Edmund Heller.

SYLLABUS

OF

A COURSE OF LECTURES

ON

ECONOMIC GEOLOGY

BY

JOHN C. asper BRANNER, PH. D.,
Professor of Geology

AND

JOHN F. NEWSOM, A. M.,
Assistant Professor of Mining and Metallurgy

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PREFACE.

This syllabus is intended for the use of students both while in college and afterwards. The outlines given can be expanded by notes taken from the lectures, from reading, and from observation, and written out on the opposite pages left blank for that purpose.

One of the most important things a student of economic geology needs to learn is where to find and how to use information that has been published. We have therefore endeavored to give references: first, to the works on the general subject of economic geology; second, to periodicals in which articles are to be looked for upon various economic subjects; third, to papers and reports upon special subjects.

The general works and periodicals are listed on pages iv and vi, and the references to special topics are given as foot-notes in the body of the syllabus under each topic. The list of references is not complete in any case, but it is usually sufficient to put the student in the way of finding other titles.

By posting titles in the syllabus as the articles appear the student can add greatly to its usefulness, and in this way keep his own copy up to date.

More space is given to the economic geology of the United States than to that of foreign countries. Some of the substances are necessarily but briefly treated.

For the sake of uniformity the tons mentioned in this syllabus have all been reduced to short tons of 2,000 pounds.

The compositions of minerals, unless otherwise stated, are the theoretic ones, and are taken from Dana's System of Mineralogy.

The charts showing the production, imports, and prices were made chiefly from the data of the United States Geological Survey. Space has been left on the right side of these diagrams so that the lines can be continued for several years.

A few blank pages are left at the back of the book for the addition of notes and memoranda on special subjects not treated in the syllabus.

Inasmuch as most institutions in which economic geology is taught have courses of lectures upon mining law, the notes on that subject, given in the first edition of the syllabus, are left out of the present one. On page 346, however, a few references are given to important works on mining law.

The authors are under special obligations to D. M. Barringer of Philadelphia for the use of the cuts illustrating the geological introduction to his "Law of Mines and Mining."

GENERAL WORKS ON ECONOMIC GEOLOGY.

Books and articles upon special subjects are mentioned under each topic.

The metallic wealth of the United States. By J. D. Whitney. Philadelphia, 1854; 510 pages. Scarce.

A treatise on ore deposits. By B. von Cotta; translated from the German by F. Prime, Jr. New York, 1870; 575 pages. Scarce.

Economic geology. By David Page. London, 1874; 336 pages.

Popular fallacies regarding precious metal ore deposits. Ry Albert Williams, Jr. Fourth ann. rep. U. S. Geol. Survey, 257–271. Washington, 1884.

Applied geology. By S. G. Williams. New York, 1886; 386 pages.

Poor A treatise on metalliferous minerals and mining. By D. C. Davies. Fifth edition, London, 1892; 548 pages.

Poor A treatise on earthy and other minerals and mining. By D. C. Davies. Second edition. London, 1888; 336 pages.

Excellent Traité des gîtes minéraux et métallifères. Par Ed. Fuchs et L. de Launay. 2 vols. Paris, 1893. (Contains many valuable references.)

Étude industrielle des gîtes métallifères. Par George Moreau. Paris, 1894; 453 pages.

Economic geology of the United States. By R. S. Tarr. New York, 1894; 509 pages.

Best in M.S. The ore deposits of the United States. By J. F. Kemp. New York, 1893; second edition, 1895; 343 pages; third edition, 1900, 484 pages.

The genesis of ore deposits. By F. Posepny. Transactions of the American Institute of Mining Engineers, 1893, XXIII, 197–369; also a separate publication of the Institute. New York, 1895.

A treatise on ore deposits. By J. A. Phillips. London, 1884; 651 pages. Second edition rewritten, etc. By Henry Louis. London, 1896; 943 pages.

Mineral Statistics.

The mineral resources of the United States. Published annually from 1883 to 1893 by the U. S. Geological Survey. Since 1893 these reports are included in the annual reports of the Director of the Survey.

The mineral industry. Edited by R. P. Rothwell. Published annually since 1893. Prior to 1893 the Engineering and Mining Journal published annually statistics of the mineral industries of the United States.

The Director of the Mint publishes an annual report upon the production of the precious metals in the United States.

The census reports.

The Ore Deposits of the U.S. and Canada
J. F. Kemp. 1900.

PERIODICAL PUBLICATIONS.

B – 1. Annales des Mines. Published at Paris since 1794.

B – 2. American Journal of Science. Published monthly at New Haven, Conn., since 1819.

B – 3. Bulletin de la Société Géologique de France. Paris, France; one volume annually since 1830.

B – 4. Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie. Stuttgart, annually since 1830.

5. Berg- und Hüttenmännische Zeitung. Leipzig since 1842.

B – 6. Quarterly Journal of the Geological Society of London. One volume annually since 1845.

B – 7. Geological Magazine. Begun in 1858 as The Geologist; continued since 1865 as The Geological Magazine. Published monthly at London, England.

B – 8. Engineering and Mining Journal. Published weekly at New York since 1866.

B – 9. Transactions of the American Institute of Mining Engineers. New York; one volume annually since 1870.

B – 10. School of Mines Quarterly. Published quarterly at New York since 1879.

B – 11. Technology Quarterly. Published quarterly by the Massachusetts Institute of Technology, Boston, since 1887.

B – 12. American Geologist. Published monthly at Minneapolis, Minn., since 1888.

B – 13. Bulletin of the Geological Society of America. One volume annually since 1890.

L – B – 14. Journal of Geology. Published semi-quarterly at the University of Chicago since 1893.

15. Zeitschrift für Praktische Geologie. Berlin, Germany, since 1893.

16. Annales des Mines de Belgique. Brussels, since 1896.

B – 17. Monographs, bulletins, and annual reports of the United States Geological Survey, Washington, since 1880.

SUBDIVISIONS OF THE GEOLOGICAL COLUMN, OR ORDER OF THE STRATIFIED FORMATIONS.

CHARACTERISTIC LIFE	ERA		PERIOD	
Man			Recent	
Mammals	Cenozoic		Pleistocene	Terrace Champlain Glacial
			Tertiary	Pliocene } Miocene } Neocene Eocene
Reptiles	Mesozoic		Cretaceous	Upper Lower
			Jurassic	Upper Middle Lower
			Triassic	Upper Middle Lower
Acrogens Amphibians	Paleozoic		Carboniferous	Permian
				Coal Measures
				Lower Carboniferous
Fishes			Devonian	Catskill Chemung Hamilton Corniferous Oriskany
Invertebrates		Silurian	Silurian or Upper Silurian	† Lower Helderberg Salina Niagara
			Ordovician or Lower Silurian	Trenton Canadian
			Cambrian	Potsdam Acadian Georgian
	Archean		* Algonkian	Keweenawan Huronian
			Archean	Laurentian

* Van Hise places the Algonkian as a separate formation between the Archean and Paleozoic.

† Some geologists regard the Lower Helderberg as Devonian.

ECONOMIC GEOLOGY.

INTRODUCTORY.

What is meant by economic geology; geology in its relations to arts and industries.

Necessity of understanding pure geology before attempting to apply it.

Geological products are used, directly or indirectly, in every branch of human industry. The prosperity of a nation depends largely upon its geological products.

Geology in its relations to agriculture.

- Soils are geological products.
    - Soil belts of Tennessee, Kentucky, Indiana, Missouri.
    - Residual soils varying with the rock.
    - Soils transported by water: river bottoms; by ice: drift area of the United States.
- Fertilizers.
    - Green-sand marls of New Jersey.
    - Apatite deposits of Canada.
    - Phosphates of South Carolina, Florida, Tennessee, and Arkansas.
    - Land-plaster, or gypsum, of New York, Michigan, etc.

*Geology and forests.**

Geology and industries.

The great industries of nations, states, and cities are often determined by local geology.

Relations of England's wealth and power to the mineral resources of that country.

The wealth and power of the United States have increased in proportion to the development of our mineral resources.

Note the commercial importance of various states, and how each owes its importance to some geological product, omitting purely mining and purely manufacturing states:

Alabama: iron, coal.
California: gold, quicksilver.
Indiana: natural gas, building stone, glass, coal.
Maine: granite.
Michigan: copper, iron ore.

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*The relation between forestry and geology in New Jersey. By A. Hollick. Amer. Nat., Jan. 1899, XXXIII, 1–14; Feb. 1899, XXXIII, 109–116.

Missouri: zinc, lead, iron ore, glass-sands, fire-clays.
New Jersey: marls, clays, zinc.
Ohio: coal, building stone, natural gas, petroleum.
Pennsylvania: iron, coal, petroleum.
Tennessee: marble.
Vermont: marble.

Cities and towns have often had their locations determined by the proximity to some mineral or mineral-bearing formation; others owe their importance to such proximity.

*Geology and art.**

The local beginnings of ceramic art were made possible by the existence of available clays. The great art manufacturing industries of Staffordshire, England, and of Limoges, France, sprang up in those places partly because of the presence of the necessary clays in those regions.

The influence of the clays of New Jersey and Ohio upon the pottery industries.

Influence of Parian and Carrara marbles on sculpture.

How the geology of Holland affected the landscape paintings of that country.

Influence of building stones and brick-clays on architecture. Examples:—brownstones of New Jersey and Connecticut; limestones of Montreal; brick-clays of Philadelphia, St. Louis, and Milwaukee.

Geology and roads.

Character of roads affected by local geology or by the presence or absence of good road-making materials.

Limestone "road-metal" of Southern France.

Drift gravels of the glaciated portion of the United States.

Jaspers of San Francisco and the Coast Ranges.

Geology and railways.

Location of railways often determined by the presence of minerals that promise business.

Geologists employed by railways.

Geology and migration.

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* Landscape geology. By Hugh Miller. Trans. Edin. Geol. Soc., 1892, VI, pt. III, 129. Also London, 1891.

MAPS AND SECTIONS FOR GEOLOGIC PURPOSES.

When a geological deposit or formation has economic value, its precise location and distribution become important; these can be shown by maps and sections.

Advantages of maps over verbal descriptions.

Maps may show horizontal location alone, or both horizontal and vertical position.

Importance of horizontal location.

Horizontal location determining ownership, extent, and value.

How maps are made.[*]

Regional maps; local maps.

Every geologic map is based upon some kind of topographic map, and if a topographic map is not available one must be made.

Knowledge of map-making indispensable to geologists.

Triangulation.

By U. S. Coast and Geodetic Survey; by U. S. Geological Survey; by Lake Survey; special surveys.

Chaining: telemeter or stadia measurements.[†]

Plane-table surveying.[‡]

Advantages of finishing a map on the ground.

Photo-topography.[§]

Maps made by reconnoissance methods.[||]

Odometers; pacing; pedometers.

Ordnance maps of England.

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[*] Outlines of field geology. By Archibald Geikie. London and New York, 4th ed., 1891.

A manual of topographic methods. By Henry Gannett. Monograph XXII, U. S. Geol. Survey. Washington, 1893.

The aims and methods of cartography. By Henry Gannett. Special publication, Maryland Geol. Survey, vol. II, pt. III*a*. Baltimore, 1898.

[†] A new prismatic stadia. By R. H. Richards. Jour. Assoc. of Eng. Socs., 1894, XIII.

Topographical surveying by means of transit and stadia. By J. B. Johnson. New York, 1885.

The theory of stadia measurements, accompanied by tables of horizontal distances and differences of level for the reduction of stadia field observations. By Arthur Winslow. First report of progress in the anthracite coal region. Sec. Geol. Sur. of Pa., A A, 1883, pp. 325–344.

Stadia surveying. By Arthur Winslow. Van Nostrand's Science Series, no. 77; New York.

[‡] A treatise on the plane-table and its use in topographic surveying. Appendix XIII, U. S. Coast and Geodetic Survey Rep. for 1880. Washington, 1882.

[§] Photo-topographic methods and instruments. By J. A. Flemer. U. S. Coast and Geodetic Survey Rep. for 1897, pp. 617–735. Washington, 1898.

[||] The construction of topographic maps by reconnoissance methods. By Arthur Winslow. Trans. Ark. Soc. of Engineers, Architects, and Surveyors; 1888, vol. II, 75–83.

Graphic field notes for areal geology. By Bailey Willis. Bul. Geol. Soc. Am., 1891, II, 177–188.

Maps made by the U. S. Coast and Geodetic Survey.
Maps made by the U. S. Geological Survey.
Maps made by the U. S. Land Office.
Use of township sheets.
Spanish grants and irregular surveys.

Elevations.

Vertical location upon maps shown by shading, hachures, or contours.
Importance of elevations in obtaining water supplies; artesian waters; mine draining; prospecting for bedded deposits.
Value of a common datum; advantages of mean tide level as a datum.
Methods of determining elevations.
  Precise levels.*
  Ordinary spirit levels; hand level.
  Vertical arc; use of slide-rule in connection with arc observations.
  Mercurial barometer.
  Aneroid barometer.†
Limitations of each method.
The accuracy should depend upon the demands placed or likely to be placed upon the work.

How sections are made.

How geology is put on maps.
How geology is put on sections.
  Relation of sections to the map.
The importance of the proper location of structural features illustrated by synclines in the coal regions.
The cost of errors.
The difference between general geologic maps and those used for mining.
The uses and advantages of an engineer's training in geological work.

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* Precise levels. Rep. U. S. Coast and Geodetic Survey for 1879, Appendix XV.

Transcontinental line of geodetic spirit-leveling. Rep. U. S. Coast and Geodetic Survey for 1882, Appendix XI. Washington, 1883.

† A new method of measuring heights by means of the barometer. By G. K. Gilbert. Second ann. rep. U. S. Geol. Survey for 1880–81, pp. 405–562.

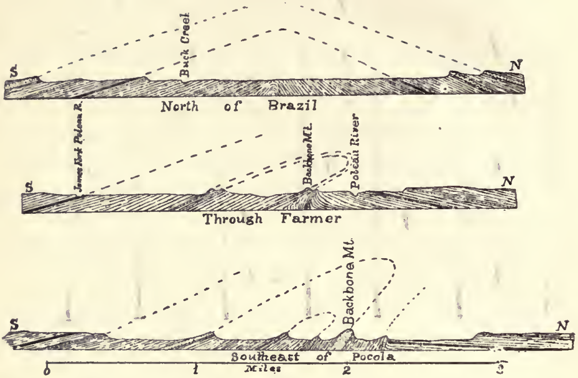
How to use the aneroid barometer. By Edward Whymper. New York, 1891.

The measurement of altitudes. By Henry Gannett. Mazama I, 243–264. Portland, Or., 1897.

The barometric determination of heights. By F. J. B. Cordeiro. London, 1898. (Spon.)

Township divided into sections,

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36



North-south sections, ten miles apart, across an anticline in the coal measures of Indian Territory. The heavy black lines represent coal beds; the shaded areas represent shales, and the dotted areas sandstones.

GEOLOGICAL SURVEYS.

Immediate objects.

- Determining geological formations and structure.
- Exhibiting formations and structure on maps and sections.

Ultimate objects.

- Turning maps and sections to account.
- Pure science: knowledge of former physical conditions. But original conditions often determined the contents of the rocks and hence their present values.
- Applied science: knowledge of the nature and distribution of deposits of economic value.

Methods.

- How the rocks are grouped; the use of groups when valuable deposits are confined to certain ones.
- How groups or divisions are put on maps.
  - Method with ordinary maps.
  - Method with township sheets; inaccuracies of township sheets.
  - Method with special topographic maps.
  - Method with maps in construction; the advantages of exact locations.
- Relations of map scale to geologic details.
- Field notes to be made on the spot.
- Field work usually best done with reference to the season and the weather.
- Office work can be done during inclement weather.

Government Surveys.

Necessity of knowing what geologic work has been done in a region to be investigated, and where the results have been published.

European surveys.[*]

The geological map of Europe.

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[*] [Geological survey of Great Britain.] By Sir A. Geikie. Geol. Magazine, July, 1898, V, 306–317, 358–366.

The national geological surveys of Europe. By William Topley. Brit. Assoc. Rep. for 1884, pp. 221–240. London, 1885.

Cost of European geological surveys. By E. A. Schneider. Eng. and Min. Jour., Oct. 10, 1896, p. 342; Oct. 17, 1896, p. 366; Oct. 24, 1896, p. 392.

*U. S. geological surveys.**

- Exploring expeditions with geological attachés.
- Wheeler survey, U. S. Engineers, War Department.
- Hayden survey, under the Department of the Interior.
- Powell survey, Department of the Interior.
- King survey, 40th parallel, under the War Department.

Present U. S. Geological Survey, under the Department of the Interior.

- Duties as defined: to make a geologic map of the public domain.
- Scope of work.
  - Paleontology, economic geology, topography, mineral statistics, hydrography, irrigation, chemistry, physics, engraving.
- Publications.
  - Annual reports since 1880 (quartos); contents.
  - Monographs (quartos) now number 38 volumes; contents.
  - Bulletins (octavos) now number 159 on geology and 31 on water-supply and irrigation.
  - Mineral resources (octavos) from 1882 to 1893; since 1895 they form part of the annual reports (quartos).
  - Folios of the geologic atlas of the United States, 55 published; show topography and geology, with brief descriptions.
  - How the U. S. Survey reports may be obtained.

State geological surveys.

- State surveys usually established for economic purposes.
- Purposes and success often depend upon the state geologist.
  - Methods of selecting state geologists: appointment, election.
- Methods and results of typical state surveys.
  - The New York survey.
  - Pennsylvania survey.
  - Arkansas survey.
  - Political surveys.
- Boards of commissioners or control.
- Relations of national and state surveys.
  - Aid of state surveys by the U. S. Coast and Geodetic Survey.
  - Aid by the U. S. Geological Survey.

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*Surveys of the Territories. House miscellaneous document no. 5. 45th Cong., 3d ses.

On the organization of scientific work of the general government. By J. W. Powell. Washington, 1886.

Testimony before the Joint Commission. Senate mis. doc. 82, 49th Cong., 1st ses. Washington, 1886.

Relations of state and national geological surveys. By J. C. Branner. Proc. Amer. Assoc. Advancement of Science, XXXIX, 219-237.

The geology of government explorations. By S. F. Emmons. Presidential ad., Geol. Soc. Washington, 1896.

Official geology. By H. H. Stoek. The Mining Bulletin, II, 38-52. [State College, Pa.] March, 1896.

- Publications.
    - Annual reports.
    - Bulletins.
    - Monographs.
    - Publication of field notes; objections to such reports.
- Cost of state surveys.
- Appropriations by legislatures.
- Special provisions for surveys.

Private geological surveys.

- By scientific societies and exploring parties.
- By private corporations.
    - Northern Pacific Railway, coal companies, and other mining companies, for business purposes.
    - By individuals.

ECONOMIC GEOLOGIC DEPOSITS.

The nature of geologic products.

Great variation in characters in single classes.

Structual materials: stone, glass-sand, slates, asphaltum.

Fuels: coal, oil, gas.

Ores of base metals: iron, zinc, lead, tin, copper.

Ores of the precious metals: gold, silver.

Precious stones: diamonds, emeralds, rubies.

Earthy minerals: clays, bauxites, fertilizers, chalks.

The origin of geologic deposits.

Geological deposits of economic value orginate in ways as widely different as the deposits themselves.

They may be classified according to the processes of their formation as (1) mechanical; (2) chemical; (3) igneous; (4) organic.

The following are illustrations:

I. Mechanical deposits: building stones, grindstones, marls, clays, sands, some limestones and marbles.

Mechanical concentrations: placer gold, some diamonds, some tin.

II. Chemical deposits from concentration: salt, gypsum.

Deposits from solution on exposure: stalactites, "onyx" marble.

Deposits from solution on relief of pressure or lowering of temperature or both; many important ore deposits.

III. Poured out as igneous rocks.

Crystallized out in rock masses: feldspar, rutile, diamonds, emery, certain precious stones.

IV. Organic deposits from plants: peat, coal; from animals: tripoli, some limestones.

Distillations from organic deposits: petroleum, gas, asphaltum, ozokerite.

Any of these deposits are liable to be changed by metamorphism, and many deposits owe their value to their having passed through such changes.

Some marbles are metamorphosed limestones.

Slates are metamorphosed clay shales.

Anthracite is changed coal.

Coal is changed peat.

Kaolin is decayed feldspar.

Some polishing powders are decayed cherts or novaculites.

Relation of the method of its formation to the form and distribution of a deposit of economic value.

The classification of economic geologic deposits.

The classification of geologic deposits is a matter of convenience, and the basis of the classification must be determined by the purposes for which it is intended. It may be based upon:

I. Geographic distribution.
  National, state, and local reports.

II. The minerals contained.
  This would group together all similar minerals, regardless of their origin, geographic or geologic position. Example: hydrocarbons of different origins, various compositions and occurrences.

III. Geologic distribution, or that of the rocks containing the minerals. Relations of such grouping to historical geology.

IV. Shape of the deposits.
  Classifications of ore deposits by different writers.

Von Cotta's.*

1. Regular deposits.
2. Irregular deposits.

Whitney's.†

1. Superficial.
2. Stratified
    - Constituting the mass of a bed.
    - Disseminated through sedimentary beds.
    - Deposited from solution, metamorphosed.
3. Unstratified
    - Irregular
        - Eruptive masses.
        - Disseminated in eruptive rocks.
        - Stockwork deposits.
        - Contact deposits.
        - Fahlbands.
    - Regular
        - Segregated veins.
        - Gash veins.
        - Fissure veins.

Penrose follows Whitney's classification, with the following modifications:

- Superficial deposits
    - Stream and littoral
        - Placers.
        - Stream tin.
        - Magnetic iron sands.
    - Bog and lake deposits.
    - Residuary deposits.
- Irregular unstratified deposits
    - Eruptive and disseminated in eruptives.
    - Impregnations.
    - Reticulated veins.
    - Contact deposits.
    - Chamber deposits.

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* A treatise on ore deposits. By B. Von Cotta. New York, 1870.

† The metallic wealth of the United States. By J. D. Whitney, p. 34. Philadelphia, 1854.

V. Origin and method of formation: genetic.

Kemp's classification of ore deposits.

1. Igneous origin.*
2. From solution.
3. From suspension.

Posepny's two classes of ore deposits.†

1. Idiogenous (contemporaneous with the rock).
2. Xenogenous (of later origin than the rock).

Crosby's classification of economic deposits.‡

1. Igneous origin.
2. Aqueo-igneous origin.
3. Aqueous origin.

These and others may be useful each in its place, and according to the purpose for which it is made.§

In the present lectures the minerals are taken up separately and no particular classification is followed.

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* On the igneous origin of certain ore deposits. By F. D. Adams. Montreal, 1894.

† The genesis of ore deposits. By F. Posepny. Trans. Amer. Inst. M. Eng., 1893, XXIII, 197–369, and the separate publication by the Amer. Inst. Mining Engineers, New York, 1895.

‡ A classification of economic geological deposits. By W. O. Crosby, American Geologist, 1894, XIII, 249–268. Further discussed in Engineering and Mining Journal, January, 1895, LIX, 28.

A new classification of economic geological deposits. By R. W. Raymond, Engineering and Mining Journal, Nov. 3, 1894, pp. 412–413. (A criticism of Prof. Crosby's classification.)

§ For other classifications see Kemp's Ore deposits, pp. 44–55.

Phillips' Ore deposits, p. 3.

Report of the state geologist of Mich. for 1891–92. By M. E. Wadsworth. p. 144.

ROCK CAVITIES.

The forms of ore-bodies lead to the belief that many of them are deposited in cavities and fissures in the rocks. To understand such deposits it is therefore necessary to understand the forms and relations of rock cavities.

Two Ways of Making Cavities.

In studying rock cavities it must not be forgotten that the depth at which cavities can remain open is limited.*

Cavities formed by solution.

- Solvent power of acidulated waters.
- Dissolved matter in spring and stream waters.
  - All the matter in solution has been removed from the rocks through which the water has passed.
- Cavities small and large produced by constant action of percolating waters.

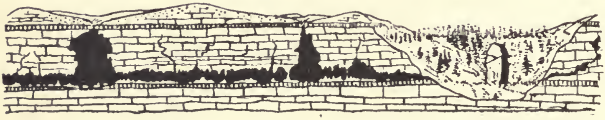

Fig. 2.—Ideal section through a limestone region, showing caves left by the removal of the rock.

- Cave-making hastened by mechanical action.
  - Mammoth Cave of Kentucky has thirty-five to forty miles of tunnels along which one can walk; cavern 70 feet to 200 feet high in places; 12 million cubic yards of rock removed.
  - Caves in limestone regions.
  - More than 100,000 miles of caves in Kentucky.†
- Supposed to be formed above drainage, but in Florida they must be formed below drainage.

Cavities formed by fracturing.

Some of the rock cavities in which ore deposits have been formed have the appearance of having originated as fractures.

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* The form of fissure-walls as affected by sub-fissuring and by the flow of rocks. By William Glenn. Trans. Am. Inst. M. Eng., 1895, XXV, 499–513.

Flow and fracture of rocks as related to structure. By L. M. Hoskins. Sixteenth ann. rep. U. S. Geol. Survey, pt. I, 1896, pp. 845–874.

Deformation of rocks. By C. R. Van Hise. Journal Geol., 1896, IV, 195–213.

† The Mammoth Cave of Kentucky. By H. C. Hovey and R. E. Call.

Dolomization = replacing of part of the lime in limestone by magnesia, forming dolomite.

I. Fractures produced by shrinkage.

Contraction produced by cooling.

Deep-seated rocks are highly heated; if by erosion, faulting, or other means, they are brought near the surface, they must cool and shrink.

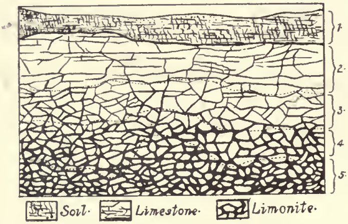

Fig. 3.—Iron ore filling the cavities in fractured limestone, Wythe county, Virginia. (Benton.)

Expansion for increase of one degree Fahrenheit:

Granite, one inch in about 15,000 feet.
Marble, one inch in about 10,000 feet.
Sandstone, one inch in about 8,000 feet.
Slate, one inch in about 14,400 feet.

Contraction produced by dolomitization.*

Common in some limestone regions.
Shrinkage twelve per cent.
Breccia.†

II. Fractures produced by folding of the strata.‡

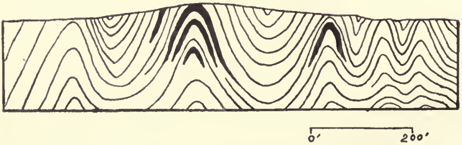

Fig. 4.—Section across saddle-reef folds at Hargreaves, New South Wales. The black areas represent ores deposited in openings made at the anticlinal crests.

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* (On dolomitization.) By E. de Beaumont, Bull. de la Soc. Géol. de France, VIII, 1836, pp. 174-177.

Robert Bell, Bull. Geol. Soc. Amer., VI, 295.

† Lead and zinc deposits of Missouri. By A. Winslow. Trans. Am. Inst. M. E., 1894, XXIV, 673-674.

Origin of the brecciated character of the St. Louis limestone. By C. H. Gordon. Jour. Geol., 1895, III, 307.

‡ Etudes synthetiques de géologie experimentale. Par A. Daubrée. Paris, 1879. pp. 300-374.

The mechanics of Appalachian structure. By Bailey Willis. Thirteenth ann. rep. U. S. Geol. Survey, 1891-92, pp. 211-281.

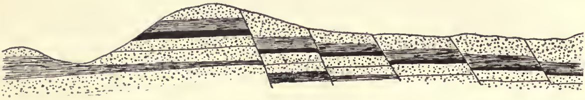

Fig 5.—Normal or step faults in the coal measures of Scotland.

Strain caused by lateral pressure.
Relief by fractures along anticlines.*
Widespread folding of rocks.

III. Fractures produced by faulting.
Faults are displacements of strata, either vertical or horizontal.

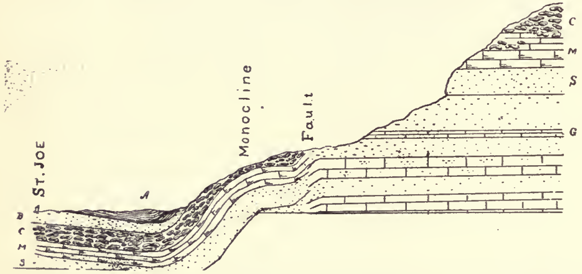

Fig. 6.—A normal fault in the zinc region of North Arkansas. The fault in the middle of the section has broken and displaced all the beds.

Normal and reversed faults.
Character of fracture depends partly on the character of the rock.
Fault fractures sometimes left open or filled with debris that permits percolation of water.

IV. Fractures produced by earthquakes.†
Examples of Japanese earthquake faults.‡
Fractures may be opened without faults being produced.
Examples of Charleston earthquake.§

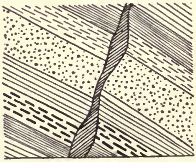

Fig. 7.—Fracture filled along a fault plane.

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* Saddle reefs at Hargreaves. By J. A. Watt. Records Geol. Survey N. S. Wales, V, pt. IV, 1898, p. 153; VI, pt. II, 1899, p. 83.

† Across Vatna Jökull, or scenes in Iceland. By W. L. Watts, 101, 109, 119, 153–157. London, 1876. (Fissures in volcanic regions.)

‡ The great earthquake in central Japan. By B. Kotô. Journal of the College of Science, Imperial University of Japan, vol. V, pt. IV. Tokyo, 1893.

§ The Charleston earthquake. By C. E. Dutton. Ninth ann. rep. U. S. Geol. Survey, 1887–88, pp. 203–528.

Fig. 8.—Open fracture formed during an earthquake in Arizona.

Debris filling such cavities.

Other fractures not included under either of these heads may be produced by any constant shifting of the strains in the earth's crust or by the elevations and depressions of large areas.

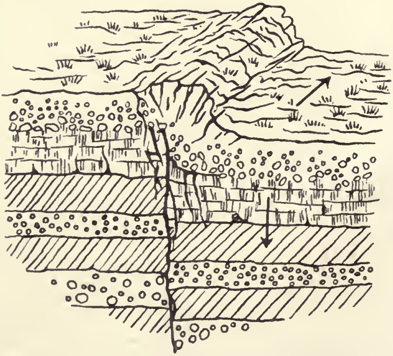

Fig. 9.—Section of a fault formed during a Japanese earthquake. (Kotô.)

THE FORMATION OF ORE-BODIES.*

Ore is a metalliferous mineral or rock, especially one of sufficient value to be mined. (Cent. Dict.)

Ore as distinguished from earthy mineral.

Ore deposits as distinguished from other geologic deposits of economic importance.

Following a general genetic classification ore-bodies occur as: (1) bedded deposits; (2) vein deposits; (3) surface deposits of recent date.

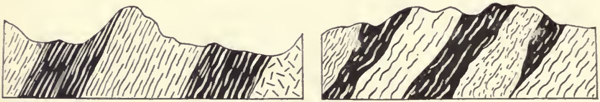

Fig. 10.—Iron ores of Michigan and N.Y. interbedded with other rocks. (Emmons.)

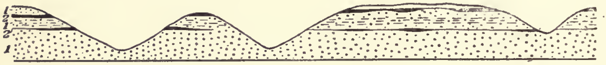

Fig. 11.—Geological section in the manganese region of North Arkansas. The black bands represent beds of manganese that were deposited in layers alternating with the accompanying rocks.

I. Bedded deposits contemporaneous with the rocks in which they occur.

- The origin of bog iron ores.
- Originally surface deposits.
- Why they are sometimes interbedded with other rocks.
- Changes through which the ore and its accompanying rocks may have passed: folds, faults, erosion. metamorphism, replacement.
- The structural features of such ore-bodies are involved in the general structure of the region.
- Conglomerate beds subsequently filled; lead mine in bedded deposits at Doe Run, Missouri.
- Auriferous conglomerates of South Africa.†

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* The metallic wealth of the United States. By J. D. Whitney. pp. 33–68.
The genesis of ore deposits. By Franz Posepny. New York, 1895.
The ore deposits of the United States. By J. F. Kemp. New York, 1893. pp. 28–65.

† The gold mines of the Rand. By Hatch and Chalmers. London, 1895.
Diamonds and gold in South Africa. By T. Reunert. Capetown, 1893.
Les mines d'or du Transvaal. Par L. de Launay. Paris, 1896. pp. 143–158; 177–311.

II. Vein deposits.*

"*Veins* are aggregations of mineral matter in fissures in rocks. *Lodes* are therefore aggregations of mineral matter containing ore in fissures."—Von Cotta.†

Importance of definitions in law.

The formation of ore-bodies (except surface and bedded deposits) takes place:

a. By the filling of open cavities;

b. By the replacement of one mineral by another;

c. By accretion.

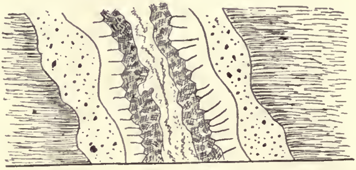

Fig. 12.—Banded structure of a mineral vein formed by layers filling a cavity in the rocks.

The formation of ore-bodies by

A. The filling of cavities.

The general size and shape of an ore-body formed by the filling of a cavity is necessarily determined by the size and shape of the cavity.

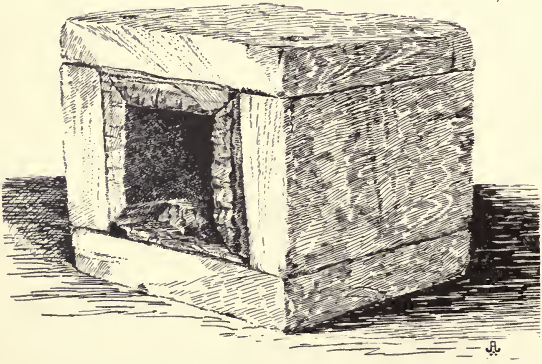

Fig. 13.—Section of a box pipe used for ten years in the Comstock mines to carry mine water from the 600 to the 1000 foot level. This box is lined by a crust of aragonite more than half an inch thick, deposited by the water passing through it.

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* A treatise on ore deposits. By J. A. Phillips; 2d ed. by Henry Louis. London, 1896, pp. 119–141.

† A treatise on ore deposits. By B. Von Cotta. Translated by F. Prime. New York, 1870, p. 26.

Crustification as distinguished from stratification. (Fig. 12.)

Vein matter precipitated from solution on the walls of cavities.

Methods of filling cavities.

Deposition from solutions by cooling and relief of pressure. (Fig. 13.)

Sublimates deposited by solfataric action.

Origin of the mineral-bearing solutions.

Theory of ascending waters.

Sandberger's theory of lateral infiltrations.*

Relation of structural features of a region to the origin of different deposits.

B. The replacement of one mineral by another.

Examples of such replacement in the silicification of corals, wood, and shells, and the replacement of organic matter by iron pyrites.

This process is called metasomatic replacement.

Replacement in dolomitization.

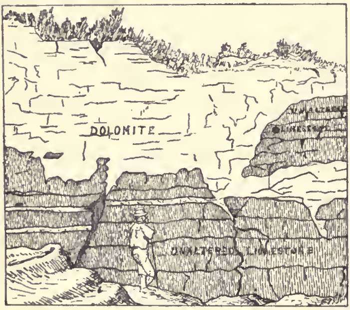

Fig. 14.—Vertical section in a quarry at Kilkenny, Ireland, showing the unaltered limestone and dolomite. (Prestwich.)

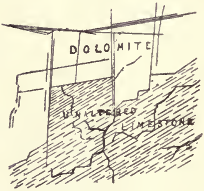

Fig. 15.—Horizontal plan of Fig. 14.

C. The enlargement of veins by accretion.

Enlargement of quartz grains.

Illustration of needle ice and crystallization in the soil.

The size, form, and structural relations of certain geodes due to enlargement.†

Evidences of the mechanical force of the process.

Possible relations to vein enlargement and to brecciation. (Fig. 16.)

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*Canadian Naturalist, new ser., 1877, VIII, 345–362. American Geologist, Dec., 1896 p. 393.

†Formation of dikes and veins. By N. S. Shaler. Bul. Geol. Soc. America, 1899, X, 253–262.

Breccia formed by the cementing together of talus.

Dolomitization = replacement of part of the lime in limestone by magnesia, forming dolomite.

Pressure and heat are too great at great depths to allow cavities to be formed. Deep seated ore could not therefore be deposited in cavities

III. Deposits of recent date, at or near the surface.*

The usual classification of mineral deposits as "surface deposits" is open to the objection that many of these are no longer either at or near the surface. Examples: bog iron of Carboniferous age; placer gold of Cretaceous age.†

Surface deposits are local, and are forming at present: they are formed (1) by mechanical concentration; (2) by chemical action.

Many valuable deposits that are not classed as ores are formed by these methods. Examples: many phosphates; salt; gypsum; kaolin; monazite sands; and others.

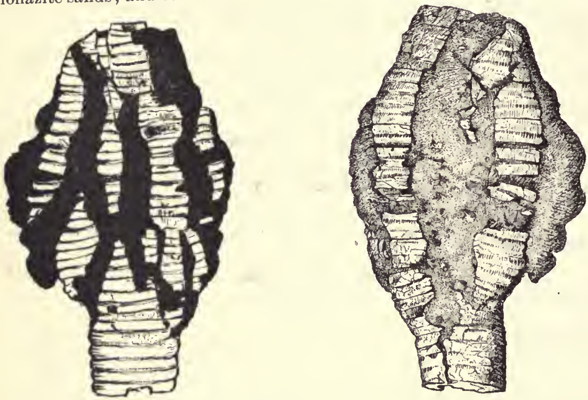

Fig. 16.—A geode formed in the stem of a crinoid. The accretion started in the hollow stem, burst it, and pushed the fragments apart. Two views of the same specimen; natural size.

I. Deposits formed by mechanical concentration.

These result from the decay of rocks and the mechanical concentration of the minerals contained.

Examples:

- Stream and littoral deposits.
  - Placer gold.
  - Stream tin.
  - Magnetic sands.
  - Brazilian diamonds.

II. Deposits formed by chemical action.

Surface deposits from chemical action or chemical alterations at the

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* For references see titles given under the heads of the minerals mentioned as examples.

† Auriferous conglomerate in California. By R. L. Dunn. Twelfth rep. State Mineralogist, 1893-94, pp. 459-471.

surface result in many ways. Examples of such deposits are bog iron ores, salt, gypsum, nitre, soda.

Incrustations of smithsonite. "Mexican onyx."

Some ore-bodies and deposits, though not necessarily deposited by chemical action, owe their value to chemical alterations at or near the surface.

Residuary deposits produced by chemical (and mechanical) action and concentration.

  Manganese ores of Arkansas, Georgia, Virginia, and Brazil.
  Gossan, the altered part of a lode.
  Kaolins and clays by decomposition.
  Fullers' earth in Arkansas.

FEATURES OF ORE DEPOSITS.

The features of ore deposits, their shape, structure, and general relations, depend partly upon the methods of their formation, that is, whether they were laid down as bedded deposits contemporaneous with their accompanying rock beds, or were deposited later in cavities, or occur as replacements.

General forms.

- Shapes of cave deposits. Example: Marble Cave, Missouri.
- Shapes of bedded deposits determined by the conditions of deposition.
    - Example: the iron ores of Pennsylvania.
    - Thinning out; causes. (Fig. 17.)
- Shapes of fissure deposits.
    - Fissure veins.
    - Gash, lenticular, bedded, and contact veins.

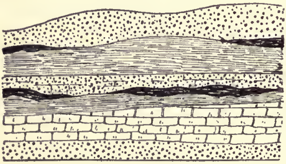


Fig. 17.—Lens-shaped masses of manganese interbedded with sedimentary rocks.

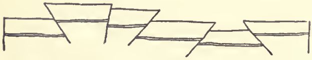


Fig. 19.—Reversed faults in horizontal rocks that have broken the original beds but left them parallel.

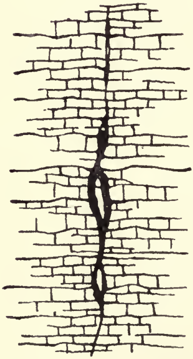
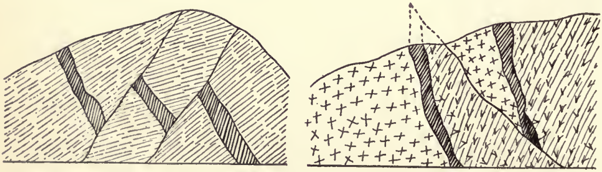


Fig. 18.—Gash vein in magnesian limestone of Wisconsin. (Chamberlain.)



Figs. 20-21.—Illustrations of single veins repeated by faulting that left the different pieces parallel.

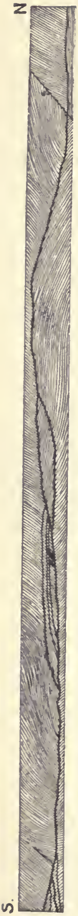


Fig. 22.—Horizontal plan in the C. O. D. Mine, Cripple Creek, Colorado, showing system of fissures. (Penrose.)

Irregularities of thickness; cause of pinching out.
Irregularities of direction, outcrop, dip, and strike.
Groups of veins (Fig. 22); feeders; ore-shoots or chutes and chimneys.
Parallelism of veins.
Produced by torsion or other fractures, or by bedding.
Complications produced by faulting. (Figs. 19, 20, 21.)
Effect of vertical displacements; of lateral displacements. (Fig. 24.)
Complications by intersection of several ore deposits.
Mother lode of California 112 miles long.*
Relations to other lodes.
Size and extent of ore deposits.
Uncertainties regarding the size and form of ore-bodies.

