

OCCURRENCE, PROPERTIES, AND USES OF SOME NATURAL BITUMENS

By E. P. Carman and F. S. Bayes

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INTRODUCTION AND SUMMARY

In this report, the Federal Bureau of Mines presents a summary of the occurrence, properties, and uses of some natural bitumens, using the layman's or dictionary definition of bitumens - that is, naturally occurring hydrocarbons. Emphasis is on the less common solid and semisolid bitumens, particularly those occurring or used to some extent in the United States. This comprises data from many sources and references to these sources for more detail than is given in this summary.

This paper was prepared primarily to answer questions about some of the less known bituminous materials. The word hydrocarbons could just as well have been substituted in the title for bitumens, but bitumens was used, since an abstract of the paper was presented at a meeting where the major emphasis was on bituminous materials. The reader will realize that coals, of which only the more unusual such as the cannel coals and torbanites are discussed in this paper, are primarily mixtures of bituminous materials and carbon. The amount of bituminous material, or volatile matter, in coals is greatest in the lower rank coals and the unusual types described in this paper, and decreases as coal rank increases. However, since no method other than destruction of the original coal substance by heat is known that will separate the volatile matter from the carbon, it appears reasonable to classify the coals with other bituminous materials, particularly since bituminous coal - the most widely used coal - by its name indicates the combination of bituminous materials and carbon.

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Acknowledgment is hereby given, in addition to the references cited, to Herbert Abraham and the D. Van Nostrand Publishing Co., Inc., for permission to use analyses, tabular data, and brief excerpts from the two-volume fifth edition of Abraham's "Asphalts and Allied Substances," copyright D. Van Nostrand Co., 1945.

DEFINITIONS AND CLASSIFICATION SYSTEMS

Before discussing individual bitumens, the status of the definition and classification of bitumens will be reviewed. According to Abraham,^{4/} "Bitumen" is a generic term applied to native substances of variable color, hardness and volatility; composed principally of hydrocarbons, substantially free from oxygenated bodies; sometimes associated with mineral matter, the nonmineral constituents being fusible and largely soluble in carbon disulfide, yielding water-insoluble sulfonation products." In a footnote, he states, "The interpretation of the term 'bitumen' as employed in this treatise is entirely dissociated from the idea of solubility...." Abraham, in discussing the classification of bituminous substances, notes four definitions, as follows:^{5/}

- (a) Bitumens - naturally occurring hydrocarbons.
- (b) Bitumens - naturally occurring hydrocarbons; likewise residues obtained from the distillation of petroleum (e.g., petroleum asphalts).
- (c) Bitumens - naturally occurring hydrocarbons, likewise residues obtained from the distillation of petroleum, likewise, artificial hydrocarbon substances (e.g., tars and pitches);
- (d) Bitumens - only those components of (c) which are soluble in carbon disulfide.

In this paper, the first definition (a) is used, without taking exception to or in any way criticizing the other definitions that have their appropriate use and place in the technical literature.

The Bureau of Mines Glossary^{6/} defines bitumen as, "A general name for various solid and semisolid hydrocarbons"; that is, Abraham's definition (c). In 1912 the term "bitumen" was used by the American Society for Testing Materials to include all those hydrocarbons that are soluble in carbon bisulfide, whether gases, easily mobile liquids, viscous liquids, or solids; that is, Abraham's definition (d).

A book by the British author Tomkeieff,^{7/} defines bitumen as "A very old name originally applied to mineral pitch and later extended to cover all

^{4/} Abraham, Herbert, Asphalts and Allied Substances, Their Occurrence, Modes of Production, Uses in the Arts, and Methods of Testing: D. Van Nostrand Co., Inc., 5th ed. vol 1, 1945, p. 60.

^{5/} Work cited in footnote 4, pp. 64-65.

^{6/} Fay, Albert H., A Glossary of the Mining and Mineral Industry: Bureau of Mines Bull. 95, 1947 (reprinted from 1920 edition, without changes), 743 pp.

^{7/} Tomkeieff, S. I., Coals and Bitumens and Related Fossil Carbonaceous Substances, Nomenclature and Classification: Pergamon Press Ltd., London, 1954, 122 pp.

natural hydrocarbons of different degrees of consistency and purity. Besides carbon and hydrogen, bitumens usually contain variable amounts of oxygen, nitrogen, and sulfur. In their consistency, bitumens range from mobile liquids (petroleum), through viscid (mineral tar) and elastic (elaterite) to solid varieties (asphalt, pyrobitumen, and anthraxolite).... In contrast to coals, bitumens are but seldom found in the place of their formation, but are transplanted in a gaseous, liquid, or plastic state...." Tomkeieff thus takes Abraham's definition (a) but eliminates natural gas and the coals from his definition.

Abraham's definition (a) has appeared to be most suited to the present review. Within the broad category of this definition, the naturally occurring bitumens are found in all physical phases. Natural gas represents the gaseous phase; petroleum, the liquid phase; and, within the semisolid and solid phase, the largest and best known group includes coals of all kinds and ranks. Since there are many good summaries of data on the occurrence, properties, and uses of natural gas,^{8/} petroleum,^{9/} and the more common or humic series of coal,^{10/} only the rarer coals of the humic-sapropelic and sapropelic series, such as cannel and boghead coals or torbanites, will be discussed from the three groups of the more plentiful natural bitumens.

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- ^{8/} (a) Anderson, C. C., and Hinson, H. H., Helium-Bearing Natural Gases of the United States--Analyses and Analytical Methods: Bureau of Mines Bull. 486, 1951, 141 pp.
- (b) American Gas Association-American Petroleum Institute, Reports on Proved Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States, and Proved Reserves of Crude Oil and Natural Gas Liquids in Western Canada: Dec. 31, 1954 (annually), vol. 9, 22 pp.
- ^{9/} (a) Production Review Committee, Petroleum Branch, Statistics of Oil and Gas Development and Production, 1954: AIME, New York, N. Y., vol. 9, 1955, 542 pp.
- (b) Work cited in footnote 8 (b).
- (c) McKinney, C. M., and Blade, O. C., Analyses of Crude Oils From 283 Important Oil Fields in the United States: Bureau of Mines Rept. of Investigations 4289, May 1948, 154 pp.
- ^{10/} (a) Sherman, Allan, and MacMurphy, Allen B., Facts About Coal: Bureau of Mines, 1955, 26 pp.
- (b) Moyer, Forrest T., and Vaughan, James A., Anthracite; Ch. in Mineral Facts and Problems: Bureau of Mines Bull. 585, 1960, 18 pp.
- (c) Staff, Division of Bituminous Coal, Bituminous Coal; Ch. in Mineral Facts and Problems: Bureau of Mines Bull. 585, 1960 30 pp.
- (d) Staff, Division of Bituminous Coal, Lignite and Peat; Ch. in Mineral Facts and Problems: Bureau of Mines Bull. 585, 1960, 16 pp.
- (e) Fieldner, A. C., and Rice, W. E., Typical Analyses of Coals of the United States: Bureau of Mines Bull 446, 1942 (reprinted 1955), 45 pp.
- (f) Moore, Elwood S., Coal: John Wiley and Sons, Inc., New York, N. Y., 1940, 473 pp.

Concerning classification, the variations are as wide as the definitions, since, of necessity, classification depends largely on the definitions used. The most recently published classification that has come to the author's attention is that of Tomkeieff.^{11/} This classification is shown in figure 1.

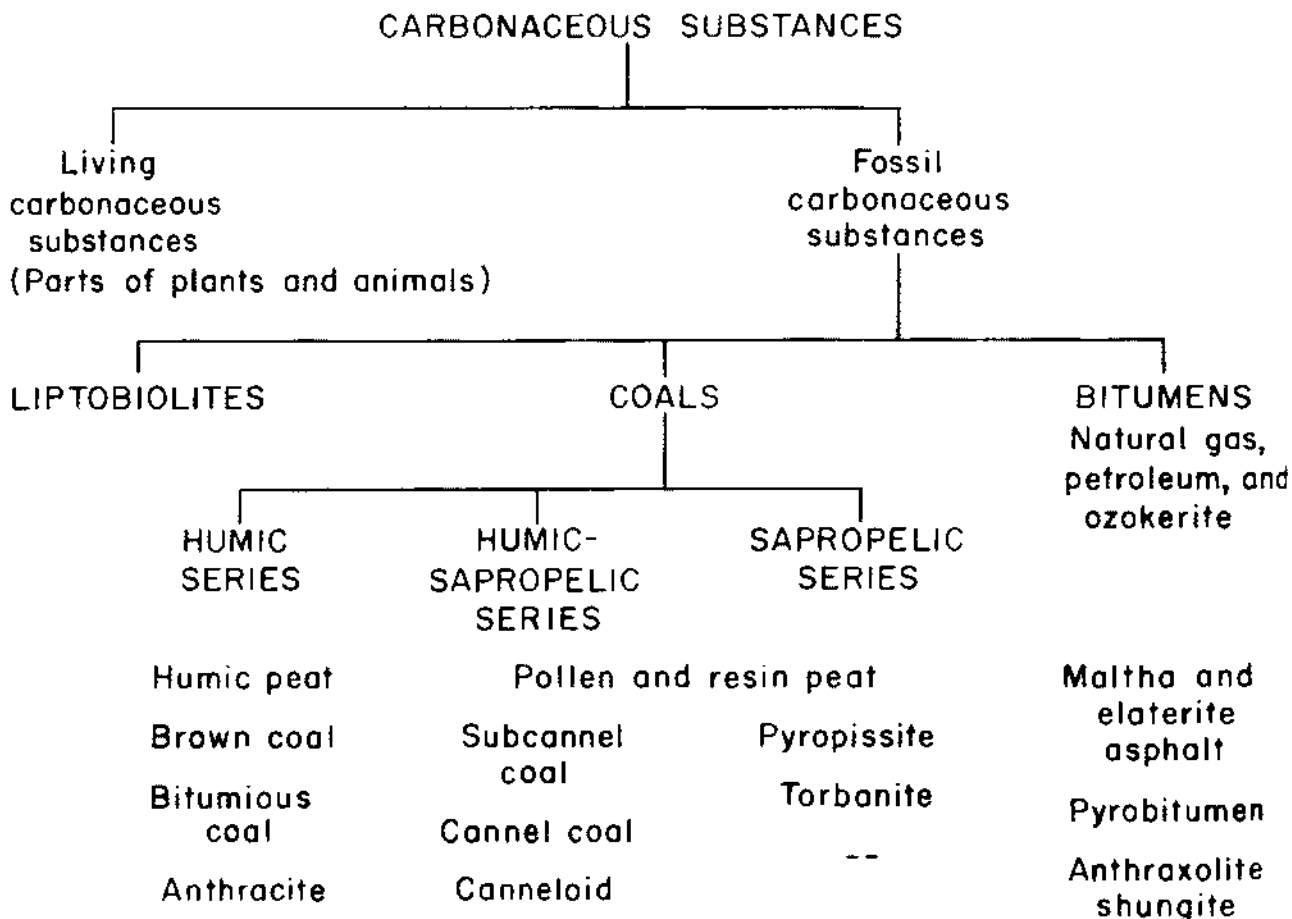


FIGURE 1. - Tomkeieff's Classification of Carbonaceous Substances.

Abraham advocates the use of his definition (a) and has prepared a classification based on this definition, shown as table 1 (Abraham's table III) which covers bitumens, pyrobitumens, pyrogenous distillates, and pyrogenous residues.

A classification has been developed by the senior author, based largely on that of George H. Eldridge of the Federal Geological Survey,^{12/} modified to include Tomkeieff's classification of coals,^{13/} in turn modified to include the United States standard classification of coals.^{14/} This classification appears

^{11/} Work cited in footnote 7 (p. 2), p. 10.

^{12/} Eldridge, George H., The Asphalt and Bituminous Rock Deposits of the United States: Geol. Survey Annual Rept. pt. 1. 1901, p. 220.

^{13/} Work cited in footnote 7 (p. 2), p. 10.

^{14/} Work cited in footnote 10e (p. 3), p. 13.

to be a convenient way of classifying bitumens by physical and chemical properties and is shown in table 2.

DESCRIPTION OF BITUMENS

The bitumens are listed and discussed in alphabetical order, rather than in the order of classification, to facilitate use of this study for reference. Attention is given to the viscous, elastic, and solid natural bitumens (excluding the humic-series coals), and the resinous, cereous, and crystalline hydrocarbons listed in table 2.

Albertite (Also Called Libollite, Nigrite, Stellarite, and Tasmanite)

"Albertite is a generic term," according to Abraham,^{15/} "applied to a group of asphaltic pyrobitumens similar to the albertite or 'Albert coal' formerly mined at the Albert mines, Albert County, New Brunswick." The terms "carboids," "kerotenes," and "kerites" have been suggested to designate these hydrocarbons, which are insoluble in carbon disulfide.

The New Brunswick, Canada, deposit, mentioned earlier, comprises a major vein about one-half mile in length and with a thickness varying from a few inches up to about 17 feet. From this major vein there are smaller offshoots and still smaller ones from these. Maximum depth reached in mining was about 1,400 feet. The main vein was a true fissure vein, cutting across beds of so-called oil shales. The surrounding shales containing fossil remains of fish indicate that albertite is of animal origin.

