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VOLATILE MATTER IN PENNSYLVANIA COALS

By

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INTRODUCTION.

Besides discussing the problem of volatile matter, this paper shows the relation of oil and gas pools to volatile matter in Pennsylvania coals, and the use of coals from different districts.

The value of this publication is twofold. It has economic value in that it presents, for the first time, the location of lines of equal volatile matter in Pennsylvania coals, thereby giving the coal buyer accurate locations of coals suitable for various domestic and manufacturing purposes. It has scientific value by showing graphically the relation of the folding, faulting, and movement to the chemical character of the coals; and by defining the relation of the oil and gas pools of Pennsylvania to the volatile content of the coals.

Analyses.

The Pennsylvania Geological Survey has been cooperating for several years with the United States Bureau of Mines in sampling and analyzing Pennsylvania coals. These analyses will appear in forthcoming bulletins of the Bureau of Mines. They are of three types; first, analyses from samples taken at various points in mines by making a cut from roof to bottom. Impurities are rejected or included according to Bureau of Mines specifications. The gross sample is reduced by crushing and quartering, and the reduced sample is packed

in air-tight can for shipment. Second, car samples taken from coal shipped to Pittsburgh for testing purposes. Definite quantities of coal were taken from car as it was unloaded, and reduced to a convenient size, usually about 50 pounds, and a gross sample thus obtained. Third, samples taken at the mine and at points of delivery by persons not employees of the United States Government. These analyses may vary in moisture and ash content from mine analyses because of impurities included in the coal, and absorption or volatilization of moisture during transit.

The U. S. Bureau of Mines has analyzed a great many commercial samples taken for various organizations of the United States Government particularly during war time. Coal was shoveled from pit cars, crushed, and quartered, and shipped to the laboratory in air-tight cans. Other cars were sampled at their destination.

Analytical results are published in three forms: first, coal "as received" represents the samples as received at the laboratory or, in other words, is the coal as it was cut in the mines or taken off the car; second, the "moisture-free" analysis represents the relative composition and heating value of dry coal, and is used primarily for comparing similar coals of variable moisture content; third, the "moisture-free" and "ash-free" analysis, known as the "pure coal" basis, represents approximately the relative composition and calorific value of the dry organic or combustible matter. The volatile matter on a "pure coal" basis is obtained by the following formula:

$$\frac{\text{"As received" volatile matter}}{100 - (\text{ash} \quad \text{moisture})} = \text{Volatile matter in "pure coal."}$$

This form of analysis was used in the compilation of the isovol map.

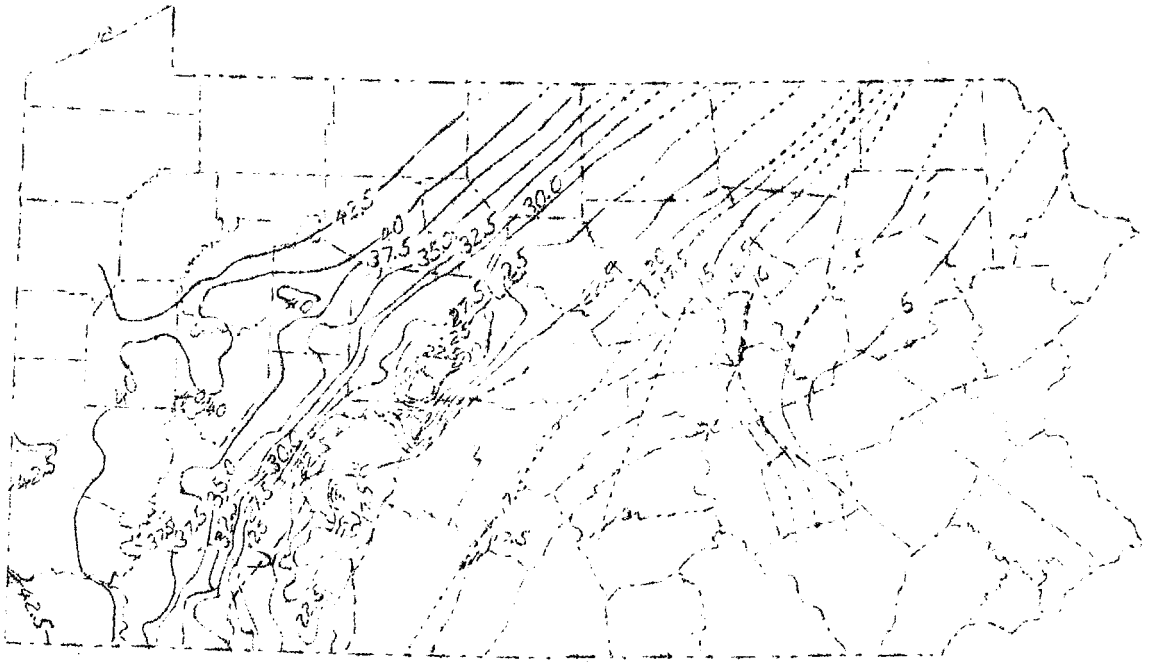
In compiling the isovol map approximately 1500 analyses from 606 mines were used as a basis. Analyses of approximately 7500 car samples from 75 mines in Pennsylvania were also used. The number of mines sampled in each county is as follows:

