effected in 1872 proved that the nitrate beds extended northward beyond the Camarones Gully and that they reached as far as the Chaca Gully and even as far as the Azapa Valley, in the province of Alrica. * * * The quantity and quality of the caliche varies very considerably in different parts of the zone, but the dimensions of the nitrate area may be set down at 120 geographical miles in length north to south, and 2 geographical miles in width east to west. It is estimated that the beds contain the enormous quantity of 1,980,630,502 quintals of niter, and it is stated that with the present export duty which is equal to 27 pence per quintal, the deposits will yield a revenue of £230,809,474.

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[1] Volume VI, 1887, pp. 228, 229.

It is elsewhere stated that the point on the slope of the mountains where the deposits of caliche are found is some 500 or 600 feet higher than the valley, but that the material diminishes in quantity and richness as the valley is approached and disappears entirely at the bottom.

An examination of the workings of these beds discloses the following conditions:

(1) That the surface to the depth of 8 or 10 inches is covered with a layer of fine, loose sand.

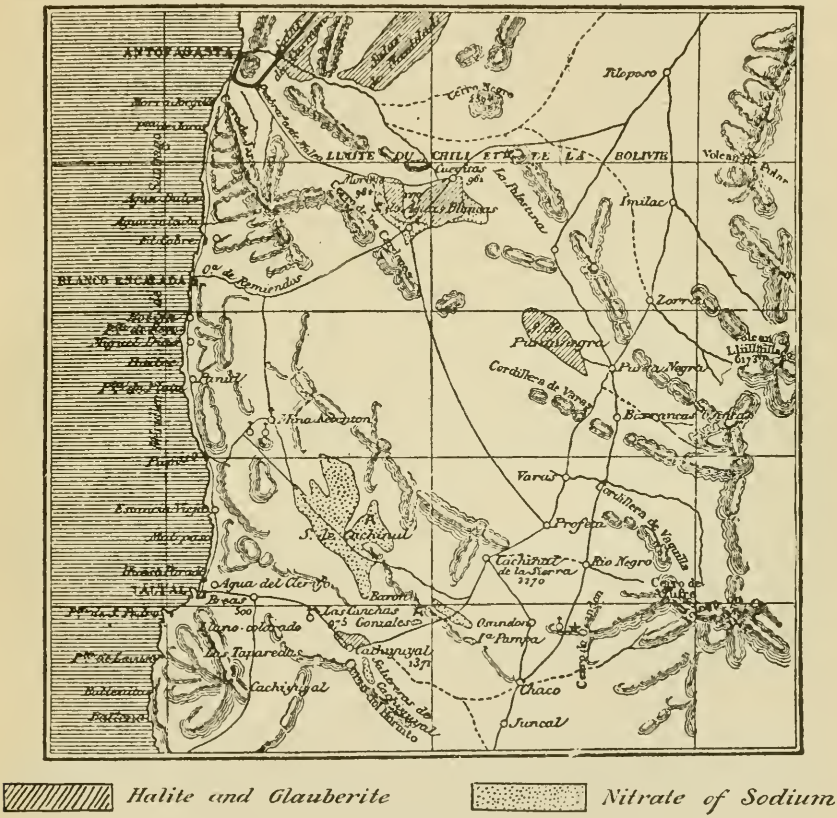

Fig. 12.

MAP OF NITRATE REGION, CHILE.

After Fuchs and De Launay.

(2) That underneath the sand is a conglomerate of amorphous porphyry, feldspar, chloride of sodium, magnesia, gypsum, etc., cemented by the sulphate of lime into a hard, compact mass to a depth of 6 to 10 feet, called the "costra" or crust.

(3) That below this crust the caliche, or impure nitrate, is found, presenting to the view a variety of colors—yellowish-white, orange, bluish-gray, etc.

The nitrate deposit is quarried by blasting with a coarse-grained powder, of which as much as 150 pounds are sometimes used at a single blast. Neither dynamite nor nitroglycerine is used, as it would shatter and pulverize the caliche so as to occasion a serious loss.

After being brought to the surface the caliche is carefully assorted by experts, broken into pieces double the size of an orange, and carted to the refinery establishment, situated on the pampas or on the seacoast, or carried to Iquique, Pisagua, Patillos, and Antofagasta by rail, all of these places having connection, by narrow-gauge railways, with the nitrate deposits and which, consequently, are rapidly becoming the chief centers of nitrate production and export.

According to the reports of Consul-General Walker, the southern limit of the nitrate fields is in Antofagasta province, latitude 25° 45′ S., and the northern in latitude 19° 12′ S., its extreme north and south length being some 260 geographical miles and its average width some 2½ miles.

This narrow strip of nitrate lands stretches along the eastern slope of the coast range of barren, verdureless mountains which wall in the Pacific Ocean from the northern limit of Peru to the Straits of Magellan, upon which, for more than 2,000 miles, no rain ever falls and upon which there is no living vegetation. Some of the peaks reach an altitude of 4,000 or 5,000 feet above the sea level, but the usual height of the range is about 2,000. The average distance from the coast to the nitrate beds is about 14 miles, but many of them are not more than 10 miles.

The accompanying map, p. 393, from Fuchs and De Launays, Traité des Gites Mineraux, will serve to show the geographic position of the deposits.

Specimen No. 62111, U.S.N.M., show the varying character of the material as mined.

3. Nitro-Calcite.

Nitro-calcite, or calcium nitrate, $CaN_2O_6+nH_2O$, is not uncommon as a silky efflorescence on the floors and walls of dry limestone caverns and may be extracted in considerable quantities from their residual clays by a process of leaching. During the war of 1812 the clays upon the floors of Mammoth Cave, Kentucky, were systematically leached and the dissolved nitrate obtained by evaporation and crystallization. The wooden tanks and log pipes for conducting the water are still in a remarkable state of preservation, owing to the dry air of the cavern.

The nitrous earths of Wyandotte Cave in southern Indiana, and doubtless of other localities, were similarly treated during these times of temporary stringency. (See Specimens Nos. 68165, 68166, U.S.N.M. in cave exhibit.)

According to the reports of the State geologist[1] this earth, in its air-dry condition, has the following composition:

Loss at red heat	16.50
Silica	20.60
Ferric oxide	6.03
Manganic oxide	0.75
Alumina	20.40
Lime	8.06
Magnesia	4.58
Carbonic acid	10.38
Sulphuric acid	6.55
Phosphoric acid	2.43
Nitric acid	3.50
Chlorides of alkalies and loss	0.32
	100.10

The researches of Muntz and Marcano[2] have shown that the soils as well as the earth from the floor of caves, in Venezuela and other portions of South America may be rich in calcium nitrate to an extent quite unknown in other countries.

Origin.—The source of the nitrates, both of caves and of the Chilean pampas has been a subject of considerable discussion. There appears little doubt but the deposits in caves and those disseminated in soils are due to the nitrifying agencies of bacteria acting upon organic matter whereby the organic nitrogen is converted into nitric acid which immediately combines with the most available bases, be they of lime, soda, or potash. The accumulation of the niter in caves is probably due, as suggested by W. H. Hess (see Bibliography), to the retention by the clay of the nitrates brought in from the surface by percolating waters.

In other words, the caves serve merely as receptacles, or storehouses, for nitrates which had their origin in the surface soil. The Chilean nitrate beds are considered by Muntz and Marcano as having a very similar origin. The material being soluble is gradually leached out from the soils in which it originated and drained into inclosed salt marshes or inland seas where a double decomposition takes place between the sodium chloride and calcium nitrate, whereby sodium nitrate and calcium chloride are produced. That such a double decomposition may take place has been shown by actual experiment.

This is not widely different from the view taken also by W. Newton.[3]

After discussing briefly theories previously advanced including Darwin's theory of derivation from decomposing seaweeds accumulated on old sea beaches, and the even less plausible one of its derivation from guano, he goes on to show that the plain of Tamarugal

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[1] Geological Report of Indiana, 1878, p. 163.

[2] Comptes Rendus de l'Academie des Sciences, CI, Paris, 1885, p. 1265.

[3] Geological Magazine, III, 1896, p. 339.

within which the deposits lie, is covered by an alluvial soil rich in organic matter. This organic matter under the now well-known action of bacteria, aided by the prevailing high temperatures of the region, gives rise to nitrates, which owing to the absence of rains for long periods, accumulates to an extent impossible under less favorable circumstances. Mountain floods which occur at periods of seven or eight years, swamp the plain, bringing in solution the nitrate drained from the soils of the surrounding slope, and to accumulate in the lower levels. On the evaporation of the water this is again deposited. The occurrence of the nitrate so far up the slope of the hills is regarded by Newton as due to the tendency of the nitrate salt, in saturated solutions, to creep up, as in experiment it may be seen to creep up and over the sides of a saucer or other shallow dish in which the evaporation is progressing.

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X. BORATES.

Of the ten or more species of natural borates but three, or possibly four, are commercial sources of borax, and need consideration here. These are, (1) borax or tincal; (2) ulexite, or boronatrocalcite; (3) priceite, colemanite, or pandermite, and (4) boracite, or stassfurtite. Sassolite, or native boric acid, occurs chiefly in solution. The intimate association of these minerals renders it advisable to treat of their origin and mode of extraction in common, after giving the composition and general physical characters of each by itself.

1. Borax or Tincal; Borate of Soda.

Composition $Na_2B_4O_7.10H_2O$,=boron trioxide, 36.6 per cent; soda, 16.2 per cent; water, 47.2 per cent. Color, white to grayish, and sometimes greenish; translucent to opaque. It crystallizes in short, stout prisms, belonging to the monoclinic system (Specimen No. 15514, U.S.N.M.) Hardness, 2 to 2.5; specific gravity, 1.7. Readily soluble in water; taste sweetish alkaline.

2. ULEXITE; BORONATROCALCITE.

Composition $NaCaB_5O_9.8H_2O$,=boron trioxide, 43 per cent; lime, 13.8 per cent; soda, 7.7 per cent; water, 35.5. Color, white, with silky luster. Occurs usually in rounded masses of loose texture, which consist mainly of fine acicular crystals or fibers. (See Specimen No. 18128, U.S.N.M., from Rhodes Marsh, Nevada.) Insoluble in cold water, and only slightly so in hot, the solution being alkaline. Hardness, 1; specific gravity, 1.65.

3. COLEMANITE.

Composition $Ca_2B_6O_{11}.5H_2O$,=boron trioxide, 50.9 per cent; lime, 27.2 per cent; water, 21.9 per cent. Color, milky to yellowish-white, or colorless; transparent to translucent. Hardness, 4 to 4.5; specific gravity, 2.41. Insoluble in water, but readily so in hot hydrochloric acid. Priceite and pandermite are hydrous calcium borates closely allied to colemanite, occurring in loosely coherent and chalky or massive forms. (Specimen No. 63362, U.S.N.M.).

4. BORACITE OR STASSFURTITE; BORATE OF MAGNESIA.

Composition $Mg_7Cl_2B_{16}O_{30}$,=boron trioxide, 62.5 per cent; magnesia, 31.4 per cent; chlorine, 7.9 per cent. Color, white to yellow or greenish. In crystals transparent to translucent. Crystals cubic and tetrahedral. Insoluble in water; readily soluble in hydrochloric acid. Hardness, 7; specific gravity, 2.9 to 3. (Specimen No. 64742, U.S.N.M., from Stassfurt.)

Localities and mode of occurrence.—As has been stated by Kemp[1] the Great Basin region of the United States contains, along the Nevada-California border at least ten salines or marshes which have been found to hold boracic deposits. The marshes are regarded as the beds of relatively restricted lakes which received boracic water, probably from hot springs. Volcanic phenomena are abundant and were doubtless the stimulating causes. Besides borax, ulexite (borate of lime and soda) and priceite (borate of lime) are found commingled with more or less gypsum, carbonate, chloride, and sulphate of soda and various other alkaline salts. The best known of the salines in Nevada are Teels Marsh, Columbus Marsh, Fish Lake Valley, and Rhodes Marsh, all in Esmeralda County. These cover an area of thousands of acres, but the productive portions are comparatively limited. In Churchill County, this same State, there is a minor deposit at Salt Wells (Specimen No. 15522, U.S.N.M.). In California there is an important deposit known as Searles Marsh, in San Bernardino County, and a vein

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[1] The Mineral Industry, 1892, p. 43.

of calcium borate (colemanite) in the Calico District, this same county. The Saline Valley, the Amargosa, and Furnace Creek deposits, in Inyo County, are also extensive. (Specimen No. 62444, U.S.N.M.). Large deposits of priceite are also found 5 miles north of Chetco, in Curry County (Specimen No. 63362, U.S.N.M.), Oregon. The mineral is stated by Dana to occur in a hard, compact form in layers, between a bed of slate above, the cavities and fissures of which it fills, and a tough, blue steatite below; also occurring in bowlders or rounded masses completely embedded in the steatite. These masses vary from the size of a pea to those of 200 pounds weight each.

The Calico District colemanite above referred to occurs, according to W. H. Storms,[1] as a bedded "vein" in sedimentary strata which in Tertiary times were uplifted in the Calico Range, the sedimentary rocks consisting of sandstones, sandy clays, and clayey sands. "The borax 'vein' is traceable for several thousand feet, striking along the western and northern side of the largest sedimentary hill in the range, and finally passing down a canyon to the eastward, where it becomes a well-defined vein. Toward the western end the borate of lime appears to be much mixed with the sandy sediments, gypsum, and clays, giving the appearance of having been formed near the shore line of the basin in which this great mass of material has been left as a residuary deposit, due to the evaporation of the water containing the calcium borate." There are apparently two beds of borate from 7 to 10 feet in thickness in close proximity, but which are believed by Mr. Storms to be portions of the same bed repeated as the result of an anticlinal fold, and exposed through erosion. See Plate 21.

The following description of Searles Marsh, in San Bernardino County, is from the reports of the State mineralogist.[2]

This marsh is situated in the northwestern corner of San Bernardino County, occupying a portion of T. 25 S., R. 43 E., M. D. M. The site is distant from San Francisco southeast 500 miles; from San Bernardino, the shire town of the county, due north 175 miles, and from Mohave, nearest station on the Southern Pacific Railroad, northeast 72 miles; these distances being measured by the usually traveled routes.

Locally considered, Searles Marsh lies near the center of an extensive mountain-girdled plain, to which the phrases "Alkali Flat," "Dry Lake," "Salt Bed," "Borax Marsh" have variously been applied, the contents and physical features of the basin-shaped depression well justifying the several names that have so been applied to it. It is, in fact, a dry lake, the bed of which has been filled up in part with the several substances named. Its contents consist of mud, alkali, salt,

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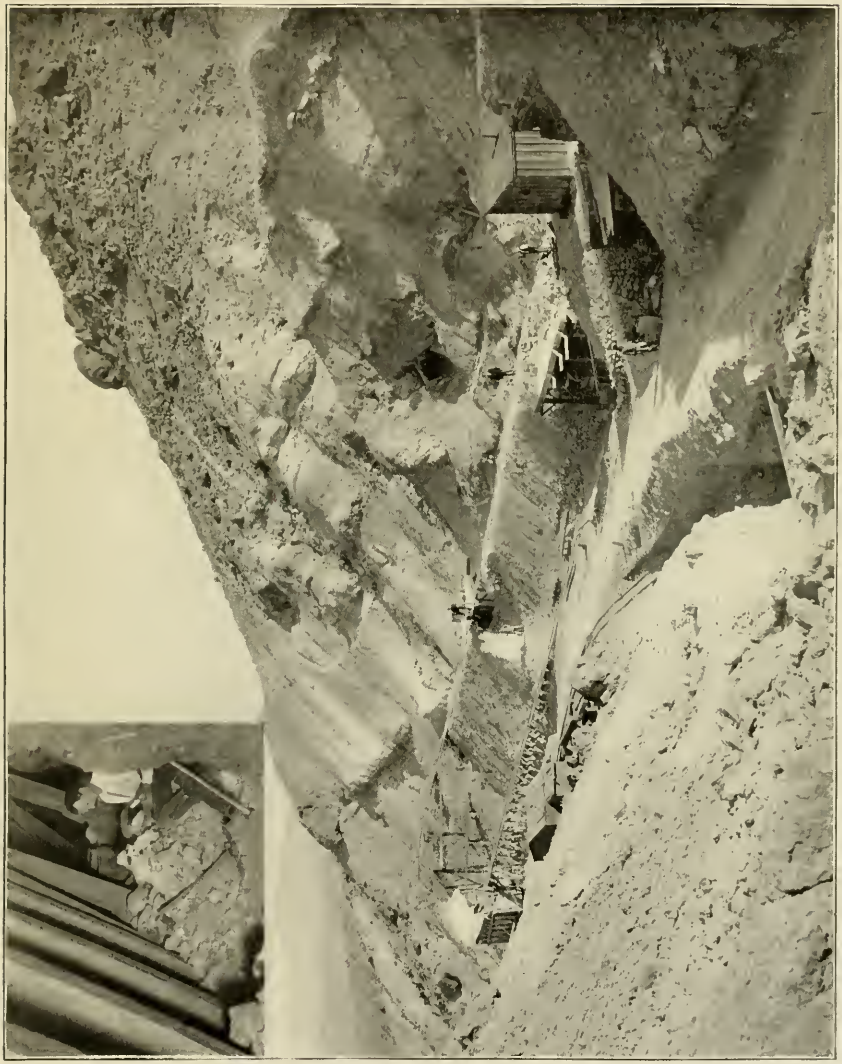
[1] Eleventh Annual Report of the State Mineralogist of California, 1892, p. 345.

[2] Tenth Annual Report of the State Mineralogist of California, 1890, p. 534.



BORAX MINE NEAR DAGGETT, CALIFORNIA.
Interior and exterior views.

and borax, largely supplemented with volcanic sand. This depression, which has an elevation of 1,700 feet above sea level, and an irregular oval shape, is about 10 miles long and 5 miles wide, its longitudinal axis striking due north and south. It is surrounded on every side but the south by high mountains, the Slate Range bounding it on the east and north, and the Argus Range on the west.

There is no doubt but this basin was once the bed of a deep and wide-extended lake, the remains of a former inland sea. The shore line is distinctly visible along the lower slopes of the surrounding mountains at an elevation of 600 feet above the surface of the marsh. Farther up, one above the other, faint marks of former water lines can be seen, showing the different levels at which the surface of the ancient lake has stood. In the course of time the lake became extinct, having been filled with the sediments from the adjacent mountains.

What may have been the depth of the lake has not yet been ascertained, borings put down 300 feet having failed to reach bed rock. These borings, commenced in 1878, disclosed the following underlying formations:

First, 2 feet of salt and thenardite [Na_2SO_4]; second, 4 feet of clay and volcanic sand, containing a few crystals and bunches of hanksite, [$4Na_2SO_4$, Na_2CO_3]; third, 8 feet of volcanic sand and black, tenacious clay, with bunches of trona, of black, shining luster, from inclosed mud; fourth, 8-foot stratum, consisting of volcanic sand containing glauberite, thenardite, and a few flat, hexagonal crystals of hanksite; fifth, 28 feet of solid trona of uniform thickness; sixth, 20-foot stratum of black, slushy, soft mud; smelling strongly of hydrosulphuric acid, in which there are layers of glauberite, soda, and hanksite. The water has a density of 30° Baumé; seventh, 230 feet (as far as explored) of brown clay, mixed with volcanic sand and permeated with hydrosulphuric acid.

Overlying No. 5 a thin stratum of a very hard material was encountered. Being difficult to penetrate, and its character not recognized, this was simply called "hard stuff," its more exact nature being left for future determination.

As is the case with all salines of like character, this has no outlet, the water that comes into it escaping only by evaporation, which process goes on here very rapidly for two-thirds of the year.

While most of the water contained in this basin is subterranean, a little during very wet winters accumulates and stands for a short time on portions of the surface. In no place, however, does it reach a depth of more than a foot or two, hardly anywhere more than 3 or 4 inches.

Within the limits of the actively producing portion of the marsh, which covers an oblong area of about 1,700 acres, the water stands on a tract of some 300 acres for a longer period than it does elsewhere; but even here it nowhere reaches a depth of more than a foot.

Between this 300-acre tract and the main flat lying a little lower there interposes a slight ridge, which prevents the surface water from escaping to the lower ground.

The water of the lake is of a dark-brown color, strongly impregnated with alkali, and has a density of 28° Baumé. The salts obtained from it by crystallization contain carbonate and chloride and borate of sodium, with a large percentage of organic matter.

Summarized, the following minerals have been found associated with the borax occurring in the Searles marsh: Anhydrite, calcite, celestite, cerargyrite, colemanite, dolomite, embolite, gay-lussite, glauberite, gypsum, halite, hanksite, natron, soda, niter, sulphur, thenardite, tincal, and trona, the most of these occurring, of course, in only minute quantities. There is, however, reason to believe that hanksite will yet be found abundantly, both here and in the other salines of this region.

The submerged tract above described is called the "Crystal Bed," the mud below the water being full of large crystals, which occur in nests at irregular intervals to a depth of 3 or 4 feet. Many of these crystals, which consist of carbonate of soda and common salt with a considerable percentage of borate, are of large size, some of them measuring 7 inches in length. The water 15 feet below this stratum of mud contains, according to Mr. C. N. Hake, who made, not long since, a careful examination of these deposits, carbonate of soda, borax, and salts of ammonia. The ground in the immediate vicinity, a dry hard crust about 1 foot thick, contains, on the same authority:

Sand	50
Sulphate of soda	16
Common salt	12
Carbonate of soda	10
Borax	12

The borax here occurs in the form of the borate of soda only, no ulexite (borate of lime) having yet been found.

The chief foreign sources of borax salts are northern Chili, Stassfurt in Germany, Italy, Asia Minor, and Thibet.

The Chilean mineral is ulexite and is reported as occurring throughout the province of Atacama and the newly acquired portions of Chile. Ascotan, which is now on the borders of the Republic, but formerly belonged to Bolivia, and Maricunga, which is to the north of Copeapo, are the places which have proved most successful commercially. The crude material occurs in both places in lagoons or troughs, which, instead of being entirely filled with common salt, as is usually the case in the desert, contains zones or layers of boronatrocalcite embedded in it. The lagoons of Maricunga lie about 64 kilometers from the nearest railway station and are estimated to cover 3,000,000 square meters. The boronatrocalcite occurs in beds alternating with layers of salt and salty earth.

The raw material contains, in the form of gypsum and glauberite, a large amount of calcium sulphate.

Dana also mentions ulexite as occurring also in the form of rounded masses from the size of a hazelnut to that of a potato in the dry plains of Iquique, where it is associated with pickeringite, glauberite, halite, and gypsum. The German mineral is boracite (stassfurtite) and is found in small granular masses associated with the salt deposits of Stassfurt. In Italy sassolite, or crystallized boric acid, has long been obtained by the evaporation of hot springs in Sienna, in Tuscany. Concerning the deposits of Asia Minor little is accurately known. The mineral is pandermite (colemanite), which is found in thick white lumps at Suzurlu, south of the sea of Marmora. Borax or tincal, from Thibet, in northern India, was probably the first of the boron salts to be utilized. It is stated to be brought on the backs of sheep from the lakes in which it is formed across the Himalayas to the shipping points in India.

Methods of mining and manufacture.—At the East Calico Colemanite mine, in San Bernardino County, the mineral is taken out in the same manner as ores of the precious metals. Inclined shafts are sunk, drifts and levels run, and stopes carried up as in any other mine. The material, when hoisted to the surface, is loaded into wagons and hauled to Dagget, whence it is shipped to the works at Alameda. The process of extracting the boracic acid is not known to the public.

At Searles's marsh the overlying crust mentioned constitutes the raw material from which the refined borax is made.

The method of collecting it is as follows: When the crust, through the process of efflorescence, has gained a thickness of about 1 inch, it is broken loose and scraped into windrows far enough apart to admit the passage of carts between them, and into which it is shoveled and carried to the factory located on the northwest margin of the flat, 1 to 2 miles away.

As soon as removed, this incrustation begins again to form, the water charged with the saline matter brought to the surface by the capillary attraction evaporating and leaving the salt behind. This process having been suffered to go on for three or four years, a crust thick enough for removal is again formed, the supposition being that this incrustation, if removed, will in like manner go on reproducing itself indefinitely.[1]

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[1] In order to determine the proportionate growths of the various salts contained in this crust while undergoing this recuperative process, analyses were made on samples representing respectively six months'. two, three, and four years' growth. From the

Uses.—The various borax salts are used in the preparation of boracic acid and the borate of sodium, the borax of commerce.

XI. URANATES.

1. URANINITE; PITCHBLENDE.

Composition very complex, essentially a uranate of uranyl, lead, thorium, and other metals of the lanthanum and yttrium groups. The mineral is unique in containing nitrogen, being the only one among the constituents of the primary rocks of the earth's crust in which the presence of this element has been thus far determined.[1] The analyses given below are for the most part by Hillebrand, to whom is due the credit of a large share of the present knowledge on the subject.

Locality.	UO_3.	UO_2,	ThO_2.	CeO_2.	La_2O_3.	Y_2O_3.	PbO.	CaO.	N.	H_2O.	Fe_2O_3.	Misc.
Glastonbury, Connecticut	23.03	59.93	11.10				3.08	0.11	2.41	0.43	0.29	1.11
North Carolina......	50.83	39.31	2.78	0.26	0.50	0.20	4.20	0.85	0.37	1.21	....	0.48
Ånneröd, Norway ..	30.63	46.13	6.00	0.18	0.27	1.11	9.04	0.37	1.17	0.74	0.25	4.66
Johanngeorgenstadt.............	59.30	22.33	......	......	....	......	6.39	1.00	0.02	3.17	0.21	5.53

Several varieties of uraninite are recognized, the distinctions being based upon the relative proportions of the two oxides UO_2 and UO_3 (see analyses above). Inasmuch, however, as these variations may be

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ground from which these were taken the crust had been removed several times during the preceding twelve years.

The analysis of samples gave the following results:

Constituents.	Six months' growth.	Two years' growth.	Three years' growth.	Four years' growth.
Sand	58.0	55.4	52.4	53.3
Carbonate of soda	5.2	5.0	8.1	8.0
Sulphate of soda	11.7	6.7	16.6	16.0
Chloride of soda...............	10.9	20.0	11.1	11.8
Borax	14.2	12.9	11.8	10.9
Total	100.0	100.0	100.0	100.0

From this list it will be seen that the first six months' growth is richest in borax, and that the proportion of carbonate of soda to borax increases regularly. The presence of so much sand as is here indicated is caused by the high winds that blow at intervals, bringing in great quantities of that material from the mountains to the west. This sand, it is supposed, facilitates the formation of the surface crust by keeping the ground in a porous condition.

[1] The mineral has since been found to contain some 0.23 per cent of the new elements helium and argon.

due merely to oxidation they need not be taken into consideration here. When crystallized, the mineral assumes octahedral and dodecahedral forms, more rarely cubes. Hardness 5.5, specific gravity 9 to 9.7. Color grayish, greenish to velvet black, streak brown; fracture conchoidal, uneven. The massive and probably amorphous variety, containing few, if any, of the rarer earths and no nitrogen, is known under the name of pitchblende. This last is the chief commercial source of uranium salts. Through oxidation and hydration the mineral passes into gummite, a gum-like yellow to brown or red mineral of a hardness of but 2.5 to 3 and specific gravity of 3.9 to 4.2. (See Specimen No. 53062, U.S.N.M., showing zone of gummite around a nucleal mass of unaltered uraninite.)

Localities and mode of occurrence.—Uraninite occurs as a primary constituent of granitic rocks and as a secondary mineral, with sulphide ores of silver, lead, gold, copper, etc. In this form, according to Dana, it is found at Johanngeorgenstadt, Marienberg, and Schneeberg, Saxony; at Joachimsthal (Specimen No. 53061, U.S.N.M.) and Příbram, in Bohemia (Specimens Nos. 66843, 67755, U.S.N.M.), and Rezbánya, in Hungary. Considerable quantities have been mined from the tin-bearing lodes of Cornwall, England. The crystallized variety *bröggerite* is found in a pegmatite vein near Ånneröd, Norway, and the variety *cleveite* in a feldspar quarry at Arendal. In the United States the mineral has been found in small quantities in several localities, but only those of Mitchell and Yancey Counties, North Carolina (Specimens Nos. 53062, 60927, 62755, U.S.N.M.), where the mineral occurs partially altered to gummite and uranaphane, in mica mines; Llano County, Texas; Black Hawk, near Central City, Colorado (Specimen No. 83629, U.S.N.M.), and the Bald Mountain district of the Black Hills of South Dakota need here be mentioned. Of the above the Cornwall localities are at present of greatest consequence, having during 1890 yielded some 22 tons of ore, valued at some £2,200 ($11,000). During 1891, it is stated, the output was 31 long tons, valued at £620, and in 1892, 37 tons, valued at £740. The next most important locality is that of Joachimsthal, in Bohemia, where 22.52 metric tons of ore were produced in 1891 and 17.71 tons in 1892, the value being some 1,000 florins a ton.

In the Cornwall mines the pitchblende is stated[1] to occur in small veins crossing the tin-bearing lodes. At the St. Austell Consols Mines it was associated with nickel and cobalt ores; at Dolcoath with native bismuth and arsenical cobalt in a matrix of red quartz and purple fluorspar; at South Tresavean with kupfer-nickel, native silver, and argentiferous galena. At the Wood Lode, Russell district, in Gilpin County, Colorado, pitchblende was found in the form of a

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[1] The Mineral Industry, II, p. 572.

lenticular mass in one of the ordinary gold-bearing lodes traversing the gneiss and mica schists of the district. The body occurred some 60 feet below the surface and was some 30 feet long by 10 feet deep and 10 inches thick. The mass yielded some 4 tons of ore carrying 70 per cent oxide of uranium.