Another albertite deposit occurs in Pictou County, Nova Scotia. This material, a layer about 22 inches thick in a bed comprising 16 inches of coal, the albertite vein, and 22 inches of pyrobituminous shale, has been exploited under the name "stellarite."

In the United States, a vein of albertite, which Eldridge called "nigrite," was found 5 miles east of Soldier Summit, Uintah County, Utah. This vein was 120 feet long and had a maximum width of 20 inches.

Albertite deposits have been reported in the Falkland Islands, South America; in the Province of Hanover, south of the city of Bentheim, Germany; in Tasmania, Australia, near the river Mersey (this material was called "tasmanite"), and in the Province of Angola, District of Libollo, Portuguese West Africa.

Albertites are natural, jet-black, pitchlike brittle hydrocarbons, with conchoidal to hackly fracture. Distinctive characteristics are: Infusibility; insolubility in carbon disulfide and most common solvents; specific gravity ranging from 1.07 to 1.10; fixed carbon percentage ranging from 25 to 50 percent; usually less than 3 percent oxygen present in the nonmineral constituents; only about 30 percent soluble in turpentine; very imperfect fusion when heated; on destructive distillation, yields relatively large volumes of gas, and oils and coke.

^{15/} Work cited in footnote 4 (p. 2), pp. 293-298.

TABLE 1. - Classification of bituminous substances, according to Abraham¹

Genus	Species	Member	Remarks	
Bitumens....	Petroleums.....	Nonasphaltic petroleum....	Contains an appreciable quantity of crystallizable paraffin and no asphalt.	
		Semiasphaltic petroleum...	Contains crystallizable paraffin, also asphalt.	
		Asphaltic petroleum.....	Contains an appreciable quantity of asphalt and no crystallizable paraffin.	
	Native mineral waxes.....	Ozokerite.....	A paraffinaceous mineral, called ceresine when refined.	
		Montan wax.....	The wax extracted from lignite or pyropissite by means of solvents.	
	Native asphalts.....	Pure or fairly pure.....	Comparatively free from associated mineral matter (less than 10 percent on dry weight.)	
		Associated with mineral matter.....	Containing a substantial proportion of sand, sandstone, limestone, clay or shale, or filling the voids in a matrix of rock (that is, "rock asphalt.")	
		Asphaltites.....	Gilsonite.....	Extremely pure.
		Glance pitch.....	Pure to moderately pure.	} Have a higher fusing point than asphalts-- derived from petroleum.
		Grahamite.....	Pure to quite impure.	
		Elaterite.....	Rubbery, partly saponifiable	} Generally pure.
		Wurtzilite.....	Depolymerizes on heating, becoming fusible and soluble.	
		Asphaltic pyrobitumens..	Albertite.....	Depolymerizes partially on heating.
			Impsonite.....	Does not depolymerize on heating.
	Pyro-bitumens..		Asphaltic pyrobituminous shales.....	Mineral matters predominate. Infusible and insoluble.
		Peat.....	Pure or fairly pure. Infusible and insoluble.	
		Lignite.....	Contain more or less oxygenated bodies. Derived from vegetable growths. Gradual transition from peat to lignite to coal.	
		Nonasphaltic pyrobitumens..	Bituminous coal.....	Gradual transition from peat to lignite to coal.
			Anthracite.....	Mineral matters predominate, otherwise the same as the foregoing.
		Lignitic and coal shales..	Mineral matters predominate, otherwise the same as the foregoing.	

Pyrogenous waxes.....	Wax tailings.....	Distillate from petroleum obtained immediately before coking.	
	Petroleum paraffin.....	Solid paraffin obtained from nonasphaltic petroleum.	
	Peat paraffin.....	Solid paraffin obtained from peat tar.	
	Lignite paraffin.....	Solid paraffin obtained from lignite tar.	
	Shale paraffin.....	Solid paraffin obtained from shale tar.	
	Oil-gas tar.....	Produced by cracking petroleum vapors in manufacturing oil gas.	
	Water-gas tar.....	Produced by cracking petroleum vapors in manufacturing carburetted water gas.	
	Pine tar.....	Produced by the destructive distillation of the wood and roots of coniferae.	
	Hardwood tar.....	Produced by the destructive distillation of hardwoods.	
	Peat tar.....	Produced by the destructive distillation of peat.	
Pyrogenous dis- tillates..	Tars.....	Lignite (brown coal) tar..	Produced by the destructive distillation of lignite (brown coal).
		Shale tar.....	Produced by the destructive distillation of pyro-bituminous shales.
		Gas-works coal-tar.....	Produced from gashouse retorts in manufacturing gas from bituminous coal.
		Coke-oven coal-tar.....	Produced from byproduct coke ovens in manufacturing coke from bituminous coal.
		Blast furnace coal-tar....	Produced from blast furnaces upon smelting metals with bituminous coal.
		Producer-gas coal-tar.....	Produced from gas producers in manufacturing producer gas from coal.
		Bone tar.....	Produced by the destructive distillation of bones.

TABLE 1. - Classification of bituminous substances, according to Abraham^{1/} (Con.)

Genus	Species	Member	Remarks
Pyrogenous residues..	Pyrogenous asphalts.....	Residual oils.....	Produced by the dry distillation of nonasphaltic petroleum, the dry or steam distillation of semiasphaltic petroleum, or the steam distillation of asphaltic petroleum.
		Pressure tars.....	Produced from petroleum by cracking at high temperatures under pressure.
		Blown petroleum asphalts..	Produced by blowing air through heated residual oils.
		Residual asphalts.....	Produced by the steam distillation of semi-asphaltic and asphaltic petroleums.
		Sludge asphalts.....	Produced from the acid sludge obtained in the purification of petroleum distillates with sulfuric acid.
		Wurtzilite asphalt.....	Produced by depolymerizing wurtzilite in closed retorts.
		Oil-gas-tar pitch.....	Residues obtained by the partial evaporation or distillation of the corresponding tars.
		Water-gas-tar pitch.....	
		Wood-tar pitch.....	
		Peat-tar pitch.....	
	Lignite-tar pitch.....		
	Shale-tar pitch.....		
	Pitches.....	Gas-works coal-tar pitch..	Residue obtained by the partial distillation of the resinous sap of coniferae.
		Coke-oven coal-tar pitch..	
		Blast-furnace coal-tar pitch.....	
Producer-gas coal tar pitch.....			
Bone-tar pitch.....			
	Rosin pitch.....	Residue obtained by the steam distillation of fatty acids.	
		Fatty-acid pitch.....	

^{1/} Abraham, Herbert, Asphalts and Allied Substances, Their Occurrence, Modes of Production, Uses in Arts, and Methods of Testing: D. Van Nostrand Co., Inc., 1945, pp. 66, 67.

TABLE 2. - Classification of Natural Bitumens, According to Senior Author

-
- Gaseous: Marsh gas, natural gas
 - Liquid and solid:
 - Fluid: Naphtha, petroleum
 - Viscous: Maltha, mineral tar, brea, chapapote
 - Elastic: Elaterite, wurtzilite
 - Solid:
 - Natural asphalt:
 - Asphaltites, albertite, impsomite,
 - Grahamite, nigrite, uintaite or
 - Gilsonite, glance pitch
 - Coals:
 - Humic series: (in order of increasing rank)
 - Humic peat
 - Lignitic coals: Brown coal, lignite, jet
 - Subbituminous coals: Subbituminous C, B, and A
 - Bituminous coals: High-volatile C, B, and A; medium-volatile; and low-volatile
 - Anthracitic: Semianthracite; anthracite; meta-anthracite
 - Humic-sapropelic series:
 - Pollen and resin peat
 - Subcannel coal
 - Cannel coal
 - Canneloid
 - Sapropelic series:
 - Pyropissite
 - Boghead coal
 - Torbanite
 - Bituminous shales
 - Bituminous sands
 - Resinous hydrocarbons: Succinite or amber, copal, copalite, ambrite
 - Cerous (waxy) hydrocarbons: Ozokerite, hatchettite, scheererite, kabaite, montan wax
 - Crystalline hydrocarbons: Fichtelite, hartite
-

Ultimate analyses of several samples of New Brunswick albertite are shown in table 3, taken from Abraham.

TABLE 3. - Analyses of some New Brunswick albertites^{1/}

Carbon.....percent..	83.4 to 87.3
Hydrogen.....do.....	9.2 to 10.1
Sulfur.....do.....	Traces to 1.2
Nitrogen.....do.....	.4 to 3.1
Oxygen.....do.....	2.0 to 2.2
Undetermined.....do.....	.1 to 6.0

^{1/} Work cited in footnote 1, table 1, p. 295.

Major reported use of albertites was to enrich bituminous coal used in manufacturing coal gas.

Amber or Succinite

"Amber - Tear of the Heliades" is the title of an interesting paper by McLaren^{16/} on one of the natural bitumens, which has a most interesting history and many uses, beginning in the Stone Age and continuing with the ancient Egyptian and Greek civilizations through Roman and medieval times to the present. According to McLaren, in the legend of the Heliades, Phaëthon, favorite child of the sun god Hélios, attempted to drive his father's chariot of the sun. He lost control and drove too near earth, setting it on fire and making it necessary for Jupiter to call a halt to the proceedings with a well-placed thunderbolt. Phaëthon's sisters, who aided and abetted the plot and found his tomb, were changed into trees at the spot for being accessories to the crime; and their tears, dropping from the branches, are alleged to have been hardened by the sun and became amber.

This story is possibly lacking in scientific accuracy; however, it does indicate early recognition of the derivation of amber from the resin of trees. As McLaren states, "To make it scientifically correct and up to date, it is only necessary to add that amber is the resin of an extinct pinus, called "Pinites succinifer," which flourished in the Lower Tertiary period." This statement, in turn, indicates the origin of another name for amber - succinite. A Bureau of Mines Information Circular^{17/} gives the history, occurrence, properties, and uses in more detail, as well as many references to articles in the technical press.

The yellow Baltic variety of amber, believed the major source since time immemorial, is the most widely recognized amber. Prockat^{18/} has described mining of this amber along the Baltic coast of Germany. Scattered deposits of amber are widely distributed over the northern part of the earth, and these have varying rare colors. Amber from Sicily has a distinctive lustre and fluorescence, described as being due to its power of modifying light incident upon it. Specimens that are actually straw yellow and faint olive green show sapphire blue, pale rose, violet, and ruby hues under varying light conditions.

Sicilian amber is frequently washed out of the clayey soil during the spring and fall heavy rains, transported down the streams and rivers to the sea, and washed ashore by the waves, where it is picked up on the beaches.

Common amber is various shades of yellow, sometimes extending into white and brown, but almost all colors of the spectrum may be noted in Sicilian

^{16/} McLaren, D. C., Amber - Tear of the Heliades, Some Facts and Myths of an Intriguing Gift of Nature: Canadian Min. Jour., vol. 66, August 1945, pp. 541-544.

^{17/} Petar, Alice B., Amber: Bureau of Mines Inf. Circ. 6789, 1934, 13 pp.

^{18/} Prockat, Friedrich, Amber Mining in Germany: Eng. Min. Jour., vol. 129, No. 6, March 24, 1930, pp. 305-307.

amber. When cut and polished for jewelry and related uses, amber tends to darken in color; in time it develops the patina or greenish-rusty color of antiquity. A material called "sakal" by the Egyptians and used in jewelry, is believed to be Sicilian amber. The Greeks called amber "elektron," and the Romans called it "succinum" and "lapis ardens." The Germans named it "berstein," signifying, as did the latter Roman name, "stone that burns." The Aestians, who gathered it along the Baltic, called it "gless," from whence comes our word "glass."

Amber is a transparent or translucent solid, has a hardness of 2 to 3 on Mohs' scale, and a specific gravity of 1 to 1.1. Amber is partly soluble in alcohol, ether, turpentine, and chloroform. Its melting point ranges from 300 to 380° C.; on distillation, it yields various succinic acids, formic acid, butyric acid, etc.^{19/}

As suggested, amber has been used since the stone age for jewelry. An interesting recent use was the study of insects, and sugars attached thereto, buried in amber during its formation, compared with present-day insects caught on flypaper.^{20/} The common variety has been used for centuries in the Orient for incense and is believed to have been one of the four aromas employed in the tabernacle according to the prescription of Moses. It was used in ancient times as a medicine, and is reported to be still prescribed by physicians in France, Germany, and Italy. For ages it has been worn as an amulet and has been pronounced of service, whether taken internally or worn as an amulet around the neck.^{21/} Amber has been considered a "lucky stone" to protect the wearer against evil influences. Amber thus appears to have been one of the most popular and widely known bitumens in all civilized history, although quantitatively, it appears to have been one of the rarer ones.

Ambrite

Ambrite is a fossil resin, resembling amber, found in masses in Auckland, New Zealand.^{22/}

It is a yellowish-gray, greasy, amorphous, oxygenated hydrocarbon, insoluble in ether, benzene, and chloroform.

No reported analyses or uses have been found.

