REPORT OF THE DIVISION OF GEOLOGY

W. N. LOGAN, State Geologist.

ORGANIZATION

The working organization of the Division of Geology consists of a technical unit, an office unit, a field unit and a gas-inspection unit. The members of the office unit are the only staff members drawing salaries regularly from the Division funds. A few members of the field unit draw salaries from the Division funds for one or two months each year. The gas inspectors are paid from gas inspection fees collected by them. A part of the funds collected by the inspectors is used to help defray office expenses.

TECHNICAL UNIT

The members of the Department of Geology of Indiana University serve as members of the technical force as follows:

W. N. Logan, Ph. D., Economic Geology.
E. R. Cumings, Ph. D., Stratigraphy and Paleontology.
C. A. Malott, Ph. D., Physiographic Geology.
S. S. Visher, Ph. D., Geography.
W. M. Tucker, Ph. D., Hydrology.
J. R. Reeves, Ph. D., Oil Shale Technologist.
H. W. Legge, Preparator.

OFFICE UNIT

Theodore Kingsbury, Supervisor of Natural Gas.
W. H. Hershman, Curator of Museum.
Margaret L. VanNess, Clerk and Stenographer.

FIELD UNIT FOR 1923

W. N. Logan.	G. G. Bartle.
C. A. Malott.	E. L. Lucas.
W. M. Tucker.	A. B. Hoadley.
J. R. Reeves.	H. D. Logan.
R. E. Esarey.	A. W. Thomas.
M. A. Harrell.	S. Ashby.

NATURAL GAS INSPECTION UNIT

THEODORE KINGSBURY, Supervisor.

DEPUTIES

*Wm. Kelly .... Geneva
John Ersinger .... Sullivan
J. P. Horton .... Montpelier
J. E. McIntyre .... Marion
Herschell Ringo .... Muncie
Geo. H. Smith .... Owensville
John Watson .... Petersburg
Howard Legge .... Bloomington
O. H. Hughes .... Sharpsville
E. E. Wherry .... Shoals

* Replaced C. N. Brown, Geneva, December 1, 1922.

FIELD INVESTIGATIONS

The state geologist and various members of the technical force of the Division responded to many requests for geological investigations during the year. These requests asked for the examination of supposed oil-bearing lands, oil-bearing shales, supposed or actual sources of water supply, clays and shales for proposed ceramic uses, clays, marls, shales and limestones for cement manufacture, limestones for the manufacture of mineral wool, limestones, sand and gravel for road building purposes; peat, marl and limestones for agricultural uses; limestones and sandstones to be used for building purposes; sands for foundry use; and other requests of a similar nature.

Assistance was given individuals, companies, corporations, cities, and organizations, such as the chamber of commerce in local communities, in the development of the natural mineral resources in those communities.

The field investigations necessary for making structural maps of the Oatsville and the Bowman oil fields were completed during the year. The work included a survey of the fields, the location of the oil wells, the collection of the logs of the wells, the running of levels from known points to determine the elevation of the mouth of each well, the drawing of contour lines on key horizons, the drawing of cross-sections, the determination of the number and relations of the various oil sands.

The systematic survey of the Coal Measure area of Indiana which has been in progress for several years was continued during the past year. The work for the year was confined largely to the counties in the southwestern part of the state. The survey included parts of Orange, Martin, Dubois, Gibson, Pike, Spencer, Vanderburgh and Posey counties. The line of outcrop of the various coal beds was traced through these counties, the stratigraphic conditions of the coals were studied in the field, and samples of the coals were collected for study in the laboratory. Samples of clay and shales, molding sands, oil shales and building stones were also collected for examination and study in the laboratory.

The diamond drill core of a well drilled south of Princeton was secured from the Princeton Coal Company. This core represents the strata above Coal V in the Princeton district. It is 426 feet in length and weighs about one ton. A careful study of this core will enable us to solve some of the problems connected with the stratigraphy of the upper Coal Measures in the Princeton region.

Field work in mapping the eastern border of the Pottsville formation along with the collection of samples of oil-bearing shales from the Coal Measures was continued by Dr. J. R. Reeves.

The structural and stratigraphic conditions of Perry County were studied in the field by Dr. C. A. Malott who was assisted in the field work by H. D. Logan. The work was co-operative between the Empire Oil and Gas Company and the Division. An areal map and a structural map of the region are being prepared and will become the property of the Division.

PUBLICATIONS

The following reports, articles and reviews were published during the year:

"Report of the Division of Geology," Indiana Year Book, 1923. This report contains an account of the field, office, laboratory and museum work and a financial report of the Division for the year. It also contains technical papers entitled: "A Section Through the New Albany Shale," "The Peat Deposits of Indiana."

An article on the "Geology of Indiana" was published in several papers of the state. A discussion of the peat deposits of Indiana was published in the *Journal of the American Peat Society.* Two papers on oil shales in Indiana were published by the United States Bureau of Mines as a part of the co-operative work of the Bureau and the Division. A number of newspaper articles treating of phases of the state's mineral resources were published in various newspapers of Indiana during the year.

