Bulletin 510
BUREAU OF MINES

CARBONIZING PROPERTIES:

BRITISH COLUMBIA, MATANUSKA VALLEY (ALASKA), AND WASHINGTON COALS AND BLENDS OF SIX OF THEM WITH LOWER SUNNYSIDE (UTAH) COALS

By J. D. Davis, D. A. Reynolds, R. E. Brewer
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ERRATUM

BULLETIN 510, Carbonizing Properties of Coals from British Columbia, Matanuska Valley (Alaska), Washington, and Blends of Six of These Coals with Lower Sunnyside, Utah, Coal, by J. D. Davis, D. A. Reynolds, R. E. Brewer, B. W. Naugle, D. E. Wolfson, F. H. Gibson, and G. W. Birge.

Shatter and tumbler indexes of cokes from coals 446 and 447 are listed in the wrong columns in table 9, page 25. They should be as follows:

Coal No.	Shatter index, cumulative percent upon-						Tumbler index, cumulative percent upon-					
	2-inch screen	1-1/2-inch screen	1-inch screen	3/4-inch screen	1/2-inch screen	1/4-inch screen	2-inch screen	1-1/2-inch screen	1-inch screen	3/4-inch screen	1/2-inch screen	1/4-inch screen
446	41	79	95	--	--	98	00	19	53	--	--	63
447	25	76	94	--	--	98	00	18	64	--	--	75

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Oscar L. Chapman, Secretary

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J. J. Forbes, Director

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Foreword

Since its creation by Congress in 1910, the Bureau of Mines has conducted scientific and technologic investigations on the composition, properties, mining, preparation, and utilization of coal with a view to improving efficiency, promoting health and safety, and conserving national fuel resources.

The early work was directed largely toward surveying the composition and properties of coals of different ranks and types, as expressed by heating value, fusibility of ash, and conventional proximate and ultimate analysis. These data were published and proved of great value to consumers of coal in selecting the kind of fuel best-adapted to their particular equipment or purpose. However, an examination of this type, although adequate for dealing with fuels for combustion in the generation of heat and power, did not provide the data needed for evaluating coals for the production of coke, gas, and byproducts in manufactured-gas plants or byproduct-coke ovens. The Bureau's attention was called to this need in 1927 by the Carbonization Committee of the American Gas Association, and under a cooperative agreement with this association the Bureau studied testing methods and developed a standard procedure known as the BM–AGA carbonization test. As stated by J. S. Haug, chairman of the Advisory Committee of the Association on Survey of Gas- and Coke-Making Properties of American Coals, the new test procedure has three distinctive characteristics as follows:

> First, the quantity of coal per charge, 75 to 180 pounds, is small enough to keep it within laboratory scope, make it convenient to operate, and permit reproducible control of test conditions. It is large enough to produce byproducts that have in general a similar nature to those obtained in large plants, and in quantity sufficient to permit analyses and tests of quality to be made, on which study and conclusions may be based.
>
> Second, a series of tests is made on each coal at carbonizing temperatures from 600° to 1,000° C. at 100° intervals covering the low- and high-temperature range. This enables curves to be drawn showing trends of yields and qualities of products against temperature. This method brings out the idiosyncrasies of each coal in a unique manner.
>
> Third, the temperatures of carbonization are inner-wall temperatures which are the real carbonization temperatures rather than the flue temperatures commonly referred to in large-scale work. These latter temperatures are higher than the inner-wall temperatures by the temperature gradient through the oven walls, a matter of several hundred degrees.

The value of this survey of the carbonizing properties of American coals by a standard method lies in the comparability of the results on different coals. It must be recognized that no standard laboratory method of carbonization, even on a large unit, can yield results that exactly duplicate those obtained in ovens and retorts. The commercial results vary with the type of oven or retort. Allowance must be made for such differences in interpreting the BM–AGA test results in terms of commercial plants.