Asphalts

Asphalt deposits used in ancient times were scattered in the Euphrates Valley in what is now Iraq, and in areas between the Nile River in Egypt and

^{19/} Tomkeieff, S. I., Coals and Bitumens and Related Fossil Carbonaceous Substances, Nomenclature and Classification: Pergamon Press Ltd., London, 1954, p. 22.

^{20/} Brues, Charles T., Insects in Amber: Sci. Am., vol. 185, No. 5, November 1951, pp. 56-61.

^{21/} Williamson, George C., The Book of Amber: E. Benn, Ltd., London, England, 1932, 268 pp.

^{22/} Gregory, T. C., Condensed Chemical Dictionary: 3d ed., Reinhold Publishing Corp., New York, N. Y., 1942, p. 67.

the Indus River in India. The Dead Sea has been reported as a source. Asphalts are still produced from some of the long-known deposits of ancient times, but the most important sources commercially, at the present time, are in the West Indies, Cuba, Trinidad, and Venezuela, in the Western Hemisphere, and in Italy, Switzerland, Germany, and France in Europe. Many deposits of both pure asphalt and asphalts associated with mineral matter occur in the United States and Canada.

The Pitch Lake on the Island of Trinidad was visited by Columbus in 1493, and by Sir Walter Raleigh in 1595, and is today a major source of natural asphalt used in this country. Abraham^{23/} gives a thorough discussion of native asphalts associated with mineral matter, so only a brief listing of deposits, properties, and uses taken from this reference is given here, although asphalts probably comprise the most widely used of the natural bitumens described herein.

Pure Asphalt Deposits

Pure native asphalts are found in Breckenridge County, at the "Tar Springs," and in Grayson County along the Big Clifty Creek and its tributaries in Kentucky. Small occurrences have been noted in Carter and Murray Counties, Okla. In Uintah County, Utah, a pure solid asphalt has been found in Tabby Canyon, about 30 miles west of Fort Duchesne. Another Utah deposit was found below the bed of Great Salt Lake, about 10 miles south of Rozel. This material exudes through the lake bottom and floats to the surface in lumps 1 to 2 feet in diameter.

In Kern County, Calif., deposits occur in the "Asphalto" region in the western part of the county, about 50 miles west of Bakersfield. These are in the form of both springs and veins, and the overflow of the springs has covered an area of about 7 acres. Other California deposits are found at Tar Spring Creek, a seepage deposit 20 miles southeast of San Luis Obispo, in San Luis Obispo County, and in veins in the La Graciosa hills, about 4 to 5 miles east of Graciosa in the Santa Maria Region of Santa Barbara County.

In Oregon, asphalt veins have been found in coal beds in Coos County. This material is hard and brittle and similar in appearance to the coal in which it is found; it has been called "pitch coal," but its properties appear to be more like those of an asphalt than a glance pitch.

In Mexico, pure asphalt is found in the State of Tamaulipas, along the Tamesi River, and near Chijol, 25 miles west of Tampico. In the State of Vera Cruz, asphalt springs similar to those in Tamaulipas are found in the District of Tuxpan and at the head of the Tuxpan River in the District of Chapapote.

Four provinces of Cuba have deposits of pure asphalt. Pits of pure liquid asphalt are in the neighborhood of Santa Catalina, near Cardenas, in the Guametos District, and south of Hato Nuevo, Province of Matanzas. Hard

^{23/} Work cited in footnote 1, table 1 (p. 8), Chs. 8 and 9, pp. 152-249.

asphalt, approaching glance pitch, is found in the Calabazar District, Province of Santa Clara. Pure, soft asphalt deposits are found near Minas, in the Province of Camaguey; and a deposit of soft asphalt has been reported in the Victoria de las Tunas District, Province of Santiago de Cuba.

In South America, the Bermudez "Pitch Lake" is near the town of Guanoco, District of Benitez, Venezuela. This lake, one of the largest pure asphalt deposits known, covers an area of 1,110 acres, with a depth ranging from 2 to 20 feet and averaging 5 feet. It is covered with vegetation and water in pools. Another deposit in this same state is the La Brea deposit at La Brea, on the northwest coast of the Island of Capure, in the delta of the Orinoco River. The Maracaibal deposit is located in the District of Mara, Inciarte Region, and at La Paz, in the State of Zulia.

In Europe, there are seepages or deposits of pure asphalt in France, Department of Puy-de-Dôme (Auvergne); in the vicinity of the Bay of Avlona Sélénitza (Sélénitza), Albania; in the southern portion of the Island of Zante, Greece, and in two Asiatic and two European provinces of Russia: Uralsk, Kutowo, Kutais, and Tiflis.

In Asia, pure asphalt has been found in Syria and Mesopotamia (Iraq). Several deposits are on the Island of Leyte, Philippine Islands.

Deposits of Asphalts Associated With Mineral Matter

Native asphalts associated with mineral matter occur in seven counties in Kentucky: Hardin, Carter, Breckinridge, Grayson, Edmonson, Warren, and Logan; Lafayette County, Missouri; near Princeton, Indiana; and in the southern portion of Oklahoma, mainly between the 35th parallel of north latitude, the Arkansas line on the east, the Red River on the south, and the City of Granite to the west. There has been considerable commercial development of mining and refining asphalts in this area. Two counties of Arkansas, Pike and Sevier, report deposits. In Alabama, a band about 8 miles wide across Colbert, Lawrence, and Morgan Counties contains asphalt deposits. In Louisiana, a small deposit in Lafayette Parish has been reported. Montague, Burnet, Uvalde, and Kinney, as well as Anderson, Jasper and Cook Counties, Texas, have deposits ranging from fairly important commercial deposits in the first group to minor deposits of no commercial value in the second group. Four counties in Utah have deposits of asphaltic limestone or asphaltic sandstone in Carbon, Utah, Grand, and Uintah Counties, respectively. Asphalt seepages occur in Fremont County, Wyo. In California, deposits of asphaltic sand or sandstone are found in Mendocina, Santa Cruz, Monterey, San Luis Obispo, and Orange Counties, and deposits of asphalt-impregnated shale, asphalt veins, and asphaltic sands are located in Santa Barbara County.

In Canada, deposits of asphaltic sands occur in Alberta and Manitoba Provinces; these are described under the section on Bituminous Sands. Cuba has asphalt deposits associated with sand or other impurities in the Provinces of Matanzas, Pinar del Rio, Havana, Camaguey, and Santiago de Cuba.

Crude or Impure Asphalts

In South America, one of the largest deposits of crude or impure asphalt is the Pitch Lake of Trinidad on the Island of Trinidad, as well as other scattered deposits all over the Island. Although many millions of tons of crude asphalt have been removed from the lake, the level has dropped very little, as there is a continuous influx of solid material at the center, accompanied by a strong evolution of gas. Holes dug in the asphalt fill up slowly.

Other South American countries reporting impure asphalt deposits are the States of Parana and São Paulo, Brazil; the Provinces of Gujuy, Chubut; and Mendoza, Argentina; Departments of Bolivar, Antioquia, Santander, and Boyacá, Colombia; and the Province of Guayas, Ecuador.

In Europe, deposits occur in the Departments of Landes, Gard, Haute-Savoie, Ain, Basses-Alps, Puy-de-Dôme (Auvergne), Haute Vienne, and Alsace-Lorraine, France; Val de Travers region, with minor outcrops at other places, Switzerland; Province of Burgas, Spain; Provinces of Hanover, Westphalia, Hessen, Baden, and Silesia, Germany; Provinces of Dalmatia, Bosnia-Herzegovina, and Styria, Yugoslavia; Province of Tyrol, Austria; Province of Bihar, Hungary; the Provinces of Treezen, Moravia, and Silesia, Czechoslovakia; along the Matilza River, Rumania; the Province of Séléntza (Sélinitza), Albania, and the Compartments of Marches, Abruzzi e Molise, Colabria, Compania, and Sicily, Italy. Sicily contains the largest and most important deposit; it has been commercially exploited since 1838. Greece has deposits of asphaltic limestone in seven departments scattered along or near the southwest coast and islands. Portugal reports asphaltic sandstones and shales in nine provinces, but only one in Alava is reported having commercial development. European Russian deposits are known in seven provinces, with commercial development in the famous oil-producing Baku Province.

In Asia, deposits of asphaltic limestones or sands or shales are reported in Syria, Mesopotamia, Asiatic Russia, Turkey, Arabia, Egypt, India, China and Japan. Commercial production was reported only from Japan.

Deposits are reported in five states or territories in Australia, and in the Dutch East Indies on the Island of Buton. In Africa, deposits occur in Algeria, Nigeria, Rhodesia, and Madagascar.

Properties and Uses of Asphalts

Asphalts vary in consistency from plastic material to hard and brittle solids. They are black, and the solid asphalts break with conchoidal fracture. They are comparatively nonvolatile, fusible at 10 to 70° C., have specific gravity of 1 to 1.3, and are largely soluble in carbon disulfide. Average elemental composition of dry, ash-free asphalts is about 84 percent carbon, 10 percent hydrogen, and 6 percent oxygen. Typical analyses of a pure native asphalt, such as from Tabby Canyon, Uintah County, Utah, as given by Abraham, are listed in table 4.

TABLE 4. - Properties of Tabby Canyon, Uintah County,
Utah asphalt^{1/}

Fracture.....	Conchoidal.
Lustre.....	Bright.
Streak.....	Black.
Specific gravity at 77° F.....	1.006-1.010
Hardness, Mohs' scale.....	less than 1
Penetration at 77° F.....	0
Consistency at 77° F.....	80.0
Fusing-point (K. and S. method).....° F..	178
Volatile matter, 325° F. in 5 hr.....percent..	2.78
Volatile matter, 400° F. in 5 hr.....do.....	6.40
Fixed carbon.....do.....	8.08-9.2
Soluble in carbon disulfide.....do.....	94.7-92.1
Nonmineral matter insoluble.....do.....	.5-1.1
Free mineral matter.....do.....	4.8-6.8
Carbenes.....do.....	.0
Soluble in 88° petroleum naphtha.....do.....	61
Carbon.....do.....	82
Hydrogen.....do.....	11
Sulfur.....do.....	2
Nitrogen.....do.....	2-2.5
Undetermined.....do.....	2

^{1/} Abraham, Herbert, *Asphalts and Allied Substances, Their Occurrence, Modes of Production, Uses in the Arts, and Methods of Testing*: D. Van Nostrand Co., Inc., 5th ed., vol. 1, 1945, p. 153.

Of the asphalts associated with mineral matter, the Pitch Lake of Trinidad asphalt is probably of greatest commercial importance. The influx into the lake bottom is an emulsion of asphalt, gas, water, sand, and clay. An asphaltic petroleum with natural gas, occurring under pressure at some depth under the lake, moves upward, where it comes into contact with a paste of colloidal clay and silica. This converts the mixture into a crude, semiliquid mineralized asphalt, which is honeycombed by the natural gas to give a porous structure. Near the points of evolution, the material has some mobility, although it will bear the weight of a man, but as it moves slowly outward from the points of egress, it gradually hardens. This material is extremely uniform in composition; a fresh sample at the center, according to Abraham, was analyzed as follows:

TABLE 5. - Analysis of fresh sample from
Center of Lake Trinidad^{1/}

Water and gas volatilized at 100° C...percent..	29.0
Asphalt soluble in carbon disulfide.....do.....	39.0
Asphalt absorbed by mineral matter.....do.....	0.3
Mineral matter on ignition.....do.....	27.2
Water of hydration in mineral matter.....do.....	4.3

TABLE 5. - Analysis of fresh sample from
Center of Lake Trinidad (Con.)

Typical dried, pulverized samples show:	
Soluble in carbon disulfide.....percent..	53.0 to 55.0
Free mineral matter.....do....	35.5 to 37.0
Water of hydration, and other residues..do....	9.7

1/ Work cited in footnote 1, table 4, (p. 15) p. 199.

The crude Trinidad asphalt is refined by heating to 160° C. to drive off the water, and the refined product is called "parianite." Abraham^{24/} gives detailed analyses of the refined product.

Evidence has been found indicating use of asphalt as far back in history as 3600 B.C. Early applications included use as a mortar, as a glue or sticking material to fasten blades of tools into handles, and for setting jewels in works of art. As a mortar, asphalt served both as a binder and waterproofing material. It was used as a burning coating on town walls to repel invaders.

Asphalt construction of roads and sidewalks is reported to have begun in 1838, when a sidewalk was laid for the portico of the old Merchants Exchange Building in Philadelphia.^{25/} The first asphalt road was reported in France in 1852, and the first in this country in 1870 in Newark, N. J.

In addition to widespread use as a roadbuilding material, asphalts are used as waterproofing and insulating materials in roofing, building papers, and other construction materials, as components of waterproofing paints, as waterproofing coatings for building materials, as insulating materials in electrical equipment, and for many related applications. Adding asphalt to an insulating oil, used in preparing oil-paper dielectrics, results in papers with high power factors.^{26/}

Asphaltites (See Also Gilsonite, Glance Pitch, and Grahamite)

Asphaltites or asphaltenes are harder and less fusible bitumens than asphalts. Abraham^{27/} classes three fairly well known bitumens (gilsonite, glance pitch, and grahamite) as asphaltites, whereas Hoiberg^{28/} considers asphaltites as the insoluble and infusible constituents left after extracting the fractions of natural asphalts soluble in light hydrocarbons, such as n-heptane.