The "Handbook of Indiana Geology," which was issued near the beginning of the fiscal year, was described in the last annual report. This publication has been well received by scientists, teachers, oil operators and others. More than half of the edition has already been distributed. It is being sold within the state at $3 per volume and for $5 per copy outside the state.

CO-OPERATIVE OIL SHALE WORK

The investigation of the oil shales of the state under the co-operative agreement with the United States Bureau of Mines was continued throughout the year and three reports treating of various phases of the subject were accepted and published by the Bureau.

STATE FAIR EXHIBIT

The exhibit made by the Division at the State Fair consisted of ceramic materials. The methods of testing these materials was demonstrated as well as such demonstrations could be made outside of a laboratory equipped for such work. Mr. R. E. Esarey was in charge of the exhibit. He was assisted for a portion of the time by Mr. H. W. Legge.

ROCK AND MINERAL DETERMINATION

A large number of rocks and minerals were received at the office and the laboratory during the course of the year. The samples were accompanied by requests for determinations of their fitness for commercial uses. The testing of some of these samples required only a qualitative test, others required a careful quantitative analysis and consumed much time.

The following is a summary of the tests made during the year:

	No. of Samples		No. of Samples
Oil sands	104	Gravel	3
Pyrite	80	Oil water	3
Shale	78	Peat	3
Quartz	62	Silver bearing Galena	3
Coal	57	Asbestos	2
Well drillings	53	Calcareous tufa	2
Mica	51	Chalcopyrite	2
Clay	47	Feldspar	2
Granite	40	Gold and Platinum	2
Limestone	29	Jasper	2
Oils	24	Meteorites (supposed)	2
Calcite	23	Mineral Water	2
Water	22	Natural Gas	2
Galena	21	Phosphate Rock	2
Limonite	21	Sandstone	2
Iron ore	20	Schists	2
Molding sand	12	Soils	2
Hematite	10	Tourmaline	2
Loams and Silt	10	Agate	1
Marcasite	9	Barnite	1
Road material	6	Quartzite	1
Chert	5	Selenite	1
Gypsum	4	Tripoli	1
Marl	4		
Siderite	4	Total	846
Sphalerite	4		

NATURAL GAS SUPERVISION

Theodore Kingsbury, assisted by ten deputies named at the beginning of this report, had charge of plugging abandoned oil and gas wells, preventing waste of oil and gas, collecting well logs and other work in connection with the development and activities in oil and gas. Deputies receive no salary, but as compensation for supervising the plugging of wells as prescribed by law, they receive $8 of the $10 fee collected for each well plugged. The State Gas Supervisor inspects wells outside of territory not covered by deputies and the fees he collects are turned over to the state. During the year, 326 wells were plugged, as compared to 245 during the previous year. Wells were plugged in thirty-two counties, as follows:

County	No. of Wells	County	No. of Wells
Adams	24	Madison	2
Blackford	17	Martin	3
Boone	1	Miami	1
Clay	1	Morgan	2
Daviess	5	Pike	20
Decatur	2	Putnam	1
Delaware	26	Randolph	8
Gibson	19	Rush	12
Grant	21	Shelby	5
Greene	1	Sullivan	54
Hamilton	2	Vermillion	1
Hancock	10	Vigo	3
Henry	12	Wabash	1
Huntington	19	Warrick	2
Jay	34	Wells	12
Jasper	1		
Knox	4	Total	326

A special effort was made to co-operate more closely with individuals and companies active in the oil and gas business, in order that the office might be better able to assist them by supplying information and in order to prepare the way for collecting information from them which is both needed and required.

It has been difficult to collect some of this information, such as well logs, because no contact was maintained with operators. A list of individuals and companies interested in developing Indiana's oil and gas resources was compiled and checked. Some correspondence has been kept up with this list. There are nearly 350 names on it at present.

Each month a report on current oil and gas activities in the state was prepared, and under the name "Indiana Oil and Gas News" mimeographed copies were sent to a mailing list on which there are now about 200 names. Much interest has been shown in this report by operators and it has been of material assistance in getting in closer touch with oil and gas men. This report showed that during one month there were activities in 24 of the 92 counties in the state.

The office has on file logs or records of more than 600 oil and gas wells, in addition to those which appear in publications. These are available to supply information to operators. Of this number 106 were collected during nine months, January 1 to September 30, 1923. This number is 26 more than were collected during all of 1922.

The General Assembly of 1923 enacted a law (Chapter 134, page 378, Acts of 1923) relating to leases and the cancellation thereof. It repeals the leasing law enacted in 1921, which required that at least one well should be drilled on each lease in order to hold the lease. The new law will stimulate development particularly in new territory.

Indiana produced 1,087,000 barrels (42 gallons each) of petroleum during the calendar year 1922. Of this amount the southwestern part of the state produced 848,000 barrels and the older northeastern Indiana field produced 239,000 barrels. What is reported to be the deepest well ever drilled in Indiana was completed during the year in Putnam County, the depth being 3,410 feet.