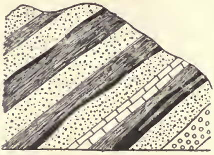


Fig. 23.—Parallelism of coal beds produced by the original bedding of the rocks.

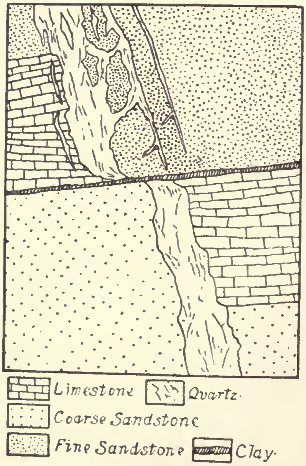


Fig. 24.— Section showing both vertical and horizontal faulting of a vein, Enterprise mine, Rico, Colorado. (Rickard.)

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* Geology of the mother lode region. By H. W. Fairbanks. Tenth ann. rep. State Mining Bureau of California, pp. 23-90.

Internal and structural features.

Banded structure produced by crustification.

Brecciated structure produced by cementing of fractured materials.

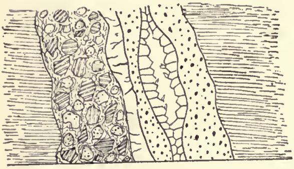


Fig. 25.—A vein brecciated on one side and banded on the other.

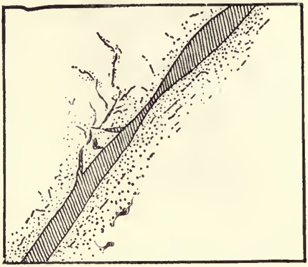


Fig. 26.—Ore-bearing quartz vein. The country rock is altered, but contains no ore. (Lindgren.)

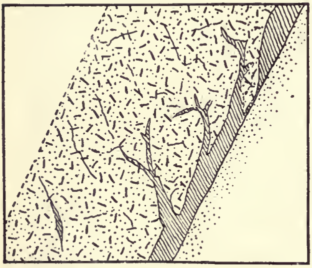


Fig. 27.—Quartz vein along the foot-wall of a porphyry dike, with stringers running off into the porphyry. (Lindgren.)

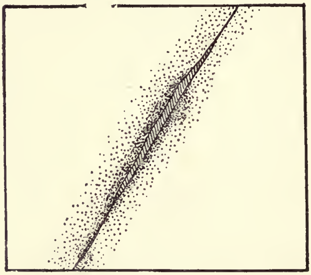


Fig. 28.—Vein with its ores extending into the altered country rock. (Lindgren.)

Definitions of terms.

Hanging-wall; foot-wall; country rock.

Selvage, gouge, or flucan is the clay seam between vein and wall-rock.

Possible relation of clay to the vein matter.

Ore.

Gangue.

Association of ores and gangues.

Some veins sharply defined; others merge into their walls. (Figs. 25, 28.)

Distribution of ores in veins.

Distribution due to variation in size of the vein.

Lode = vein with ore worth mining.
Deposition may be greater at great depths on account of the increased pressure and heat.

Distribution due to other causes.

Bonanzas are ore pockets or local enlargements of the vein.

Horses; stringers (Fig. 27); chutes, chimneys.

Effect of change of dip on the character of the lode.

Effect of country rock on the lode.*

Ore-bodies often found at the contact between two formations.

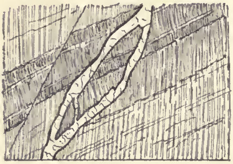


Fig. 29.—A horse with the vein passing around it on both sides.

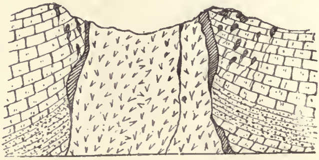
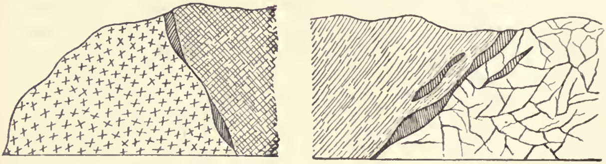


Fig. 30.—Contact deposits in the neck of an extinct volcano.



Figs. 31–32.—Examples of contact deposits or ore-bodies at the contact between two different kinds of rock.

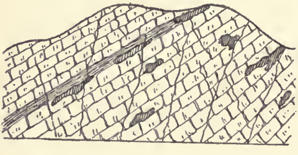


Fig. 33.—Contact deposits in limestone beneath shale.

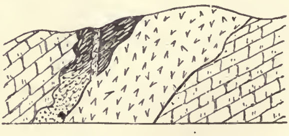


Fig. 34.—Superficial alteration of a contact deposit.

Ores affected by superficial alteration.†

Oxidation at the immediate surface.

Gossan, *colorado*, *chapeau de fer*, *eisener hut*.

Origin of these names from the rusty brown color of the oxidized ores.

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* An inquiry into the deposition of lead ore. By L. Bradley. London, 1862.

† The superficial alteration of ore deposits. By R. A. F. Penrose, Jr. Journal of Geology, vol. II, pp. 288–317.

Why free gold near the surface is replaced by sulphides in depths.
Depths to which alterations extend and the nature of the changes with various ores.
  Iron ores.
  Copper ores in Chili affected to 1,500 feet.
  Lead.
  Silver in Granite Mountain, Montana, to 900 feet.
  Gold.
  Zinc changed to carbonate to the depth of weathering.
Effect of these changes upon the value of the ores.
  Different treatment required for the unaltered ores.

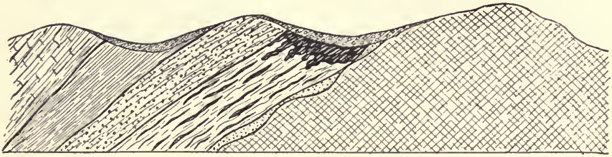

Fig. 35.—Ideal section showing the superficial alteration of iron ores in Michigan and Minnesota.

IRON.*

Importance of iron.
Prevalence of iron in rocks.
Iron is seldom found in the native state; some meteorites are native iron.

The ores of iron: oxides, carbonates, sulphides.

- Oxides: anhydrous; hydrous.
  - Anhydrous.
    - Hematite (Fe_2O_3), oxygen 30, iron 70, if chemically pure. Most important of American ores.
      - Specular iron.
      - Red hematite, "kidney" ore when reniform.
        - Fossil ore.
      - Itabirite, iron schist.
      - Red ochres.
    - Magnetite (Fe_3O_4), oxygen 27.6, iron 72.4.
      - Magnetic ore; often titaniferous.†
      - Franklinite deposits of New Jersey.
  - Hydrous oxides.
    - Limonite, or brown hematite ($2Fe_2O_3 . 3H_2O$), oxygen 25.7, water 14.5, iron 59.8.
      - Bog iron; how formed.
      - Ochres (excepting red ochre).
      - Other forms of limonite.
- Carbonates.
  - Siderite, or spathic iron ($FeCO_3$), carbon dioxide 37.9, iron protoxide 62.1, equivalent to 48.2 metallic iron.
    - Clay ironstone.
    - Blackband.
    - Brown carbonate.
- Sulphide. (Iron pyrites, FeS_2), sulphur 53.4, iron 46.6.
  - Used in the manufacture of sulphur and sulphuric acid.
    - (See under Iron Pyrites.)

Impurities found in the ores of iron.

Phosphorus makes iron "cold short."

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* History of the manufacture of iron in all ages. By James M. Swank. Philadelphia, 1884.

The iron manufacturer's guide. By J. P. Lesley. New York, 1859.

† A brief review of the titaniferous magnetites. By J. F. Kemp. School of Mines Quarterly, July, 1899, XX, 323-356; Nov., 1899, XXI, 56-65.

Iron is the most abundant metal. All the reds and blacks in nature are due to iron.

Iron has been known since ancient times but copper was the first metal used.

Magnetite - Japan.

Magnetic sands - Japan.

Franklinite Mn Fe

Bog-iron is formed by water which holds the iron in solution as long as their is enough CO_2 gas to hold it, when the water strikes a pond where the gas can be given off the iron is deposited as bog iron at the bottom + sides of the pond.

Carbonates of little importance in the production of iron in the U.S.

Sulphur makes iron brittle at a red heat ("hot short") and destroys its welding power.

Silica.

Titanium.

Copper.

Arsenic.

Antimony.

Processes have been devised for using ores containing impurities.

The Thomas-Gilchrist process of steel making uses pig iron high in phosphorus.

The Clapp-Griffiths process permits much phosphorus when silicon is carefully excluded.

In general the impurities that damage ore for one purpose may be beneficial for some other.

The properties that determine the value of iron ores.

The Bessemer process of decarburizing cast iron, by which steel is cheapened.

Bessemer ore should not contain more than 0.05 per cent. phosphorus.

Non-Bessemer iron ore.

Distribution of the ores of iron.

Geological.

Iron is found in all ages, but is of more importance in some than in others.

Pre-Cambrian iron of Lake Superior.

Cambro-Silurian iron of Brazil.

Silurian ore of Missouri.

Archean, Cambro-Silurian, Silurian, and Carboniferous iron belts of the Appalachians.

Tertiary iron of Texas and Arkansas.*

Iron deposits forming at the present time.

Geographical distribution.

Foreign iron regions.

United Kingdom, Germany, France, are the principal foreign producers.

Other countries.

Distribution in America outside of United States.

The iron ores of Brazil, Cuba, and Canada.

IRON REGIONS OF THE UNITED STATES.†

There are three general regions: Appalachian region; Lake Superior region; western region.

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* The iron deposits of Arkansas. By R. A. F. Penrose, Jr. Geol. Survey of Ark., for 1892, I. Little Rock, 1892.

† The mining industries of the United States (exclusive of the precious metals). By Raphael Pumpelly. Tenth census, XV. Washington, 1886.

Iron high in sulphur is worthless as the sulphur cannot be extracted. Iron containing phosphorous can be used for making castings.

In Bessemer process the ore is smelted in blast furnace then cast as pig iron and remelted in bessemer furnace and air blown over it which decarbonizes it changing the iron to steel.

In England the iron ore occurs as carboniferous, interbedded with coal.

I. The Appalachian region: Ores mostly non-Bessemer.

- Iron occurs in four general northeast-southwest belts following the geological structure.
- Beginning with the easternmost, these are:
  - Archean belt: Ores chiefly lenticular deposits of magnetite in gneisses and other metamorphic rocks. This belt is most important in the Adirondacks — New York, New Jersey, and Virginia.
  - Cambro-Silurian belt: Ores chiefly non-Bessemer limonites, associated with schists, limestones, and clays. This belt is most important in Virginia, Alabama, Tennessee, and Pennsylvania.
  - Upper Silurian belt: Ores non-Bessemer red hematites, "fossil ore," limited to the Clinton beds, which contain intercalated beds of iron ore almost everywhere that they occur. They are of the greatest importance in the Birmingham, Ala., district, where they are the chief source of supply.
  - Carboniferous belt: Carbonate ores are of little importance at present. Western Pennsylvania, Ohio, and Kentucky ores are of this type.

The most important producing states in the Appalachian region (in the order of their importance in 1897) are:

- Alabama:* Production in 1897, 2,350,456 tons, worth 66 cents per ton at the mines.
  - Ores: Non-Bessemer hematites in the Clinton beds (Upper Silurian) are the most important.
  - Brown hematites (limonite) belonging to Cambro-Silurian belt are also important.
  - Associated rocks.
  - Birmingham is the chief district.
- Pennsylvania: Product in 1897, 810,591 tons; value per ton at the mines, $1.05.
  - Ores: The Archean magnetites and Cambro-Silurian limonites in the eastern part of the State are the most important; Hematites and carbonates are of little importance.
- Virginia:‡ Production in 1897, 796,463 tons; value per ton at the mines, $1.22.
  - Ore: Chiefly limonite.
  - Geological relations of the ores.
    - The Rich Patch deposits.† (Figs. 36, 37.)

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* Iron-making in Alabama. By W. B. Phillips. Geol. Survey of Ala., 1896; 2d ed., 1898.

† The Rich Patch iron tract, Virginia. By H. M. Chance. Trans. Am. Inst. Min. Eng. 1899.

‡ Geol. Atlas, U. S. G. S. Staunton folio. 1894.

Alabama iron ore is a replacement of fossils by iron.

Tennessee:* Production in 1897, 677,037 tons; value per ton at the mines, $0.71.
  Ores: Red hematite and limonite of non-Bessemer quality.
    Localities and geological relations of the Tennessee ores.
Other producing states in the eastern or Appalachian region are:
  New York: Ores chiefly magnetites from Archean rocks. Also Cambro-Silurian. (Fig. 38.)
  New Jersey: Magnetites in Archean rocks.
  Georgia, North Carolina, Ohio, Kentucky.
    Relative production and geological relations of the ores.

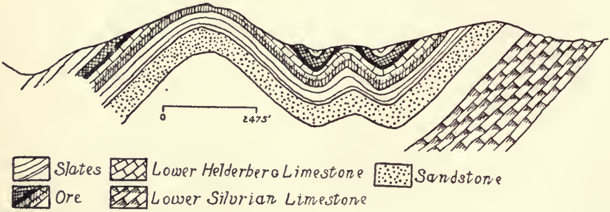

Fig. 36.—Section across the folds of the Rich Patch iron tract, Alleghany county, Va. (Chance.) The left end of the section is north.

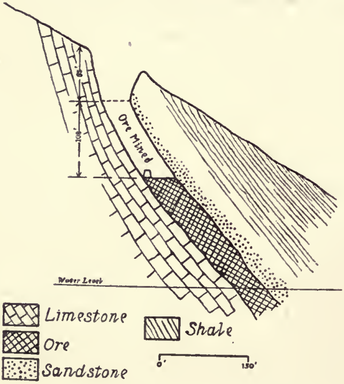

Fig. 37.—Section through an open cut at the Rich Patch mines in Alleghany county, Va. (Chance.)

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* Geologic Atlas of the U. S. G. S. Ringold, Sewanee, Cleveland, Chattanooga, and Loudon folios.

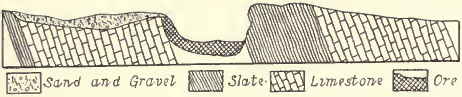

Fig. 38.—Section showing the geology of the Cambro-Silurian iron ore deposit of the Amenia mine, Dutchess county, N. Y. (Putman.)

II. The Lake Superior region.

Ores: hematites and magnetites usually of Bessemer quality.

The ores occur in masses associated with greatly disturbed schists, jaspers, cherts, and quartzites, of pre-Cambrian age.

Soapstone is often an important associated rock.

Importance of dikes in the Gogebic range.

Extent of the ore-bodies.

Norrie mines; Lake Angeline mine; Biwabik mine.

Theories regarding the origin of the ores:

Sedimentary origin.

Igneous origin.

Replacements.

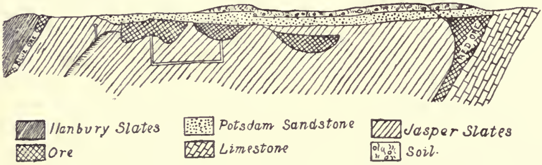

Fig. 39.—Section through the Cyclops and Norway mines in the Menominee iron region, Michigan. The north end of the section is to the right. (Fulton.)

The principal districts or "ranges" are:

a. The Menominee range is mostly in Michigan, forty miles west of Lake Michigan along the Menominee river, near the boundary between Michigan and Wisconsin.

Ores: soft hematites of Bessemer and non-Bessemer quality, containing 60 to 67 per cent. iron.

b. The Marquette range* (Michigan); best developed near the towns of Marquette and Ishpeming.

Ores: magnetites, and hard and soft hematites, mostly of Bessemer quality.

Geological relations and occurrence.

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* Preliminary report on the Marquette iron-bearing district of Michigan. By C. R. Van Hise and W. S. Bayley. Fifteenth ann. rep. U. S. Geol. Surv., 1893–94. Washington, 1895. pp. 477–650.

The Marquette iron-bearing district of Michigan. By C. R. Van Hise, W. S. Bayley, and H. L. Smyth. Monograph XXVIII, U. S. Geol. Surv. Washington, 1897.

c. The Penokee-Gogebic range* (called the Gogebic range) passes from Wisconsin into Michigan at the town of Ironwood.

Ores: soft hematites of high grade Bessemer quality; 60 to 66 per cent. iron.

The ore-bodies are concentrated in the apices of V-shaped troughs formed by southward dipping dikes cutting northward dipping impervious strata. They are intimately associated with cherts, which were originally heavily charged with carbonate ore. These carbonate ores underwent chemical change, and by solution and metasomatic replacement were concentrated in the troughs (Van Hise).

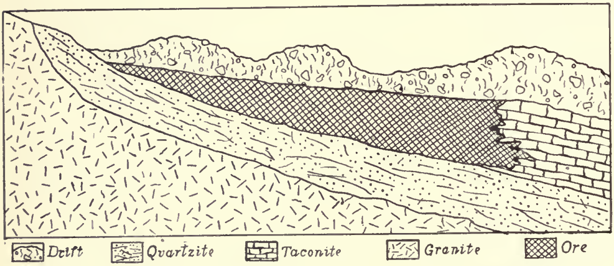

Fig. 40.—Section showing the usual occurrence of iron ore in the Mesabi range. It is below the glacial drift and resting upon quartzite. (Winchell.)

d. The Vermillion range:† at Vermillion Lake in northeast Minnesota, near the Canadian border.

Tower and Ely are the principal mining towns.

Ores: mostly hard hematites of Bessemer and non-Bessemer quality, with from 60 to 67 per cent. iron. They are closely associated with schists, "jaspillites," and quartzites. The ore masses are in sedimentary rocks and were probably concentrated by metasomatic replacement.

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*The Penokee iron-bearing series. By R. D. Irving and C. R. Van Hise. Monograph XIX, U. S. Geol. Surv. (Contains bibliography.) Washington, 1892.

The iron ores of the Penokee-Gogebic series of Michigan and Wisconsin. By C. R. Von Hise. Amer. Jour. Sci., 1889, CXXXVII, 32-48.

† The iron range of Vermillion Lake. By N. H. Winchell. Fifteenth an. rep. Geol. and Nat. Hist. Surv. Minnesota for 1886, 217 et seq.

The iron ores of Minnesota. By N. H. Winchell and H. V. Winchell. Bull. VI, Minn. Geol. Surv. Minneapolis, 1891.

e. The Mesabi range:* southwest of the Vermillion range, in Minnesota. Its first ore shipments of importance were made in 1893.

Ores: mostly soft hematites of Bessemer quality. The associated rocks are slates, quartzites, and jasper, all covered by glacial debris. The ore masses are probably the result of metasomatic replacement. (Fig. 40.)

Comparative importance of the districts in the Lake Superior region.

III. The western region.

This region includes the iron-producing States west of the Missouri river.

Missouri:† two localities have been of considerable importance.

a. Iron Mountain: hard hematite ores about a porphyry hill.

Iron boulders: residuary deposit, from the weathering of porphyry.

Geological horizon.

b. Pilot Knob: ore hard specular hematite, in two beds, associated with "slate" and porphyry sheets.

These ores are thought by Nason to be of sedimentary origin. (Figs. 41 to 45.)

The Cherry Valley ore bank.

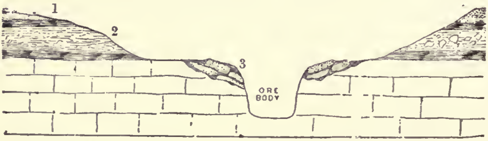

Fig. 46.—Section showing the relative positions of the country rock and the iron ore at the Cherry Valley mine in Missouri. The iron ore was mined from the pit marked "ore-body." (Nason.)

Other western iron regions:

Colorado ‡ is the most important producer.

Texas.§

Oregon.

Deposit near Oswego. (Fig. 47.)

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*The iron-bearing rocks of the Mesabi range. By J. E. Spurr. Bul. X, Geol. Surv. Minn. Minneapolis, 1894.

† A report on the iron ores of Missouri. By Frank L. Nason. Geol. Survey of Missouri, 1892, II. Jefferson City, 1892.

Preliminary report on the iron ores and coal fields. By Raphael Pumpelly. Geol. Surv. of Mo., 1872.

‡ Iron resources of Colorado. By Regis Chauvenet. Trans. Amer. Inst. Min. Eng., 1890, XVIII, 266–273.

§ The iron ores of east Texas. By R. A. F. Penrose, Jr. First ann. rep. Geol. Surv. Texas for 1889, pp. 65–86. Austin, 1890.

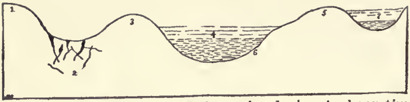

Fig. 41.—I. Ideal section across the region during Archean times.

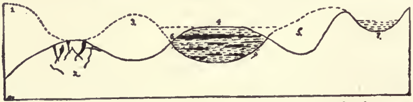

Fig. 42.—II. The same as I, after the deposition of the iron ores, and after erosion.

Fig. 43.—III. The same as II, showing the growth of the boulder ore beds.

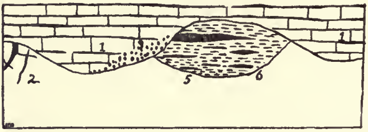

Fig. 44.—IV. The same as III, after being covered by the Cambrian deposits.

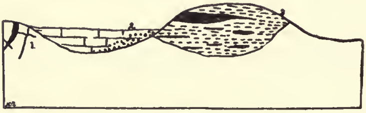

Fig. 45.—V. Section across the same region, showing the present conditions.

A GROUP OF IDEAL SECTIONS SHOWING THE PROBABLE HISTORY OF THE IRON ORES OF PILOT KNOB, MISSOURI, ACCORDING TO NASON.

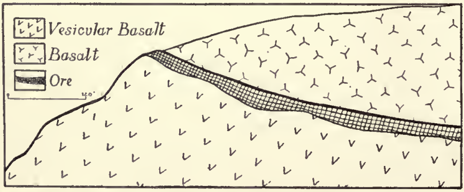

Fig. 47.—Section through the Prosser iron mine, near Oswego, Oregon. (Putman.)

Relative importance of the iron regions of the United States:

1. Lake Superior region.
2. Appalachian region.
3. Western region.

The principal iron ore producing States in the order of their importance in 1897: Michigan, Minnesota, Alabama, Pennsylvania, Virginia, Tennessee, New York.

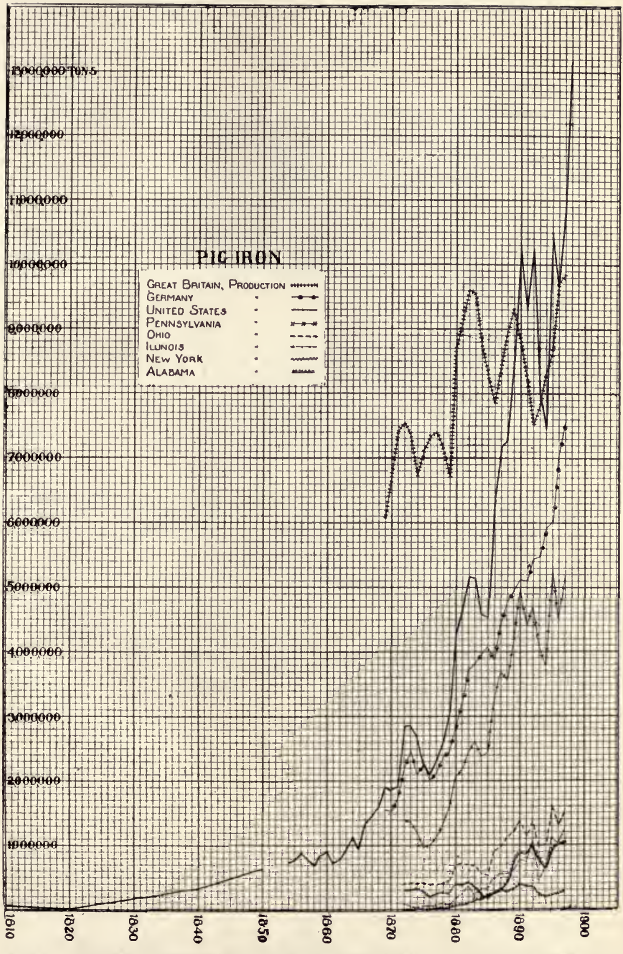

Fig. 48.—The pig-iron production of Great Britain, Germany, the United States, and the various States.

CHROMIUM.*

Uses of chromium.

In manufacturing chrome steel for armor plate, shoes and dies for stamp mills, and burglar-proof safes.†

As a pigment in certain greens and yellows.

Refractory material for furnace linings.‡

Ores of chromium.

Chromium is not found native, but occurs principally as the chromate of iron, or chromite ($FeCr_2O_4$), chromium sesquioxide 68, iron protoxide 32.

Occurrence in serpentine.

Irregular pockets.

Probable origin of the chromium segregations found in serpentine.§

Distribution of chromium in the United States.

Appalachian region.‖

California.¶

Chromium imported from Asia Minor.**

Statistics of chromium production.

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* Notes on chromic iron ore. By J. E. Carne. Mineral resources [of N. S. Wales], no. 1. Sydney, 1898.

† Alloys of iron and chromium. By F. L. Garrison. Sixteenth ann. rep. U. S. Geol. Survey, pt. III, 610–614.

‡ Engineering and Mining Journal, 1897, LXIII, 89, 136, 207, 375.

§ Occurrence, origin, and chemical composition of chromite. By J. H. Pratt. Eng. and Min. Jour., 1898, LXVI, 696.

‖ Chrome in the southern Appalachian region. By William Glenn. Trans. Amer. Inst. Min. Eng., 1895, XXXVI. 481.

Chromite in North Carolina. By J. H. Pratt. Eng. and Min Jour., 1899, LXVII, 261.

¶ Eleventh rep. California State Mineralogist, 1893–94, pp. 35–38. Thirteenth rep., 1896, 48–50.

** Emery, chrome ore, etc., in the Villayet of Aidin, Asia Minor. By W. F. A. Thomae. Trans. Am. Inst. M. E., 1898, XXVIII, 215.

chromium occurs chiefly in serpentine rocks.

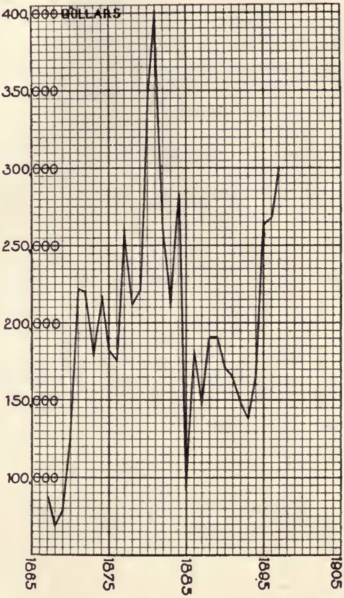

Fig. 49.—Value of the chromium imported into the United States since 1867.

MANGANESE.*

The uses of manganese.

- In the manufacture of steel.
  - Spiegeleisen has less than 20 per cent. of manganese; ferro-manganese has more than 20 per cent. of manganese.
  - For coloring and decolorizing glass and pottery.
  - Manufacture of bromine and chlorine.
- In colors for calico printing.
- For making dryers used in painting.
- As disinfectants.
- In the manufacture of oxygen.
- Leclanche battery.

Associated minerals.

Iron; cobalt and nickel; zinc; silver; and others.

The ores of manganese.

- Oxides.
  - Psilomelane ($MnO = 77.85$, variable).
  - Pyrolusite, manganese dioxide (MnO_2), $Mn = 63.2$.
  - Braunite ($Mn = 69.68$), silica 10, manganese protoxide 11.7, manganese sesquioxide 78.3.
  - Wad, or bog manganese.
- Carbonates.
- Silicates.

Relative importance of different ores in the production of manganese.

The oxides are the most important; the carbonates are next in importance.

Distribution of manganese.

- Geological.
  - Manganese nodules dredged from the deep sea.†
  - Manganese is found in all geological horizons.
  - Principal horizons in America.
    - Cambrian; Silurian; Carboniferous.
  - Probable source of manganese.

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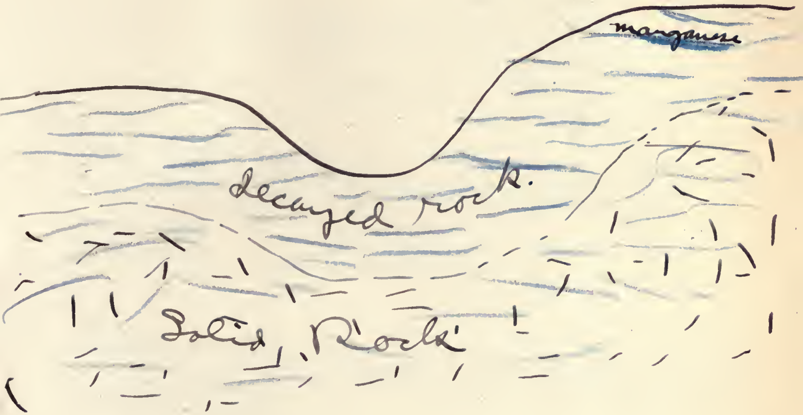
* Manganese: its uses, ores, and deposits. By R. A. F. Penrose, Jr. Ann. rep. of the Geol. Survey of Ark. for 1890, I.

Bibliography of the chemistry of manganese. Annals of the N. Y. Lyceum of Natural History, 1876, XI, 208-249.

† Alexander Agassiz, Science, December 8, 1899, pp. 834-835.

Voyage of the Challenger. By Wyville Thomson. II, 15. New York, 1878.

Manganese occurs chiefly as pyrolusite, crystalized form. Usually concentrated from moss-shaped forms.



Geographical (outside of the United States).
Manganese deposits of the Caucasus.*
The manganese deposits of Brazil.† (Figs. 50, 51.)
The Panama, Columbia, deposits.‡

Manganese of the United States.

The Appalachian region.
Principal districts: Georgia, Virginia, Vermont.
Other localities of the Appalachian region.
Principal ores.
Geological horizons and occurrences of the ores. (Fig. 53.)

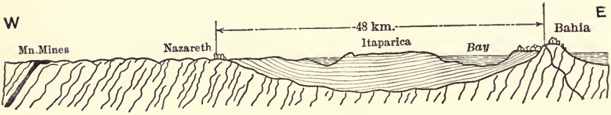


Fig. 50. –Section across the cretaceous basin of Bahia, Brazil, showing the geologic position of manganese deposits.

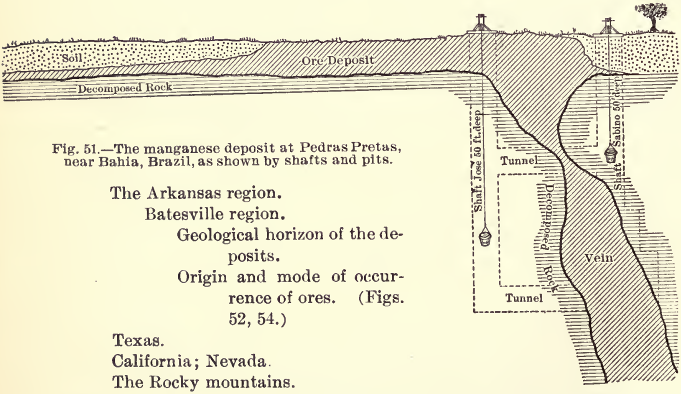


Fig. 51.—The manganese deposit at Pedras Pretas, near Bahia, Brazil, as shown by shafts and pits.

The Arkansas region.
Batesville region.
Geological horizon of the deposits.
Origin and mode of occurrence of ores. (Figs. 52, 54.)
Texas.
California; Nevada.
The Rocky mountains.
Relative importance of the different regions in the United States.

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[*] The manganese ore industry of the Caucasus. By Frank Drake. Trans. Amer. Inst. Min. Eng., 1898. XXVIII, 191–208.

[†] The manganese deposits of Bahia and Minas, Brazil. By J. C. Branner. Trans. Amer. Inst. Min. Eng., 1899. XXIX.

[‡] The manganese deposits of the Department of Panama, Republic of Columbia. By E. J. Chibas. Trans. Amer. Inst. Min. Eng., 1897, XXVII, 63–76.

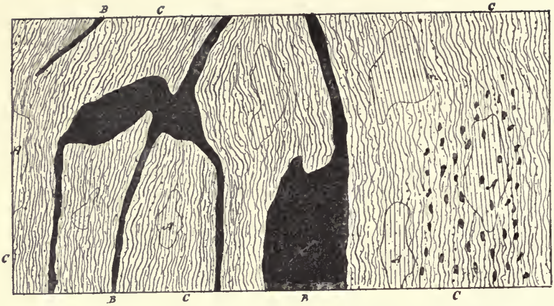

Fig. 53.—Section exposed in a pit at the Dobbins mine in Georgia. The black bands represent manganese ore, and the shaded portion clays. (Penrose.)

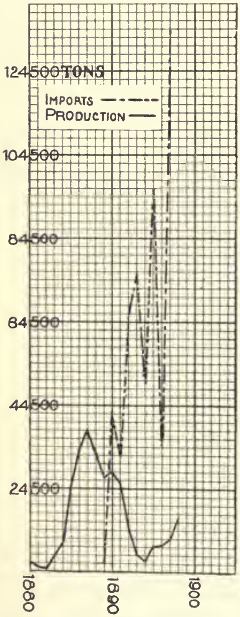

Fig. 55.—The production and imports of manganese ore in the United States since 1880.

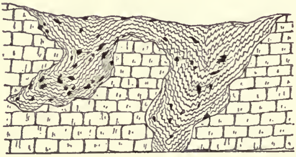

Fig. 54.—Section in the manganese region of North Arkansas, showing the formation of manganese-bearing clay by the decay of the St. Clair limestone. (Penrose.)

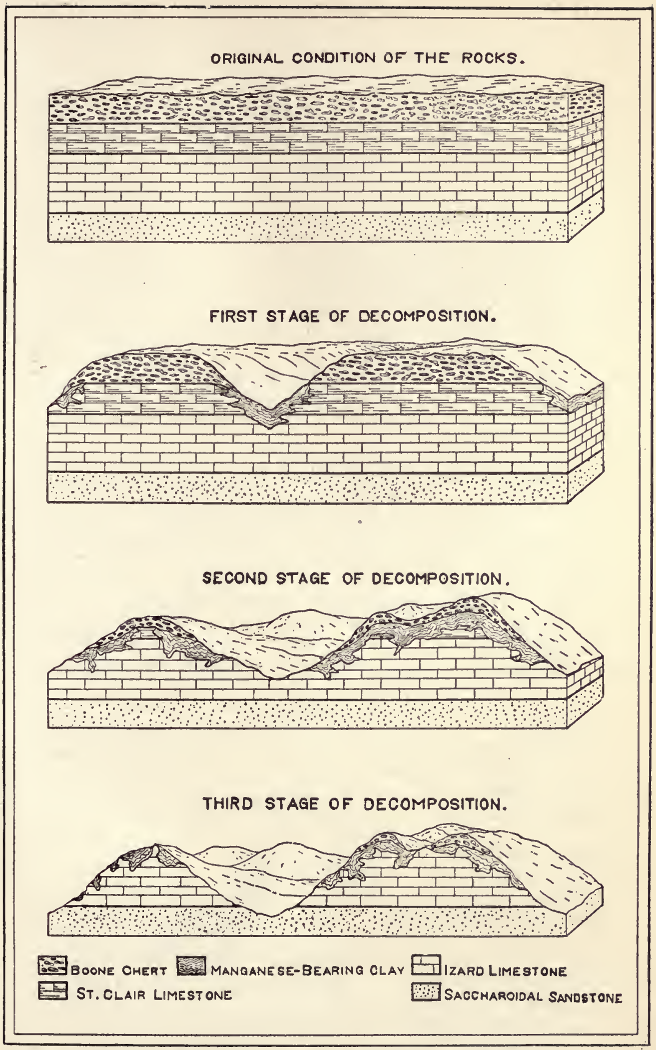

Fig. 52.—Ideal sections showing the formation of manganese-bearing clay from the St. Clair limestone in Arkansas. (Penrose.)

COPPER.

The uses of copper.

- For conductors of electricity.
    - Conductivity of silver 100, of copper 96.
- In making alloys, brass, bronze, etc.
- Copper-plate engraving, calico printing.

Many minerals associated with copper.

- Silver in Montana.
- Tin in Cornwall.
- Sulphur (combined).

The ores of copper.

- Native copper ($Cu = 100$).
- Sulphides.
    - Chalcocite, cuprous sulphide ($Cu = 79.8$, $S = 20.2$).
    - Chalcopyrite ($Cu = 34.5$, $Fe = 30.5$, $S = 35.0$). $CuFeS_2$ or $Cu_2S \cdot Fe_2S_3$, sometimes with silver and gold.
    - Bornite, crystallized $Cu_3 FeS_3$, ($Cu = 55.5$, $Fe = 16.4$, $S = 28.1$), proportions varying.
- Oxides.
    - Cuprite, cuprous oxide, Cu_2O ($Cu = 88.8$, $O = 11.2$).
    - Tenorite, cupric oxide, CuO ($Cu = 79.8$, $O = 20.2$).
- Carbonates.
    - Malachite ($Cu = 57.4$), say carbon dioxide 19.9, cupric oxide 71.9, water 8.2.
    - Azurite ($Cu = 55.22$), Co_2 25.6, cupric oxide 69.2, water 5.2.
- Silicates.
    - Chrysocolla ($Cu = 36.1$ + silica and water), silica 34.3, copper oxide 45.2, water 20.5.
- Relative values.

The occurrences of copper.

- In fissure veins.
- In irregular bodies.
- Disseminated through the rocks.

The distribution of copper.

- Geological distribution.
    - It occurs in rocks of all ages.

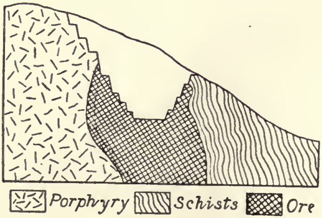

Fig. 56.—Cross-section of the south vein of the Rio Tinto copper mine in Spain. (De Launay.)

- Keweenawan age of the Lake Superior copper-bearing rocks.
- Ages of other deposits.

Geographical distribution.

- Copper in Spain; the Rio Tinto mines.
- Austria.
- Prussia.
    - The Mansfeld mines.
- Great Britain.
    - The Cornwall mines.
- Russia.
    - The Ural district.
- Japan.
- New South Wales.[*]
- Chili.
    - Absence of a home market.

THE PRINCIPAL COPPER REGIONS OF NORTH AMERICA.

Most of the copper produced in America comes from three regions: (1) the Lake Superior region of Michigan; (2) the Butte City region of Montana; (3) the Arizona region.

I. The Lake Superior region, Michigan.[†]

- Keweenawan age of the ore-bearing rocks.
- Nature of the ores: native copper ramifying the rocks.
- Character of the ore deposits.
    - Veins.
    - Bedding planes.
    - Impregnations.
        - The copper-bearing conglomerate.
        - The copper-bearing amygdaloids.
- Depth of the mines, 4,700 feet +.[‡]

II. The Butte region of Montana.

- Age and character of the rocks.

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[*] The copper-mining industry . . . in New South Wales. By J. E. Carne. Sydney, 1899.

[†] Report of the geology and topography of Lake Superior land district, in the state of Michigan. By J. W. Foster and J. D. Whitney. Part I, copper lands. Washington, 1850.

The copper-bearing rocks of Lake Superior. By R. D. Irving. Monograph V, U. S. Geol. Survey. Washington, 1883. (Bibliography.)

For bibliography of the history of mining in the Lake Superior region, see Twenty-third ann. rep. Geol. Survey of Minn. for 1894, 148–155, and Bul. Mus. Comp. Zool., VII, 133–157. Cambridge, 1880.

The origin and mode of occurrence of the Lake Superior copper deposits. By M. E. Wadsworth. Trans. Am. Inst. Min. Eng., 189, XXVII, 669–696.

[†] Amer. Jour. Science, CL, 503.

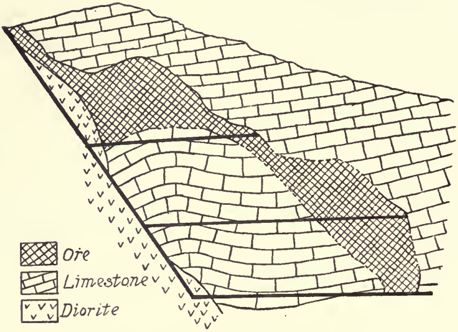

Fig. 57.—Section of the Globe copper mine, Maricopa county, Arizona. The limestone is of Carboniferous age. (Wendt.)

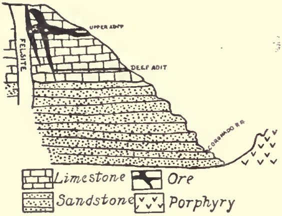

Fig. 58.—Section across Longfellow Hill and Chase Creek Canyon, Longfellow copper mine, Clifton district, Arizona. (Wendt.)

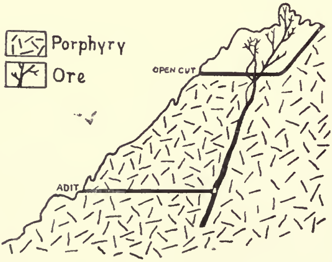

Fig. 59.—Section of Metcalf Hill, Clifton copper basin, Arizona. (Wendt.)

- Nature of the Butte ores.
  - Copper sulphide and silver.
  - The upper 400 feet leached of copper; the lode first worked for silver.
  - Bornite and chalcocite below.
- Character of the deposits.
  - In fissure veins.