^{24/} Work cited in footnote 1, table 4, (p. 15) pp. 200-203.

^{25/} Hoiberg, A. J., History, Source, and General Nature of Asphaltic Bitumen: Petrol. Refiner, vol. 26, January 1947, pp. 77-83 (pp. 1-7 of bound volume).

^{26/} Piper, John D., Treend, Portia, and Bevis, Kathryn S., Oil-Paper Dielectrics: Ind. Eng. Chem., vol. 40, February 1948, pp. 323-328.

^{27/} Work cited in footnote 1, table 4, (p. 15) p. 250.

^{28/} Work cited in footnote 25, pp. 77-83 (pp. 1-7 of bound volume).

Gilsonite, glance pitch, and grahamite are discussed under these respective names; therefore, this discussion is confined to the insoluble residues from native asphalts. The location of asphalt deposits has been given under Asphalts.

Yield of asphaltites from native asphalts will vary from 3 to 60 percent, depending upon the source of the crudes, the solvent used, and the degree of reduction of the asphalt by distillation or oxidation in air. The soluble fractions of asphalts are removed by extraction with large volumes of light hydrocarbons; n-heptane is the most commonly used. The n-heptane asphaltene content of some asphalts is reported as follows, in weight-percent:^{29/}

Mexican.....	40/50 --	25.7	Venezuelan..	40/50 --	17.2
Venezuelan..	180/200 -	14.3	Egyptian....	170/210 -	17.5
Trinidad....	170/210 -	7.4	Java S. B...	40/50 -	11.8

Ultimate analyses of six asphaltites showed 80 to 90 percent carbon, 6 to 10 percent hydrogen, and 0.6 to 8 percent sulfur, with some ash, oxygen, and traces of nitrogen and chlorine. Reported molecular weights range from 2,000 to 140,000. Generally, the asphaltites have no melting point, but sinter and fuse on heating and finally decompose.

Although the natural asphaltites, gilsonite, glance pitch, and grahamite are mildly to strongly soluble in petroleum naphtha, the asphalt-extraction residues described here are, by definition, essentially insoluble in light petroleum hydrocarbons. For this reason, this type of asphaltite is particularly suited for use as a component in waterproofing, acid- and alkali-resisting paints and mastics, and for such materials subject to action of light petroleum hydrocarbons. They can also be used in dyes and lacquers, finishes for materials of construction, and in insulating materials and pipe coatings.

Bituminous Sands

The Athabasca oil sands of northern Alberta, Canada, are reported to contain the world's largest single reserve of oil.^{30/} These bituminous sands are an unconsolidated silica sand formation, saturated with a particularly viscous, heavy black oil. Drilling and examination of outcrops indicate this deposit underlies at least 1,500 square miles in northern Alberta and may cover more than 30,000 square miles. In one area - the Mildred-Ruth Lakes - the average thickness of the oil-sand deposit is 140 feet, under about 60 feet of overburden. Oil content of the sand averages about 13.6 weight-percent, with small, irregular pools containing 18 to 80 percent of oil. The sand has been mined by open-pit methods for pilot-scale tests of recovering the oil, but as yet full commercial-scale operation has not proved economical. Two general methods of recovery have been tried, since viscosity of the oil is very high

^{29/} Eisma, E., and Krom, C. J., n-Heptane as a Standard Solvent for the Asphaltene Determination in Asphaltic Bitumen: Jour. Inst. Petrol. (British), vol. 37, 1951, pp. 582-587.

^{30/} Hodgson, G. W., Matchen, Ben, Peterson, W. S., and Gishler, P. E., Oil From Alberta Bitumen: Ind. Eng. Chem., vol. 44, 1952, pp. 1492-1496.

and it cannot be separated from the sand by conventional petroleum-recovery processes. One method is a direct distillation of oil from the sand in a fluidized bed to produce a clean, dry-coker distillate in a single operation. The other method makes use of water as a partition agent for separating the oil from the sand in a flotation step, using either a hot-water or a cold-water process. The water-separation processes reject the bulk of the sand and produce an unaltered crude oil containing considerable emulsified water; the hot-water process yields a product containing 64 percent oil, 32 percent water, and 4 percent solids. The authors of the reference just cited experimented with a pilot plant to take this hot-water-process material and prepare a suitable crude-refinery feedstock in a simultaneous dehydration and coking process, using fluidized solids.

The specific gravity of the bitumen from the Athabasca sands varies from about 1.27 to 1.005; gravity tends to decrease northerly from the Fort McMurray area to the Ells River area. Viscosity of the unaltered bitumen is reported to be much greater in the southern part of the fields (Fort McMurray area) than in the northern area, with a range from 600,000 poises at 50° F., at the Abasand quarry, down to 6,000 to 9,000 poises in the Ells River and Bitumont districts.^{31/} Sulfur content varies appreciably throughout the area, but is generally between 4.5 and 5.5 percent, dry basis. This is considerably higher than most crude petroleum; even "sour" crudes usually have less than 1.75 percent. The sulfur in the Athabasca bitumen is combined chemically and distills over almost uniformly throughout the whole range of distillates. This, and the high viscosity, create recovery, distillation, and purification problems that have been the subject of research for many years.

The metal content of the Athabasca bitumens varies considerably; some show a metal content 10 times that of petroleum crudes. Metals found include vanadium, iron, manganese, nickel, lead, copper, zinc, tin, aluminum, magnesium, and calcium. Their potential danger lies in possible poisoning of refining catalyts.

The refined bitumen from the Athabasca sands probably will be used largely for the same purposes as refined petroleum products when this material becomes economical to produce on a large scale.

Bituminous Shales (Including Oil Shales)

Abraham considers the oil-forming shales in his chapter on Pyrobituminous Shales^{32/} and lists two classes. They are:

"1. Asphaltic pyrobituminous shales in which asphaltic pyrobitumens (elaterate, wurtzilite, albertite, and impsonite) are associated with shales, and

^{31/} Peebles, A. A., The Bituminous Sands of Alberta: Eng. (British), vol. 175, No. 4543, Feb. 20, 1953, pp. 229-231; and No. 4544, Feb. 27, 1953, p. 260.

^{32/} Work cited in footnote 1, table 4 (p. 15), pp. 302-304.

"2. Nonasphaltic pyrobituminous shales in which nonasphaltic pyrobitumens (cannel coal, lignite, or bituminous coal) are associated with shales."

He also gives methods for differentiating between the two classes.

Since these various pyrobitumens are described here under their respective names, the material in this section relates primarily to oil shale, which contains kerogen, a solid from which a liquid in some respects like crude petroleum can be distilled.

Belser^{33/} has estimated that the oil-shale reserves of the Green River formation in northwestern Colorado (mainly in Rio Blanco, Garfield, and Mesa Counties), contain an estimated oil yield from 25-gallon-a-ton shale of 125 billion barrels, and from 25- and 15-gallon-a-ton shale, 494 billion barrels. The U.S. Geological Survey has published a paper in which the estimate for shale of over-15-gallon-a-ton yield of shale oil is given as 959 billion barrels.^{34/} In addition to the massive tertiary Colorado shale reserves, other shales of the same geologic period are found in Nevada, Utah, and Wyoming. Estimated reserves in Utah and Wyoming amount to billions of barrels of recoverable oil. Devonian black shales occur in Indiana and Kentucky, and cannel shales in Pennsylvania and West Virginia, although estimated recoverable oil from the last two are negligible compared with those in Colorado, Utah, Indiana, and Kentucky. In Canada, important deposits, both in yield and abundance, occur in Nova Scotia, New Brunswick, and Ontario.

Oil-shale deposits have been worked commercially in Scotland, Australia, and Sweden. Important deposits are also in Spain, France, Germany, Austria, Hungary, Yugoslavia, Estonia, Rumania, Bulgaria, Russia, Sweden, England, Wales, South Africa, Australia, New Zealand, and Tasmania.^{35/}

The oil content and thickness of oil-shale deposits^{36/} vary widely, often within the same deposit. Although many strata are relatively low in oil-forming constituents - 15 gallons a ton or less - some of the seams may yield up to 60 or more gallons per ton; however, these richer seams usually are so thin and interbedded with leaner strata that it is impracticable to try to work them alone. The Green River shales of Colorado and Utah seem to have the best potential for commercial exploitation, since some of the deposits attain a total thickness of 2,600 feet, with persistent seams up to 50 feet thick, capable of yielding up to 35 gallons or more of oil per ton of shale.

^{33/} Belser, Carl, Green River Oil-Shale Reserves of Northwestern Colorado: Bureau of Mines Rept. of Investigations 4769, 1951, 13 pp.

^{34/} Donnell, J. R., Preliminary Report on Oil-Shale Resources of Piceance Creek Basin, Northwestern Colorado U.S. Geological Survey Bulletin 1042-H, pp. 255-271, 1957.

^{35/} Guthrie, Boyd (compiled by), Studies of Certain Properties of Oil Shale and Shale Oil: Bureau of Mines Bull. 415, 1938, 159 pp.

^{36/} Stanfield, K. E., Rose, C. K., McAuley, W. S., and Tesch, W. J. Jr., Oil Yields of Sections of Green River Oil Shale in Colorado, Utah and Wyoming, 1945-52: Bureau of Mines Rept. of Investigations 5081, 1954, 153 pp.

Although shale oil is in some respects similar to petroleum, the two materials are unlike enough to require different distillation and analytical procedures; therefore the Bureau of Mines modified its routine method for analyzing crude petroleum and used it for shale oil.^{37/} Table 6 shows analytical data on a shale oil obtained from Rifle, Colo., by treatment of oil shale in a gas-combustion retort. The last reference cited gives analyses of oils from other shales obtained by treatment in various types of retorts.

Shale oil was produced originally for medicinal purposes; its possibilities as a source of fuel oil was recognized later, when commercial production was established in France about 1840 and in Scotland in 1850. The Scottish shale-oil industry has been more active and highly developed than in any other country, although in recent years competition from petroleum has forced conversion of oil-shale refineries to refining of imported petroleum. Sporadic shale-oil industries have developed at various times in Australia, Estonia, Manchuria, and the U.S.S.R., but there is little evidence of appreciable commercial success. However, note references to torbanite distillation operations in South Africa and Australia under "Torbanite."

Medicinal use of specially treated shale oil continued in Europe, at least until very recent years; however, the major use of past production, and that proposed for future production, is for combustion as a boiler fuel and as fuel for internal-combustion engines to supplement petroleum oils now used for these purposes.

Boghead Coal

The name "boghead" was first applied to coal of the variety found on the Boghead Estate, near Bathgate, Scotland. There is a difference of opinion, discussed in more detail under the section on Torbanite, as to whether boghead coals are the same class of material as torbanites, but a reference is cited giving reasons for classifying them separately. The terms "boghead" and "cannel" also frequently have been used interchangeably. Thiessen^{38/} investigated these various materials and concluded that true boghead coals appeared to be a distinct species, derived largely from colonies of algalike organisms, similar to organisms now living in salt lakes and lagoons of South Australia and neighboring islands and called "elacophyton." These algalike organisms appear to be the source of the peculiar, irregular, oval yellow bodies that characterize thin sections of boghead coals when examined under the microscope and are different from the spores observed in thin sections of cannel coal.

Thiessen examined boghead coals from New South Wales, Australia; the torbanite, which he calls "boghead coal," from Torbane Hill, Scotland; a deposit at Bathgate, Scotland; a deposit from a district drained by the Colville River, in northern Alaska; and a thin bed in Pennsylvania. Another well-known deposit is at Autun, France. Thiessen also examined specimens from cannel coalbeds at Lesley, near Paintsville, Ky., and near Leesburg, Mercer

^{37/} Stevens, R. F., Dinnen, G. U., and Ball, John S., Analysis of Crude Shale Oil: Bureau of Mines Rept. of Investigations 4898, 1952, 20 pp.

^{38/} Thiessen, Reinhardt, Origin of the Boghead Coals: Geol. Survey Prof. Paper 132-1, 1925, pp. 121-138.

County, Pa. In the boghead coals and torbanite, Thiessen found abundant remains of the algal colonies characteristic of boghead coals. Some of these colonies were found in the cannel coals, but the coals were predominately of spore origin and would fit better into the humic-sapropelic series, as shown in the classification scheme of table 2.