PRODUCTION OF PETROLEUM IN INDIANA IN 1923*

(In barrels of 42 gallons)

Month	Southwestern Field	Northeastern Field	Total
January	71,000	21,000	92,000
February	60,000	16,000	76,000
March	64,000	19,000	83,000
April	69,000	19,000	88,000
May	72,000	20,000	92,000
June	70,000	20,000	90,000
July	68,000	22,000	90,000
August	70,000	26,000	96,000
September	63,000	24,000	87,000
October	64,000	28,000	92,000
November	62,000	18,000	80,000
December	59,000	20,000	79,000
Total for year	7,920,000	253,000	1,045,000

* From reports of United States Geological Survey, co-operating with this Division in collecting statistics.

OFFICE WORK

The office work is attended to by the State Gas Supervisor, who serves also as assistant state geologist, and the stenographer. It consists principally of attending to correspondence; mailing reports on request; tabulating circulars, reports and other sources of information received in the office; collecting and recording well logs, reports of wells plugged and names of operators; collecting data on the natural resources of the state for the office, individuals by requests, and newspapers; and giving information to callers.

Following is a summarized report of office work for the year:

	Office	Laboratory	Total
Letters mailed	3,753	654	4,407
Packages mailed	772	325	1,097
Letters received	2,016		2,016
Packages received	961		961
Reports, etc., distributed—			
Geological	234		234
Handbooks of Indiana Geology	911		911
Petroleum and Natural Gas	108		108
Kaolin	131		131
Personal conferences	1,748		1,748

MUSEUM

The registered attendance of the museum was 44,607, as compared to 42,760 for the previous year, an increase of 1,847 visitors. This may be indicative of continued increase, and is probably the direct outcome of a growing interest in the conservation movement and the interest being taken in the state's resources as evidenced in the organization of county historical societies and museums. Increased travel in automobiles augments the attendance, for tourists invariably seek the museum, public buildings, and art galleries of cities they visit. During August, when automobile touring is at its height, there were visitors from 37 different states, and the total attendance was greater than that of any other month.

Special effort has been made to interest the public in the museum and give publicity to its educational value by:

1. Encouraging classes in public schools to visit in charge of their teachers and by giving talks on birds and animals to visiting classes, using museum specimens as illustrations.

2. Preparing for publication in the Indianapolis *Star* a series of stories with illustrations on Indiana birds, specimens of which are in the museum.

3. Talking with visitors and calling their attention to exhibits of especial educational value.

4. Soliciting Indiana factories to furnish instructive exhibits of Indiana wood, with show cases. Three companies have agreed to comply with this request.

5. Soliciting other kinds of educational exhibits from Indiana companies, with the result that the Standard Oil Company is preparing an exhibit, with cases, showing the by-products of petroleum.

6. Placing instructive labels on exhibits. M. Tandy, a capable entomologist of Dallas City, Illinois, assisted materially in this connection by classifying and labeling all entomological specimens, as well as shells.

7. Giving material to newspapers on special and newly acquired exhibits and comments made by visitors.

Unquestionably the time is near when the citizens of Indiana will demand suitable space for a State Museum where there will be adequate facilities for displaying exhibits of state and national interest. Until that time shall come, there is need to preserve and protect much valuable material on hand.

1. A taxidermist is needed to rejuvenate the present specimens.
2. Several exhibit cases in need of repair.
3. Some system is needed for the circulation of air. With so many visitors and no outside ventilation, the air becomes stale in a very short time, especially during the winter months.
4. A more efficient lighting system is needed.

MUSEUM DONATIONS, ADDITIONS, ETC.

Copper Head Snake—From McCormick's Creek State Park, Owen County.

Cucumber in Bottle—Grown in 1872; donated by Mrs. Sarah Sutherman, Mooresville, Ind.

Copper Ore—Probably from Michigan copper deposits. Found in a field and donated by Jas. T. Hipple, Acton.

African Reptiles and Relics—15fish, etc., native hat of grass, bed roll, sea weeds and native clothing from west coast of Africa. Donated by Marietta Hatfield, a missionary of the U. B. Church, through her sister, Miss Lizzie Hatfield, Terre Haute.

Sugar Bowl—118 years old. Donated by Mary D. Clapp, Scottsburg, great granddaughter of owner of the bowl.

Stiletto—Found on streets of Chicago Heights, Illinois, in January, 1923. Presented to W. H. Hershman, who donated it to Museum.

Indian Arrow Heads (2)—Found near Smith's Valley by Ralph McCay, who donated them.

Prairie Chicken, Mounted—Donated by Wm. Allen Wood.

Surgeon's Lance—Had been in use more than 100 years. Donated by Mrs. Katherine Meridith, Indianapolis.

Orthoceras—Lower Silurian fossil blown from State Quarry at Clifty Falls State Park.