Other natural uranium compounds, but which at present have no use in the arts, are as below: Torbernite, a hydrous phosphate of uranium and copper; autunite, a hydrous phosphate of uranium and calcium; zeunerite, an arsenate of uranium and copper; uranospinite, an arsenate of uranium and calcium; uranocircite, a phosphate of barium and uranium; phosphuranylite, a hydrous uranium phosphate; trögerite, a hydrous uranium arsenate; walpurgite, probably an arsenate of bismuth and uranium; and uranosphærite, a uranate of bismuth.

Carnotite is a recently described uranium compound containing, according to analyses, some 52 per cent uranium oxide (UO_3); 20 per cent of vanadium oxide (V_2O_5), and 11 per cent of potash. It is of a beautiful light lemon-yellow color and of an earthy or ocherous texture. According to descriptions gleaned from correspondence, and from samples received at the U. S. National Museum (Specimens Nos. 53491, 53492, 53649, U.S.N.M.), the material occurs mainly as an impregnation in the form of an extremely fine, crystalline powder in the Dakota sandstones in the vicinity of La Sal Creek and Roc Creek, Montrose County, and near Placerville, San Miguel County, Colorado.[1]

Uses.—Uranium is never used in the metallic state, but in the form of oxides, or as uranate of soda, potash, and ammonia, finds a limited application in the arts. The sesquioxide salt imparts to glass a gold yellow color with a beautiful greenish tint, and which exhibits remarkable fluorescent properties. The protoxide gives a beautiful black to high-grade porcelains. The material has also a limited application in photography. Recently the material has been used to some extent in making steel in France and Germany, but the industry has not yet passed the experimental stage. It has been stated that the demand, all told, is for about 500 tons annually. Should larger and more constant sources of supply be found, it is probable its use could be considerably extended. According to Nordenskiold, £50,000 worth of uranium minerals are consumed every year, the various salts produced being used in porcelain and glass manufacture, in photography, and as chemical reagents.[2]

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[1] Since the foregoing was written Mr. W. F. Hillebrand, of the U. S. Geological Survey, has published (American Journal of Science, Vol. X, 1900, pp. 120–144) the results of an exhaustive study of the material from this and other localities, and shows that the so-called carnotite is probably a mixture of minerals made up to a large extent of calcium and barium compounds intimately mixed with amorphous silicates containing vanadium in the trivalent state.

[2] Quarterly Journal of the Geological Society of London, LVI, 1900, p. 527.

XII. SULPHATES.

1. Barite; Heavy Spar.

Composition $BaSO_4$,=Sulphur trioxide 34.3 per cent, baryta 65.7 per cent; specific gravity 4.3 to 4.6; hardness 2.5 to 3.5.

Occurrence.—The sulphate of barium to which the mineralogical name of barite is given occurs as a rule in the form of a white, translucent to transparent, coarsely crystalline mineral, about as hard as common calcite, but from which it may be readily distinguished by its great weight and its not effervescing when treated with acid. A common form of the mineral is that of an aggregate of straight or somewhat curved plates, separating readily from one another when struck with a hammer, and cleaving readily into rhomboidal forms much like calcite. (Specimens Nos. 54988, 67372, U.S.N.M.) It is also found in globular and nodular concretions (Specimen No. 66851, U.S.N.M.), stalactitic and stalagmitic (Specimen No. 63778, U.S.N.M.), granular, compact, and earthy masses, and in single and clustered broad and stout crystals. In nature the material is rarely pure, but nearly always contaminated with other elements, as noted in the following analyses of samples from Fulton, Blair, and Franklin counties, Pennsylvania.[1]

Constituents.	Fulton County.		Blair County.	Franklin County.	
	(699) Locke.	(345) Locke.	(698) Galbreath.	(735) Shockey.	(582) Shockey.
Sulphate of barium	95.22	96.91	97.08	95.91	98.65
Oxides of iron and aluminum	0.38	0.31	0.76	0.24	0.14
Oxide of manganese	0.05	None.	None.	None.	None.
Lime	0.59	Trace.	None.	0.17	Trace.
Magnesia	0.18	Trace.	Trace.	0.11	Trace.
Carbonic acid	0.65	None.	None.	None.	None.
Water	0.23	0.08	0.32	0.09	0.20
Silica	2.45	2.35	1.74	2.80	1.11
Total	99.75	99.65	99.90	99.32	100.10

The mineral occurs commonly in connection with metallic ores or as a secondary mineral associated with sand and limestones, sometimes in distinct veins, or as in southwest Virginia, where it fills irregular fractures in certain beds of the Cambrian limestone or in part replaces the limestone itself. (Specimen No. 67357, U.S.N.M.). In Washington County, in this State, the mineral has been mined in an itinerant manner by farmers on whose land it occurs, and who work mostly from open cuts or trenches, rarely making an opening of sufficient size to be termed a mine. As the material is less soluble in atmospheric waters than is the limestone in which it occurs, it follows that often

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[1] Pennsylvania Second Geological Survey, Chemical Analyses, pp. 368, 369.

the barite is found in loose, disconnected masses embedded in a residual clay, and the process of mining is resolved into merely digging so long as the yield is sufficient to pay expenses.

Preparation and uses.—The mineral is washed and ground like grain between millstones and used as an adulterant for white lead or to give weight and body to certain kinds of cloth and paper.

According to a writer in the Mineral Resources of the United States for 1885, the "floated" or "cream-floated" barite used for paint is prepared as follows: The crude mineral as mined is first sorted by hand and cleaned, after which it is crushed into pieces about the size of the tip of one's finger. Next, it is refined by boiling in dilute sulphuric acid until all the impurities are removed, when it is washed by boiling in distilled water and dried by steam. It is then ground to flour, mixed with water, and run through troughs or sluiceways into receiving vats, whence it is taken, again dried by steam, and barreled. This cream-floated barite is quoted as worth about $30 a ton, while the crude material is worth only about one-fourth as much.

Sources.—The principal sources in the United States are Lynchburg, Hurt, Toshes, and Otter River, Virginia; Sandy Bottom and Hot Springs, in North Carolina, and Cadet, Old Mines, Mineral Point, Morrellton, and Potosi, in Missouri. A small amount is imported from Mackellar Islands, Lake Superior. The total production for 1897 was some 27,316 tons, valued at $4 a ton.[1]

2. Gypsum.

Composition $CaSO_4 + 2\ H_2O$, = sulphur trioxide 46.6 per cent, lime 32.5 per cent, water 20.9 per cent. The natural mineral is often quite impure through the presence of organic, ferruginous, and aluminous matter, together with small quantities of the carbonates of lime and magnesia (see analysis, p. 407). Specific gravity 2.3, hardness 1.5 to 2. Color usually white or gray, but brown, black and red through impurities. The softness of the mineral, which is such that it can be easily cut with a knife or even by the thumb nail, is one of its most marked characteristics. Three principal varieties are recognized, (1) the crystallized, foliated, transparent variety, selenite (Specimens Nos. 53593, 53608, 62089, U.S.N.M.), (2) the fine fibrous, often opalescent variety, satin spar (Specimen No. 62477, U.S.N.M.), and (3) the common massive, finely granular variety, gypsum (Specimen No. 53348, U.S.N.M.). When of a white color and sufficiently compact for small statues and other ornamental works, it is known as alabaster (Specimen No. 63394, U.S.N.M.), though this name has unfortunately become confounded with the calcareous rock travertine and stalagmite.[2]

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[1] The Mineral Industry, VI, 1897, p. 57.

[2] See The Onyx Marbles, their Origin, Uses, etc., Report of the U. S. National Museum, 1893, pp. 539–585.

The following is an analysis of a commercial gypsum from Ottawa County, Ohio, as given by Professor Orton:[1]

Lime	32.52
Sulphuric acid	45.56
Water	20.14
Magnesia	0.56
Alumina	0.16
Insoluble residue	0.68
	99.62

Origin.—Gypsum in considerable quantities occurs associated only with stratified rocks and is regarded mainly as a chemical deposit resulting from the evaporation of waters of inland seas and lakes; it may also 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 (limestone) and the sulphates of iron, copper, and other metals; through the hydration of anhydrite and through the action of sulphurous vapors and solutions from volcanoes upon the rocks with which they come in contact. According to Dana,[2] the gypsum deposits in western New York do not form continuous layers in the strata, but lie in imbedded, sometimes nodular masses. In all such cases, this authority says, the gypsum was formed after the beds were deposited, and in this particular instance are the product of the action of sulphuric acid from springs upon the limestone. "This sulphuric acid, acting on limestone (*carbonate* of lime), drives off its carbonic acid and makes *sulphate* of lime, or gypsum; and this is the true theory of its formation in New York." Dr. F. J. H. Merrill, however, regards a portion at least of the New York beds as a product of direct chemical precipitation from sea water.[3]

The gypsum deposits of northern Ohio are regarded by Professors Newberry and Orton as deposits from the evaporation of landlocked seas, as was also the rock salt which overlies it. By this same process must have originated a large share of the more recent gypsum deposits of the Western States.

Geological age and mode of occurrence.—As may be readily inferred from what has gone before, beds of gypsum have formed at many periods of the earth's history and are still forming wherever proper conditions exist. The deposits of New York State occur in a belt extending eastward from Cayuga Lake and in beds belonging to the Salina period of the Upper Silurian age. The rock is often earthy and impure, and is used nearly altogether for land plaster. It is associated with dark, nearly black, limestones and shales and beds of rock salt. In southwest Virginia, along the Holston River, are also beds

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[1] Geology of Ohio, VI, 1888, p. 700.

[2] Manual of Geology, p. 234.

[3] Bulletin No. 11, of the New York State Museum, April, 1893.

of gypsum associated with salt and referred by Dana to this same horizon. The rock is mined at Saltville in Washington County from underground pits, and is used mainly for fertilizing. (Specimens Nos. 27129, 27153, U.S.N.M.)

Gypsum deposits of varying thickness and occurring at various depths below the surface are found continuous over thousands of square miles in northern Ohio, but are at present worked only in Ottawa County at a station on the Lake Shore and Michigan Southern Railway which bears the appropriate name of Gypsum (Specimens Nos. 31624, 17969, U.S.N.M.). The associated rocks are Lower Helderberg limestones and shales and the beds, which vary from 3 to 7 feet in thickness, are found at all depths up to 200 or 300 feet.

The following is a section of the Ottawa County beds as given by Orton:

		Feet.
Drift clays		12 to 14
No. 1.	Gray rock, carrying land plaster	5
	Blue shale	½
No. 2.	Bowlder bed carrying gypsum in separate masses embedded in shaly limestone	5
	Blue limestone, in thin and even courses	1
No. 3.	Main plaster bed	7
	Gray limestone in courses	1
No. 4.	Lowest plaster bed, variable	3 to 5
Mixed limestone and plaster, bottom of quarry.[1]		

Sections like the above are stated to be capable of yielding 50,000 tons of plaster an acre.

The purest gypsum of the region occurs in No. 2, the bowlder bed, as given above. It consists of calcareous shales through which are scattered concretionary balls of gypsum varying in diameter from 6 to 24 inches. This pure variety is used mainly for *terra alba;* about 40 per cent of the total product has in years past been calcined for use as stucco or plaster of paris and 60 per cent for land plaster.

At Fort Dodge, in Iowa, is a deposit of quite pure, light gray, regularly bedded gypsum, resting unconformably upon St. Louis limestone and lower coal strata and overlain by drift. It is supposed to cover an area of some 25 square miles. The material was at one time used for building purposes but proved too soft[2] and is now used mainly for land plaster (Specimens Nos. 26804, 63058, 63059, U.S. N.M.). (See Plate 22.)

There are large deposits of gypsum in Michigan, the most extensive, so far as explored, being near Grand Rapids, Kent County, in the western part of the State (Specimen No. 56397, U.S.N.M.), and at Alabaster Point, in Iosco County, on the eastern margin of the State.

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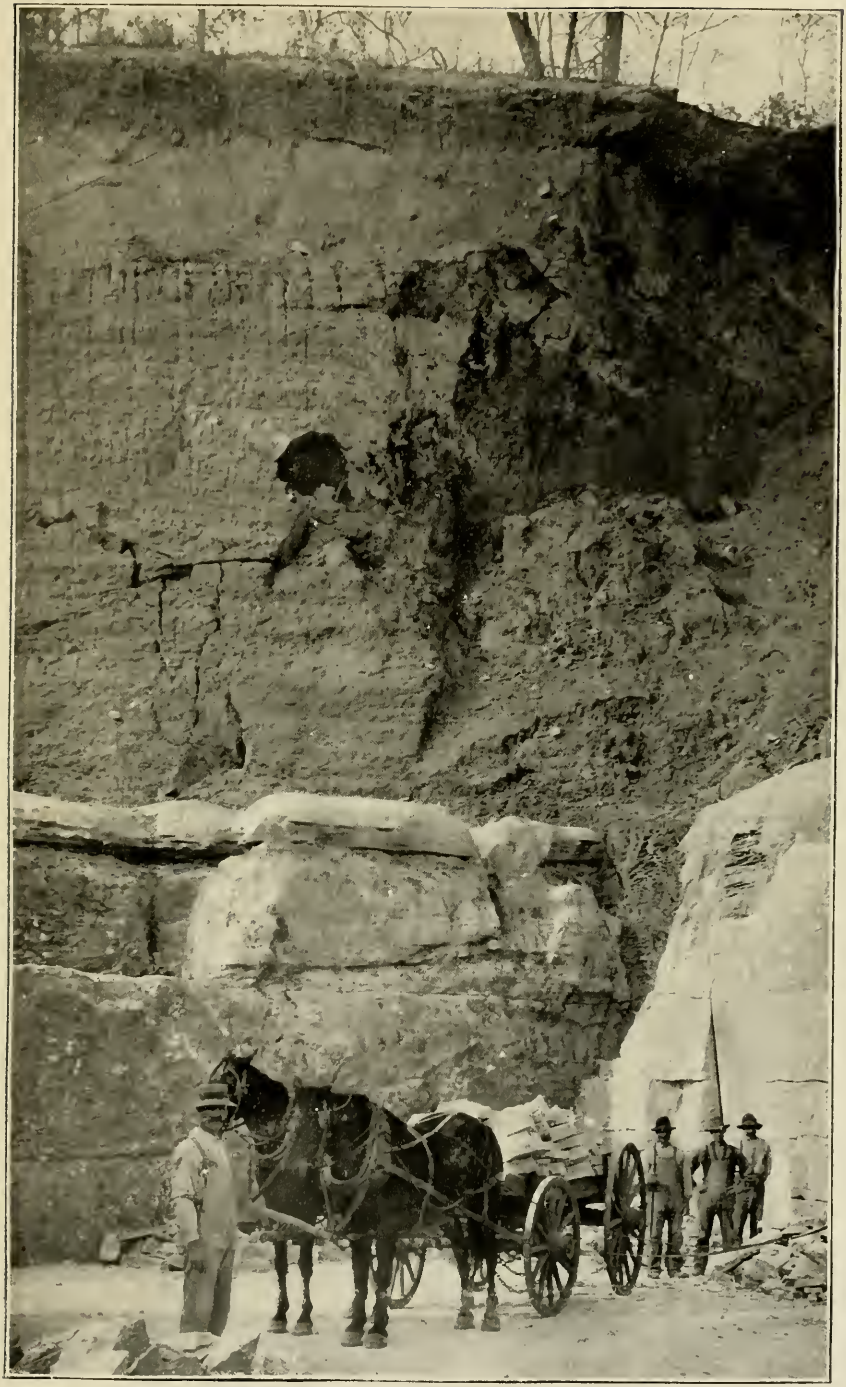
[1] Geological Survey of Ohio. Economic Geology, VI, 1888, p. 698.

[2] Stones for Building and Decoration, 2d ed., 1897, p. 76.



VIEW OF A GYPSUM QUARRY, FORT DODGE, IOWA.
From a photograph by the Iowa Geological Survey.

At both localities there is a succession of beds beginning at or near the surface and aggregating many feet in depth. The beds are regarded as of Carboniferous age. The following section shows the number and thickness of the beds thus far discovered:

	Feet.
Earth stripping	20
Gypsum	8
Soft shale, slate	1
Gypsum	12
Shale or clay slate	7
Gypsum	6½
do	8½
Slate, shale	3½
Gypsum	12½
Shale or clay slate	1½
Gypsum	9½
Shale, clay slate	8
Total	98

West of the front range of the Rocky Mountains are many important beds of gypsum, but which have as yet been but little exploited owing to cost of transportation, there being but little local demand. These beds so far as yet worked are mostly of more recent origin than those in the eastern United States, many being of Tertiary or even Quarternary age.

Near Fillmore, Utah, are deposits of gypseous sand formed by the winds blowing up from the dry beds of playa lakes the minute crystals deposited by evaporation (Specimen No. 35380, U.S.N.M.). The material thus blown together forms veritable dunes from which the material may be obtained by merely shoveling. Prof. I. C. Russell has estimated these dunes to contain not less than 450,000 tons of gypsum.

Important deposits of gypsum also occur in Kansas (Specimen No. 53348, U.S.N.M.), Colorado (Specimen No. 53265, U.S.N.M.), South Dakota (Specimen No. 53462, U.S.N.M.), Wyoming (Specimen No. 63485, U.S.N.M.), California (Specimens Nos. 56419 and 67690, U.S.N.M.), and New Mexico (Specimens Nos. 62254, 67948, and 28586, U.S.N.M.).

Gypsum is a very abundant mineral in New Brunswick, the deposits being numerous, large, and in general of great purity. They occur in all parts of the Lower Carboniferous district in Kings, Albert, Westmoreland, and Victoria, especially in the vicinity of Sussex, in Upham, on the North River in Westmoreland, at Martin Head on the bay shore, on the Tobique River in cliffs over 100 feet high, and about the Albert Mines. At the last-named locality the mineral has been extensively quarried from beds about 60 feet in thickness, and calcined in large works at Hillsborough.[1]

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[1] Dawson's Acadian Geology, p. 249.

The mineral is usually met with in very irregular masses, associated with red marls, sandstones, and limestones, and varies much in character. At Hillsborough, in the quarries being worked, ten to fifteen years ago there was exposed a total head of rock from 90 to 100 feet, of which about 70, forming the upper portion, consists mostly of "soft plaster" or true gypsum, which rests on beds of hard plaster or anhydrite of unknown depth. At the same point considerable masses of very beautiful snow-white gypsum or alabaster are also met with, associated with the varieties named above, but comparatively little selenite, while at Petitcodiac, where the deposits has a breadth of about 40 rods and a total length of about 1 mile, the whole is fibrous and highly crystalline and traversed by a vein of nearly pure selenite, 8 feet wide, through its entire extent. The rock on the Tobique River, which rises in bluffs along the stream some 30 miles above its mouth, is mostly soft, granular or fibrous, and of a more decidedly reddish color than in the other localities.

Important beds of gypsum belonging to the same geological horizon likewise occur in Nova Scotia, particularly at Wentworth and Montague in Hants County, at Oxford, River Philip, Plaster Cove, Wallace Harbor, and Bras d'Or Lake, Cape Breton. At Wentworth there are stated to be "cliffs of solid snowy gypsum from 100 to 200 feet in height." (Specimen No. 13690, U.S.N.M., from Windsor, Hants County.)

Gypsum deposits occur in the Onondago formations of Ontario, Canada, and are exploited along the Grand River between Cayuga and Paris. The mineral here occurs in lenticular masses varying from a few yards to a quarter of a mile in horizontal diameter and from 3 to 7 feet in thickness. (See Specimen No. 62145, U.S.N.M.).

The foreign sources of gypsum are almost too numerous to mention. Important beds occur in Lincolnshire and Derbyshire, England; near Paris, France, in Spain, Italy, Germany, Austria, and Switzerland. The Paris beds are of Tertiary age, and the mineral carries some 10 to 20 per cent of carbonate of lime, together with silica in a soluble form. The presence of these constituents is stated to cause the plaster to set much harder, permitting it, therefore, to be used for external work. The Italian gypsum is often of great purity. The finest alabaster is stated to come from the Val di Marmolago, near Castellina. (Specimen No. 63394, U.S.N.M.)

Uses.—These have been already, in part, noted. The principal uses of gypsum of the ordinary massive varieties is for fertilizers (land plaster) (Specimen No. 63059 U.S.N.M.), and in the manufacture of plaster of paris, or stucco. (Specimens Nos. 53348, 53462, U.S.N.M.)

As above noted, gypsum is but little used for building purposes, being too soft. Several residences, a railway station, and other minor structures are, however, stated to have been built of this stone at Fort Dodge, in Iowa. (Specimen No. 26804, U.S.N.M.) The variety satin spar is sometimes used for small ornamentations, but it is only the snow-white variety (alabaster) that is of any economic importance as an ornamental stone. The main use of alabaster is for small statues, vases, fonts, and small columns; it is too soft for exposed positions where subjected to much wear. At present there are not known any deposits of alabaster within the limits of the United States which are of sufficient purity and extent to be of commercial value. A large share of the alabaster statuettes now on our markets are of Italian make as well as of Italian materials.

In preparing the gypsum for market the stone is first broken in a crusher into pieces of the size of a hickory nut, after which it is ground between millstones (French buhrstones) to a proper degree of fineness and then put up in bags or barrels, if designed for land plaster; if for stucco it is calcined after being ground. This process is in Michigan carried on in large kettles some 8 feet in diameter, and capable of holding about 14 barrels at a charge. The powder is heated until all the included water is driven off, being subjected to constant stirring in the meantime, and is then drawn off through the bottom of the kettles and conveyed by carrying belts and spouts to the packing room.[1]

Under the name of "terra alba" (white earth) ground gypsum is used as an adulterant in cheap paints.

The commercial value of gypsum depends mainly on accessibility to market. In 1899 the ground material was quoted at $2.00 a ton in New York. In Michigan the average price of crude material has been some $1.25 a ton, and for calcined plaster (plaster of paris) $3.00 to $5.00 a ton.

3. CELESTITE.

Composition sulphate of strontium $SrSO_4$, = sulphur trioxide, 43.6 per cent; strontia, 56.4 per cent. Hardness, 3 to 3.5; specific gravity, 3.99; color, white, often bluish, transparent to translucent. Differs from the carbonate (strontianite) by being insoluble in acids, but gives the characteristic red color to the blowpipe flame.

According to Dana the mineral occurs usually associated with limestones or sandstones of Silurian or Devonian, Jurassic, and other geological formations, occasionally with metalliferous ores. It also occurs in beds of rock salt, gypsum, and clay, and is abundantly associated with the sulphur deposits of Sicily. (Specimen No. 60877, U.S.N.M.) The principal localities in the United States are in the limestones of Drummond Island, Lake Huron; Put in Bay, Lake Erie (Specimen No. 53094, U.S.N.M.); Kingston, Ontario, in crystalline

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[1] See Mineral Statistics of Michigan, 1881, for details of plaster work of that State.

masses, and in radiating fibrous masses in the Laurentian formations about Renfrew. Large crystals of a red color are also found in Brown County, Kansas, and at Lampasas and near Austin, Texas. (Specimen No. 67936, U.S.N.M.) Near Bells Mills, Blair County, Pennsylvania, the mineral occurs in lens-shaped masses between the bottommost beds of the Lower Helderberg (No. VI) limestone. On South Bass Island, in Put in Bay, Lake Erie, the mineral occurs frequently in the form of beautiful crystals of all sizes up to 100 pounds in weight, transparent to translucent and sometimes of a fine blue color, lining the walls and floor of limestone caverns.

Uses.—Celestite is used in the preparation of nitrate of strontia employed in fireworks, its value for this purpose being due to the fine crimson color it imparts to the flame. The demand for the material is very small.

4. Mirabilite or; Glauber Salt.

This is a hydrous sodium sulphate, $Na_2SO_4+10\ H_2O$, =sulphur trioxide, 24.8 per cent; soda, 19.3 per cent; water, 55.9 per cent. In its pure state white, transparent to opaque; hardness, 1.5 to 2; specific gravity, 1.48. Readily soluble in water, taste cool, then saline and bitter.

Occurrence.—Aside from its occurrence in soda lakes associated with other salts as described later this sulphate is of common occurrence as an efflorescence on limestones, and in protected places, as in Mammoth Cave, Kentucky, may accumulate in considerable quantities, though not sufficient to be of economic value. (Specimen No. 68156, U.S.N.M., in Cave series.) Salt Lake, Utah, contains a proportionately large amount of this sulphate, which during the winter months is precipitated to the bottom, whence it is not infrequently thrown upon the shore by waves.

According to Prof. J. E. Talmage,[1] when the temperature falls to a certain point, the lake water assumes an opalescent appearance from the separation of the sulphate. This sinks as a crystalline precipitate and much is carried by the waves upon the beach and there deposited. Under favorable circumstances the shores become covered to a depth of several feet with crystallized mirabilite. The writer has on several occasions waded through such deposits, sinking at every step to the knees. Speaking only of the amounts thrown upon the shores, and of most ready access, the source is practically inexhaustible. The substance must be gathered, if at all, soon after the deposit first appears; as, if the water once rises above the critical temperature, the whole deposit is taken again into solution. This change is very rapid, a single day being oftentimes sufficient to effect the entire disappearance of all the deposit within reach of the waves. Warned by these circumstances, the collectors heap the substance on the shores above the lap of the waters, in which situation it is comparatively secure until needed. To a slight depth the mirabilite effloresces, but within the piles the hydrous crystalline condition is maintained. At the present time there are thousands of tons of this material, heaped in the manner described, remaining from the collections of preceding winters. The sodium sulphate thus lavishly sup-

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[1] Science, XIV, 1889, p. 446.

plied is of a fair degree of purity, as will be seen from the following analyses of two samples of the crystallized substance, taken from opposite shores of the lake:

Constituents.	Per cent.	Per cent.
Water	55.070	55.760
Sodium sulphate (Na_2SO_4)	43.060	42.325
Sodium chloride (NaCl)	0.699	0.631
Calcium sulphate ($CaSO_4$)	0.407	0.267
Magnesium sulphate ($MgSO_4$)	0.025	0.018
Insoluble	0.700	0.756
Total	99.961	99.757

Some 14 miles southwest of Laramie, in Albany County, Wyoming, there exist deposits of sulphate of soda, such as are locally known as "lakes." The deposits in question comprise three of these lakes lying within a stone's throw of one another. They have a total area of about 65 acres, the local names of the three being the Big Lake, the Track Lake, and the Red Lake. Being the property of the Union Pacific Railroad Company, they are generally known as the Union Pacific Lakes.

In these lakes the sulphate of soda occurs in two bodies or layers. The lower part, constituting the great bulk of the deposit, is a mass of crystals of a faint greenish color mixed with a considerable amount of black, slimy mud. It is known as the "solid soda," of which an analysis is given below.

Constituents.	Anhydrous.	Crystallized.
Na_2SO_4	36.00	81.63
$CaSO_4$	1.45	1.82
$MgCl_2$	0.77	1.64
NaCl	0.21	0.21
	38.43	85.30
Insoluble residue (at 100 C.)		13.86
		99.16

Total chloride calculated as NaCl equals 1.16 per cent. This, calculated on 100 parts anhydrous Na_2SO_4, equals 3.22 per cent NaCl.

This solid soda is stated to have a depth of some 20 or 30 feet. Borings were made a number of years ago under the direction of the Union Pacific Railroad agents, but, as the records have been mislaid or lost, with what results is not definitely known. There is nothing to prove that the depth is not less than stated above.

Above the solid soda occurs the superficial layer of pure white crystallized sulphate of soda. This is formed by solution in water of the upper part of the lower body, the crystals being deposited by evaporation or by cooling, or by the two combined. A little rain in the spring and autumn furnishes this water, as do also innumerable small, sluggishly flowing springs present in all the lakes. But on account of the dry air of this arid region the surface is generally dry or nearly so, and in midsummer the white clouds of efflorescent sulphate that are whirled up by the ever-blowing winds of Wyoming can be seen for miles. Even should there be a little water present there is no difficulty in gathering the crystals by the train load. The spring, however, is the worst season of the year, on account of the warm weather and of the rains—conditions unfavorable to the formation of crystals. The layer of this white sulphate is from 3 to 12 inches in thickness. When the crystals are removed the part laid bare is soon replenished by a new crop.

The following is an analysis of the purest of this white sulphate of soda, calculated upon an anhydrous basis, that being the condition, of course, in which it would be used:

Na_2SO_4	99.73
$MgCl_2$	.26
Insoluble	Trace.
	99.99

Below is given an analysis of the water of the lake:

Density = 14½° Tw. (= 1.0725 specific gravity). Ten cubic centimeters contains:

	Grams.	Per cent.
Na_2SO_4	0.7563 =	92.23
$CaSO_4$	0.0146 =	1.79
$MgSO_4$	0.0070 =	.85
$MgCl_2$	0.0300 =	3.66
$Na_2B_4O_7$	0.0121 =	1.47
Total solids	0.8200	100.00
Total solids by evaporation	0.8240	

One cubic foot of this water contains 10.72 of pure crystallized sulphate of soda.[1]

(See Specimens Nos. 62086, 53427, U.S.N.M., from Albany County, Wyoming.)