TABLE 6. - Analysis of shale oil from a Colorado oil shale^{1/}

PROPERTIES OF CRUDE SHALE OIL										
Specific gravity.....	0.943		Nitrogen.....percent..	2.13						
A.P.I. gravity.....	18.6		Pour point.....°F..	85						
Sulfur.....percent..	.69		Viscosity, S. U. seconds at 100° F.....	310						
PROPERTIES OF COMPOSITE FRACTIONS										
			Volume- percent	Specific gravity	°A.P.I.	Nitrogen, percent				
Naphtha (fractions 1-7).....			4.4	0.822	40.6	1.17				
Light distillate (fractions 8-10).....			14.6	.872	30.8	1.37				
Heavy distillate (fractions 11-14).....			31.3	.927	21.1	2.03				
Residuum ^{2/}			49.7	.986	12.0	2.47				
Loss.....			----	-----	----	----				
DISTILLATION AND ANALYSIS										
Distillation at 760 mm. Hg.					Analysis					
Frac. No.	Cut at-		Per- cent	Sum, percent	Specific gravity	Product	Naphtha (fractions 1-7), percent	Light distillate (fractions 8-10), percent		
	°C.	°F.								
1	50	122	---	---	----	Tar acids.....	4.4	5.3		
2	75	167	---	---	----	Tar bases.....	7.5	10.5		
3	100	212	---	---	----	Neutral oil:				
4	125	257	---	---	----	Paraffins and				
5	150	302	---	---	----	naphthenes.....	27	27		
6	175	347	1.5	1.5	0.806	Olefins.....	51	42		
7	200	392	2.9	4.4	.831	Aromatics ^{3/}	22	31		
DISTILLATION AT 40 mm. Hg.										
Frac. No.	Cut at-		Percent	Sum, percent	Gravity		Aniline point, °C.,	Viscosity at 100° F.		
	°C.	°F.			Specific, 60/60° F.	°A.P.I., 60° F.		K.V., c.s.	S.U., sec.	
8	150	302	3.2	77.6	0.849	35.2	32.4	----	---	
9	175	347	5.7	13.3	.867	31.7	33.5	----	---	
10	200	392	5.7	19.0	.889	27.7	34.4	----	---	
11	225	437	5.9	24.9	.899	25.9	34.8	8.2	53	
12	250	482	7.6	32.5	.915	23.1	33.6	15.2	78	
13	275	527	7.6	40.1	.935	19.8	32.9	32.1	150	
14	300	572	10.2	50.3	.945	18.2	38.3	68.4	315	
Residuum ^{3/}			49.7	100.0	.986	12.0				

^{1/} Source of shale: Rifle, Colo.; reduction method: gas combustion retort.

^{2/} Includes some sulfur and nitrogen compounds.

^{3/} Carbon residue of residuum, 5.2 percent; carbon residue of crude, 2.7 percent.

In outward appearances, many boghead coals resemble ordinary cannel coals; some resemble bituminous shales. They are dark grayish black or brown, with dull surfaces; and most show little if any lamination, although a few boghead coals are laminated. Most coals break with a conchoidal fracture, although some split along horizontal bedding planes.

Boghead coals have been distinguished from other bituminous coals by the very great yields of low-temperature tar from the boghead coals, and this tar is almost free of phenols. Extracting boghead coals with solvents yields relatively small amounts of extractable bitumen. Natural bed moisture is low. Hydrogen content is relatively high, compared with other coals. Table 7 gives analyses of some Siberian (U.S.S.R.) boghead coals.

TABLE 7. - Analysis of Siberian boghead coals^{1/}

Location	Percent ^{2/}							Heating Value ^{2/}	
	In dried coal		In organic matter					Cal./g.	B.t.u./lb.
	H ₂ O	Ash	S	C	H	O	N		
Khakhareisky.....	4.0	14.8	0.6	76.5	9.8	11.9	0.8	7,584	13,650
Cheremkhowsky.....	1.7	5.3	.7	81.1	8.3	8.7	1.1	8,325	14,990
Matagansky.....	1.3	10.4	2.7	78.7	10.4	7.3	.6	8,322	14,980
Sukhokujatsky.....	4.1	7.8	-	76.8	8.9	12.8	.8	7,902	14,220

^{1/} Stadnikoff, George L., The Nature and Properties of Siberian Bogheads; Proceedings of the Second International Conference on Bituminous Coal, vol. 1, 1929, pp. 625-631.

Karawajew, N. M., Sapropelic Coals of the Kusnetzk Basin: Fuel (in Science and Practice), vol. 13, 1934, pp. 299-310.

^{2/} Data rounded to nearest 0.1 percent and 10 B.t.u.

Uses of boghead coals abroad have included low-temperature carbonization to obtain the high yields of liquid products, and for gasmaking and burning in fireplaces.

Brea

The names "brea" and "chapapote" are of Mexican-Spanish origin, according to Abraham,^{39/} and designate some of the softer, natural asphalts. Eldridge^{40/} reported a deposit of brea at Wheeler, Okla., as the uppermost bituminous-impregnated layer of a series resulting from a long-since extinct oil seepage. The deposit was 6 inches to 3 feet thick, comprising a hardened petroleum residue resulting from volatilization of the lighter oils, with perhaps a certain amount of oxidation. In the flow, and settling to its final state of rest, the bitumen acquired a certain amount of sand, bark, twigs, and other

^{39/} Abraham, Herbert, Asphalts and Allied Substances, Their Occurrence, Modes of Production, Uses in the Arts, and Methods of Testing: Fifth Edition, vol. 1, 1945, copyright D. Van Nostrand Company, Inc., p. 64.

^{40/} Eldridge, George H., The Asphalt and Bituminous Rock Deposits of the United States: Geol. Survey 22d Ann. Rept. (1900-1901), 1901, pt. 1, p. 314.

materials; so it is variable in composition. It is primarily black, earthy or clear, and waxlike in texture; brittle, yet tenacious, and under a slight rise in temperature, it becomes gumlike in consistency.

Its uses, if any at present, are the same as those for asphalts.

Cannel Coal (and Jet)

Cannel coal is the familiar, easily burning, long-flame coal preferred for fireplace use where it is available in this country. It was originally called "candle coal", because splinters of it will ignite easily and burn with a luminous flame, like a candle.

Cannel coal occurs most frequently in small basins, lenses, or lenticular intrusions in bituminous coalbeds. Ashley^{41/}, in 1918, reported deposits of cannel coal in: Centre, Clearfield, Indiana, Westmoreland, Armstrong, Allegheny, Butler, and Beaver Counties, Pa.; Mahoning, Coshocton, Licking, Jackson, Holmes, Scioto and Jefferson Counties, Ohio; Daviess, Perry, and Parke Counties, Ind.; McLean County, Ill.; several scattered areas in Michigan; Preston, Barbour, Upshur, Braxton, Webster, Nicholas, Kanawha, Boone, Lincoln, Logan, and Wayne Counties, W. Va.; Greenup, Carter, Elliott, Lawrence, Johnson, Morgan, Magoffin, Floyd, Wolfe, Pike, Clay, Laurel, Whitley, and Hancock Counties, Ky.; Campbell County, and other small deposits, Tenn.; scattered places in the Cahaba coalfield, Ala.; a place near Fort Dodge, Iowa; Callaway, Cole, Cooper, Crawford, Jasper, Lincoln, Miller, Moniteau, Morgan, and Saline Counties, Mo.; a place near Camden, Ouachita County, Ark.; Webb County, the reportedly largest deposit in the United States, a few miles above Laredo, near the Rio Grande River, Tex.; and the Colob coalfield, Iron County, Utah.

Since most deposits were of relatively limited area and tonnage, many have been partially or entirely worked out. None of the companies or mines listed in 1918 by Ashley as producing cannel coal are now listed as producing companies or mines under those names. Two more recent publications describe cannel coals and cannel shales in Ohio,^{42 43/} with particular attention given to products of distillation.

Cannel coal is a massive, nonbanded coal derived by solidification and partial distillation or oxidation of water-laid deposits of plant spores and pollen grains and remains of water plants and animals of low order. It burns readily with a bright flame. It is a clean coal, usually breaking with a conchoidal fracture, has a very dark gray even color, fine compact grain, gives a brown, or brownish-black streak and has a dull lustre. It does not cake during burning, and if any coke or char is formed at all, it is weak and

41/ Ashley, George H., Cannel Coal in the United States: U.S. Geol. Survey Bull. 659, 1918, 127 pp.

42/ Kerr, T. H., Some Studies of Ohio Coals, Shales, and Oils: Ohio State Univ. Eng. Exp. Sta. Bull. 133, September 1948, 63 pp.

43/ Bowen, Charles H., Further Studies of Ohio Coals and Oil Shales, Part III, Ohio Shales and Cannel Coals: Ohio State Univ. Eng. Exp. Sta. Bull. 143, May 1951, pp. 56-70.

very friable. Cannel coal is so uniform in structure that it may be carved into works of art.

Jet, used almost exclusively for making jewelry and other works of art, is a compact velvety-black variety of coal, resembling cannel coal, that can be carved and highly polished. Deposits of jet occur in England, Germany, France, and Spain.

Chemically, cannel coal is characterized by a relatively high percentage of volatile matter and lower percentage of fixed carbon than most bituminous coals. Table 8 gives typical proximate analyses of some American cannel coals.

Upon distillation or carbonizing at high temperature (1,000°-1,200° C.), large volumes of gas, with as much as twice the heating value of coal gas from bituminous coal, are given off. Ashley reports production of about 10,000 to 16,000 cubic feet of gas per long ton (2,240 pounds). Heating value was not given, but illuminating value in candlepower was reported as ranging between that of methane and ethane. High-temperature distillation also gives small quantities of tar and char equal to half or more of the original weight of coal.

At distillation temperatures under 800° C. (medium- to low-temperature carbonizing) gas yields will decrease materially, char yields will increase slightly, and substantial quantities of low-temperature tar and oils and some ammoniacal liquors will evolve. Distillation tests on American cannel coals gave reported yields of crude oil ranging from 47 to 130 gallons per ton (presumably 2,240 pounds), and char yields ranging from about 39 to 66 percent of the original coal.

About the middle of the last century, distillation of cannel coal and refining the "coal oil" became an active industry. Ashley^{44/} reported 55 coal-oil companies in existence in this country in 1860. However, discovery of petroleum and production of enough crude oil to supply all the lighting and heating oils then needed forced the coal-oil refineries either to convert to petroleum refining, which many of them did, or to go out of business. Cannel coal now is used mainly as a fireplace fuel, and jet serves as a material to carve and polish to make ornaments, jewelry, and other works of art.

Canneloid

Canneloid is the term applied to coal having the appearance of cannel coal and the same general origin; that is, largely from spores and pollen. However, canneloids have less volatile matter than true cannels, and are thus intermediate between cannel and high- or medium-volatile bituminous and anthracitic coals with which they may be associated in the bed. They are "lean" cannels, which in many instances do not have sufficiently distinctive properties from the low-volatile coals or semianthracite and anthracite with which they may be associated to make their separate mining and commercial use economic.^{45/} Table 9 gives analyses of some canneloid benches from beds of high- and low-volatile bituminous coal and semianthracite from Pennsylvania, with comparative analyses of the bituminous and anthracitic beds with which the canneloids are associated.

^{44/} Work cited in footnote 41 (p. 23), p. 43.

^{45/} Work cited in footnote 41 (p. 23), p. 10.

TABLE 8. - Analyses of some American cannel coals

State	Source				Proximate, percent - as received					
	County	Location	Mine	Bed	H ₂ O	Volatile matter	Fixed Carbon	Ash	S	B.t.u.
Pennsylvania	Beaver	---	Beaver Cannel	Upper Kittanning	3.2	39.5	50.3	7.0	3.0	13,550
Ohio	Columbiana	---	---	Lower Kittanning	4.6	42.6	45.3	7.5	---	---
Kentucky	Breathitt	Nichols Fork	Frozen Creek	---	1.2	58.8	35.3	4.7	---	---
Kentucky	Carter	Stinson Creek	---	---	2.0	57.0	34.5	6.5	---	---
Kentucky	Bell	Chenoa	Rear Creek	---	1.0	51.6	40.4	7.0	.7	---
Kentucky	Jackson	---	Coyle	---	1.8	41.0	43.3	13.9	1.0	---
Kentucky	Magoffin	---	Colvin	---	2.4	51.9	37.5	8.2	1.4	---
Indiana	Daviess	Cannelburg	---	---	3.5	48.5	42.0	6.0	1.0	---
Arkansas ^{1/}	---	---	Brown	---	38.7	36.9	16.9	7.5	.5	---
West Virginia	Kanawha	Paint Creek	Wacomah	---	.4	41.3	46.2	12.1	.5	---

^{1/} Typical of brown subcannel.

TABLE 9. - Proximate analyses of Pennsylvania canneloids and associated bituminous and anthracitic coals^{1/}

Location in Pennsylvania	Canneloid bench, percent				Bituminous or anthracitic bench, percent			
	H ₂ O	Volatile matter	Fixed Carbon	Ash	H ₂ O	Volatile matter	Fixed Carbon	Ash
Armstrong County, SE. of New Salem....	2.4	37.8	53.1	6.7	2.7	37.9	52.7	6.7
Tioga County, Fall Brook.....	1.8	17.1	66.2	14.9	1.9	20.8	70.8	6.5
Bradford County, Barclay.....	1.6	15.0	71.3	12.1	1.7	17.0	75.9	5.4
Sullivan County, Bernice.....	2.7	9.0	63.7	24.6	2.6	9.6	82.3	5.5

^{1/} Work cited in footnote 41 (p. 23), p. 17.

As canneloids do not have the same advantage of distinctive use properties over their associated coals that cannel coals have over the bituminous coals, they are usually mined, sold, and used with their associated high-rank bituminous and anthracitic coals, without the price premiums that accrue to cannel coals.