Allegheny	20	Greene	21
Armstrong	40	Huntingdon	5
Beaver	6	Indiana	33
Bedford	5	Jefferson	26
Blair	2	Lawrence	3
Bradford	2	Luzerne	2
Butler	17	Lycoming	1
Cambria	92	McKean	2
Cameron	1	Mercer	5
Center	13	Somerset	77
Clarion	22	Sullivan	4
Clearfield	59	Tioga	9
Clinton	2	Washington	31
Elk	8	Westmoreland	44
Fayette	54		
			606

Definition of "Isovol."

The word "isovol" is a combination of two terms, "iso" from the Greek, meaning equal, and "vol," an abbreviation of volatile. Therefore an "isovol line connects locations of samples having approximately equal amounts of volatile matter. An "isovol map" delineates areas of equal volatile matter.

To illustrate: The isovol line of 40 per cent crosses eastern Greene County in the vicinity of Monongahela River. The isovol line of 42.5 per cent crosses the county west of Waynesburg in a northwest-southeast direction. Theoretically, all coal between the isovol line of 40 and 42.5 per cent falls within these limits. Unfortunately, however, there are local variations of a few per cent which would show as "islands" having smaller or larger percentages of volatile matter. The isovol lines must necessarily be somewhat generalized, but are, in the main, accurate. Some analyses appear anomalous, due probably to local variations in pressure and folding. These analyses must be disregarded on a small scale map.



ISOVOL MAP OF PENNSYLVANIA

Accuracy Limitations.

The accuracy of the map is limited primarily by lack of analyses in various localities. This Survey proposed to execute a plan of sampling whereby the coal from every mine in the State will be analyzed. Unfortunately, inadequate appropriations have seriously curtailed this work. For the many outlying districts having no authoritative analyses, reports of the Second Pennsylvania Geological Survey and private companies were used. These analyses, of course, are less accurate than those made by the U. S. Bureau of Mines under ideal conditions.

The "pure coal" basis of representing analyses is only an approximation because ash does not have the same weight as the inorganic or incombustible matter in the coal. However, the maximum error is less than 1.5 per cent in comparing coals which do not vary much in physical character and in amount of ash and sulphur. The greater the percentage of ash and sulphur, the greater the error in this form of representation.

In areas where the coal has been eroded, isovol lines are dotted. These dotted lines are hypothetical, being based on the extent of folding and faulting in the district. The reader should note that volatile matter is discussed in this paper on the "pure coal" basis, that is, with the moisture and ash eliminated and recalculated to 100 per cent. Volatile matter on a "pure coal" basis is higher than the "ash received" basis which is ordinarily used in discussing composition of coals. In coals having 20 per cent or less volatile matter on the "as received" basis, the volatile matter in the "pure coal" basis is approximately 1 per cent higher, and increases in direct ratio of 1 per cent to every 10 per cent of volatile matter on the "pure coal" basis.

DETAILED DESCRIPTION OF MAP.