Other similar deposits occur in Carbon and Natrona counties, and still others are reported in Fremont, Johnson, and Sweetwater counties.

It has recently been stated[2] that glauber salts has been found on the bottom of the Bay of Kara Bougas, an inlet of the Caspian Sea, in deposits sometimes a foot in thickness.

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[1] Journal of the Franklin Institute, CXXXV, 1893, pp. 53, 54, 56.

[2] Engineering and Mining Journal, LXV, 1898, p. 310.

5. GLAUBERITE.

Composition sodium and calcium sulphate. $Na_2SO_4.CaSO_4$, = sulphur trioxide, 57.6 per cent; lime, 20.1 per cent; soda, 22.3 per cent. This is a pale yellow to gray salt, partially soluble in water—leaving a white residue of sulphate of lime—and with a slightly saline taste. On long exposure to moisture it falls to pieces, and hence is to be found only in protected places or arid areas. It occurs associated with other sulphates and carbonates, as with thenardite and mirabilite at Borax Lake, in San Bernardino County, California, and with halite in rock salt at Stassfurt (Specimen No. 40229, U.S.N.M.) and other European localities.

6. THENARDITE.

Composition anhydrous sodium sulphate. Na_2SO_4, = sulphur trioxide, 43.7 per cent; soda, 56.3 per cent. Color when pure, white, translucent to transparent; hardness, 2 to 3; specific gravity, 2.68; brittle. In cruciform twins or short prismatic forms roughly striated. Readily soluble in water. Is found in various arid countries, as on the Rio Verde in Arizona, at Borax Lake, California, and Rhodes Marsh in Nevada, associated with other salts of sodium and boron.

7. EPSOMITE; EPSOM SALTS.

Composition sulphate of magnesia $MgSO_4+7H_2O$, = sulphur trioxide, 32.5 per cent; magnesia, 16.3 per cent; water, 51.2 per cent.

This is a soft white or colorless mineral readily soluble in water and with a bitter saline taste. It is a constant ingredient of sea water and of most mineral waters as well. Being readily soluble, it is rarely met with in nature except as an efflorescence in mines and caves. In the dry parts of the limestone caverns of Kentucky, Tennessee, and Indiana it occurs in the form of straight acicular needles in the dirt of the floor and in peculiar recurved fibrous and columnar forms or in loose snow-white masses on the roofs and walls. (Specimens Nos. 68145, 68153, U.S.N.M., from Wyandotte Cave, Indiana.) In all these cases it is doubtless a product of sulphuric acid set free from decomposing pyrites combining with the magnesia of the limestone. It is stated that at the so-called "alum cave" in Sevier County, Tennessee, masses of epsomite very pure and nearly a cubic foot in volume have been obtained. The material in all these cases is of little value, the chief source of the commercial supply being that obtained as a by-product during the manufacture by evaporation of common salt (sodium chloride).

In Albany County, Wyoming, are several lakes, the largest of which has an area of but some 90 acres, in which deposits of epsom salts are formed on a very large scale, but which are of little commercial value, owing to cost of transportation. The material forms compact, almost snow-white aggregates of small acicular crystals of a high degree of purity. (Specimen No. 62088, U.S.N.M.) The composition of the natural salt is given as follows:[1] Insoluble residue, 0.08 per cent; magnesium sulphate (containing traces of calcium and sodium sulphates), 51.22 per cent; water, 47.83 per cent; chloride of sodium, calcium, and magnesium, 0.42 per cent; iron, trace; loss, 0.45.

8. POLYHALITE. 9. KAINITE. 10. KIESERITE.

For description of these minerals see under Halite, p. 195.

11. ALUMS.

Under this head are included a variety of minerals consisting essentially of hydrous sulphates of aluminum or iron, with or without the alkalies, and which are not always readily distinguished from one another but by quantitative analyses. The principal varieties are kalinite, tschermigite, mendozite, pickeringite, apjohnite, halotrichite, and alunogen. Aluminite and alunite are closely related chemical compounds, but differ in hardness and general physical qualities and in being insoluble except in acids.

Although possible sources of alum, none of these minerals have been to any extent utilized in the United States, owing to a lack of quantity or inaccessibility, the main source of the alum of commerce being cryolite, bauxite, and clay, as elsewhere noted. (See pp. 214, 229, and 325.)

KALINITE is a native potash alum; composition $K_2SO_4.Al_2(SO_4)_3+24H_2O$, = sulphur trioxide, 33.7 per cent; alumina, 10.8 per cent; potash, 9.9 per cent; water, 45.6 per cent, or, otherwise expressed, potassium sulphate, 18.1 per cent; aluminum sulphate, 36.3 per cent; water, 45.6 per cent. Hardness, 2 to 2.5; specific gravity, 1.75. This in its pure state is a colorless or white transparent mineral, crystallizing in the isometric system, readily soluble in water, and characterized by a strong astringent taste. In nature it occurs as a volcanic sublimation product, or as a secondary mineral due to the reaction of sulphuric acid set free by decomposing iron pyrites upon aluminous shales. Its common mode of occurrence is therefore in volcanic vents (Specimen No. 60685, U.S.N.M., from Vulcano) or as an efflorescence upon pyritiferous and aluminous rocks. Being so readily soluble, it is to be found in appreciable amounts in humid regions only where protected from the rains, as in caves and other sheltered places. So far as known to the author, the mineral is nowhere found native in such quantities as to have any great commercial value.

TSCHERMIGITE is an ammonia alum of the composition $(NH_4)_2SO_4.Al_2(SO_4)_3+24H_2O$, = aluminum sulphate, 37.7 per cent; ammonium sulphate, 14.6 per cent; water, 47.7 per cent. So far as reported this salt has been found only at Tschermig and in a mine near Dux, Bohemia.

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[1] Bulletin No. 14, October, 1893, Wyoming Experiment Station.

It is obtained artificially from the waste of gas works. Mendozite is a soda alum of the composition $Na_2SO_4.Al_2(SO_4)_3+24H_2O$, = sodium sulphate, 15.5 per cent; aluminum sulphate, 37.3 per cent; water, 47.2. The mineral closely resembles ordinary alum, and has been reported from Mendoza, in the Argentine Republic, hence the name. Pickeringite is a magnesium alum of the composition $MgSO_4.Al_2(SO_4)_3+22 H_2O$, = aluminum sulphate, 39.9 per cent; magnesium sulphate, 14 per cent; water, 46.1 per cent. The mineral is of a white, yellowish, or sometimes faintly reddish color, of a bitter, astringent taste, and occurs in acicular crystals or fibrous masses. (Specimen No. 53043, U. S. N. M., from Tarapacá, Chile.) Halotrichite has the composition $FeSO_4.Al_2 (SO_4)_3+24H_2O$, = aluminum sulphate, 36.9 per cent; ferrous sulphate, 16.4 per cent; water, 46.7 per cent. The mineral is of a white or yellowish color, and of a silky, fibrous structure, hence the name from the Greek word ἅλς, salt, and θρίξ, a hair. Apjohnite has the formula $MnSO_4.Al_2(SO_4)_3+24H_2O$, = manganese sulphate, 16.3 per cent; aluminum sulphate, 37 per cent; water, 46.7 per cent. It occurs in silky or asbestiform masses of a white or yellowish color, and tastes like ordinary alum. It has been found in considerable quantities in the so-called "alum cave" of Sevier County, Tennessee. According to Safford:[1]

> This is an open place under a shelving rock. * * * The slates around and above this contain much pyrites, in fine particles and even in rough layers. * * * The salts are formed above and are brought down by trickling streams of water. * * * Fine cabinet specimens could be obtained, white and pure, a cubic foot in volume.

Dana states that the cave is situated at the headwaters of the Little Pigeon, a tributary of the Tennessee River, and that it is properly an overhanging cliff 80 or 100 feet high and 300 feet long, under which the alum has collected. It occurs, according to this authority, in masses, showing in the cavities fine transparent needles with a silky luster, of a white or faint rose tinge, pale green or yellow. Epsomite and melanterite occur with it. Alunogen has the composition $Al_2 (SO_4)_3+18H_2O$, = sulphur trioxide, 36 per cent; alumina, 15.3 per cent; water, 48.7 per cent; hardness, 1.5 to 2; specific gravity, 1.6 to 1.8. This is a soft white mineral of a vitreous or silky luster, soluble in water, and with a taste like that of the common alum of the drug stores. It occurs in nature both as a product of sublimation in volcanic regions, and as a decomposition product from iron pyrites (iron disulphide) in the presence of aluminous shales. So far as the present writer is aware, the native product has no commercial value, being found (on account of its ready solubility) in too sparing quantities in the humid East, while the known deposits in the arid regions are remote and practically inaccessible. A white fibrous variety is

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[1] Geology of Tennessee, 1869, p. 197.

stated by Dana to occur in large quantities at Smoky Mountain, in North Carolina, and large quantities of an impure variety, often of a yellowish cast, are found in Grant County, on the Gila River, about 40 miles north of Silver City, New Mexico. (Specimen No. 67841, U.S.N.M.) The mineral is also found in Crooke and Fremont counties, Wyoming (Specimen No. 62087, U.S.N.M.); in Schemnitz, Hungary (Specimen No. 53047, U.S.N.M.), and in Japan (Specimen No. 34402, U.S.N.M.).

The chief use of the material, were it procurable cheaply and in quantities, would be as a source of alumina for use in chemical manufacture and as an ore of aluminum.

Concerning the occurrence of alunogen on the Gila River, New Mexico, W. P. Blake writes:

> In a region about half a mile square, of nearly horizontal strata of volcanic origin, there has been extensive alteration and change by solfataric action, or possibly by the decomposition of disseminated pyrites producing aluminous solutions, which, flowing slowly by capillary movement from within outwards, suffer decomposition at the surface with the production of sulphate of alumina (alunogen) in crusts and layers upon the outer portions of the rocks, attended by the deposition of siliceous crusts and the separation of ferric sulphate, while the rocks so traversed appear to be deprived of a part, at least, of their silica and of their alkalies, with the formation of bauxite.
>
> The alunogen is thus an outer deposit, while the bauxite is not a deposit, but is an internal residual mass in place. Its color is generally bluish-white; structure, amorphous, granular, without concentric or pisolitic grains. When dried in the sun and air it will still lose about 20 per cent by ignition. It gives only about 1 per cent of soluble matter by leaching with water; is infusible, and reacts for alumina. The amount of residual silica and alkalies has not yet been ascertained, and no careful full analysis has been made. The composition is no doubt variable in samples from different places, for the original rocks give evidence of a great difference within short distances.[1]

Material from this locality (represented by Specimen No. 67841, U.S.N.M.) analyzed in the laboratories of the United States Geological Survey, yielded results as below:[2]

Alumina (Al_2O_3)	15.52
Sulphur trioxide (SO_3)	34.43
Water (H_2O)	42.56
Insoluble residue	7.62
	100.13

An asbestiform halotrichite from the same locality yielded—

Alumina (Al_2O_3)	7.27
Iron protoxide (FeO)	13.59
Sulphur trioxide (SO_3)	37.19
Water	40.62
Insoluble residue	0.50
	99.17

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[1] Transactions of the American Institute of Mining Engineers, XXIV, 1894, p. 572.

[2] American Journal of Science, XXVIII, 1884, p. 24.

In New South Wales the material is commonly met with as an efflorescence in caves and under sheltered ledges of the Coal Measure sandstone, usually with epsomite, as at Dabee, County Phillip; Wallerawang and Mudgee road, County Cook; the mouth of the Shoalhaven River, and other places. Also found in the crevices of a blue slate at Alum Creek, and at the Gibraltar Rock, County Argyle. Occurs as a deposit, with various other salts, from the vents at Mount Wingen, County Brisbane, together with native sulphur in small quantities; and at Appin, Bulli, and Pitt Water, County Cumberland. At Cullen Bullen, in the Turon district, County Roxburgh; at Tarcutta, County Wynyard; Manero; Wingello Siding, and Capertee.

A specimen in the form of fibrous masses, made up of long, acicular crystals, white, silky luster, like satin spar, found as an efflorescence in a sandstone cave near Wallerawang, was found to have the following composition:

Water	47.585
Matter insoluble in water	1.079
Alumina	15.198
Sulphuric acid	34.635
Soda	.931
Potash	.337
Loss	.235
	100.000

The formula for the above is practically $Al_2O_3.3SO_3+18H_2O$. Another specimen from the same place was found to contain a notable quantity of magnesium sulphate.

Water, by difference	47.388
Silica	1.908
Alumina	13.113
Sulphuric acid	33.067
Lime	.798
Magnesia	3.726
Total	100.000

The formula for the above is also practically $Al_2O_3.3SO_3+18H_2O$.

Aluminite.—Aluminite is a dull, lusterless earthy, aluminum sulphate of the composition indicated by the formula $Al_2O_3.SO_3,9H_2O=$ sulphur trioxide 23.3 per cent; alumina 29.6 per cent; water 47.1 per cent. It is soluble only in acids, white in color, opaque, and occurs mainly in beds of Tertiary and more recent clays.

Alunite.—Composition $K_2O.3Al_2O_3.4SO_3.6H_2O=$sulphur trioxide 38.6 per cent; alumina 37.0 per cent; potash 11.4 per cent; water 13.0 per cent. Hardness 3.5 to 4; specific gravity 2.58 to 2.75. This mineral occurs native in the form of a fibrous, or compact finely granular rock of a dull luster somewhat resembling certain varieties of aluminous limestones. It is infusible and soluble only in sulphuric acid. The more compact varieties are so hard and tough as to be used for millstones in Hungary. No deposits of such extent as to be of economic importance are known within the limits of the United States. Alunite as an alteration product of rhyolite has been described by Whitman Cross[1] as occurring at the Rosita Hills in Colorado, the alteration being brought about through the influence of sulphurous vapors incident to the volcanic outbursts. The altered rhyolite as shown by analyses had the following composition: Silica 65.94 per cent; alumina 12.95 per cent; potash 2.32 per cent; soda 1.19 per cent; sulphur trioxide 12.47 per cent; water 4.47 per cent; Fe_2O_3, etc., 0.55 per cent. This indicates that the rock is made up of alunite and quartz, in the proportion of about one-third of the former to two-thirds of the latter. The most noted occurrences of alunite are at Tolfa, near Rome; Montioni, in Tuscany, Italy (Specimen No. 62863, U.S.N.M.); Musaz, in Hungary (Specimens Nos. 60925, 66854, U.S.N.M.) on the islands of Milo, Argentiera and Nevis in the Grecian Archipelago; Mount Dore in France, and at Bulledelah in New South Wales. At the last-named locality the mineral occurs in compact, micro-crystalline forms of a slight flesh pink tint, in "a large deposit forming the summit of a ridge about three-fourths mile long by one-half mile wide, and rising about 1,000 feet above the level of Lyall Creek, on which it is situated. Viewed from the creek it presents a massive outcrop resembling limestone. It yields from 60 to 80 per cent of alum upon roasting, lixiviating, and evaporating[2] (Specimen No. 62179, U.S.N.M.).

Alunite from the mines at Tolfa varies considerably in composition. The crystallized variety contains about 32 per cent alumina, whereas the cruder specimens which contain a large quantity of silica have only about 17.5 per cent. The following is an analysis of an average sample:

Alumina	27.60
Sulphuric acid	29.74
Potash	7.55
Water	11.20
Iron	1.20
Silica	22.71
Total	100.00

When crushed it is easily reduced to a powder, the finer portions of which are richer in alumina than the coarser portions, and for this reason the author recommends that only the former should be exported, the latter being converted into commercial products in the vicinity of the mine.[3]

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[1] American Journal of Science, XLI, 1891, p. 468.

[2] Catalogue of New South Wales Exhibits, World's Columbian Exposition, Chicago, 1893, Dept. E, p. 358.

[3] Journal of the Society of Chemical Industry, I, 1882, p. 501.

Alum Slate or Shale is a somewhat indefinite name given to fine-grained arenaceous rocks consisting essentially of siliceous and feldspathic sands and clays with disseminated iron pyrites. The following analyses from Bischof's Chemical Geology will serve to show their varying composition:

Constituents.	I.	II.	III.
Silica	65.44	72.40	50.13
Alumina	14.87	16.45	10.73
Iron oxides	1.05	....	2.27
Lime	.15	.17	.40
Magnesia	1.34	1.48	1.00
Potash	4.59	5.08	....
Soda	.48	.53	....
Iron pyrites	1.25	2.26	7.53
Carbon and water	Undet.	Undet.	25.04

(I) An alum slate from Opsloe, near Christiania, Norway, (II) from Bornholm, and (III) from Garnsdorf, near Saalfeld, Prussia. Concerning No. III it is stated that "on the roof of the adit, driven into the slate, there are almost everywhere yellow or white opaque stalactites, and more rarely a green transparent deposit is produced. Both consist of hydrated basic sulphate of alumina and peroxide of iron. In the former, iron predominates; in the latter, alumina. Both substances are quite insoluble in water.

From shales and slates of this type the alum is obtained by crushing and allowing to undergo prolonged weathering or submitted to a roasting process. The essential part of the reaction consists in oxidizing the bisulphide to the condition of a sulphate and finally into iron sesquioxide, with separation of free sulphuric acid which attacks the alumina, forming an equivalent quantity of sulphate of aluminum or alum. So far as is known this process is not carried on at all in the United States.

The alum shale of the English Upper Liassian formation consists of hard blue shale with cement stones. On exposure to the air it gradually becomes incrusted with sulphur, and occasionally with alum.

In composition the alum shale is as follows:

Iron sulphide	8.50
Silica	51.16
Iron protoxide	6.11
Alumina	18.30
Lime	2.15
Magnesia	0.90
Sulphuric acid	2.5
Potash	Trace.
Soda	Trace.
Carbon	8.29
Water	2.00
Total	99.91

From this shale potash-alum was formerly made near Whitby and Redcar, the aluminum sulphate being extracted from the shale, and the potash-salt being added. The trade which since the days of Queen Elizabeth has been largely carried on, has now almost passed away, as alum is now manufactured in other places from coal-shale. Alum works formerly existed at the Peak, Robin Hood's Bay, Stow Brow, Sandsend, Kettleness, Lofthouse (Loftus), Osmotherly, etc.[1]

According to F. Stolba,[2] the so-called Bohemian fuming sulphuric acid is made from vitriol obtained from Silurian pyritiferous schists ("vitriolschiefer"). The method as given is as follows: Large masses of the schist, which consist essentially of a quartzose matrix containing pyrite, carbonaceous matter, and clay, are exposed to the weathering action of the atmosphere for three years. The products of oxidation so formed are ferrous sulphate and sulphuric acid, which latter acts energetically upon the clay, and finally aluminum sulphate and other sulphates are yielded. The ferrous sulphate at first formed becomes by oxidation ferric sulphate, which, together with the aluminum sulphate, is the principal product of the weathering of the vitriol slate. Ferrous sulphate remains only in small quantities. The next operation is lixiviation of the mass with water, after which the liquor obtained is concentrated to a density of 40° Baumé, and finally evaporated in pans until, on cooling, a crystalline cake of vitriol stone is obtained. The vitriol stone is now calcined in order to remove the greater part of its water. The resulting product, when heated to a very high temperature in clay retorts, yields sulphuric anhydride, and a residue, termed colcothar, remains in the retorts. The composition of vitriol stone and colcothar will be seen from the following analyses:

VITRIOL STONE.	
Fe_2O_3	20.07
Al_2O_3	4.67
FeO	0.64
MnO	Traces.
CaO	0.14
MgO	0.39
K_2O	0.07
Na_2O	0.05
CuO	0.10
SiO_2	0.10
P_2O_5	Traces.
SO_3	40.51
As	Traces.
H_2O	32.58=99.32

VITRIOL STONE.	
$Fe_2(SO_4)_3$	50.17
$Al_2(SO_4)_3$	11.94
$FeSO_4$	1.35
$MgSO_4$	1.17
$CaSO_4$	0.33
$CuSO_4$	0.20
K_2SO_4	0.13
Na_2SO_4	0.11
H_2SO_4	1.49
MnO, As, and P_2O_5	Traces.
SiO_2	9.10
H_2O	32.31=99.29

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[1] The Geology of England and Wales, p. 279.

[2] Journal of the Society of Chemical Industry, V, 1886, p. 30.

COLCOTHAR.

Fe_2O_3	74.62
Al_2O_3	12.53
MgO	3.23
CaO	0.82
SO_3	5.17
SiO_2	1.17
CuO	0.20
H_2O	1.30=99.04

XIII. HYDROCARBON COMPOUNDS.

1. Coal Series.

Here are included a variety of more or less oxygenated hydrocarbons varying widely in physical and chemical properties, but alike in originating from decomposing plant growth protected from the oxidizing influences of the air. According to the amount of change that has taken place in the original plant material, the amount of volatile matter still retained by it, its hardness and burning qualities, several varieties are recognized.

Origin.—The idea long prevalent but never entirely accepted to the effect that the coal beds resulted from the accumulation *in situ* of organic matter growing on gradually subsiding marshes has of late given way quite largely to another more in accord with the facts as now known.

While we have indubitable proof that peat may and does thus originate, as is to be seen in many a modern peat bog, and while, too, there is no doubt as to the possibility of such, under proper conditions, becoming converted into coal, still there are many facts which tend to show that perhaps the most and the largest of the coal deposits are due to the accumulation of transported plant remains laid down at the mouths of rivers as in deltas and lagoons. They are in fact as true sedimentary deposits as the shales and sandstones with which they are associated. This view best accounts for the constant interlamination of the coal with clay and sand, with the marked stratification of the coal itself, as well as the amorphous nature of the material, since, as is well known, calcium sulphate, a constituent of sea water, tends to decompose organic matter, reducing it to a pulplike, and at times almost mucilaginous condition.

The idea, too, long prevalent, that anthracite is but a bituminous coal from which a large portion of the volatile matter has been driven off by the heat and pressure incidental to mountain making or the intrusion of igneous rocks is also in part being set aside. Undoubtedly anthracite may be thus produced and in some cases has been thus produced, as in the Cerrillos coal field of New Mexico, where a bituminous coal containing some 30 per cent of volatile matter has been locally converted into anthracite through the intrusion of a mass of an andesitic trachyte.[1]

Prof. J. J. Stevenson has, however, argued[2] that the difference between anthracite and the bituminous coals is due, not to metamorphism through heat and pressure after being buried, but rather to the former having been longer exposed to the percolating action of water, whereby the volatile constituents were removed, prior to its final burial, and the consolidation of the inclosing rocks.

The subject is, however, altogether too large to be satisfactorily discussed here, and the reader is referred to the special works on the subject noted in the bibliography.

Peat represents the plant matter in its least changed condition. It results from the gradual accumulation in bogs and marshes of growths consisting mainly of sphagnous mosses, a low order of plants having the faculty of continuing in growth upward as they die off below. In this way the deposits often assume a very considerable thickness. When sufficently thick the weight of the overlying matter may have converted the lower portions into a dense brownish-black mass somewhat resembling true coal. The deposits of peat are all comparatively recent and occur only in humid climates. They are developed to an enormous extent in Ireland—about one-seventh of the entire country being covered by them—and average in some cases 25 feet in thickness. (Specimen No. 53242, U.S.N.M., from County Kerry.) They are also abundant on the continent of Europe and various parts of North America. In Europe, and especially in Ireland, the material is extensively utilized for fuel, and there would seem no good reason for not so utilizing it in America. As prepared for use the material is simply dug from the bogs and stacked up until sufficiently dry for burning, or pressed into bricks of suitable size and shape for convenient handling. Many processes have been invented for reducing the material to a pulp and subsequently condensing by pressure, but all involve too great an outlay to be profitable.[3]

In America the chief use of the material is as a fertilizer, a material for "mulching."[3] An impure variety containing a considerable quan-

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[1] Bulletin of the Geological Society of America, VII, 1895–96, p. 525.

[2] Idem, V, 1894, p. 39.

[3] A new method of making charcoal from peat has been patented in England by Mr. Blundell and is to be tried in Italy, where there are large deposits of peat which can, it is claimed, be handled very cheaply. In this process the peat is first reduced to a fine paste and leaves the machine in a continuous thick tube 3 to 5 inches in diameter, and is then cut off in sticks and dried for three days on wooden supports and for a longer period in the air on wire netting. After twenty-five days the sticks become dry and hard and may be burned as fuel; but it is more profitable to convert these sticks into charcoal. This is accomplished in six hours in a retort, and 3 tons of peat make 1 ton of charcoal.—Engineering and Mining Journal, LXV, February 26, 1898, p. 248.

VIEW OF PEAT BEDS OVERLYING GOLD-BEARING GRAVELS, MIAS, RUSSIA.

From a photograph by A. M. Miller.

tity of silicious sand, and locally known as "muck," is thus used throughout New England.

According to J. E. Kehl, United States consul at Stettin, Germany, the manufacture of peat briquettes in that country is likely to become an industry of some importance. The material fresh from the moor is cut and ground quite finely by machinery, dried by steam, and pressed into the desired form. The material thus prepared is said to be clean to handle, gives a good heat, and burns satisfactorily in both stoves and open grates. The peat briquettes retail at the rate of 8 for a cent, American money.[1]

From a study made by Drs. J. W. Dawson and B. J. Harrison some years ago[2] it was concluded that the peat deposits of Prince Edward Island were capable of economic utilization. Three deposits were referred to, the possibilities of which were given as below:

Lenox Island bog, at $4 a ton, 20,000 tons, value	$80,000
Squirrel Creek bog, at $4 a ton, 500,000 tons, value	2,000,000
Black Bank bog, at $4 a ton, 1,777,248 tons, value	7,108,992
Total	9,189,992

The following analyses of peats are given by this authority:

Constituents.	Hydroscopic water.	Volatile combustible matter.	Fixed carbon.	Ash.
Champlain peat	14.96	59.60	22.20	3.24
Hodges peat	17.06	50.725	25.96	6.265
Indian Island peat	23.71	41.195	19.835	15.26
Black Bank peat	16.52	53.29	22.48	7.71

Below are given the results of analyses of I, peat from bog of Allan, Ireland; II, a "muck" from Maine, United States; and III, Commander Islands in Behring Sea (Specimen No. 59320, U.S.N.M.):

Constituents.	I.	II.	III.
	Per cent.	*Per cent.*	*Per cent.*
Carbon	61.04	21	60.48
Volatile matter	37.53	72	39.53
Ash	1.83	7	3.30

LIGNITE OR BROWN COAL.—This name is given to a brownish-black variety of coal characterized by a brilliant luster, conchoidal fracture, and brown streak. Such contain from 55 to 65 per cent of carbon and burn easily, with a smoky flame, but are inferior to the true coals for heating purposes. They are also objectionable on account of the soot they create, and their rapid disintegration and general deterioration

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[1] United States Consular Reports, January, 1899, p. 99.

[2] Report on the Geological Structure and Mineral Resources of Prince Edward Island, 1871.

when exposed to the air. They occur in beds under conditions similar to the true coals, but are of more recent origin. The lignitic coals of the regions of the United States west of the Mississippi River are mainly of Laramie (Upper Cretaceous) age, and often show easily recognizable traces of their organic origin, such as compressed and flattened stems and trunks of trees with traces of woody fiber (Specimen No. 4795, U.S.N.M.).