Chapapote

Chapapote is the name formerly given to a very pure, soft, asphalt found in the District of Chapapote, State of Vera Cruz, Mexico.^{46/} The material tested 99-percent soluble in carbon disulfide, with less than 1 percent mineral matter. It varies in consistency from a semiliquid, as exuded from the asphalt springs, to a comparatively hard solid, depending upon the length of its exposure to the weather.

In early days, the name "chapapote" was applied generally to various semiliquid asphalts corresponding in properties to those found in the Chapapote District. (See "Asphalts", for general properties and uses.)

Copal

The term "copal" designates both fossilized natural resins, such as obtained from the Congo,^{47/} and exuded gum resins from presently living species of trees. The Philippine copals, variously known under the names Philippine, Manila, Camarine, and Lagonoy copals, and copals from Brazil, are of modern origin, and are mainly hardened gum exudings from native trees. The fossilized copal from the Congo and some of the Philippine copals are dug by native labor, washed, and graded by color, size, and hardness. Copal ranges from transparent

^{46/} Work cited in footnote 39 (p. 22), p. 157.

^{47/} Sutton, Donald C., The Chemistry of Congo Copal, Part I. Source, Properties, and Subdivision of Raw Resin: Jour. Chem. Soc., (London), March 1949, pp. 676-682.

glasslike material to brown chips containing grit and bark. The grade known as "pale ivory" is milky white or pale yellow and may be almost transparent.

For the Congo copal, carbon and hydrogen percentages are reported close to those required for an empirical formula $(C_{20}H_{22}O_{1.9})_n$. Extraction with various solvents, including ethers, alcohols, aqueous alkaline solutions, and various hydrocarbon liquids, have yielded preferentially dissolved constituents.

Copal is quite soluble in linseed oil when heated to about 300° C. and is extensively used in lacquer, varnish, drier, and paint manufacturing. Other uses are in adhesives, chewing gum, printing inks, linoleums and oilcloth manufacturing, paper and textile sizing, plastics, polishes, and rubber compounds, and as a substitute for amber.^{48/}

Copalite (See Also Kauri)

Copalite (or copaline) is a fossil resin resembling gum copal and is used for many of the same purposes.

Coorongite

(See Elaterite.)

Elaterite (or Coorongite)

Elaterite (or coorongite) is one of the elastic bitumens, sometimes called mineral rubber. It is found in beds in eastern Utah, usually associated with other hydrocarbons.^{49/} Elaterite deposits have also been found in Derbyshire County, England, in the Coorong District of South Australia, and in Turkestan, in the Soviet Union, at the mouth of the Ili River. Material from the Coorong District has been called "coorongite."

Elaterite is an asphaltic pyrobitumen, derived from metamorphosis of petroleum and characterized by its unfusibility and comparative freedom from oxygenated compounds. It is elastic when freshly mined, but on exposure it becomes hard and brittle. Average composition of elaterite is: Carbon 84.5 percent; hydrogen 11.5 percent, oxygen 0.4 percent, specific gravity 0.9 to 1.2. It decomposes without fusing. Emulsifiers and solvents for elaterite have been published.^{50/}

Elaterite is used in solution as a paint, waterproofing, and weather-proofing coating for articles made of wood, iron, steel, tin, leather, rubber,

^{48/} Mantell, C. L., and Rubenkoenig, H. L., Manila Resins, Origin, Properties, and Applications: Ind. Eng. Chem., vol. 29, August 1937, pp. 855-859.

^{49/} Palmer, Elihu, Recent Uses of Utah Elaterite: Eng. Min. Jour., vol. 102, No. 20, Nov. 11, 1916, p. 856.

^{50/} Oil, Paint, and Drug Reporter (staff article), What You Can Use - Information on Various Materials Suitable for Operating Purposes in the Chemical Processing Industries, Elaterite, Emulsifiers for Elaterite, and Solvents for Elaterite: Vol. 126, No. 26, Dec. 10, 1934, p. 48.

cork, concrete, and other substances. When the solvent evaporates, the elaterite remains as an intensely close-grained, lustrous, ebony-black veneer, practically impervious to acids, alkalis, water and brines, oxygen, and nitrogen; it is a good electrical insulator. Wooden posts and pilings and underground pipelines coated with elaterite paint are reported to have excellent rot and corrosion resistance. When applied to porous or semiporous materials like wood, leather, concrete, and similar materials, the elaterite penetrates the pores of the coated substance and forms threadlike supports of the coating, preventing cracking and peeling. The secret of this sealing and waterproofing capacity of elaterite is said to reside in the refining process that removes 11.2 percent hydrogen, 4.8 percent oxygen, 0.2 percent nitrogen, and 0.2 percent sulfur from the crude product, leaving a material containing 99 percent pure carbon. This, of course, explains its chemical inertness.

Fichtelite

Fichtelite is a white, translucent hydrocarbon, occurring in the form of crystalline scales in partly or completely fossilized conifer wood found in European peat and lignite beds.^{51/}

The white crystalline fichtelite has a melting point of 46° C., and is soluble in ether but not in alcohol. A structure of 12-methylperhydroretene or perhydroabietane, C₁₉H₃₄, has been suggested.^{52 53/} Because of its scattered and relatively rare occurrence, there are no known commercial uses, and most specimens are retained as display pieces or used in laboratory studies.

Gilsonite (or Uintaite)

Deposits of gilsonite (or uintaite) have been found only in the Uintah Basin, in a belt about 65 miles long extending from Rio Blanco County, Colo., through Uintah County, Utah, into Duchesne County. It occurs in almost pure form in vertical parallel veins, which outcrop at the surface, vary in thickness from thin fissures up to 22 feet, and range in depth from about 100 feet near the eastern end of the belt to about 2,000 feet at the western end, where it has been mined to a depth of 1,500 feet.^{54/} The reference just cited gives a map showing location and direction of occurrence of the gilsonite beds.

^{51/} Tomkeieff, S. I., Coals and Bitumens and Related Fossil Carbonaceous Substances, Nomenclature and Classification: Pergamon Press Ltd. London, 1954, p. 47.

^{52/} Boget, Marston, Taylor, and Sterling, Edward C., An Approach to the Synthesis of Fichtelite: Science, vol. 87, No. 2252, Feb. 25, 1938, p. 196.

^{53/} Fieser, L. F., and Jacobsen, R. P., Precision Combustion of Natural Products: Am. Chem. Soc. Jour., vol. 58, June 1936, p. 943-946.

^{54/} Cottingham, P. L., Tihen, S. S., Brown, J. F., Kindschy, E. O. Jr., Kelley, R. E., Schunter, W. E., and Murphy, W. T. R., Gilsonite as a Source of Synthetic Fuels: Ind. Eng. Chem., vol. 47, February 1955, pp. 328-332.

Gilsonite was produced at Bonanza, Utah, for many years, and refined there by the Barber Asphalt Corp. before a disastrous fire in November 1945, which nearly wiped out the operations and the town. Following this fire, the American Gilsonite Co., a subsidiary of Standard Oil of California and of Barber Asphalt Corp., was formed and has been mining and selling gilsonite from the Bonanza deposits.^{55/} A refinery for gilsonite has been constructed near Grand Junction, Colo., by the America Gilsonite Co., Salt Lake City, Utah; the gilsonite from the Utah deposit is now hydraulically mined and transported from the mine to the refinery or carbonizing plant,^{56/} where it is carbonized to produce coke and gasoline.

Gilsonite is a bright, black hydrocarbon resembling glossy asphalt. It breaks with a conchoidal fracture, has a bright to fairly bright lustre, and a reddish-brown streak. Typical chemical and physical properties are given in table 10.

TABLE 10. - Chemical and physical properties
of gilsonite^{1/}

Specific gravity.....	60°/60° F..	1.01-1.10
Hardness (Mohs' scale).....		2
Melting point.....	°F..	250-350
Fixed carbon.....	weight-percent..	10-20
Ultimate analysis:		
Carbon.....	do.....	85-86
Hydrogen.....	do.....	8.5-10.0
Nitrogen.....	do.....	2.0-2.8
Sulfur.....	do.....	0.3-0.5
Oxygen.....	do.....	0-2

^{1/} Work cited in footnote 53, p. 328.

Gilsonite has been used in manufacturing storage batteries, foundry forms, paints, varnishes, inks, and lacquers, and as a binder ingredient with plastics. When incorporated in rubber compounds, it materially improves the physical and electrical insulating properties of the compounds. It is used in asphalt floor tiles (usually mixed with fatty-acid pitch) and as an insulating coating for underground piping and tanks and a lining for chemical tanks. Its major use now is in the production of coke and gasoline in the Colorado carbonizing and refining plant.

Glance Pitch (or Manjak)

According to Abraham, glance pitch, although resembling gilsonite in external appearance, differs in having a black streak rather than the brown of gilsonite, has higher specific gravity, and yields a larger percentage of

^{55/} Business Week (staff article), Develop Gilsonite: No. 854, Jan 12, 1946, p. 67.

^{56/} Chem. Eng. News (staff), Industry, Solid Source of Gasoline: Vol. 34, No. 30, July 23, 1956, p. 3546. Min Eng. News (staff article), Gilsonite: Vol. 2, No. 12, August 1956, pp. 785-790.

fixed carbon. Like gilsonite, it seems to be derived from petroleum, but from a crude of character different from that which became gilsonite.^{57/}

Abraham reports glance-pitch deposits^{58/} in the Archangel Province of the U.S.S.R. (formerly in European Russia); on Barbados Island of the West Indies, where the name "manjak" was originally used for the material obtained from a number of localities on the island; in Cuba, where glance-pitch deposits are mined or have been reported in the Provinces of Pinar del Rio, Santa Clara, and Camaguey; in Mexico, where deposits have been reported in the Districts of Chapapote and Papantla, State of Vera Cruz; at Temple and Flat Top Mountains, Emery County, Utah, in the United States; in the District of Chontales, Nicaragua, and Department of San Miguel, Salvador, Central America; in the Province of Neuquen, Argentina^{59/}, and the Department of Tolima and Bolivar, Colombia, and the Territoria Magallanes, Chile, in South America; in the vicinity of Bentheim, Germany, and near Port Kunda on the Gulf of Finland, Estonia, in Europe; and in Asia, and the Near East, in Syria, Palestine, Mesopotamia (Iraq), and the Ufa Province of the formerly Asiatic portion of Russia, now part of the U.S.S.R.

In addition to the properties mentioned previously in comparison with gilsonite, glance pitch can be described as being jet black, with brilliant lustre, conchoidal fracture, and moderately hard, brittle structure at usual ambient temperatures, since it has a fusing point in the range between 230° and 350° F. (K. and S. method). It is highly soluble in carbon disulfide - usually more than 95 percent, and in some specimens over 99 percent. A peculiar characteristic of the Emery County, Utah, deposits is their relatively high uranium and vanadium content. Table 11 gives physical and chemical properties, as reported by Abraham, for samples of "selects" glance pitch mined in the Province of Camaguey, Cuba, and shipped from the Port of Tariffa.

Glance pitch has been used extensively in manufacturing varnishes and japans because of its high purity, gloss, and intense, black color. In ancient times, and perhaps locally in modern times, it has been used as a substitute for asphalt.

Grahamite

Grahamite is another of the group of natural asphaltlike materials that Abraham classes as "asphaltites."^{60/} Kirkpatrick^{61/} reports deposits of

^{57/} Abraham, Herbert, *Asphalts and Allied Substances, Their Occurrence, Modes of Production, Uses in the Arts, and Methods of Testing*: D. Van Nostrand Co., Inc., 5th ed., vol. 1, 1945, p. 260-261.

^{58/} Work cited in footnote 57, pp. 260-270.

^{59/} Allen, A. W., *Argentine Glance Pitch*: Eng. Min. Jour., vol. 133, November 1932, pp. 563-566.

^{60/} Work cited in footnote 57, pp. 270-288.

^{61/} Kirkpatrick, Sidney D., *Marketing the Natural Hydrocarbons. How Gilsonite, Wurtzilite, Elaterite, Manjak and Grahamite and the Mineral Waxes, Ozocerite and Ceresine, Are Sold*: Eng. Min. Jour.-Press, vol. 119, No. 8, Feb. 21, 1925, p. 331.

grahamite in Ritchie County, W. Va.; Grand County, Colo.; Fayette and Webb Counties, Tex., and Pushmataha, Atoka, and Stephens Counties, Okla. Deposits of grahamite are also known in the States of Vera Cruz, San Louis Potosi, and Tamaulipas, Mexico; Provinces of Pinar del Rio, Havana, and Santa Clara, Cuba; on the Island of Trinidad; Provinces of Mendoza and Neuquen, Argentina, and in Peru, Province of Tarma. Abraham reports that mining is or has been conducted in quite a number of the deposits in Mexico, Cuba, and South America; the first deposit found in this country, that in Ritchie County, W. Va., has been worked out.