Hair Trunk containing 62 specimens dating from 1790 to 1872. Donated by E. Grace Johnson, Frankfort, Ind.

Centipede, Tarantula, cypress knees and specimen of stones from Nogales Mines, Arizona. Collected by Wm. Whitehead. Donated by his widow, Indianapolis.

Surveyor's Compass, chain, note book, text book published in 1799 and pocketbook used by Henry Bryan, a surveyor in Ft. Wayne in the early eighties. Donated by his great-granddaughter, Mrs. Alfred H. White, Ann Arbor, Michigan.

U. S. Army Buckles—found on "Wounded Knee" battlefield, Dakota; an oldtime pistol, found in 1830 near Pendleton, Ind., by G. W. Pavey; a cannon ball and grape shot, found in 1903 on batlefield near Franklin, Tenn., by Samuel Pavey. Donated by Frank Pavey, grandson of G. W. and son of Samuel, a Civil War Veteran.

Iron Pyrite—Found near Norway, Ind. Donated by Arthur Sluyter, Monticello.

Large Dinner Bell—History and donator not known.

Old Shotgun and Powder Flask—Bought by Gen. Benjamin Harrison in 1843. Donated by Mrs. Lula Ermentraut, Indianapolis.

Phoebe's Nest, containing Phoebe and cowbird eggs. Donated by Capt. Wm. Miller, Indianapolis.

Gypsum specimen from Harrison County. Donated by Roscoe Haymond, Columbus.

Sage Grouse—One cock and two hens, mounted. From Montana. Donated by Dr. R. I. Blakeman, Indianapolis.

Large Blastoid Head—Fossil of ancient sea weed. Donated by W. R. Bowman, Lawrence County.

Indian Ceremonial Stone—Donated by Chas. Hart, Greencastle.

Quartz Geode—A crinoid. Donated by J. K. Johnson, Indianapolis.

Dental Forceps—Used by Dr. Edmondson, Springfield, Mo., more than 50 years ago. Donated by W. H. Herrshman, Indianapolis.

Spanish War Cartridges (6)—Donated by A. C. Gall.

Tomato Sphinx—Donated by A. E. Barthal, Indianapolis.

Civil War Badges (2)—Donated by E. Wilson, Indianapolis.

Iron Pyrite—Richard Dempsey, Dubuque, Mont.

Confederate Money—A $20 bill and a $5 bill. Donated by F. A. Shields, Indianapolis.

Sea Horses (2)—Found off Gaum Island. Donated by Miss Julia Kerr, Indianapolis.

Two specimens of Euplectella Aspergellum or Venus' Flower Basket—Found off Cebu, Philippine Islands. Donated by Miss Julia Kerr, Indianapolis.

PETROLEUM CONSERVATION

W. N. LOGAN, State Geologist.

The extent of the influence of petroleum on human activities is not generally recognized. It is one of the most valuable of the mineral resources. Many of its products have become nearly indispensable. One of its products, kerosene, furnished the first source of adequate illumination for a wide range of environments. Other products, such as gasoline, lubricating oils and paraffin are almost essential to man's needs. So necessary have become the products of petroleum to man's activities that the sudden exhaustion of the world's petroleum resources would bring about an industrial catastrophe of immeasurable extent.

History: The use of petroleum products was known for at least two thousand years before the Christian era, for bitumen was used as a cement in the construction of the ancient cities of Babylon and Nineveh. The first reference to the collection of petroleum is thought to have been given in the writings of Herodotus about 450 B. C. He described a well at Ardericca from which salt, asphalt and oil were obtained. The oil was described as being black and emitting a strong odor. About the beginning of the Christian era petroleum collected in Sicily was burned in lamps in the temple of Jupiter. Prior to 1700 A. D. crude oil was used for illumination at several places in Europe. Refined oil was first drilled and used for illumination in Prague in 1810.

In America petroleum springs were found by early explorers and settlers and the oil was used for medicinal purposes. At first the supplies were obtained from springs but later in sinking wells to obtain supplies of salt, larger quantities of petroleum were discovered. The oil obtained from the salt wells was distilled in 1852 and the distillate placed upon the market as "carbon oil". In 1859 the petroleum industry in America received a great impetus by the drilling of a well for oil by Edwin L. Drake on Oil Creek near Oil City, Pa. The success of Drake started an oil boom and hundreds of wells were drilled along Oil Creek.

The total production of petroleum in the United States in 1859 was only 2,000 barrels, but so rapid has been the development of the industry that in 1921 the amount produced was 469,639,000 barrels, which is about 64 per cent of the world's production. Mexico produced about 24 per cent, and these two countries produced about 88 per cent of the world's production in 1921. In 1923 the United States broke all records in the production of petroleum, producing 725,702,000 barrels.