A comparison of BM–AGA tests and commercial-plant yields for 11 coals gives the following results:

1. Plant yields of coke, gas, and B. t. u. of gas per pound of coal usually fall between the test results obtained at carbonizing temperatures of 900° and 1,000° C. (1,652° and 1,832° F.).
2. The quantity of light oil scrubbed from the gas of the test apparatus is less than that scrubbed from the gas of commercial plants, because the test condensing train throws down more of the light oil with the tar; however, the total yields at 900° C. from gas plus light oil in the tar are approximately the same as the total from plants.
3. The yield of tar from the 1,000° C. carbonization shows the best agreement with plant yields, although on several coals the plant yields were 1 to 2 gallons per ton of coal less than those in the test apparatus.
4. The yields of tar and gas from the 18-inch retort usually are closer to those obtained in industrial practice than yields from the 13-inch retort.
5. At a carbonizing temperature of 900° C. the 13-inch retort indicates the relative shatter and tumbler indexes of the coke, but the figures are lower than those obtained for the same coals in byproduct ovens. Much of this difference is eliminated by the use of the 18-inch-diameter retorts and a 1½-inch shatter index. The larger retort gives larger pieces of coke that are less fractured owing to the slower rate of heating.
6. The coke from the test retorts has a lower apparent density and a higher percentage of cells than byproduct-oven cokes made from the same coals. Tamping the charge of coal in the retort increases the apparent density and lowers the porosity to figures closely approaching those obtained in byproduct plants.

A secondary objective of the Bureau of Mines carbonization studies is to obtain information on the chemical and physical properties of different coals that may affect the yield and nature of the gas, coke, and byproducts.

Microscopic examination, high- and low-temperature assays, and special physical tests to determine plasticity, agglutinating value, and friability have been made since the investigation was begun. The petrographic analyses based upon microscopic examination explain variation in carbonizing properties due to the types of coal making up the coal bed; plastic and agglutinating-value tests indicate to some extent the expansion or swelling of the coal during formation of coke, and the assays furnish an approximate measure of the yields of products at low and high coking temperatures.

In recent years the carbonization studies have been broadened to include tests of the expansion of coals and blends of coals while being heated under coke-oven conditions. Moreover, the effect of oxidation of coal during storage on its carbonizing properties is being determined by making carbonization tests on oxidized or unoxidized coals.

The BM–AGA test apparatus and method were first described in Bureau of Mines Bulletin 344, Method and Apparatus Used in Determining the Gas-, Coke-, and Byproduct-Making Properties of American Coals with Results on a Taggart-Bed Coal from Roda, Wise County, Va., published in 1931. They were discussed in detail in Bureau of Mines Monograph 5, Gas-, Coke-, and Byproduct-Making Properties of American Coals and Their Determination, published in 1934 and obtainable from the American Gas Association, 420 Lexington Avenue, New York City (164 pp., price $2 to members, $3 to nonmembers). Recent improvements in the apparatus and method are published in Bureau of Mines Technical Paper 685, Procedure and Apparatus for Determining Carbonizing Properties of American Coals by the Bureau of Mines-American Gas Association Method.

A bibliography of other publications of the carbonization series that are obtainable from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., is given at the end of this paper.

RALPH L. BROWN,
Coal Technology Coordinator.

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CARBONIZING PROPERTIES

BRITISH COLUMBIA, MATANUSKA VALLEY (ALASKA), AND WASHINGTON COALS AND BLENDS OF SIX OF THEM WITH LOWER SUNNYSIDE (UTAH), COALS[1]

By

J. D. Davis,[2] D. A. Reynolds,[2] R. E. Brewer,[3] B. W. Naugle,[2] D. E. Wolfson,[2] G. H. Gibson,[2] and G. W. Birge[3]

Introduction and Summary

THIS report gives results of an investigation of the carbonizing properties of 18 coals, including 2 from Alaska, 12 from British Columbia, 3 from Washington, and 1 from Utah. Each coal was carbonized in the standard 13-inch Bureau of Mines-American Gas Association (BM–AGA) retort at 900° C. Plastic properties were determined by the Gieseler and Davis methods, and agglutinating and free-swelling properties were determined by standard methods. Expanding properties were measured in the Bureau of Mines sole-heated oven. From the results of the tests on these single coals, three coals from the Crowsnest area in British Columbia, representing Elk River Nos. 4, 9, and 10, were selected for blending with the Utah coal, which was from the Lower Sunnyside bed, Horse Canyon mine, Emery County. Lower Sunnyside also was blended with Wilkeson Nos. 2 and 3 (Washington) coals, Pocahontas No. 3 from McDowell County, W. Va., and the Oklahoma low-volatile coal used in the blend carbonized at the Provo, (Utah) coke plant at the time this investigation was started. Most of the blends contained 3 percent hard pitch, which is the proportion used at the Provo plant. The blends were also carbonized in 13-inch BM–AGA retorts at 900° C.