TABLE 11. - Properties of "selects" glance pitch from the
Province of Camaguey, Cuba^{1/}

Color in mass.....	Black.
Fracture.....	Conchoidal.
Lustre.....	Bright.
Streak.....	Black.
Specific gravity at 77° F.....	1.12
Hardness, Mohs' scale.....	2
Fusing point (K. and S. method).....° F..	315
Fusing point (R. and B. method).....° F..	284
Fixed carbon.....percent..	26
Soluble in carbon disulfide.....do....	99.25
Nonmineral matter insoluble.....do....	0.23
Mineral matter.....do....	0.52
Carbenes.....do....	0.1
Soluble in 88° petroleum naphtha.....do....	18.0
Carbon.....do....	79.7
Hydrogen.....do....	8.2
Sulfur.....do....	7.4
Undetermined (nitrogen and oxygen).....do....	4.8
Total.....do....	100.0

^{1/} Work cited in footnote 57, p. 263.

Grahamite is a brittle, black, asphaltlike material, differing from gilsonite in having higher specific gravity and higher content of mineral matter. It fractures with irregular, hackly surfaces, instead of bright conchoidal; and the broken surface is often, although not always, dull instead of lustrous like gilsonite; hardness ranges from 2 to 3 on Mohs' scale, and its fusion or intumescence temperature ranges from 350° to 600° F. It goes through a stage of intumescence and swelling at high temperature rather than melting like most other asphaltic-type bitumens, except albertite.^{62/} Grahamite is sometimes found in a fairly pure state, relatively free of mineral matter, but more frequently associated with mineral matter, which may run as high as 50 percent. Abraham, in a description of a cross section of the bed of grahamite

^{62/} Ladoo, Raymond B., The Natural Hydrocarbons; Gilsonite, Elaterite, Wurtzilite, Grahamite, Ozokerite, and Others: Bureau of Mines Rept. of Investigations 2121, 1920, 12 pp.

at the Grahamite mine near Tushkahoma, Okla., notes that the material taken from the center of the bed (called type a) is more like gilsonite in appearance and fracture than the more dull and hackly material found at the edges of the deposit (type b), and gives analyses of these types, shown in table 12.

TABLE 12. - Properties of grahamite from
mine near Tushkahoma, Okla.^{1/}

Color in mass (types <u>a</u> and <u>b</u>).....	Black.
Fracture (type <u>a</u>).....	Conchoidal.
Fracture (type <u>b</u>).....	Hackly.
Lustre (type <u>a</u>).....	Bright.
Lustre (type <u>b</u>).....	Semibright to dull.
Streak (types <u>a</u> and <u>b</u>).....	Black.
Specific gravity at 77° F. (types <u>a</u> and <u>b</u>)...	1.18-1.195
Hardness, Mohs' scale.....	2
Fusing point (K. and S. method) (types <u>a</u> and <u>b</u>).....	530-604° F.
Behavior on heating in flame (type <u>a</u>) ^{2/}	Intumesces violently.
Behavior on heating in flame (type <u>b</u>) ^{2/}	Softens, splits and burns.
Volatile matter 500° F., 5 hr.....percent..	< 1
Fixed carbon (types <u>a</u> and <u>b</u>).....do.....	52.76-55.00
Solubility in carbon disulfide.....do.....	> 99.5
Nonmineral matter insoluble.....do.....	< .5
Free mineral matter (types <u>a</u> and <u>b</u>)...do.....	0.21- 0.70

^{1/} Work cited in footnote 57 (p. 30), p. 275.

^{2/} No appreciable difference in fusing point between the two varieties (a and b).

Grahamite is used in roofing materials, varnishes, and paints, as rubber substitutes for water proofing, and as compounding materials for electrical insulation. Grahamites with higher mineral-matter content are used as components of street-paving mixtures. Because grahamite fuses with difficulty, it is usually softened with asphaltic fluxes; it is then less susceptible to temperature changes and forms an elastic material very satisfactory for roofing and waterproofing uses.

Hartite

Hartite is a crystalline hydrocarbon in the class with fichtelite. It has been found in brown coal and lignite deposits near Gloggnitz, Austria.^{63/}

^{63/} Fay, Albert H., A Glossary of the Mining and Mineral Industry: Bureau of Mines Bull. 95, 1920 (reprinted 1947), p. 332.

Hartite occurs in transparent masses or small triclinic crystalline tablets resembling wax.^{64/} It melts at 75° C. No commercial uses have been reported.

Hatchettite (or Hatchettine)

A member of the cereous or waxy hydrocarbon group, hatchettite or hatchettine, was discovered in 1823 in Argyllshire, Scotland, and named after the English chemist Charles Hatchett.^{65/} It occurs in bogs or is associated with coalbeds, but Scotland is the only country of occurrence listed in the literature.

Hatchettite is a yellowish-white to greenish-yellow, soft, waxlike material, which darkens on exposure to light. Specific gravity ranges from 0.892 to 0.983, and melting or fusing point is about 46° C. It is sparingly soluble in boiling alcohol and cold ether and decomposed by sulfuric acid.^{66/} Approximate chemical composition is given as $C_{86}H_{14}(C_nH_{2n})$.^{67/}

No commercial uses have been listed.

Impsonite

A member of the group of natural asphalts, impsonite is found in the Americas and in Australia. A deposit that has been commercially developed occurs in Le Flore County, Okla., and another deposit has been reported in Murray County of the same State. Deposits have also been reported in Scott County, Ark., Eureka County, Nev., and Keweenaw County, Mich. In South America, impsonite has been found, and in some instances mined, in the Provinces of Canta, Huarochiri, and Yauli, Peru; in the Province of Mendoza and La Pampa Territory, Argentina; and in the State of Sao Paulo, Brazil. A deposit has also been reported in Western Australia.^{68/}

Analysis of the Le Flore County impsonite, as given by Abraham, is given in table 13.

Impsonite is a black, asphaltic material, characterized by: (1) Infusibility and insolubility in carbon disulfide; (2) Specific gravity (1.10 to 1.25); (3) High percentage of fixed carbon (50 to 85 percent), and (4) Comparatively small percentage of oxygen (less than 5 percent), which differentiates it from the nonasphaltic pyrobitumens. Impsonite represents the final stage in the metamorphosis of the natural asphalts and does not depolymerize on heating, as do some other members of this group.

^{64/} Work cited in footnote 51 (p. 28), p. 53.

^{65/} Work cited in footnote 57 (p. 30), p. 51.

^{66/} Gregory, Thomas C. (Editor), *The Condensed Chemical Dictionary*: Reinhold Publishing Corp., 3d ed., 1942, p. 339.

^{67/} Work cited in footnote 51 (p. 28), p. 53.

^{68/} Work cited in footnote 57 (p. 30), pp. 298-301.

TABLE 13. - Properties of impsonite from
Le Flore County, Okla.^{1/}

Color in mass.....	Black.
Fracture.....	Hackly.
Lustre.....	Semidull.
Streak.....	Black.
Specific gravity at 77° F.....	1.235
Hardness, Mohs' scale.....	2-3
Fusing point.....	Infusible.
Heating in flame.....	Decrepitates.
Fixed carbon.....percent..	75.0-81.6
Soluble in carbon disulfide.....do.....	4-6
Nonmineral matter insoluble.....do.....	93-96
Mineral matter.....do.....	.7-2.5
Solubility in pyridine (boiling).....do.....	3.88
Moisture.....do.....	.1-1.5
Sulfur.....do.....	1.69

^{1/} Work cited in footnote 57 (p. 30), p. 298.

Impsonite has been used as a railroad fuel in Peru, where a deposit was found near the railroad, and it has been carbonized or distilled for its gaseous products.

Jet

Jet is classed with the coals, since jet is a dense, black type of lignite, consisting of coalified fragments of coniferous wood, usually found in isolated masses in shale. (See Cannel Coal.)

Kabaite

Kabaite is one of the cereous hydrocarbon or mineral wax group. The name has been applied exclusively to material found in meteorities; it is therefore of relatively rare occurrence and has no commercial uses.

Kauri

Kauri is another of the resins or gums in the general class of resinous hydrocarbons. Kauri is used to designate both the resin obtained from the living trees (*Agathis australis*) growing in New Zealand, as well as the fossil resin^{69/} found in areas where this tree has flourished in the past. The fossil resin is found at or near the surface and recovered by stripping methods. It occurs in small chunks or pieces, varying from microscopic to masses weighing as much as 75 pounds. These are found intermingled with earth and are separated by float-and-sink operations.

^{69/} Myers, W. M., New Zealand's Fossil Gums, Kauri: Chem Met. Eng., vol. 31, No. 17, Oct. 27, 1924, pp. 663-664.

Kauri is quite similar in chemical and physical properties to copal resin recovered from living trees. It is soluble in oil of turpentine and linseed oil but only sparingly soluble in the usual solvents. It is yellow to yellowish brown, of hard consistency with conchoidal fracture, and odorless and tasteless.

Kauri is used in varnishes, lacquers, cements, as an amber substitute, and as a constituent of the material used to coat the textile underfabric of oilcloth and linoleum.^{70/}

Libollite

(See Albertite.)

Maltha

Maltha is included in the viscous group of bituminous materials listed in table 2. Eldridge^{71/} describes a seepage of the color and consistency of thick tar, except where dried by the sun, about 3 miles southeast of Fort Sill, Comanche County, Okla. The term "maltha" is derived from the Greek and was used in ancient times for some of the softer native asphalts. Abraham notes this derivation and use but omits further discussion.^{72/}

Maltha is stated to be soluble in benzene and carbon bisulfide but insoluble in water.^{73/} No commercial uses are given.

Mineral Tar

"Mineral tar" is a term that has been used to designate the softer and more viscid natural asphalts. For a description of these, see elaterite, wurtzilite, and other natural asphalts listed in table 2.

Montan Wax

Montan wax is a constituent of many lignites, although most American lignites have too low a montan wax content to make its recovery economical at the present time. However, certain Arkansas and California lignites contain moderate amounts of montan wax, and the American Lignite Products Co., Ione, Calif., using lignite from Amador County, and the Humacid Co., Comanche, Calaveras County, Calif., are or have been producing montan wax from California lignites. During World War II, the American Dyewood Co. operated a plant at Malvern, Ark., for making dyes and stains and extracting wax from Arkansas

^{70/} Work cited in footnote 57 (p. 30), p. 205.

^{71/} Eldridge, George H., The Asphalt and Bituminous Rock Deposits of the United States: U. S. Geol. Survey Twenty-Second Annual Rept., 1900-1901, 1901, Part 1, p. 320.

^{72/} Abraham, Herbert, Asphalts and Allied Substances, Their Occurrence, Modes of Production, Uses in the Arts, and Methods of Testing: D. Van Nostrand Co., Inc., 5th ed., vol. 1, 1945, pp. 2, 38, 49, 64.

^{73/} Work cited in footnote 66 (p. 33), p. 414.

lignites, but this plant suspended operations shortly after the close of the war.^{74/}

While lignites in central Germany, Australia, New Zealand, Czechoslovakia, and Russia also contain montan wax, principal production has historically been in central Germany. In recent years, Czechoslovakia has also been supplying wax to this country.

Chemically, montan wax is a sort of link between the true waxes and the solid hydrocarbons, such as paraffin and ozokerite. In appearance, montan wax is a hard, brittle material at normal room temperature, black in color, with a brownish cast, and with typical conchoidal fracture. The analysis varies considerably, depending on geographical occurrence, but typical analyses are within the ranges shown in table 14.

TABLE 14. - Physical and chemical properties
of montan waxes^{1/}

Melting point.....° C...	72-103
Acid value.....	24-88
Saponification value.....	78-159
Ester value.....	41-79
Ash.....percent...	0.1-0.6
Specific gravity at 20° C.....	1.03-1.09
Resin ^{2/}percent...	14-72
Asphaltic material.....do.....	3-31

^{1/} Work cited in footnote 74 (p. 36), p. 34.

^{2/} Ethyl ether solubility.

The American Lignite Products Co. has reported production of two types of wax - a deresinified wax, dark in color, but with a high melting point (around 87°-88° C.), and a light-colored montan, with excellent oil retention and flow properties and melting point around 81° C.^{75/}

Crude (dark) montan wax is used in shoe polishes, stick wax, last wax, carbon papers, printing inks, and related products. The refined (lighter colored) wax is even more versatile and can be used to replace expensive carnauba wax in a variety of products. Both the crude and modified waxes exhibit excellent binding properties with oils and solvents, although polishes containing montan wax require a little time to set.

Niorite

(See Albertite.)

^{74/} Selvig, W. A., Ode, W. H., Parks, B. C., and O'Donnel, H. J., American Lignites: Geological Occurrence, Petrographic Composition, and Extractable Waxes: Bureau of Mines Bull. 482, 1950, p. 17.

^{75/} The Chemical Age (Staff article), Montan Wax, Development Over the Last Fifty Years: Chem. Age (British), vol. 68 No. 1765, May 9, 1953, pp. 701-703.

Ozokerite (and Ceresine)

There is only one known productive deposit of ozokerite in the United States. It is in southern Utah, at Soldier Summit, on the Denver and Rio Grande Western Railroad. Another deposit was reported at Thrall, Tex. Other deposits are in the Carpathian Mountain districts of Drohobycz and Stanislau of Poland, in a spur of the Carpathian Mountains of Rumania, in the U.S.S.R. (southern European and southwestern Asiatic parts), and in the Philippine Islands.

The Utah deposit is worked by the Ozokerite Mining Co.^{76/} The mineral occurs in vein or fissure deposits, much like the ore bodies of metallic minerals. Unlike gilsonite, which is usually found in masses, ozokerite is well disseminated through the vein filling.