III. The Arizona copper region.[*]

- Three copper-producing districts in southeastern Arizona.
  1. The Globe district.
     - Character and occurrence of the ores.
  2. The Clifton district.
     - Character and occurrence of the ores.
  3. The Bisbee district.
     - Character and occurrence of the ores.

Other copper districts of the United States.

- New Mexico.
- California.[†]
  - Copperopolis; Iron Mountain mines at Keswick.
- Utah.
- Colorado.
- Wyoming.
- Missouri: chalcopyrite with chert in Cambrian magnesian limestones.
- New Jersey.
- Tennessee, Vermont.[‡]

Relative importance of the different regions in the United States.
American copper mines compared with foreign mines.
Effect of metallurgical processes upon cost of production.
- Importance of the electrolytic process.

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[*] The copper ores of the southwest. By Arthur F. Wendt. Trans. Amer. Inst. Min. Eng., 1887, XV, 25–77.

The Copper Queen mine, Arizona. By James Douglas. Trans. Amer. Inst. Min. Eng., 1899, XXIX.

The mines of Yavapai county, Arizona. By J. F. Blandy. Eng. and Min. Jour., June, 1897, LXIII, 632.

[†] Copper resources of California. By Herbert Lang. Eng. and Min. Jour., April, 1899, LXVII, 442, 470.

[‡] The pyrites deposits of the Alleghanies. By A. Wendt. School of Mines Quarterly, VII, 154–188, 218–235, 301–323. New York, 1886.

Copper deposits of Vermont. By H. A. Wheeler, School of Mines Quarterly, IV, 219.

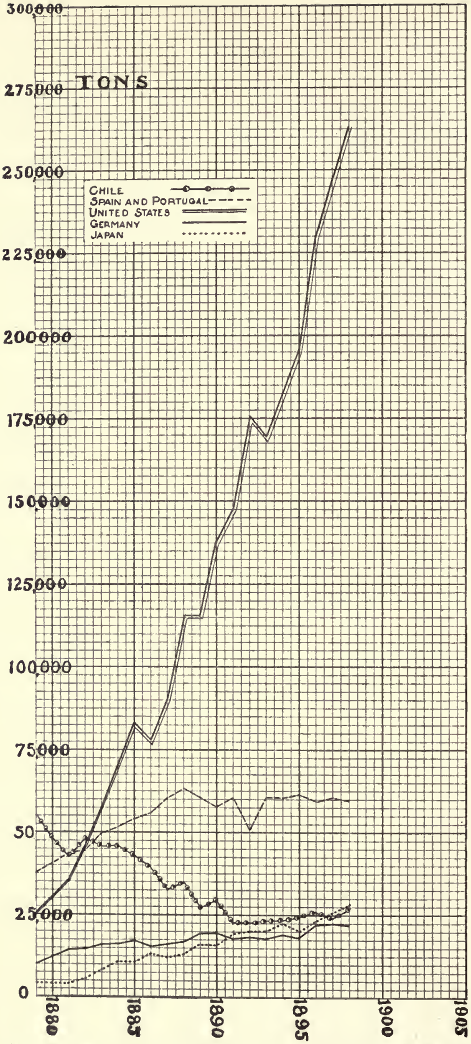

Fig. 60.—Comparative output of copper in the chief copper-producing countries since 1878.

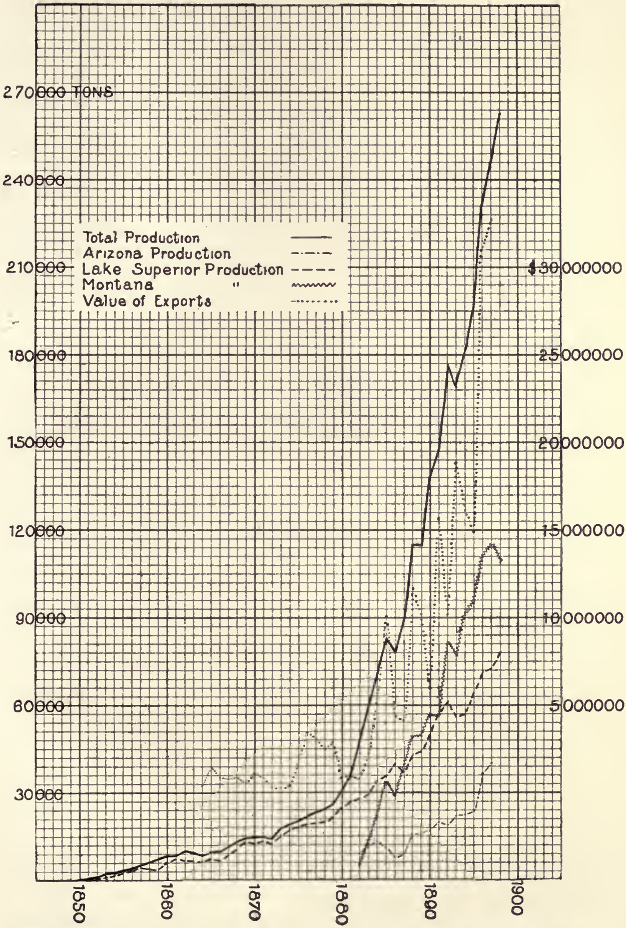

Fig. 61.—Statistics of the production of copper in the United States since 1850, and the value of copper exported since 1864.

TIN.*

Uses of tin.

- Manufacture of alloys.
  - Pewter.
  - Bronze.
  - Britannia metal.
  - Gun metal.
  - Bell metal.
- As tin plate.
- Tin foil.
- Calico printing.

Ores.

Tin is mined only as Cassiterite (SnO), tin 78.67, oxygen 21.33.

Stannite (perhaps $Cu_2S_1FeS_1SnS_2$), tin 27.5, copper 29.5, iron 13.1, sulphur 29.9. It sometimes contains zinc. (Sn 27, Cu 30, Fe 13, S 30.)

Occurrence.

Tin ores are found in, or associated with, granites, and as stream tin.

The stream deposits, derived from the granites, are the chief source of supply.

Distribution of tin.

- Geological.
- Geographical.
  - The tin deposits of Cornwall and Devonshire, England.
    - Mode of occurrence of the ore.†
  - Tin deposits elsewhere in Europe.
    - Prussia.
    - Russia.
  - The tin of the East Indies.
    - The Malay Peninsula.‡
    - Islands of Banca and Biliton off Sumatra.

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* Tin. By W. de L. Benedict. The Mineral Industry, I, 439–462.

† A treatise on ore deposits. By J. A. Phillips and Henry Louis. Tin, pp. 28–31, 197–231. London, 1896.

On the great flat lode south of Redruth, etc. By C. Le Neve Foster. Quarterly Journal, Geol. Soc., London, 1878, XXXIV, 640–659.

‡ Tin deposits of the Malayan Peninsula. By P. Doyle. Journal Geol. Soc. London, 1879, XXXV, 229–232.

Mines d'étain du royaume de Pérak. Par J. de Morgan. Annales des Mines, 8me ser., IX, 408–442.

The alluvial tin deposits of Siak, Sumatra. By Charles M. Rolker. Trans. Amer. Inst. Min. Eng., 1891, XX, 50–84.

Used in manufacture of salts and acids.

The ore cassiterite associated only with granite, quartz-porphyry and slate only.

Cornwall tin mine of England has been worked for 2000 years. It produces about 300 tons per day of tin.

Australia: Queensland, Victoria, and New South Wales.
China.
Bolivia. At Potosi tin is a by-product of silver.
Argentina.
Japan.

Tin in America.

Mexico produces small quantities of tin.

The United States at present produces no tin. The two principal regions where tin is known in this country are the Southern California region and the Black Hills region of South Dakota. Although small quantities of tin are found elsewhere, these are the only localities where the deposits promise to be of any value.

Tin of the Black Hills.*
- Harney's Peak.
- Mode of occurrence.

Tin of Southern California.†
- Temescal mines.
- Mode of occurrence: in granite intrusions in slate and schist.

Other occurrences of tin in the United States.

Statistics of tin.

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* Tin ore deposits of the Black Hills. By W. P. Blake. Trans. Amer. Inst. Min. Eng., 1884-85, XIII, 691-696.

Eleventh census, 1890, pp. 257-264.

† Fourth annual report of the State Mineralogist of California, 1884. By H. G. Hanks. pp. 115-123.

The tin deposits at Temescal, Southern California. By H. W. Fairbanks. Am. Jour. Sci., 1897, CLIV, 39-42.

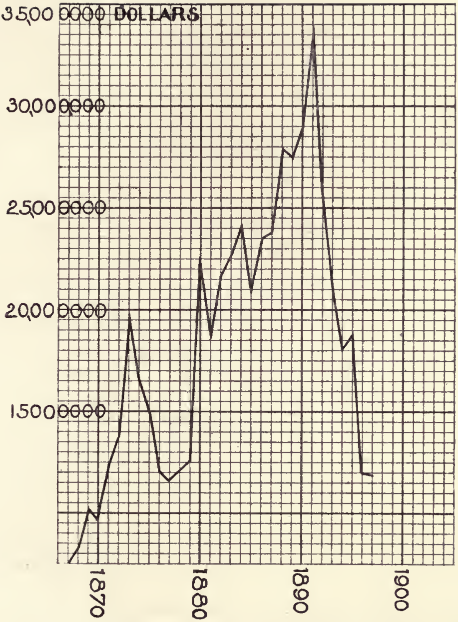

Fig. 62.—Value of the imports of tin in the United States since 1867.

COBALT AND NICKEL.[*]

Uses of cobalt.

- As a pigment for blue paints and porcelain.
- Chemical uses.

Uses of nickel.

- Nickel plating.
- German silver, an alloy of nickel,[†] copper, and zinc.
- In some kinds of steel.
  - Effect of nickel on steel.[‡]
- Coins.

Cobalt and nickel are always associated in nature.
Most cobalt is a by-product of nickel.

The ores of cobalt and nickel.

- Linnæite (Co 57.9, S 42.1) is a cobalt sulphide with some of the cobalt replaced by nickel.
  - Nine analyses have the sulphur ranging from 39 to 43, cobalt from 11 to 45, and nickel from 12 to 42.
- Millerite (Ni 64.6, S 35.3) is a nickel sulphide.
- Niccolite (Ni 43.9, As 56.1) is a nickel arsenide.
- Garnierite is a hydrous silicate of nickel and magnesia, variable.
  - Thirteen analyses give silica 35.45 to 50.15, nickel oxide 10.20 to 45.15, magnesia oxide 2.47 to 21.70, water 5.27 to 21.65.

Distribution of cobalt and nickel.

- The most important cobalt-nickel bearing regions of the world are the Sudbury region (Ontario, Canada), New Caledonia, and Norway and Sweden.
- 1. The New Caledonia region, about 1,000 miles east of Australia.[§]
  - The ore was discovered in 1867; the mines worked since 1874.
- Norway and Sweden.
- The other foreign regions are Great Britain, Germany, and Hungary.

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[*] Mineral Industry, 1892, I, 343–358; VI, 495–506.

[†] Alloys of iron and nickel. By Robert A. Hadfield. The Inst. Civ. Engs. London, 1899.

[‡] Nickel-steel; a synopsis of experiment and opinion. By D. H. Browne. Trans. Amer. Inst. Min. Eng., 1899, XXIX.

[§] Minerais de nickel (de la Nouvelle Calédonie). Par E. Heurteau. Ann. des Mines, 7me ser. IX, 390–398.

[‖] The Sudbury ore deposits. By E. D. Peters, Jr. Trans. Amer. Inst. Min. Eng., 1889–90, XVIII, 278–289.

The Sudbury nickel mines in Ontario. By A. M. Charles. Eng. and Min. Jour., Feb., 1899, LXVII, 144.

Cobalt and nickel in North America.

2. The Sudbury (Ontario) region of Canada[‖] is the only American region important in the production of cobalt and nickel.
    The ore is in Huronion gneiss; it contains but little cobalt.

Cobalt and nickel regions of the United States.
    Cobalt and nickel occurs in several localities in the United States, but these have so far proved of no importance.
    At the mine la Motte of Missouri some nickel is obtained in smelting the lead.
    Pennsylvania.
        Gap Mine,[*] Lancaster county, was worked for copper prior to 1852; mine now about exhausted.

Relative importance of different regions.

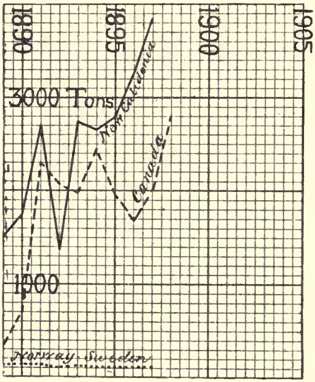

Fig. 63.—The nickel output of the chief nickel-producing countries.

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[*] The nickel mine at Lancaster Gap, Pa. By J. F. Kemp. Trans. Amer. Inst. Min. Eng., 1894, XXIV, 620–633. (Has bibliography of the Gap mines.)

ZINC.

Uses of zinc.

- As an alloy with copper.
  - Brass.
  - White metal.
  - Imitation gold foil.
- Zinc white (ZnO) is of much use for paint.
- Galvanizing nails, iron pipe, sheet iron for roofing.
- Electric batteries.
- The importance of zinc as compared with iron, copper, and other metals.

The occurrence of zinc.

Zinc usually occurs in nature associated with lead, and often with copper and silver.

Ores of zinc.

- Sphalerite (Zn 67, S 33).
  - Common names: blende, jack, black-jack, rosin jack.
- Smithsonite (ZnO 64.8, CO_2 35.2), 51.4 metallic zinc.
- Calamine (Zn 54.2, SiO_2 25 + water).
- Zincite (Zn 80.3, O 19.7).
- Franklinite (ZnO, varies from 16 to 23 +).
- Willemite (Zn 58.5, SiO_2 27.1).
- Comparative importance of the ores.

Methods of preparing and treating the ores.

- Hand-picking.
- Crushing.
- Jigging.*
- Roasting.
- Manufactured as
  - Spelter.
  - Oxide for paint.

Distribution.

Although zinc has a very wide distribution, the zinc of the commerce of the world comes from comparatively few regions. (See statistics below.)

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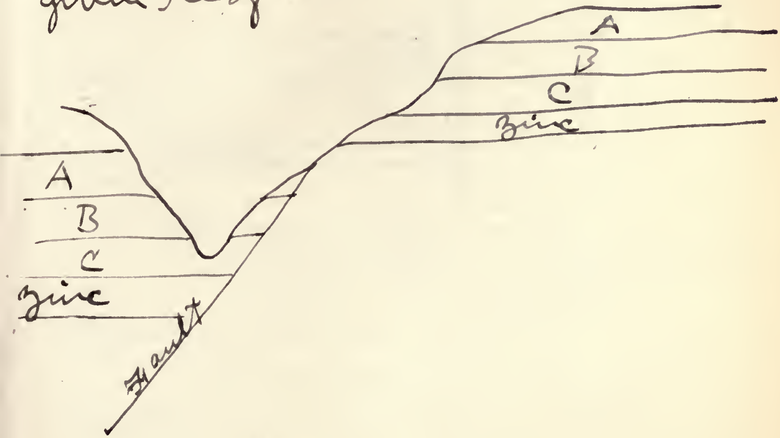
* The concentration of ores. By R. H. Richards. Technology Quarterly, 1898, XI, 54–64.

Brass 60-70% copper, 30-40% zinc. Zinc found usually associated with lead and silver. Very difficult to separate from gold and silver. Zinc usually bedded in sedimentary deposits occurring always in beds of the same age in a given region



Geological distribution.

Zinc has a very general geologic distribution, but by far the greater part of the zinc mined comes from Silurian and Lower Carboniferous limestones and cherts.

Geographical distribution.

Zinc-producing regions in the order of their importance.

1. Silesia.
2. Belgium.
3. United States.
4. Great Britain.
5. France.
6. Spain.

Zinc of the United States.

There are two principal regions in the United States.

The eastern or Appalachian region.

The western or Mississippi valley region.

The eastern region.

New Jersey, Sussex county.

The ores occur in Lower Silurian and older limestones.

The ores are the red oxides: Franklinite, Willemite, and Zincite.

Pennsylvania.

Ores from brecciated Chazy magnesian limestone.

The ores are calamine above and sphalerite below.

Virginia; ore is calamine in crystalline limestone.

New Hampshire.

Eastern Tennessee.

At Mossy Creek the ore is sphalerite in brecciated magnesian limestone.

The surface ores first worked were carbonates.

The Mississippi valley region.

The two principal zinc-producing districts of the Mississippi valley are the Illinois-Wisconsin district and the Missouri-Kansas district.

The Illinois-Wisconsin district.*

Extent.

The nature of the ores.

Modes of occurrence. (Figs. 64 to 67.)

Relative occurrence of lead and zinc.

Geological horizons.

The Missouri-Kansas zinc fields.†

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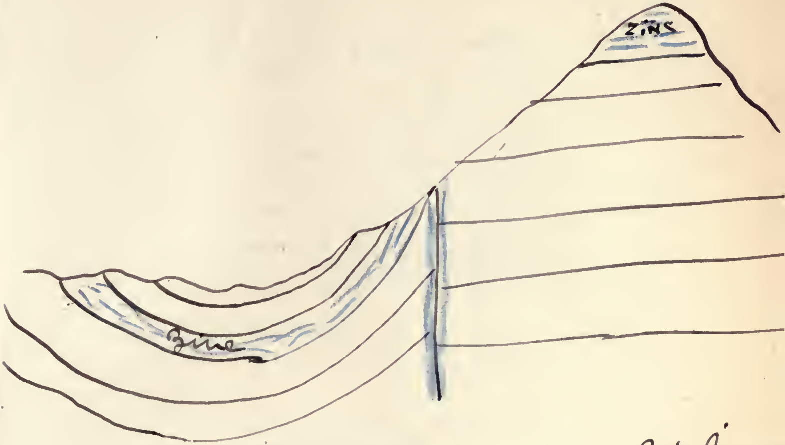
* The ore deposits of southwest Wisconsin. By T. C. Chamberlin. Geol. of Wisconsin, 1873-79, IV, pt. IV, 365-568.

† The mining and metallurgy of zinc. By F. L. Clerc. Min. Resources of the U. S. for 1882, pp. 346-386.

The lead and zinc deposits of Missouri. By Arthur Winslow. Geol. Survey of Mo., vol. VII. Jefferson City, 1894. (This work contains a bibliography of lead and zinc.) An abstract of this report is published in the Trans. Amer. Inst. Min. Eng., 1894, XXIV, 634.

Lead and zinc mining industry of southwest Missouri and southeast Kansas. By J. R. Holibaugh. New York, 1895.

The Mississippi Valley zinc mines supply most of the zinc produced in the U.S.



Occurs often along fault lines

Missouri-Kansas zinc ores are associated with lead.

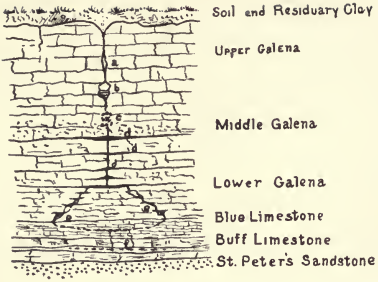


Fig. 64.—Ideal section in the lead and zinc region of Wisconsin, showing the forms of ore deposits at the different horizons. (Chamberlin.)

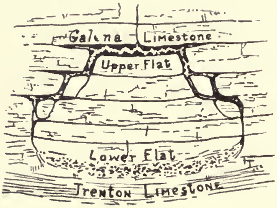


Fig. 65.—Ideal section through "flats and pitches" of the lead and zinc region of Wisconsin. (Chamberlin.)

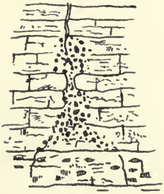


Fig. 66.—Section showing the zinc ore deposit in the Atkinson range in Wisconsin. (Chamberlin.)

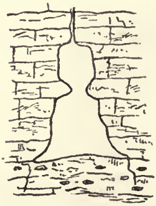


Fig. 67.—Section of a mine in this ore deposit (shown in Fig. 66) after it is worked out. (Chamberlin.)

  - Their extent.
    - Missouri, Kansas, and Arkansas.
  - Nature of the ores.
  - Geological horizons.
  - Modes of occurrence. (Figs. 68–70.)
- The Iowa zinc deposits.*
- Zinc found in the silver mines.
  - Effect of zinc on gold and silver ores.
- Probable origin of zinc deposits.†
- Relative importance of the zinc regions of the United States.
- Relative importance of the zinc regions of the world.

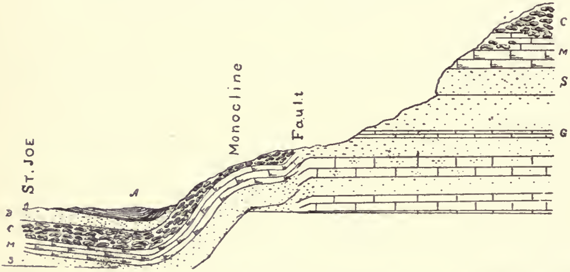


Fig. 68.—Section across the St. Joe fault, near St. Joe, Searcy county, Arkansas. The mines are on the fault.

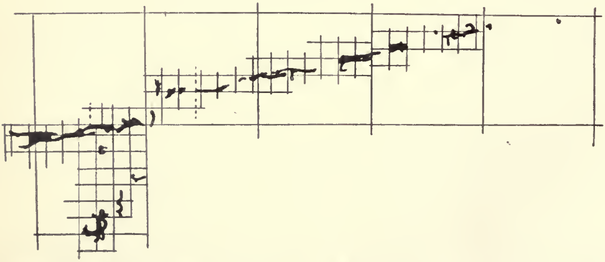


Fig. 69.—General map of the lead and zinc mines of North Aurora, Lawrence county, Missouri, showing the linear arrangement of the ore-bodies. Scale, 3 inches = 1 mile. (Winslow.)

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* Lead and zinc deposits of Iowa. By A. G. Leonard. Iowa Geol. Survey, 1896, VI, 11–66.

† Origin of the Iowa lead and zinc deposits. By A. G. Leonard. Amer. Geologist, 1895, XVI, 288.

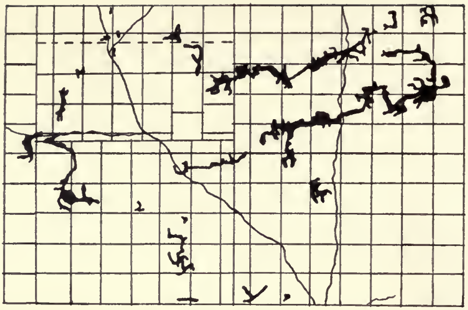

Fig. 70.—Map of a portion of the Eagle lead and zinc mines in Jasper county, Missouri, showing the linear distribution of the ores. Scale, 1 inch = 800 ft. (Winslow.)

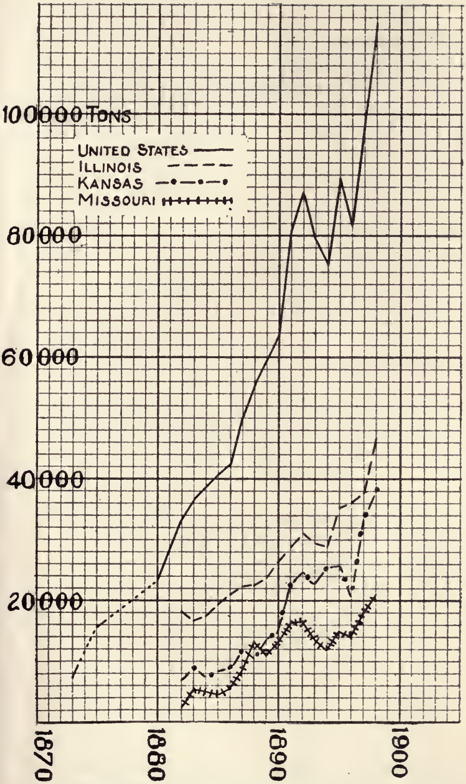

Fig. 71.—The zinc production of the United States since 1873.

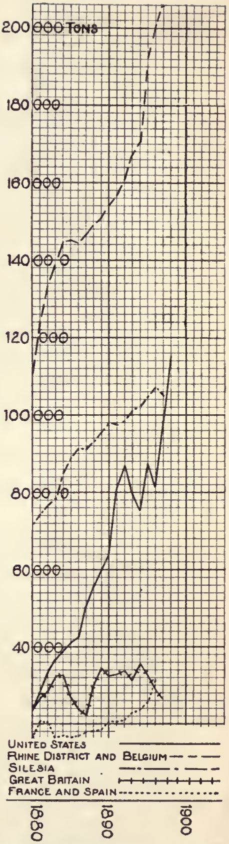

Fig. 72.—Comparative production of zinc in the chief zinc-mining countries since 1880.

LEAD.

Uses of lead.

- Paint: white lead is *lead carbonate*, some is *lead oxide*, and a white *lead sulphate* is now made for paint.
- Pigments: certain yellows and red lead.
- Alloys of lead.
  - Pewter.
  - Organ-pipe metal.
  - Solder.
  - Type metal.
  - Babbit metal and other anti-friction alloys.
  - Shot.
- Pipes for plumbing; importance of ductility.
- Sheet lead for roofing.
- Glass making.
- Medicine (acetate, carbonate, iodide, etc.).

Associations.

Lead is usually associated with zinc or silver. The greater part of the lead of commerce is mined as a by-product of silver.

The ores of lead.

- Galena (Pb 86.6, S 13.4).
  - Argentiferous galena from the silver mines.
  - Non-argentiferous galena of the Mississippi valley region.
- Cerussite (PbO 83.5, CO_2 16.5), known as "dry bone."
  - Galena and cerussite are usually found together.
- Anglesite (PbO 73.6, and SO_3, 26.4.)

*Treatment of the ores.**

Modes of occurrence of lead ores.†

- In veins.
- In cavities.

Distribution of lead.

Lead has a very wide geologic and geographic distribution. Most countries yield some lead, but Spain is the most important lead producer.

Geologic distribution.

Lead is confined to rocks of no particular age, but most of the lead of commerce is taken from Paleozoic rocks.

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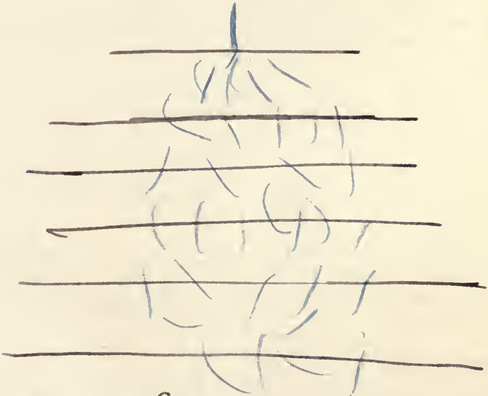
* The metallurgy of lead. By H. O. Hofman. New York, 1894.
The metallurgy of lead and silver. Part I, Lead. By Henry F. Collins. London, 1899.

† Figures illustrating the occurrence of lead ores will be found under the subjects of zinc and silver.

Occurrence of lead ore



Section through a series of lead-bearing sedimentary beds.

Geographic distribution (principal producers only).*

- Spain.
- United States.
- Germany.
- Mexico.
- Australia (New South Wales).
- Great Britain.
- Italy.

Lead regions of the United States.

There are three principal lead regions in the United States: (1) the Appalachian region; (2) the Mississippi valley region; (3) the Rocky Mountain region.

The Appalachian region.

- Ore in veins in metamorphic rocks, from Georgia to Maine; of no importance now.

The Mississippi region.†

- Wisconsin district;‡ principal mines about Mineral Point and Plattville.
- Iowa district; principal mines about Dubuque.§
  - Galena associated with zinc in Lower Silurian (Galena) limestone; in veins, cavities, "flats," and "pitches."
- Illinois.
  - Nature and modes of occurrence similar to that of the Wisconsin-Iowa district; in Galena limestone.
- Missouri, Kansas,‖ and Arkansas.
  - Galena, in veins, cavities, and scattered masses in Paleozoic limestone, from the Cambrian to the Lower Carboniferous, mostly the latter. The ore is often associated with zinc.

The Rocky Mountain region.

- Most of the lead produced at present in the United States comes from the Rocky Mountain region, where it is taken as a by-product of silver from argentiferous galena.

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* Lead and zinc mining in foreign countries. Special Consular Reports, vol. X. Washington, 1894.

† The upper Mississippi lead region. By J. D. Whitney. Albany, N. Y., 1862.

‡ Geology and topography of the lead region. By Moses Strong. Geology of Wisconsin, 1873-77, vol. II, pt. IV, and vol. IV, pt. IV. The ore deposits of southwest Wisconsin. By T. C. Chamberlin.

§ Report on the geology of Iowa. By C. A. White. Vol. II, Des Moines, 1870, p. 339.

‖ The lead and zinc region of southwest Missouri. By Adolf Schmidt and Alexander Leonhard. Geol. Survey of Mo., 1873-74, vol. I, 381-50.—Same vol., 503-577. The lead region of central Missouri. By Adolf Schmidt.—Same vol., 602-637. Lead mines of southeast Missouri. By J. R. Gage.

Lead and zinc deposits of Missouri. By Arthur Winslow. Trans. Amer. Inst. Min. Eng., 1894, XXIV, 634-931.

Lead and zinc deposits. By Arthur Winslow. Mo. Geol. Survey, vols. VI and VII. Jefferson City, 1894.

- Colorado.
  - Leadville district.*
    - Lead-silver ores oxidized at the surface, in Carboniferous limestone associated with porphyry.
    - Sulphide ores at depths.
  - Aspen. Lead-silver ores oxidized at the surface, in Carboniferous limestone.
  - Other Colorado districts.
- Montana. Lead produced from argentiferous galena in silver mining.
- Utah. The silver mines yield much lead as a by-product.
- Idaho.
  - The Cœur d'Alene district.
    - Lead-silver ores, in highly faulted and folded quartzites and schists.
- New Mexico.
  - Lead produced from argentiferous galena in silver mining.
  - Magdalena district.
    - Non-argentiferous lead ores.
- Nevada. Lead a by-product in silver mining.
- Relative importance of the different regions of the United States.
- Lead was first smelted in the United States in 1825; in 1872 the silver-lead ores came into market.

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* Geology and mining industry of Leadville. By S. F. Emmons. Monograph XII. U. S. Geol. Survey. Washington, 1886.

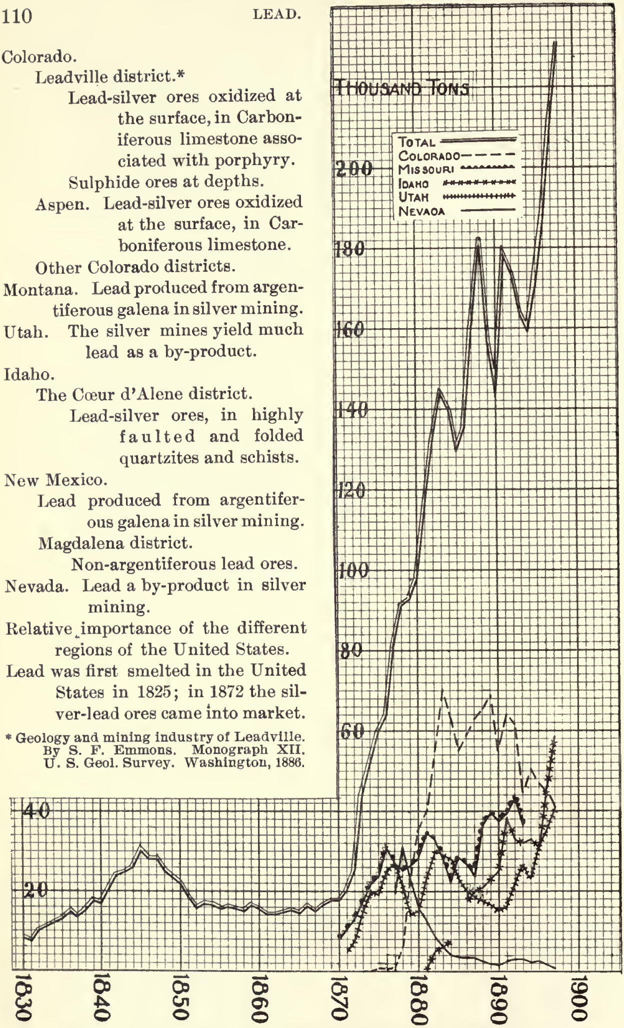

Fig. 73.—The lead production of the principal lead-producing States since 1830.

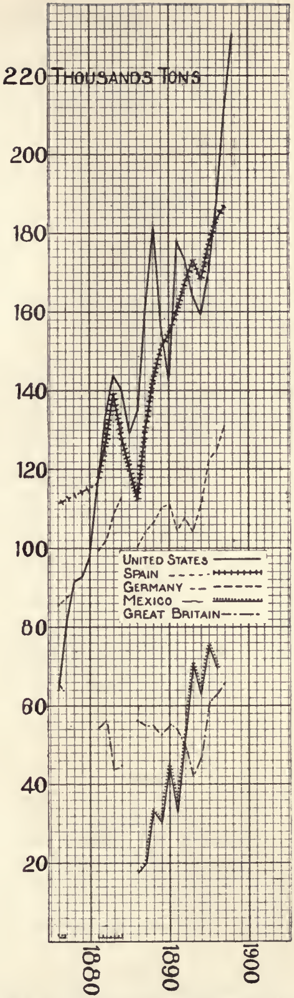

Fig. 74.—The lead output of the chief lead-producing countries since 1876.

SILVER.

The uses of silver.

Coinage.

In alloys.

Table ware.

For jewelry and ornamental purposes.

In photography and medicine.

Ores of silver.

Native silver (usually an alloy with copper, gold, or bismuth).

Argentite. Silver glance (Ag_2S), (Ag 87.1, S 12.9).

Pyrargyrite. Ruby silver ($Ag_3\ SbS_3$ or $3\ Ag_2\ SSb_2\ S_3$), (Ag 59.8, Sb 22.5, S 17.7).

Proustite. Light ruby silver ($3\ Ag_2S,\ As_2S_3$ or $Ag_3\ AsS_3$), (Ag 65.5, As 15.1, S 19.4).

Stephanite. Brittle silver; black silver ($Ag_5\ SbS_4$ or $5\ Ag_2S\ Sb_2S_3$), (Ag 68.5, Sb 15.3, S 16.2).

Cerargyrite. Horn silver, silver chloride (Ag 75.3, Cl 24.7).

Bromyrite (Ag 57.4, Br 42.6).

Embolite (49 per cent. AgBr to 51 per cent. AgCl).

Argentiferous galena (lead and silver in varying proportions).

Argentiferous tetrahedrite, or freibergite, a sulphide of copper and antimony, contains varying proportions of silver.

Relative importance of the different ores.

Distribution.

Geologic.

Silver occurs in rocks of all ages.

Geographic.

Silver has a very general geographic distribution, but few countries not having it in some quantity. The following are the most important silver-producing countries in the order of their importance: United States, Mexico, Australasia, Bolivia, Germany, Spain, Peru, France, Chile, Austria-Hungary, Central America, Japan.

SILVER OF THE UNITED STATES.

The silver of the United States comes almost entirely from west of the Mississippi river: Colorado, Montana, Utah, Nevada, and Idaho producing over 90 per cent. of the total output.

Native silver usually occurs as thin wires through the rocks. Silver is usually associated with galena

Colorado.*

Leadville.†

Ores: oxidized lead-silver, passing into sulphides at depths; in faulted Carboniferous limestone.

Probable mode of formation of the deposits.

Aspen.‡

Ores: oxidized lead-silver; in highly folded and faulted Carboniferous limestones.

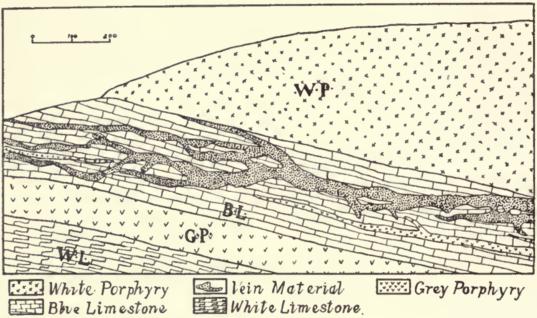

Fig. 75.—Section on the "gold ore chute" of Iron Hill, Leadville, Colorado. (Blow.)

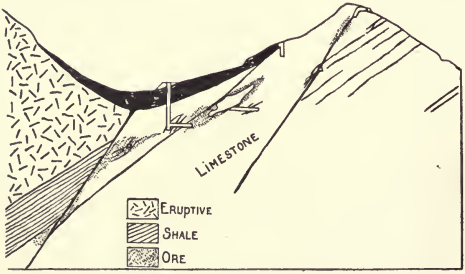

Fig. 76.—Northwest-southeast vertical section through Spar ridge and Vallejo gulch, in the Aspen district, Colo. Washington shaft is shown near Vallejo gulch.

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* Geology of Colorado and western ore deposits. By Arthur Lakes. Denver, 1893.

† Geology and mining industry of Leadville, Colorado. By S. F. Emmons. Monograph XII, U. S. Geol. Survey.

‡ Geology of the Aspen mining district, Colorado. By J. E. Spurr. Monograph XXXI, U. S. Geol. Survey. Washington, 1898.

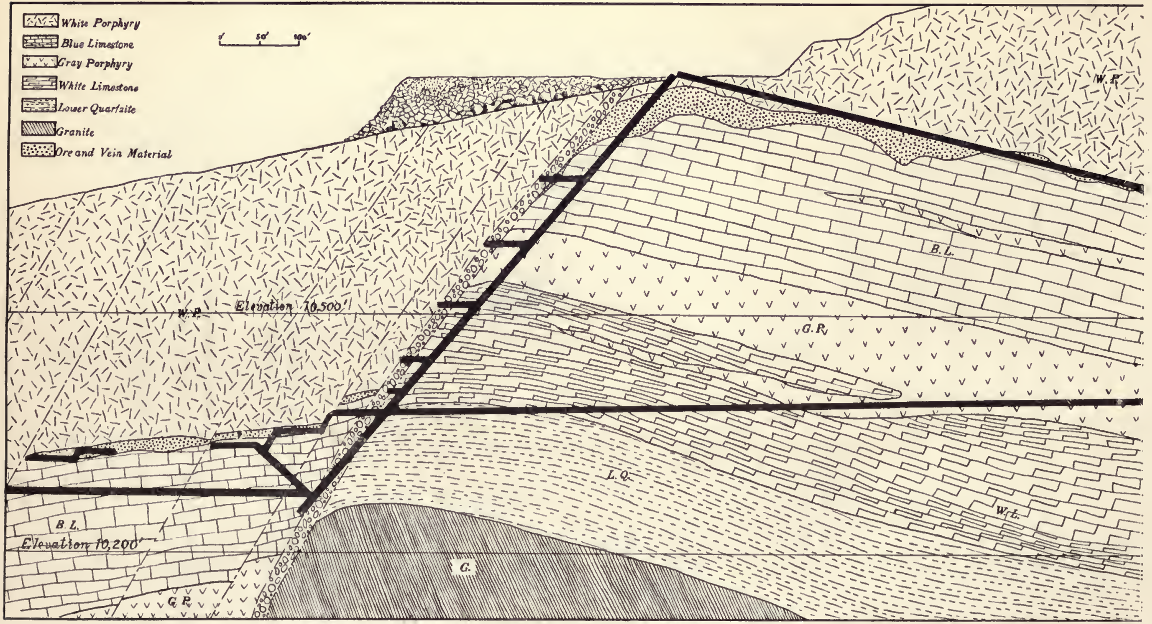

Fig. 77.—East-west section through the McKeon shaft, Leadvillle, Colorado, showing the faulted ore-bodies along the contacts. (Blow.)

Creede.

Ores: oxides in fissure veins in igneous rocks.

Cripple Creek.*

Other Colorado districts: Eagle River, Ten Mile, Monarch, Rico, Red Mountain, Custer county.†

Montana.

Butte City region.‡

Ores: native silver and galena in veins with quartz gangue containing some Mn; country rock of granite.

Granite Mountain.

Ores: ruby silver associated with gold in veins in gray granite.

Other Montana silver regions are: Cook City, Flint Creek, Glendale.

Utah.

Big and Little Cottonwood Cañons. Ores: oxidized lead-silver; in bedded veins in Carboniferous limestone.

Beaver county. Oxidized lead-silver ores occur in contact fissures (Horn Silver mine); in chambers in limestone (Cave mine); in fissure veins (Carbonate mine).

Summit county. Ores in veins through quartzite (Ontario mine).

Other silver regions of Utah are Bingham Cañon, the Mercur district,§ the Tintic district, Silver Reef.

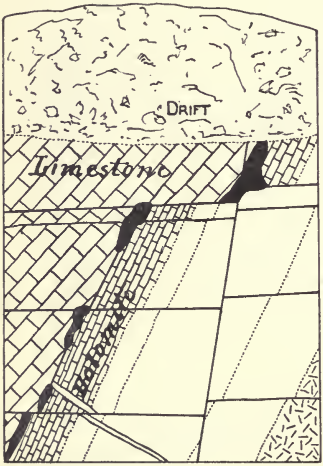

Fig. 78.—Section showing faults and ore-bodies in the Bushwhacker-Park Regent mine, Aspen. (Spurr.)

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* Geology and mining industries of the Cripple Creek district, Colorado. By W. Cross and R. A. F. Penrose, Jr. Sixteenth ann. rep. U. S. Geol. Survey, pt. II, 13-209. Washington, 1895.

† The mines of Custer county, Colorado. By S. F. Emmons. Seventeenth ann. rep. U. S. Geol. Survey, pt. II., 405-472. Washington, 1896.