High-volatile B coal from the No. 3 bed, Evan-Jones mine, Lower Matanuska Valley, Alaska, yielded poorly fused coke or char. M-bed coal from the Chickaloon mine, Upper Matanuska Valley, Alaska, ranked as medium-volatile bituminous and coked strongly. It expanded 39.6 percent in the sole-heated oven at a charge density of 55.5 pounds per cubic foot.

Two washed samples from the No. 2 bed, representing the No. 8 mine in the Comox area and the T'Sable River mine near Union Bay, Vancouver Island, ranked as high-volatile A bituminous. Both coals yielded well-fused coke, which was more abradable than the average coke from high-volatile A coals. The coke from T'Sable River mine was the stronger.

Four Elk River coals from the Crowsnest area in southeastern British Columbia represented the No. 9 bed and No. 9 mine, the No. 10 bed and No. 1 East mine, No. 3 bed and No. 3 mine, and No. 4 bed and No. 4 mine. They were medium-volatile coals containing 10.1 to 23.8 percent ash and 0.3 or 0.4 percent sulfur. No. 3 yielded weak, abradable coke, which probably would be strengthened were the ash content of the coal (23.8 percent) lowered. The other samples coked strongly.

A- and B-bed coals from the Michel mine in the Crowsnest area ranked as medium-volatile bituminous. The A-bed sample contained 17.4 percent ash, which accounts for the rather high abradability of its coke. The coke from B-bed coal was less abradable but did not withstand breakage in the shatter test well. A-bed coal contracted 7.9 percent in the sole-heated oven, and B-bed coal expanded 3.7 percent.

No. 5- and No. 4-coal beds were sampled from prospects in the Aldridge Creek mine in the Upper Elk River area. Both were of medium-volatile rank but had dissimilar coking properties. No. 5 coal, which contained 18.3 percent ash, yielded coke that was satisfactorily stable in the shatter test but was rather abradable. This coal contracted 6.6 percent during carbonization in the sole-heated oven. The coke from No. 4-bed coal had lower-than-average shatter indexes, although its tumbler indexes were satisfactorily high. This coal expanded 4.6 percent in the sole-heated oven.

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[1] Work on manuscript completed February 1, 1951.
[2] Chemist, Central Experiment Station, Bureau of Mines, Pittsburgh, Pa.
[3] Chemical engineer, Central Experiment Station, Bureau of Mines, Pittsburgh, Pa.

The prospect sample from an unknown bed in the Peace River area ranked as high-volatile A bituminous. It contained only 4.9 percent ash and 0.7 percent sulfur. It yielded small coke that fractured readily in the shatter test, although it had low abradability.

Robertson-mine coal from Graham Island ranked high in the high-volatile A classification. The sample, which was taken from an old dump, contained 37.3 percent ash. Shatter indexes of the coke were satisfactorily high; tumbler indexes, which were rather low, indicate the coke to be rather abradable.

Three Washington coals ranked as high-volatile A bituminous, although No. 5, from Kittitas County, was rather low in that classification and coked less strongly than No. 3- and No. 2-bed coals from Pierce County. The coke from No. 2 coal was exceptionally strong for the coal rank.

Lower Sunnyside coal from the Horse Canyon mine, Emery County, Utah, ranked as high-volatile B bituminous, although very high in that group. It coked more strongly than most of the seven samples from this bed that were tested previously. Carbonization tests of the single coal and one of its blends showed that its coke-making property deteriorated slightly dur-4 months' storage.

Medium-volatile Elk River coals from beds 4, 9, and 10 were selected for blending with Lower Sunnyside coal, because their chemical composition and carbonizing properties were superior to those of the other British Columbia coals. They were blended in the same proportion (15 percent) that Oklahoma low-volatile coal was blended at a commercial plant with 82 percent Lower Sunnyside and 3 percent pitch. The blends coked as strongly as those made with Oklahoma coal. The cokes from blends containing No. 9 and No. 10 coals were less abradable than coke made from the corresponding blend of No. 4 coal.

Tests made on Lower Sunnyside-Oklahoma blends with and without pitch showed that the addition of 3 percent pitch increased coke strength significantly. Blends of Pocahontas No. 3 and Lower Sunnyside coals coked strongly; the strength of their cokes increased as the proportion of Pocahontas was raised from 8 to 10, 15, and 20 percent. Wilkeson No. 2 and No. 3 coals from Pierce County, Wash., with 3 percent pitch improved Lower Sunnyside coke physically when blended with 82 percent of Lower Sunnyside coal.