Jet is a resinous, coal-black variety of lignite sufficiently dense to be carved into small ornaments (Specimens Nos. 62930, 62804, U.S.N.M.). According to Professor Phillips, it is simply a coniferous wood, and still shows the characteristic structure under the microscope. It has been known since early British times, having at first been found on the seashore at Whitby and other places. The largest seam on record was obtained from the North Bats, near Whitby. It weighed some 5,180 pounds and was valued at about $1,250. The material is now regularly mined both in the cliffs and inland, and is one of the most valuable products of the Yorkshire coast.[1]

BITUMINOUS COALS.—Under this name are included a series of compact and brittle products in which no traces of organic remains are to be seen on casual inspection, but which under the microscope often show traces of woody fiber, spores of lycopods, etc. These coals are usually of a brown to black color, with a brown or gray-brown streak, breaking with a cubical or conchoidal fracture, and burning readily with a yellow, smoky flame. They contain from 35 to 75 per cent of fixed carbon, 18 to 60 per cent of volatile matter, from 2 to 20 per cent of water, and only too frequently show traces of sulphur, due to included iron pyrites. Several varieties of bituminous coals are recognized, the distinctions being based upon their manner of burning. *Coking* coals are so called from the facility with which they may be made to yield coke. Such give a yellow flame in burning and make a hot fire. (Specimens Nos. 55490, U.S.N.M., Connellsville, Pennsylvania, and 59260, U.S.N.M., from New River, West Virginia.) Other varieties of apparently the same composition and general physical properties can not for some unexplained reason be made to yield coke, and are known as *noncoking coals*. (Specimens Nos. 59428, U.S.N.M., from Vigo County, Indiana, and 59208, U.S.N.M. (splint coal), from Fayette County, West Virginia.) *Cannel* coal has a very compact structure, breaks with a conchoidal fracture, has a dull luster, ignites easily, and burns with a yellow flame. It does not coke. Its chief characteristic is the large amount of volatile matter given off when heated, whereby it is rendered of particular value for making gas. (Specimens Nos. 56280, 56284, and 58496, U.S.N.M., are characteristic.) Before the discovery of petroleum it was used for the distillation of oils. Below is given the composition of a (I) coking coal from the

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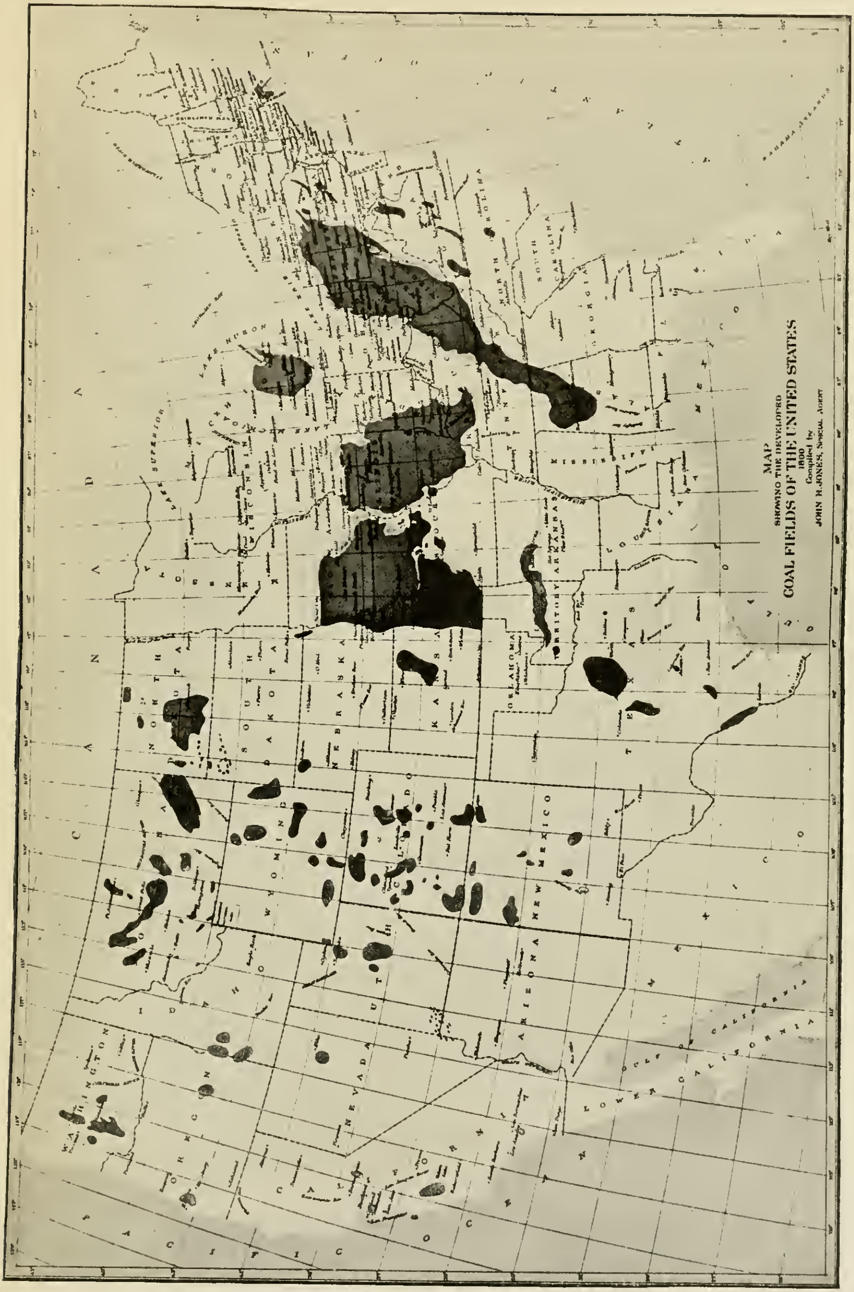
[1] Geology of England and Wales, p. 278.



Map showing the Developed Coal Fields of the United States.

From the Report of the Eleventh Census.

Connellsville Basin of Pennsylvania, and (II) a cannel coal from Kanawha County, West Virginia.[1]

Constituents.	I.	II.
Water	1.105	....
Volatile matter	29.885	58.00
Fixed carbon	57.754	23.50
Ash	9.895	18.50
Sulphur	1.339	....
Total	99.978	100.00

Anthracite Coal.—This is a deep black, lustrous, hard and brittle variety, and represents the most highly metamorphosed variety of the coal series. Traces of organic nature are almost entirely lacking in the matter of the anthracite itself, though impressions of ferns, lycopods, sigillaria and other coal-forming plants are frequently associated with the beds in such a manner as to leave little doubt as to their origin. Anthracite is ignited with difficulty and burns with little flame, but makes a hot fire. Below is given the average composition of a coal from the Kohinoor Colliery, Shenandoah, Pennsylvania.[2]

Water	3.163
Volatile matter	3.717
Fixed carbon	81.143
Sulphur	0.899
Ash	11.078
	100.00

(Specimens Nos. 59058, 59062, from Pennsylvania, and 30854, from Colorado, are sufficiently characteristic.) Like the other coals, anthracite occurs in true beds, but is confined mostly to rocks of the Carboniferous age. Thin seams of anthracite sometimes occur in Devonian and Silurian rocks, but which are too small to be of economic value. Rarely coals of more recent geological horizon have been formed locally, altered into anthracite by the heat of igneous rocks. Through a still further metamorphism, whereby it loses all its volatile constituents, coal passes over into graphite (Specimens Nos. 17299 and 59099, from near Newport, Rhode Island), and it is possible, though scarcely probable, that all graphite may have originated in this way.

The principal anthracite coal regions of the United States are in eastern Pennsylvania. From here westward throughout the interior States to the front range of the Rocky Mountains the coals are all soft, bituminous coals. Those of the Rocky Mountain region proper are largely lignitic, passing into the bituminous varieties.

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[1] F. P. Dewey, Bulletin 42, United States National Museum, 1891, p. 231.

[2] Idem, p. 221.

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MAP SHOWING AREAS WHERE BITUMEN OCCURS IN THE UNITED STATES AND CANADA.

From the Report of the Tenth Census.

2. Bitumen Series.

Under this head are included a series of hydrocarbon compounds varying in physical properties from solid to gaseous and in color from coal black through brown, greenish, red, and yellow to colorless. Unlike the members of the series already described, they are not the residual products of plant decomposition *in situ*, but are rather, in part at least, distillation products from deeply buried organic matter of both animal and vegetable origin. The different members of the series differ so widely in their properties and uses that each must be discussed independently. The grouping of the various compounds as given below is open to many objections from a strictly scientific standpoint, but, all things considered, it seems best suited for the present purposes.[1]

Tabular classification of hydrocarbons.[2]

Hydrocarbons.	Bituminous	Gaseous	Marsh gas (Natural gas).
		Fluidal	Petroleum (Naphtha).
		Viscous and semisolid	Pittasphalt (Maltha). Mineral tar. Asphalt.
		Elastic	Elaterite. Wurtzillite.
		Solid	Albertite. Grahamite. Uintaite.
	Resinous		Succinite. Copalite. Torbanite. Ambrite.
	Cerous (waxy)		Ozokerite. Hatchettite.

Tabular classification or grouping of natural and artificial bituminous compounds.

Bituminous Compounds.	Natural.	Mixed with limestone, "asphaltic limestone."	Seyssel, Val de Travers, Lobsan, Illinois, and other localities.
		Mixed with silica and sand, "asphaltic sand."	California, Kentucky, Utah, and other localities. "Bituminous silica."
		Mixed with earthy matter, "asphaltic earth."	Trinidad, Cuba, California, Utah.
		Bituminous schists	Canada, California, Kentucky, Virginia, and other localities.
	Artificial.	Fluid	Thick oils from the distillation of petroleum. "Residuum."
		Viscous	Gas-tar. Pitch.
		Solid	Refined Trinidad asphaltic earth. Mastic of asphaltite. Gritted asphaltic mastic. Paving compounds.

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[1] See article What is Bitumen? by S. F. Peckham, Journal of the Franklin Institute, CXL, 1895, pp. 370 to 383.

[2] W. P. Blake, Transactions of the American Institute of Mining Engineers, XVIII, 1890, p. 582.

Table of occurrence of important natural bitumen.[1]

Important natural bitumens.	Natural gas			Ohio, Pennsylvania, California, etc., in the United States; Russia, France, etc.
	Natural naphtha			Found in petroleum districts (of little value, superseded by artificial naphtha from crude petroleum).
	Petroleum			Pennsylvania, Ohio, Wyoming, California, etc., in United States; Russia, etc. (consult books on petroleum).
	Maltha			California, Wyoming, Alabama, Utah, Colorado, Kentucky, New Mexico, Ohio, Texas, Indian Territory, etc.; Russia, France, Germany, etc.
	Asphaltum	Asphaltum almost pure.	North America	Utah, California, Texas, etc.
			Central America	Cuba, Mexico, etc.
			South America	Trinidad, Venezuela, Peru, Colombia, etc.
			Europe	Caucasia, Syran-on-the Volga, Germany, France, Italy, Austria, etc.
			Asia	Hit on the Euphrates, Asia Minor, Palestine, etc.
			Africa	Oran in Egypt; probably other places.
		Asphaltic compounds.	North America	West Virginia, Kentucky, Texas, Wyoming, Utah, Colorado, California, Indian Territory, Montana, New Mexico.
			Central America	Mexico, Cuba, etc.
			South America	Trinidad (largest supply, most used), Venezuela, Peru, Colombia, etc.
			Europe	Germany, Switzerland, France, Italy, Sicily, Russia, Austria, Spain, etc.
			Asia	Asia Minor, Palestine, Bagdad, and probably in China.
			Africa	Egypt, and probably elsewhere in Africa.

Origin.—Of the many views, mainly theoretical, that have been put forward to account for the origin of bituminous compounds, but two need be noted in detail here. Interested readers are referred to the bibliography given on page 460, and particularly to the works of Peckham, Orton, and Redwood. Prof. Edward Orton, after an

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[1] J. W. Howard, as quoted by S. P. Sadtler, Journal of the Franklin Institute, CXL, 1895, p. 200.

exhaustive consideration of the occurrence of petroleum, natural gas, and asphalt in Kentucky,[1] gives the following precise summary:

1. Petroleum is derived from organic matter.
2. Petroleum of the Pennsylvania type is derived from the organic matter of bituminous shales, and is probably of vegetable origin.
3. Petroleum of the Canadian type is derived from limestones, and is probably of animal origin.
4. Petroleum has been produced at normal rock temperatures (in American fields), and is not a production of destructive distillation of bituminous shales.
5. The stock of petroleum in the rocks is already practically complete.

Hofer[2] regards petroleum as of animal origin only, and advances the arguments given below in support of his theory:

1. Oil is found in strata containing animal, but little or no plant remains. This is the case in the Carpathians, and in the limestone examined in Canada and the United States by Sterry Hunt.
2. The shales from which oil and paraffin were obtained in the Liassic oil shales of Swabia and of Steirdorf, in Styria, contained animal, but no vegetable remains. Other shales, as, for instance, the copper shales of Mansfield, where the bitumen amounts to 22 per cent, are rich in animal remains and practically free from vegetable remains.
3. Rocks which are rich in vegetable remains are generally not bituminous.
4. Substances resembling petroleum are produced by the decomposition of animal remains.[3]
5. Fraas observed exudations of petroleum from a coral reef on the shores of the Red Sea, where it could be only of animal origin.

The relationship which exists between the solid or viscous bitumen and the fluidal petroleum have not in all cases been satisfactorily worked out, though Peckham has shown[4] that in California at least there are almost infinite gradations from one extreme to the other. In Ventura County, for instance, the petroleum is held, primarily, in strata of shale, from which it issues as petroleum or maltha, accordingly as the shales have been brought into contact with the atmosphere, the asphaltum being produced by a still further exposure to the atmosphere after the bitumen has reached the surface. This relationship between the more fluidal and viscous varieties is shown in fig. 13, copied from Professor Peckham's paper above referred to, and which represents a section across a portion of Sulphur Mountain between the Hayward Petroleum Company's tunnels in Wheeler Canyon, and the Big Spring Plateau on the Ojai ranch. In this section it will be noted that the mountain is formed of a synclinal fold of shale, the strata dipping

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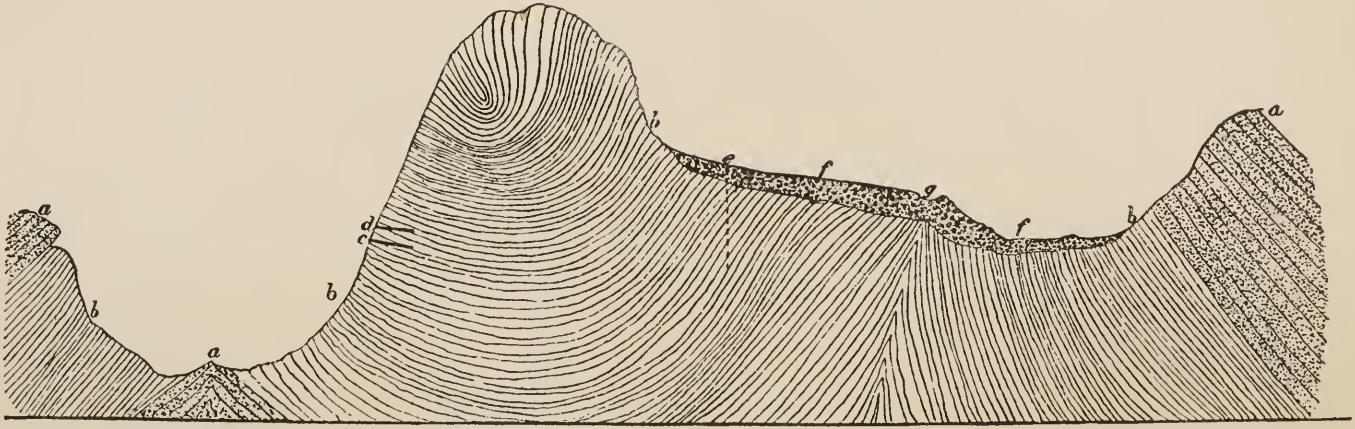
[1] Report on the Occurrence of Petroleum, etc., in Western Kentucky. Geological Survey of Kentucky, John R. Proctor, director, 1891.

[2] As quoted by Redwood, I, p. 238.

[3] Dr. Engler, as quoted by Redwood, obtained by distillation of menhaden oil, among other products, a substance remarkably like petroleum, and a lighting oil indistinguishable from commercial kerosene.

[4] See Report of the Tenth Census, p. 68.



a. Sandstone.
b. Shale.
c d. Tunnels.
e. Well on Ojai ranch.
f. Soil.
g. Big spring on Ojai ranch.

[Fig. 6—page 68.]

Section through Sulphur mountain and Ojai plateau, Ventura county, California.

Fig. 13.

SECTION THROUGH SULPHUR MOUNTAIN, CALIFORNIA.

After S. F. Peckham.

inward on both sides and coming to the surface almost vertically on the right, and more nearly horizontally on the left (the south). The tunnels are driven into the nearly vertical face of the mountain and the oil-bearing rock is protected by some 700 or 800 feet of overlying shales. The oil obtained is the lightest thus far found in southern California. On the other hand, the material which exudes on the north side, when the shales are upturned at such an angle as to give free access to atmospheric agencies, is in the form of maltha, or mineral tar, and so viscous, in December, 1865, that it could be gathered and rolled into balls like dough.

The relationship between petroleum and natural gas is scarcely better defined. That the gas can be derived from petroleum is undoubted, and indeed the latter apparently never occurs free from gas. But on the other hand, as Professor Orton states, the gas often originates under many conditions in which petroleum does not occur. The formation of marsh gas from decomposing plant remains on the bottom of stagnant pools, and its presence in coal mines would show with seeming conclusiveness that a part, at least, of the gas is formed quite independently of petroleum. It would seem on the whole most probable that no one theory was universally applicable to all cases.

Marsh Gas; Natural Gas.—This is a colorless and odorless gas arising from the decomposition of organic matter protected from the oxidizing influence of atmospheric air. By itself it burns quietly, with a slightly luminous flame, but when mixed with air it forms a dangerous explosive. It is this gas which forms the dreaded fire damp of the miners. In small quantities this gas may be found and collected, if desired, from the bottom of shallow pools and stagnant bodies of water by merely disturbing the decomposing plant matter at the bottom, when the bubbles of the gas will rise to the top. Under this head may properly be considered the so-called *natural gas*, which has of late years become of so much importance from an economic standpoint. This gas is, however, by no means a simple compound, but a variable admixture of several gases, samples from different wells showing considerable variation in composition, as well as those from the same well collected at different periods. This last is shown by the seven analyses following, and which may serve well to illustrate the average composition, though in some instances the percentage of marsh gas has been found greater.[1]

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[1] From Orton's Report on Petroleum, Natural Gas, and Asphalt in Kentucky, pp. 108–110.

Constituents.	I.	II.	III.	IV.	V.	VI.	VII.
Hydrogen	1.89	1.64	1.74	2.35	1.86	1.42	1.20
Marsh gas	92.81	93.35	93.85	92.67	93.07	94.16	93.58
Olefiant gas	0.20	0.35	0.20	0.25	0.49	0.30	0.15
Carbonic oxide	0.55	0.41	0.44	0.45	0.73	0.55	0.60
Carbonic acid	0.20	0.25	0.23	0.25	0.26	0.29	0.30
Oxygen	0.35	0.39	0.35	0.35	0.42	0.30	0.55
Nitrogen	3.82	3.41	2.98	3.53	3.02	2.80	3.42
Sulphuretted hydrogen	0.15	0.20	0.21	0.15	0.15	0.18	0.20
Total	100.00	....	....	....	....	....	....

I, Fostoria, Ohio; II, Findlay, Ohio; III, St. Marys, Ohio; IV, Muncie, Indiana; V, Anderson, Indiana; VI, Kokomo, Indiana; VII, Marion, Indiana.

Natural gas in quantities to be of economic importance is necessarily limited to rocks of no particular horizon. It is not, however, indigenous to the rocks in which it is now found, but occurs in an overlying more or less porous sand or lime rock into which it has been forced by hydrostatic pressure. The first necessary condition for the presence of gas in any locality may indeed be said to depend upon the existence of such a porous rock as may serve as a reservoir to hold it, and also the presence of an impervious overlying strata to prevent its escape. In Pennsylvania the reservoir rock is a sandstone of Carboniferous or Devonian age; in Ohio and Indiana a cavernous dolomitic limestone of Silurian (Trenton) age.

Petroleum.—This is the name given to a complex hydrocarbon compound, liquid at ordinary temperatures, though varying greatly in viscosity, of a black, brown, greenish, or more rarely red or yellow color, and of extremely disagreeable odor. Its specific gravity varies from 0.6 to 0.9. Through becoming more and more viscous the material passes into the solid and semisolid forms asphalt and maltha. Chemically it is considered as a mixture of the various hydrocarbons included in the marsh gas, ethyline and paraffin series.

An ultimate analysis of several samples, as given by the reports of the Tenth Census of the United States (1880), showed the following percentages of the three essential constituents:

Locality.	Hydrogen.	Carbon.	Nitrogen.
West Virginia	13.359	85.200	0.54
Mecca, Ohio	13.071	86.316	0.23
California	11.819	86.934	1.109

Petroleum is limited to no particular geological horizon, but is found in rocks of all ages, from the Lower Silurian to the most recent, its existence in quantities sufficient for economic purposes being dependent upon local conditions for its generation and subsequent preservation. Inasmuch as its accumulation in large quantities necessitates a rock of porous nature to act as a reservoir, the petroleum-bearing rocks are mostly sandstones, though not uniformly so. Petroleums are found in California and Texas in Tertiary sands; in Colorado in the Cretaceous; in West Virginia both above and below the Crinnoidal (Carboniferous) limestones; in Pennsylvania in the "mountain" sands (Lower Carboniferous) and the Venango sands (Devonian); in Canada in the Corniferous (Lower Devonian) limestones; in Kentucky in the Hudson River shales (Lower Silurian), and in Ohio in the Trenton limestone. (See series illustrating geological distribution.)

In some instances petroleum oozes naturally from the ground, forming at times a thin layer on the surface of pools of water, whence in times past it has been gathered and used for chemical and medicinal purposes. The so-called "Seneca oil" thus used some fifty or sixty years ago was thus obtained from a spring in Cuba, Allegany County, in New York. The immense supply now demanded for commercial purposes is, however, obtained altogether from artificial wells of varying depths, and which are in some cases self-flowing, while in others the oil is raised by means of pumps. Wells of from 500 to 1,500 feet in depth are of common occurrence, while those upwards of 2,000 feet are not rare. The principal sources of petroleum are in the United States—New York, Pennsylvania, and Ohio, with smaller fields in West Virginia, Kentucky, Tennessee, Indiana, Texas, Colorado, and California. The chief foreign source is the Baku region on the Caspian Sea, and Galicia, in Austria.

Uses of petroleum.—The early uses of petroleum in America seem to have been for medicinal purposes only (Specimen No. 59834, U.S.N.M., from Kentucky). The oil as pumped from the wells has but a limited application in its crude condition excepting as a fuel, and owes its great value to the large and varied series of derivatives which it yields. A discussion of the methods employed in obtaining these derivatives belongs properly to the department of chemical technology and can not be dwelt upon here. It must suffice for present purposes to say that the treatment as ordinarily carried out at present involves a process of destructive distillation whereby the crude material, heated under pressure, is resolved into a variety of products of different densities, and varying from gaseous through liquid to solid forms. Prominent among these derivatives may be mentioned, aside from the gaseous compounds, rhigolene, gasoline, naphtha, benzine, kerosene, various lubricating oils, paraffin, and the solid residues (coke, etc.). Various pharmaceutical compounds are prepared from petroleum products, many of which are well known to the public, as vaseline, cosmoline, etc. It is also used as a basis for ointments and in soaps.

The accompanying map (Plate 25) from the reports of the Tenth Census will serve to show the distribution of petroleum and allied bituminous compounds in the United States. For full and detailed information relative to the petroleum industry of the world the reader is referred to the works mentioned in the Bibliography, that of Boverton Redwood being the most systematic and complete.

The petroleum series in the Museum collections is quite large (some 303 samples), and is arranged for exhibition so as to illustrate (1) variation in specific gravity, (2) in color, (3) geological distribution, (4) depth of source, (5) geographical distribution. This last, nearly as it stands to-day, was described in Mr. Dewey's Handbook, Collections in Economic Geology,[1] and the list is not entirely reprinted here.

In this connection reference should be made to the series of sands and rocks associated with petroleums and bituminous deposits in a separate case. This comprises oil-bearing sands from wells in Washington County, Pennsylvania (Specimens Nos. 52025, 62997, 59930, 59932, U.S.N.M.); Oil City, Venango County, Pennsylvania (Specimen No. 62998, U.S.N.M.); Butler County, Pennsylvania (Specimen No. 62996, U.S.N.M.), and a block of sandstone weighing 8 pounds, blown from well No. 9, on Barse tract, McKean County, Pennsylvania, at a depth of 1,730 feet. Also oil sands from Marion County, West Virginia (Specimens Nos. 62790, 62994, 62995, U.S.N.M.); oil-bearing shales from Ventura County, California (Specimens Nos. 62785, 62914, 62915, U.S.N.M.); oil-bearing shales from Santa Barbara County, California (Specimens Nos. 62939–62943, U.S.N.M.); core of diamond drill from well No. 19, Pico oil field, California (Specimen No. 62921, U.S.N.M.); bituminous dolomite from Cook County, Illinois (Specimen No. 62789, U.S.N.M.); geodes of quartz filled with bitumen from Hancock County, Illinois (Specimen No. 40364, U.S.N.M.); asphaltic sands from Wyoming (Specimen No. 62716, U.S.N.M.); Indian Territory (Specimen No. 62245, U.S.N.M.); Germany (Specimen No. 66855, U.S.N.M.); a series of sands, sandstones, and shales, with varieties of asphalt, from the island of Trinidad (Specimens Nos. 68050–68066, U.S.N.M.); trappean rock with bitumen, Hartford County, Connecticut (Specimen No. 59934, U.S.N.M.); andesite with bitumen, Lake Tahoe, Nevada (Specimen No. 33884, U.S.N.M.); shale associated with albertite, Albert County, New Brunswick (Specimens Nos. 59936, 59938, 59939, U.S.N.M.); and clays associated with ozokerite and salt, Boryslaw, Galicia (Specimens Nos. 66087, 66088, U.S.N.M.).

1. EXHIBIT ILLUSTRATING VARIATION IN SPECIFIC GRAVITY.

The series is arranged to show gradually decreasing specific gravity. It begins with a very dark oil of 22° Baumé=0.9210 specific gravity. In general as the specific gravity decreases the color grows lighter. To this, however, there are several notable exceptions. For instance, No. 59736 (32½° Baumé=0.8614 specific gravity) is much lighter in

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[1] Bulletin No. 42 of the U. S. National Museum, 1891.

color than its associates. The same is also true of No. 59735 (45° Baumé=0.8000 specific gravity) and No. 59743 (47° Baumé=0.7909 specific gravity). On the other hand, Specimens Nos. 59506 (48° Baumé=0.7865 specific gravity) and 59591 (48¼° Baumé=0.7843 specific gravity) are darker than their associates, while the color of Specimen No. 59584, with the very low gravity of 50½° Baumé=0.7755 specific gravity, is as dark as any member of the series.

(1) 22° Baumé=0.9210 specific gravity, dark greenish. Colorado. (59741.)

(2) 23½° Baumé=0.9120 specific gravity, black. From the Trenton limestone. J. W. Mitchell well, Plum Lick Creek, near Middletown, Bourbon County, Kentucky. (59594.)

(3) 27° Baumé=0.8917 specific gravity, black. From the millstone grit (Carboniferous). Lem Beck well, near Volcano, Wood County, West Virginia. (59553.)

(4) 28¼° Baumé=0.8833 specific gravity, black. From the millstone grit (Carboniferous), near Volcano, Wood County, West Virginia. (59555.)

(5) 29° Baumé=0.8805 specific gravity, black. Brockin well, Johnson County, Kentucky. (59597.)

(6) 30° Baumé=0.8750 specific gravity, black. From the millstone grit (Carboniferous), near Volcano, Wood County, West Virginia. (59557.)

(7) 31½° Baumé=0.8668 specific gravity, dark greenish. Broward well, Johnson County, Kentucky. (59598.)

(8) 32½° Baumé=0.8614 specific gravity, dark greenish red. Greensburgh, Westmoreland County, Pennsylvania. (59736.)

(9) 33° Baumé=0.8588 specific gravity, black. From the Trenton limestone. Taskin well, near North Baltimore, Wood County, Ohio. (59566.)

(10) 34° Baumé=0.8536 specific gravity, black. Oil in sand; here 23 feet in thickness; depth of well 551 feet; drilled, 1877; torpedoed; yielded 3 barrels of oil on first day of flow. Lot 4823, Howe, Forest County, Pennsylvania. (59805.)

(11) 35° Baumé=0.8484 specific gravity, black. From the first sandstone of the Great Conglomerate (Upper Carboniferous). Well No. 6, West Virginia Oil and Oil Land Company, White Oak district, Ritchie County, West Virginia. (59857.)

(12) 36° Baumé=0.8433 specific gravity, dark greenish. From the first sandstone of the Great Conglomerate (Upper Carboniferous). Oil in sand. Well No. 7, West Virginia Oil and Oil Land Company, White Oak district, Ritchie County, West Virginia. (59858.)

(13) 37° Baumé=0.8383 specific gravity, black. Oil in limestone, here 50 feet in thickness; depth of well 1,321 feet; drilled 1885; torpedoed; yielded 50 barrels of oil on first day of flow. Brick Yard well, Findlay, Hancock County, Ohio. (59807.)

(14) 38° Baumé=0.8333 specific gravity, dark greenish. From the first sandstone of the Great Conglomerate (Upper Carboniferous). Oil in sand. West Virginia Oil and Oil Land Company, White Oak district, Ritchie County, West Virginia. (59860.)

(15) 39° Baumé=0.8284 specific gravity, dark greenish red. From Clarion County sand; depth of well 860 feet; drilled 1883; torpedoed; yielded 2 barrels of oil on first day of pumping. Cumming's well No. 1, Cumming's farm, Tionesta, Forest County, Pennsylvania. (59816.)

(16) 40° Baumé=0.8235 specific gravity, dark greenish. Bradford County, Pennsylvania. (59734.)

(17) 41° Baumé=0.8187 specific gravity, dark greenish. Parker County, Pennsylvania. (59733.)

(18) 42° Baumé=0.8139 specific gravity, dark greenish. From the third sandstone of the Petroleum Measures (Venango). Black Gas well, Pleasantville, Venango County, Pennsylvania. (59580.)

(19) 43° Baumé=0.8092 specific gravity, dark greenish red. Oil-bearing sand here 20 feet in thickness; depth of well 1,855 feet; drilled 1883; torpedoed; yielded 2,200 barrels of oil on first day of flow. Reno well No. 1, Cooper tract, Sheffield, Warren County, Pennsylvania. (59765.)

(20) 44° Baumé=0.8045 specific gravity, dark greenish. Bullion district, Warren County, Pennsylvania. (59737.)

(21) 44½° Baumé=0.8023 specific gravity, dark greenish. From third sandstone of the Petroleum Measures (Venango). Sand here 14 feet in thickness. Oil in sand; depth of well 708 feet; drilled 1868; torpedoed; yielded 330 barrels of oil on first day of flow. Well No. 6, Hamby farm, Rockland, Venango County, Pennsylvania. (59788.)