‡ Silver mining and milling at Butte, Montana. By W. P. Blake. Trans. Amer. Inst. Min. Eng., XVI, 38-45.

Notes on the geology of Butte, Montana. By S. F. Emmons. Trans. Amer. Inst. Min. Eng., XVI, 49-62.

§ Economic geology of the Mercur mining district, Utah. By Emmons and Spurr. Sixteenth ann. rep. U. S. Geol. Survey, pt. II, 343-455.

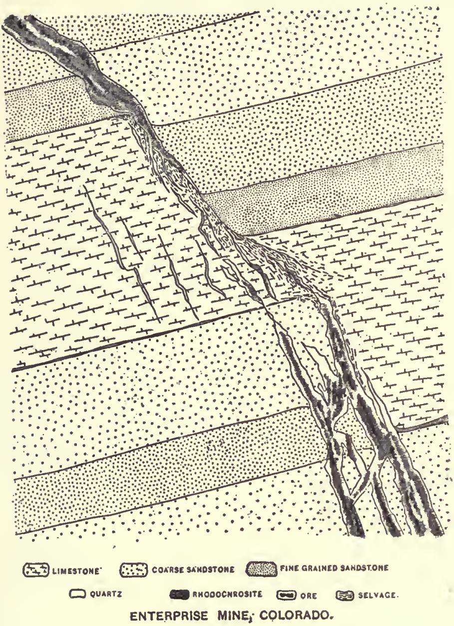

Fig. 79.—Section exposed in a breast of the Enterprise mine at Rico, Dolores county, Colorado. (Rickard.)

Nevada.

The Comstock lode,* the largest silver-gold deposit ever discovered, is a great fissure vein, four miles long, several hundred feet broad, with branching ends; it follows a fault line; the greatest displacement is at the centre, where it is nearly 3000 ft. The mines reach a depth of about 3000 ft.

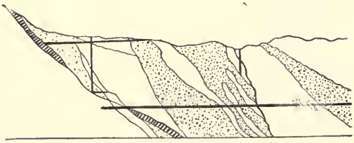

Fig. 80.—East-west section through the Comstock lode in Nevada, showing the position of two of the ore-bodies, and of the Sutro tunnel.

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* Geology of the Comstock lode and the Washoe district. By G. F. Becker. Monograph III, U. S. Geol. Survey.
Comstock mining and miners. By E. Lord. Monograph IV, U. S. Geol. Survey.

Development and importance.

Ores: high grade, associated with gold.

Ores in bodies irregularly distributed through the quartz gangue; bonanzas.

The country rock is diorite and diabase.

Theories of the origin of the ores.

The Eureka district.*

Ores: oxidized lead-silver, with some gold irregularly distributed through veins in often brecciated Cambrian limestones and shales. Depth of alteration of ores over 1300 feet.

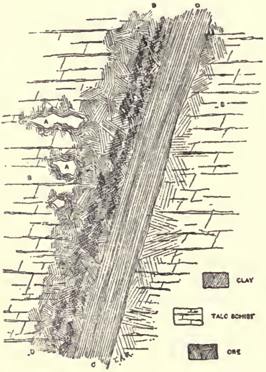

Fig. 81.—Section across a vein in the Hillside mine, Yavapai county, Arizona, showing the ore scattered through clay. (Rickard.)

Idaho.

The Cœur d'Alene district.

The ore is galena with siderite gangue in country rocks of highly folded schists and quartzites.

Wood River district.

Ores largely altered by surface oxidation. Irregularly distributed in limestones.

New Mexico.

Lake Valley district.

Ores: galena, cerussite, and chloro-bromides in Paleozoic limestones.

The silver districts about Silver City.

Arizona.

Tombstone region.

Ore: horn silver, associated with galenite, free gold, pyrite, lead carbonate.

Geologic relations.

Other silver regions of the United States.

California produces some silver as a by-product of gold. Texas, Washington, Dakota (the Black Hills), Michigan, North Carolina, Oregon, Alaska, are all silver producers. The production in 1893 ranged from 349,400 ozs. in Texas to 9,600 ozs. in Alaska, in the order named.

Relative importance.†

Effect of coinage legislation upon the price and output of silver.

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* Silver-lead deposits of Eureka, Nevada. By J. S. Curtis. Monograph VII, U. S. Geol. Survey.

Geology of the Eureka district, Nevada. By Arnold Hague. Monograph XX, U. S. Geol. Survey.

† Production of the precious metals in the United States. By Clarence King. Second ann. rep. U. S. Geol. Survey, 333–401.

SILVER OUTPUT OF THE LEADING STATES.

(Commercial value.)

Years.	Colorado.	Montana.	Utah.	Idaho.	Arizona.
1895	11,687,150	9,825,305	4,296,115	2,236,951	561,174
1896	15,097,500	10,548,120	5,933,526	3,623,400	1,342,000
1897	12,722,227	10,049,112	3,999,804	3,587,400	796,577
1898	13,866,535	8,743,011	3,876,451	3,707,999	1,622,500
1899					
1900					

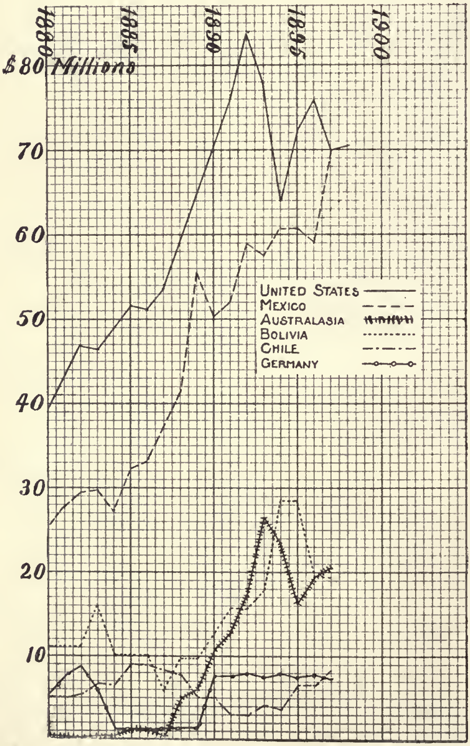

Fig. 82.—The silver output of the principal silver-producing countries since 1880.

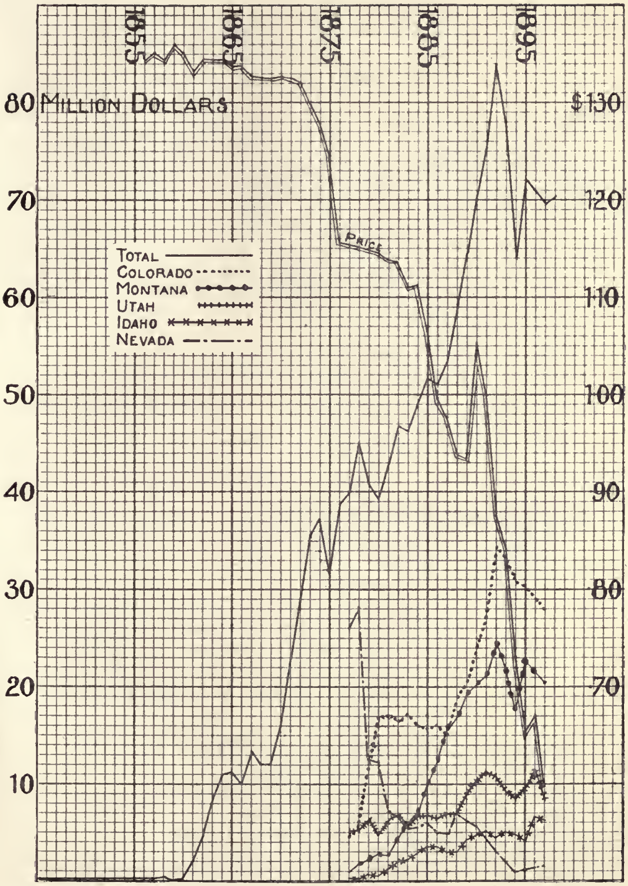

Fig. 83.—The value of the silver production of the United States since 1845, and the price per ounce of silver since 1856.

GOLD.[*]

Uses.

Gold has been used from the earliest times in coinage and for ornamental purposes.

Coinage. The stability in value of gold coin.

Ornamental purposes, foil, dentistry, medicine.

Ores.

Most of the gold mined is found as native gold; often alloyed with silver and other metals. California gold contains from 11 per cent. to 13 per cent. silver; Australian gold contains 5 per cent. silver, and the percentage is increasing.

Other combinations are:

- Sylvanite (Te 62.1, Au 24.5, Ag 14.4, variable).
- Nagyagite (one analysis, Te 30.52, S 8.07, Pb 50.78, Au 9.11 + Ag and Cu. Other analyses yield: Te 15.11 up, S to 10.76, Pb to 57.16, Au 7.41 to 12.75).
- Petzite (Au 25.5, Ag 42.00, Te 32.58, variable).

Modes of occurrence.

Gold is found:

- In veins, as free gold, and in combination.
  - Gangue generally quartz; exceptions.[†]
  - Mining vein deposits.
    - Milling,[‡] concentrating.
    - The chlorination process is based upon the "property of chlorine gas to transform metallic gold into soluble chloride of gold." Gold must be metallic.[§]
    - The cyanide process is based upon the principle that a dilute solution of cyanide of potassium dissolves gold and silver.[‖]

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[*] Contributions to the bibliography of gold. By A. Liversidge. Proc. Austral. Assoc. Adv. Sci., Jan. 1895, pp. 240–256. This contains titles not given in Lock's Gold.

Gold. By A. G. Lock. London, 1882. (Bibliography.)

La géographie de l'or. Par A. de Foville. Ann. de Géographie 6me Année, Paris, 1897, pp. 193–211.

L'or dans la nature. Par Cumenge et Robellaz. Paris, 1898.

[†] Gold in granite. Trans. Amer. Inst. Min. Eng., 1896, XXVI, 290–298.

Amer. Jour. Sci., April, 1896, CLI, 309–311.

[‡] Gold mill practices. By E. B. Preston. Bulletin 6, California State Mining Bureau. Sacramento, 1895.

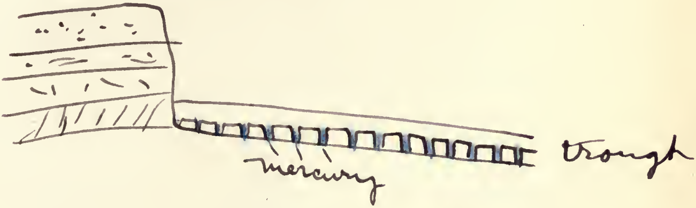
[§] The extraction of gold by chemical methods. By T. K. Rose. Nature, March, 1897, LV, 448–9.

[‖] The cyanide process. By A. Scheidel. Bulletin 8, California State Mining Bureau, 1894. (Reprinted, London, 1895.)

The cyanide process of gold extraction. By James Park. Auckland, New Zealand. Melbourne, 1896. (132 pp.)

Placer gold deposits alike all over the world in appearance and composition because always made up of heavy minerals.

Placer gold usually amalgamated with mercury in s l water troughs through which the gravel is run.



- In stream or placer deposits, as flakes, grains, or nuggets.
  - Origin of placer gold.
    - Beach deposits.
    - Stream deposits.
    - Geographic changes subsequent to their deposition.
      - The high terrace gravels of the Sierras.[*]
  - Methods of mining placer deposits.
    - Panning, sluicing, booming, dredging,[†] amalgamation.

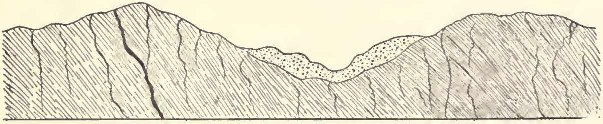


Fig. 84.—Theoretical section showing the origin of the auriferous gravels. The dark lines represent gold-bearing veins, of which the coarser and heavier materials accumulate in the valleys.

Distribution.

Gold is one of the most widely distributed elements: it is found in rocks of all ages and kinds, and is even a constituent of sea water.

The principal gold-producing countries were:

	1898.	1899.	1900.	1901.
South African Republic	$78,070,761			
United States	65,082,430			
Australasia	62,294,481			
Russia	24,734,418			
Mexico	8,236,720			
British India	7,765,807			
China	6,641,190			
Colombia	3,700,000			

South African deposits.[‡]

Though long known, the gold deposits of the Transvaal have been worked only since 1886.

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[*] Age of the auriferous gravels of Nevada. By W. Lindgren. Jour. Geol., 1896, IV, 881

[†] Dredging for gold in southern rivers. Eng. and Min. Jour., 1897, LXIII, 211–212.

A practical treatise on hydraulic mining. By Aug. J. Bowie, Jr. New York, 1893.

Notes on gold dredging. By J. B. Jacquet. Mineral Resources [of New South Wales], No. 3 Sydney, 1898.

Recent gold dredges. Eng. and Min. Jour., Dec., 1898, LXVI, 728–9.

[‡] The deposition of gold in South Africa. By S. Czyszkowski. Amer. Geologist, 1896, XVII, 306–323.

The gold mines of the Rand. By F. H. Hatch and J. A. Chalmers. London and New York, 1895. (306 pp.)

Diamonds and gold in South Africa. By Theo. Reunert. Johannesburg, 1893.

The Witwatersrand gold field and its working. By L. de Launay. Eng. and Min. Jour., June, 1897, LXIII, 631, 659.

The Witwatersrand gold fields, banket and mining practice. By S. J. Truscott. London and New York, 1898.

Les mines d'or du Transvaal. Par L. de Launay. Paris, 1896.

Auriferous conglomerate of the Transvaal. By G. F. Becker. Amer. Jour. Sci., March, 1898, V, 193–208.

The gold yield of the Witwatersrand fields increased from about $400,000 in 1887 to $73,677,000 in 1898.

Gold in quartz conglomerate beds, occasionally broken by faults or dikes.

Simplicity of geologic structure as compared with other gold fields.

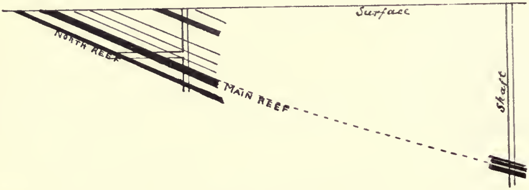

Fig. 85.—Section through shafts in the Rand gold field showing the structure and continuation of the beds at great depths. (Hatch and Chalmers.)

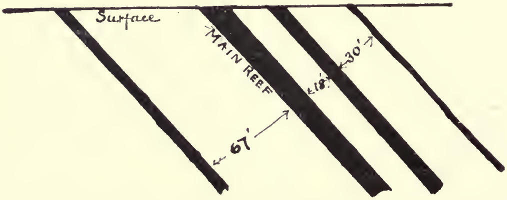

Fig. 86.—Section of the Glencairn property in the Rand, showing portions of the four reefs or bedded ore deposits. (Hatch and Chalmers.)

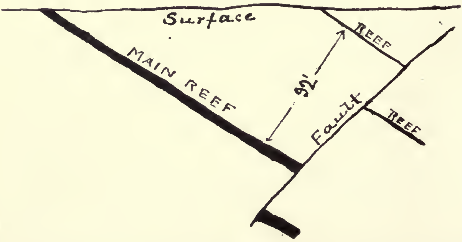

Fig. 87.—Section across the reefs of the Rand showing the faulting. (Hatch and Chalmers.)

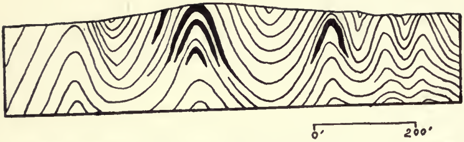

Fig. 88.—Section across saddle-reef folds at Hargreaves, New South Wales. The black areas represent the ores. (Watt.)

*Australasian gold fields.**

- The gold-producing colonies in the order of output.
  - Victoria, New Zealand, New South Wales, Queensland, West Australia, Tasmania, and South Australia.
- Veins and lodes are called "reefs."
- "Saddle reefs" in the Bendigo fields of Victoria and in the Hargreaves fields of New South Wales.

Fig. 89.—Section across anticlinal and synclinal saddle reefs at Tambaroora, N. S. Wales. (Watt.)

Fig. 90.—Section of a "saddle reef," or iode, New Chum Consolidated mine, Bendigo gold field, Victoria, Australia. (Schmeisser.)

Gold in Russia.†

Gold regions of the United States.

- The Appalachian region.
  - Gold was first discovered in the United States in 1799 in North Carolina.
  - Between 1843 and 1848 the annual production was near $2,000,000.
  - Gold occurs in quartz veins, in slates, gneiss, and schists, and in the residual clays derived from these rocks. Rocks Archean or lowest Paleozoic.

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* The genesis of certain auriferous lodes. By John R. Don. Trans. Amer. Inst. Min Eng., 1897, XXVII, 564–668; 993–1003.

The gold fields of Australasia. By K. Schmeisser. London, 1898.

Mining and milling gold ores in western Australia. By H. C. Hoover. Eng. and Min. Jour., Dec., 1898, LXVI, 725–726.

† The gold placers of Siberia. Eng. and Min. Jour., Jan., 1897, LXIII, 90.

The industries of Russia. IV, Mining and metallurgy. By A. Keppen. St. Petersburg, 1893.

Fig. 91.—Section through the Bendigo gold fields, Victoria, Australia, showing the saddle reefs. (Schmeisser.)

Gold is mined in Virginia, N. Carolina,* S. Carolina, Georgia.†

The Rocky Mountain district.

Colorado.‡

Gilpin county: gold with pyrites in fissure veins through gneiss.

Boulder county: gold as telluride ores, in small veins, along fault planes, in granite or gneiss, associated with porphyry.

Clear Creek county: gold in fissure veins through granitic rocks.

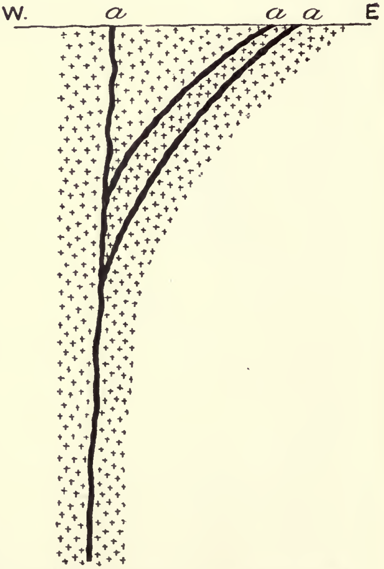

Fig. 92.—Vertical section showing the forking of the Pike's Peak vein, Cripple Creek district, Colorado. (Penrose.)

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* Gold mining in North Carolina and adjacent southern Appalachian regions. Bulletin 10, Geol. Survey of North Carolina. Raleigh, 1897.

† Gold deposits of Georgia. By Yeates, McCallie and King. Bulletin 4, Geol. Survey of Georgia, 1896.

Gold mining in Georgia. By William Tatham. Jour. Franklin Institute, July, 1898, CXLVI, 19–26.

‡ Geology of Colorado and western ore deposits. By Arthur Lakes. Denver, 1893.

Lake county: the Leadville district is in this county; gold in limestone associated with porphyry, in porphyry dikes, in veins through granite, and in placers.

Teller county: the Cripple Creek region;* ore native gold, and tellurides in fissures and associated with dikes. The country rocks are eruptives. (Figs. 92–97.)

San Miguel county: Telluride district.†

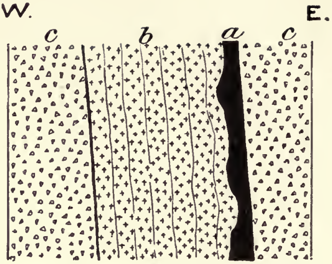

Fig. 93.—Section in the Elkton mine, Cripple Creek district, showing the relation of the vein *a* to the dike *b* and to the country rock *c*. (Penrose.)

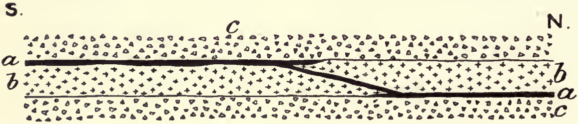

Fig. 94.—Horizontal section in the Elkton mine, Cripple Creek district, Colorado, showing the relation of the vein *a* to the dike *b* and to the country rock *c*. (Penrose.)

Fig. 95.—Section in the Victor, Smuggler Lee, and Buena Vista mines, Cripple Creek district, showing the parallel ore-bodies (*a*). (Penrose.)

Fig. 96. — Another section showing the form of the ore-body in the Victor, Smuggler Lee, and Buena Vista mines, Cripple Creek district, Colorado. (Penrose.)

Fig. 97.—Section showing the forms of the vein in the Blue Bird mine, Cripple Creek district. The ore is shown black, *b* is the country rock. (Penrose.)

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* Geology and mining industries of the Cripple Creek district, Colorado. By W. Cross and R. A. F. Penrose, Jr. Sixteenth ann. rep. U. S. Geol. Survey, pt. II, 1–209. Washington, 1895.

† Mining industries of the Telluride quadrangle. By C. W. Purington. Eighteenth ann. rep. U. S. Geol. Survey, pt. III, 751–848. Washington, 1898.

Wyoming and South Dakota: the Black Hills region.

Gold in schists, in Cambrian sandstones, in segregation veins, and in placers of Pleistocene age.

Montana.

Silver Bow county: gold in placers near Butte.

Deer Lodge county: gold in placers and quartz veins; also in granite, where silver in large quantities is often associated with it.

Lewis and Clarke county: gold in placers, near Helena, and in quartz veins through granite and slate.

Fergus county: gold chiefly in deposits associated with igneous rocks.*

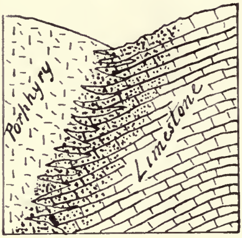

Fig. 98. — Diagrammatic section showing the contact of porphyry and limestone and the zone of ore deposition, Maginnis mine, Judith Mountains, Montana. (Weed and Pirsson.)

Idaho.†

Boisé county: placers developed in 1863.

Alturas county: gold associated with silver in quartz veins.

The Great Basin region.

Utah.

Salt Lake county: Bingham Cañon; gold associated with silver in bedded quartz veins.

Mercur district:‡ in the Oquirrh Range, Utah.

Gold (probably originally deposited as telluride) occurs native (where altered by weather) and as tellurides, in altered limestones, mostly along the under sides of thin intruded porphyry sheets, but sometimes in the porphyries themselves, and in the limestones immediately above them.

The ores were deposited by agencies ascending along fracture planes.

The rocks of the locality are Lower and Upper Carboniferous sandstones and limestones, aggregating 12,000 feet in thickness; they are exposed along a low anticlinal arch. (Spurr.)

Nevada.

White Pine county: Egan Canyon; gold with silver occurs in quartz vein traversing slate.

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* Geology and mineral resources of the Judith mountains of Montana. By Weed and Pirsson. Eighteenth ann. rep. U. S. Geol. Survey, pt. III, 589–616. Washington, 1898.

† The mining districts of the Idaho basin and the Boisé ridge, Idaho. By W. Lindgren. Eighteenth ann. rep. U. S. Geol. Survey, pt. III, 625–719. Washington, 1898.

‡ Economic geology of the Mercur mining district. By J. Edward Spurr, with introduction by S. F. Emmons. Sixteenth ann. rep. U. S. Geol. Survey, II, 343–455.

The Comstock lode:* gold with silver, in a great quartz vein, with country rock of diorite and diabase. Ore in rich masses, bonanzas. Proportion of gold to silver, 2:3.

The Pacific Slope region.

California.†

- Gold occurs:
    - In quartz veins in slates of Devonian and Carboniferous, but found mostly in Triassic and Jurassic rocks.‡
    - In placers derived from the quartz veins.
        - River gravels.§
        - High gravels.
            - Origin and age of the high gravels.‖
- Extent of the California gold fields.
- The mother lode.¶
- Methods of mining.
    - Quartz mining.
    - Hydraulic mining.
    - River and bar mining.
    - Dredging.

Oregon.

- Gold in quartz veins and placers, as in California.
- At Port Orford gold occurs in beach sands.

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* Geology of the Comstock lode and the Washoe district. By George F. Becker. Monograph III, U. S. Geol. Survey. Washington, 1882.

Comstock mining and miners. By E. Lord. Monograph IV, U. S. Geol. Survey. Washington, 1883.

† California mines and minerals. Published by the California Miners' Association. San Francisco, 1899.

‡ Characteristic features of California gold quartz veins. By W. Lindgren. Bulletin Geol. Soc. Amer., VI, 221-240. 1895.

Gold ores of California. By H. W. Turner. Amer. Jour. Sci., June, 1894, CXLVII, 467-473.

Further notes on gold ores of California. By H. W. Turner. Amer. Jour. Sci., May, 1895, p. 374.

Gold quartz veins of Nevada City and Grass Valley districts, California. By W. Lindgren. Seventeenth ann. rep. U. S. Geol. Survey, pt. II, 1-864. Washington, 1896.

§ The auriferous gravels of the Sierra Nevada of California. By J. D. Whitney. [Cambridge], 1880.

Mineral resources of the United States west of the Rocky Mountains. By J. Ross Brown. Washington, 1868.

Ancient river beds of the Forest Hill divide. By R. E. Brown. State Mining Bureau [Calif.], 1890, pp. 435-465; also 1880-82, pp. 133, 190.

The auriferous gravels of California. By J. H. Hammond. Ninth rep. State Mineralogist [Calif.] for 1889, pp. 105-138.

Auriferous gravels of the Sierra Nevada. By H. W. Turner. Amer. Geologist, XV, June, 1895, p. 371.

The gold regions of California are shown on U. S. Geol. Survey folios: 3, Placerville; 5, Sacramento; 11, Jackson; 15, Lassen Peak; 17, Marysville; 29, Nevada City; 37, Downieville; 41, Sonora; 51, Big Trees.

‖ Old river beds of California. By J. Le Conte. Amer. Jour. Sci., 1880, CXIX, 176.

Ancient channel system of Calaveras county. By W. H. Storms. State Mining Bureau [Calif.], 1893-94, pp. 482-492.

¶ Geology of the Mother Lode gold belt. By H. W. Fairbanks. Amer. Geol., 1891, VII, 209-222. Tenth ann. rep. State Mineralogist [of California], 1890, pp. 23-90. Eng. and Min. Jour., 1896, LXII, 248.

The mother lode of California. By Ross E. Brown. California Mines and Minerals, 57-72. San Francisco, 1899.

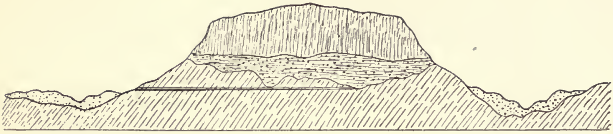

Fig. 99.—Section through Table Mountain, Tuolumne county, Cal., showing old river auriferous gravels covered by a bed of lava, and the method of tunneling to reach them. At the sides are shown river gravels of later age.

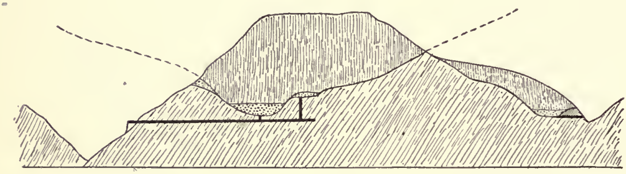

Fig. 100.—Section through the Red Point and Damm channels from El Dorado canyon (right) to Humbug canyon, California, showing the auriferous gravels covered by lava, and the method of reaching them by tunneling. The dotted lines at the sides suggest the ancient outlines of the hills.

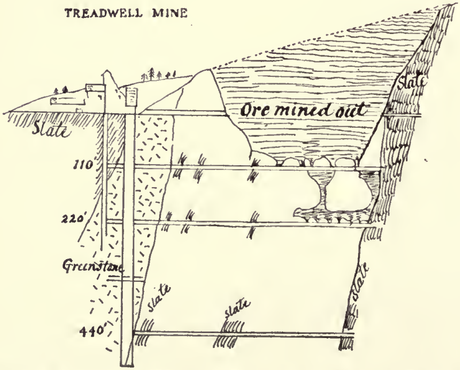

Fig. 101.—Section through the Alaska-Treadwell mine, Douglas Island, near Juneau, Alaska.

- Washington.
  - Gold has been mined from placers.
- Alaska.*
  - Placer deposits and quartz veins.
  - Cape Nome beach placers.†
  - The Juneau district. (Fig. 101.)
- Michigan.
- The gold production of the most important gold States.
- Statistics.‡
- Effect of silver legislation on gold production.

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* Geology of the Yukon gold district, Alaska. By J. E. Spurr. Eighteenth ann. rep. U. S. Geol. Survey, pt. III, 101–392. Washington, 1898.

Reconnaissance of the gold fields of southern Alaska. By George F. Becker. Eighteenth ann. rep. U. S. Geol. Survey, pt. III, 1–86. Washington, 1898.

† The new gold fields at Cape Nome, Alaska. By Ivan Brostrom. San Francisco. 1899.

Cape Nome gold district. By F. C. Schrader. Nat. Geogr. Mag., Jan., 1900, XI, 15–23.

Eng. and Min. Jour., Dec., 1899, LXVIII, 727.

‡ Statistics and technology of the precious metals. By Emmons and Becker. Tenth Census, vol. XIII. Washington, 1885.

Notes on Nome Alaska by
P. H. Travis, Engineering and
Mining Journ. Jan. 27, 1900,
p. 105-6

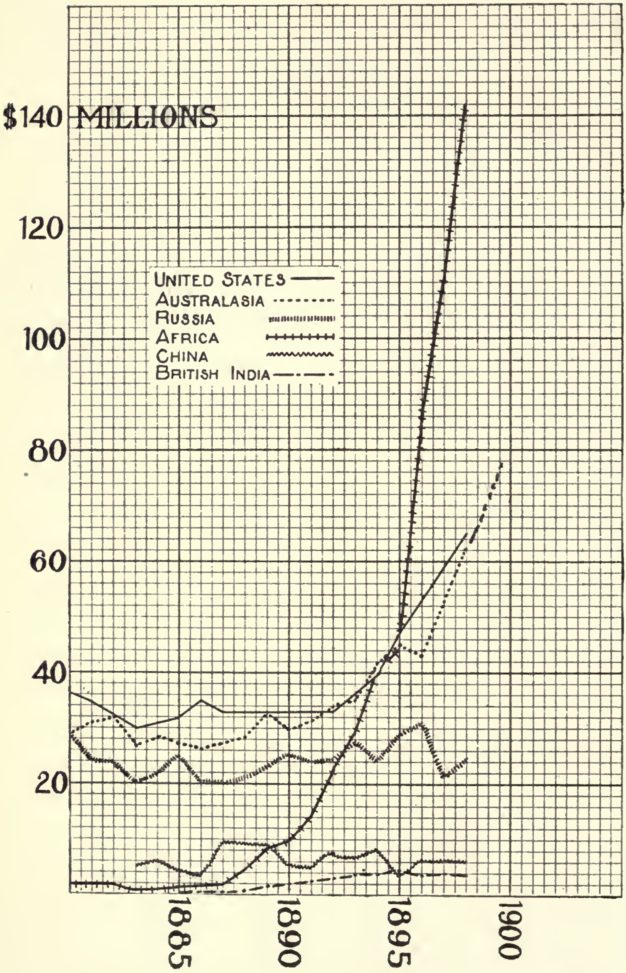

Fig. 102.—The gold yield of the chief gold-producing countries since 1880.

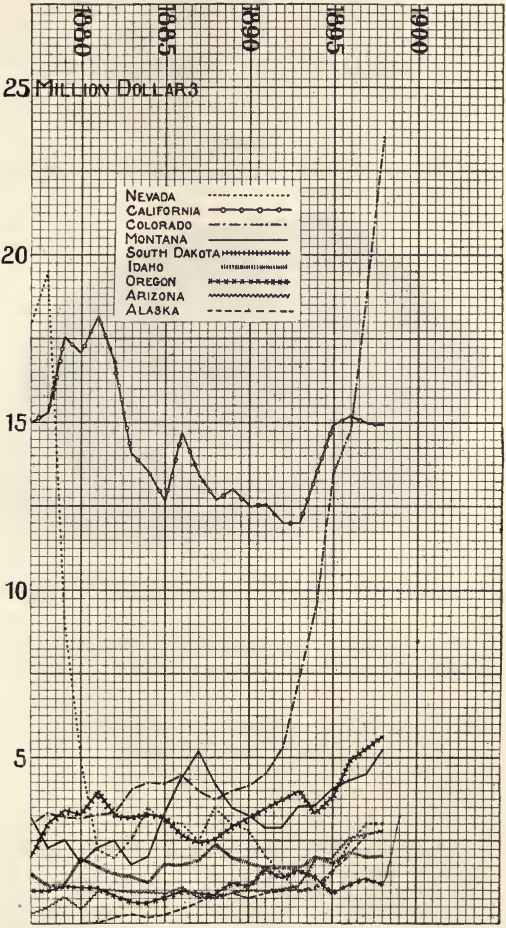

Fig. 103.—The comparative gold production of the several States since 1882.

METALS OF THE PLATINUM GROUP.

Platinum.*

Platinum is a rare metal; it is heavy, silver-white, ductile, and fusible only at a very high temperature (1779° C.).

Fig. 104.—The largest platinum nugget ever found in America. Natural size, 3″x 2¾″; weight, nearly two pounds; from the west coast of South America. (Baker & Co., Newark, N. J.)

Uses.

It was used for coinage in Russia from 1828 to 1845.

In chemical, electrical, and surgical apparatus.

Ores.

Native platinum occurs alloyed with the other metals of the platinum group. It is often associated with gold.

Sperrylite ($PtAs_2$).

Treatment.

Occurrence.

It is usually mined from placers, where it is often found associated with gold.

At the Gongo Soco mines of Brazil it was taken with gold from decayed shistose rocks.

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* Bibliography of the metals of the platinum group, 1748–1896. By J. L. Howe. The mineral industry, vol. I, 373–397. New York, 1893.

Distribution.

Platinum is mined at but few places in the world. Most of the world's supply comes from the Ural Mountains of Russia.*

Borneo, Australia, Colombia, and British Columbia all supply small amounts. Brazil formerly furnished a considerable quantity.

Discovery reported in New South Wales.†

The gold mines of California yield some platinum.

Statistics.

Iridium.

Iridium is a rare metal, extremely hard, lustrous, and steel-white. It has a very high melting point, and is not attacked by any single acid.

Uses.

In alloys: standard weights and measures.

As a coloring matter in photography, ceramic art, and jewelry.

In pointing gold pens, fine tools, and in the knife-edges of delicate balances.

Iridium plating.

Occurrence.

Iridium is found as iridosmine (alloy of iridium with osmium) associated with platinum, in Colombia, province of Choco; in the Urals of Russia; in Australia; it is found also in the gold-bearing beach sands of northern California. Iridium occurs alloyed with platinum.

Very little iridium is used, the world's production being but a few tons annually.

Osmium.

Osmium is the heaviest and most difficultly fusible metal known (never been fused).

Uses.

It is used in the form of iridosmine for pointing pens and fine tools.

Occurrence.

Osmium occurs alloyed with iridium (iridosmine), and alloyed with platinum.

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* Daubrée: On platinum in the Urals. Comptes Rendus de l'Academie des Sciences, 1875, LXXX, 707–714.

The platinum deposits of the Tura river-system, Ural mountains, Russia. By C. W. Purington. Trans. Amer. Inst. Min. Eng., Feb., 1899, XXIX. Eng. Ming. Jour., March 25, 1899, LXVII, 350–351.

Sur l'industrie de l'or et du platine dans l'Oural. Par M. Laurent. Annales des Mines, Nov., 1890.

† Eng. and Min. Jour., Feb. 22, 1896, LXI, 182; Aug. 8, 1896, LXII, 126, 220; April, 3, 1897, LXIII, 333.

The occurrence of platinum in New South Wales. By J. B. Jacquet. Records of the Geol. Survey, V, pt. I, 33–38. [1896.]

Palladium.

Palladium is ductile and malleable; it is a whitish steel-gray metal with metallic lustre.

Uses.

For finely graduated scales.
Compensating balance wheels and hair springs for watches.
Some mathematical and surgical instruments.

Occurrence.

Palladium occurs alloyed with platinum and iridium.

TUNGSTEN.

Tungsten is never found in the native state, and the pure metal is seldom produced artificially.

Uses.

Ferro-tungsten. Tungsten added to steel in small proportion (2 to 12 per cent.) gives greatly increased hardness and brittleness.*

As a mordant.

Ores.

Wolframite (FeO 19.16, MnO 4.96, WO_3 75.88, individual analysis).

Scheelite, calcium tungstate (CaO 19.4, WO_3 80.6).

Occurrence.

Tungsten is usually found associated with deposits of tin; it is found at many places, but is produced at few. Cornwall, Saxony, Bohemia, Australia, and New Zealand produce practically all the tungsten of commerce. The total production of Europe in 1892 was 263.3 tons.

In New South Wales.†

Tungsten is not produced in the United States. It occurs, and attempts have been made to work it, in Connecticut at Monroe and Trumbull, and in Maine near Blue Hill Bay. It has been found elsewhere, but no attempts at mining have been made.

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* Alloys of iron and tungsten. By F. L. Garrison. Sixteenth ann. rep. U. S. Geol. Survey, pt. III, 615–623. Washington, 1895.

Relative resistance of tungsten and molybdenum steel. By R. Helmhacker. Eng. and Min. Jour., Oct. 8, 1898. LXVI, 430.

† Tungsten ores in New South Wales. By J. E. Carne. Mineral Resources [of N. S. Wales], no. 2. Sydney, 1898.

MOLYBDENUM.*

Molybdenum is a white metal with a silvery lustre; it is as malleable as iron; its sp. gr. is 9.01.

Use.

Principal use is in the manufacture of molybdenum steel.

Ores.

Molybdenite, the sulphide (MoS_2 = Mo 59, S 41), is the principal source of supply; it is lead gray in color, very soft, and greatly resembles graphite.

Wulfenite ($Pb\ Mo_4$ = MoO_3 39.3, PbO 60.7).

Modes of occurrence.

Molybdenum does not occur in the native state.

Molybdenite usually occurs as disseminations or veins in granite or gneiss.

Distribution.

The metal is produced in commercial quantities in but few places.

In the United States: 9,550 lbs. of the metal, valued at about $1.25 per lb., were produced in 1898; 2,000 lbs. ferromolybdenum (50% Mo) were produced the same year. New Mexico and Arizona are the sources of supply.

Formerly the chief supply of the world has come from Sweden.

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* The mineral industry, vol. VI, 485-486; vol VII, 514-516.

ANTIMONY.

Antimony: metal with a tin-white color, crystalline structure, and very brittle; it fuses at a low temperature (430° C.).

Uses.

- Medicine.
- Pigments, q. v.
- Alloys:
  - Alloyed with other metals, antimony gives a hard and brittle product.
  - Type-metal is an alloy of antimony with lead and bismuth; when less than 15 per cent. antimony is used the product expands on cooling.
  - Babbitt metal is an alloy of tin with antimony and copper (Sn 83 per cent., Cu and Sb 17 per cent.).
  - Pewter is an alloy of lead and tin with antimony, bismuth, or copper.
  - Britannia metal is an alloy of tin with antimony and other metals.

Ores.

- Stibnite (Sb 71.4, S 28.6).
- Senarmontite (Sb 83.3, O 16.7).
- Kermesite (Sb 75.0, S 20, O 5).
- Stibnite is the most important. It is soft, has a metallic steel-gray color, and will melt in a candle flame.

Occurrence.

Antimony usually occurs in veins with a quartz gangue.

Distribution.

- The principal antimony-producing countries of Europe are those adjacent to the Mediterranean.
- France is the most important antimony producer in the world: annual output about 5,000 tons.
- Portugal, Spain, Austria-Hungary, Italy, Asia Minor, Servia, and Macedonia all produce some.
- Borneo and Japan are large producers: annual output from 3,000 to 4,000 tons.
- Other regions are Australia, Nova Scotia, New Brunswick.

Antimony of the United States.[*]

Antimony is found in many localities in the United States, but little is mined.

Arkansas. (Antimony City.)[†]

Stibnite in the southwestern part of the State in bedded quartz veins in Carboniferous sandstones and shales.

California. (Inyo, San Benito, and Kern counties.)

Ore: Stibnite in veins with quartz gangue.

Nevada. (Near Austin, Lander county.)

One of the most important American localities; ore occurs as a small vein of almost pure stibnite.

In Humboldt county stibnite occurs in quartz veins.

Utah. (Iron county.)

Stibnite is disseminated through sandstone and conglomerate, following the stratification.

Montana. (Near Thompson's Falls.)

Relative importance.

Nevada is the most important producer in the United States.

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[*] Antimony. By W. P. Blake. Mineral Resources of the U. S., 1883–84, pp. 641–653. The mineral industry. Vol. II, 13–24. New York, 1894.

[†] Geology of western central Arkansas. By T. B. Comstock. Ann. rep. Geol. Survey of Ark., vol. I for 1888, pp. 136–144.