Pennsylvania has very few coals exceeding 42.5 per cent volatile matter. The Pittsburgh bed in the western part of Greene County and the southern part of Washington may exceed 42.5 per cent volatile. A small area in the northwestern part of Washington, southern Beaver, and western Allegheny County exceeds 42.5 per cent. The 42.5 volatile line marks, in general, the northwest limits of the bituminous coal fields. Northwest of this line only the beds in the lower part of the Allegheny group, and in the Pottsville series have not been eroded. The area of these beds is small and their future value is negligible.

The area containing coals ranging from 37.5 to 40 per cent volatile matter runs in a general north-south direction on Monongahela and Allegheny rivers and Redbank Creek. It extends northeast in the vicinity of St. Marys and Coudersport. Several small local areas have over 40 per cent volatile matter. These are near New Geneva and Lamberton in Fayette County; Fredericktown and Millsboro in Washington

County; Herminie in Westmoreland; Freeport, Johnetta, Manorville, and Eddyville in Armstrong; Summerville and Knoxdale in Jefferson County.

A rather extensive area on Monongahela and Youghiogheny rivers in the vicinity of Charleroi, Monongahela, Sutersville, Irwin, Elizabeth, and Versailles has, in general, volatile matter below 37.5 per cent.

The area between 27.5 and 37.5 isovol lines extends in a northeast-southwest direction through eastern Fayette and western Somerset counties; central Westmoreland and Indiana counties; southeastern Jefferson, northwestern Clearfield, southeastern Elk, Cameron, and the center of Potter County.

The area containing coal ranging from 25 to 27.5 volatile matter lies in southwestern Somerset, northeastern Fayette, eastern Westmoreland and Indiana, northern Cambria, eastern Clearfield, western Clinton, southeastern Potter, and the central part of Tioga.

Local exceptions are as follows: In eastern Clearfield County a large area in the vicinity of Glasgow, Madera, Woodland, Karthaus, Peale, and Houtzdale, ranges from 22.5 to 25 per cent volatile matter.

Two local areas in the vicinity of Smoke Run and Osceola range from 20 to 22.5 per cent volatile matter.

A large area in the northeastern part of Cambria County and the northwestern part of Blair County ranges from 27.5 to over 32.5 per cent volatile matter.

The area containing coals of 22.5 to 25 per cent volatile matter extends across western Somerset, eastern Westmoreland, southeastern Indiana; northern Cambria, northwestern Blair, western Center, central Clinton, northwestern Lycoming; and southeastern Tioga counties. This area is very irregular, wide in western Somerset, thinning in the vicinity of Boswell, to widen again in the vicinity of Wilpen, Westmoreland County. From Spangler, Cambria County, eastward to the Allegheny Front the area is much contracted, especially on the western slope of the mountain. It widens again in Clinton, Lycoming, Tioga, and Bradford counties.

Coals containing 20 to 22.5 per cent volatile matter lie in central and northwestern Somerset, northeastern Westmoreland, southeastern Indiana, central Cambria, northwestern Blair, western Center, southeastern Clinton, central Lycoming, and southeastern Tioga County.

Coals having 17.5 to 20 per cent volatile matter occur in eastern and northeastern Somerset, southern Cambria, northeastern Bedford, and southern Huntingdon counties.

A local exception is as follows: In the vicinity of Stoyestown, Hooversville, Holsopple, Ashtola, Somerset County, and Dunlo, South Fork, Franklin, and Dale, Cambria County, the coals range

from 15 to 17.5 per cent volatile matter. In the vicinity of Windber, on the Somerset-Cambria county line, the coals have 15 per cent or less volatile matter. East of Johnstown in a local area the volatile matter ranges from 17.5 to 22.5 per cent.

The limits of the area containing coals ranging from 12.5 to 17.5 per cent volatile matter were drawn on very little data because practically all the coals have been eroded. This area extends through southeastern Lycoming and western Sullivan counties.

The area containing 7.5 to 12.5 per cent volatile matter includes the Lykens and Bernice districts. This area extends northeast-southwest through eastern Sullivan, Northumberland, eastern Dauphin, northwestern Lebanon, and the western tip of Schuylkill County.

The area containing coals ranging from 5 to 7.5 per cent volatile matter includes the outlying areas of the anthracite district. It extends through northern Lackawanna, central Luzerne, southern Columbia, eastern Northumberland, and the western part of Schuylkill County.