(22) 45° Baumé=0.8000 specific gravity, dark amber. Clarion County, Pennsylvania. (59735.)

(23) 45½° Baumé=0.7977 specific gravity, dark greenish red. Thom Creek district, Butler County, Pennsylvania. (59746.)

(24) 46° Baumé=0.7954 specific gravity, dark greenish. Foxburgh, Clarion County, Pennsylvania. (59739.)

(25) 46½° Baumé=0.7932 specific gravity, black. Depth of well 660 feet; drilled 1866; yielded 600 barrels of oil on first day of flow. Well No. 184, Burtes lease, Allegheny County, Pennsylvania. (59769.)

(26) 46¾° Baumé=0.7921 specific gravity, black. From the third sandstone of the Petroleum Measures (Venango). Titusville, Venango County, Pennsylvania. (59507.)

(27) 47° Baumé=0.7909 specific gravity, dark amber. Smith's Ferry, Allegheny County, Pennsylvania. (59743.)

(28) 47½° Baumé=0.7887 specific gravity, dark greenish red. From the first sandstone of the Petroleum Measures (Venango). Beck well, near Pleasantville, Venango County, Pennsylvania. (59583.)

(29) 47¾° Baumé=0.7876 specific gravity, dark greenish red. From the fourth sandstone of the Petroleum Measures; oil in sand; depth of well 14 feet; drilled 1871; torpedoed; yielded 900 barrels of oil on first day of flow. Well No. 1, farm of J. Blaney, Fairview, Butler County, Pennsylvania. (59799.)

(30) 48° Baumé=0.7865 specific gravity, black. Webb Oil Company, Taskill, Venango County, Pennsylvania. (59506.)

(31) 48¼° Baumé=0.7843 specific gravity, dark greenish. From the third sandstone of the Petroleum Measures (Venango), Cogley Field, Ashley, Clarion County, Pennsylvania. (59591.)

(32) 48½° Baumé=0.7832 specific gravity, dark amber. Oil in sand, here 16 feet in thickness; depth of well 1,025 feet; drilled 1878; torpedoed; yielded 20 barrels of oil on first day of flow. Well No. 1, Lot No. 55, Mead, Warren County, Pennsylvania. (59780.)

(33) 49° Baumé=0.7821 specific gravity, light greenish red. Oil in sand; depth of well 1,254 feet. Tiona Oil Company, Warren County, Pennsylvania. (59514.)

(34) 50° Baumé=0.7777 specific gravity, light greenish red. Oil in sand, here 50 feet in thickness. Cameron well, Smith pool, Washington County, Pennsylvania. (59589.)

(35) 50½° Baumé=0.7755 specific gravity, black. Haskell well, Wigglesworth Tract, Venango County, Pennsylvania. (59584.)

(36) 51° Baumé=0.7734 specific gravity, light greenish yellow. Oil in sand, here 50 feet in thickness. Nicholas well, Vanceville, Washington County, Pennsylvania. (59600.)

(37) 54° Baumé=0.7608 specific gravity, dark amber. Oil in sand; depth of well 2,113 feet; drilled 1885; torpedoed; yielded 15 barrels of oil on first day of flow. Gantz well No. 1, Little Washington, Washington County, Pennsylvania. (59777.)

2. EXHIBIT ILLUSTRATING VARIATION IN COLOR.

The series may be divided into two portions, beginning with a thoroughly black specimen and following through increasing amounts of green and red to a light greenish yellow in the first portion, and in the second beginning with a dark red and following through to a light straw, in which the greenish element of the color does not appear:

(1) Black. Bear Creek, Burkesville, Cumberland County, Kentucky. (59832.)

(2) Black, tinged with green. Mecca, Trumbull County, Ohio. (59757.)

(3) Dark greenish. Anchor well No. 3, Glade, Warren County, Pennsylvania. (59761.)

(4) Dark greenish red. Dale Brothers' well No. 1, Batten farm, near Rockland, Venango County, Pennsylvania. (59767.)

(5) Dark greenish red. Kane, Armstrong County, Pennsylvania. (59752.)

(6) Light greenish red. Gordon well, Washington, Washington County, Pennsylvania. (59526.)

(7) Greenish yellow. Leedecker well, Butler County, Pennsylvania. (59750.)

(8) Dark red. New Brinker well, Pleasant Valley, Westmoreland County, Pennsylvania. (59520.)

(9) Light red. Galtz well, Washington, Washington County, Pennsylvania. (59527.)

(10) Amber. Hess, Sacket & Eichner well No. 1, Reidsburgh, Clarion County, Pennsylvania. (59581.)

(11) Yellow. Riggs Gas well, Moundsville, Marshall County, West Virginia. (59579.)

(12) Light yellow. Farm of J. Somerville, near Brady's Bend, Armstrong County, Pennsylvania. (59494.)

(13) Light straw. Holden Run, Armstrong County, Pennsylvania. (53516.)

(14) Nearly colorless. Venezuela. (59835.)

3. EXHIBIT ILLUSTRATING GEOLOGICAL DISTRIBUTION.

The series is arranged in a generally descending order. There is a certain amount of overlapping, however, between the West Virginia and Pennsylvania series, since the oil-bearing strata in these two States have not been correlated.

(1) From the Tertiary sandstone. Dark greenish. Pico district, Los Angeles County, California. (59552.)

(2) From the Cretaceous formation. Dark greenish. Cañon City, Fremont County, Colorado. (59548.)

The following thirteen specimens are from the West Virginia oil field. Their location in depth is referred to the Crinoidal limestone as a datum line:

(1) 50 feet above the Crinoidal limestone. Black; specific gravity 28° Baumé. Oil in sand; depth of well 56 feet; drilled 1859; not torpedoed; yielded 100 barrels of oil on first day of pumping. Well No. 1, Dutton farm, Aurelius, Washington County, Ohio. (59855.)

(2) 100 feet below the Crinoidal limestone. Dark greenish. Oil in sand; depth of well 150 feet; drilled 1882; torpedoed; yielded 10 barrels of oil on first day of pumping. Farm of Frank Atkinson, Aurelius, Washington County, Ohio. (59854.)

(3) 200 feet below the Crinoidal limestone. Black. Oil in sand; depth of well 160 feet; not torpedoed. Rathbone oil tract, Burning Springs district, Wirt County, West Virginia. (59837.)

(4) 250 feet below the Crinoidal limestone. Dark greenish. Oil in sand; depth of well 350 feet. Well No. 6, farm of George Rice, Aurelius, Washington County, Ohio. (59853.)

(5) 300 feet below the Crinoidal limestone. Black. Oil in sand; depth of well 275 feet. Rathbone oil tract, Burning Springs district, Wirt County, West Virginia. (59838.)

(6) 450 feet below the Crinoidal limestone. Dark greenish. Oil in sand; depth of well 500 feet; drilled 1865; torpedoed; yielded 8 barrels of oil on first day of pumping. Well No. 1, farm of George Rice, Aurelius, Washington County, Ohio. (59852.)

(7) 650 feet below the Crinoidal limestone. Black. Oil in sand; depth of well 800 feet; not torpedoed; yielded 5 barrels of oil on first day of pumping. Newton Farm, Aurelius, Washington County, Ohio. (59850.)

(8) 820 feet below the Crinoidal limestone. Black. Oil in sand; depth of well 840 feet. Petty Farm, Burning Springs district, Wirt County, West Virginia. (59839.)

(9) 930 feet below the Crinoidal limestone. Dark greenish; specific gravity 28° Baumé. Oil in sand; depth of well 400 feet. Volcanic Coal and Oil Company, White Oak district, Ritchie County, West Virginia. (59844.)

(10) 980 feet below the Crinoidal limestone. Dark greenish; specific gravity 30° Baumé. Oil in sand; depth of well 400 feet. Volcanic Oil and Coal Company, White Oak district, Ritchie County, West Virginia. (59843.)

(11) 1,100 feet below the Crinoidal limestone. Dark greenish; specific gravity 47° Baumé. Oil in sand; depth of well 1,100 feet. Gracy lease, Burning Springs district, Wirt County, West Virginia. (59840.)

(12) 1,350 feet below the Crinoidal limestone. Amber; specific gravity 39° Baumé. Oil in sand; depth of well 1,350 feet; drilled 1880; torpedoed; yielded 18 barrels of oil on the first day of flow. Well No. 14, farm of George Rice, Aurelius, Washington County, Ohio. (59851.)

(13) 1,500 feet below the Crinoidal limestone. Dark greenish; specific gravity 50° Baumé. Oil in sand; depth of well 1,000 feet. Gale tract, White Oak district, Ritchie County, West Virginia. (59849.)

The following eleven specimens illustrate the occurrence at different depths in the Pennsylvania field:

(1) 180 feet below the Pittsburg coal bed. Light greenish red; specific gravity 34° Baumé. Bailey farm, Dunkard Creek, Greene County, Pennsylvania. (59536.)

(2) 460 feet below the Pittsburg coal bed. Greenish red; specific gravity 35° Baumé. Maple well, Dunkard, Greene County, Pennsylvania. (59577.)

(3) 650 feet below the Pittsburg coal bed. Drilled in 1885, and only a few gallons of oil were obtained; light greenish red. Clark's farm, Washington County, Pennsylvania. (59523.)

(4) "Mountain Sand" of the Petroleum Measures (Lower Carboniferous). Dark greenish red. Manifield well No. 1, Washington County, Pennsylvania. (59519.)

(5) 1,400 feet below the Pittsburg coal bed. Light greenish red. Huskill well, Mount Morris, Greene County, Pennsylvania. (59534).

(6) From the first sandstone of the Petroleum Measures (Venango). Sand here 16 feet in thickness; oil in sand; depth of well 337 feet; drilled, 1870; torpedoed; yielded 225 barrels of oil on first day of pumping. Black; specific gravity 32° Baumé. Well No. 1, farm of J. Blakely, Sugar Creek, Venango County, Pennsylvania. (59781.)

(7) From the second sandstone of the Petroleum Measures (Venango). Sand here 38 feet in thickness; oil in sand; depth of well 583 feet; drilled 1872; torpedoed; yielded 2 barrels of oil on first day of pumping. Black; specific gravity 43° Baumé.

Well No. 3, farm of Jennings & Ralston, Jackson, Venango County, Pennsylvania. (59774.)

(8) From just above the third sandstone of the Petroleum Measures (Venango). Sand here 22 feet in thickness; oil in sand; depth of well 1,076 feet, drilled 1885; torpedoed; yielded 18 barrels of oil on first day of pumping. Dark greenish; specific gravity 49° Baumé. Well No. 5, Diamond farm, Cranberry, Venango County, Pennsylvania. (59795.)

(9) From the third sandstone of the Petroleum Measures (Venango). Sand 18 feet in thickness; oil in sand; depth of well 957 feet; drilled 1885; not torpedoed; yielded 35 barrels of oil on first day of pumping. Black; specific gravity 48½° Baumé. Well No. 1, Heckerthorne farm, Cranberry, Venango County, Pennsylvania. (59815.)

(10) From the fourth sandstone of the Petroleum Measures. Dark greenish red; specific gravity 44½° Baumé. Kangaroo well No. 1, East Brady, Clarion County, Pennsylvania. (59489.)

(11) From the third Bradford sand. Black. Nile Oil Company, Wert, Allegany County, New York. (59477.)

The following five specimens from various localities continue the section to the lowest point at which petroleum has been found:

(1) From the Middle Devonian formation. Black. Near Glasgow, Barren County, Kentucky. (59544.)

(2) From the Corniferous limestone. Black; specific gravity 35.5° Baumé. Crown well, Enniskillen, Province of Ontario, Canada. (59569.)

(3) From the Upper Hudson River shales (Lower Silurian). Dark greenish; specific gravity 43.5° Baumé. Well No. 2, near Glasgow, Barren County, Kentucky. (59599.)

(4) From the Hudson River group (Lower Silurian). Black; specific gravity 32° Baumé. Pioneer well, Francisville, Pulaski County, Indiana. (59575.)

(5) From the Trenton limestone. Black. Farm of Whitacre, Liberty, Wood County, Ohio. (59601.)

ASPHALTUM; MINERAL PITCH.—These are names given to what are rather indefinite admixtures of various hydrocarbons, in part oxygenated and which for the most part solid or at least highly viscous at ordinary temperatures, pass by insensible gradations into pittasphalts or mineral tar and these in turn into the petroleums. They are characterized by a black or brownish-black color, pitchy luster, and bituminous odor. The solid forms melt ordinarily at a temperature of from 90 to 100 F., and burn readily with a bright flame, giving off dense fumes of a tarry odor. The fluidal varieties become solid on exposure to the atmosphere, owing to evaporation of the more volatile portions.

The nature of the material, its mode of occurrence, and indeed the uses to which it can be put vary to such an extent with each individual occurrence that a few only of what are the most noted or best known can here be mentioned.

On the island of Trinidad is an immense superficial deposit having an area of about 114 acres and a depth varying from 18 to 78 feet. The surface is nearly level and of a brownish-black color. (See Specimens Nos. 68063, 68065, 68066, U.S.N.M.)

The deposit has in numerous publications been compared to a lake and stated to be fluidal and at a high temperature in the center.[1] This is quite erroneous and misleading.

The crude material has the following composition and physical characteristics:[2]

Specific gravity, 1.28; hardness at 70° F., 2.5 to 3 of Dana's scale color, chocolate brown; composition:

Bitumen	39.83
Earthy matter	33.99
Vegetable matter	9.31
Water	16.87
	100.00

In western Kentucky asphalt exudes from the ground in the form of "tar springs," and occurs also disseminated through sandstones and limestones of sub-Carboniferous age. (Specimen No. 63345, U.S.N.M.) Frequently, as in the dolomite underlying Chicago, Illinois, the bituminous matter is so diffused throughout the rock as to give it on exposure a brownish-black appearance, and cause it to exhale an odor of petroleum appreciable for some distance. (Specimen No. 62789 U.S.N.M.) In the Dead Sea bituminous masses of considerable size have in times past risen like islands to the surface of the water and furnished thus the material used by the ancients in pitching the walls of buildings and rendering vessels water-tight. The ancient name of this body of water was *Lake Asphaltites*, and from it our word asphalt is derived. These illustrations are sufficient to indicate the numerous conditions under which the substance occurs. The material is world-wide in its geographic distribution and equally cosmopolitan in its geological range, being found in gneissic rocks of presumably Archæan age in Sweden, and in rocks of all intermediate horizons down to late Tertiary.

Some 10 miles east of the city of Habana, Cuba, is a deposit of asphalt described[3] as occupying an irregular branching fissure in a soft clay rock, with eruptive rocks, diorites, and euphotides in the near vicinity. The asphalt, described as "Coal" in the paper referred to lies in parallel horizontal layers of from 1 to 4 inches in thickness across the vein, the laminæ being somewhat deflected near the walls as if pressed by the sides or walls. The deposit is regarded as having originated as an open fissure terminating upward in a wedge-like form and into which was subsequently injected from below the carbonaceous matter. The asphalt itself was described as of a jet-black

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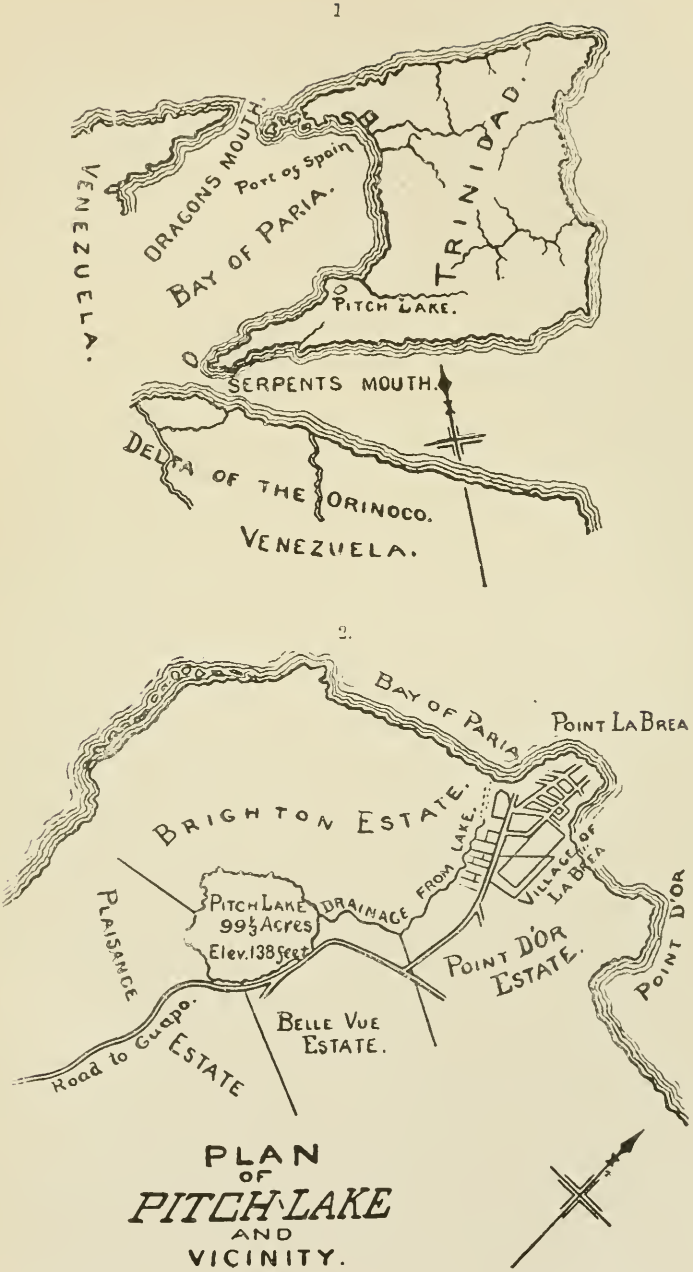
[1] See Mineral Resources of the United States, 1883–84, p. 937; also Dana's System of Mineralogy, 1892, p. 1018; and especially S. F. Peckham's paper on the Pitch Lake of Trinidad, American Journal of Science, July, 1895, p. 33.

[2] Transactions of the American Institute of Mining Engineers, XVII, 1889, p. 363.

[3] London and Edinburgh Philosophical Magazine and Journal of Science, X, 1837, p. 161.



PLAN OF PITCH LAKE, TRINIDAD.
After S. F. Peckham.

color, resplendent luster, conchoidal fracture, and specific gravity varying from 1.42 to 1.97. An analysis showed 63 per cent volatile matter, 34.97 per cent carbon, and 2.03 per cent ash.

According to R. T. Hill,[1] asphaltum of unusual richness occurs beneath the waters of the Cardenas Bay of Cuba and in several other parts of the island in beds of late Cretaceous and early Eocene age. The Cardenas deposits, four in number, are of interest in that all are submerged beneath the waters of the bay. The material has been mined for the past twenty-five years by mooring a lighter over the shaft, which is from 80 to 125 feet in depth below the water surface. The material is loosened by dropping a long, pointed iron bar from the vessel, the detached blocks being loaded into a net by a naked diver and then brought to the surface. The asphalt thus obtained is stated to resemble cannel coal in appearance, though with a more brilliant luster. Only from one to one and a half tons are mined in this manner daily, the material being shipped to New York and being used in the manufacture of varnishes. The price formerly obtained varied from $80 to $125 a ton.

A large deposit of an inferior grade, and used mainly for roofing, is situated near Diana Key, 15 miles from the city of Cardenas, and a massive bed, some 12 feet in thickness, near Villa Clara. Material from this last source has, during years past, been used for making the illuminating gas used in the city.

Baron H. Eggers has described[2] the two groups of asphalt deposits near the Gulf of Maracaibo, South America (Specimen No. 51720, U.S.N.M.), which are perhaps sufficiently distinctive to merit attention. One, the El Menito deposit, is in the form of a rounded hill composed of reddish stony soil covered with scanty grass. Over its summit are scattered a number of small truncated cones about 2 feet high, with round, crater-like openings, from which the asphalt, or pitch, flows in a black, viscous stream down to the foot of the hill, where it collects and forms pools or small lakes. The outflowing asphalt is quite cold, and hardens in the course of a few days. The Mene Grande deposit is quite similar, but much larger, and has been calculated to yield some 2 tons a day. Other deposits occur in the region.

Sandstones and limestones are sometimes so impregnated with bituminous matter that they may be used as sources of the material by refining processes or for the direct manufacture of pavements by simply crushing. Such are the so-called bituminous or asphaltic sand rocks and limestones of Kentucky (Specimen No. 63345, U.S.N.M.), Texas (Specimen No. 63342, U.S.N.M.), Utah, Colorado, California, Wyoming (Specimen No. 53181, U.S.N.M.), and other States, and of

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[1] Cuba and Porto Rico, 1898, p. 83.

[2] Scottish Geographical Magazine, XIII, 1897, p. 209. An abstract of original paper in the Deutsche Geographische Blätter, XIX, Pt. 4.

Canada (Specimen No. 59927, U.S.N.M.) and Spain (Specimen No. 40011, U.S.N.M.).

According to G. H. Stone,[1] the asphaltic sandrock of western Colorado and eastern Utah consists of grains of sand which are in contact with one another, the spaces between the grains being filled with asphalt, the proportioned amount of which varies up to 15 per cent by weight, or 27 per cent by volume. The thickest stratum of fully charged rock in the region described was nearly 40 feet in thickness, though usually the strata of high-grade material are not more than 4 to 10 feet thick and alternate with others which are quite poor or barren, so that the amount of "pay rock" is often grossly exaggerated.

Shales and marls may often be so highly charged with bituminous matter as to be nearly or quite black, and even approach cannel coal in composition, though much richer in ash. Those of Colorado and Utah, according to Stone, contain but from 10 to 20 per cent of carbonaceous matter, though burning readily with a bright flame. They are of Tertiary age. Asphaltic sands and sandrocks are of common occurrence in Kern, San Luis Obispo, Santa Barbara, Santa Cruz, Ventura, and other counties in California, and in some cases are quite extensively utilized.[2]

In Ventura County the material is reported as occurring in the form of a fissure vein in siliceous clay, of Miocene age, the vein being from 7 to 15 inches thick on the surface, but widening rapidly in descent to a thickness of 5 feet at a depth of 65 feet (Specimens Nos. 67675, 67676, U.S.N.M.). This material is as taken from the vein far from pure asphalt, but rather an asphaltic sand. The Las Conchas Mine in Santa Barbara County consists of a body of sand soaked with maltha, embracing an area of 75 acres and estimated to be 25 feet or more in thickness. At the Pacific Asphalt Company's mine the asphalt occurs in irregular masses and veinlike bunches in soft, sandy clay, and is said to be 50 to 60 per cent pure.

On the Sisquoc Grant, 8 miles north of Los Alamos are two very large deposits, one some 10,560 feet long, 500 feet wide, and averaging 300 feet in thickness, and the other 5,000 feet long, 800 feet wide, and 100 feet thick. In Santa Cruz County there are enormous deposits of bituminous rock lying in nearly horizontal strata in the foothills facing the coast west and north of the city of Santa Cruz. The beds have been extensively eroded so that the outcrops occur in irregular, detached hillocks. At one of the open cut mines the materials lie as follows:

	Feet.
Light-colored shales	60
Massive bituminous rock	30
Very soft sandstone	8
Massive bituminous rock	12

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[1] American Journal of Science, XLII, 1891, p. 148.

[2] See Thirteenth Annual Report State Mineralogist of California, 1894.

These underlaid by soft sands and shales. The analyses given below are of interest as showing percentage of bituminous matter in samples from various localities.

San Luis Obispo Bituminous Rock Company's mine.

Sand	6.83
Clay	3.36
Lime	2.81
Asphaltum	87.00

Waldorf Mine, Santa Barbara County.

Bitumen	76.2
Moisture	1.8
Mineral residue	22.0
	100.0

Punta Gorda Mine, Ventura County.

Bitumen	28.53
Silica	51.64
Clay	4.76
Sulphate of lime	2.45
Carbonate of lime	11.96
Carbonate of magnesia	.55
	99.89

Uses.—The uses of the common type of material such as is known simply as asphalt are quite varied. The walls of Babylon are stated to have been cemented with it, and doubtless it was so used in other ancient cities. It was also, as at present, used for making vessels water-tight. At the present day the refined asphalts are used, according to F. V. Greene,[1] as a varnish or paint, as an insulating material, for waterproofing, as a cement in ordinary construction, and as a cement in roofing and paving compounds. For these purposes it is first tempered with some form of oil, the kind and amount used depending on the purposes to which it is to be applied. A mixture of asphalt and sand forms the ordinary concrete for sidewalks and basement floors. The most extensive use of asphaltic compounds is at present for street pavements, the material for this purpose being mixed with fine sand and sometimes powdered limestone. The asphaltic sands, sandstones, and limestones are sometimes so evenly impregnated with bituminous matter that they may be crushed and applied directly to the roadbed. The uses to which are put the higher grades of asphaltic compounds, such as are designated by special names, are given further on.

Manjak.—The local name of *manjak* is applied to a variety of bitumen somewhat resembling uintaite, occurring on the island of Barbados,

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[1] Asphalt and its Uses, Transactions of the American Institute of Mining Engineers, XVII, 1889, p. 335.

in the West Indies. The material is described[1] as a very pure hydrocarbon of a black color, high luster, and with a bright conchoidal fracture. It is brittle, and so friable that it can be ground to powder between the thumb and fingers. (Specimen No. 53539, U.S.N.M.) It occurs in seams or veins, varying from one-fourth of an inch to 30 feet in thickness, cutting the country rock, which is an argillite or shale, at all angles with the horizon and with a general NNE strike. In places the bituminous matter has saturated the entire rock in the neighborhood of the veins, producing a shale from which as much as 37 gallons a ton of petroleum has been obtained by destructive distillation. Thus far the greatest development is along a vein 200 feet in length, 100 feet in depth, and from 8 to 9 feet in width. One vein, which has been explored to a depth of 200 feet, is stated to have dwindled down to a width of 6 feet, though 30 feet wide at the surface.

Uses.—Like gilsonite, the material is used for making varnishes, insulating electric wires, etc., bringing the price of this mineral, from $5 to $10 a ton, according to quality and freedom from impurities.

ELATERITE; MINERAL CAOUTCHOUC.—This is the name given to a soft and elastic variety of bitumen much resembling pure india rubber. It is easily compressible in the fingers, to which it adheres slightly, of a brownish color, and of a specific gravity varying from 0.905 to 1.00. It has been described from mines in Derbyshire and elsewhere in England (Specimens Nos. 63848, 68001, U.S.N.M.), but so far as the writer is aware is of no commercial value. Its composition, so far as determined, is carbon 85.47 per cent, hydrogen 13.28 per cent.

WURTZILLITE.—The name *wurtzillite* has been given by Prof. W. P. Blake to a hydrocarbon very similar in appearance to the uintaite (described on page 450), but differing in physical and chemical properties. It is described as a fine black solid, amorphous in structure, brittle when cold, breaking with a conchoidal fracture, but when warm tough and elastic, its elasticity being best compared with that of mica. If bent too quickly it snaps like glass. It cuts like horn, has a hardness between 2 and 3, a specific gravity of 1.03, gives a brown streak, and in very thin flakes, shows a garnet-red color. It does not fuse or melt in boiling water, but becomes softer and more elastic; in the flame of a candle it melts and takes fire, burning with a bright luminous flame, giving off gas and a strong bituminous odor. It is not soluble in alcohol, and but sparingly so in ether, in both of which respects it differs from elaterite. In the United States it occurs near Scofield, Carbon County, and in the Uinta Mountains of Wasatch County, Utah (Specimens Nos. 53356, 67265, 67860, U.S.N.M.).

ALBERTITE.—This is a brilliant jet black bitumen compound breaking with a lustrous, conchoidal fracture, having a hardness of between

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[1] W. Merivale, Engineering and Mining Journal, LXVI, 1898, p. 790; also the Mineral Industry, VI, 1897, p. 54.

1 and 2 of Dana's scale, a specific gravity of 1.097, black streak, and showing a brown color on very thin edge. In the flame of a lamp it shows signs of incipient fusion, intumesces somewhat and emits jets of gas, giving off a bituminous odor; when rubbed it becomes electric. According to Dana it softens slightly in boiling water, is only a trace soluble in alcohol, 4 per cent in ether, and some 3 per cent soluble in turpentine. The following is the composition as given by Wetherill: Carbon, 86.04 per cent; hydrogen, 8.96 per cent; oxygen, 1.977 per cent; nitrogen, 2.93 per cent; ash, 0.10 per cent.

Dr. Antisell made the following comparative tests to show the relative richness of the material in volatile matter:

Constituents.	Cannel coal.	South American asphalt.	Lake asphalt.	Albertite.
Volatile matter	50.52	70.15	71.67	59.88
Coke	47.69	29.85	28.04	39.59
Ash	1.79		0.29	0.53
Total	100.00	100.00	100.00	100.00

The mineral is described by C. H. Hitchcock[1] as occuring in "true cutting veins" in shale of Lower Carboniferous age in Hillsborough County, New Brunswick. The shales themselves contain a large amount of carbonaceous matter and by distillation have been made to yield 30 gallons to the ton of refined illuminating oil. They contain immense numbers of fossil fish and are mostly inflammable. The veins vary from a fraction of an inch to 12 feet in width with a general N. 65° east course, sometimes vertical and sometimes inclined northwestward from 75° to 80°. They enlarge and contract very irregularly, but in general increase in thickness as followed downward. Hitchcock regards the veins as having been filled by the injection of the material in a liquid state and being subsequently indurated.