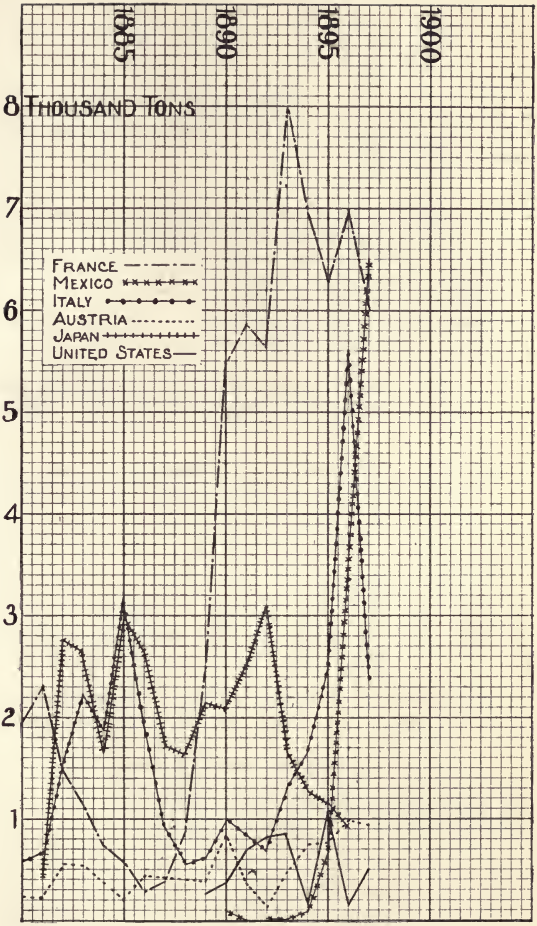

Fig. 105.—The antimony ores of the chief producing countries since 1880.

BISMUTH.*

Bismuth is white with a red tinge, very brittle, melts at 264° C. and expands on solidifying.

Uses.

Its principal use is as an alloy; its alloys melt at extremely low temperatures and expand upon solidification.

Alloys of bismuth, lead, and tin fuse at very low temperatures.

- Newton's fusible metal (melts at 94.5° C.).
- Darcet's metal (melts at 93° C.).
- Rose's metal (melts below 100° C.).
- Lipowitz's metal (contains cadmium and melts at a little over 60° C.).

The alloys are used for making safety plugs in boilers, for which they are untrustworthy, and for automatic fire plugs in buildings.

Ores.

Bismuth often occurs native in crystalline rocks and slates, and associated with cobalt and nickel, and with silver and gold. Most of it is derived from the native metal.

Distribution.

Most of the bismuth of commerce comes from Saxony, Australia, Peru, and Bolivia.

United States.

- Bismuth occurs frequently in the Rocky Mountains with silver ores, but the deposits have so far proved of no commercial importance.
- The best known localities are: Colorado, the Bismuth Queen lode, near Golden; Utah, west of Beaver City; Arizona, near Tucson.
- In 1885 the United States produced only about one ton of bismuth.

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* Notes on the occurrence of bismuth ores in New South Wales. By J. A. Watt. Mineral Resources [of N. S. Wales], no. 4. Sydney, 1898.

CADMIUM.*

Cadmium is a ductile, malleable metal, somewhat harder than tin, with a tin-white color. When fresh it has a brilliant lustre, but dulls from oxidation upon exposure to the air. It melts at about 320° C.

Uses.

It is used as a metal only in alloys which fuse at very low temperatures.

Lipowitz's metal (60° C.).

Wood's metal (melts at about 66° C.).

As a pigment, cadmium sulphide gives various shades of yellow.

Occurrence.

Cadmium is not found native, but occurs very generally with the ores of zinc, from which the metal of commerce is derived.

Yellow smithsonite called "turkey-fat" contains cadmium.

Distribution.

The cadmium of commerce is produced in Silesia. The output in 1892 was about 6,600 metric tons.

In the United States it is sometimes found with the zinc ores of Missouri, Kansas, Arkansas, and Pennsylvania as yellow zinc carbonate known as "turkey-fat."

The price of cadmium in New York is from $1.50 to $2.00 per pound (January, 1900).

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* Zinc and cadmium. By W. R. Ingalls. Mineral industry, 1898, VII, 723-750.

ARSENIC.*

Arsenic is a brittle, grayish-white metal, that tarnishes easily; it is seldom found native.

Uses.

Medicine, as tonics.
(Arsenic compounds are poisonous.)
Insecticides.
In preservatives of wood and biological specimens.
Alloyed with lead for shot.
As a pigment: many of the green colors contain arsenic.

Ores.

The principal ores of arsenic are: Realgar (As 70.1, S 29.9); Orpiment (As 61.0, S 39.0); Mispickel (As 46.0, Fe 34.3, S 19.7).
There are also arsenides of iron, nickel, cobalt.
Mode of treatment.

Distribution.

Arsenic occurs extensively, but seldom in sufficient quantities to mine with profit. Cornwall and Devonshire are the principal producers of arsenic at present. It is also produced in Saxony and Bohemia and has been produced at Deloro, Ontario, where it occurs in gold-bearing mispickel.

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* The mineral industry. Vol. II, 25-36. New York, 1894.

The treatment of gold-bearing arsenical ores at Deloro, Ontario, Canada. By R. P. Rothwell. Trans. Amer. Inst. Min. Eng., 1882, XI, 191-196.

MERCURY (QUICKSILVER).

Quicksilver is a lustrous, tin-white metal which differs from the other metals in being a liquid at ordinary temperatures; it becomes solid at -40^0 F.

Uses.

- In forming amalgams.
  - The amalgamation process in extracting gold and silver.
  - In silvering mirrors.
- In medicine.
- In thermometers and mercurial barometers.
- As a pigment, especially in China.

Ores.

- Quicksilver occurs native, usually in liquid globules scattered through the gangue, but sometimes in cavities in quantities large enough to be dipped up.
- Cinnabar, mercuric sulphide (Hg 86.2, S 13.8), is the most important ore; most of the quicksilver of commerce is supplied from it.
- Native amalgam of mercury with silver.
- There are several other combinations of mercury, but they are of little importance as ores.

Modes of occurrence.

- In veins, irregular masses, and impregnations. Confined to no particular kind of country rock. The principal deposits occur in regions of great disturbance, and of former igneous activity and are newer than the enclosing rock.
- All, or nearly all, are contact deposits made by sublimation, or from the solution of dissolved mercury.

Distribution.

- Geologic.
  - Quicksilver deposits are confined to no particular horizon; the deposits of Almaden, Spain, are in Silurian rocks; those of New Almaden, California, are in rocks supposed to be of Jurassic age.
- Geographic.
  - Although quicksilver has a wide distribution, practically all of the metal of commerce is supplied from a few localities; the most important, with their production in metric tons for 1898, are:

Spain (Almaden) 1,852.
United States (California) 1,165.
Austria (Idria) 544.
Russia 398.
Mexico 389.
Italy 187.

China and Peru also produce quicksilver.

Spain.

The Almaden mines of Spain are the most important in the world. The ore is cinnabar, in three parallel vein-like beds standing nearly vertical, approximately parallel to the strike of country rocks of interstratified Upper Silurian slates and sandstones. The average thickness of the ore deposits is about 20 ft. The deposits at Almaden are very persistent and of even richness.

Austria.

Idria. Ore: some native metal, but mostly cinnabar; in veins, reticulated masses, and impregnations; in Triassic schists, limestones, and sandstones. Gangue materials: quartz, calcite, dolomite. The ore becomes richer as the depth increases.

Italy (Vallalta region).

Ore is cinnabar in impregnations and stringers at the contact of Triassic rocks and quartz porphyry.

Russia.

Cinnabar is found in the gold-mining regions of the Urals, and at other places.

China.

Cinnabar has been produced in great quantities from Kai-Chau.

Peru.

Huancavelica district. The ore is cinnabar in almost vertical Jurassic rocks. Ore thought to be sublimed.

Quicksilver is known to occur in many other foreign countries, but they are not producers.

*Quicksilver of the United States.**

Quicksilver occurs in California, Oregon, Utah, Nevada, but only in California have the deposits proved of much commercial importance.

California. All of the quicksilver deposits of California are found in the Coast Range.

New Almaden, after the Almaden region of Spain, has been the most important quicksilver region of the world.

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* Geology of the quicksilver deposits of the Pacific Slope. By Geo. F. Becker. Monograph XIII, U. S. Geol. Survey. Washington, 1888. (Contains bibliography.)

Ore is cinnabar, with some native metal, in chambered veins; reticulated masses and impregnations in the country rock; gangue of quartz, calcite, and dolomite.

Two principal fissures unite at a depth enclosing a wedge-shaped mass of country rock, which has ore-bearing channels through it.

New Idria (Fresno county).

Ore: cinnabar, in reticulated masses, in impregnations, and in fissure veins. Country rock mostly much fissured metamorphosed sandstones and shales.

Veins apparently still filling.

Near Clear Lake and south of it there are numerous quicksilver deposits.

Sulphur Bank. Ore: cinnabar associated with sulphur below the zone of oxidation; in shattered rock masses and as impregnations.

Great Western mine.

Ore in "tabulated masses" at contact of altered sandstone and serpentine.

Great Eastern mine (Sonoma county).

Ore in an irregular pipe, or chimney deposit, in opalized rock.

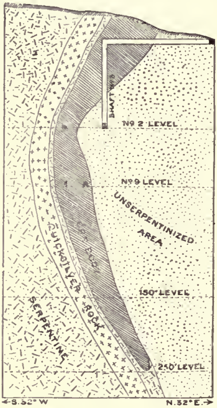

Fig. 106.—Vertical section through shaft No. 3, Great Western quicksilver mine, Lake county, California. (Becker). Scale, 200 feet to 1 inch.

Oregon.

Quicksilver occurs in the Cascade Mountains.

Nevada.

Steamboat Springs. Cinnabar as impregnations through decomposed granite, in connection with hot springs.

Statistics usually given in flasks of 76½ pounds.

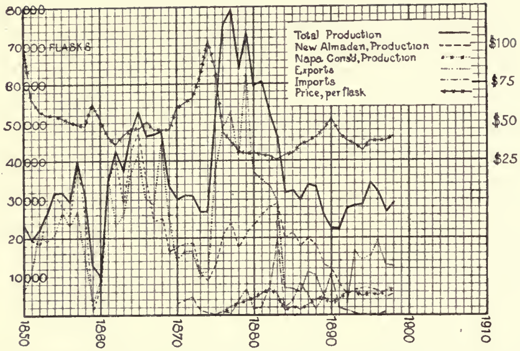

Fig. 107.—Statistics of the price, production, exports, and imports of quicksilver in the United States since 1850, in flasks of 76½ pounds.

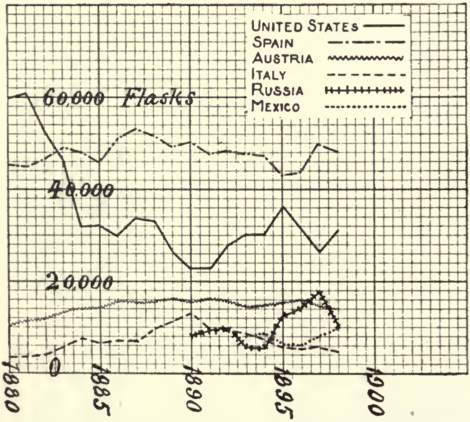

Fig. 108.—The quicksilver production of various countries since 1880.

PRECIOUS STONES.*

Precious stones are no particular kind of stones; the value of those used as such is a matter of fancy and fashion.

Interest in precious stones; amount invested by individuals in the United States.

Essential qualities of precious stones are hardness, beauty of color, and rarity.

Examples:

Diamond, h. 10.
Oriental ruby, h. 9.
Oriental emerald, h. 9.

Diamonds.

Uses.

Brilliants.
Glass cutting.
Polishing (powder).
Diamond drills of bort or *carbonado.*

Occurrence and origin.†

Diamonds are crystals of pure carbon.
In placers, conglomerates, and rocks in place.
Theory of plant origin; graphite in Brazilian rocks.
Theory of igneous or metamorphic origin.
Method of cutting and polishing.
Common sizes; sizes of famous diamonds.
Artificial production of diamonds.‡
Diamonds found in commercial quantities only in India, Borneo, Brazil, and South Africa.

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* Precious stones and gems: their history, sources, and characteristics. By E. W. Streeter. Fifth ed. London, 1892.

Gems and precious stones of North America. By George F. Kunz. New York, 1892.

The production of precious stones in 1898. By G. F. Kunz. Twentieth ann. rep. U. S. Geol. Sur., pt. VI, 1-50. Washington, 1899.

The production of precious stones in 1898. By G. F. Kunz. Twentieth ann. rep. U. S. Geol. Survey, pt. VI, 1-50. Washington, 1899.

† Brazilian evidence on the genesis of the diamond. By O. A. Derby. Jour. Geol., 1898, VI, 121-146.

Diamonds. By Wm. Crookes. Nature, Aug. 5, 1897, LVI, 325-331.

Occurrence and origin of diamonds in California. By H. W. Turner. Amer. Geol., March, 1899, XXIII, 182.

Amer. Naturalist, April. 1884, XVIII, 418. Min. Mag., V, 199.

‡ Amer. Jour. Sci., March, 1897, III, 243.

Annales de Chimie, 7me ser, 1896, VIII, 466.

Comptes Rendus, 1896, CXXIII, 206, 210; CXIII, 277.

Jour. Franklin Institute, Sept., 1898, CXLVI, 236-237.

*India.**

The Indian mines the oldest known diamond mines. They supplied Europe until the discovery of diamonds in Brazil, about 1729.

The mines are all south of the Ganges.

The most famous mines are those of Parteal, near Golconda, the old diamond market, and of Panna.

The stones are found in two deposits: (1) in a conglomerate at the base of the Karnul beds (pre-Cambrian); (2) in recent stream deposits derived in part from the conglomerate.

The Karnul conglomerates and their diamonds are derived from earlier rocks; Indian diamonds not known to have been found in their original matrix.

Method of working the conglomerates.

Relations of structure to the occurrence of diamonds.

Possibilities of improved methods of work.

Borneo.

Diamonds have been found in several islands of Oceanica, but Borneo has been the only one to produce them in quantity.

They are found there mostly in river gravels overlying Tertiary, and in smaller quantities in rocks in place. The rocks of the region are schists, granites, and other igneous rocks.

1836 to 1848 yield averaged $36,179 worth per year.

1876 to 1880 yield averaged $63,750 worth per year.

Brazil.†

Diamonds discovered in the gold mines in 1727 or 1728.

Brazil was then a Portuguese colony; the diamond lands were appropriated by the crown and worked by contractors and later by the royal treasury.

Total production of Brazilian diamonds by the best possible estimates from 1728 to 1885, 12,000,000 carats, or about two and a half tons, and worth about $100,000,000.

Geographically the diamonds are confined to limited areas in the states of Bahia, Minas Geraes, and Matto Grosso.

Geologically they are found almost exclusively in the gravels of ancient or modern streams.

Methods of working on a small scale.

Heavy work of turning the streams.

Ancient methods used for dams, flumes, and cleaning up. Mawe's visit in 1809.

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* The diamond in India. By R. F. Burton. Quar. Jour. Sci., XIII, 351–360. London, 1876.

A manual of the geology of India, pt. III, economic geology, pp. 1–50. By V. Ball. Calcutta, 1881.

† Travels in the interior of Brazil. By John Mawe. Philadelphia, 1816.

Monographie du diamant. Par H. Jacobs et N. Chatrian. Paris, 1880.

Encyclopédie chimique de M. Fremy. Le Diamant. Par M. E. Boutan. Paris, 1886.

In Brazil diamond regions the rains occur for about a third of the year. The diamonds are mined from pot-holes in the stream beds by building temporary dams during the dry season + diverting the streams. Dams periodically wash away and they construct new ones each year

- Possibilities of improved methods of work.
    - Camara's use of machinery; why it failed.
- Condition of the common roads.
- Character of the labor available.
- Black diamonds (*carbonado*) found in the state of Bahia.
    - Their uses in diamond drills.
    - Demand produced by boring machines.

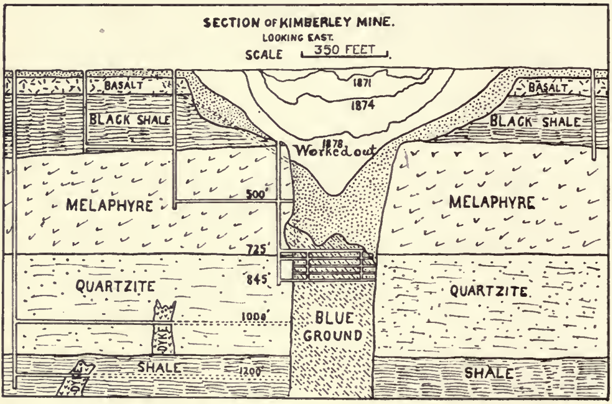

Fig. 109.—Vertical section through the Kimberly diamond mine, South Africa. (Reunert.)

South Africa.[*]

- Effect of the discovery of African diamonds in 1865 upon the other diamond mines.
- Geology: peridotite dike in Carboniferous black shales.[†]
    - Supposed influence of these rocks on the formation of the diamonds.
    - Effect of depth on African diamonds.
        - Cracking after removal.
    - The use of machinery favored by the nature of the deposits.

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[*] Africa since 1888. By G. G. Hubbard. Nat. Geogr. Mag., May, 1896, VII, 161-162.
Diamonds and gold in South Africa. By T. Reunert. Johannesburg, 1893.
The diamond mines of Kimberly. By Wm. Crookes. Nature, April 1, 1897, LV, 519-523.
Monographie du diamant. Par H. Jacobs et N. Chatrian. Paris, 1880.

[†] Parent rock of the South African diamond. By T. G. Bonney. Nature, Oct. 26, 1899. LX, 620-621.

Other Stones.

Corundum[*] (oxide of aluminium; O 47.1, Al 52.9).

Varieties of corundum differing chiefly in colors due to small amounts of metallic oxides are:

Sapphire, blue, from Burma.
Oriental emerald is a green sapphire.
Oriental ruby, red.
Topaz, yellow.
Oriental amethyst, purple.

These stones all come from Burma,[†] Ceylon, and Siam, where they occur as crystals in limestones, or derived from them by decay.

Turquois (hydrous phosphate of aluminium: water 20.6, alumina 46.8, phosphorus pentoxide 32.6; it usually contains some copper and iron).

Color from sky-blue to greenish-gray.

Oriental turquois from thin seams in igneous rocks in Persia.

Egyptian turquois changes from blue to green.

American turquois from Los Cerrillos, New Mexico; Cochise county, Arizona, about twenty miles from Tombstone.[‡]

Garnet. The precious garnet is almandite (silica 36.2, alumina 20.5, iron protoxide 43.3) and pyrope (silica 44.8, alumina 25.4, magnesia 29.8).

Several minerals are included under this head; the finest of them are from India; fire pyrope from the Kimberly diamond mines, South Africa.

Beryl. Aqua-marine, emerald, and oriental cat's-eyes are varieties of beryl. The former occur as isolated crystals and in geodes in clay slate in New Grenada; in Brazil, Hindostan, Ceylon, and Siberia.

Tourmaline. Rubellite[§] is a red variety; indicolite is a blue variety; Brazilian emerald is a green variety.

Quartz. Many beautiful gems made from quartz and from various minerals belonging to the quartz group. Extensive use of common clear quartz and gold quartz.

Under crystalline quartz belong amethyst, cairngorm, cat's-eye, false topaz, and many others.

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[*] Corundum and its uses. Nature, April, 1899, LIX, 558–559.

[†] The rubies of Burma and associated minerals. By C. B. Brown and J. W. Judd. Philosophical Trans. Roy. Soc. London, 1896, vol. CLXXXII, 151–228.

[‡] A turquois deposit in Mohave county, Arizona. By A. B. Frenzel. Eng. and Min. Jour., Dec. 10, 1898, LXVI, 697.

[§] On rubellite see The rubies of Burma. By Brown and Judd.

Turquois found only in thin streaks usually less than half an inch in thickness, Under cryptocrystalline quartz are agate (from southern Brazil),* moss agate, chalcedony, carnelian, jasper, onyx (used for cameos), silicified wood or wood-agate (Arizona).†

Opal is silica-like quartz with varying amount of water. Fire opal from Mexico.

Pearls are not stones, although grouped with precious stones commercially. "Pearls are lustrous concretions, consisting essentially of carbonate of lime interstratified with animal membrane, found in the shells of certain mollusks."—Kunz.

Probably formed about foreign bodies in the mantle.

Pearls of commerce are from bivalve shells, most of them from the pearl oyster (Meleagrina). They are furnished also by some fresh-water shells, Unio, Anadon, etc.

La Paz, Lower California, the centre of the pearl-fishery in America.‡

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* H. H. Smoth in Amer. Naturalist, Oct., 1883, XVII, 1012–1013.

On the formation of agate, see Bischof's Chemical geology, I, 53–54. London, 1854.

† Stone forest of Floressant. By Angelo Heilprin. Pop. Sci. Monthly, August, 1896, XLIX, 479.

‡ Gems and precious stones of North America. By George F. Kunz. New York, 1892.

Brazilian agates formed in cavities in lava beds.
Moss in moss-agates simply a crystaline form of manganese or other dark mineral which assumes a moss like form.

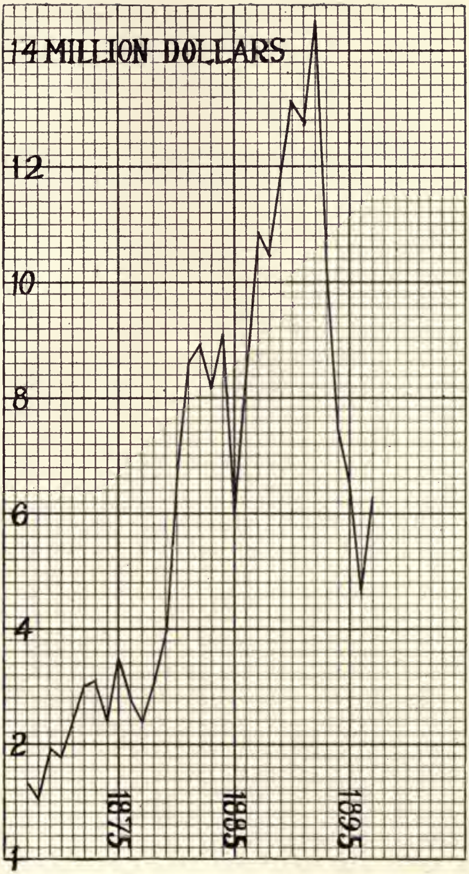

Fig. 110.—Value of the precious stones imported into the United States since 1867.

COAL.

National importance of coal.

The coal product of the United States in 1898 was capable of doing the work of 361,622,007 men working ten hours a day for 365 days in the year.

Uses of coal.

- Domestic purposes.
  - Fuel; illuminating gas.
- Steam producing.
  - Locomotives; navigation; driving machinery.
- Production of electricity.
  - Problem of converting coal into electricity directly.
- Metallurgical purposes, including coke.
  - Reduction of ores.
  - Blacksmithing.
- Exportation.
- The proportions of coal used for various purposes shown approximately by the consumption of Great Britain in 1876:
  - Domestic purposes, including gas, 10 fortieths.
  - Manufacturing and locomotion, 11 fortieths.
  - Metallurgical purposes, 15 fortieths.
  - Exportation, 4 fortieths.

The origin of coal.[*]

- The vegetable origin of coal shown by:
  - Fragments of plants in the shales above and below coal beds. In some cases the impressions contain the coal made by individual plants.
  - Microscopic plant fragments and spores through the coal.
  - Chemical composition.
  - Intergradation of peat and coal.
- The physical conditions under which coal was deposited.[†]
  - Evidence of the nature of accompanying rocks.
  - Evidence of the accompanying fossils.

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[*] On the vegetable origin of coal. By Leo Lesquereux. Ann. rep. Geol. Survey of Pa. for 1885, pp. 95–124. Harrisburg, 1886.

Observations regarding the occurrence of anthracite, with a new theory of its origin. By W. P. Gresley. Amer. Geologist, July, 1896, XVIII, 1–21.

On the origin of coal. By J. E. Bowman. Trans. Manchester Geol. Soc., 1840, I, 90–111.

[†] On the physical conditions under which coal was formed. By J. S. Newberry. School of Mines Quarterly, 1883, IV, 169–173.

Colorado possesses anthracite coal of Cretaceous ages, which was formed by the metamorphosed, rocks in which it occurs

Geologic distribution of coal.

The bulk of the world's coal comes from rocks of Carboniferous age, but it is also found in rocks of all ages except the oldest and newest.

Thin beds in the Devonian; the most important beds in the Carboniferous.

Permian coal in Australia.

Triassic coal in Virginia and North Carolina.

Carboniferous and Jurassic over a large part of China.

Cretaceous and Jurrasic anthracite in Peru.

Tertiary coal on the Pacific coast of the United States.

Geographic distribution.

The largest coal fields are those of China; they are but little known.

The greatest coal-producing countries are Great Britain, the United States, and Germany; these countries produce four fifths of the coal of the world.

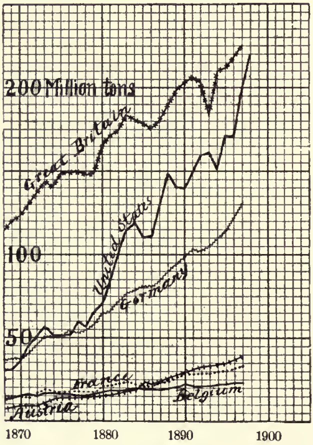

Fig. 111.—The coal production of the principal coal-mining countries since 1868.

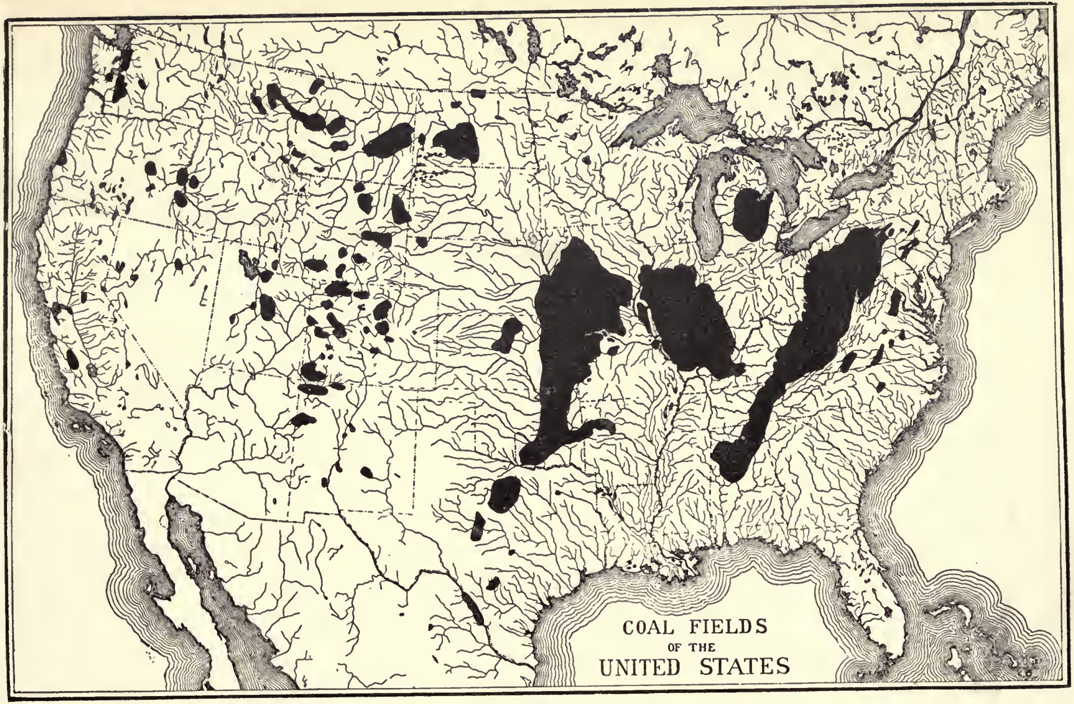

Fig. 112.

The coal deposits of North America.[*]

- The Carboniferous coals are the most abundant and most important.
  - The workable beds of Carboniferous coal cover an area of 193,000 square miles in the United States.
  - The Carboniferous geography of the United States.
  - Relations of the anthracite to the bituminous coal fields.
  - The Triassic coal of Virginia and North Carolina.
  - Coal of Cretaceous age in Colorado, Wyoming, North Dakota, Montana, and California.[†]
  - Tertiary coal about Puget Sound, in Oregon,[‡] Alaska, and in Arkansas and Texas.

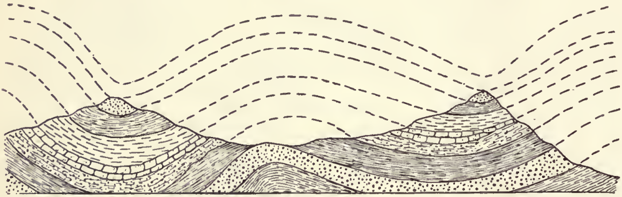

Fig. 113.—Section through synclinal hills of the coal regions left by the removal of intervening anticlinal hills. The dotted lines show the former continuation of the beds.

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[*] Geology of the coal regions of Arkansas. By Arthur Winslow. Little Rock, 1888.

Report of the geological survey of Ohio. Economic Geology, vols. V and VI. By Edward Orton. Columbus, 1884 and 1888.

Manual of coal and its topography. By J. P. Lesley. Philadelphia, 1856.

The coal regions of America. By James Macfarlane. New York, 1873.

Mining methods and appliances used in the anthracite coal fields. By H. M. Chance. (Report AC of the sec. Geol. Survey of Pa.) Harrisburg, 1883.

Report of progress in the anthracite region. By C. A. Ashburner. (Report AA of the sec. Geol. Survey of Pa.) Harrisburg, 1883.

I. The Pittsburg coal region. III. Anthracite coal region. Ann. rep. of the Geol. Survey of Pa. for 1886. Harrisburg, 1887.

The coal deposits of Indiana. By George H. Ashley. Twenty-third ann. rep. Department of Geology and Natural Resources, 1898, pp. 1–1573. Indianapolis, 1899.

[†] California and Pacific Coast coals. By Peckham and Goodyear. Geol. of California, Appendix III.

Folio 9. Anthracite—Crested Butte Folio, Colorado. Geologic Atlas of the United States. U. S. Geol. Survey, Washington, 1894.

Coal beds of California. By H. W. Fairbanks. Eng. and Min. Jour., July 4, 1896, LXII, 10.

[‡] The coal mines of the western coast of the United States. By W. A. Goodyear. New York, 1879.

Some coal fields of Puget Sound. By Bailey Willis. Eighteenth ann. rep. U. S. Geol. Survey, pt. III, 393–435. Washington, 1898.

[Coal in Oregon]. Geological reconnoissance in northwestern Oregon. By J. S. Diller. Seventeenth ann. rep. U. S. Geol. Survey, pt. I, 490–508. Washington, 1896.

Coal and lignite of Alaska. By W. H. Dall. Seventeenth ann. rep. U. S. Geol. Survey, pt. I, 771–907. Washington, 1896.

The Coos Bay coal field, Oregon. By J. S. Diller. Nineteenth ann. rep. U. S. Geol. Survey, pt. III, 309–376. Washington, 1899.

Coal field of the north Pacific Coast. By R. Brown. Trans. Edinburgh Geol. Soc., 1870, I, 305–325.

Coal resources of Washington. By T. B. Corey. Mining, I, 231–239. Spokane, 1896.

Folding and compression has produced the anthracite.

Structural features of coal regions.

Structural features of coal geology vary from nearly horizontal beds to highly folded, faulted, and eroded ones.

In the bituminous regions of the United States the beds are mostly horizontal; in the anthracite regions they are much folded; in Scotland they are extensively faulted.

- Separation of coal fields in folded areas.
- Origin of the outliers in regions of horizontal beds.
- Relations of dip and folds to development.
- Splitting of beds.
- Surface features in glaciated areas.
- Danger from pot-holes; the Nanticoke disaster.

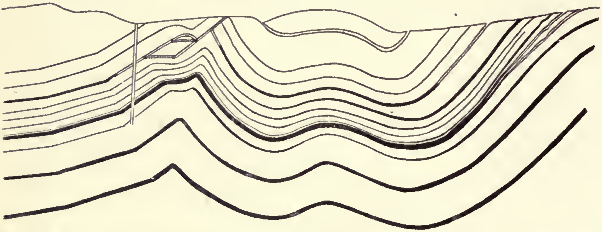

Fig. 114.—Section showing the folded coal beds of the anthracite region in Schuylkill county, Pennsylvania.

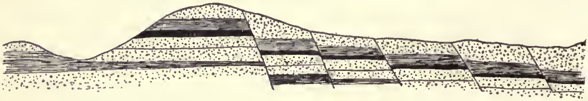

Fig. 115.—Section showing faulted coal beds in Scotland.

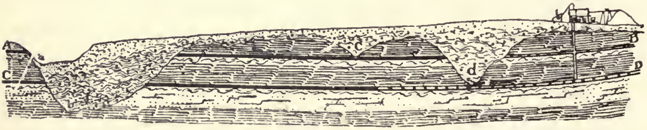

Fig. 116.—Geologic section in the glaciated part of the coal region of Indiana, showing how the outcrops are mostly concealed by drift. (Ashley.)

Rocks associated with coal.

- Conglomerates: their relations to the coal.
- Sandstones: lithologic characters not important.
- Shales: not confined to coal-bearing horizons.
- "Coal blossom."

Coal occurs in beds, not in veins, properly speaking.

COMPOSITION OF COALS.

(Individual cases.)

Quality	Water	Sulphur	Ash	Fixed Carbon	Volatile Hydro-carbon
Lignite*	12.45	0.56	12.45	35.53	39.00
	30.58	0.65	9.10	28.56	31.01
Bituminous	0.70	0.86	3.56	78.99	15.87
Semi-bituminous	0.74	4.06	9.96	72.60	12.61
Anthracite	2.49	0.65	8.54	83.96	4.34

*These two analyses of lignite are of the same specimen, one having been made shortly after the lignite was taken from the mine, the other after it had air-dried for one month.

Classification by fuel ratio.

Formula: $\text{Fuel ratio} = \dfrac{\text{fixed carbon}}{\text{volatile hydrocarbon}}$.

Bituminous	1 to 5.
Semi-bituminous	5 to 8.
Semi-anthracite	8 to 12.
Anthracite	12 to 99.

This classification may or may not hold in trade.

Effect of water in coal; objection to lignite.

Effect of sulphur; aids combustion but attacks grates and boilers; injures pig iron.

Fixed carbon determines steaming value of bituminous coals.

Influence of fixed carbon in manufacturing coke.

Volatile hydrocarbon in gas manufacture.

Influence of the physical properties of coal.

Cannel coal.

The coal supply.

Statistics of production.

The structural features of coal make it easy to compute the available coal supply.

Consumption of coal in the United States.

Increase of output, past and future.

Difficulties of determining the period of exhaustion.

Possibility of working thinner beds.

Decreasing loss.

Possibility of utilizing other sources of energy.

Natural gas.

Petroleum.

Waterpower available through electric transmission.

The waste of coal.

Not more than 10 per cent of the energy of coal is utilized.

The amount of coal in the world is limited, and all unnecessary waste should be avoided.

- Waste in using through loss of heat; imperfect combustion.
- Waste in getting.
  - In England the loss was formerly two-thirds; now one-fourth.
  - The coal waste commission of Pennsylvania[*] estimates the total loss in the Anthracite region at from 65 per cent to 70 per cent, and that this will be reduced to 60 per cent.
  - This loss is constant for the whole region, but varies greatly with individual mines.
    - Waste in pillars, 30–45 per cent of the whole bed.
      - How they may be saved. Longwall mining.[†]
    - Waste in blasting.
      - Wedging, mining machinery.[‡]
        - Effect of strikes on the use of machinery.
    - Waste in sorting, 7 per cent of what is mined.
      - Influence of thin beds of shale in coal bed.
    - Waste in handling.
      - Breaker waste, 24–32 per cent of what goes to the breaker.
        - Culm heaps of the anthracite regions.
      - Results of different methods of breaking and screening.
        - Gyrating screens.[§]
      - Waste in shipping.
- The amount of loss affected by the friability of the coal.
  - Waste is much less now than formerly.
- Waste caused by leaving behind beds that would become valuable in the future.
- Utilization of coal waste.
  - Burning culm on special grates.[‖]
  - Made into briquettes and eggettes.[¶]
    - Extensively used in Europe.
  - Pulverized fuel; doubtful results.
  - Filling mines.
- Importance of stacking coal waste and other waste separately.
- Utilization of peat.[**]

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[*] Report of commission on waste of coal mining (in Pennsylvania). By E. B. Coxe and others. Philadelphia, 1893.

[†] Eng. and Min. Jour., Nov. 21, 1896, LXII, 487; April 10, 1897, LXIII, 350.

[‡] Coal-cutting machinery. By E. W. Parker. Trans. Amer. Inst. Min. Eng., 1899, XXIX.

[§] Winslow in ann. rep. Geol. Survey of Ark., 1888, III, 105.

[‖] Burning anthracite culm. By John R. Wagner. Cassier's Mag., Nov., 1895, IX, 1–26.
The yield of the Reynolds anthracite culm bank. By A. D. Smith. Eng. and Min. Jour., April 15, 1899, LXVII, 440.

[¶] Patent fuel and its manufacture. By C. Archibald. Jour. Fed. Can. Min. Inst., 1898, II, 288.

[**] On peat and its uses. By T. S. Hunt. Canadian Naturalist, Dec., 1864, I, 426–441.
Turf (peat) briquettes in Germany. By John E. Kehl. U. S. Consular reps., LIX, 98.

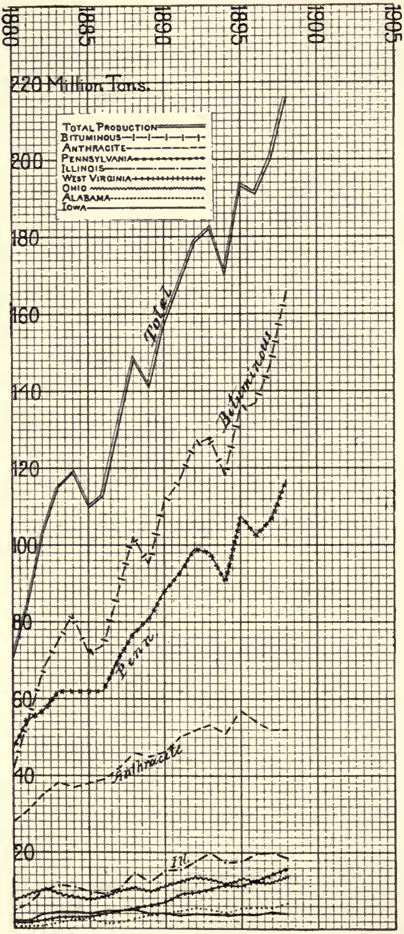

Fig. 117.—Comparative production of coal in the chief coal-mining States since 1880.

GRAPHITE, PLUMBAGO, OR BLACK LEAD.

Graphite is pure carbon, having a greasy feel and a black metallic lustre.

Uses.[*]

- Best qualities for lead pencils and crayons.
- Its most important use is for making crucibles and other refractory materials.
- As a lubricant; advantages: not affected by cold, heat, or air.[†]
- Inferior grades for stove polish.
- In electrotyping.

Occurrence.

- Most abundant in old metamorphic rocks.
  - Vein-like deposits.
  - Bed-like deposits.
- Theory of its organic origin.[‡]
  - Graphite found in pig iron: why.

Distribution.

- Widely distributed, but mined in few countries.
- The leading producers in the order of their importance at present are:
  - Austria,
  - Ceylon,
  - Germany,
  - Italy,
  - United States, and
  - Japan.
- Product of the Alibert mine, Siberia, used for the best pencils.
- Ceylon product noted for its purity.

Austria.[§]

- The Austrian deposits are in gneiss and schist; in places eighteen feet thick.

Ceylon.

- The veins are in gneiss; some of the graphite 99.79 per cent carbon.

Germany.

- In Bavaria a vein in gneiss sometimes 16 feet thick; product impure.

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[*] Der Graphit und seine wichtigsten Annendungen. Von Dr. Heinrich Weger. Berlin, 1872.

[†] Mineral industry, 1898, VII, 385–387.

[‡] Coal converted into graphite. By A. Taylor. Trans. Edin. Geol. Soc., 1874, II, 368.
Origin of grahamite. By I. C. White. Bul. Geol. Soc. Amer., 1899, X, 284.

[§] La géologie et l'exploitation des gites de graphite de la Bohême Méridionale. Par M. Bonnefoy. Annales des Mines, 7 ser., 1879, XV, 157–208.

Japan; Italy; India.[*]

Canada.[†]

In veins and thin seams in Laurentian rocks; most important deposits in Province of Quebec.

United States.

Many occurrences. The only mines worked are those at Graphite, near Ticonderoga, N. Y., and at Cranston, R. I.[‡] At the latter place it is associated with anthracite.

It occurs in the Coal Measures of New Mexico.

In Gunnison county, Colorado, are graphite beds 2 feet thick.

In Albany county, Wyoming, it occurs in veins.

In California, mixed with kaolin; importance and difficulty of separation.

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[*] Manual of the geology of India. Economic geology. By V. Ball. Calcutta, 1881, pp. 50–58.

[†] Quar. Jour. Geol. Soc., 1869, XXV, 406.

Amer. Jour. Sci., 1870, C, 130.

[‡] A graphite mine. By R. H. Palmer. Eng. and Min. Jour., Dec. 9, 1899, LXVIII, 694.