The veins are vertical or steeply dipping, and a simple square-set stope method of mining is used; the ore is loaded into cars, trammed to a shaft, and hoisted. Also, unlike gilsonite, ozokerite does not create a fire hazard in the mine, probably because of dissemination of the material in the gangue. The ore is crushed to minus-1/4-inch and dumped in water, whereupon the ozokerite of 0.9 specific gravity floats, and the gangue sinks.

The concentrate has a melting point ranging between 58° and 100° C. It is melted and blended with various vegetable waxes and high-grade paraffins to meet the specifications of the trade and is packed in 400-pound drums for shipment.

Ozokerite produced in this country is a compact, hard, waxy, jet black, natural hydrocarbon, soluble in turpentine and chloroform. Lighter colors, tending to yellow, brown, or brownish-green occur in foreign ozokerite. It is a higher member of the C_nH_{2n+2} and C_nH_{2n} series of hydrocarbons.^{77/} It is negatively electrified when rubbed. It breaks with a conchoidal fracture and has a characteristic waxy lustre. An old analysis showed Utah ozokerite 85.25 percent carbon and 15.09 percent hydrogen. Various physical and chemical tests on ozokerite, given by Abraham, are listed in table 15. A method for identifying ozokerite and other waxes^{78/} and a list of emulsifiers^{79/} have been published.

When bleached by acid or alkali treatment and hot filtering, an almost white product known as ceresine is obtained.

^{76/} McCullough, C. W., A Mine for Your Secretary: Eng. Min. Jour., vol. 151, No. 5, May 1950, p. 91.

^{77/} Work cited in footnote 72 (p. 35), p. 140.

^{78/} Zweig, Samuel and Taub, Abraham, Identification of Commonly Used Waxes in Admixture: Ind. Eng. Chem., Ann. ed., vol. 12, No. 1, Jan. 15, 1940, pp. 9-14.

^{79/} Oil, Paint and Drug Reporter (Staff), What You Can Use - Guide to Materials That Are Suitable for Various Purposes in Chemical Converting, Compounding, and Processing Industries. Ozokerite, Emulsifiers for Ozokerite: Vol. 137, No. 7, Feb. 12, 1940, p. 39.

TABLE 15. - Properties of Purified Ozokerite and Ceresine^{1/}

Color in mass.....	White to yellow to brown.
Fracture.....	Conchoidal.
Lustre.....	Dull to waxy.
Streak.....	Transparent white to yellow.
Specific gravity at 77° F.....	0.85 to 1.00
Hardness, Mohs' scale.....	<1
Penetration at 32° F.....	0
Penetration at 77° F.....	20-30
Penetration at 115° F.....	150-250
Consistometer hardness at 32° F.....	Above 100
Consistometer hardness at 77° F.....	20-40
Consistometer hardness at 115° F.....	5-15
Susceptibility factor.....	Greater than 80.
Fusing point (K. and S. method).....° F..	140-200
Fusing point (R. and B. method).....° F..	155-225
Fixed carbon.....percent..	1/2 to 10
Soluble in carbon disulfide.....do....	95 to 100
Nonmineral matter insoluble.....do....	0 to 1
Mineral matter.....do....	0 to 5
Carbenes.....do....	0 to 3
Nonmineral matter soluble in 88° petroleum naphtha.....do....	75 to 95
Carbon.....do....	84 to 86
Hydrogen.....do....	16 to 14
Sulfur.....do....	0 to 1.5
Nitrogen.....do....	0 to 0.5
Oxygen.....do....	0 to 2
Solid paraffins.....do....	50 to 90
Sulfonation residue.....do....	90 to 100
Saponifiable constituents.....do....	0 to 2

^{1/} Work cited in footnote 72 (p. 35), pp. 142-143.

A paraffinaceous petroleum almost invariably occurs in the strata underlying the ozokerite veins, which, according to Abraham, "...would seem to indicate that the latter (ozokerite) must have been produced by the slow hardening and probably also the oxidation of petroleum throughout centuries of time,...by a process of metamorphosis or polymerization,..." since ozokerite is virtually free of oxygen.

Ozokerite and ceresine are used in manufacturing high-grade carbon papers and typewriter ribbons, which do not smudge easily, yield a sharp image with good color, and do not fade, or get too hard during storage. They are also used in manufacturing high-grade candles, colored lead pencils, in shoe polishes and waxes for finishing heels and soles of shoes, in floor waxes, as an acidproof coating for electrotype plates and for electrical insulation. Ozokerite and ceresine are used as waterproofing agents in cement mixes, in

phosphorescent compounds, in manufacturing wallpaper and moistureproof paper, in molding compounds, antiseptic agents, and in textile-coating agents.^{80/}

Stellarite

(See Albertite.)

Tasmanite

(See Albertite.)

Torbanite

Authorities differ as to whether "torbanites" are the same as "boghead coals" or are of a different species. Schopf^{81/} stated he believed that "The four rock types designated by the names 'cancel,' boghead,' 'torbanite,' and 'oil shale' were probably members of a closely and complexly intergradational series, and that coal is distinguished from them (if at all) only by some arbitrary degree of purity - a patently artificial boundary in the sense of genetic relationships." He notes that Cadman^{82/} stated, "It is now generally accepted that a torbanite differs from a coal so markedly that it must be regarded as a distinct class of mineral." He also notes other authorities with opposing views (see Schopf's footnote references 3 and 4).

Schopf (see reference 81) and Thorne and Kraemer^{83/} describe a commercial South African torbanite deposit in which the torbanite vein is 14 inches thick and lies about 36 inches from the top of a coalbed, about 53 inches thick. Schopf states that "The distinctive microscopic feature, and the only one, that separates the torbanite layer from the rest of this coalbed is the abundance of fossil remains of a colonial alga - the so-called boghead alga that Blackburn and Temperley have shown to be botanically identifiable with the modern species of *Botryococcus braunii* Kutz...."^{84/}

According to Cane^{85/}, torbanite is formed from algal masses that first pass through a period of decay. The action of decay would raise the temperature of the sapropel and cause polymerization of the partially freed acids to

^{80/} Oil, Paint and Drug Reporter (Staff article), Industrial Uses of Chemicals and Related Materials, Ozokerite: Vol. 130, No. 14, Oct. 5, 1936, p. 63.

^{81/} Schopf, James M., Cannel, Boghead, Torbanite, Oil Shale: Econ. Geol., vol 44, No. 1, January-February 1949, pp. 68-71.

^{82/} Cadman, W. H., The Oil Shale Deposits of the World and Recent Developments in Their Exploitation and Utilization, Reviewed to May 1947: Inst. Petrol. Jour., vol. 34, 1948, p. 109-132.

^{83/} Thorne, H. M., and Kraemer, A. J., Oil-Shale Operations in the Union of South Africa: Bureau of Mines Rept. of Investigations 5019, Jan. 1954, 31 pp.

^{84/} Work cited in footnote 81.

^{85/} Cane, R. F., A Note on the Chemical Constitution of Torbanite Kerogen: Jour. Soc. Chem. Ind. (British), vol. LXV, December 1946, pp. 412-414.

a tough, semisolid, low-degree polymer. After the first stage of polymerization, the rubbery mass became covered with an overburden, and further polymerization took place until a high polymer was formed. Small quantities of nitrogen, sulfur, and oxygen are believed to have some effect in the polymerization, possibly as linking elements between polymer molecules.

Probably the most famous torbanite deposit is that at Torbane Hill, near Bathgate, Scotland. In the Transvaal, South Africa, vast deposits are reported, and torbanites from several workings of the South African Torbanite Mining and Refining Co. have been studied by Neppe^{86/} and Thorne and Kraemer.^{87/} As noted, Cane has studied torbanites from Australia.

Cane quotes the ultimate analyses of Australian torbanites shown in table 16.

TABLE 16. - Ultimate analyses of Australian torbanites, moisture and ash free^{1/}

	Rich	Normal
Carbon.....percent..	84.2	81.8
Hydrogen.....do.....	11.9	10.3
Oxygen.....do.....	2.5	6.4
Mn+S+P.....do.....	1.4	1.5
C/H ratio.....	7.1	7.9
Empirical formula, based on C ₁₈	C ₁₈ H ₃₀ O _{0.5}	

^{1/} Work cited in footnote 85 (p. 39), p. 413.

Proximate analyses of 24 torbanites from South Africa are given in Neppe's study. The torbanites contained 22 to over 40 percent ash, volatile matter (dry basis) ranged from 21 to about 65 percent, and fixed carbon from about 12 to 40.5 percent.

In appearance, torbanite is a layered, compact, brownish-black to velvety-black coallike substance, with conchoidal or subconchoidal fracture, tough and difficult to break. The microscope reveals that it is composed of ellipsoidal yellow bodies, consisting of colonies of blue-green algae.

On distillation, torbanite gives a high yield of oil which can be refined to give liquid products somewhat similar to petroleum products of like physical properties. Neppe^{88/} reported oil yields from carbonization of South African torbanites ranging from 12.4 to as high as 106.4 gallons per ton of torbanite, as carbonized, or from 17.2 to 140.2 gallons per ton, dry, ash-free basis. (Note: The d.a.f. (dry, ash-free) basis was not given for the 12.4 gallons per ton torbanite, the lowest d.a.f. torbanite being reported yielding 16.45 gallons per ton as carbonized.) Also reported are ammoniacal liquors ranging

^{86/} Neppe, S. L., A Technical Study of Transvaal Torbanite: Inst. Petrol. Jour. (British), vol. 27, No. 208, February 1941, pp. 31-65.

^{87/} Work cited in footnote 83, p. 39.

^{88/} Work cited in footnote 86, table 7, pp. 46-47.

from 5 to over 15 gallons per ton and from about 1,100 to about 2,300 cubic feet of gas ranging in gross heating value from 360 to 1,122 B.t.u. per cubic foot.

Wurtzilite

Classified in table 2 as a member of the elastic bituminous materials, wurtzilite can be considered to be one of the softer, natural asphalt-type materials, sometimes called mineral tars. Wurtzilite has been called elat-erite, but Abraham maintains this is an improper use of the latter term.

Wurtzilite is found only in an area about 50 miles southwest of Fort Duchesne, Uintah County, Utah. About 30 veins, similar to those in which gilsonite is found, have been observed. They vary in length from a few hundred feet up to about 3 miles, and in width from about 1 to 22 inches. Although most of the veins are vertical, many split into smaller veins, either in a vertical or horizontal direction.⁸⁹ The deposits have been worked commercially on a small scale since 1912.

Wurtzilite is a black material with conchoidal fracture, bright lustre, light-brown streak, hardness between 2 and 3 on Mohs' scale, and specific gravity of 1.05 to 1.07. It resembles gilsonite in appearance but is more elastic. Thin slivers or sections show red color by transmitted light. The material is sectile; that is, it can be cut easily and smoothly, like horn or whalebone. Slivers or thin sections are fairly elastic, but when they are bent beyond a certain point, they snap like glass. Wurtzilite does not melt or fuse on heating up to 800° F. but softens and burns when sufficient heat is applied. It has been called elastic bitumen or mineral rubber because of its elastic, rubberlike properties. Table 17 gives chemical and physical properties.

Wurtzilite has been treated by heating up to 500° F. under pressure for several days to obtain a material known to the trade as kapak, which has a melting point of 265° to 270° F. and is soluble in ordinary solvents. This kapak is used as a constituent of water proofing and chemical proofing paints and varnishes for tanks and apparatus handling acids and corrosive salts. Such paints and varnishes also have been used for underground iron and wood preservation, and for insulation of electrical conduits. The material has been used in roofing compounds and in flooring and hard rubber compounds. Kapak has also been used in rubber compounding, utilizing its elastic properties.

⁸⁹ Abraham, Herbert, *Asphalts and Allied Substances, Their Occurrence, Modes of Production, Uses in the Arts, and Methods of Testing*: D. Van Nostrand Co., 5th ed., vol. 1, 1945, p. 291.

TABLE 17. - Properties of Wurtzilite from
Uintah County, Utah^{1/}

Color in mass.....	Black.
Fracture.....	Conchoidal.
Lustre.....	Bright.
Streak.....	Light brown.
Specific gravity at 77° F.....	1.05-1.07
Hardness, Mohs' scale.....	Between 2 and 3.
Hardness at 77° F. (penetrometer).....	0
Hardness at 77° F. (consistometer).....	> 150
Fusing point.....	Does not fuse with- out decomposition.
On heating in flame.....	Softens and burns quietly.
Volatile at 325° F., in 5 hr.....percent..	1-3
Fixed carbon.....do.....	5-25
Soluble in carbon disulfide.....do.....	5-10
Nonmineral matter insoluble.....do.....	85-95
Mineral matter.....do.....	.2-2.5
Carbenes.....do.....	.0-1.5
Soluble in 88° petroleum naphtha.....do.....	0-2
Carbon.....do.....	79.5-80.0
Hydrogen.....do.....	10.5-12.5
Sulfur.....do.....	4.0-6.0
Nitrogen.....do.....	1.8-2.2

^{1/} Work cited in footnote 89 (p. 41), p. 293.