Uses.—This vein seems to have been discovered about 1840 by Dr. Abraham Gesner who, in 1850 took out a patent in the United States for the manufacture of illuminating gas from this and other asphalts.[2] A company was organized and for some years active mining operations were carried on, but have been discontinued since the discovery of petroleum. (Specimens Nos. 59935, 66701, U.S.N.M.)

GRAHAMITE.—Grahamite is a hydrocarbon compound closely related to albertite, but differing physically in having a duller luster and more cokelike aspect. It has been described by Dr. Henry Wurtz as occur-

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[1] American Journal of Science, XXXIX, 1865, p. 267; see also Dawson's Acadian Geology, 3d ed., pp. 231–241.

[2] Review of reports on the Geological Relations, etc., of the coal of the Albert Coal Mining Company, situated in Hillsborough, Albert County, New Brunswick, as written and compiled by Charles T. Jackson, M. D., a Fellow of the Geological Society of London, etc., New York, 1852.

ring in shrinkage fissures whose course is N. 76° to 80° E. in Carboniferous shales and sandstones, on a branch of Hughes River, Ritchie County, West Virginia. It is completely soluble in chloroform and carbon disulphide, nearly so in turpentine, and partially so in naphtha and benzine, but not at all in alcohol. Melts somewhat imperfectly, beginning to smoke and soften like coking coal at a temperature of about 400° F. (Specimen No. 59924, U.S.N.M.)

As occurring in the vein the material shows four distinct, though somewhat irregular, divisional planes, having a general parallelism with the walls. Next to the walls the structure of the mineral is coarsely granular, with an irregularly cuboidal jointed cleavage, very lustrous on the cleavage surfaces, that in immediate contact with the walls usually adhering thereto very tenaciously, as if fused fast to the granular sandstone. (Specimen No. 59941, U.S.N.M. A "horse" or fragment of sandstone from the vein, showing adhering grahamite.)

Next to these two outside layers, which are very irregular and from 2 to 3 inches or more in thickness, is found, on each side of the vein, a layer averaging from 15 to 16 inches in thickness, which is composed of a variety highly columnar in structure and very lustrous in fracture, the columns being long and at this place at right angles to the walls. Finally, in the center of the vein, varying in thickness, but averaging about 18 inches, is a mass differing greatly in aspect from the rest, being more compact and massive, much less lustrous in fracture, and with the columnar structure much less developed, in places not at all. The fracture and luster of this portion of the vein are clearly resinoid in character.

The general aspect of the mass, as well as all the results of a minute examination of the accompanying phenomena, lead irresistibly to the conclusion that we have here a fissure which has been filled by an exudation, in a pasty condition, of a resinoid substance derived from or formed by some metamorphosis of unknown fossil matter contained in deep-seated strata intersected by the fissure or dike.

The density of a mass of the mineral was found to be 1.145. The horizontal extent of visible outcrop actually measured by me was 530 fathoms, thinned out at east end to 30 inches and at west end to 8 inches; but as these points were at least 70 to 80 fathoms vertically higher than the bottom of the ravine, the width (averaging about 50 inches) at the latter depth points to a rapid widening of the fissure in descent.[1]

J. P. Kimball has described[2] a deposit of similar material on the west bank of the Capadero River in the Huasteca, Vera Cruz, Mexico. The country rock is a fossiliferous Tertiary shale overlaid by conglomerate.

The grahamite occurs in a fissure some 34 inches in thickness terminating in an "overflow" some 6½ feet in maximum thickness, thinning away at the edges, but the full extent of which was not determined. The evidence showed that the fissure had been filled by material oozing up from below and spreading out upon the surface prior to the deposition of the overlying gravel. The strike

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[1] Proceedings of the American Association for the Advancement of Science, XVIII, 1869, pp. 125–128.

[2] American Journal of Science. XII, 1876, p. 277.

of the fissure was nearly north and south, and at the time of making the report noted (1876) it had been developed to a distance of some 300 feet. The material is described as more uniformly lustrous than that from Ritchie County, and of a greater coherence, though none the less distinctly cleaved and jointed. An analysis of a sample from the Cristo mine, as given, yielded results as follows:

Specific gravity	1.156
Volatile matter:	
Illuminating gas	63.32
Sulphur	0.46
Water	0.36
	64.14
Coke:	
Fixed carbon	31.63
Sulphur	0.37
Ash	5.86
	37.86
	100.00

Carbonite or natural coke is the name given to a peculiar hydrocarbon compound occurring in the form of beds like bituminous coal, in Chesterfield County, Virginia, and having a dull black and, for the most part, lusterless aspect, somewhat resembling coke. (Specimens Nos. 63499, 63500, U.S.N.M.)

An analysis by Wurtz[1] yielded the following:

	Per cent.
Coke	84.57
Volatile combustible matter	15.43

Other analyses by Dr. T. M. Drown[2] on two portions, the one dull and lusterless and the other lustrous, yielded:

Constituents.	Dull portion.	Lustrous portion.
Specific gravity	1.375	1.350
Loss at 100° C	2.00	0.69
Volatile matter	15.47	11.10
Ash	3.20	6.68
Fixed carbon	79.33	81.53
	100.00	100.00
Sulphur	4.08	1.60

Occurrence.—The material occurs interbedded with shales much like ordinary bituminous coal, there being, according to Raymond, three distinct beds varying from 1 foot 9 inches to 9 feet in thickness, inter-

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[1] Transactions of the American Institute of Mining Engineers, III, 1875, p. 456.

[2] Idem, XI, 1883, p. 448.

stratified with the shales, the lowermost bed of 9 feet thickness being underlaid by fire clay. The origin of the material is in doubt, the earlier writers regarding it as a bituminous coal coked by the heat of intrusive rocks. Later writers throw doubt upon this by stating that there are in the vicinity no intrusives of such size as to warrant any such assumption.

Uses.—The material is said to burn without smoke or soot, like anthracite, and to have been used for domestic purposes.

UINTAITE; GILSONITE. This is a black, brilliant, and lustrous variety of bitumen, giving a dark-brown streak, breaking with a beautiful conchoidal fracture, and having a hardness of 2 to 2.5 and a specific gravity of 1.065 to 1.07. It fuses readily in the flame of a candle, is plastic, but not sticky while warm, and unless highly heated will not adhere to cold paper. Its deportment is stated to be much like that of sealing wax or shellac. Like albertite and grahamite it dissolves in turpentine and is not soluble in alcohol. It is a good nonconductor of electricity, but like albertite becomes electric by friction. Its composition as given is: Carbon, 80.88 per cent; hydrogen, 9.76 per cent; nitrogen, 3.30 per cent; oxygen, 6.05 per cent, and ash, 0.01 per cent. Specimens Nos. 62379, 53355, U.S.N.M., are characteristic.

Occurrence.—According to George H. Eldridge[1] the gilsonite deposits of Utah occur filling a series of essentially vertical fissures in Tertiary sandstones lying within the Uncompahgre Indian Reservation, or in its immediate vicinity. The fissures have smooth, regular walls and vary in width the sixteenth of an inch to 18 feet, and in length from a few hundred yards to 8 or 10 miles.

The larger veins are somewhat scattered, one lying about 3½ miles east of Fort Duchesne, a second in the region of the Upper Evacuation Creek, and the three others of most importance in the vicinity of the White River and the Colorado-Utah line. Besides these there is a 14-inch vein crossing the western boundary of the reservation near the fortieth parallel; another about equal size about 6 miles southeast of the junction of the Green and White rivers; a third in the gulch 4 or 5 miles north of Ouray Agency, west of the Duchesne River, and a number from one-sixteenth of an inch to a foot in thickness in an area about 10 miles wide, extending from Willow Creek eastward for 25 miles along both sides of the Green and White rivers. The veins are sometimes slightly faulted, and often pinch out to mere feather edges. The filling material is quite structureless excepting where, as near the surface, it has been exposed to the atmospheric influences, where it shows a fine pencillate or columnar structure at right angles to the walls. The walls of the veins themselves are impregnated with the gilsonite for a distance of several inches, but all indications point

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[1] Seventeenth Annual Report U. S. Geological Survey, 1895–96, Pt. I, p. 915.

to their having been filled, not by lateral impregnation, but by injection from below.

The mining of gilsonite is conducted in the ordinary manner by means of shafts and tunnels. The work is, however, attended with considerable difficulty and some danger, owing to the fine dust arising from it. This penetrates the skin and lungs and is a source of great annoyance, and moreover becomes highly explosive when mixed with atmospheric air.

Uses.—The principal use of gilsonite thus far has been in the manufacture of varnishes for ironwork and baking japans. It is not well adapted for coach varnishes. It has been also used for mixing with asphaltic limestone for paving material. Other possible uses suggested by Mr. E. W. Parker, in the Mineral Resources of the United States for 1893, are as below: For preventing electrolytic action on iron plates of ship bottoms; for coating barbed-wire fencing, etc.; for coating sea walls of brick or masonry; for covering paving brick; for acid-proof lining for chemical tanks; for roofing pitch; for insulating electric wires; for smokestack paint; for lubricants for heavy machinery; for preserving iron pipes from corrosion and acids; for coating poles, posts, and ties; for toredo-proof pile coating; for covering wood-block paving; as a substitute for rubber in the manufacture of cotton garden hose; as a binder pitch for culm in making brickette and eggette coal.

3. Ozokerite; Mineral Wax; Native Paraffin.

This is a wax-like hydrocarbon, usually with a foliated structure, soft and easily indented with the thumb nail; of a yellow brown or sometimes greenish color, translucent when pure, with a greasy feeling, and fusing at 56° to 63°; specific gravity, 0.955. It is essentially a natural paraffin. The name is derived from two Greek words, signifying to smell, and wax. Below is given the composition of (I) samples from Utah and (II) from Boryslaw, in Galicia.

Constituents.	I.	II.
Carbon	85.47	85.78
Hydrogen	14.57	14.29
Total	100.04	100.07

The substance is completely soluble in boiling ether, carbon disulphides, or benzine, and partially so in alcohol.

The following, from a paper by Boverton Redwood,[1] will serve to show the varying characters of the material from the various reported sources.

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[1] Journal of the Society of Chemical Industry, XI, 1892, p. 114.

Colorado.—Dull black, hard, and pulverizable; melting point, 76° C. Yields on distillation:

	Percentage (by difference).
Paraffin and oil	90.00
Loss in gas	2.12
Loss in water	2.60
Residue	5.28
	100.00

It commences to distill at 360° C., when nearly 3 per cent of oil setting at 30° C. comes over. At a much higher temperature it distills steadily and furnishes a product suitable for use as a source of paraffin.

Baku.—Specific gravity. 0.903; melting point, 76° C.:

Paraffin mass	81.80
Gas	13.80
Coke	4.40
	100.00

Persia.—Dark green, rather hard; specific gravity, 0.925:

Light oil, 0.740 to 0.780	2.35
Light oil, 0.800 to 0.820	3.50
Oil, 0.880	16.63
Paraffin	53.55
Coke	16.73
Loss	7.24
	100.00

England (Urpeth, near Newcastle).—Soft and sticky, brownish. Specific gravity, 0.890; melting point, 60° to 70° C.:

Light oil, boiling point 80° to 120° C	3.00
Light oil, boiling point 150° to 200° C	7.50
Lubricating oil, boiling point 200° to 250° C	7.80
Paraffin	64.95
Coke	11.15
Gas, loss	5.60
	100.00

Boryslaw.—Specific gravity, 0.930—I, dark yellow; II, dark brownish black:

Constituents.	I.	II.
Benzine, 0.710 to 0.750	4.32	3.50
Kerosene, 0.780 to 0.820	25.65	27.83
Lubricating oil, 0.895	7.64	6.95
Paraffin, etc	56.54	52.27
Coke	2.85	4.63
Loss	3.00	4.82
	100.00	100.00

Olive-green, rather hard; specific gravity, 0.9236; melting point, 60.5° C.:

Light oil, boiling point up to 150° C	6.25
Heavy oil, with paraffin, 150° to 300° C	35.10
Paraffin, etc., over 300° C	49.73
Residue in retort, and loss	8.92
	100.00

Occurrences.—Ozokerite occurs in the United States in Emery and Uinta counties, Utah, where, in the form of small veins in Tertiary rocks, it extends over a wide area (Specimens Nos. 59984, 62805, and 63203, U.S.N.M.). It is also found in Galicia, Austria, in Miocene deposits (Specimens Nos. 66077, 66079, 66080, 66083, 66084, 66086, and 66860, U.S.N.M.); in Roumania, Hungary, Russia, and other Asiatic and European localities. As a rule, the deposits are in beds of Tertiary or Cretaceous age. The Galician deposits are the most noted of the above. According to Redwood it is difficult to say whether ozokerite is peculiar to any particular geological formation. Regarding it as a derivative of petroleum with a high melting point, Rateau points out that it would not be reasonable to expect that it would be confined to any one formation, and in fact it is found in many, though chiefly in the Tertiary and Cretaceous. The Boryslaw, Dwiniacz, and Starunia deposits are in Miocene, but ozokerite has been met with in the shales of Teschen, as well as in Neocomian and other formations elsewhere. The Kouban deposits are on the borders of the Lower Tertiary and Upper Cretaceous. In Tcheleken it is found accompanying petroleum in pockets in beds of sand above the clay shales and muschelkalk of the Aralo-Carpathian formation. In southern Utah and Arizona it occurs in Tertiary rock, probably Miocene.

The soil of the valley in which Boryslaw lies is a bed of diluvial deposit some meters in thickness. In sinking a shaft, first yellow clay, then rounded flints and gravel, and then plastic clay are met with. Below this sandstone and blue shale, much disturbed, alternate, and it is in these beds, which have a thickness of some 200 meters, that the ozokerite is found. The ozokerite-bearing formation lies on a basis of petroliferous menilite shale, the strata of which, as they approach the surface, are disposed almost vertically, but inclined toward the south. The strata are composed of layers of coarse-grained sandstone, green marl, fine-grained sandstone with veins of calcite, dark shale alternating with gray sandy shale, imperceptibly merging into the main beds of the nonpetroliferous sandstone and shale. Below these are the Carpathian sandstones of the lower Eocene (nummulitic sandstone) and upper Cretaceous formations.

The geological conditions prevailing at Dwiniacz and Starunia are similar to those at Boryslaw, but the ozokerite is more largely mixed with petroleum. The soil is gray and red diluvial clay, below which is a bed of gravel, lying on the Miocene formation, in which the ozokerite and petroleum occur in association with native sulphur, iron pyrites, and zinc blende. Still lower a highly porous calcareous rock is met with, containing cavities filled with petroleum and sulphureted water, and below this again is a marl with gypsum and the salt-clay formation destitute of petroleum.

The ozokerite occurs in the form of veins of a thickness ranging from a few millimeters to some feet, and is accompanied with more or less petroleum and gaseous hydrocarbons. It fills the many fissures with which the disturbed shales and Miocene sandstone abound, and frequently forms thus a kind of network. The Boryslaw deposit extends over a pear-shaped area, the axis of which lies E. 30° S. The upper layers of the richest portion of the deposit occupy an area of about 21 hectares, with a length of 1,000 meters and a maximum breadth of 350 meters, but outside this there is an outer zone of less productive territory which increases the total superficies to about 60 hectares, with dimensions of 1,500 meters by 560 meters. The deposit narrows considerably as the depth increases, and at a distance of 100 meters from the surface of the ground has a breadth of only 200 meters.

Uses.—The ozokerite, after being freed so far as possible from impurities, is melted and cast into loaves or blocks of the form of a truncated cone, and weighing about 50 to 60 kilos. There are two or three recognized commercial qualities of the melted and cast ozokerite. The first quality is transparent in thin sheets and its color ranges from yellow to greenish brown. Adulteration by means of crude petroleum, heavy oils, the residues from refineries, asphaltum, and even earthy matter, are not unknown, and occasionally by a process of double casting the exterior of the block is made to differ in quality from the interior.

The refined material is known as ceresin (Specimen No. 63204, U.S.N.M.). It is used for candles, an adulterant or a complete substitute for beeswax, in the manufacture of ointments and pomades. A residual product from the purifying process, of a hard waxy nature, is combined with india rubber and used as an insulating material for electrical cables. In this form it is known as *okanite.* A ball blacking, used on the heels of shoes, is also manufactured from it. (See Specimens Nos. 63204, 62235, 62236, 66076, U.S.N.M.)

The names scheererite, hatchettite, fichtelite, and könlite are applied to simple hydrocarbons closely allied to ozokerite found in beds of peat and coal, but, so far as the writer is aware, never in such abundance as to be of commercial value.

The name torbanite or kerosene shale has been given to a dense coal-black substance appearing and breaking much like cannel coal, and which occurs in irregular, isolated, circumscribed, and lenticular deposits near the base of the carboniferous beds of New South Wales, Australia, and near Bathgate in Linlithgowshire, Scotland. The better varieties contain from 70 to 80 per cent of volatile hydrocarbon, 6 to 8 per cent of fixed carbon, 7 to 20 per cent of ash, with a little sulphur and water. The material is used mainly for gas and oil making by distillation, the best qualities yielding from 150 to 160 gallons of crude oil to the ton and about 20,000 feet of gas of 48-candle intensity.[1] (Specimen No. 12786, U.S.N.M.)

4. RESINS.

SUCCINITE; AMBER. The mineral commonly known as amber is a fossil resin consisting of some 78.94 parts of carbon, 10.53 parts of oxygen, and 10.53 parts of hydrogen, together with usually from two to four tenths of a per cent of sulphur. It is not a simple resin, but a compound of four or more hydrocarbons. According to Berzelius, as quoted by Dana, it "consists mainly (85 to 90 per cent) of a resin which resists all solvents, along with two other resins soluble in alcohol and ether, an oil, and 2½ to 6 per cent of succinic acid.

The mineral as found is of a yellow, brownish, or reddish color, frequently clouded, translucent or even transparent, tasteless, becomes negatively electrified by friction, has a hardness of 2 to 2.5, a specific gravity when free from inclosures of 1.096, a conchoidal fracture, and melts at 250° to 500° F. without previous swelling, but boils quietly, giving off dense white fumes with an aromatic odor and very irritating effect on the respiratory organs.

As above noted, amber is a fossil resin or pitch, an exudation product principally of the *Pinus succinifer*, a now extinct variety of pine which lived during the Tertiary period.

Occurrence.—Amber or closely related compounds has been found in varying amounts at numerous widely separated localities, but always under conditions closely resembling one another. The better known localities are the Prussian coast of the Baltic; on the coast of Norfolk, Essex, and Suffolk, England; the coasts of Sweden, Denmark, and the Russian Baltic provinces; in Galicia, Westphalia, Poland, Moravia, Norway, Switzerland, France, Upper Burma, Sicily (Specimen No. 61140, U.S.N.M.), Mexico, the United States at Martha's Vineyard and near Trenton and Camden, New Jersey.

The substance occurs in irregular masses, usually of small size. One of the largest masses on record weighed 18 pounds. This is now in the Berlin Museum. A mass found in the marl pits near Harrisonburg, New Jersey, weighed 64 ounces. This last is presumably not true amber, since it contained no succinic acid, which is now regarded as the essential constituent.

The amber of commerce comes now, as for the past two thousand

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[1] Minerals of New South Wales, by A. Liversidge, p. 145.

years, mainly from the Baltic, where it occurs in a strata of lignite-bearing sands of Lower Oligocene age. According to Berendt[1] these are two amber-bearing strata, the one carrying the amber in nests and both underlaid and overlaid by clayey seams, and the second and lower a glauconitic sand commonly known as the blue earth. The material is mined by open cuts where the strata come to the surface; by means of shafts and tunnels, as in coal mining; and by dredging or diving, in the latter case the material having been derived originally from the amber-bearing strata and redeposited on the present sea bottom.[2]

The pieces obtained vary from the size of a pea to that of the hand. The annual product at present amounts to some 300,000 pounds, valued at about $1,000,000. The price of the material varies greatly with the size and purity of the pieces. Pieces of one-fourth pound weight bring about $15 a pound, while the small granules will not bring one-twentieth that amount. The value of the material is often lessened by the presence of flaws and impurities, or inclosures, such as insects and twigs of plants. (Specimens Nos. 53056, 61140, 66812, 67748, U.S.N.M.)

Uses.—Amber is used mainly in jewelry, in small ornamentations, and smokers' goods, the smaller pieces being used in making varnish. The clear pieces and chippings have of late been compressed by a newly discovered process into tablets some 6 by 3 by 1 inches in size, which can be utilized in the manufacture of articles for smokers' use.

RETINITE.—The name retinite is used by Dana to include a considerable series of fossil resins allied to amber, differing mainly in containing no succinic acid. They occur in beds of brown coal of Tertiary and Cretaceous age, much as does the amber proper. The principal varieties that have thus far proven of any economic importance are noted below:

CHEMAWINITE.—This is the name given by Professor Harrington[3] to an amber-like resin found associated with woody débris on the south east shore of Cedar Lake in Canada (Specimen No. 62602, U.S.N.M.). The material occurs in granular form and in small sizes only, such as are quite unsuited for manufacturing purposes. The true gum-bearing stratum, if such exists, has not yet been discovered, the material thus far found being washed up by waves on the beach. According to O. J. Klotz[4] the beach matter resembles the refuse of a sawmill, no stones and very little sand being associated with the débris, which is everywhere underlaid by clay. The principal beach was estimated to contain some 700 tons of granular material.

A somewhat similar resin is found in the lignite and soft greenish

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[1] Schriften der Physikalisch-ökonomischen Gesellschaft, VII, 1866.

[2] According to the Engineering and Mining Journal of May 20, 1893, the dredging process on the Baltic coast has been discontinued as no longer profitable.

[3] American Journal of Science, XLII, 1891, p. 332.

[4] American Jeweler, No. 2, XII, 1892.

NODULE OF GUM COPAL FROM CONGO RIVER REGION, AFRICA.
Weight, 8¼ pounds.
Specimen No. 62717, U.S.N.M.

sandstone near Kuji, Japan.[1] It is reported as being of inferior quality, opaque, cloudy, and much fissured. It is, however, mined and shipped to Tokio, where it is presumably worked up into small ornaments.

The so-called Burmese amber, or *Burmite* from the Hukong Valley, is reported as occurring in a soft blue clay, probably of Lower Miocene age, and in lumps not exceeding the size of a man's hand.

GUM COPAL.—The name copal or gum copal is made to cover, commercially, a somewhat variable series of resins more or less fossilized and found for the most part buried in the sands in tropical and subtropical regions. They are in general amber-like or resin-like in appearance, of a hardness inferior to that of true amber, of a light yellow to brown color, brilliant glass-like luster, transparent to translucent, and have a conchoidal fracture. When cold they are brittle and can be readily crushed to powder, but possess a slight amount of elasticity. When rubbed on cloth they become electric and emit a peculiar resinous odor. The specific gravity varies from 1 to 1.10. When heated the material softens, swells up, and bubbles, finally melting, remaining liquid until carbonized. It burns with a yellow smoky flame; is partially soluble in alcohol, wholly so in ether, and also in turpentine on prolonged digestion. The so-called Kauri gum is a light amber-colored variety from the *Dammara Australis*, a living coniferous tree of New Zealand (Specimens Nos. 62468, 62469, U.S.N.M.). The principal source is the northern portion of the Auckland provincial district which has exported since 1863 (and up to 1897) some 134,630 tons of gum valued at £5,394,687, the product for 1890 being 7,438 tons valued at £378,563.

The gum-digging industry is one that gives employment to both Europeans and natives.[2] The gum is found but a short distance below the surface and is dug with the aid of a few implements, the entire outfit often consisting of a steel prod, a spade, and knife and haversack. With the copal is often found the more amber-like resin *ambrite*, which has a slightly greater hardness (2), a specific gravity of 1.034, a yellowish gray to reddish color and which yields on analysis carbon, 76.88; hydrogen, 10.54 per cent, and oxygen, 12.77 per cent. It becomes strongly electric by friction and is insoluble in alcohol, ether, chloroform, benzine, or turpentine and burns with yellow, smoking flame. Quite similar to the kauri gum is the copal of the African coasts. According to Dr. F. Welwitsch[3] gum of the west coast and probably all the gum resin exported under this name from tropical Africa is to be regarded as a "fossil resin produced by trees which,

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[1] Transactions of the American Institute of Mining Engineers, V, 1876, p. 265.

[2] Report of the Mining Industry of New Zealand for 1888. In the report for 1887 it is stated that "according to the last census" the number of persons employed in the occupation of gum digging was 1,283.

[3] Journal of the Linnaean Society of London, Botany, IX, 1866, p. 287.

in periods long since past, adorned the forests of that continent, but which are at present either totally extinct or exist only in a dwarfed posterity." The gum, which is called by the Bunda negroes Ocate Cocoto, or Mucocoto, is found in the hilly or mountainous districts all along the coast of Angola, including the districts of Congo and Benguella, and is brought by the natives to the different market places on the coast of Angola, including the districts of Congo and Benguella. The larger quantities of the resin are mostly found in the sandy soil and it is apparently limited in its geographical distribution with that of the tree *Adansonia digitata*, the lands in the Government of Benguella extending along the mountain terrace of Amboin, Selles, and Mucobale, south of the Cuanza River being most productive, having yielded between 1850 and 1860 some 1,600,000 pounds of gum a year.

> It is a general and widely spread opinion [writes Welwitsch] that the gum copal in Angola is gathered from trees; but this, according to my own observation, is obviously erroneous; for the gum copal is either dug out of the loose strata of sand, marl, or clay, or else it is found in isolated pieces washed out and brought to the surface of the soil by heavy rainfalls, earth-falls, or gales; and such pieces, where found, induce the negroes to dig for larger quantities in the adjacent spots. This digging after larger quantities is, as may be supposed, often very successful; but sometimes it is less satisfactory, or totally without result, just in the same manner as with people digging for gold. At times numerous larger and smaller pieces of copal are found close to the surface of the sand, or within the depth of a few feet; while in other places, after digging to the depth of 5 to 8 or even 10 or more feet, only single pieces, or sometimes none at all, are brought to light. As soon as a negro has discovered in any spot one or more pieces of copal, he hastens to his relations and to his commercial friends, telling them of his fortunate treasure-trove, showing what he has found, and concludes with them a kind of treaty of partnership whereby he becomes entitled to the larger share in the probable gains. The members of this partnership then provide themselves with digging implements, including large sacks, mostly made of the bark of the Adansonia or Raphia leaves, and they then proceed to the indicated spot to commence researches. As is natural, such a spot and its neighborhood are not left until the diggers have convinced themselves that they have completely exhausted the district, or that no more gum copal is to be found beyond the first indicating pieces. In the latter case it is supposed that the first pieces met with were washed down from afar, and further researches are then made accordingly.
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> If, after prolonged researches in the same district, no more gum copal is found, the diggers leave that place; the secured resin is cleaned by washing and packed in sacks, to be ready for sale in the markets on the coast. Different varieties of unequal value being often obtained on the same spot, the resin, when brought to market, has to be sorted before being sold. It is classified mostly according to its color; and the price is determined by weight. The deep-colored quality is generally worth double the price of the lighter sort. The shape in which the gum is found is quite variable; it often has the form of an egg, a ball, or a drop, at other times it looks like a flat, pressed cake, and it is also met with in sharp-canted pieces. The pieces vary as much in size as in shape; they are rarely larger than a hen's egg, and there are many much smaller, others (which, however, seldom occur) are as big as a man's fist, or even a child's head, weighing 3 to 4 pounds and more. All the pieces of different shape and size have one common characteristic, namely, that on their sur-

face they are covered with a thinner or thicker close-sticking whitish, nearly chalky crust, which exhibits on many pieces veins or network, while in most instances it covers the surface like an earthy powdery coat. The surface of fresh-broken pieces appears conchoidal, with finely radiating lines in each conchoidal impression. The luster is glossy, the mass is hard and transparent to a certain depth, and where scratched with a knife or needle it leaves a white powdered stroke. It can easily be scraped with a knife into powder which, if sprinkled over red-hot coals, changes instantaneously into thick vapors, at first with a slight yellow color, with a strong aromatic smell, somewhat similar to that of incense. Large pieces brought into contact with a light soon burn up, developing at the same time the above-mentioned vapors. When chewed it crackles between the teeth without leaving a noticeable taste.

The fact that there is often seen, even on the canted broken sides of many pieces, the same hard, whitish, earthy crust which covers the other unbroken surface of the same piece, tends to prove that after their falling off the mother tree they were forcibly transported from their original spot by floods or earth falls, by which they were broken before they came into the marl or sandy plains in which they are now found. At times the crust just alluded to is very hard, of considerable thickness, and with a glossy polish, which leads to the supposition that pieces in which it is found have been embedded for a long time in the ground, or perhaps in water basins. While an earthy crust of greater or less thickness is noticed on all pieces of gum copal before it is washed or rubbed off, the color in different pieces varies very much; some samples are yellowish white, some of honey or gold color, and others are distinguished by an intense reddish orange color. The general appearance of the pure pieces of this resin, especially in the gold-colored kind, has delusive resemblance to amber, with which, though much softer, it has the common properties of igniting and of becoming electrical by friction. The interior of the Angola copal pieces, when not mixed with earthy substances, or with remains of bark, is even glossy and transparent; but I have never observed insects in any of the numerous samples which, partly in Angola and partly at Lisbon, came under my notice, while in the copal sent to Lisbon from the province of Mozambique, on the east coast of Tropical Africa, various hymenopterous insects are to be met with. The different colors of the copal of Angola just described are connected more or less with its availability for varnishes, etc. Thus the copal dealers distinguish three sorts, namely, (1) red copal gum (gomma copal vermellia); (2) yellow (G. C. amarella); (3) whitish (G. C. bianca). The red and whitish sorts furnish the best and finest varnish, and therefore are most in request and the dearest, while the whitish quality is sold at the lowest price.[1]

According to Burton[2] the present limit of distribution of the gum-yielding trees on the east coast is less extensive than that of the extinct forests which have yielded the true or "ripe" copal, or "sandarusi," as it is locally called. Every part of the coast from Ras Gomani, in south latitude 3, to Ras Delgado, in 10° 41′, with a mean depth of 30 miles inland, may be called the copal coast. The material is found in red, sandy soil, but is not evenly distributed, occurring rather in patches, as though produced by isolated trees. Dr. Kirk considers

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[1] Journal of the Linnean Society of London, Botany, IX, 1866, pp. 291–293.