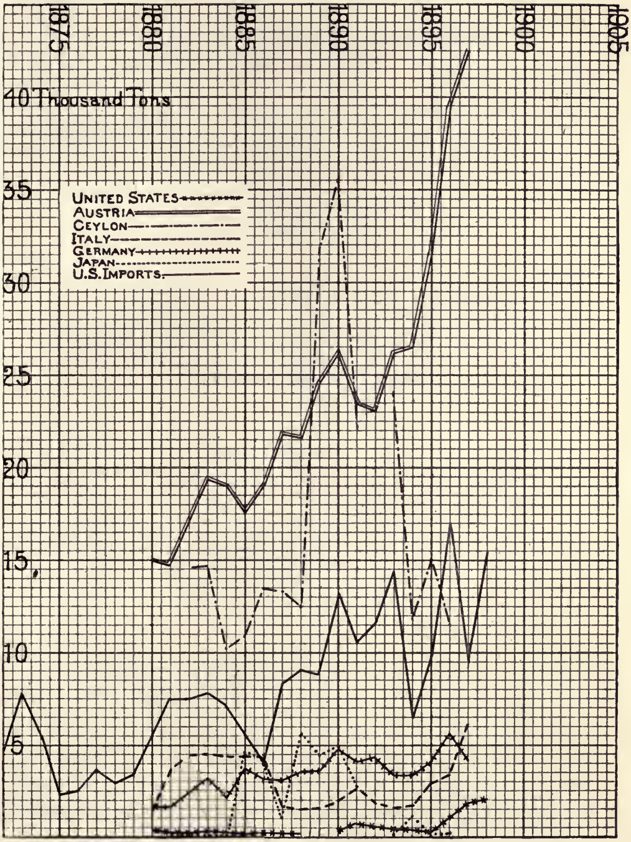

Fig. 118.—The production of graphite in the principal countries since 1872.

PETROLEUM AND NATURAL GAS.[*]

These substances are so related that it is convenient to discuss them together.

The hydrocarbon series is natural gas, naphtha, petroleum, mineral tar, asphalt. Petroleum is formed from naphtha by loss of volatile matter and oxidation; petroleum oxidizes to mineral tar or ozokerite, which oxidizes to asphalt.

Petroleum.[†]

Uses.

- In its crude condition.
  - Lubricating, fuel, driving engines.
- After being refined, as
  - Kerosene, gasoline, and paraffine, for illuminating and heating.
  - Benzine for paints and varnishes.
  - Vaseline for medicinal and other purposes.
  - Naphtha, rhigolene, cymogene.

Origin.[‡]

- Mendeljieff's theory (1877): water in contact with hot carbides of metals, especially of iron, decomposes; oxygen unites with iron; hydrogen takes up carbon, ascends, and condenses to oil and gas. Objection to this theory.
- Generally accepted theory that oil and gas are slowly and spontaneously distilled from organic matter.[§]
  - Deposits of organic origin in accompanying beds.
  - Diatomaceous beds in California.
  - Diatoms contain oil.[‖]

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[*] Report on the production, technology, and uses of petroleum and its products. By S. F. Peckham. Tenth Census, vol. X. Washington, 1884.

Petroleum and natural gas. By Joseph D. Weeks. Eleventh Census. Report on mineral industries, 425–578.

Petroleum. By B. Redwood and G. T. Holloway. 2 vols. [Lippincott Company, Philadelphia.]

Le pétrole, l'asphalte et le bitume au point de vue géologique. Par A. Jaccard. Paris, 1896.

[†] Composition of the American sulphur petroleums. By C. F. Mabery. Jour. Franklin Inst., June–July, 1895.

Several articles by Sadtler, Peckham, and Day, in Proc. Amer. Phil. Soc., 1897, XXXVI, 93–136.

[‡] The origin of petroleum. By O. C. D. Ross. Geol. Magazine, 1891, pp. 506–508.

Beiträge zur Theorie der Petroleumbildung. Von Leopold Singer. Wien, 1893.

On the origin of petroleum. By Richard Anderson. Trans. Geol. Soc. Glasgow, 1871–74, IV, 174–177.

Petroleum: its history, origin, occurrence, etc. By Wm. Brannt. Philadelphia, 1894.

[§] Geological probabilities as to petroleum. By Edward Orton. Bul. Geol. Soc. of America, 1898, IX, 85–100.

[‖] Canadian Diatomaceæ. By W. Osler. Canadian Naturalist, 1870, V, new ser. 143.

Geology.

- Oil and gas in sedimentary rocks of almost all ages.
- Diffused through many rocks where it is now useless; possibility of distilling oil-bearing shales.*
- Association of gas, oil, and salt water; necessity of studying them together.
- Essential conditions are the same in all fields.†
  - Rocks containing accumulations of oil and gas are:
    1. Conglomerates or porous sandstones (Pennsylvania, New York, West Virginia, Kentucky).
    2. Porous limestones (Ohio and Indiana).
       - Why other rocks in the same places contain no oil or gas.
       - Why Trenton limestone yields oil in some places and not in others.
    - Origin of porosity of sandstone; porosity of limestone due to dolomitization; joint cavities in shales.
    - Theory of oil caves; caving of crust.
    - Importance of overlying impervious beds to confine oil and gas.
- Relations of structure to accumulations of oil and gas. (Figs. 120, 121, 123.)
  - Accumulations are local; not found wherever the rock is found.
- Why oil and gas accumulate in some places and not in others.
- T. S. Hunt's anticlinal theory of oil.‡
- Why anticlines are only locally productive.
- How monoclines may serve the same purpose.
- Influence of gentle and violent folds.
  - How folds are recognized and located.
- Oil found in highly disturbed areas pockety, and its distribution difficult to determine.
- Necessary conditions:
  1. Source from which the oil is distilled.
  2. Adjacent porous rock to hold it.
  3. Impervious cover.
  4. Structural features favoring accumulation.
- Where petroleum and natural gas are not to be sought.
  - Crystalline or eruptive rocks.
- Relations of oil, salt-water, and gas.

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* A practical treatise on mineral oils and their by-products. By I. I. Redwood. London and New York (Spon.).

† The geology of petroleum and natural gas. By W. Topley. Geol. Magazine, 1891, VIII, 508–511.

‡ Petroleum and natural gas. [By I. C. White.] West Virginia Geol. Survey, 1899, I, 223–378.

Notes on the history of petroleum or rock oil. By T. S. Hunt. Canadian Naturalist, August, 1861, VI, 249.

The anticlinal theory of natural gas. By I. C. White. Bul. Geol. Soc. of Amer., 1892, III, 204–216.

Rock pressure of oil and gas:
  In western Ohio from 650 lbs. to square inch down; usually between 300 and 400 lbs.
  In Indiana from 325 to 250 lbs.
  In Pennsylvania and West Virginia the highest recorded is 1000 lbs.
  The highest pressure reported is 1525 lbs. in New York State.
Origin of rock pressure.*
  Lesley's theory of expansion of gas.
  Orton's theory of hydrostatic pressure. sufficient
    Trenton rocks outcrop on Lake Superior.
  Orton's law: *Rock pressure of Trenton limestone gas is due to a salt-water column measured from about 600′ a. t. to the level of stratum yielding gas.*
  How practically demonstrated.
  Why oil wells of Pennsylvania are "watered out."
  Applicability of this law modified to other territories.
Decrease of rock pressure.
  In Indiana the average pressure was originally (1888) 325 lbs; in 1897 it was 191 lbs.; in November, 1898, it was 173 lbs.†
  Artificial pressure used.

PETROLEUM IN THE UNITED STATES.

The salt industry the forerunner of petroleum industry.
  Boring for salt water; early drill; seed bag.
High price of whale oil.
Oil from cannel coal and shale.
E. L. Drake's successful effort to get oil by boring at Titusville, Pa., in 1859.‡
Low price from over-production.
Spouting wells; spread of exploration.
The Pennsylvania,§ New York, West Virginia area.
  The Pennsylvania oil field centers at Oil City; the West Virginia field at Sisterville.
  First considerable flowing well struck in 1861; 300 barrels a day.

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* Consideration of the pressure, composition, and fuel value of rock gas. By J. P. Lesley. Ann. rep. Geol. Survey of Pennsylvania for 1885, pp. 657–680.

Origin of the rock pressure of natural gas in the Trenton limestone of Ohio and Indiana. By Edward Orton. Bul. Geol. Soc. of America, 1890, I, 87–98.

† Twenty-third ann. rep. Geol. and Nat Hist. Survey of Indiana, 1886. Indianapolis, 1899.

‡ The first oil well. By J. S. Newberry. Harper's Magazine, Oct., 1890, LXXXI, 723–729

The oil regions of Pennsylvania. By William Wright. New York, 1865. (275 pp.)

§ Oil and gas fields of Western Pennsylvania for 1887–88. By J. F. Carll. Geol. Survey of Pennsylvania. Harrisburg, 1890.

The oil and gas regions. By J. F. Carll. Part II, ann. rep. Geol. Survey of Pennsylvania for 1886. Harrisburg, 1887.

Petroleum; its production and products in Pennsylvania. By A. S. Bolles. Ann. rep Bureau of Industrial Statistics, 1892. Harrisburg, 1893.

Petroleum Oliph, F.H., 20th Ann. Rep.,
Geol. Sur. Part VI cont., pp. 1-202

Phillips' well 3,000 barrels a day. A well near Bradford that yielded 25,000 barrels in 1875, yielded 6,500,000 in 1878, and 23,000,000 in 1881.

6,358 wells put down in 1890.

The western Ohio, Indiana area.*

The Ohio oil fields center at Lima; the Indiana fields center at Montpelier.

Oil and gas from Trenton limestone.

Confined by Utica shale.

Rocks gently folded.

In 1889 single wells in Ohio began with a yield of 10,000 barrels per day.

Colorado region: Florence, between Pueblo and Canon City.

Oil from Cretaceous shales.

General structural features.

California regions.† Deposits of limited capacity

Oil from the Tertiary. on account of rock porosity

Relations to diatomaceous earths.

Wyoming district.‡

Limits of the supply of petroleum.

Order of gas, oil, and water in producing wells.

Sequence of their exhaustion.

Natural process of distillation slow.

Good but dearer oil can yet be manufactured from shale.

Locating oil wells.

How far geology may be depended upon. & thickness of

The elements of uncertainty. Size of pools the beds.

Indications of oil in the rock; "Trenton rock"; "surface indications."

Oil may or may not appear at the surface.

Method of drilling.

Growth of deep well drilling in America.

Determining the geological position of the drill.

The use and preservation of borings.

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* Report of the Geol. Survey of Ohio. Vol. VI, Economic geology. By Edward Orton. Columbus, 1888.

The natural gas field of Indiana. By A. J. Phinney. Eleventh ann. rep. U. S. Geol. Survey, 1889–90, pp. 617–742.

First ann. rep. Geol. Survey of Ohio. By E. Orton. 55 et seq. Columbus, 1890.

Petroleum, natural gas, and asphaltum in western Kentucky. By E. Orton, Frankfort, 1891.

† Oil- and gas-yielding formations of Los Angeles, Ventura, and Santa Barbara counties, California. By W. L. Watts. Bul. 11, Calif. State Mining Bureau, 1896.

The genesis of petroleum and asphaltum in California. By A. S. Cooper. Bul. 16, Calif. State Mining Bureau. San Francisco, 1899.

‡ The petroleum of Salt Creek, Wyoming. Petroleum series, Bul. I of the School of Mines, University of Wyoming. Laramie, 1896.

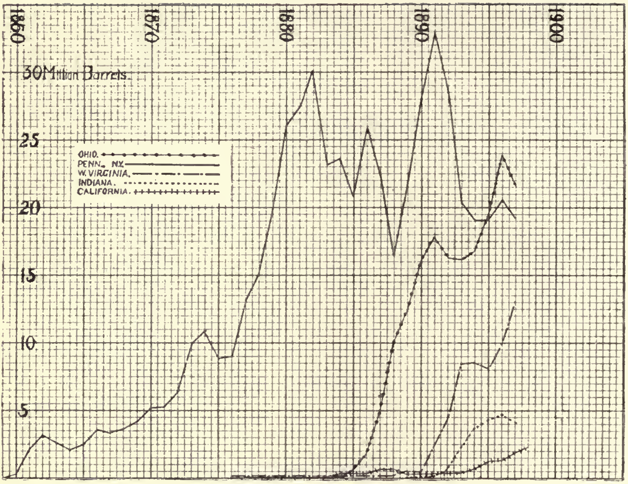


Fig. 119.—The petroleum yield of the States since 1859.

In some rocks one well drains five acres; others fifty.
Oil and gas drawn from the lands of others without redress.
How torpedoes increase or decrease the flow of wells.

[illegible]

Transportation of petroleum.

Originally in barrels, then in tank cars; dangers and losses.
Now about 25,000 miles of pipe in Pennsylvania fields.
Pumping from the oil fields of Pennsylvania, West Virginia, Ohio, and Indiana, through pipe lines to the sea-board at Baltimore, Philadelphia, New York, Buffalo, Cleveland, and Chicago.
Pumping stations from twenty-five to fifty miles apart, according to grade.

Refining petroleum.

Importance of oil due largely to its being refined.
  Effect of good, cheap light on civilization.
Limestone oils contain more sulphur.
  These were first used for lubricating; in 1893 most illuminating oils from these.
Special values for certain oils: lubricating; lighting; fuel.

Eng. + Min. Jour., July [illegible]
Electric [illegible]-lamps

PETROLEUM IN OTHER COUNTRIES.

Russia.

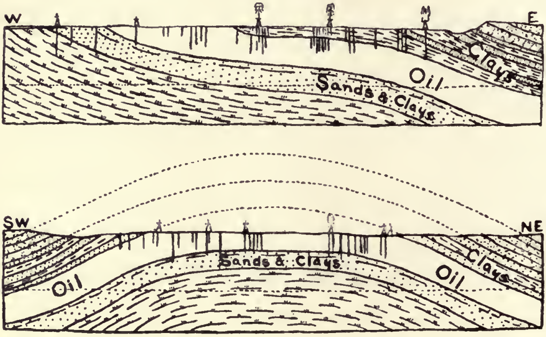
One of the greatest known oil fields is about Bakou on the Caspian Sea, at the southeast end of the Caucasian Mountains.*

Oil from Tertiary rocks; wells averaged 715′ in 1891; formerly much less.

Yield from about 1800 acres.

From pumped wells water and oil come together.

Product, 2,000,000 barrels in 1880 to 33,355,669 barrels in 1893.



Figs. 120, 121.—Cross-sections showing the geological structure of the oil-bearing strata in the Trans-Caucasian region, Russia. (Konchin.)

Burma's petroleum comes from Miocene rocks.

Galicia, on the north flank of the Carpathian Mountains, produces petroleum from Tertiary rocks. Gentle anticlines; shallow wells; oil viscous.

The following figures will give some idea of the importance of the minor oil-producing countries:

	Barrels.	
Canada	798,406	in 1893
	709,857	in 1897
Peru	350,000	in 1890
	68,452	in 1897
India	146,107	in 1891
	430,203	in 1896
Roumania	383,227	in 1890
	570,886	in 1897

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* The industries of Russia. Mining and metallurgy. By A. Keppen. pp. 81–90. St. Petersburg, 1893.

De Tiflis a Bakou. Gisements de naphte de Bakou. Par A. Konchin. Guide des Excursions du VII. Congrès Géologique International, XXIV, art. St. Petersburg, 1897.

Bakou and its oil industry. Nature, July 9, 1896, p. 232.

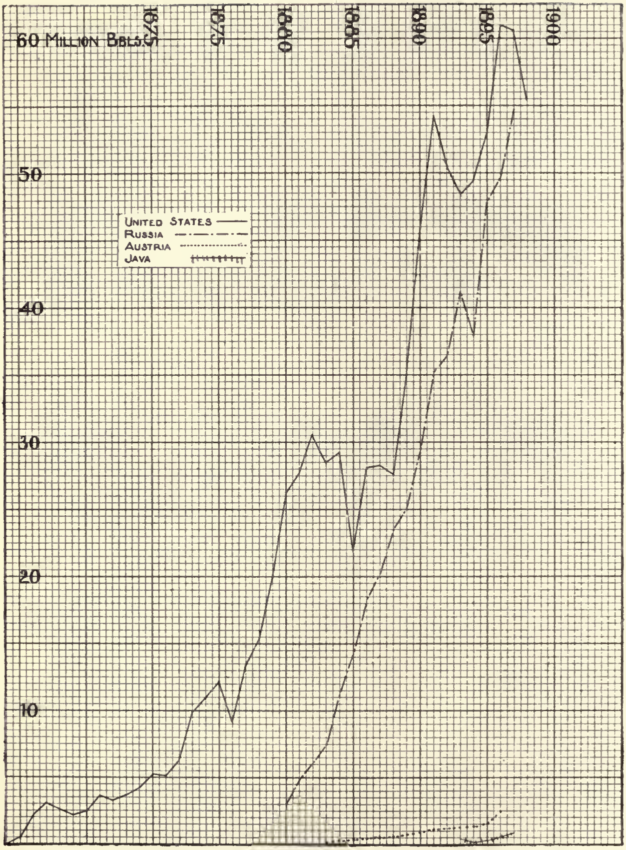

Fig. 122.—Comparative yield of petroleum of the chief producing countries since 1859.

Natural Gas.

Advantages as a fuel:

Readily transported; no refuse; easily regulated; boilers and grates last longer.

In 1885 natural gas about Pittsburg replaced 3,650,000 tons of coal, and displaced 5000 men.

1889 it replaced coal as follows:

In Pennsylvania	$11,593,989	worth.
In Ohio	5,123,569	"
In Indiana	2,002,762	"

Two modes of occurrence:

1. In shales and limestones.
2. Reservoir gas in sandstones, conglomerates, and certain dolomitic limestones.

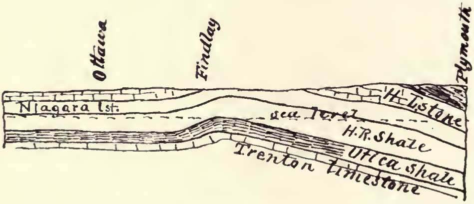

Fig. 123.—Section through Findlay, Ohio, showing the anticline at whose crest the great oil and gas wells are located. (Orton.)

The relations of geological features of natural gas to those of petroleum.

Wells at crowns of anticlinal domes last longest.

Small quantities of gas of common occurrence and no importance.

*Characteristics of shale gas.**

1. It is of small volume.
2. It lacks uniformity of pressure.†
3. The gas comss from no definite horizon.
4. Often independent of the oil production.
5. It has good staying properties.
6. It is not dependent upon structure.

---

* Geological structure of the Iola (Kansas) gas field. By Edward Orton. Bul. Geol. Soc. of America, 1899, X, 99-106.

† Hydrostatic vs. lithopiestic theory of gas well pressure. By A. M. Miller. Science, February 1900, XI, 192-3.

Nat. Gas. F. H. Oliphant
21st Ann. U.S.G.S. pt VI Cont.
Washington 99 p. 203 —

Characteristics of reservoir gas.

1. The largest known wells are of this kind.
2. Pressure uniform.
3. Gas is at definite horizons.
4. Oil accompanies the gas.
5. Geologic structure is of great importance.

The waste of natural gas.

The store of natural gas is limited; so excellent a fuel should not be wasted.

Murraysville well in Pennsylvania played into the air for six years at the rate of 20,000,000 cubic feet of gas per day.

In 1885 the waste of gas in piping distance of Pittsburg was 70,000,000 cubic feet per day ($3,500 of coal per day).

Gradual exhaustion.

Only time can show how long individual wells can last.

Natural gas prepares the way for artificial gas.

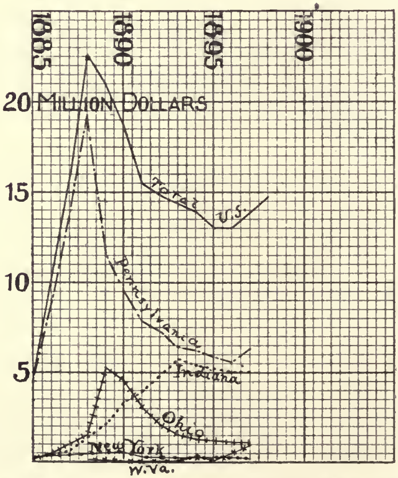

Fig. 124.—Value of the natural gas in the chief producing States since 1885.

OZOKERITE OR OZOCERITE.[*]

Ozokerite or mineral tar is partially oxidized petroleum. It is as hard as beeswax, and has the odor of petroleum.

Uses.

Its principal use is for making paraffine candles; other uses are wax matches, as a lubricant, protecting metals from rust, and for insulating purposes, calking ships, adulterating beeswax, making wax dolls, varnishes, and blacking.

Occurrence.

It is always associated with petroleum in sedimentary rocks.

The principal known deposits are in the Tertiary sandstones of Galicia, Austria, north of the Carpathian Mountains, where it fills thin, irregular veins. It gets softer with depth on account of the greater oxidation near the surface.

American deposits.

In the Wasatch Mountains, 100 miles east of Salt Lake, are the only known American deposits of any importance; they are not worked.

It probably occurs in the petroleum and asphaltum regions of Southern California.

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[*] On the origin of carbonaceous matter in bituminous shales. By J. S. Newberry. Annals of the New York Acad. of Sci., 1883, II, 357–369.

Notes on the origin of bitumens. By S. F. Peckham. Proc. Amer. Phil. Soc., 1865–68, X, 445–462; 1898, XXXVII, 108–139; Amer. Jour. Sci., 1869, XCVIII, 420; XLVIII, 362–370. (Has references.) Amer. Jour. Sci., 1866, XCII, 420.

Sur. les gîtes bitumineux de la Judée. Par L. Lartet. Bul. Soc. Géol. de France, 2me ser., 1866, XXIV, 12–32.

A treatise on ozokerkite. By Edgar B. Gosling. The School of Mines Quarterly, November, 1894, XVI, no. 1, pp. 41–68.

ASPHALT.*

Varities of asphalt are known also as grahamite, gilsonite, unintaite, albertite, wurtzilite, elaterite, etc.

Asphalt or asphaltum is oxidized petroleum in which the oxidation has been carried further than in ozokerite; it is brown to black, brittle to a blow; melts at 200° F.

Uses.

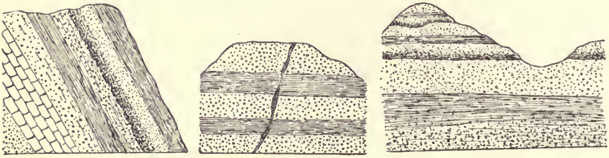
Its principal use is street paving.

In architecture; lining reservoirs; foundations for heavy machinery; coating for pipes, piles, and paving blocks, wire poles; insulator.

Occurrence.

It occurs in beds and veins mixed with more or less earthy matter or impregnating limestone or sandstone.

The most important asphalt deposit known is on the island of Trinidad off the coast of Venezuela, where it occurs at the surface like a lake, covering 116 acres.†



Figs. 125–127.—Sections illustrating the occurrence of asphalt in sedimentary strata and in a crevice cutting such strata.

DEPOSITS IN THE UNITED STATES.

California.‡

The most important asphalt deposits in the United States are in the Tertiary rocks of California.

Kern county: in veins and superficial beds.

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* The production of an asphalt resembling gilsonite by the distillation of a mixture of fish and wood. By W. C. Day. Proc. Amer. Phil. Soc., 1898, XXXVII, 171–174.

The laboratory production of asphalts. By W. C. Day. Jour. Frank. Inst., September, 1899, CXLVIII, 205–239.

Origin of grahamite. By I. C. White. Bul. Geol. Soc. of Amer., 1899, X, 277–284.

† Trinidad pitch. By S. F. Peckham and Laura A. Linton. Amer. Jour. Sci., March, 1896, CLI, 193–207.

‡ The gas- and petroleum-yielding formations of the central valley of California. By W. L. Watts. California State Mining Bureau, Bul. no. 3. Sacramento, 1894.

The genesis of petroleum and asphaltum in California. By A. S. Cooper. California Mines and Minerals, 114–174. San Francisco, 1899. Same in Bul. 16, California State Mining Bureau, San Francisco, 1899.

The technology of California bitumens. By S. F. Peckham. Jour. Frank. Inst., July, 1898, CXLVI, 45–54.

Asphaltum & Bituminous Rock
E. W. Parker 20th Ann. Rep. U.S.
G.S. pt VI cont. 261–268

Santa Cruz county: bituminous beds are mined.

San Luis Obispo county: asphalt occurs in strata and as superficial deposits from springs.

Santa Barbara county: liquid asphalt and asphalt mixed with sand and other substances found in veins and beds and in sandstone and shales.

Ventura county: in irregular veins, and impregnating sandstone.

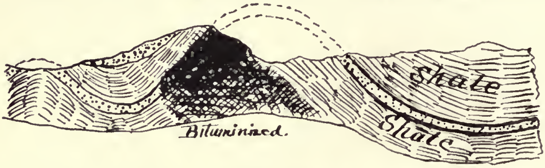

Fig. 128.—Section near La Brea creek, Santa Barbara county, California, showing the geological structure and the accumulation of bitumen. (Cooper.)

Other States.

The only other States that have produced asphalt in commercial quantities are Kentucky, Texas, and Utah;* in Utah it is known as *gilsonite* and *uintaite*.

The output of California increased from $152,500 worth in 1888 to $598,502 worth in 1897.

Value of asphalt imported since 1889:

1889	$138,163
1890	223,368
1891	299,350
1892	336,868
1893	196,314
1894	313,680
1895	247,214
1896	$382,045
1897	417,865

---

* The uintaite deposits of Utah. By G. H. Eldridge. Seventeenth ann. rep. U. S. Geol. Survey, pt. I, 915–949. Washington, 1896.

Mineral resources, 1893, pp. 627–669. Washington, 1893.

Uintaite, albertite, grahamite, and asphaltum. By W. P. Blake. Trans. Amer. Inst. Min. Eng., 1890, XVIII, 563–582.

Pure asphalt of great value because [illegible] [illegible] [illegible] [illegible] with [illegible] [illegible] [illegible] [illegible] in [illegible] [illegible] [illegible] asphalt [illegible] [illegible]

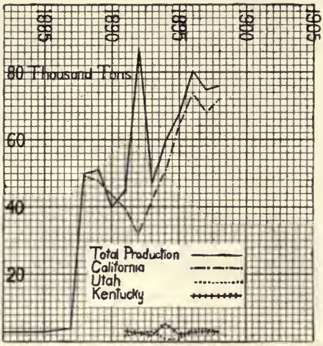

Fig. 129.—The asphalt and bituminous rock product of the United States since 1882.

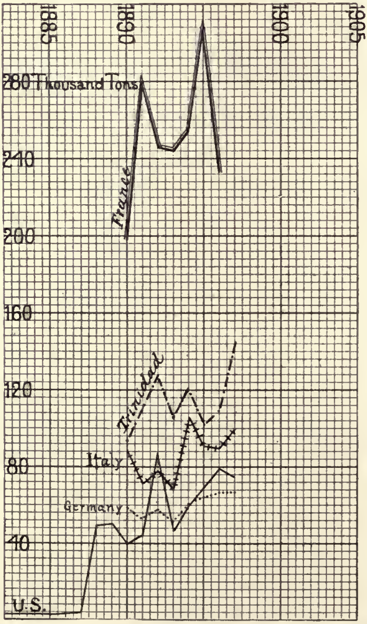

Fig. 130.—The asphalt and bituminous rock yield of the chief producing countries since 1890.

SALT.*

Common salt (NaCl) as a geological product occurs as salt water or brine, or as rock-salt interstratified with sedimentary rocks.

Uses.

Preserving meats, and domestic purposes.
Manufacture of soda.
Chloridizing ores in metallurgy.
Manufacture of chlorine; glaze of pottery.

Origin.

By the natural evaporation of salt water.
Thick deposits of rock-salt by high tides flowing into closed basins in arid regions, or by evaporation that produces a constant influx from a larger to a smaller basin.†

Distribution.

Salt occurs in sedimentary rocks from the Lower Silurian to those now forming, and in almost all countries.
Among the most remarkable salt deposits known are those of:
  Galicia and Transylvania in Austria-Hungary.
    At Wieliczka, Galicia, it is mined and stoped out like coal.
  The Austrian and Bavarian Alps.
  Western Germany: at Sperenberg, near Berlin, 3600′.‡
  Cardona, near Barcelona, Spain: open quarry of rock-salt.
  Mined in Peru.§

SALT IN THE UNITED STATES.‖

New York.¶

Onondaga district near Syracuse: brine from the Salina; rock-salt to the south.
Warsaw district (in Wyoming, Genesee, and Livingston counties), bed of rock-salt in the Upper Silurian from 70′ to 318′, underlying many counties. Shafts 825′–1430′ deep.

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* Spons' encyclopaedia of industrial arts. Salt, II, 1710–1740. London, 1882.

† Karamania. By F. Beaufort. 283–84. London, 1818.

‡ The salt deposits of Stassfurt. By H. M. Cadell. Trans. Edin. Geol. Soc., 1885, V, pt. I, 92–103.

§ A Peruvian salt mine. By Robert Peele, Jr. School of Mines Quarterly, 1893–94, XV, 219.

‖ Salt-making processes in the United States. By Thomas M. Chatard. Seventh ann. rep. U. S. Geol. Survey, 497–535. Washington, 1885–86.

¶ Salt and gypsum industries in New York. By F. J. H. Merrill. Bul. New York State Mus., III, no. II. Albany, 1893.

Report on the geology of the Livonia salt shaft. By D. D. Luther. Rep. State Geologist [of New York] for 1893, pp. 11–130. Albany, 1894.

[illegible] Salt [illegible] of N. Y.,
+ the [illegible] of the Salt District
[illegible]

Salt [illegible] deposits [illegible] and
region [illegible] from
natural evaporation [illegible]

Mined by [illegible] arrange-
ment & [illegible] the [illegible]
[illegible] the [illegible]
[illegible] the
[illegible]

Michigan.[*]

Rock-salt and brines from Carboniferous limestone, accumulating in the Marshall sandstone.

Structural features of the Peninsula syncline.

Why the deeper brines are stronger.

One well 1964′ deep found 32′ rock-salt in Manistee county.

Wells average 880′ in depth.

Kansas.[†]

Rock-salt horizon of the Trias underlies many counties in the central and southern parts of the State; deposits lenticular, from a few inches to 200′ thick; from 400′–1000′ below the surface.

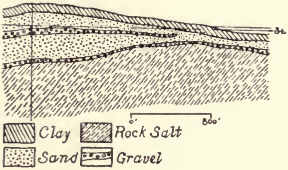

Fig. 131.—Section showing the order of the deposits accompanying the rock-salt beds of Louisiana. (Lucas).

Utah.

Most of the salt is made from the waters of Salt Lake.[‡]

How Salt Lake came to be salty.

Louisiana.

The Petite Anse deposits; Tertiary; structure.[§]

The chief salt-producing States:

	1887.		1897.	
New York	2,353,560	barrels.	6,805,854	barrels.
Michigan	3,944,309	"	3,993,225	"
Ohio	365,000	"	1,575,414	"
Kansas	———	"	1,538,327	"
Utah	325,000	"	405,179	"

---

[*] Geological studies. By A. Winchell. Geology of salt, 186–193. Chicago, 1889.

[†] Geology of Kansas salt. By Robert Hay. [No date.]

[‡] The great Salt Lake. By J. E. Talmage. Utah University Quarterly, Sept., 1896, II, 137–152.

[§] Rock-salt in Louisiana. By A. F. Lucas. Trans. Amer. Inst. Min. Eng., 1899, XXIX.

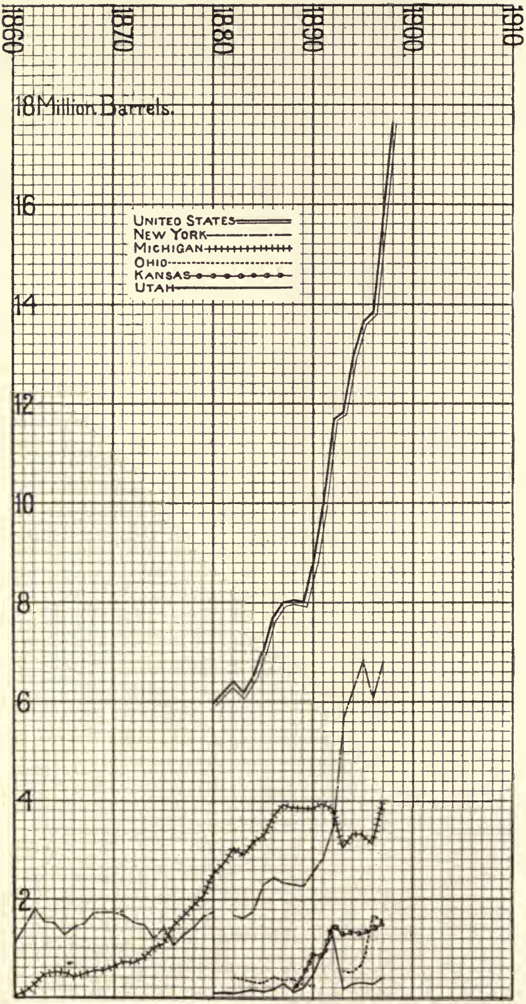

Fig. 132.—The salt production of the United States since 1860.

SODA.

[Most of the soda of commerce is an artificial product from common salt.]

Natural soda is the carbonate (Na_2CO_3) or bicarbonate ($NaHCO_3$) of soda.

Origin.

It is produced by the evaporation and concentration of surface waters flowing from or over igneous rocks containing soda.

It is to be expected in any country where the geologic and climatic conditions are favorable.

Natural soda in the United States.†

It forms a large part of the alkali of the arid regions of the western United States.

Nevada: two lakes at Ragtown.

California: Mono Lake, Inyo county.

Oregon: Abert and Summer Lakes.

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† Natural soda: its source and utilization. By Thomas M. Chatard. Bul. 60, U. S. Geol. Survey, 27–101. Washington, 1890.

BORAX.

Borax is sodium biborate ($Na_2B_4O_7 + Aq$).

Uses.

- Antiseptic.
- Manufacture of enamels for pottery.
- Manufacture of soap.
- Flux in metallurgy.

Occurrence and origin.

- Most of the borax of commerce is from the native mineral and from Colemanite (calcium sodium borate). The native mineral occurs:
  - In the dry beds of old lakes.
  - As crystals in the mud at the bottom of borax lakes.
  - In the water of certain lakes.
- The borax in the lake waters, in the mud at the bottoms of the lakes, or in the ancient lake bottoms has been concentrated by evaporation from waters containing boron in solution.
- Occurs as geological deposits only in arid regions.
- Thibet, Chili. Turkey

*Borax in the United States.**

- California.
  - Discovered by Dr. Veatch at Borax Lake, Lake county, 1856.
  - Searles Borax marsh, San Bernardino county, the dry bed of an old lake; shore terraces 600′ above.
    - Igneous rocks of the surrounding country.
    - Succession of deposits in bottom of the valley.
  - At Calico, San Bernardino county, is a lime borate (Colemanite) deposit interbedded with other sedimentary rocks. It is mined by shafts and drifts.
  - Death Valley, Inyo county.
  - Saline Valley, Inyo county, in marsh.
  - Water pumped from wells in the valleys and evaporated.
- Nevada.
  - Lake near Ragtown; Sand Springs.
- Oregon.
  - Chetco mine, Curry county, *priceite* as boulders from a few ounces to several hundred pounds.

---

* Borax. By Charles G. Yale. Mineral Resources of the United States for 1889-90, pp. 494-506.

Report on the borax deposits of California and Nevada. By Henry G. Hanks. Third ann. rep. State Mineralogist of California. Sacramento, 1883.

Borax. Fourth ann. rep. State Mineralogist of California, 80-93. Sacramento, 1884.

The borax industry of the United States began in California in 1865; the product in 1878 was 1401 tons.
In 1888 was 3795 tons.
In 1898 was 8000 tons.

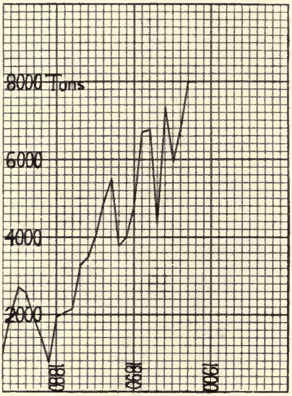

Fig. 133.—Borax production of the United States since 1870.

NITER OR SALTPETER.

Niter or saltpeter is nitrate of potash (KNO_3).

Uses.

Manufacture of gunpowder and fireworks.
Medicinal purposes.
Antiseptic.
Fertilizer.

Occurrence and distribution.[*]

It occurs mostly in surface deposits; mingled with the dry earth in caves; as a dirty white efflorescence on the ground in arid regions. Prepared by leaching.

Relation to decaying organic matter.

In the caves of Ceylon, Teneriffe, Minas Geraes, Brazil; Kentucky, Missouri.

Stassfurt mines of Germany.

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[*] Sur la formation des terres nitrées dans les régions tropicales. Par Muntz et Marcano. Comptes Rendus, 1885, CI, 65; CI, 1265.

SODA NITER.

Soda niter is sodium nitrate ($Na_2O + N_2O_5$): nitrogen pentoxide 63.5, soda 36.5.

Uses.

Manufacture of nitric acid.
Potting of sulphuric acid.
Manufacture of potassium nitrate.
Medicine.
Fertilizers.

*Occurrence.**

In the deserts of northern Chili and Bolivia.
Associated with gypsum and salt.
The deposits are mostly about two feet below the surface.

---

* Nitrate and guano deposits in the desert of Atacama (Chili). By A. Pissis. London, 1878.

Recherches sur la formation des gisements de nitrate de soude. Par A. Müntz. Comp. Rend., 1885, CL, 1265.

BARYTES.

Barite, barytes, or heavy spar is the sulphate of barium (sulphur trioxide 34.3, baryta 65.7).

Uses.

Manufacture of paint as a substitute for white lead or zinc oxide.

Weighting paper and putty.

Lithophone, used as a pigment for special purposes, is a mixture of barium sulphate (68%), zinc oxide (7.28%), and zinc sulphide (24.85%).

Occurrence and distribution.

It occurs as vein-stone associated with ores of lead, copper, silver, etc., as pockets in limestone, and as amygdules in eruptive rocks. In the United States the principal deposits worked are in Missouri and Virginia. It occurs also in North Carolina, South Carolina, Tennessee, Kentucky, Arkansas, New Jersey, and many other States.

In Tennessee it is mined from clays formed by the decomposition of the containing rock.

Production of crude barytes in the United States in 1898 was 28,247 short tons, worth $112,988; the imports in 1898 amounted to 2000 tons.

SULPHUR.

Uses.

- Manufacture of gunpowder, sulphuric acid, and matches.
- Insecticide.
- Medicine.

Occurrence.

- Native and in combination with other elements.
  - Native sulphur.
    1. In volcanic regions deposited from sulphurous gases.
    2. As an alteration of gypsum.
  - Sulphur of organic origin.*
  - In combination its most important form as a source of sulphur is that of iron pyrites, which occurs in veins, beds, and irregular pockets. (See *Iron Pyrites.*)

Distribution.

- Geologic.
  - Native sulphur is found principally in Tertiary, Pleistocene, and recent deposits.

Geographic.

- Sicily is the principal source of native sulphur.
  - Mines spread over 5000 square miles, the sulphur occurring in veins and masses 3′–10′ thick, in Miocene limestone. Some petroleum and bitumen is associated with the sulphur.
  - Crude and antiquated methods of exploitation.
  - Rock containing less than 8% sulphur is not worked.
- Sulphur deposits of Japan of the solfatara type.
  - Island of Hokkaido is the principal source of supply.
- Mexico, New Zealand: sulphur occurs about several volcanic mountains; but little is produced.
- In Iceland† solfataric.
- New Hebrides Islands: sulphur occurs on a volcanic cone on the Isle of Tauna.

Sulphur in the United States.‡

- Large deposits on Kadiak Island, Alaska; not worked; deposits also on Unalaska.

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* On sulphur formed by bacteria, see Amer. Naturalist, June, 1898, XXXII, 456.

† Across the Vatna Jökull, or scenes in Iceland. By W. L. Watts. 113–116, 129, 141, 154. London, 1876.

‡ Sulphur. By J. F, Kemp. Mineral Industry for 1893, II, 585–602. New York, 1894.

California: in connection with igneous rocks at Sulphur Bank, Lake county; Colusa and Kern counties; western rim of Salton desert, San Diego county.

Nevada: in Humboldt mountains, in irregular masses associated with gypsum.

Utah: the largest American producer. Cove Creek mines, 26 miles east of Black Rock, in volcanic region. Gravels overlie volcanic tuffs; sulphur at the junction of the two; sulphur rock 30′ thick and less.

*Louisiana: sulphur deposit interbedded with Pleistocene sediments.

Texas: sulphur occurs near Guadalupe.

UNITED STATES IMPORTS OF SULPHUR.

	1895	1896	1897	1898	1899	1900
Short tons..	136,748	155,994	158,934			
Value.......	$1,613,754	$2,172,569	$2,454,073			

* Sulphur. J. D Harris, and Veach
Prel. Rep. Geol. La. 126-127,
Baton Rouge, 1889.

In some localities hot water driven down through pipes and the sulphur melted and forced to the surface through another pipe after which it is poured into tanks and evaporated. This is similar to the methods used in salt mining in N. Y.

PYRITE OR IRON PYRITES.

[Other than that valuable for its gold or other metallic contents.]

Iron pyrites (FeS_2 = Fe 46.7, S 53.3) is a hard brassy-yellow mineral, usually with a metallic lustre.

Uses.

Pyrites often carries gold, or other metals of value, but where these are absent it is often mined for the sulphur contained, for the manufacture of sulphuric acid. Formerly used extensively for the manufacture of sulphur. It is valueless as an ore of iron on account of the sulphur it contains.

Pyrites carrying less than 40% sulphur is not salable.

Occurrence.

It usually occurs in veins and lenticular masses, but it is not limited to these modes of occurrence.