The area containing coals having approximately 5 per cent volatile matter includes northern Schuylkill, southern Columbia, southern Luzerne and northern Carbon counties.

Causes and Significance of Variations in Volatile Matter.

Recent work by Thiessen, Jeffrys, Turner, and Randall on the microscopy of coals has proven conclusively that coals are of organic origin. They have undoubtedly been altered into many classes by two general processes: the biochemical and the dynamo-chemical. The biochemical process which includes microbian action and all environmental factors, does not carry the original organic matter farther in the forming of coal than peat and oozes. The dynamo-chemical process, which is the greatest factor in the alteration of coals, involves changes both in physical and chemical character of the original organic matter. The cause of dynamo-chemical action is twofold; heat, which is generated by movement of the strata in folding and faulting; and pressure, including compression caused by the weight of superimposed sediments and by movement of strata. This action causes gradual dehydration and consolidation of the organic material into coal of different types. The volatile matter, including combined oxygen, hydrogen, and nitrogen, is progressively eliminated.

The exact origin of the dynamic forces resulting in mountain building with accompanying folding and faulting in Pennsylvania has long been discussed by geologists. At the present time most geologists concur in believing that the dynamic force in the Pennsylvania region was an enormous thrust originating somewhere to the southeast of the State and dissipating its force in a general fan-shaped northwest direction. Whether this pressure created by dynamic action was sudden is not known, but it is supposed to have occurred through a long period of geologic time. The theory of isostasy has

presented many new aspects to the problem and has discredited some of the hypotheses of the old theory. The subject is too extensive to discuss here.

It is a known fact that Pennsylvania coals are progressively less volatile from northwest to southeast. Presumably the alteration forces were greater in eastern Pennsylvania than in western. The anthracite fields, lying principally in Luzerne, Lackawanna, Carbon, and Schuylkill counties, have evidently borne the brunt of the alteration process, for they contain coals ranging only from 4 to 8 per cent volatile matter. The alteration process was slightly relieved in the western end of the southern field in the Lykens and Dauphin areas, and the volatile matter ranges from 7.5 to 16.5 per cent. Northwest of the northern anthracite field in the vicinity of Bernice, the coals are of the semi-anthracite type and contain approximately 10 per cent volatile matter. The coals progressively increase in volatile matter in the northern part of Pennsylvania until the western limit of 42 to 45 per cent is reached in central McKean County.

Coals, if deposited in the counties southwest of Harrisburg and east of the mountains, have been eroded, and formations geologically many hundred feet below are exposed. In this area the rocks are closely folded and are cut by numerous faults.

The easternmost coal field in southern Pennsylvania is in Huntingdon and Bedford counties, and is known as the Broad Top. Volatile matter in the coals averages approximately 17.5 per cent. This field lies in an area of much folded rocks and its comparatively high volatile matter seems anomalous. The Broad Top field, however, is in a fault block where the pressure was somewhat relieved and compensated.

The coals have been eroded east of the Allegheny Front in central Pennsylvania. Along the west slope of the Allegheny Front great variations occur in the quantity of volatile matter. Along the southern part of the Allegheny Front the coals range from 17.5 to 20 per cent volatile matter. Northeast of Gallitzin, in Cambria and Blair counties, is a local area wherein the coals have 32.5 per cent and more of volatile matter. This local variation is evidently caused by local relief of pressure. Along the northern part of the Allegheny Front the percentage of volatile matter is normal, ranging from 22.5 to 27.5 per cent.

The volatile matter progressively increases, as might be expected, westward from the Allegheny Front to the limits of severe folding in Fayette, Westmoreland, Indiana, and Jefferson counties. The most anomalous variation is in the vicinity of Windber where the coals have 15 per cent and less of volatile matter but are surrounded by areas having from 15 to 20 per cent volatile matter. The exact cause of this local variation is unknown. The writer believes, however, that beds of sandstone and limestone in this vicinity were very resistant to dynamic forces, and the coal beds underwent more devolatilization because they were incompetent. David White believes that coal is more responsive to pressure than the environing strata.