[2] Lake Region of Central Africa, II, p. 403. See also report by Dr. M. C. Cooke on the gums, resins, etc., in the India Museum, or produced in India. London, India Museum, 1874.

this gum as a product of trees of the same species as those at present producing the raw gum called by the natives and Arabs sandarusiza miti or chakazi; that is, the *Trachylobium mozambicense* Peters. The gum when dug from the soil has superficially a peculiar pebbled appearance, best described as "goose skin" (Specimens Nos. 62472, 62473, U.S.N.M.), and which Burton considered as due to the impress of the sandy grains in which it had been buried, but which Dr. Kirk regards as due to the structure of the cellular tissues of the tree. The copal when dug up has, according to this authority, exteriorly no trace of the loose skin structure.

As is the case with the New Zealand and West African gums, the methods of digging are very crude, careless, and desultory. The diggings are mostly beyond the jurisdiction of Zanzibar, but as this is the principal port, most of the material is known commercially as Zanzibar copal.

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XIV. MISCELLANEOUS.

1. Grindstones; Whetstones; and Hones.

The custom of sharpening edge tools on pieces of stone has been practiced by barbarous and civilized nations ever since the adoption of cutting implements of any kind, however crude and of whatever materials.

With the first crude implements, it is safe to say almost any stone possessing the requisite grit would serve to produce the rough edge desired. With the improvement in the cutting implement there has, however, been necessitated a corresponding improvement in the character of the sharpening implement as well. Formerly, it may be safely assumed, every man used that which was most accessible and could be made to best answer its purpose. Now the grindstone and whetstone industry is as well organized as any other branch of manufacture, and forms no inconsiderable feature of the nation's trade. Localities are ransacked and material is brought from far and near, carried long distances, overland or across the ocean, to the workshops of the manufacturer to be cut into the desired shapes and sizes, classified and assorted according to quality, and sent abroad once more to meet the demands of the ever-increasing trade. The use of the grindstone, it should be noted, is not confined merely to sharpening edge tools, but, as will be noted later, they are made from a variety of materials and of an equal variety of sizes, from the 2-inch wheel of novaculite, used by jewelers, to a coarse grit monster of over 2 tons weight for the grinding of rough castings in machine shops.

A stone to be suitable for grinding purposes must possess a fine and even grain, free from all hard spots and inequalities of any kind. It is essential, too, that the various particles of which it is composed be cemented together with just sufficient tenacity to impart the necessary strength to the stone, and yet allow them to crumble away when exposed to friction, thus continually presenting fresh sharp grains and surfaces to act upon the material being ground. Simple as these essential qualities may seem they are in reality but rarely met with in perfection, and the majority of grindstones now on the market are quarried from a comparatively limited number of sources. If the stone be too friable it wears away too rapidly, and the grinding done is coarse and uneven; a sharp edge or polish is unobtainable. If too hard it glazes and loses its cutting qualities, or cuts so slowly as to be no longer desirable. If, moreover, the particles composing the stone adhere with too little tenacity, the stone, particularly if it be a large one, such as is used for grinding castings, is liable to burst, perhaps to the serious injury of workmen and machinery.

The requisite qualities as above enumerated are found mainly in those stones that have originated as sandy deposits on sea bottoms and have undergone little if any metamorphism—in other words, in sandstones. For some particular reason, or rather owing to certain peculiar conditions, although sandstones were formed throughout a great number of periods in the earth's history, those formed during the Carboniferous age seem best adapted for the purpose, and from stone found somewhere in this formation are manufactured a large share of the grindstones now in use.

A majority of the grindstones now found in the markets of the United States are made from sandstones quarried from the Upper, Middle, and Lower Carboniferous formations of Ohio, Michigan, Nova Scotia, or New Brunswick, or England and Scotland. A few are, or have been, made from stone from Missouri and Kentucky. The Ohio stones are obtained nearly altogether from quarries in the sub-Carboniferous sandstones at or near Berea, Amherst, Bedford, Constitution, Massillon, Marietta, Independence, and Euclid. Few if any of the quarries are worked wholly for grindstones, but in the majority of cases the stone is sought for building purposes as well, and the grindstone output may be merely incidental, certain layers only being adapted for the latter purpose. This is well illustrated by the following section, as shown at one of the Amherst quarries and as described[1] by Professor Orton, the State geologist. The reader will understand that by section is meant the various layers exposed in the quarry wall, or that would be passed through in digging or boring from the surface downward.

At Amherst, then, the stone lies as follows, beginning at the surface:

	Feet.
Drift material (soil, sand, etc.)	1 to 3
Worthless shell rock	6 to 10
Soft rock used only for grindstones	12
Building stone	3
Bridge stone	2
Grindstone	2
Building and grindstone	10
Building stone	4 to 7
Building stone or grindstone	12

Commenting on the condition of affairs as here displayed, Professor Orton says:

> As will be noticed in this section, the different strata are not applicable alike to the same purpose, and the uses for which the different grades of material can be employed depend principally upon the texture and the hardness of the stone. The softest and most uniform in texture is especially applicable for certain kinds of grinding, and is used for grindstones only, and the production of these forms an important part of the quarry industry. In its different varieties the material is applicable to all kinds of grinding, and stones made from it are not only sold throughout this coun-

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[1] Geological Survey of Ohio, V, p. 586.

try, but are exported to nearly all parts of the civilized world. Some of the finest-grained material is also used in the manufacture of whetstones. There are various points in the system of the Berea grit where the stone is adapted to this use, but such a manufacture is best carried on when joined with a large interest in quarrying, so that the small amount of suitable material can be selected; and thus it happens that only at Amherst and at Berea are whetstones manufactured in large quantities.

Below are given in brief outline the sources and main characteristics of the principal grindstones now in the market, beginning with those of the United States. In speaking of the texture of any stone, that of Berea has been taken as the standard. This is the stone most used for grinding cutting tools, such as axes and scythes. It must be remarked here that the term Berea grit is applied not merely to the stone from the immediate vicinity of the town of Berea, but is rather a general name applied to this particular subdivision of the Subcarboniferous formation of Ohio and extending over a wide field.

Berea.—Medium fine; blue gray, light yellowish, or nearly white. For edge tools in general; the finer varieties also used for whetstones. Four quarries a few miles west of Berea produced alone upward of $10,000 worth of grindstones during the last census year. (Specimen No. 25059, U.S.N.M.)

Amherst.—Medium fine, like the Berea, being a part of the same formation. Light gray, with small rust-colored spots due to iron oxides. For grindstones and whetstones for edge tools in general; the softer varieties for saws. (Specimens Nos. 25079, 25421, U.S.N.M.)

Independence.—Similar to the Amherst, and especially adapted for the manufacture of large grindstones for dry grinding; stones said not to glaze when used for this purpose. (Specimen No. 25080, U.S.N.M.)

Bedford.—Rather coarser, though of even texture and filled with brown spots of iron oxide. Especially adapted for grinding springs.

Euclid.—Fine, light bluish-gray; for wet grinding edge tools.

Massillon.—Medium to rather coarse; the microscope shows it to be an aggregate of rounded, colorless grains of quartz, with little, if any, cementing material. Not so finely compacted as the last, and small fragments can be readily broken from the sharp edges by means of the thumb and fingers. Color, light yellowish or pinkish; for edge tools, springs, files, and nail cutters' face stones, but mainly for the dry grinding of castings. (Specimens Nos. 25054, 25055, U.S.N.M.)

Constitution.—Medium; light gray and rather more friable than the last. A variety of textures, however, and all kinds of grits for wet grinding are furnished. (Specimens Nos. 25056, 25057, U.S.N.M.)

Huron, Michigan.—Fine; uniform blue-gray color, with numerous flecks of silvery mica. Smells strongly of clay when breathed upon. For wet grinding of edge tools; produces a fine edge. (Specimen No. 25076, U.S.N.M.)

The Joggins, Nova Scotia.—Fine gray; of uniform texture; used for wet grinding all kinds of edge tools; the larger stones for grinding springs, sad irons, and hinges; extensively exported to the United States.

Bay of Chaleur, New Brunswick.—Fine dark bluish-gray; of firm texture; smells strongly of clay when breathed upon. Resembles the stone of Huron, Michigan, but contains less mica. Used in the manufacture of table cutlery; also machinists' tools and edge tools in general.

Newcastle, England.—Light gray and yellowish; with a sharp grit; rather friable, and texture somewhat coarser than that of the Berea stone, which it otherwise somewhat resembles. The finer grades used for grinding saws and the coarser and harder ones for sad irons, springs, pulleys, shafting, for bead and face stones in nail work, and for dry grinding of castings; also used by glass cutters.

Wickersly, England.—A dull brownish or yellowish, somewhat micaceous stone of medium texture and rather soft. For grinding saws, squares, bevels, and cutlers' work in general.

Liverpool, or Melling, England.—Dull reddish; a somewhat loosely compacted aggregate of siliceous sand, so friable that the sharp angles are easily crumbled away by the thumb and fingers. A very sharp grit, used for saws and edge tools, particularly axes in shipyards.

Craigleith, Scotland.—Fine-grained and nearly white. A very pure siliceous sandstone with a sharp grit. Said to be the best stone known for glass cutting, though the Newcastle, Warrington, and Yorkshire grits are also used for a similar purpose.

Grindstones from France and Saxony find their way into our markets but rarely.

For whetstones the same qualities are essential as for grindstones, though as a rule the whetstones are designed for a finer class of work, and hence a finer grade of material is utilized. For sharpening scythes and other coarse cutting tools, however, the same stone is used as for grindstones, the same quarry producing stone for building, grindstones, and whetstones, as above noted. The so-called Hindostan, or Orange stone, from Orange County, Indiana, is a very fine-grained siliceous sandstone of remarkably sharp and uniform grit, and which for carvers and kitchen implements is unexcelled. (Specimens Nos. 38901–38905, 38910–38912, 38918–38924, 72896, 72899, etc., U.S.N.M.) The so-called Labrador stone is also a sandstone of a dark blue-gray color and of less sharp grit than that just mentioned. (Specimens Nos. 38957, 38959, 38963, 38964, 38968, 38974, 38980–38982, and 38985–38987, etc., U.S.N.M.) Many scythestones like "Indian Pond" (Specimen Nos. 38950, 38873, 38874, U.S.N.M.), "Chocolate," "Farmers' Choice," "Black Diamond," "Vermont Quinebaug," and the "Lamoille" (Specimens Nos. 38926 and 38878, U.S.N.M.), are fine-grained mica schists from New Hampshire and Vermont quarries (Specimens Nos. 38947 to 38951, etc., U.S.N.M.). These as a rule are very

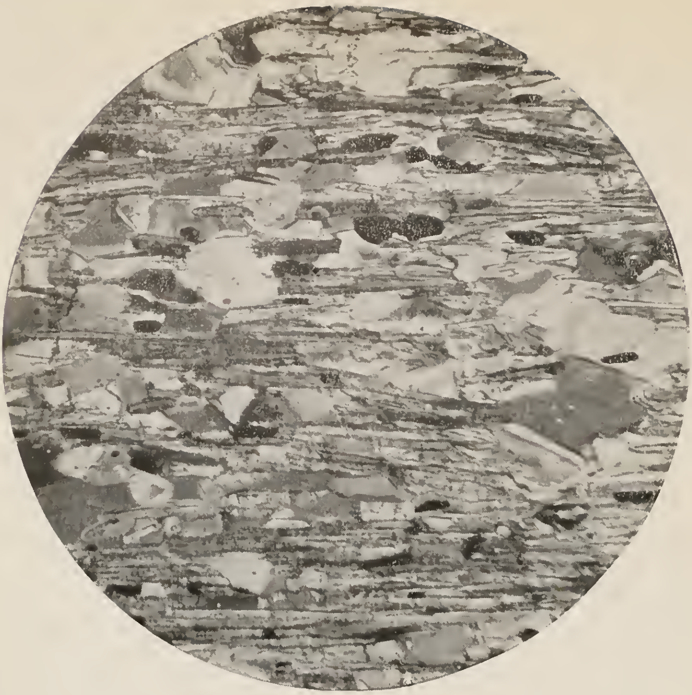

Fig. 1.

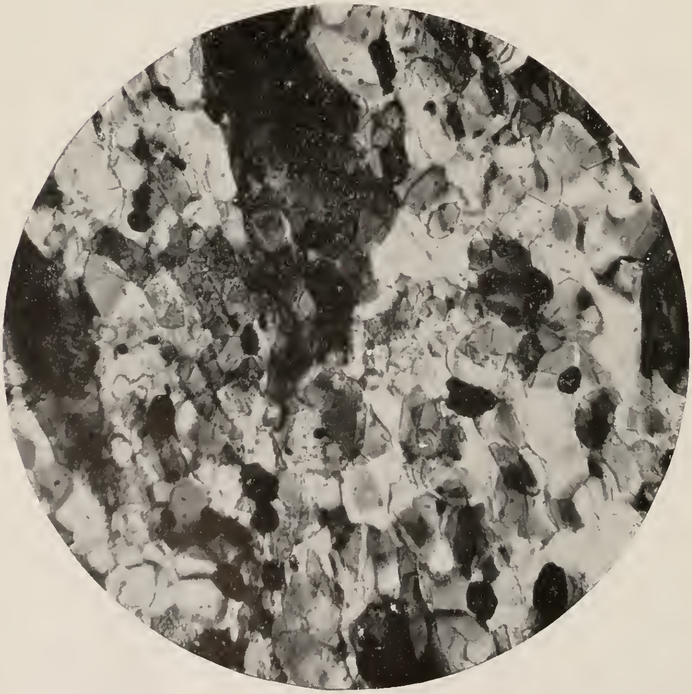

Fig. 2.

MICROSECTION OF MICA SCHIST USED IN MAKING WHETSTONE.

Fig. 1, cut across foliation; Fig. 2, cut parallel to foliation.

fine-grained schistose dark-gray rocks, sometimes of a light chocolate color on a freshly fractured surface. The microscope shows them to consist of a compact and slightly schistose aggregate of quartz and mica in which are frequently included very abundant small octahedral crystals of magnetic iron and sometimes garnets. (See Plate 28.) So abundant are these magnetite granules in some of these rocks, especially those of Grafton, New Hampshire, as to constitute an important feature, and it is doubtless very largely to them that the stone owes its excellent abrasive qualities. Magnetite, it will be remembered, has a hardness of about 6.5 of the scale, and constitutes a very considerable proportion of the ordinary emery of commerce. We have here, then, what is almost a natural equivalent of the artificial emery stone, the compact groundmass of quartz and mica serving as a binding material for the magnetite grains while they perform their work in wearing away the implement being ground. A part of the abrading quality of these stones is, however, due to the abundant quartz and mica scales and their peculiar arrangement in relation to one another.

The well-known Water of Ayr, Scotch hone, or snake stone, as it is variously called, is also a very compact schist. It is said to come from Dalmour, in Ayrshire, Scotland. (Specimens Nos. 38931, 38937, 38946, 54146, U.S.N.M.)

The name novaculite is applied to a very fine-grained and compact rock consisting almost wholly of chalcedonic silica, and which, owing to the fineness of its grit, is used only in the finer kinds of work, as in sharpening razors, knives, and the tools of engravers, carpenters, and other artisans. The true novaculites are, so far as the writer is aware, at present quarried in America only in Montgomery, Saline, Hot Springs, and Garland counties, in Arkansas, and are known commercially as the Washita (or Ouachita, as the name is properly spelled) (Specimens Nos. 38955, 38966, 38969, 38977, 72900, etc., U.S.N.M.), and Arkansas stones (Specimens Nos. 38954, 38971, U.S.N.M.). Both varieties are nearly pure silica, the Ouachita being often of a yellowish or rusty red tint (Specimen No. 72900, U.S.N.M.), and the Arkansas of a pure snow whiteness, the latter variety being also the hardest, most compact, and highest priced. The analyses given below show the average composition of the two varieties:

Constituents.	Arkansas.	Ouachita.
SiO_2	99.50	99.49
Al_2O_3	0.20	0.13
Fe_2O_3	0.10	0.06
CaO	0.10	0.04
MgO	0.05	0.08
K_2O	0.10	0.16
Na_2O	0.15	0.10
H_2O	0.10	0.14

According to Griswold stone suitable for the manufacture of whetstones occurs in quantity in two distinct horizons in the Arkansas novaculite series of rocks, both of which are now being worked. The principal quarries are in the massive white beds of the Hot Springs region, the material being mainly of the fine, compact white "Arkansas" type. Within a limited region, northeast of Hot Springs, the stone becomes more porous, owing in part to the existence of a larger number of the rhomboidal cavities, and passes over to the Ouachita type.

The microscopic structure of the Arkansas novaculite is shown in Plate 30, fig.1, the large white areas being angular granules of quartz.

Owen regarded the Arkansas novaculites as belonging to the age of the millstone grit formation; that is, to the lower part of the Carboniferous, and considered them as a sandstone metamorphosed and freed from impurities by the action of hot alkaline waters. State Geologist Branner, however, regards the finer grade of novaculite as a metamorphosed chert, a conclusion more in accordance with the microscopic structure of the rock, which is more that of chalcedony than of an altered sandstone. Griswold, on the other hand, regards the novaculite as a product of sedimentation of a fine siliceous silt, and of Lower Silurian age,[1] while Rutley[2] considers it as a product of chemical replacement by silica of the calcareous material of dolomite or dolomitic limestone beds.

The view of Suttons quarry No. 7 in Plate 29 shows the novaculite beds dipping 60° to the southeast, the bed of good stone being some 12 or 15 feet in thickness. The rock is everywhere badly jointed, in one case mentioned by Griswold as many as six different systems being developed in a single quarry. The natural result is that pieces of only very moderate dimensions are obtainable even under the most favorable of circumstances. Fine veins of quartz intersecting the rock in various directions increase the difficulty of getting homogeneous material and thereby increase the cost of the output.

The Arkansas stone is now used for many purposes. The whetstones are used by engravers, surgeons, carvers, dentists, jewelers, cutlers, and other manufacturers of fine-edge tools, and by machinists and woodworkers of the more skilled class. Small whetstones for penknives are made in considerable quantity and some stones are sold for razor hones.

The stone is also used by wood carvers, jewelers, manufacturers of fine machinery and metal work, and by dentists in various forms of

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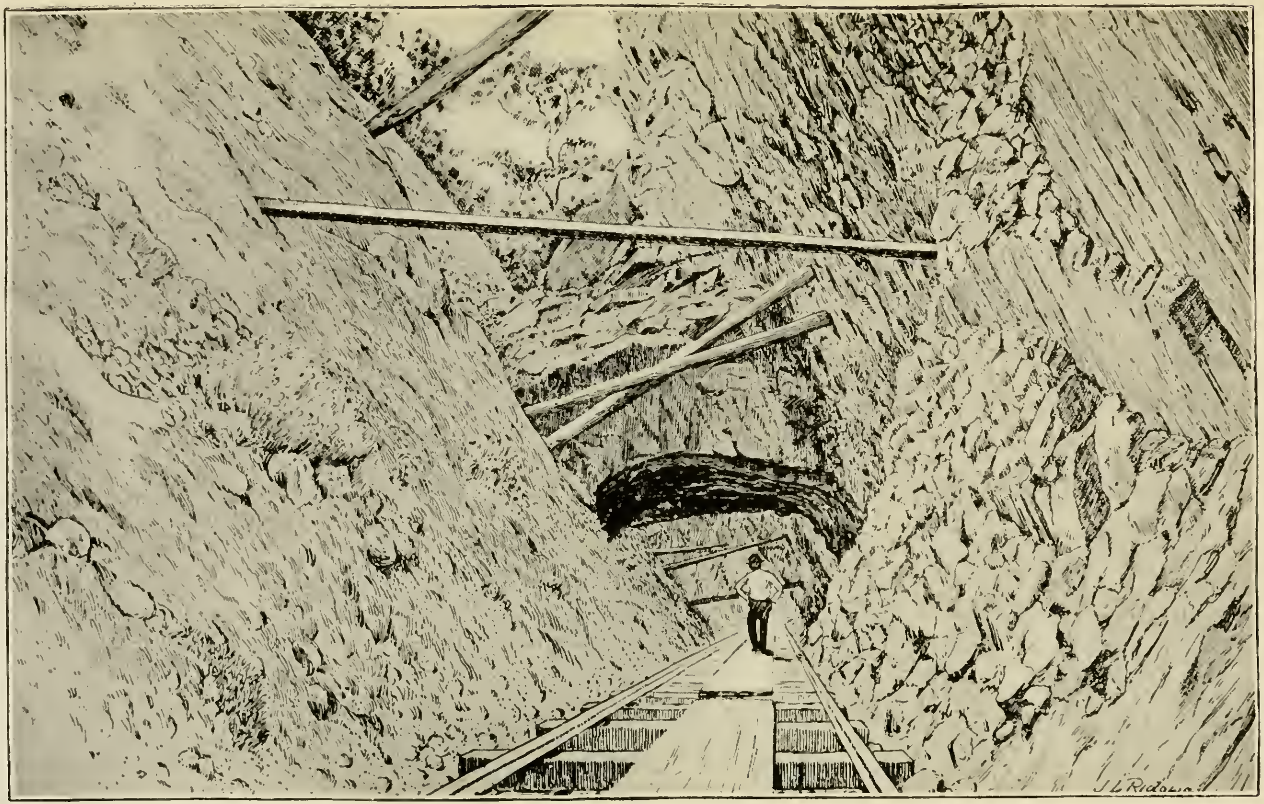
[1] See Whetstones and Novaculites, by L. S. Griswold, Annual Report of the Geological Survey of Arkansas, III, 1892. This report contains a very full discussion of the Arkansas novaculite in all its bearings.

[2] Quarterly Journal of the Geological Society of London, L, 1894, p. 377.



VIEW OF NOVACULITE QUARRY, ARKANSAS.

After Griswold, Annual Report of the Geology of Arkansas, III, 1890.

files and points. Dentists use particularly the "knife blade," a very thin, broad slip of stone, triangular in section, with one short side, the other two forming a thin edge as they come together (Specimens Nos. 38998, 53721, U.S.N.M.). They are used for filing between the teeth. Carvers use wedge-shaped, flat, square, triangular, diamond-shaped, rounded, and bevel-edged files for finishing their work. (Specimen No. 38996, U.S.N.M.). Jewelers, especially manufacturing jewelers and watchmakers, use all these forms of files and also points. These last are sometimes made the size of a lead pencil, having a cone-shaped end, and are about 3 inches long and ¼ inch square, tapering to a point. They are used chiefly in manufacturing watches to enlarge jewel holes (Specimens Nos. 38995, 53726–53727, U.S.N.M.).

Wheels of various thicknesses and diameter are also made from Arkansas stone. They are used chiefly by jewelers and dentists, but could be made of service in all workshops where an Arkansas whetstone is used (Specimens Nos. 38992, 38962, 53710, U.S.N.M.). The difficulty of obtaining pieces of clear stone large enough for wheels several inches in diameter makes the price very high, and the difficulty of cutting out a circular form increases the cost. Wheels are quoted at from $1.10 to $2.20 an inch of diameter.

Arkansas stone is used for finishing and polishing metal rolls, journals, cross-head slides, piston rods, crank pins, and all kinds of lathe work.

Fragments of the Arkansas stone are saved at the factories, and now and then sent away to be ground for polishing powder. In the manufacture of this powder millstones are worn out so rapidly that the process is rather expensive, but as waste stone is utilized, the powder can be sold by the barrel at 10 cents a pound. It makes a very fine, pure white powder of sharp grit, suitable for all kinds of polishing work; it is known as "Arkansas powder." A large amount of energy is wasted, however, in the manufacture of this powder, for the silica of the Ouachita stone is in every way identical with that of the Arkansas stone, and it would be much more easily reduced to powder than the Arkansas.

The so-called Turkish oilstone from Smyrna, in Asia Minor, is both in structure and abrasive qualities quite similar to the Arkansas novaculites. (Specimens Nos. 38956, 38967, 38997, U.S.N.M.) It, however, is of a drab color and carries an appreciable amount of free calcium carbonate and other impurities, as shown by the analysis given below, as quoted by Griswold:

TURKEY STONE.

Silica (SiO_2)	72.00
Alumina (Al_2O_3)	3.33
Lime (CaO)	13.33
Carbonic acid (CO_2)	10.33

According to Renard,[1] the celebrated Belgian razor hone quarried at Lierreux, Sart, Salm-Chateau, Bihau, and Recht is a damourite slate containing innumerable garnets, more than 100,000 in a cubic millimeter. Like the Ratisbon hone, this occurs in the form of thin, yellowish bands, some 6 centimeters wide ($2\frac{3}{8}$ inches) in a blue-gray slate (phyllade). The bands are essentially parallel with one another and with the grain of the slate, into which they at times gradually merge. The chemical composition of a sample from Recht is given as below. The microscopic structure of the stone as described and figured by Renard is essentially the same as that of the Ratisbon stone in the collection of the U. S. National Museum (see Plate 30, fig. 2), and the stones are practically identical in color and texture as well.

Silica (SiO_2)	46.5
Titanic oxide (TiO_2)	1.17
Alumina (Al_2O_3)	23.54
Ferric iron (Fe_2O_3)	1.05
Ferrous iron (FeO)	0.71
Manganese oxide (MnO)	17.54
Magnesia (MgO)	1.13
Lime (CaO)	0.80
Soda (Na_2O)	0.30
Potash (K_2O)	2.69
Water (H_2O)	3.28
Carbon dioxide (CO_2)	0.04
Phosphoric acid (P_2O_5)	0.16
Sulphur (S)	0.18
Organic matter	0.02
Total	99.11

The cutting property of the stone would appear to be due to the presence of the small garnets above noted. (Specimens Nos. 38938–38940, U.S.N.M.)

The so-called holystone is but a fine, close-grained sandstone of the same nature as that used in grind and whet stones. The greater part of those made in this country are from the Berea sandstone of Ohio, though some are said to be imported from Germany. The stones are used mainly on shipboard, and the trade is small.

2. PUMICE.

The material to which the name pumice is commonly given is a form of glassy volcanic rock, which, by the expansion of its included moisture while in a molten condition, has become, like a well-raised loaf, filled with air cavities or vesicles. The cutting or abrasive quality

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[1] Mémoires Couronnés et Mémoires des Savants Étrangers de L'Academie Royal des Sciences, etc., Belgique 1878, pp. 1–44.

Fig. 1.

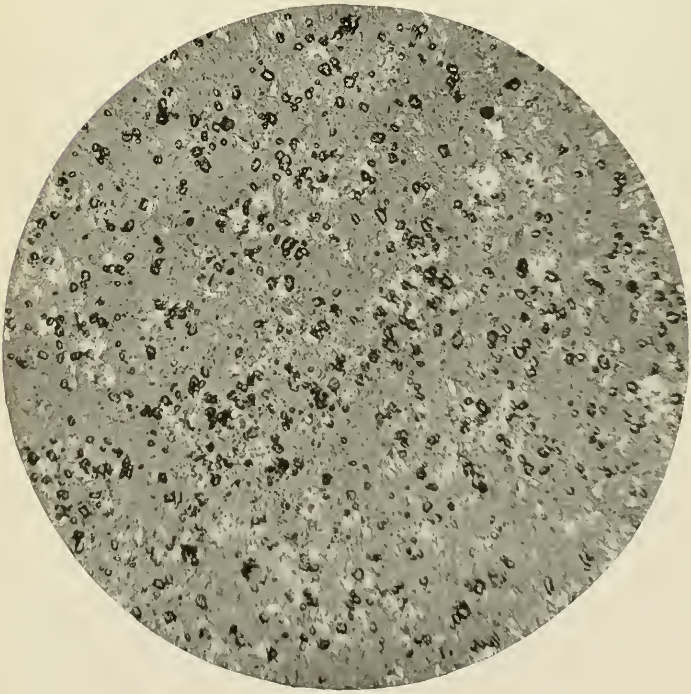

Fig. 2.