Some important pyrite deposits are bedded deposits.

Often associated with slates, schists, and gneiss in the eastern United States, but it also occurs associated with other country rocks.

It is common in many mining camps of the country.

Distribution.

Pyrite may occur in rocks of any geologic age; it is also widely distributed geographically.

The principal producing countries in the order of their output in 1897 were:

France,
Spain,
Germany,
United States.

United States.*

Pyrites occurs in nearly every State. It is mined for the production of sulphuric acid only in the region along the Atlantic coast.†

Virginia:‡ (Louisa and Prince William counties).

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* R. P. Rothwell, Mineral Resources of the United States for 1886, pp. 650–675. Washington, 1887.

H. J. Davis, Mineral Resources of the United States for 1885, pp. 506–517. Washington, 1886.

E. W. Parker, Mineral Resources of the United States for 1895–96, pt. III, 973–977. Washington, 1896.

† The pyrite deposits of the Alleghanies. By A. F. Wendt. School of Mines Quarterly, 1885–86, VII, 218–235.

‡ The pyrite deposits of Louisa county, Virginia. By W. H. Adams. Trans. Amer. Inst. Min. Eng., 1883–84, XII, 527–535.

Massachusetts: (the Davis mines, Franklin county) supplies 90% of ore mined in this country.

Deposits occur also in Vermont, New York, Pennsylvania, North Carolina,* South Carolina, Tennessee, and Arkansas.

PRODUCTION AND IMPORTS OF PYRITES IN THE UNITED STATES, AND SULPHUR DISPLACED BY IT.

Year.	United States production—short tons.	Value.	Imports—short tons.	Sulphur displaced—short tons.
1895	101,495	$322,845	213,287	146,152
1896	129,341	320,163	224,188	159,149
1897	160,385	391,541	290,692	202,984
1798				
1899				
1900				

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* Pyrites deposits of North Carolina. By A. Winslow. Ann. rep. N. C. Agr. Exp. Sta. Raleigh, 1886.

FELDSPAR.*

Composition of three kinds of feldspar.

	Orthoclase.	Albite.	Anorthite.
Silica	64.7	68.7	43.2
Alumina	18.4	19.5	36.7
Potash	16.9	Soda 11.8	Lime 20.1

Orthoclase is the feldspar of commerce.

Uses.

Manufacture of glass.

Manufacture of pottery; used as a flux, and for glazing.

The gem "moonstone."

Occurrence.

Feldspar is one of the constituent minerals of granites, gneisses, and syenites, in which it sometimes occurs in segregations.

Most of the feldspar of the United States comes from Connecticut. New York, and Pennsylvania.†

Annual production of feldspar in the United States is about 23,000 tons.

The price at Trenton in 1898 was from $5 to $9 per ton.

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* Feldspar; its occurrence, mining, and uses. By T. C. Hopkins. The Mineral Industry for 1898, VII, 262-268.

† Clays and feldspars of southern Pennsylvania. By T. C. Hopkins. Mining Bulletin, Sept., 1898, IV, 106-107.

FLUORITE OR FLUORSPAR.

Fluorspar is calcium fluoride (fluorine 48.9, calcium 51.1); it is a transparent or semi-transparent mineral; is brittle and easily scratched with a knife. Yellow, white, purple, or light green are its most common colors. The colors are often banded. It is usually found crystallized in cubes.

Uses.

When massive, fluorspar takes a very fine polish, and is made into vases and other such ornaments.

The principal uses are:

- For the manufacture of hydrofluoric acid, for which the purest qualities are used.
- As a flux in the reduction of various ores.
- It is especially important in the basic open-hearth steel process, where phosphorus and sulphur are removed by it.
- In the manufacture of opalescent glass.

Occurrence.

Fluorite is limited to no particular kind of rock or mode of occurrence; it occurs sometimes in beds, but usually as a veinstone of various ores in gneiss, slate, limestone, and sandstone. It frequently constitutes the entire mineral of a vein.

Fluorite occurs in many localities in the United States, but all that is produced comes from the Illinois*–Kentucky locality.

Illinois: (production in 1897 approximately 2,500 tons, worth about $7.34 per ton).

In Harden county (southern Illinois), near Rosiclare, are extensive deposits of fluorite, associated with galena and blende in veins following fault lines in Carboniferous rocks.

Kentucky: (production in 1897 approximately 2,500 tons, worth about $7.34 per ton).

Crittenden county (in western Kentucky, south of the Illinois deposits), has large vein deposits, similar to those in Illinois.

The fluorite of the Illinois-Kentucky locality is thought by Emmons to be derived from the associated limestones.

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* Fluorspar deposits of southern Illinois. By S. F. Emmons. Trans. Amer. Inst. Min. Eng., 1892–93, XXI, 31–53.

MINERAL PIGMENTS.*

Many pigments are minerals, either natural or artificial products.

The more important minerals used as pigments are here brought together for convenience of reference.

Antimony is a constituent of antimony yellow, Naples yellow, antimony red.

Arsenic is extensively used as a pigment, especially for green colors; it is a component of emerald green (Paris green), Scheele's green, orpiment (King's yellow), realgar, Schweinfurth blue.

Barium is a constituent of manganese green and "constant white."

Cadmium is used in making cadmium red.

Calcium is a constituent of Venetian red.

Gypsum (calcium sulphate) is used in making "terra alba."

Chromium is an important pigment as a green and yellow. It is a constituent of chrome yellow (lead chromate), "perfect yellow" (zinc chromate), chrome green, Guinet's green, Mittler's green, Veronese green.

Cobalt is used in making yellow, blue, and green pigments; cobalt yellow, cobalt green, Gellert's green, cobalt blue, cerulean blue, Leitch's blue.

Copper is extensively used in making greens and blues. It is a constituent of Bremen green, Brunswick green, Casselmann's green, Elsner's green, emerald green (Paris green), Gentele's green, "mineral greens," Scheele's green, Alexandria blue, Bremen blue, Schweinfurth blue.

Graphite paint is used for metal exposed to the weather.

Iron† is a constituent of the ochres, of Prussian green, Alexandria blue, Antwerp blue, Chinese blue, Leitch's blue, Prussian blue, Indian red, Venetian red, sienna, umber.

Lead is a constituent of chrome yellow, Naples yellow, and of various varieties of white (white lead is lead carbonate or sulphate), Pattison's white, red lead (lead oxide).

Magnesium is used in making Indian yellow.

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* Spons' encyclopædia of arts and manufactures, vol. II, 1548–1556. London, 1882.

Paints and painting materials. By H. H. Harrington and P. S. Tilson. Bul. 44, Texas Agr. Exp. Sta. Austin, 1898.

The chemistry of manufacturing processes. By Blount and Bloxam. XV, 449–367. Philadelphia, 1897.

Paint analysis. By Thomas B. Stillman. the digest of physical tests, 1897, II, 114–127. (Contains bibliography.)

Mineral paints. By E. W. Parker. Sixteenth ann. rep. U. S. Geol. Survey, 1894–95, pt. IV, 694–702. Washington, 1895.

Robert Hay in Trans. Kansas Acad. Sci., 1893–94, XIV, 243. Topeka, 1896.

† Ochres and oxide of iron pigments. The mineral industry, VII, 532–536. New York, 1899.

Metallic paint ores along the Lehigh River. By F. A. Hill. Geol. Survey of Pennsylvania for 1886, pt. IV, 1386–1408. Harrisburg, 1887.

Manganese is a constituent of manganese green, sienna, and umber.

Potassium is a constituent of cobalt yellow, Casselmann's green, Schweinfurth blue.

Tin is a constituent of cerulean blue.

Ultramarine is a combination of silica, alumina, sulphuric acid, soda, iron, sulphur, magnesia.

*Vanadium** is used in the preparation of analine black, for coloring porcelain, and in metallurgy.

Whiting is pure chalk.

Zinc is used in "perfect yellow," cobalt green, Gellert's green, methyl green, zinc white.

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* Nature, July 30, 1896, LIV, 300.

ABRASIVES.*

Diamond Dust.

(See pages 174–178.)

Corundum.†

Corundum for abrasive purposes; forms not available for precious stones (see page 180).

Uses.

Powdered corundum is used as a polishing powder.

Emery, an impure variety containing iron is used, as a polishing powder and in making abrasive wheels (emery wheels).

Occurrence.

Corundum occurs in crystalline limestones and metamorphic rocks (gneiss, schists, slates, etc.). It occurs at various places in the Appalachian Mountain region; emery is mined at Chester, Mass., and corundum at Laurel Creek, Georgia; Corundum Hill, N. C.; at Salida, Colo., it occurs in a quartz vein in gneiss.

In 1898 4,072 tons of corundum and emery were produced in the United States, valued at about $253,630.

The imports of emery in the United States in 1898 were valued at $133,399.

Corundum was discovered in Canada in 1896.

Garnet.‡

(See page 180.)

Hardness usually 6.5 to 7.5, sometimes nearly 8.

Crushed garnet used in preparing abrasive paper and belts for various kinds of high polishing, especially leather in boot and shoe factories.

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* Mineral Industry, VI, 11–26.

† Preliminary report on the corundum deposits of Georgia. By Francis P. King. Georgia Geol. Survey, Bul. II. Atlanta, 1894. (Contains bibliography.)

Corundum in the Appalachian crystalline belt. By J. V. Lewis. Trans. Amer. Inst. Min. Eng., 1895, XXV, 852–906. New York, 1896. (Contains bibliography.)

Mineral Industry, VII, 15–21.

Corundum in Ontario. By A. Blue. Trans. Amer. Inst. Min. Eng., 1898, XXVIII, 565–578.

On the origin of corundum associated with the peridotites of North Carolina. By J. H. Pratt. Amer. Jour. Sci., 1898, CLVI, 49–65.

Corundum mining in North Carolina. Eng. and Min. Jour., April 23, 1898, LXV, 490.

Corundum and its uses. Nature, April 13, 1899, LIX, 558–559.

Emery, etc., in the Villayet of Aidin, Asia Minor. By W. F. A. Thomæ. Trans. Amer. Inst. Min. Eng., 1898, XXVIII, 208–225.

‡ Garnet as an abrasive material. By F. C. Hooper. School of Mines Quarterly, Jan., 1895, pp. 124–127. New York.

Garnet for abrasive purposes mined in the Adirondack Mountains is of superior hardness; it occurs in pockets in hornblende-feldspar. Product in 1892 about 2,000 tons.

Sand.*

The principal use of sand as an abrasive is in connection with gang-saws in sawing marble, limestone, and other stones.

Pumice.†

Pumice is a very porous light lava, used in polishing various substances; most of the pumice of commerce comes from Mt. Vesuvius and the Lipari Islands.

Tripoli.

Tripoli is fine grained infusorial earth, composed of the siliceous skeletons of microscopic animals and plants.

Uses.

As a polishing powder. Its grains must be small enough to produce no perceptible scratch on the surface being polished.

As an absorbent for nitroglycerin.

In blocks for blotters.

Distribution and occurrence.

Tripoli is found in the United States in Virginia near Richmond; in California near Monterey, and at Crow's Landing, Stanislaus county; in Nevada. In Newton county, Missouri, a deposit of siliceous limestone from which the lime has been leached is called tripoli.

Deposits of siliceous powder found in Arkansas.

Tripoli is limited to no particular geologic horizon.

Whetstones.‡

Most whetstones are varieties of sandstone, schist, or novaculite, with silica as the abrasive element; of sedimentary origin. Their abrasive powers depend largely upon the size and sharpness of the grit grains.

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* Carborundum, crushed steel, and chilled iron shot, artificial products, are largely used as abrasives, for purposes similar to those of corundum, sand, etc.

† South Italian volcanoes. Ed. by H. J. Johnston. pp. 67–71. Naples, 1891.

‡ Whetstones and the novaculites of Arkansas. By L. S. Griswold. Geol. Survey of Arkansas for 1890, III. Little Rock, 1892.

The whetstones and grindstones of Indiana. By E. M. Kindle. Twentieth ann. rep. Geol. and Nat. Hist. Survey of Indiana, 1895, pp. 329–368. Indianapolis, 1896.

Properties of whetstones.

Effect of coarse-grained and of fine-grained stones upon tools.
Uniformity in size and distribution of grains essential.
Effect of foreign matter between grains.
Compactness of the stone due to the particles being cemented, or to their being jammed together with or without cementing matter.
Character of grains.
  In sandstones: irregular rough grains.
  In schists: irregular massive, or minute angular grains.

Wear of whetstones.

Should be faster in stone than in metal, to prevent glazing.
Glazing is due to wearing away or dulling of the cutting points, clogging of spaces between the points, or both.
Hard fine grained stones most apt to glaze.
Fast wearing stone.
Slow wearing stone.
Oilstones so called because oil is used to float away the abraded metal. They are very fine grained.
Scythe-stones may be used dry.
Water is sufficient to carry away the metal from coarse-grained stones.

Varieties of whetstones.

Sandstones furnish most of the whetstones of the United States.
Labrador stone from Cortland county, New York.
Hindostan stone from Indiana.*
Adamscobite stone from Pierce City, Mo.
Schists furnish scythe-stones especially.
Whetslates.
Novaculites. The novaculites of Arkansas furnish the finest oilstones and honestones in the world.
The Turkey stone.

Whetstones of the United States.

Arkansas, Indiana, Vermont, and New Hampshire furnish most of the whetstones of the United States.
The Arkansas stone (novaculites): exceedingly hard; adapted to grinding fine-edged tools of all sorts.
  The "Arkansas stone."
  The "Ouachita stone."
Indiana.
  Oilstones obtained from Orange county; very fine grained sandstone of Carboniferous age.

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* At an Indiana whetstone quarry. By O. C. Salyards. Stone, 1896, XIII, 539-543.

Vermont.

Whetstones and scythe-stones; principally mica schists of Cambrian and Huronian ages.

New Hampshire.

Scythe-stones and other whetstones from Grafton county; mica schists of Huronian and Silurian ages.

Other states.

New York produces Labrador stone, a fine grained green sandstone, in Cortland county.

Missouri produces Adamscobite stone at Pierce City.

Ohio (Berea, Cuyahoga county), and Michigan (Grindstone City, Huron county), furnish sandstone scythe-stones.

Statistics.

Grindstones.

Grindstones are made from sharp-grained compact sandstones; grains should be of uniform size, and the stone should be soft enough to wear without glazing.

Most of the grindstones of the United States are produced in Ohio, Michigan, South Dakota, and California. Other states supply stones for local demands.

Ohio.

Grindstones are quarried in northern part of state from Berea Grit (Lower Carboniferous). Cuyahoga, Lorain, and Summit counties are the principal producers; there are also quarries in Stark and Washington counties.

Michigan.

Great grindstone quarries at Grindstone City, 90 miles north of Port Huron; fine-grained sandstone free from foreign matter.

Statistics.

Millstones.

Millstones are not properly abrasives. They are made from hard, sharp-grained, tough rocks, of coarse texture. Conglomerates are frequently used.

Millstones in the United States are produced principally in New York, Pennsylvania, Virginia, and Ohio.

Buhrstone is a quartz rock with an open cellular structure especially adapted to the manufacture of millstones. Best qualities of buhrstones come from the Paris basin (Tertiary). Somewhat similar stones occur in Alabama, Georgia, and South Carolina.

Uses.

In grinding grain.
Crushing other materials.
Effect of the roller process in manufacture of flour on use of millstones.

MARBLE.*

"Any limestone, whether compact, crystalline, or granular, which will receive a polish and is suitable for ornamental purposes, is considered a marble."

Uses.

The various uses of ordinary limestone.

Monumental and decorative interior work; statuary.

Adaptations of special colors and varieties.

Origin and occurrence.

Marbles are mostly metamorphosed limestones, and originated as organic sedimentary beds.

Forms, structural disturbances, and changes of the beds.

Kinds of marble.

Marbles vary from mottled impure limestone to the finest and most highly crystalline white varieties; from white through all mottled and variegated colors to black.

Statuary marble must have a perfectly uniform color and be free from flaws; rare.

Parian marble the finest statuary marble; supply about exhausted.

Pentelican marble much used by the ancients.

Cararra marble, from the Apennines, used almost entirely by sculptors at present. Color snow-white; texture saccharoidal.

Marbles of all kinds, mottled, banded, or of uniform color, are used for ordinary interior decorations. Light tints most used; black marble rare.

"Onyx" marble, a crystalline cave deposit; its beauty and scarcity.†

Distribution.

Marble has a very general distribution, both geologic and geographic.

Foreign marble (principal producers):

Austria, Belgium, France, Italy, Spain, Portugal.

These countries all rich in marbles. The Italian marbles from the Apennines, used for sculpturing, are the most noted.

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* Report on the building stones of the United States. Tenth census, 1880, X, 1–393, with plates.

Stones for building and decoration. By George P. Merrill. Pp. 83–166. New York, 1891.

The building and ornamental stones of Great Britain and foreign countries. By Edward Hull. London, 1872.

† The onyx-marbles. By Courtenay De Kalb. Stone, Nov., 1898, XVII, 397–405.

Trans. Amer. Inst. Min. Eng., 1895, XXV, 557.

The onyx deposits of Barren county, Kentucky. By S. S. Gorby. Eng. and Min. Jour., June 17, 1899, LXVII, 707–708.

Mexico. A large deposit of marble, called "Mexican onyx"; this deposit practically exhausted; most of "Mexican onyx" from other sources.

Marble of the United States.

The principal producing states are:
  Vermont:[*] marble "white, clouded, or blue."
    Principal quarries at Rutland.
  Tennessee:[†] marble variegated; of Lower Silurian age; extensive quarries of colored marble.
  Georgia:[‡] the same marble as that of Tennessee.
  New York.[§]
    The largest quarries are at Gouveneur, where the "St. Lawrence" marble is quarried.

Production of marble in	1897.	1898.	1899.
Vermont	$2,050,229		
Georgia	598,076		
Tennessee	441,954		
New York	354,631		
Maryland	130,000		
Colorado	99,600		
Massachusetts	79,721		
Pennsylvania	62,683		
California	48,690		

Arkansas[‖] marble the same as Tennessee and Georgia.
  Extent of the Arkansas marbles; not now worked.

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[*] Geology of Vermont. By A. D. Hager. II, 751-780. Claremont, N. H., 1861.

[†] Geology of Tennessee. By James M. Safford. Nashville, 1869.

[‡] A preliminary report on the marbles of Georgia. By S. W. McCallie. Geol. Survey of Georgia, Bul. no. 1. Atlanta, 1894.

[§] Building stone in the State of New York. By J. C. Smock. Bul. no. 3, New York State Museum of Nat. Hist. Albany, 1888.

Building stone in New York. By J. C. Smock. Bul. of the New York State Museum, II, no. 10. Albany, 1890.

[‖] Marbles and other limestones. By T. C. Hopkins. Ann. rep. Geol. Survey of Arkansas for 1890, IV. Little Rock, 1893.

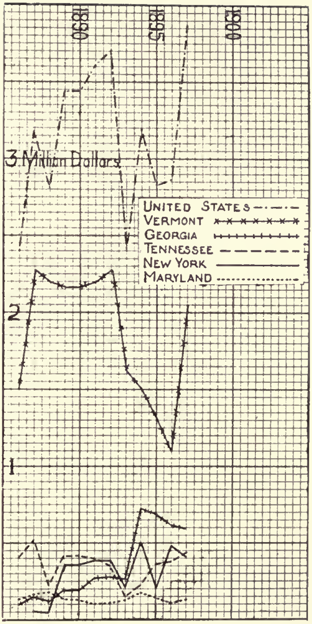

Fig. 134.—The value of the marble quarried in the United States since 1885.

LIMESTONES OTHER THAN MARBLES.*

Limestone is a sedimentary rock; it is composed of calcium carbonate, often with magnesium carbonate; it always contains impurities.

Uses.

- For building purposes.
    - Importance as a building stone.
    - Crushing strength per sq. in. from 62 samples, 14,545 lbs., ranging from about 5,000 lbs. to 25,000 lbs.
- As a flux in smelting ores.
- Lithographing.
- Lime; cement.
- Carbonic acid gas (marble usually used).
- Whiting (from chalk).
- Effect of limestone on the mineral and agricultural wealth of a country.

Origin.

- Organic.
    - Kinds of organisms: rhizopods, pteropods, and heteropods (deep sea); corals, echinoderms, crustaceans, bryozoans, brachiopods, lamellibranchs, gasteropods, cephalopods (off shore or comparatively shallow water); calcareous algæ.
- Chemical.
- Methods of formation.

Occurrence and distribution.

- Of sedimentary origin, subject to laws of sedimentary rocks.
- Universal geographic and geologic distribution.
- Approximate thickness of limestone formations.

Varieties.

- Through all grades from calcareous shales and sandstones to pure limestones.
- Shaly limestones; sandy limestones.
- Crystalline limestones (mostly marbles).
- Chalk.
- Oölitic limestones (Ex. Bedford stone).

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* Report on the building stones of the United States. Tenth census, 1880, X, 1–393, with plates.

Stones for building and decoration. By George P. Merrill. Pp. 122–166. New York, 1891.

Marbles and other limestones. By T. C. Hopkins. Geol. Survey of Arkansas for 1890, IV. Little Rock, 1893.

Lithographic limestone.

Dolomitic limestone.[*]

Dolomite is a carbonate of calcium and magnesium, with the proportions varying 1 to 1, 1 to 3, or 1 to 5.

Hydraulic limestone.

Prevalent colors in limestones.

Blue, gray, buff, white, the most common.

Alteration of colors by weathering.

Principal limestone-producing states.

Pennsylvania: Lower Silurian, Devonian, and Lower Carboniferous limestones; used largely for building, and as a flux in smelting.

Indiana: the "Bedford oölitic stone"[†] (Lower Carboniferous) the most important in the state. Principal quarries in Lawrence and Monroe counties.

Ohio: Silurian, Devonian, Carboniferous stone; dull in color; quarried in various parts of the state; used mostly for rough work.

Illinois: largest quarries in Will county (at Lemont and Joliet); Niagara group; stone light drab, fine grained; Trenton limestone of Jo Daviess county also important.

Production of limestone in	1897.	1898.	1899.
Pennsylvania	$2,327,870		
Indiana	2,012,608		
Ohio	1,486,550		
Illinois	1,483,157		
Missouri	1,018,202		
Other states	6,494,274		

Lithographic Limestone.

Character of lithographic stone.

It must contain no grains or crystals.

Distribution.

The lithographic limestone of commerce is produced at Solenhofen, Bavaria; it is of Upper Jurassic age.

Lithographic limestone found, but not proved commercially important, in Alabama, Arizona, Arkansas, Illinois, Indiana, Iowa, Kentucky, Missouri, Tennessee, Texas, Utah, Virginia.

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[*] The origin of dolomite. Amer. Jour. Sci., May, 1895, CXLIX, 426–427.

Origin of the dolomites. By Hall and Sardeson. Bul. Geol. Soc. of America, 1894, VI, 193–198.

[†] The Bedford oölitic limestone of Indiana. By T. C. Hopkins and C. E. Siebenthal. Twenty-first ann. rep. Geol. Survey of Indiana, 1896, pp. 290–427.

Lime.

The importance of lime.

Lime (CaO) is made by driving off the carbonic acid (CO_2) from limestone.

Uses.

- In making mortar and cements.
- Plastering, whitewashing.
- As a fertilizer.
    - Value of lime as a fertilizer; its effect upon soil.
- As a disinfectant.
- Uses in chemistry.

Kinds of lime.

- Common limes.
- Hydraulic limes.

Characteristics of lime.

- Slaking.
- Rehardening (setting) with foreign substances.
    - Sand in mortar furnishes points on which the lime crystallizes in setting.
- Lime can be produced in any locality that has limestone.
    - Importance of lime in engineering works.

Hydraulic Limestone.*

Hydraulic limestone contains clay and furnishes a lime that will set under water.

The hydraulic limestones of the United States are usually shaly and contain considerable magnesia.

Used for making hydraulic lime and cement.

ANALYSES.

	Rosendale, N. Y.†	New York.	Wisconsin.
Lime carbonate	44.34	45.54	43.29
Magnesia carbonate	23.92	25.94	29.19
Silica	22.14	15.37	17.56
Alumina	3.80	9.13	1.40
Iron oxide		2.25	2.24
Water and organic matter	.83	1.20	

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* On limes, hydraulic cements, and mortars. By Q. A. Gillmore. Ninth edition. New York, 1888.

† Mineral industry for 1894, III, 91.

Distribution.

Geologic.

Most of the hydraulic limestone of the United States occurs in Paleozoic rocks.

Geographic.

Hydraulic limestone is by no means so widespread as ordinary limestone. The principal states in which it occurs and is utilized are New York, Indiana, and Kentucky (Louisville region), Pennsylvania, Wisconsin, and Illinois.

Hydraulic cement.

Hydraulic cement is made from hydraulic limestone; it has the power of setting under water.

Composition.

How made.*

Uses and importance.

The principal manufacturing district is Rosendale, Ulster county, New York. The industry was established there in 1823. The output of the Rosendale district in 1848 was 190,000 barrels, worth $260,000; in 1898 it was 3,245,225 barrels, worth $2,103,554.

The district next in importance is that of Kentucky and Indiana, in the vicinity of Louisville. Its output in 1898 was 1,929,018 barrels, worth $482,254.

Chalk.†

Chalk is an earthy, white limestone, for the most part composed of the skeletons of minute organisms.

Mode of formation.

Uses.

For making whiting.

For crayons.

In the manufacture of Portland cement.‡

In fertilizing.

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* The manufacture of Rosendale cement. Eng. and Min. Jour., Oct. 16, 1897, LXIV, 459.

† The Neozoic geology of southwestern Arkansas. By R. T. Hill. Geol. Survey of Ark. for 1888, II, 153–162. Little Rock, 1888.

The Niobrara chalk. By Samuel Calvin. American Geologist, Sept., 1894, XIV, 140–161.

‡ Portland cement; its manufacture, testing, and use. By D. B. Butler. London and New York, 1899; 360 pages.

The science and art of the manufacture of Portland cement, with observations on some of its constructive applications. By Henry Reid. New York, 1877.

On the manufacture of Portland cement. By John C. Branner. Geol. Survey of Ark. for 1888, II, 291–302.

Portland cement. A monograph. By C. D. Jameson. Iowa City, 1895.

Portland cement. By S. B. Newberry. Seventeenth ann. rep. U. S. Geol. Survey, pt. III, 881–893. Washington, 1896.

American cements. By U. Cummings. Boston, 1898.

Distribution.

Geographic.

England and France are the principal producers of chalk.

Deposits of chalk are found in the United States in Arkansas, Texas, Iowa, and Nebraska.

Portland cement is a hydraulic cement, made from carbonate of lime (chalk) and clay. "Not over thirty or forty per cent of ordinary Portland cement which is active in the hardening process. The rest is inert and like so much sand."*

Methods of manufacture.†

Sixty per cent of silica required in the clay, magnesia limit 3%.

The cement yield is about 60% of the weight of the chalk and clay.

Uses of Portland cement.

In mortar, for cementing building stones, for paving purposes.

Artificial stone for building purposes.

Advantages of Portland cement.

Gypsum.‡

Gypsum is a soft hydrous sulphate of calcium, varying in color—white, red, yellow, brown, blue, black.

Uses.

In manufacture of "plaster of Paris,"§ and cement plasters.‖

As "land plaster."

In statuary (alabaster).

Varieties.

Selenite.

Fibrous gypsum (satin spar).

Alabaster.

Modes of occurrence.

Usually dull colored; mixed with impurities; in beds often of great thickness, interstratified with limestones, clays, and salt.

Origin: deposited from solution.

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* J. B. Johnson. Proc. Amer. Assoc. for Adv. of Sci., 1898, XLVII, 244.

† History of the Portland cement industry in the United States. By Robert W. Lesley. Jour. Frank. Inst., Nov., 1898, CXLVI, 324–348.

‡ Geology and mineral resources of Kansas. By Robert Hay. Pp. 46–48. Topeka, 1893.

Mineralogy of New York. By Lewis C. Beck. Pp. 61–67. Albany, 1842.

§ Journal Frank. Inst., February, 1899, CXLVII, 171.

‖ The technology of cement plaster. By P. Wilkinson. Eng. and Min. Jour., Nov. 12, 1898, LXVI, 576.

Report on gypsum and gypsum cement plasters. By G. P. Grimsley and E. H. S. Bailey. Univ. Geol. Survey of Kansas, V. Topeka, 1899.

Distribution.

Gypsum is widespread, geographically as well as geologically.

Its distribution in the United States is fairly well shown by the following statistics.*

Principal gypsum-producing states in	1897. Short tons.	1898.	1899.
Michigan	94,874		
Iowa	83,783		
Kansas			
New York	33,440		
Texas	24,454		
Colorado	12,309		
Indian Territory			
South Dakota	8,350		
Virginia	6,374		

It is quarried somewhat in other states.

The total product of the United States in 1897 was 288,982 tons, worth $755,864.

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* The salt and gypsum industries in New York. By F. J. H. Merrill. Bul. New York State Museum, III, no. 11. Albany, 1893.

Gypsum in Arizona. By W. P. Blake. Amer. Geologist, Dec., 1896, XVIII, 394.

The origin and age of the gypsum deposits of Kansas. By G. P. Grimsley. American Geologist, Oct., 1896, XVIII, 236.

Gypsum in Kansas. By G. P. Grimsley. Kansas Univ. Quarterly, 1897, VI, 15-27.

Gypsum in Iowa. By C. R. Keyes. Mineral Industry, 1895, IV, 377-388.

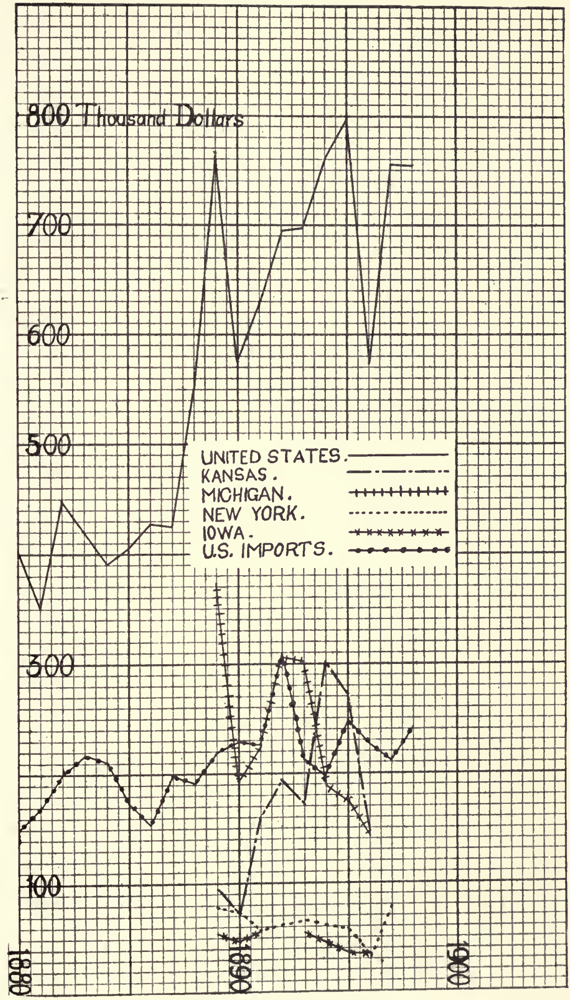

Fig. 135.—The production and imports of gypsum in the United States since 1880.

BUILDING STONES IN GENERAL.*

Few kinds of stone cannot be used for building; those most used are granites, sandstones, and limestones.

Properties to be considered in building stones.

- Ability to withstand weather.†
- Ability to withstand heat.
- Color.
- Hardness before and after being worked.
- Density.
- Crushing strength.
  - Building stones are seldom subjected to more than from one-sixth to one-tenth the pressure they can withstand.
  - Stone subjected to a gradual pressure can withstand more than the same stone subjected to sudden pressure.

CRUSHING STRENGTH (LBS. PER SQ. IN.) OF SOME BUILDING STONES.

Granite.		Limestone.		Sandstone.	
East St. Cloud, Minn.	28,000 26,250	Bedford, Indiana	6,500 10,125	Belleville, N. J.	11,700 10,250
Mystic River, Conn.	18,125 22,250	Conshohocken, Pa.	16,340	Albion, N. Y.	13,500
		Joliet, Illinois	14,775	Middleton, Con.	6,950 5,550
Fourche Mt., Ark. (Seyenite)	33,620	Bloomington, Ind.	13,750		
Cape Ann, Mass.	19,500	Ellettsville, Ind.	13,500	Berea, Ohio	10,250
Vinalhaven, Maine	15,698	Quincy, Illinois	9,787	Vermillion, O.	7,840
Penryn, Cal.	6,117	Average of 62 samples	14,545	Portland, Conn.	4,945
Average of 72 samples	17,591	Average of 31 in Wisconsin	25,102	Average of 100 samples	9,046
Average of 37 Wisconsin granites and rhyolites	26,649			Avg. 45 in Wis.‡	6,427

Distribution.

Stone that may be utilized for building occurs in all countries, and in almost all geologic formations.

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* Steinbruchindustrie und Steinbruchgeologie. Technische Geologie nebst praktischen Winken für die Verwertung Gesteinen. Von Dr. O. Herrmann. Berlin, 1899.

The physical, chemical, and economic properties of building stones. By G. P. Merrill. Special publication Maryland Geol. Survey, II, pt. II. Baltimore, 1898.

The collection of building and ornamental stones in the U. S. Nat. Museum. By G. P. Merrill. Smithsonian rep., 1886, pt. II, 277–648. Washington, 1889.

Report on the building stones of the United States. Tenth census, 1880, X, 1–393, with colored plates. Washington, 1880.

Stones for building and decoration. By George P. Merrill. New York, 1891.

Stone. An illustrated magazine, issued monthly. Chicago, Illinois.

† The decay of the building stones of New York city. By A. A. Julien. Trans. N. Y Acad. Sci., 1883, II, 67–79, 120–138.

Durability of building stones. By H. A. Cutting. Amer. Jour. Sci., 1881, CXXI, 410.

‡ On the building and ornamental stones of Wisconsin. By E. R. Buckley. Pp. 390–394. Madison, 1898.

Granite.

Granite (average sp. gr. 2.66) is a highly crystalline rock, varying widely in texture and color, with quartz and feldspar as essential constituents; mica and hornblende with other minerals are usually present.

Uses.

In massive structures.
As an ornamental stone: monuments; interior decorations.
Damage done granite buildings by fire.

Varieties.

Biotite granite; muscovite granite; hornblende granite, etc.

Geologic relations.

Granites may be of any age.
They occur massive, never stratified; often as cores of mountain ranges; sometimes as dikes.

Distribution.

Granite has a general distribution. It is the fundamental rock of the earth's crust.
The New England States are the principal granite producers of the Union.
  Maine: granites gray (largely), pink, and red.
    Largest quarries at Vinalhaven.
  Massachusetts: Quincy quarries the most important; stone coarse grained, usually dark blue-gray.
  Rhode Island: principal quarries near Westerly; biotite granites, fine grained; color, pink to light gray.
  Connecticut: granite and gneiss, fine grained; color, mostly light gray. Used locally.
  New Hampshire: granite in eastern part of state; color, light gray, white; fine grained.
    "The muscovite-biotite granite of West Concord."
  California:* granite very generally distributed through the state. Quarries at Rocklin and Penryn. Stone fine grained; color, "light to dark gray."
    Quarries near Raymond and elsewhere in the state.
  Georgia: light-gray granite near Atlanta.
Granite is quarried in many other states, but to a less extent.

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* Folio 5. Sacramento folio, California. Geologic Atlas of the United States. By the U. S. Geol. Survey. Washington, 1894.

Value of production in	1897.	1898.	1899.
Massachusetts	$1,736,069		
Maine	1,115,327		
Vermont	1,074,300		
New Hampshire	641,691		
Rhode Island	629,564		
Connecticut	616,215		
New Jersey	561,782		
Georgia	436,000		
New York.	422,216		
Pennsylvania	349,947		
Delaware	272,469		
Maryland	247,948		
California	167,518		
Other states	634,029		

Limestones.

See pp. 274–276, "Marble," and pp. 278–288, "Limestones other than marbles."

Sandstones.

Sandstones are fragmental sedimentary rocks occurring in all geologic formations, having quartz-sand as an essential constituent; in color they vary from white to blue, brown, and red; color and adaptability determined largely by cementing material. Freshly quarried sandstone usually soft, owing to the water contained.

Varieties.

Quartzites.
Flagstones.
Freestones.
Calcareous sandstones; ferruginous sandstones.
Other varieties.

Geologic relations.

Of sedimentary origin, subject to the conditions of other sedimentary deposits.

Sandstone in the United States.

Sandstone suitable for building is widely distributed.

Ohio: most important quarries in the Berea Grit (Lower Carboniferous) in northern part of the state. Stone fine grained; color, buff to blue.

Pennsylvania: Triassic sandstone.[*] Principal quarries in Dauphin county. Color, "deep bluish-brown, slightly purple," with reddish-brown layers. Sandstone of importance in the Trenton formation.

Connecticut: Triassic sandstone, brown and red. Quarries at Portland most important.

New York:[†] Cambrian sandstone (Potsdam); color, very light to light red; very hard.

Upper Silurian (Medina) sandstone; gray to red; rather coarse texture.

Devonian (Hamilton) sandstone; color, "dark blue-gray"; compact, fine grained.

New Jersey: Triassic sandstone; red and dark brown.

Other states.

Value of product in	1897.	1898.	1899.
Ohio	$1,600,058		
New York	544,514		
Pennsylvania	380,813		
Connecticut	364,604		
Massachusetts	194,684		
New Jersey	190,976		
Other states	789,796		

Other Building Stones.

Conglomerates: coarse grains or pebbles, held together by some cementing material; breccias are conglomerates in which the fragments are angular.

Slates:[‡] metamorphosed clay shale, usually of some dark color; largely used in roofing.

Other uses: tiles, school slates, blackboards, mantels, flagging, billiard tables. Usually found in regions of folded rocks.

Tuff: consolidated and unconsolidated volcanic rocks are sometimes used in buildings. Extensively used on the Santa Fé route for railway ballast.

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[*] Building materials of Pennsylvania. I, Brownstones. By T. C. Hopkins. Appendix to ann. rep. Pennsylvania State College for 1890.

[†] Building stone in the State of New York. By J. C. Smock. Bul. of the New York State Museum, no. 3. Albany, 1888.

Building stone in New York. By J. C. Smock. Bul. of the New York State Museum, II, no. 10. Albany, 1890.

[‡] The slate regions of Pennsylvania. By Mansfield Merriman. Stone, July, 1898, XVII, 77–90.

The strength and weathering qualities of roofing slates. By M. Merriman. Trans. Amer. Soc. Civil Eng., 1892, XXVII, 332–349; 1894, XXXII, 529–543.

The New York slate industry. By J. N. Nevins. Eng. and Min. Journal, May, 1899, LXVII, 587–588, 622.

Gneiss: composition same as granite, but it shows a foliated or banded structure; it is extensively used in buildings in Brazil.

Schists: structure similar to that of gneiss; with little or no feldspar. The schists split readily; much used for flagging, and sometimes in foundations.

Syenite: like granite, except that it contains no quartz. The syenite near Little Rock, Arkansas, an excellent building stone, is blue or gray in color. Average crushing strength (per sq. inch in 2-inch cubes) 33,620. Used in buildings and paving.*

Augite: a dark-colored eruptive rock, usually containing magnesium and iron. It is used some for buildings, and extensively in paving.

Serpentine: a hydrous silicate of magnesia, probably derived from alteration of eruptive rocks; color usually green or yellowish, sometimes brown, red, or almost black; variety known as verde-antique much used for interior decoration.

Its softness makes serpentine objectionable for decorations.

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* The igneous rocks of Arkansas. By J. Francis Williams. Ann. rep. Geol. Survey of Arkansas for 1890, II, 42-53. Little Rock, 1891.

KAOLIN.

Kaolin is mostly kaolinite, a hydrous silicate of alumina, containing silica 46.5%, alumina 39.5%, water 14.0%. Kaolin always contains other substances as impurities. Varieties of kaolin with water varying from 7.49% in rectorite to 24.46% in newtonite.

*Uses.**

- The finest grades for making fine porcelain and chinaware.
  - Kaolin from near St. Yrieix, France, used for the Limoges and Sèvre porcelain.
- The common grades for cream-colored ware, sanitary ware, and other ordinary grades of pottery, and for decorative tiles.

Origin.

- Kaolin is formed by decomposition from aluminous minerals, especially from the feldspars.
  - Composition of feldspar.
  - Changes necessary to produce kaolin.
  - Experiments of Daubrée on pulverized feldspar.

Occurrence.

1. In irregular beds in decayed granites, porphyries, and gneisses.
   - Quarries near St. Yrieix, France.
   - Formerly mined at Brandywine Summit, Pa.†
     - Quarrying and mining methods.
   - Original deposits to be sought only in rocks whose decay would furnish kaolin.
2. In regular sedimentary beds by the removal and deposition in water of original deposits.
   - Examples of Arkansas kaolins.
   - Conditions under which sedimentary kaolins may be formed.
   - Determination of sedimentary kaolin.

- Kaolin may occur in rocks of any geologic age, and in any part of the world containing rocks capable of forming it upon decay.

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* Kaolin; its occurrence, technology, and trade. By T. C. Hopkins. Mineral Industry for 1898, VII, 148–160.

Traité des arts céramiques. Par A. Brongniart. Paris, 1854.

Handbuch der gesammten Thonwaarenindustrie. Von Bruno Kerl. Braunschweig, 1879.

For lists of books on pottery, see Bibliographie Céramique. Par Champfleury. Paris, 1881.