Properties and Origin of Petroleum: Definition: Petroleum is a mixture of gaseous, liquid and solid hydrocarbons in which the liquid constituents predominate, but in which the percentage of each element is not a fixed quantity, but varies in different oils. The solid constituents may be asphaltum or paraffin. Those oils containing asphaltum are said to have an asphalt base and those containing paraffin to have a paraffin base. Paraffin oils predominates in the oil fields of the eastern portion of the United States and asphaltic oils in the western part.

Composition: The elementary analysis of a large number of petroleums indicates that the amount of the element carbon varies from 83.5 to 86.6 per cent, that the hydrogen varies from 12 to 14.8 per cent and that the oxygen content varies from 0.1 to 6.9 per cent. These three elements make up the larger part of the oil, but minute quantities of sulphur and nitrogen are usually present. The carbon and hydrogen elements in petroleum are combined to form hydrocarbons and members of a number of series are present. They include the marsh gas series, $C_n\ 2n+2$, ranging from CH_4 to $C_{35}H_{72}$. The first member is gaseous, the middle members liquid and the last members are solids. The olefiant series, C_nH_{2n}, is represented by a few of its members in small quantities. The acetylene series, C_nH_{2n+2}, is represented in some petroleums.

Color and Odor: The color of petroleum varies with the sand or field. Some oils in Pennsylvania have a greenish color; some oils in Kansas and Oklahoma have a yellow tint; some Indiana oils are greenish-black; some California oils are black and some Kentucky oils are green by reflected light and red by transmitted light. Colorless oils are said to occur.

The odor of most petroleum is not distinct, but the escape of hydrogen-sulphide from some oils give a distinct odor, while others emit odors resembling that of gasoline, kerosene, or lubricating oils.

Boiling and Flashing Points: The temperature of boiling ranges from 180 degrees F. in Pennsylvania oils to 338 degrees F. in some German oils. The point of solidification varies from 32 degrees F. to several degrees below zero. The flashing point varies from zero in some Italian oils to 370 degrees F. in some African oils.

Specific Gravity and Density: Petroleum usually has a specific gravity less than that of water upon which it floats. The specific gravity varies from 0.77 in light oil to 1 in the heavier oils. The specific gravity of oil may be expressed as a decimal fraction, as .8588, or the Baume scale may be used for oils lighter than water and the specific gravity expressed in degrees. If the oil has a specific gravity equal to water, its specific gravity as expressed on the Baume scale is 10 degrees.

Petroleum Products. A long list of useful substances are obtained from crude petroleum. Among some of the more important products are kerosene, gasoline, benzine, naphtha, rhigolene, vaseline, paraffin, lubricating oils, petroleum, formolit, asphalt, oil coke and gas carbon. In the crude state some petroleums are used for fuel under boilers—to a limited extent in engines of the Diesel type and as lubricants. Rhigolene is used as an anaesthetic in surgery. Gasoline is used as a fuel in internal-combustion engines, and in stoves and furnaces, as an illuminant, and in the manufacture of gas. Lubricating oils are used to prevent heat and friction in the bearings of machinery. Kerosene is used as an illuminant, as a fuel in stoves and farm tractors. Naphtha is used as a solvent and for blending in the manufacture of casing-head gasoline. Paraffin is used in the manufacture of candles and in canning. Paraffin waxes are used in the manufacture of salves and surgical dressings. Coke produced from petroleum is used in arc-light pencils, battery carbons and in metallurgical processes. Fuel oils are used in furnaces, under boilers, in railroad engines and for fuel on steamships. Asphalt and road oils are used on highways and railroads.

Origin of Petroleum. Many theories of the origin of petroleum have been suggested. These theories fall into two general classes, the inorganic and the organic.

Inorganic Theories. A chemical theory was suggested by Humboldt and further elaborated by Berthelot* and Mendeleeff†. This theory assumes that the interior of the earth contains metallic iron and carbides of iron; that the high interior heat of the earth converts water into steam, which attacks the carbides of iron, producing hydrocarbons which are forced toward the surface by the expanding power of steam. According to this theory, the hydrocarbons formed should be predominately of the acetylene series, but they are predominately of the methane series; they should be associated with igneous rather than sedimentary rocks.

Another inorganic theory is the volcanic theory of Coste‡, which assumes that oil and gas are the result of volcanic activity, because oil and gas are under great pressure which must be volcanic; heated oil and gas exists in some fields; oil and gas occur in folded and fissured regions parallel with great organic movements; oil and gas and bitumens are never indigenous to the strata in which they are found; that the density of rocks precludes the possibility of anything except volcanic pressure forcing oil and gas through them. Many of these assertions do not accord with the observed facts. The almost complete restriction of oil and gas to sedimentary rocks placed at great distance from volcanic activity and the decrease in pressure in wells are not in harmony with this theory.

Organic Theory. This theory assumes that oil and gas have been generated from animal and vegetable matter by a slow process of distillation. Many accumulated geological facts may be enumerated in support of this theory, such as: The close association of rocks containing organic matter to those containing oil and gas; drops of oil have been found in decaying plant remains; natural gas, a constituent of both oil and gas, is generated from vegetable matter buried in porous

* Berthelot, E. M. P. Annales Chem. Phys., Vol. I, 1886, p. 481.