In southeastern Clearfield County in the vicinity of Smoke Run and Osceola, the coals range from 20 to 22.5 per cent volatile matter and are surrounded by a large area of coal containing 22.5 to 25 per cent volatile matter. The rocks in eastern Clearfield County are much folded and faulted. The faults are small; thrust faults predominate. The displacement is generally less than 50 feet vertically. The two small areas containing coals ranging from 20 to 22.5 per cent volatile matter have evidently been subjected to greater pressure because the environing rocks have resisted to a greater degree and subjected the coals to a greater devolatilization. In the area containing coals ranging from 20 to 22.5 per cent volatile matter the pressure has been somewhat relieved by numerous faults or compensation of the pressure by buckling of the beds.

The coals progressively increase in volatile matter in the southeastern part of the bituminous field, the isovols running in a general northeast-southwest direction. Coals ranging from 37.5 to 40 per cent volatile matter have the largest area. This area extends through eastern Greene, western Fayette, eastern Washington, western Westmoreland, eastern Allegheny, southeastern Butler; Armstrong, southeastern Clarion, central Jefferson, central Elk, northwestern Cameron, and the central part of Potter counties. Within the main area numerous small local areas contain coals ranging from 40 to 42.5 per cent volatile matter. A local area containing coals ranging from 35 to 37.5 per cent volatile matter lies on Monongahela and Youghiogheny rivers between Brownsville, Fayette County, and Pitcairn, Allegheny County. This variation is small but cannot be disregarded because it includes a large territory. Presumably the strata in this area have not resisted pressure and heat as much as the strata in the surrounding area.

The volatile matter increases westward, the highest being in southwestern Greene and northwestern Washington counties.

Relation of Isovols to Oil and Gas Pools.

David White* has advanced the theory that there is a direct relation between the rank of oils and the degree of alteration of carbonaceous deposits; that oils in formations and regions which have been little altered by dynamic forces, are heavy and of low rank. The opposite is true of regions which have been subjected to greater alteration by dynamic influences; the oils are of higher rank and are lighter. David White points out the fact that no pools of oil are present in rocks bearing coals having more than 65 per cent fixed carbon. He also points out that in general at a given point oils in successive underlying formations or in stratigraphically lower sands in the same formation are progressively higher in rank. In regions where progressive devolatilization of the organic deposits in any formation has passed a certain point, marked in most provinces by 30

* White, David, Some relations in origin between coal and petroleum: Jour. Wash. Acad. Sci., Vol. V. No. 6, pp. 189-212, 1915.

to 35 per cent volatile matter (pure coal basis) in the associated or overlying coals, commercial oil pools are not present in that formation nor in other formations normally underlying it, although commercial gas pools may occur in the border zone of higher carbonization.

Relation of volatile matter (pure coal basis)

to oil and gas accumulation.*

Volatile Matter	Type of Production.
Under 30	Practically no oil and gas
30 to 35	Small shows but no commercial production
35 to 40	Isolated gas wells common, commercial oil pools rare, but of high rank
40 to 45	Principal fields of light oil and gas of the world
45 to 50	Principal fields of medium oil of Ohio, Indiana, and mid-continent
over 50	Fields of heavy Coastal Plain oils and of unconsolidated Tertiary or other formations

The hypotheses advanced by David White hold true in Pennsylvania. The principal oil and gas pools lie west of the 35 isovol line. The principal oil pools lie west of, or in the area containing coals having 40 per cent volatile matter. The 25-isovol line appears to be the eastern limit of the small commercial oil and gas pools.

In Greene, Washington, and southern Allegheny counties the oil pools lie on or west of the 40 isovol. This line cuts through the center of the gas fields in Greene, Washington and Allegheny counties.

In northern Allegheny, Butler, and Armstrong counties the oil pools lie on the 40 isovol line. In the northwest counties all of the oil pools lie west of the 42.5 isovol. In Allegheny County the 40 isovol passes through the gas fields. In Butler County the gas fields are scattered, some of them being even west of the 42.5 isovol line. The gas fields of Armstrong County are east of the 42.5 isovol. Extensive gas pools of Greene and Jefferson counties lie west of the 37.5 isovol with the exception of the fields near

*Fuller, Myron L., Relation of oil to Carbon Ratios of Pennsylvania Coals in North Texas; Economic Geology, Vol. XIV, No. 7, pp. 536-542, November 1919.