Bibliography of clays and the ceramic arts. By J. C. Branner. Bul. 143, U. S. Geol. Survey. Washington, 1896.

† On Pennsylvania kaolin deposits. By J. P. Lesley. Ann. rep. Geol. Survey of Pennsylvania for 1885, pp. 571–614. Harrisburg, 1886.

Treatment.

- Practically no kaolin is now used as it comes from the ground.
  - Hand picking; grinding; settling; addition of "flint" or quartz and feldspar.
  - Effect of drying on different kaolins.
  - Effect of burning.
    - Loss of plasticity.
    - Color and composition.

Clay.*

Clay is for the most part an impure kaolin, formed originally in the same way.

Examples of differences shown by analyses.

Clays of organic origin.

Uses.†

- Manufacture of common bricks, "vitrified" bricks for paving, tiles (drain and roof), terra cotta (ornamental and architectural), common pottery, door knobs, chimney pots, sewer pipes, and playing marbles.
- Refractory purposes.

Occurrence.

- Residuary clays from the decomposition of rocks in place.
  - Forms of deposits from decay along the outcrops of sedimentary rocks.
  - Forms of deposits from the decay of crystalline rocks.
- Transported clays.
  - Forms of the beds.
  - Cause of areal changes in the characters of the beds.
  - Why some beds are thick and others thin.
  - Why some beds are hard and others soft.
  - The loess clays of the Mississippi valley.
  - The Milwaukee brick clays.
    - Why the bricks are cream colored.
- Formation of slates.

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* Clay materials of the United States. By R. T. Hill. Mineral resources of the U. S. for 1891, pp. 474–528.

† Annual reports of the National Brick Manufacturers' Association. Indianapolis, since 1887.

The Clay Worker (Monthly). Indianapolis, since 1884.

A practical treatise on the manufacture of bricks, tiles, terra-cotta, etc. By C. T. Davis. Philadelphia, 1889.

Distribution.

Clays are found in sedimentary rocks of all ages and in all countries.

The clay industries of the United States.

- New Jersey:* Trenton potteries.
- Ohio: East Liverpool and Cincinnati potteries.
- Missouri: St. Louis brick industries.

The value of the clay products of the United States since 1889 has been between nine and ten millions of dollars annually.

BAUXITE.

Bauxite is hydrate of alumina; essentially alumina 73.9, water 26.1%. It is massive, oölitic, or earthy; white, gray, or red.

Uses.[†]

Manufacture of alum, sulphate of alumina, and aluminum, and as a refractory material or for increasing the refractoriness of fire-clays.

Occurrence.

In southern France in massive beds at the junction between Triassic and Jurassic; in Arkansas[‡] as irregular masses in Tertiary rocks, sometimes covering several acres; in Alabama as beds interstratified with Paleozoic rocks.

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[*] Report on the clay deposits of New Jersey. By George H. Cook and J. C. Smock. Trenton, 1878.

[†] Aluminium: its history, occurrences, properties, metallurgy, etc. By J. W. Richards. Philadelphia, 1890.

[‡] The bauxite deposits of Arkansas. By J. C. Branner. Journal of Geology, 1897, V, no. 3, pp. 263–289. (Bibliography.)

ALUMINUM.*

Uses.

- Conductor of electricity.
- Manufacture of alloys.
    - Aluminum-copper alloys.
    - Aluminum-iron alloys.
- Manufacture of articles requiring strength and lightness and of articles that should not corrode.
- The high price of aluminum prevented its general use until a few years ago.

Metallic aluminium or aluminum does not occur in nature; the metal has been known since 1827, but it is only since 1889 that the price of it has been below $2.00 per pound. It was formerly made from cryolite; it is now made from bauxite.

Cryolite (fluorine 54.4, aluminum 12.8, sodium 32.8) was formerly used in the manufacture of aluminum.

The largest known deposits of cryolite are on the west coast of Greenland, 12 miles from Arksuk, where it occurs in a granite vein in gneiss.†

Aluminum is now made from bauxite,‡ which is called aluminum ore. (See page 304.)

Aluminum can be made from kaolin and common clays, but the cost of extraction from these substances is much greater than from bauxite.

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* Aluminium: its history, properties, etc. By J. W. Richards. Second ed. Philadelphia, 1890; third ed., Philadelphia and London, 1896; 666 pages.

The properties of aluminum, with some information relating to the metal. By A. E. Hunt, J. W. Langley, and C. M. Hale. Trans. Amer. Inst. Min. Eng., 1890, XVIII, 528–563.

† On the cryolite of Evigtok, Greenland. By J. W. Taylor. Proc. Geol. Soc. of London, 1856, XII, 140–144.

‡ The preparation of alumina from bauxite. By James Sutherland. Eng. and Min. Journal, Oct. 3, 1896, LII, 320–322.

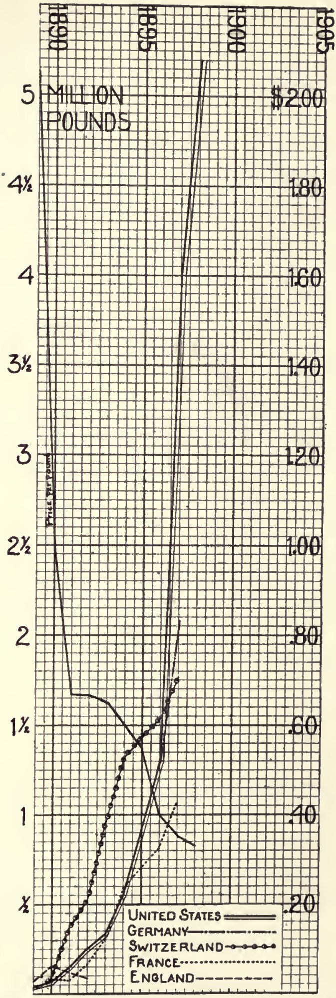

Fig. 136.—The aluminum output of the chief producers, and its market price per pound since 1889.

GLASS-SAND.*

The essential constituent for manufacturing glass is silica; it is found as loose sand or as more or less compact sandstone.

Purity of sand necessary.

ANALYSES OF GLASS-SAND.

Constituents	Isle of Wight	France
Silica	97.0	98.8
Moisture	1.0	0.5
Oxide of iron and magnesium	2.0	0.7
	100.0	100.0

Distribution.

Sand that may be used for making glass has a very general distribution. England, France, Germany, Austria, Belgium, Holland, Sweden, and Canada are all rich in glass-sand. It may occur in rocks of any geologic age.

Glass-sand of the United States.

New Jersey has extensive deposits of Tertiary age.

Pennsylvania: Oriskany sandstone in Mifflin county.

West Virginia: Oriskany sandstone in Morgan county.

Indiana: Madison, Parke, Clark, and Harrison counties.

Michigan: glass-sands from the shores of Lake Michigan.

California: recent sands near Monterey.

Wisconsin: glass made from the St. Peter's and the Potsdam sandstone.

Missouri: at Crystal Springs in Jefferson county.

Iowa: Lower Silurian (St. Peter's sandstone).

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* Geol. of New Jersey, 1868, pp. 690-695, and 293. Newark, 1868.

Geol. Survey of Missouri, 1855-1871, pp. 62, 129, 200, 273, 289, 302. Jefferson City, 1873.

Geol. Survey of Missouri, 1872, p. 289. New York, 1873.

Geol. and natural history of Indiana. Twelfth ann. rep., 1882, p. 22. Indianapolis, 1883.

Geol. of Wisconsin, 1873-77, II, 290, 546, 558. Madison, 1877.

Second Geol. Survey of Pennsylvania, 1888-89. Rep. F 3, pp. 271-274, 288-292. Harrisburg, 1891.

Iowa Geol. Survey. First ann. rep. for 1892, I, 24-25. Des Moines, 1893.

Tenth census, 1880, II, 1029-1152.

REFRACTORY MATERIALS.*

Refractory materials are substances of various compositions, capable of withstanding high temperatures without fusing.

Uses.

They are used for lining furnaces, stoves, and chimney backs, and making crucibles, hearths, retorts, and the like; clay of low refractoriness is used for making sewer pipes and "vitrified" paving bricks.

Composition.

(Some infusible substances are not mentioned here because they are not practically available.)

Refractory materials vary greatly in composition.
- Aluminous: fire-clay, bauxite, kaolin.
- Magnesian: asbestos, magnesite, talc.
- Carbonaceous: graphite.
- Calcareous: pure lime.
- Siliceous: pure quartz of Dinas brick.

The refractoriness of most substances depends upon their purity.
- Pure lime highly refractory alone; a flux with certain other substances.
- Magnesia refractory alone; a flux in combination.
- Pure silica used for Dinas brick; lowers refractoriness of other substances.

Fire-Clay.†

Clays and kaolins are hydrous silicates of alumina. Fire-clays proper are clays that do not fuse readily.

Fire-clays may occur with sedimentary rocks of any age.

How deposited.

Why so abundant in the Carboniferous.

Structural features.

Varying degrees of refractoriness.

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* Metallurgy. By John Percy. Refractory materials: crucibles, furnaces, fire-bricks, etc., pp. 87–154. London, 1875.

Fuel and refractory materials. By A. Humboldt Sexton. London, 1896.

† Determining the refractoriness of fire-clays. By H. O. Hofman and C. D. Demond. Trans. Amer. Inst. Min. Eng., 1894, XXIV, 42–66.

Die feuerfesten Thone. Von Dr. Carl Bischof. Leipzig, 1876.

Refractoriness determined by composition and physical condition.

Fluxing influence of the common constituents of clays on a silicate of alumina determined by Bischof.

Equivalents (parts by weight)
- 20 of magnesia
- 28 of lime
- 31 of soda
- 40 of iron oxide
- 47 of potash.

Bischof's formula based on chemical composition is as follows:

$$\text{Refractoriness} = \frac{(Al_2O_3)^2}{M \times SiO_2} \times 0.2759.$$

$$[M = (0.6 \times Fe_2O_3) + (0.857 \times CaO) + (1.2 \times MgO) + (0.5092 \times K_2O) + (0.7729 \times Na_2O).]$$

According to this formula fire-clay of Cheltenham, Mo., has refractoriness of 0.86; Stourbridge best clay, 1.28; clay for vitrified brick, 0.24 to 0.34.

Wherein analyses of clays may not be trusted.

The refractoriness of a single clay varies with physical condition.

Use of "grog" or "chamotte."

Increase of refractoriness of clay by the use of bauxite.

Paving-brick made of fire-clay of low refractoriness.

How to lower or raise refractoriness.

Magnesite.*

(Carbonate of magnesia: magnesia 47.6; carbon dioxide 52.4.)

Uses.

Refractory material in basic hearths of steel furnaces and fireproof buildings.

Bleaching agent in making wood-pulp paper.

Manufacture of magnesium salts.

Manufacture of carbonic acid for artificial mineral waters.

Occurrence and distribution.

Associated with serpentines, talcose schists, and other magnesian rocks, in thin veins and strings.

Mined near Veitsch, Austria, and made into fire-brick.

At Bolton, Canada, deposit said to be 60′ thick.

In Silesia, Germany, deposits at Grochau and Baumgarten.

In Greece as veins in serpentine.

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* A history and description of magnesia, and its base and compounds. By Henry G. Hanks. San Francisco, 1895.

Magnesite in India. Eng. and Min. Journal, Dec. 3, 1898, LXVI, 669.

In United States associated with serpentine beds on Staten Island; in California in Fresno, Alameda, Napa, Santa Clara, San Mateo, and other counties. It can probably be found as white veins in serpentine wherever the latter occurs. It is worked only in California.

The California output in 1898 was 1,263 tons, worth $19,075.

In January, 1900, crude German magnesite was worth $12.00 per ton and magnesite bricks $185.00 a thousand in New York.

Chrysotile ("Asbestos").*

Commercial "asbestos" is chrysotile, a fibrous variety of serpentine. Silica 44.1, magnesia 43.0, water 12.9.

Uses.

Steam packing; covering for boilers, steam pipes, hot-water pipes; fireproofing buildings and safes; gas stoves and fireplaces, fireproof cloth (theatre curtains); weighting silks.

Distribution and occurrence.

It occurs in narrow veins in serpentine rocks; the veins but few inches wide; fibers cross the veins.

Method of mining.

Nearly all the asbestos used in the United States comes from Quebec, Canada, which produces 85% of the world's supply.

California produced 10 tons in 1898, as against 1,200 tons in 1882 and 100 tons in 1888.

The imports of asbestos, including manufactured articles, were valued at $3,221 in 1877; at $140,845 in 1887; and at $268,264 in 1897.

Imports of asbestos into the United States from Canada:

1870	$ 7	1898	$
1880	9,736	1899	
1890	257,879	1900	
1897	190,971	1901	

Talc.†

Talc is also known as soapstone and steatite; its composition: silica 63.5, magnesia 31.7, water 4.8.

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* The mining industries of eastern Quebec. By R. W. Ells. Trans. Amer. Inst. Min. Eng., 1889-90, XVIII, 320-328.

Notes on asbestos and asbestiform minerals. By G. P. Merrill. Proc. U. S. National Museum, 1895, XVIII, 281-292. Washington, 1896.

† Genesis of the talc deposits of St. Lawrence county. By C. H. Smyth, Jr. School of Mines Quarterly, July, 1896, XVII, 333. (References.)

Talc and soapstone. By C. A. Waldo. The Mineral Industry, 1893, II, 603-606.

Report on the talc industry of St. Lawrence county. By C. H. Smyth, Jr. Fifteenth ann. rep. State Geologist [of New York] for 1895, pp. 661-671. Albany, 1897.

It is used for cooking utensils, heating stoves, furnace linings, for fireproof paints, adulterating soap. Fibrous talc is used for weighting paper, in paints, and for making wall plasters.

It occurs in large beds, usually in regions of metamorphic rocks.

St. Lawrence county, N. Y., principal producer of talc. Mined at Talcville in 400′ shafts; vein 18–20′, with granite walls. The output of fibrous talc in 1897 was 57,009 tons, worth $396,936.

Graphite.

(For geology of graphite, see pp. 200–202.)

Theoretically graphite is pure carbon, but analyses of a large number of samples show it to contain at most from 80 to 99% carbon.

Used for making crucibles; mixed with clay and turned on a wheel like pottery.

Lime.

(For geology of limestone, see p. 278.)

Lime alone "is one of the most refractory substances known, and no temperature has as yet been attained which has caused it to exhibit the slightest indication of fusion."—Percy, 134.

Crucibles made of unslacked lime are made by sawing the lumps in blocks and boring cavities in center.

Silica.

The Dinas fire-brick made of quartz-sand (96.73–98.31% pure silica) from the Millstone Grit, in the Vale of Neath, near Swansea, Wales. They expand on being heated; fire-clay bricks contract. Silica bricks cannot be used where the slag contains metallic oxides.

Any pure quartz may be used to manufacture silica bricks. Fire-clay is used to hold the sand together. Styrian silica bricks.

Availability of novaculites.

Occurrence and distribution of novaculites.

Chrome Iron.*

Chrome iron has lately come into use for furnace linings. It is crushed, washed, and made into bricks for this purpose.

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* Engineering and Mining Journal, Feb. 6, 1897, LXIII, 136.

Mica.*

Uses.

The large sheets of mica are used for stove and furnace doors; covers for the eyes of persons working at certain trades.

Scrap mica is ground up and used for insulating and fireproofing, and for a lubricant; also for an absorbent of nitroglycerin, in wall-paper, and in the manufacture of bronze powder.

Composition and character.

The mica of commerce is *Muscovite*, and has the following theoretical composition: Silica 45.2, alumina 38.5, potash 11.8, water 4.5%.

Its transparency and flexibility.

Occurrence.

Mica occurs of commercial importance in the Appalachian Mountains in New Hampshire, Virginia, and North Carolina; in the Black Hills of South Dakota; in northern New Mexico and western Idaho.

Found in pegmatite dikes in Archean gneisses and granites, generally cutting across the schistosity of the rocks.

"Books" or crystals are scattered through the mass, though sometimes near the walls.

Usually less than 1% of mica in the rock; sometimes as high as 10%.

Of the mined mica only from 1 to 10% is valuable as sheet mica.

The mica imported into this country comes chiefly from Great Britain, Canada, and the East Indies.

In January, 1900, the price of mica in New York was for sheets $1\frac{1}{2}\times3$ in., 60 cents, and sheets 8×10 in., $13.00 per pound.

The value of the mica produced in the United States in 1880 was $127,825; in 1890, $75,000; in 1898, $131,098. The imports were valued at $12,562 in 1880, at $207,375 in 1890.

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* Tenth Census, 1880, XV, 833.

Mica and mica mining. By C. Hanford Henderson. Pop. Sci. Monthly, 1892, XLI, 652.

The mica veins of North Carolina. By W. C. Kerr. Trans. Amer. Inst. Min. Eng., 1879–80, VIII, 457–462.

Geology of the mica deposits of the United States. By J. A. Holmes. Eng. and Min. Journal, Feb. 11, 1899, LXVII, 174.

NATURAL FERTILIZERS.*

Mineral Phosphates.†

Apatite.

The mineral phosphate, apatite, contains theoretically 42.3% phosphoric acid, 55.5% lime, and 3.8% fluorine. Analyses show from 39 to 41.37% phosphoric acid.

Found in crystalline and stratified rocks, but more plentifully in the former, especially in metamorphic limestone, in gneiss and schist.

Apatite both massive and crystalline; some crystals very large, 550 lbs.

Canadian deposits‡ in Quebec and Ontario in metamorphosed Laurentian rocks, usually associated with limestone.

In forms of veins, beds, and irregular pockets from an inch to many feet thick.

Methods of mining and preparing.

Apatite lands generally of little value for other purposes.

Effect of Florida phosphate discoveries on Canadian apatite business.

Phosphorite.

Phosphorite includes the vitreous, earthy, scaly, and fibrous forms of apatite.

It is found in Spain, Germany, and near Bordeaux, France, in veins and pockets. Not found in United States.

Rock Phosphates.

Rock phosphates have not the structure or composition of a definite mineral.

Nodular phosphates.

Nodules rolled and irregular in shape, varying in weight from a few grains to several tons.

Formed by erosion of marl beds.

Artificial concentration at Belgarde.

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* The American Fertilizer, an illustrated magazine, published at Philadelphia.

Mineral phosphates as fertilizers. By H. W. Wiley. Year-book U. S. Dept. Agriculture, 1894, pp. 177–192.

† Nature and origin of deposits of phosphate of lime. By R. A. F. Penrose, Jr. Bul. 46, U. S. Geol. Survey. Washington, 1888. (This work contains a full bibliography of the subject up to the date of its publication.)

The phosphates of America. By Francis Wyatt. Fifth edition. New York, 1894.

Florida, South Carolina, and Canadian phosphates. By C. C. Hoyer Millar. London, 1892.

‡ Apatite deposits, Ottawa county, Quebec. By J. F. Torrance. Geol. Survey of Canada, 1884, J.

Local accumulations or concentrations on land or in stream beds in South Carolina.

Worked in South Carolina only since 1868.

Dredged from streams or dug from open pits.

Burning off 12 to 18% of water.

In Florida the phosphates are in Eocene, Miocene, and recent deposits.*

As pockets in limestone.

Prospected by shafts and bore holes.

Loose local accumulations of nodules and boulders.

Disintegrated rock.

Deposits often cover several acres; 5–50′ thick.

Mined in open cuts.

As pebbles in existing streams; dredged out.

Tennessee† phosphates are in Devonian shales.

Horizontally bedded rocks, locally rich.

Form of the outcrop; tracing the beds.

To be worked like coal mines.

Fertilizer works are at Boston, New York, Philadelphia, Baltimore, and Charleston.

The phosphates of Arkansas.

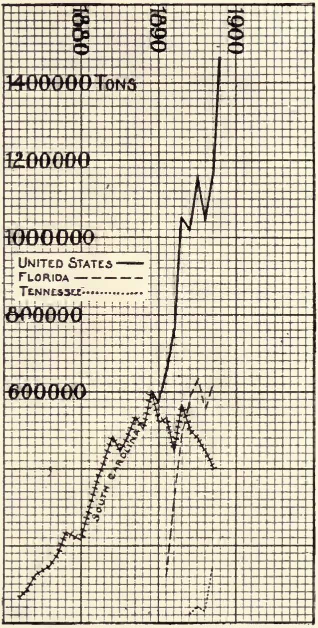

Fig. 137.—The phosphate rock production of the United States since 1871.

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* Florida land pebble phosphate. By W. B. Phillips. Eng. Min. Journal, Feb. 17, 1900, LXIX, 201–2.

† The phosphates of Tennessee. By T. C. Meadows and L. Brown. Trans. Amer. Inst. Min. Eng., 1894, XXIV, 582–594.

The white phosphates of Tennessee. By C. W. Hayes. Trans. Amer. Inst. Min. Eng., 1895, XXV, 19–28.

The Tennessee phosphates. By C. W. Hayes. Seventeenth ann. rep. U. S. Geol. Survey, pt. II, 513–550. Washington, 1896.

New source of phosphate rock in Tennessee. By J. M. Safford. Amer. Geologist, Oct., 1896, XVIII, 261–264.

Guano.

Guano is bone phosphate of lime, with hydrous phosphates and impurities.

Deposits formed of the excrement of birds.

- Considerable beds on islands off the coast of Peru.*
- These deposits are preserved by the arid climate.

Irregular in form.

Ammonia and phosphorus the fertilizing ingredients.

Beds not extensive, and supply limited.

Greensand Marls.

Greensands, or glauconite marls, are soft sedimentary deposits whose fertilizing ingredients are phosphoric acid, potash, and lime. They occur in regular apparently horizontal beds, in Cretaceous rocks of New Jersey,† Tertiary of North Carolina, Eocene Tertiary of South Carolina, and probably throughout the Cretaceous and Tertiary areas of the South and Southwest.

Value of marls to agriculture of New Jersey.

- 1,080,000 tons dug in New Jersey in 1882.
- Method of using.
- Value: will not bear much transportation.

Treatment of greensands at Belgarde, France, to save phosphatic nodules.

Gypsum.

(See pp. 286–288.)

Gypsum, or "land plaster," occurs in regular stratified beds. It is quarried and crushed before it is put on the market.

Extensively quarried in New York, Nova Scotia, Sandusky, Ohio; Michigan, and Kansas.

(For lime, see p. 282; for chalk, see p. 284; for niter, see pp. 242–244.)

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* Note on Clipperton Atoll. By W. J. Wharton. Quarterly Journal Geol. Soc., May 2, 1898, LIV, 228–229.

Phosphatic guano islands of the Pacific Ocean. By J. D. Hague. Amer. Journal Sci., 1862, LXXXIV, 224–243.

† Origin and classification of the greensands of New Jersey. By W. B. Clark. Journal Geol., February-March, 1894, II, 161–177.

MONAZITE.*

Monazite is a phosphate of cerium, lanthanum, and didymium, but it contains a small amount of thoria, which makes it valuable for its present uses.

Uses.

For making the mantels of incandescent gas burners.

Occurrence.

It occurs as small crystals scattered through certain granites and gneisses.

After the decay of the rocks the monazite is mechanically concentrated by water.

Formerly mined in North Carolina† from small placer deposits.

The largest monazite deposits known are in the beach sands of the coast of Brazil near Prado, 285 miles south of the city of Bahia. The sands are derived directly from the Cretaceous sediments that form the shore bluffs, but these sediments are derived from the older crystalline rocks.

The first shipments from Brazil sold for $425.00 a ton; in January, 1900, monazite was quoted in New York at $140.00 a ton.

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* Monazite. By L. M. Dennis. Mineral Industry for 1897, VI, 487-494.

Engineering and Mining Journal, Jan. 28, 1898, LXV, 132; April 8, 1899, LXVII, 407.

† The monazite districts of North and South Carolina. By C. A. Mezger. Trans. Amer. Inst. Min. Eng., 1895, XXV, 822-826.

Monazite. By H. B. C. Nitze. Sixteenth ann. rep. U. S. Geol. Survey, pt. IV, 667-693. Washington, 1895. (Contains bibliography.)

Monazite and monazite deposits in North Carolina. By H. B. C. Nitze. Bul. 9, North Carolina Geol. Survey. Winston, 1895.

ROAD MATERIALS.*

Reference is here made only to road-metal or top-dressing for common macadam or telford roads.

The essential qualities of good road-metal are: that it pack hard and smooth; that it resist the wear of traffic and of weather; that it produce as little dust and mud as possible.

Toughness as against hardness and brittleness.

Inferior materials.†

Materials that fail to meet the above requirements are more or less objectionable.

Feldspathic rocks on decay, or when powdered, form kaolin, a very sticky mud when wet and fine dust when dry.

Syenite (80% feldspar), granite, gneiss.

Clay shale composed of clay; when crushed makes mud or dust.

Limestone too soft, though much used; easily ground to mud and dust.

Clean sandstone has no binding and is too loose.

Clean hard pebbles from stream, if alone, do not pack readily.

Superior materials.

Gravels of hard rock with binding materials.

Paducah, Ky., gravels cemented by iron.

Sandy shales.

Mauch Chunk red shales of Pennsylvania with iron cement.

Chert gravel, natural or artificial.

Good roads of the chert region of Missouri, Arkansas, and Tennessee.

How the gravels accumulate in streams.

Necessity of screening them.

Fresh gravel from the zinc regions of Missouri.

Influence of the lime in hardening.

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* Geology of the road-building stones of Massachusetts, with some consideration of similar material from other parts of the United States. By N. S. Shaler. Sixteenth ann. rep. U. S. Geol. Survey, 1894–95, pt. II, 277–341. Washington, 1895.

Die Baumaterialien der Steinstrassen. Von E. Dietrich. Berlin, 1885.

Bulletins of the Office of Road Inquiry, U. S. Dept. of Agriculture, Washington, D. C.

The common roads. By N. S. Shaler. Scribner's Magazine, Oct., 1889, VI, 473–483.

Roads and road-making. By F. V. Greene. Harper's Weekly, August 10, 1889.

Pavements and roads: their construction and maintenance. By E. G. Love. New York, 1890.

Road materials and road-building in New York. By F. J. H. Merrill. Bul. N. Y. State Museum, IV, no. 17. Albany, 1897.

† Rocks suitable for road-making. By N. S. Shaler. Stone, 1896, XIII, 571–572.

- Novaculite and jasper gravels.
    - Breaking up of novaculite by joints.
    - Accumulation in stream channels.
    - The jasper beds of California, Wisconsin, and North Carolina.
- Hardening road-metal.
    - Influence of iron, illustrated by the canga of Brazil, and the iron-bearing gravels of Paducah, Ky.; influence of lime.
    - Possibility of improving poor materials with iron.

Distribution of materials.

- Modern gravels in glaciated areas.
- Modern gravels in stream channels; dredged at Evansville.
- Sandy shales with other sedimentary rocks.
- Chert gravels, Lower Carboniferous and Silurian.
- Novaculite follows structural features.
- Where iron may be had for hardening.
    - Poor iron ores available.

SOILS.*

Residuary soils.

- Decay of rocks in place.
  - Varying character and fertility according to the rock matrix.
- Lake- and sea-bottom soils of recent date.
- The Tertiary and Pleistocene of the Gulf States.
  - Origin of these sediments.
- The lake bottoms of Pleistocene times.
  - The San Joaquin and Santa Clara valleys.
- Adobes from three sources:
  1. Rocks decayed in place.
  2. Washed down from such decayed beds.
  3. Wind-blown.†

Talus soils.

- Talus from cliff and rock slopes.
- Soil by decay of rock fragments.

Alluvial soils.

- Silts deposited by water.
- Origin of the alluvial silts.
- Fertility of river bottoms due partly to organic matter in the silts.
- Silting up of deltas.

Glacial soils.‡

- Origin of the glacial drift.
- Variety and mingling of its ingredients.

Glacio-alluvial soils.

- Silts draining from glaciers.
- Loess deposits in water and by wind.
- Loess as a soil in the Mississippi valley.§

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* The soils of Tennessee. Bul. Agr. Expr. Station of Tenn., Sept. 1897, X, no. 3. Knoxville, 1897.

The soil: its nature, relations, etc. By F. H. King. New York, 1895.

The origin and nature of soils. By N. S. Shaler. Twelfth ann. rep. U. S. Geol. Survey, 1890–91, pp. 213–345. Washington, 1892.

Rocks and soils: their origin, composition, and characteristics. By H. E. Stockbridge. New York, 1888.

Composition, mode of formation, and properties of soils. By E. A. Smith. Geol. Sur. of Alabama for 1881 and 1882. pp. 1–154. Montgomery, 1883.

† I. C. Russell in Geol. Magazine, 1889, pp. 289, 342.

‡ Soils of Illinois. By Frank Leveritt. Report Illinois Board of World's Fair Com. Springfield, 1895.

§ Loess of North America. By R. E. Call. Amer. Naturalist, May, 1882, XVI, 369–381, 542–549. (Bibliography of loess.)

Modification of soils.

- After formation soils are variously modified by changes of temperature, by rain, plants, and animals.
- Leaching action of acidulated waters; "buckshot" soil.
- Wind-blown accumulations: Colma, China, adobe of the deserts.
- Accumulations of volcanic ashes that decay rapidly: Bolivia; Italy.
- Swamps, marshes, peat-bogs, prairies.*
- The work of burrowing animals, gophers, squirrels, ants, and earthworms.†
- The waste of soils by washing.‡
- Alkali soils.
    - Origin of the alkali.§

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* Origin of prairies. By Leo Lesquereux. Econ. Geol. of Illinois, I, 178–190. Springfield, 1882.

† The decomposition of rocks in Brazil. By J. C. Branner. Bul. Geol. Soc. of America, 1895–96, VII, 295–303.

Vegetable mould and earthworms. By Charles Darwin. New York, 1882.

‡ Washed soils: how to prevent and reclaim them. Farmers' Bul., no. 20, U. S. Dept. of Agriculture. Washington. 1894.

The economic aspects of soil erosion. By N. S. Shaler. National Geographic Magazine, Oct., 1896, VII, 328–338.

§ A report on the relations of soil to climate. By E. W. Hilgard. Bul. 3, Weather Bureau, U. S. Dept. of Agriculture. Washington, 1892.

The alkali soils of the Yellowstone valley. By M. Whitney and T. H. Means. Bul. 14, Div. of Soils, U. S. Dept. of Agriculture. Washington, 1898.

WATER.*

A country's water supply derived (1) directly from rain; (2) from lakes; (3) from rivers; (4) from springs; (5) from wells, (*a*) ordinary wells, (*b*) artesian wells.

Effect of andesite and other porous rocks on water supply.

Topography determines largely the rainfall of a region; effect of the Sierra Nevada mountains on the rainfall of California and the Great Basin.

Effect of the Andes upon the rainfall of the west coast of South America.

Lakes: size, depth, character, distribution; largely controlled by geologic relations.

Rivers: location and character fixed by geologic structure of the region.

Effect of rapids and water-falls: sources of water power; detriment to navigation.

Utilization of muddy water after filtering. Effect of alum, acids, alkalies, heat and cold.

Springs: location, character, size, determined by geologic relations of the rocks.

Springs are of all sizes, from the smallest trickling streams to those of great volume. Mammoth Spring of Arkansas discharges 9000 barrels per minute.

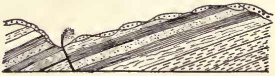

Fig. 138.—Section to illustrate the geologic reason for a spring upon a fault line.

Underground streams; traced by the use of fluoresceine.

Cities and towns often owe their locations to springs.

All spring waters contain mineral ingredients; often used for medicinal purposes.†

Hard water of limestone regions.

Soft water of granite and sandstone regions.

Mineral springs as health and pleasure resorts.

Spring waters vary from extremely cold to boiling hot.

Hot springs.

Geysers.

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* The water supply of England and Wales. By Charles E. De Rance. London, 1882.

Mineral waters of Arkansas. Ann. rep. Geol. Survey of Arkansas for 1891, I. Little Rock, 1892.

Mineral waters of Missouri. Ann. rep. Geol. Survey of Missouri, 1890-92, III. Jefferson City, 1892.

Water supplies and inland waters of Massachusetts. Part I, rep. on water supply and sewerage, 1887-90. By the State Board of Health, Boston, 1890.

The potable waters of the eastern United States. By W. J. McGee. Fourteenth ann. rep. U. S. Geol. Survey, pt. II, 5-47. Washington, 1894.

† Natural mineral waters of the United States. By A. C. Peale. Fourteenth ann. rep. U. S. Geol. Survey, pt. II, 49-88. Washington, 1894.

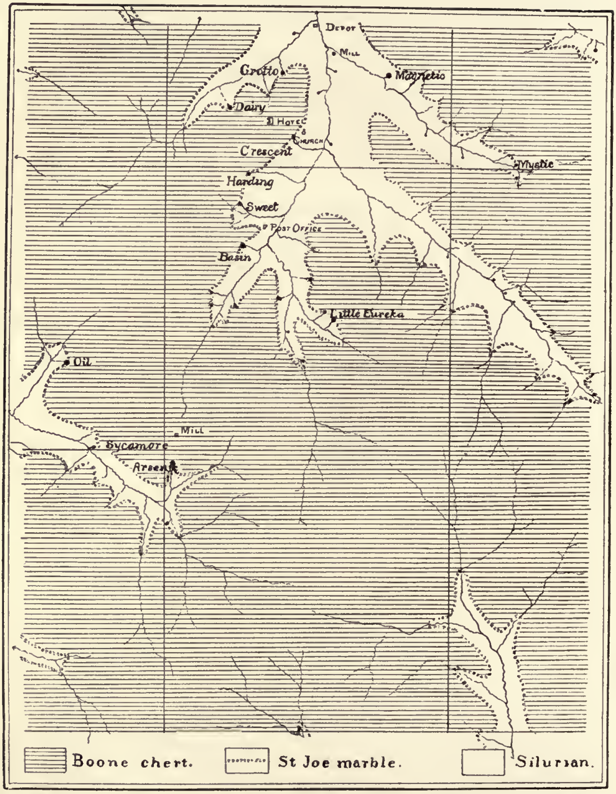

Fig. 139.—Geological map of the region about Eureka Springs, Arkansas, showing the emergence of springs at a constant horizon.

Wells: wells, except for large cities, are the chief source of water supply for domestic purposes.

Ordinary wells, especially in cities, liable to surface contamination and cannot furnish great volume.

Why some wells yield soft water and others near by yield hard water.

Why water is not always found at the same level in the glacial drift regions.

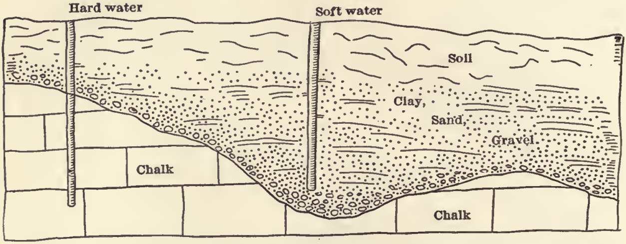

Fig. 140.—Vertical section in the chalk region of southwest Arkansas, showing why the waters of some of the wells are hard while others are soft.

*Artesian wells** are wells (usually deep) that flow at the surface.

Conditions favorable for artesian wells: a porous stratum, below an impervious stratum, with an exposed edge higher than the mouth of the well; no sufficient outlet lower than the mouth of the well; sufficient rainfall at the exposed edge of the water-bearing bed to completely saturate the whole bed. The water-bearing stratum may be either porous or fissured. The less disturbed the strata the better.

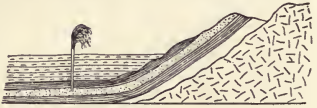

Fig. 141.—Section to illustrate the conditions controlling artesian waters.

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* The underground water of the Arkansas valley in eastern Colorado. By G. K. Gilbert. Seventeenth ann. rep. U. S. Geol. Survey, pt. II, 557–601. Washington, 1896.

Preliminary report on artesian waters of a portion of the Dakotas. By N. H. Darton. Seventeenth ann. rep. U. S. Geol. Survey, pt. II, 603–694. Washington, 1896.

Report on water supply. By C. C. Vermeule. Geol. Survey of New Jersey, vol. III. Trenton, 1894.

Well-boring and irrigation in east South Dakota. By N. H. Darton. Eighteenth ann. rep. U. S. Geol. Survey, pt. IV, 561–615. Washington, 1897.

Artesian wells of Iowa. By W. H. Norton. Rep. Iowa Geol. Survey, VI, 115–428. Des Moines, 1897.

The requisite and qualifying conditions of artesian wells. By T. C. Chamberlin. Fifth ann. rep. U. S. Geol. Survey, 1883–84, pp. 125–173. Washington, 1885.

On the occurrence of artesian and other underground waters in Texas, eastern New Mexico, and Indian Territory, west of the 97th meridian. By R. T. Hill. Senate Ex. document 41.

Uncertainties in boring for artesian water due to the variations in the character of the water-bearing bed, and to possible faults.

The general principles are simple, but the problems are often complex. Special cases require special study.

Artesian waters seldom obtained from crystalline rocks, but sometimes from the joints in them.

Artesian water not confined to rocks of any particular age. In California they are more abundant in the later formations.

Size and strength of flow depends upon:

1. Distance of discharge from outcrop.
2. Porosity of the water-bearing beds.
3. Character of the confining beds.
4. Character of the country between.
5. Height of the outcrop of the water bed.

Artesian water important for:

- City water supplies.
- Irrigation.
  - Limits of artesian water for irrigation.
- Medicinal purposes.

Examples of artesian well regions.

Impossibility of locating water and minerals by the use of the divining rod.*

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* The mechanical action of the divining rod. By M. E. Wadsworth. Amer. Geologist, Jan., 1898, XXI, 72.

The divining rod. Nature, Oct. 14, 1897, LVI, 568–569.

The theory of water-finding by the divining rod. By B. Tompkins. Chippenham, Wilts, 1899. Also Nature, Nov. 2, 1899, LXI, 1–4.

The divining rod. By R. W. Raymond. Trans. Amer. Inst. Min. Eng., 1882–83, XI, 411; and Eng. and Min. Jour., Feb. 26, 1898, LXV, 256.

REPORTS ON MINING PROPERTIES.*

Mining properties are usually bought and sold nowadays upon the reports of competent geologists.

Samples cannot be depended upon; and even when samples are trustworthy, the value of the property is not always determined by the richness of the ore alone.

Reports.

- Reports should be accompanied by maps, sections, assays, and other information relating to the value of the property, such as roads and transportation, water and water-rights, fuel, timber, labor, etc.
- Legal status of the property.

Sampling.†

- The object of the sampling of ore-bodies is to determine the nature and extent of the ores and the value of the property.
- Method of pits, shafts, and wells.
  - Wells bored with core drills; with churn drills.
- Method of cross-cutting.
- Samples to be collected by one's self.
  - Labelling.
  - Locating by surveys or measurements.
  - Care of the samples collected.
  - Specimens that may mislead.
    - How one may impose upon himself.
  - Assaying.
    - The limits of an assayer's responsibility.
- In sampling great care must be exercised to guard against mine-salting.
- By salting‡ is meant the fraudulent tampering with the materials examined for the purpose of misleading the person making the examination.

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* The responsibilities of the mining engineer. By J. B. Porter. Journal Fed. Canadian Min. Inst., 1898, II, 200–205.

† Testing and sampling placer deposits. By E. B. Kirby. Eng. and Min. Journal, July 29, 1899, LXVIII, 130.

Notes on the exploration of mineral properties. By H. S. Munroe. School of Mines Quarterly, Nov., 1897, XIX, 9–14.

The sampling and measurement of ore-bodies in mine examinations. By E. B. Kirby. Thirteenth ann. rep. State Mineralogist of California, 679–700.

Comstock ore-sampling. By John S. McGillivray. Thirteenth ann. rep. State Mineralogist of California, 701–705. Sacramento, 1896.

Sampling ore-bodies. Eng. and Min. Journal, Dec. 2, 1899, LXVIII, 672.

‡ Mining reports and mine salting. By Walter McDermott. Engineering Magazine, May, 1895, IX, 311–318. Trans. Kansas Acad. Sci., 1874 (reprint of 1896), 106–111.

Mine salting. By O. M. Dobson. The Cosmopolitan, April, 1898, XXIV, 575–583.

How bubbles are inflated and pricked. Eng. and Min. Journal, July 28, 1888; same reprinted Dec. 4, 1897, p. 668.

It is liable to be done:

On the ground before samples are taken;
In the specimens after they are collected;
In the assays.

Danger of trusting the records of a mine's monthly output.

REFERENCES TO WORKS ON MINING LAW.

The law of mines and mining in the United States. By D. M. Barringer and J. S. Adams. Boston, 1897.

A treatise on the American law relating to mines and mineral lands. By Curtis H. Lindley. 2 vols. San Francisco, 1897.

Mining law. By E. P. Clark. School of Mines Quarterly, 1884, V, 242–258.

Historical sketch of mining law. By R. W. Raymond. Mineral Resources of the U. S., 1883-84, pp. 988–1004. Washington, 1885.

The law of the apex. By R. W. Raymond. Trans. Amer. Inst. Min. Eng., 1883-84, XII, 387–444, 677–688.

Mining laws. Tenth Census, vol. XIV. Washington, 1885.

Dissertation upon American mining law. By A. H. Ricketts. Eleventh ann. rep. of the State Mineralogist [of California], 1891–92, pp. 521–574. Sacramento, 1893.

American mining code. By Henry N. Copp.

The law of mines in Canada. By W. D. McPherson and J. M. Clark. Toronto, 1898.

Minng code of the Mexican Republic, second ed. Mexico, 1893.

Ley minera y ley de imposto á la mineria con sus respectivos reglamentos. Mexico, 1894.

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