MICROSECTIONS SHOWING THE APPEARANCE OF (1) ARKANSAS NOVACULITE AND (2) RATISBON RAZOR HONE. THE DARK BODIES IN (2) ARE GARNETS.

of the material is due to the thin partitions of glass composing the walls between these vesicles. Any variety of volcanic rock, flowing out upon the surface of the ground, is likely to assume the vesicular condition known as pumiceous, but only certain acid varieties known as liparites seem to possess just the right degree of viscosity to produce a desirable pumice, and in this rock only in exceptional circumstances. Almost the entire commercial supply of pumice is now brought from the Lipari Islands, a group of volcanoes north of Sicily, in the Mediterranean Sea. (Specimen No. 60787, U.S.N.M.) The material is usually brought over in bulk and sold in small pieces in the drug and paint shops, or ground and bolted to various degrees of fineness and sold like emery and other abrasive materials. (Specimen No. 54155, U.S.N.M.) At times an inferior grade of pumice has been produced from volcanic flows near Lake Merced, in California. In Harlan County, Nebraska, and adjacent portions of Kansas, as well as in many other of the States and Territories farther west, have been found extensive beds of a fine, white powder, which was first shown by the present writer[1] to be pumiceous dust, drifted an unknown distance by wind currents and finally deposited in the still waters of a lake. Through a mistaken notion regarding its origin this material was first described in Nebraska as *geyserite*. So far as the writer is aware, these natural pumice powders have thus far been used only locally for polishing purposes and as a cleansing or scouring agent in soap. As the material exists in almost inexhaustible quantities, it would seem that a wider scope of usefulness might yet be discovered. (Specimens Nos. 53074, 60920, 37023, U.S.N.M., from Montana, Washington, and Nebraska.)

The analyses given below show (I) the composition of the pumice dust of Harlan, Orleans County, Nebraska,[2] and (II) a pumice from Capo di Costagna, Lipari Islands:

Constituents.	I.	II.
Silica	69.12	73.70
Alumina	17.64	12.27
Iron oxides		2.31
Lime	0.86	0.65
Magnesia	0.24	0.29
Potash	6.64	4.73
Soda	1.69	4.25
Ignition	4.05	1.22
Total	100.24	99.42

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[1] See On Deposits of Volcanic Dust in Southwestern Nebraska (Proceedings U. S. National Museum, VIII, 1885, p. 99), and Notes on the Composition of Certain Pliocene Sandstones from Montana and Idaho (American Journal of Science, XXXII, 1886, p. 199).

[2] Rocks, Rock-weathering, and Soils, p. 350.

According to Dr. L. Sambon, as quoted by Dr. H. J. Johnston-Lavis:

All the best pumice of commerce is obtained from the northeast region of the island of Lipari, extending as far as the summit of Mte. S. Angelo on its northern slope. * * * It is excavated at the Fossa Castagna near M. Pelato, at M. Chirica, and on the shore of the Mosche.

I visited a quarry of M. Pelato on the outer southern side. The height was about 1.50 m. and 1 m. large. The entrance was sustained by poles, faggots of brushwood, and stones; at first one descended for 160 steps, then one ascended for about 50 m. where two naked men were digging in the dull light of an oil lamp. In decending I met some young men who were carrying up baskets full of pumice. They wore short coarse linen drawers, and on their naked breast hung the blessed scapulary. On my arrival at the workes they made me sit down on an empty basket while I watched the men dig out the pieces of pumice, often the size of a human head, from the embedding matrix, which is composed of different sized fragments and dust of the same material, pressed together, and forming an incoherent tuff. They told me of their poor wages, and the dangers of their work in consequence of the frequent collapse of the workings, killing men and youths. It was horrible to hear those accounts of misery and misfortune at the bottom of these caves.

The low roof and narrow passage from which every moment fragments detached themselves seemed to threaten the collapse of the whole; and it was with great relief that I again reached the daylight. Only a few weeks previously a quarry of M. Pelato had collapsed and buried some workmen, and more than two days work were required to reach them. These unfortunate men, saved by a miracle, returned again to their work, for what else could they have done to obtain bread?

Prolonged and curious was at all times the discussion concerning the origin of pumice. It was believed to be amianthus decomposed by fire, by Pott, Bergman and Demeste; calcined lignite or schist, by Vallerio; scorified marl by Sage and granite that had become blown up and fibrous by the effect of fire and water by Dolomieu. The latter asserted having found inclosed in some pieces of pumice fragments of granite. He also declares that he had seen masses of granite which took on gradually the fibrous structure and other characters of pumice; so that he concluded that granite or granitoid schist was the primitive material which by the effect of the volcanic fire passed to the state of the pumice. Finally he declares he sent specimens to all the most learned geologists of the time. Spallanzani, who visited that same locality and hunted in every part of Campo Bianco in a most diligent manner but without being successful in finding the granite of Dolomieu, says wittily that probably the French geologist had carried them all away. Spallanzani himself, on the contrary, considers that pumice and obsidian are the result of fusion of great masses of intermediate lavas which one encounters on all parts of the mountain. Prof. J. F. Blake recently, probably ignoring the observations of Spallanzani, is satisfied in finding in that locality "Mother-pumice" as he has baptized it, from which also is derived the obsidian. But pumice, obsidian and all intermediate rock varieties more or less scoriaceous are but different forms of the same eruptive product. The whole history and modifications of pumice have been worked out by Dr. Johnston-Lavis, who has shown that by studying these eruptive products the whole mechanism of volcanic action in general is explained and the sequence of eruptive phenomena of any volcanic focus can be made out. * * *

When we descend to the shore of the Beja delle pomice by the gorge to the South East of the great obsidian flow, the slopes facing the lava are composed of immense deposits of pumice in which hundreds of holes are observable, marking the excavations made in search of the larger masses of this valuable rock, much of which could be seen in the numerous baskets standing at hand. The sight of the enormous agglomeration of pumice and dust of a glaring white colour, cut by the action of rain and wind into fantastic shapes, stands out against the blue sky like the irregular crags, spurs and ridges of a great glacier.

Along the marina are quantities of pebbles of pumice, either rounded by the torrents that descend from above or by the waves that lap the shore. When the wind blows from N. E. a veritable fleet of floating masses reaches the port of Lipari. The pumice that has been excavated is carried to the beach, and stored and sorted in sheds or caves cut out of the same pumice tuff, protected in front by a breakwater of big stones to prevent heavy seas reaching and washing away the produce.

Pumice in commerce is classified as follows—*grosse*(large size), *correnti* (medium), and *pezzani* (small); the large and middle size are subdivided into *lisconi* (flat) and *rotondi* (round). The *lisconi* are filamentous and break less easily than the *rotondi*. They are also trimmed by the sorters. The *lisconi* and *rotondi* are again subdivided into white, black, and uncertain, according to their colour.

The price varies according to the quality from 50 to 2000 lire the ton. The common price for the assorted is 350 to 500 lire the ton. As much as 5000 tons a year are exported. The best pumice is that of Campo Bianco. It is also obtained at Perera, but it is in small quantity and was produced at the eruption of the Forgia Vecchia. It is a first class grey pumice and fetches from 600 to 750 lire the ton, and does not so easily break as the Campo Bianco. Also at Vulcano a grey pumice is found but the presence of included crystals render it useless for commercial purposes. At Castagna a commoner pumice is obtained called *Alessandrina*, of which brick shaped pieces are made and used for smoothing oil-cloth.[1]

According to the Engineering and Mining Journal[2] a merchantable pumice has recently been found in Miller County, Idaho, but the demands for material of this nature is likely to be lessened by the putting upon the market of a German artificial product. In 1897 some 1,700 tons of pumice were mined near Black Rock, Millard County, Utah.

Ground and bolted pumice is quoted as worth from $25 to $35 a ton according to quality.

3. ROTTENSTONE.

The name rottenstone has been given to the residual product from the decay of silico-aluminous limestones. Percolating carbonated waters remove the lime carbonate from these stones, leaving the insoluble residue behind in the form of a soft, friable, earthy mass of a light gray or brownish color, which forms a cheap and fairly satisfactory polisher for many metals. Specimens Nos. 54150, 54153, 67390, 67791, U.S.N.M., show the material in its natural state and ground and bolted.

The chemical composition of rottenstone, as may well be imagined from what has been said regarding its method of origin, is quite variable, though alumina is always the predominating constituent. Analyses show: Alumina, 80 to 85 per cent; silica, 4 to 15 per cent;

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[1] The South Italian Volcanoes, by H. J. Johnston-Lavis, Naples, F. Furchheim, 1891, pp. 67–71.

[2] Volume LXIV, July 24, 1897, p. 91.

5 to 10 per cent of carbon, and equal amounts of iron oxides and varying small quantities of lime. The material has little commercial value.

4. MADSTONES.

These need but brief notice here. The fallacy of the madstone dates well back into the dark ages and perhaps beyond, and strange as it may seem continues down to the present day. Not longer ago than December, 1898, the Washington newspapers chronicled the sale for $450 of a madstone in Loudoun County, Virginia, and from year to year very many letters are received by the Smithsonian authorities making inquiries regarding such, or possibly offering one for sale at fabulous prices.

So far as the writer is able to learn, either from literature or from personal examination, stones of this class are almost invariably of an aluminous or clayey nature, and their supposed virtue is due wholly to their avidity for moisture—their capacity for absorption, which causes them to adhere to any wet surface, as the tongue or to a wound, until saturated, when they will drop away. It should not be necessary to state, at this late day, that their curative powers are purely imaginary. The ancient bezoar stone, used in extracting or expelling poisons, consisted of a calculus or concretion found in the intestines of the wild goat of northern India.[1]

5. MOLDING SAND.

For the purpose of making molds for metallic casts, a fine, homogeneous argillaceous sand is commonly employed.

The physical qualities which go to make up a molding sand consist, according to Nason,[2] of elasticity, strength, and a certain degree of fineness. It must be plastic in order to be molded around the pattern; it must have sufficient strength to stand when unsupported by the pattern, and to resist the impact of the molten metal when poured into the mold. Too much clay and iron present in the sand will cause the mold to shrink and crack under the intense heat; too little will cause it to dry and crumple, if not to entirely collapse.

The peculiar virtues of molding sand, as outlined above, are ascribed to the fact that each of the sand grains is coated with a thin film of clay.

The accompanying table will serve to show the varying chemical character of sands thus employed, though, according to authorities

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[1] W. J. Hoffman, Folk Medicine of the Pennsylvania Germans, Proceedings of the American Philosophical Society, XXVI, 1889, p. 337.

[2] Forty-seventh Annual Report of the Regents State Museum of New York, 1893, p. 469.

quoted by Crookes and Röhrig,[1] the "quality of the sand for molding depends less on its chemical composition than on its physical properties, namely, whether the grains are round, angular, scaly, etc., and whether they are of uniform size. The adhesiveness is dependent not alone on the quantity of clay, but upon the angularity of the grains, and by a mixture of smaller and larger grains. Reinhardt states that to the naked eye, a good sand should consist of particles seemingly uniform in size, with a sharp feel to the touch. When strewn upon dark paper it should show no dust, and when moistened with from 10 to 20 per cent of water it must be capable of being formed into balls without becoming pulpy or being too easily crushed.

Constituents.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
SiO_2	92.083	91.907	92.913	90.625	79.02	86.68	87.6	90.25
Al_2O_3	5.415	5.683	5.850	6.667	13.72	9.23	7.7	4.10
Fe_2O_3 and FeO	2.498	2.177	1.249	2.708	2.40	3.42	3.6	5.51
CaO	Traces	0.415	Traces	Traces	....	0.96	0.96	0.23
MgO	....	....	....	....	0.71	....	....	....
K_2O	....	....	....	....	4.58	....	....	....
	99.996	100.182	100.012	100.000	100.43	100.29	99.86	100.09

Of the above No. I is from Charlottenburg, Germany; No. II, a sand employed for bronze castings in Paris foundries; No. III, sand from Manchester, England; No. IV, from near Stromberg; No. V, from Ilsenburg, in the Hartz Mountains; No. VI, from Sheffield, England; No. VII, from Birmingham, England, and No. VIII, from Lüneburg.

The sand from Ilsenburg, the composition of which is given in column 5, is stated[2] to be prepared by mixing "common argillaceous sand, sand found in alluvial deposits, and sand from solid sandstone." In preparation the first two are carefully heated to dehydrate the clay and then mixed, equal proportions of each with the same amount of sandstone. The mixture is then ground and bolted, the product being as fine as flour and capable of receiving the most delicate impressions.

According to D. H. Truesdale,[3] the four essential qualities in molding sand are, in the order of their importance, (1) refractoriness, (2) porosity, (3) fineness, and (4) bond. These qualities are dependent mainly upon the varying properties of siliceous sand and clay, the refractory nature being governed by the absence of such fluxing constituents as calcium carbonate, the alkalies, or of iron oxides. Since in nature it is not always possible to obtain the admixture of just the right proportion, artificial mixtures are often resorted to, as mentioned

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[1] A Practical Treatise on Metallurgy, II, p. 626.

[2] Percy's Metallurgy, 1861, p. 239.

[3] The Iron Trade Review, October, 1897, p. 24.

above. W. Ferguson gives[1] the following analyses of molding sand in actual use in his foundries:

Constituents	No. 1, fine sand for snap work.	No. 2, medium grade for medium class of work.	No. 3, coarse sand for heavy machine castings.	No. 4, for heavy machinery in dry-sand molds.
Silica	81.50	84.86	82.92	79.81
Alumina	9.88	7.03	8.21	10.00
Ferric oxide	3.14	2.18	2.90	4.44
Combined water	3.00	2.20	2.85	2.89
Calcium carbonate	1.85	1.10	1.10	1.25
Magnesia	0.65	0.98	None.	0.88
Potassium	No estimate.	No estimate.	No estimate.	No estimate.
Manganese	Trace.	Trace.	Trace.	Trace.
Organic matter	Trace.	Trace.	Trace.	Trace.
Total	100.02	98.35	97.98	99.27

Sands containing lime or alkalies, that is those containing free calcite or feldspathic granules, are sometimes liable to fusion in the case of heavy castings. It is customary in such cases to coat the surface of the mold with graphite.

Sands suitable for ordinary castings are widespread, though the finer grades are often brought considerable distances, some of those used in bronze casting in America being imported from Europe. In the United States the beds are alluvial deposits of slight thickness. Large areas occur in New York State, in counties extending from the Adirondacks to New Jersey. At date of writing a very considerable proportion of the material used in the eastern United States is dug in Selkirk, Albany County, New York. (Specimen No. 61044, U.S.N.M.)

Nason states that these sands occur in beds varying from 6 inches to 3 feet or even 5 feet in thickness. They immediately underlie the surface soil and overlie coarser, well stratified sand beds more nearly allied to quicksands.

In gathering the sands for market, a section of land 1 or 2 rods in width is stripped of its overlying soil down to the sand, which is then dug up and carried away. When the area thus exposed is exhausted, a like area, immediately adjoining is stripped, the soil from the second being dumped into the first excavation. By this method the field, when finally stripped of its molding sand, is ready again for cultivation.

It is estimated that a bed of sand 6 inches in thickness will yield 1,000 tons an acre. The royalty paid the farmers from whose land it is taken varies from 5 to 25 cents a ton. Some 60,000 to 80,000 tons are shipped annually from Albany County alone.

The Selkirk molding sand is of a yellow-brown color, showing under the microscope angular and irregular rounded particles rarely more

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[1] Iron Age, LX, December, 1897, p. 16.

than 0.25 mm. in diameter, interspersed with finely pulverulent matter which can only be designated as clay. The yellow-brown color of the sand is due to the thin film of iron oxide which coats the larger granules. When this film is removed by treatment with dilute hydrochloric acid, the constituent minerals are readily recognized as consisting mainly of quartz and feldspar fragments (both orthoclase and a plagioclase variety), occasional granules of magnetic iron oxide, and irregularly outlined scales of kaolin, together with dust-like material too finely comminuted for accurate determination. Many of the larger granules are white and opaque, being presumably feldspar in transition stages toward kaolin. An occasional flake of hornblende is present. The term *greensand*[1] is applied to the argillaceous molding sands, in an undried state, and which is employed in its native state, new and damp. The term *dry sand* is used in contradistinction, to indicate a sand that must be dried by heat before being fit for use. The dry sand is stated to be firmer and better adapted than the green for molding pipes, columns, shafts, and other long bodies of cylindrical form.

In England good molding sands are obtained from the Lower Mottled Sands of the Bunter (Trias) beds and from those of the Thanet (Lower Eocene).

6. Mineral Waters.

From a strictly scientific standpoint any water is a mineral water, since water is itself a mineral—an oxide of hydrogen. Common usage has, however, tended toward the restriction of the name to such waters as carry in solution an appreciable quantity of other mineral matter, although the actual amounts may be extremely variable.

Of the various salts held in solution, those of sodium, calcium, and iron are the more common, and more rarely, or at least in smaller amounts, occur those of potassium, lithium, magnesium, strontium, silicon, etc. The most common of the acids is carbonic, and the next probably sulphuric.

Classification.—The classification of mineral water is a matter attended with great difficulty from whatever standpoint it is approached. Such classification may be either geographic, geologic, therapeutic, or chemical, though the first two are naturally of little value, and the therapeutic, with our present knowledge, is a practical impossibility. The chemical classification is, on the whole, preferable, although even this, owing to the great variation of methods of stating results used by analytical chemists, is at present attended with some difficulty. Dr. A. C. Peale, the well-known authority on American mineral waters, has suggested the scheme given below,[2] and from his writings has been gleaned a majority of the facts here given.

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[1] This must not be confounded with the Greensand marl, or Glauconitic sand used for fertilizing purposes, and mentioned on page 369.

[2] Annual Report of the U. S. Geological Survey, 1892–93, p. 64.

According to their temperatures as they flow from the springs the waters are divided primarily into (A) thermal and (B) nonthermal, a thermal water being one the mean annual temperature of which is 70° F. or above. Each of these groups is again subdivided according to the character of the acids and their salts held in solution as below:

- Class I. Alkaline.
- Class II. Alkaline-saline.
  - Sulphated.
  - Muriated.
- Class III. Saline
  - Sulphated.
  - Muriated.
- Class IV. Acid
  - Sulphated.
  - Muriated.
  - Silicious
    - Sulphated.
    - Muriated.

Any spring of water may be characterized by the presence or absence of gas when it is designated by one of the following terms: (1) Nongaseous (free from gas). (2) Carbonated (containing carbonic-acid gas). (3) Sulphureted (containing hydrogen sulphide). (4) Azotized (containing nitrogen gas). (5) Carbureted (having carbureted hydrogen).

In cases where there is a combination of gases such is indicated by a combination of terms, as sulphocarbonated, etc. The classes may be further subdivided according to the predominating salt in solution, as (1) sodic, (2) lithic, (3) potassic, (4) calcic, (5) magnesic, (6) chalybeate, (7) aluminous.

The alkaline waters, Class I above, include those which are characterized by the presence of alkaline carbonates. Generally such are characterized also by the presence of free carbonic acid. Nearly one-half the alkaline springs of the United States are calcic-alkaline, that is, carry calcium carbonate as the principal constituent. The saline waters include those in which sulphates or chlorides predominate. They are more numerous than are the alkaline waters. The alkali-saline class includes all waters in which there is a combination of alkaline carbonates with sulphates and chlorides; the acid class includes all those containing free acid, which is mainly carbonic, though it may be silicic, muriatic, or sulphuric.

The character of the salts held in solution is the same for both thermal and nonthermal springs, though as a general rule the amount of salt is greatest in those which are classed as thermal. Thus at the Hot Springs of Virginia one of the springs, with a temperature of 78° F., has 18.09 grains to the gallon of solid contents, while another, with a temperature of 110° F., has 33.36 grains to the gallon.

Source of mineral waters.—Pure water is a universal solvent and its natural solvent power is increased through the carbonic acid which it takes up in its passage through the atmosphere, and by this same acid and other organic and inorganic acids and the alkalies which it acquires in passing through the soil and rocks. The water of all springs is meteoric, that is, it is water which has fallen upon the earth from clouds, and gradually percolating downward issues again in the form of springs at lower levels. In this passage through the superficial portion of the earth's crust it dissolves the various salts, the kind and quantity being dependent upon the kind of rocks, the temperatures and pressure of the water, as well as the amount of absorbed gases it contains.

Both the mineral contents and the temperature of spring waters are dependent upon the geological features of the country they occupy.

As a rule springs in regions of sedimentary rocks carry a larger proportion of salts than those in regions of eruptive and metamorphic rocks. Thermal springs are as a rule limited to regions of comparative recent volcanic activity, or where the rocks have been disturbed, crushed, folded, and faulted, as in mountainous regions. Occasional thermal springs are met with in undisturbed areas, but such are regarded as of deep-seated origin, and to owe their temperatures to the great depths from which they are derived.

Distribution.—Mineral springs of some sort are to be found in each and all of the States of the American Union, though naturally the resources of the more sparsely settled States have not as yet been fully developed. For this reason the table given herewith is to a certain extent misleading:

Production of mineral waters in 1899 by States and Territories.

State or Territory.	Springs reporting.	Product.	Value.
		Gallons.	
Alabama	4	38,900	$19,917
Arkansas	5	48,602	17,442
California	38	1,464,075	698,493
Colorado	11	642,850	172,970
Connecticut	12	338,017	50,685
District of Columbia	2	168,500	10,275
Florida	2	17,000	7,250
Georgia	6	128,040	24,770
Illinois	18	858,950	101,090
Indiana	12	162,475	25,255
Iowa	3	40,200	3,320
Kansas	6	36,175	2,718
Kentucky	4	63,500	7,032
Maine	26	1,850,132	179,450
Maryland	11	100,380	13,045
Massachusetts	39	4,439,011	230,704
Michigan	21	3,015,400	368,235
Minnesota	4	2,078,700	54,701
Mississippi	6	271,500	48,292
Missouri	12	551,876	262,705
New Hampshire	6	469,800	190,990
New Jersey	7	332,000	171,380
New Mexico	5	46,800	7,770

Production of mineral waters in 1899 by States and Territories—Continued.

State or Territory.	Springs reporting.	Product.	Value.
		Gallons.	
New York	46	4,454,057	$809,056
North Carolina	7	103,150	20,715
Ohio	15	2,494,473	171,135
Oregon	2	45,500	9,700
Pennsylvania	25	1,542,800	340,254
Rhode Island	4	195,000	15,000
South Carolina	5	322,564	33,450
South Dakota	2	138,645	44,073
Tennessee	6	346,700	55,658
Texas	15	4,729,950	155,047
Utah	3	7,850	1,955
Vermont	6	53,917	15,869
Virginia	39	954,689	341,769
Washington	3	54,000	7,002
West Virginia	7	32,220	18,305
Wisconsin	30	4,089,329	701,367
Other States[a]	4	263,782	75,847
Total	479	37,021,539	5,484,694
Estimated production of springs not reporting sales	62	2,540,597	1,463,336
Grand total	541	39,562,136	6,948,030

[a] The States in which only one spring for each has made a report are included here. These States are Idaho, Louisiana, Montana, and Nebraska.

Uses.—The mineral waters are utilized mainly for drinking and bathing purposes, the thermal springs being naturally best suited for bathing, and the nonthermal for drinking purposes.

For exhibition purposes the following waters have been selected, kind and geographic distribution being the controlling factors in making up the collection. In all cases the samples are exhibited in the original bottles as put upon the market.

ALKALINE WATERS.

Poland Natural Spring Water, Poland Springs, Maine.
Ballardvale Lithia Spring Water, Ballardvale, Massachusetts.
Londonderry Lithia Spring Water, Londonderry, New Hampshire.
Otterburn Lithia Water, Amelia, Virginia.
Capon Springs Mineral Water, Capon Springs, West Virginia.
Jackson Lithia Spring Water, Jackson County, Missouri.
Algonquin Spring Water, Prince George County, Maryland.
Manitou Natural Mineral Water, Manitou, Colorado.
Rock Mineral Water, Jeffress, Virginia.
Massanetta Spring Water, Harrisonburg, Virginia.
Bethesda Natural Mineral Water, Waukesha, Wisconsin.
Clysmic Natural Mineral Water, Waukesha, Wisconsin.
White Rock Lithia Water, Waukesha, Wisconsin.
Idanha Natural Mineral Water, Soda Springs, Idaho.
Missisquoi Mineral Water, Sheldon, Vermont.

ALKALINE SALINE WATERS.

1. *Sulphated.*

Takoma Springs Water, Takoma Park, Maryland.
Fonticello Lithia Water, Chesterfield County, Virginia.
Tredyffrin Lithia Water, Chester County, Pennsylvania.
Charmian Natural Mineral Water, Franklin County, Pennsylvania.
Harris Antidyspeptic and Tonic Water, Burkeville, Virginia.
Crockett's Arsenic Lithia Water, Shawsville, Virginia.
Thompson's Bromine and Arsenic Springs Water, Ashe County, North Carolina.
Harris Lithia Water, Laurens County, South Carolina.
Stafford Mineral Water, Jasper County, Mississippi.
Bladensburg Spa Mineral Water, Bladensburg, Maryland.
Healing Springs Lithia Water, Bath County, Virginia.
Fairchild's Potash Sulphur Water, Garland County, Arkansas.
Buffalo Lithia (Spring No. 2) Mineral Water, Buffalo Lithia Springs, Virginia.
Geneva Red Cross Lithia Spring Water, Geneva, New York.
Wright's Epsom Lithia Water, Mooresburg, Tennessee.
Veronica Natural Mineral Water, Santa Barbara, California.

2. *Muriated.*

Como Lithia Water, Henrico County, Virginia.
Powhatan Natural Mineral Water, Alexandria County, Virginia.
Blackistone Island Mineral Water, St. Marys County, Maryland.
Columbia Natural Lithia Water, Washington City.
Saratoga Natural Vichy Water, Saratoga Springs, New York.
Lincoln Spring Water, Saratoga Springs, New York.
The Hathorn Mineral Water, Saratoga Springs, New York.
High Rock Springs Water, Saratoga Springs, New York.
Congress Water, Saratoga Springs, New York.
Houston Lithia Water, Houston, Virginia.

SALINE WATERS.

1. *Sulphated.*

Indian Spring Water, Sligo, Maryland.
Rockhill Spring Water, Rockville, Maryland.
Pluto Spring Water, French Lick Springs, Indiana.
Excelsior Mineral Water, Excelsior Springs, Michigan.
Greenbrier White Sulphur Water, Greenbrier County, West Virginia.
Geneva Lithia Water, Geneva, New York.
Blue Ridge Springs Water, Botetourt County, Virginia.

2. *Muriated.*

Anipa Spring Water, Rome, Georgia.
Deep Rock Spring Mineral Water, Oswego. New York.
Blue Lick Water, Blue Lick Springs, Kentucky.

ACID WATERS.

1. *Sulphated.*

Shenandoah Alum Springs Water, Shenandoah County, Virginia.
Rockbridge Alum Springs Water, Alum Springs, Virginia.
Wallawhatoola Sulphated-aluminous Chalybeate Water, Millboro Springs, Virginia.

7. Road-Making Materials.

Roadways subject to any considerable amount of traffic demand almost invariably some sort of stone bedding to prevent their becoming soft or badly cut up and rutted by wheels and hoofs of horses. Until within a comparatively few years it has been the general custom to pave the streets of cities and towns with rectangular blocks of granite, trap, or other hard rock, forming thus the well-known Belgian block and Telford pavements. Such are set in regular rows and the interspaces filled with sand and sometimes with tar or asphalt. For suburban and country roads a pavement of broken stone, the invention of a Mr. L. Macadam about 1820, and known by his name, is at present the most extensively used. The invention is based upon the property possessed by freshly broken stone of becoming compacted and to a certain degree even cemented when subject to heavy rolling and the impact of wheels. The finer particles, broken away by the action of the wheels, fill the interstices of the larger, and gradually bring about an induration forming a roadbed hard, smooth, and durable.

Not all materials are equally good for macadamizing purposes. If the rock is too hard ordinary travel is not sufficient to produce the desired amount of fine material, and satisfactory cementation does not ensue. If too soft it grinds away too rapidly. If the material is decomposed, it is stated, it does not become sufficiently indurated—refuses to set, as it were.

Obviously the bulk matter of any roadbed must be built up of materials from near-by sources, owing to cost of transportation. For surfacing, however, materials are often carried long distances. For this purpose a hard, dense rock, such as the finer grades of trappean rocks, are now most generally used.

Macadam is laid with or without a foundation of larger stones. When such is used a thickness of from 6 to 12 inches is recommended and over this is laid from 4 to 6 inches of the broken stone or "metal."

> Taking all points into consideration, it is probable that the best size for macadam, for hard and tough stones, such as basalt, close-grained granite, syenite, gneiss, and the hardest of primary crystallized rocks, is from 1½ to 1⅓ inches cube, according to their respective toughness and hardness, while stones of medium quality ought to be broken to gauge of from 1½ to 2¼ inches, and the softer kinds of stone might vary between the limits of 2 and 2½ or 2¾ inches, but the latter is a size which should seldom be specified.

On roads for light driving it is customary to place a final surfacing of smaller stone, such as will pass a 1-inch mesh.

> Considerable importance is attached to the manner in which the macadam is prepared for use. Machine-broken stone is not considered of the same value as that broken by hand. The stones are not so regular a size and shape, and there is a greater proportion of inferior stuff. A mechanical crusher is apt to stun the material, and does not leave the edges so sharp for binding as they are when the stone is broken with a small hammer.[1]

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[1] Circular No. 12, U. S. Department of Agriculture, Office of Road Inquiry, 1896.

The cost of macadamized roads from necessity varies almost indefinitely. The primary factors are (1) cost of labor, (2) accessibility of materials, and (3) character of country. From $2,000 to $2,500 a mile is perhaps an average figure for localities where materials are available close at hand.

The collections are intended to show only the average sizes employed and the varying nature of materials.