† Mendeleeff, D. Der Deutch Chem. Gesell, 1877, p. 229.

‡ Coste, E. Am. Inst. Min. Eng., Vol. XX, p. 504, 1914.

beds; it is present in coal, as are other hydrocarbons of petroleum; such gases as carbon dioxide, hydrogen, marsh gas and nitrogen are formed during the decay of seaweeds. Hydrocarbons analogous to those in natural gas, petroleum and asphalt have been derived from either plant or animal remains. Natural petroleum has optical properties similar to those of organic compounds which inorganically synthesized oil does not possess.

The presence of oil in shales, from which as much as twenty-five gallons per ton have been extracted, has strengthened the belief that the organic matter of shales is the source of petroleum. It is assumed that the bituminous matter is the form of a solid, organic gum, kerogen, which may be converted into liquid hydrocarbons by the application of heat. McCoy* placed an oil shale under pressure and secured liquid hydrocarbons from it and asserts that liquid hydrocarbons can be formed from solid bituminous material at ordinary temperatures and under pressures of 5,000 to 6,000 pounds, such as exist at the depth of oil bearing horizons; and that the only place where such compounds would be formed are in areas of differential movement.

Kemp has recently called attention to the presence of asphaltum in the beach sands of Florida and the possibility of the origin of petroleum from the marine and terrestrial organisms in buried coastal sands.

The optical behavior of petroleum under polarized light is said to be due to the presence of cholesterol, which may be derived from animal fats and phytosterol, which is also a constituent of vegetable oils, facts strongly supporting the organic theory of the origin of petroleum. In fact, the weight of evidence at the present time seems to favor the organic theory. The remains of land plants and animals may have contributed in a minor way to the accumulations of petroleum, but marine organisms were probably the greater contributors of the original compounds from which the petroleum was extracted through long periods of time at possibly only ordinary rock pressures and at moderately low temperatures.

The Petroleum Fields. The petroleum fields of the United States are the most valuable in the world. The total proven area is about 5,000 square miles. The principal fields are the Appalachian, which includes parts of the states of New York, Pennsylvania, West Virginia, Kentucky, Tennessee and Ohio.

The Ohio-Indiana field contains a portion of northwestern Ohio and northeastern Indiana. The Indiana-Illinois field includes portions of the southern part of Illinois and the southwestern part of Indiana. The Mid-Continent field underlies parts of Kansas, Oklahoma and northern Texas. The oil territory in California is in the southern part of the state on the flanks of the coastal range. The Gulf Coast field includes portions of Texas, Louisiana and Arkansas. Oil territory occurs in Colorado near Florence and Boulder. In Wyoming, oil territory occurs in the central and southwestern part of the state. Small amounts of oil have been produced in New Mexico, and Montana and other states.

* McCoy, Alex. W. Journal of Geol., Vol. XXVII, 4, p. 252.

Amount of Petroleum. The known oil fields comprise between 9,000 and 10,000 square miles. The yields per acre have ranged from 1,000 to more than 10,000 barrels. The total amount extracted in the United States to 1921 is more than five billion barrels. Recent estimates of the total petroleum reserves in the United States have placed them at ten or possibly twelve billion barrels. More recently (1922) a committee of geologists selected for the purpose estimated our petroleum reserves at 9,150,000,000 barrels. At the present rate of production these reserves will be exhausted in less than twenty years.

The production of petroleum in the United States has increased from 2,000 barrels in 1859 to 469,639,000 in 1921. The production in the last ten years has exceeded the production from 1859 to 1912.

In 1920 the United States produced 63.8 per cent of the world's production, and had produced 62 per cent of the total world's production from 1857 to 1921.

Sources of Waste. The loss of petroleum occurs both below the surface and on the surface. Both of these are due to faulty methods of development.

Losses Due to Water. Losses in oil sands are due to water, which is the *bête noir* of the oil operator. Water which is allowed to come into oil bearing sands may destroy production in a single well and ultimately for a group of wells. Water may come into an oil well from below (bottom water), from above (top water) or from the side in the oil-bearing sand (edge water). The shooting of their sands with charges of nitroglycerine which are too large may cause the drowning of an oil well by the admission of bottom or edge water. The drilling of an oil well with water standing in the bore may admit top water, or it may be admitted through faulty casing.

Losses on the Surface. Losses of petroleum after it reaches the surface are due to overflowing wells without controlling containers, to fires, to leaky machinery, and to evaporation.

Oil wells of large production are oftentimes brought in without adequate storage facilities having been provided and the oils are allowed to overflow in earthen reservoirs. The carelessness of operators in the use of fire about wells or tanks may result in large losses caused by the ignition of inflammable gases which cause the ignition of the petroleum from the flowing well or in the containers.