Punxsutawney, which lie between 35 and 37.5 isovols. The gas fields of Forest, Elk, McKean, and Potter counties lie on or west of the 40 isovol. The Cameron gas field, which has not been extensively developed, lies on the 35 isovol.

The progressive eastward intensity of dynamic forces which devolatilized the coals beyond doubt has also influenced the location of natural gas, and oils of different specific gravities. The 35 isovol appears to be the eastern limit of large commercial oil and gas pools. Some small production, however, may be obtained in areas east of this line, where the alteration of organic material is great, but the oils will be light and of sporadic occurrence. Wild-catting in eastern Pennsylvania should be stopped unless competent geologists or petroleum engineers consider the locations favorable.

Utilization of Coals from Various Districts.

The percentage of volatile matter in coal affects its burning and so determines in part its suitability for various uses.

The bituminous coals of Pennsylvania vary considerably in their composition and therefore in their use. In order to utilize it most efficiently a coal must be chosen according to its type.

The coals in Somerset and Cambria counties are low volatile, smokeless, steam coals. They are particularly valuable for railroad and bunker fuel and are in great demand for domestic use. In the vicinity of Friedens, Somerset County, the Upper Freeport is an excellent smithing coal. In the vicinity of Lilly, Cambria County, the coals are also of the smithing type. In northern Somerset County, particularly in the vicinity of Windber, the coals are extremely low in volatile matter and are particularly well adapted for steam purposes. Coals in the Johnstown region are mixed with other coals for coking. Coals on Black Lick Creek have been coked with much success, and those in the vicinity of Bennington will also coke.

Coals in the Broad Top field in Bedford and Huntingdon counties average about 17½ per cent volatile matter and are highly prized for domestic fuel. Much of this coal is also used by railroads. It has been coked with varying success for many years.

The coals of northern Cambria County, Clearfield, Jefferson, Cameron, Elk, and Clinton counties are typical steam coals. They have been coked locally for use in blast furnaces. Clearfield County includes the area underlain by the long-famous Moshannon coal which has been highly valued for steam and domestic purposes for many years. The coals belong to the so-called smokeless type.

The coals of eastern Westmoreland and Fayette counties are used entirely for steam and domestic purposes. The celebrated Connellsville basin, containing the Pittsburgh coking coal from which high grade coke has been produced for many years, lies in the central

part of these two counties. The coke from this district is unexcelled and has been used in blast furnaces since 1841. This area of coking coal probably extends southwestward into untested areas in Greene County where the Pittsburgh bed is deep under cover. Western Westmoreland and Fayette, northern Greene and southeastern Washington counties lie in a typical gas coal district. The coal in this area is particularly suitable for making illuminating gas and is used extensively for by-product coke.

The coals of Washington, Allegheny, Beaver, Mercer, and Butler counties are used almost entirely for steam and domestic purposes. Although they contain a large percentage of volatile matter they are in much demand as railroad fuel. Much of this coal is shipped to the lakes.

The coals of Indiana County are now being used almost entirely for steam purposes, although some plants are coking the coal. Indiana County coals will probably be extensively coked when the typical coking coals of southwestern Pennsylvania have been exhausted. They will at least be valuable in the near future for mixing with other coals for coking.

Coals in Armstrong and Clarion counties are high-volatile gas coals. They are now being used principally for steam and domestic fuel. When the Pittsburgh bed in the Irwin basin becomes exhausted within a few years, Armstrong and Clarion counties will then undoubtedly enjoy an unexcelled reputation as producers of high-grade gas coal, if picking and washing machinery is installed in areas where the coal is high in ash and sulphur.

Anthracite in eastern Pennsylvania is mined and sized for domestic and steaming purposes only. The great bulk of the production is used as domestic fuel, although large manufacturing concerns in the east use the fine sizes for generating steam.

Coal from outlying areas, particularly Blossburg, Ralston, and Bernice is shipped north and east and principally used for steam and domestic purposes.

The great variety of Pennsylvania coals offers the purchaser a wide field of choice. Pennsylvania produces coal suitable for most every industrial purpose. This Survey will be glad to assist both domestic and commercial consumers in the choice of coal for various purposes and designate localities where the desired coal may be obtained.