Leaky pipes, pumps, and storage tanks cause waste of petroleum in nearly all oil fields. Much gasoline is wasted through the evaporation of petroleum from open tanks.

Loss by Fire. The loss of petroleum and petroleum products by fire in the United States during the ten-year period from 1908 to 1918 is estimated at 12,850,000 barrels, having a value exceeding $20,000,000. Of 503 fires, 310 were caused by lightning and 193 from other causes. These fires were responsible for the deaths of 150 persons and for the disabling of nearly as many more.

Causes of Oil Fires. More than 60 per cent of oil fires are caused by lightning and about one-half of the property loss incurred between 1908 and 1918 due to oil fires is credited to fires caused by lightning.

Static electricity is also a cause of oil fires. The flow of gasoline generates electricity. The flow of gasoline into a metal container which is not grounded may produce sufficient potential to create a spark which will ignite gasoline vapor. Static electricity may be generated by the flow of gasoline through a fabric hose and the electricity stored in the metallic nozzle. It may be generated by the flow of gasoline through a chamois skin and the electricity stored in the metallic funnel. If the nozzle or the funnel are not grounded so that the potential becomes too great a spark may result. In the machinery used in the drilling of oil wells static electricity may be generated by band-wheel belts and stored in the band wheels, in which a high potential may result in sparks causing fires.

Oil fires may originate by the rapid slipping of metal cables through clamps. They may be started by the vapors from producing oil or gas wells coming in contact with fires in forges or under boilers; by the use of open flame torches on the rig; by the carelessness of smoking employes; in the use of compressed air in the attempt to secure a larger recovery from oil sands; and in various other ways.

Prevention and Control of Oil Fires. All moving machinery that is likely to generate static electricity should have its moving parts grounded. All sources of flame, fire or electric sparks should be placed at a safe distance from producing wells. Tanks which are properly constructed, surrounded by a levee, provided with gas vents and explosion doors, and placed at a safe distance from other tanks should be employed for the storage of oil. In case of fire in an oil tank the fire should be smothered by the use of steam. If steam can be forced over the surface of the burning oil the steam envelope will prevent the oxygen of the air from contact with the flame and smother it. Water which overflows the tank will carry burning oil with it and may fire neighboring tanks. The water which sinks to the bottom of the oil tank may be converted into steam by the heat of the burning oil and cause a serious explosion. Foam solutions may be used for extinguishing fires in tanks. The foam is produced by the mixture of two solutions. One of these may contain water, alum, and sulphuric acid, and the other water, glue, glucose, sodium carbonate and arsenious oxide. A foam covering of five inches in thickness is sufficient to extinguish the fire.

Burning oil wells have been extinguished in a number of ways. Where the topography permits, a tunnel may be made beneath the surface to the well casing, which may be drilled, and the flow either diverted from the surface or shut off. If a crater has been formed around the well a flow of thin mud may be discharged into the crater in such quantity as to extinguish the fire, provided the use of water or steam have failed. A swedge nipple attached to a line of pipe has been used to extinguish a burning oil well by placing the nipple over the well casing and diverting the flow of oil. The burning oil about the well was then extinguished by flooding and driving the flood through an underground pipe.

Methods of Conserving Petroleum. The waste of petroleum in development may be prevented by not drilling in the well until the proper preparation has been made to receive the oil. The receptacles in which the oil is placed should be constructed to prevent evaporation and to prevent losses from fire. By the exercise of greater care in the drilling of wells to prevent water from entering the oil-bearing sand and destroying the wells or reducing the production and greatly increasing pumping costs. Well drowning is often caused by drilling with the hole full of water.

Inexperienced drillers often destroy valuable oil properties by careless or indifferent methods of handling the water situation. It would be greatly to the interest of the oil producers if only skilled workmen were employed in the industry.

Use of Covered Containers. The use of open containers is estimated to be responsible for the loss of as much as 600 million gallons of gasoline in a single year. This amount would supply 2,400,000 automobiles with 250 gallons of gasoline a year. Much of this evaporation may be prevented by the use of covered containers or floating tops in the oil fields.

Effect of Exportation. The amount of crude petroleum exported is very small in comparison with the amount produced within the country or with the amount imported. In a recent year the United States produced 443 million barrels, and exported less than 9 million barrels. The exportation of the products of petroleum, however, may cause the loss to the United States of an equivalent of one-fifth of the crude petroleum produced in some years. Whenever this occurs for five years, one year is taken from the life of our petroleum reserves. At this rate of exportation four years of its life of twenty years would be given to foreign countries. To prohibit the exportation of petroleum and essential petroleum products would seem to be following a wise, conservative policy, though certain complications in trade relations with foreign countries might arise since no nation lives to itself alone.

Conservation in Water Separation. The volatile constituents of crude petroleum, especially gasoline, are often lost in separating water from crude oil. If water invades a well, some water may be pumped with oil. In the settling tank not all the water is separated from the oil because of a certain degree of emulsification produced in pumping. In removing the water losses of volatile constituents occur. These losses have been reduced in recent years by the use of an electric process for the removal of water.

Withdrawal of Petroleum Lands. About 3½ million acres of oil lands have been withdrawn from entry. All the public lands in the United States should be examined and where favorable conditions exist for the accumulation of oil, these lands should be withdrawn. These lands may then be leased at a definite rental or royalty. The royalty based upon the production will prove most advantageous to the Government. By the control of large areas of oil lands the Government may prevent monopoly and profiteering.

By-products from the Coking of Oil. By the use of the by-products from the coking of coal, substitutes for many of the petroleum products may be obtained. If a large amount of the coal now coked in the beehive coke oven should be used in the by-product oven and a large amount of the coal now used as fuel should be coked, a large amount of petroleum could be saved by substitutions.

Shale Oil Production. There are in the United States large quantities of oil-bearing shales which are capable of producing from 10 to 50 gallons of crude oil to the ton of shale. This shale oil resembles in some respects crude petroleum. For example, it contains a highly volatile portion which corresponds to the gasoline fraction of petroleum, a less volatile portion which corresponds to the kerosene fraction, and another portion from which it is possible that some lubricants can be produced, and still another portion from which some of the paraffins and waxes may be obtained.

The production of shale oil will probably begin on a commercial scale as soon as the price of crude petroleum advances to the point where it is slightly in advance of the cost of producing shale oil. This point will probably be in the neighborhood of three dollars per barrel for medium grade crude petroleum.

Since there appears to be unlimited quantities of oil-bearing shales, it is within the bounds of possibility that our petroleum resources will never be exhausted, due to the fact that when the price becomes prohibitive, shale oil will be substituted.

Oil shales occur in large quantities in Colorado, Utah, Wyoming, and Nevada. They also occur in Indiana, Ohio, Kentucky and other states. The western shales have a larger oil content but the eastern shales have advantages of market and other factors which may in a measure offset the disadvantages of lower oil content.

Substitute for Petroleum and Its Products. There are a large number of substitutes for petroleum or its products used for producing heat. The substitutes are coal, wood, charcoal, coke, peat, natural gas, artificial gas and electricity. The most widely distributed and the most economical substitute under present conditions is coal. The advantages of petroleum over coal as fuel on steamships have already been mentioned.

No very good economical substitute for the fuels of gasoline and kerosene, which are used in internal-combustion engines, has been developed. The substance filling the requirements most nearly is alcohol, but the production of a sufficient quantity of alcohol to meet the demand for these two fuels seems impossible because of the scarcity of raw materials and the difficulties of growing them. The best substitutes will probably be found in shale oil.

Substitutes for lubricating oil obtained from petroleum are difficult to find. Vegetable fats and oils may be used for bearings where high speed and high temperatures are not produced, but for high-speed and high-temperature bearings, they cannot be used as a substitute for mineral oils. The most satisfying substitute will probably be obtained from shale oil.

For oils used in illumination there are many substitutes, such as animal and vegetable oils, oils distilled from coal and shale, artificial gas and electricity. A substitute for kerosene to illuminate the isolated farm homes is more difficult to obtain, but the installation of a small electric or acetylene plant is not impossible of achievement.

Fuel Oil Substitutes. For the oil used for fuel, coal or artificial gas can be substituted, but the advantages of oil over coal for fuel in some industries makes such a substitution difficult. Oil is used for fuel on railroad engines, on steamships, in industrial plants and for heating houses.

The advantages of the use of oil over coal on steamships were clearly demonstrated in a test recently made by two steamers of equal tonnage plying between New York and Brazil.

These steamers had the same length of run under the same weather conditions. The ship using coal made the trip in 24 days, 8 hours; the oil-burning ship made the trip in 21 days, 13 hours, thus making one knot per hour greater speed. The coal ship consumed 657 tons of coal; the oil ship 359 tons of oil. The coal ship carried 9 firemen, the oil ship 3. The following is the amount saved by the oil ship over the coal ship:

2 days, 19 hours, at $1,500 per day, charter time	$4,187 50
Additional cargo at $17 per ton, 300 tons	5,100 00
Wages of six firemen at $70	420 00
Fuel saving in oil over coal	1,184 00
Total saving for the trip	$11,547 50

The test was made with steamers of small tonnage. If larger ships had been used the saving would have been larger. During the war period coal cost from $5.00 to $20.00 per ton, depending upon the coaling station. A 10,000-ton freighter burns 40 tons per day, so that its daily fuel bill was from $200 to $800 per day. Oil prices for that period were about $1.88 per barrel. Oil costs were $256 per day for the same ship. This sum is higher than the minimum daily coal cost, but the gain in speed, cargo space, and labor costs offset and gave a considerable margin of profit.

The steamship Mauretania requires the development of 68,000 horsepower in her operation and there is a loss of 10,000 horsepower each watch by drawing her fires. There is no loss of this kind on an oil-burning ship. Nearly all of the ships constructed by the Government during the war were supplied with oil burners.