The results of this investigation show that Elk River No. 9 or No. 10 coal could be substituted for Oklahoma low-volatile coal in the 82:15:3 blend of Lower Sunnyside and Oklahoma coals with pitch without loss of coke strength.

ACKNOWLEDGMENTS

The writers acknowledge indebtedness to the United States Steel Co. for supplying samples of Alaska, British Columbia, Washington, Utah, and Oklahoma coals used in this investigation. C. D. King and F. M. Becker, chairman and assistant to chairman, respectively, Coke Committee of this company, assisted in formulating the test program.

Acknowledgment is also made to the Eastern Gas & Fuel Associates of Pittsburgh, Pa., for supplying the Pocahontas No. 3 coal.

The following members of the Central Experiment Station, Bureau of Mines, Pittsburgh, Pa., cooperated in the investigation: R. F. Abernethy, chemist, supervised the coal and coke analyses; F. E. Scott and A. Bartkowiak, scientific aides, analyzed the gases and assisted with the carbonization tests; W. E. Erickson, scientific aide, and J. H. Lynch, laboratory mechanic, assisted with the carbonization tests and conducted physical tests of the cokes; G. H. Martindill, scientific aide, assisted with the analyses of tars and light oils; Mary H. Cizmarik, clerk-stenographer, and Victoria A. Hoysan, clerk-typist, assisted in tabulating the experimental data and preparing the manuscript.

GEOLOGICAL AGE OF COALS

The Lower Matanuska Valley bituminous-ɪal field of Alaska lies in the Wishbone Hill ɴcline. In both the lower and upper coal ɜlds of this valley, bituminous coal occurs only the Chickaloon formation, which is of Eocene ʒe. The No. 3 coal bed is near the top of that rmation.[4] In addition to the No. 3 bed stu- ed in this investigation, beds 4, 2, 1, 0, and 00 ɩve been identified at the Evan-Jones mine.[5]

The Upper Matanuska Valley coal field lies ɔrth of the Matanuska River and extends 20 iles eastward from Kings River. This tract underlain by the coal-bearing Chickaloon rmation[6] containing the M coal bed. oth Alaska coals included in this investiga- ɔn, therefore, are of Eocene age.

The coal deposits of British Columbia are of ɩree geological ages, namely, Lower Cretaceous ome of which may be Jurassic), Upper Creta- ›ous, and Tertiary.[7] The coals of Vancouver land are of Upper Cretaceous age, and all ɔcur in the Namaimo series; the No. 2 bed ɜlongs to the Comox formation. The most important deposits in this Province are of Lower Cretaceous age, and they include deposits of the Crowsnest field in the southeastern part and the Peace River field in the northeast. Six beds (Nos. 3, 4, 9, 10, A, and B) sampled in the Crowsnest field and beds 4 and 5 in the Upper Elk River field belong to the Kootenay formation. The unknown bed sampled in the Peace River field was reported to be part of the Dunlevy formation. Graham Island, which is the most northerly of the Queen Charlotte Islands, has small deposits of both Upper Cretaceous and Tertiary coals. The sample received for this investigation was Upper Cretaceous.

The coal beds of Pierce County, Wash., lie in the Puget formation, which is of Eocene age.[8 9] Regional metamorphism, as in other coking-coal areas of the State, has been responsible for the changes in rank and properties. The beds in Pierce County are generally sharply tilted; some are extremely folded and faulted, and in certain local instances are intruded by igneous masses. The coking properties, however, are due to the major structural forces and not to igneous action.

Martin, G. C., and Katz, F. J., Geology and Coal Fields of the Lower atanuska Valley, Alaska: Geol. Survey Bull. 500, 1912, 98 pp.

Toenges, Albert L. and Jolley, Theodore R., Investigation of Coal ɜposits in South Central Alaska and Kenai Peninsula: Bureau of Mines ɜpt. of Investigations 4520, 1949, 37 pp.

Capps, S. R., Geology of The Upper Matanuska Valley, Alaska: ɜol. Survey Bull. 791, 1927, 92 pp.

McKay, B. R., Coal Reserves of Canada. Reprint of Chapter 1 and ɔpendix A of Report of the Royal Commission on Coal, 1946: Ottawa, 17, 113 pp.

[8] Willis, Bailey, Report on the Coal Fields of Washington Territory: Tenth Census of the United States, vol. 15, 1886, pp. 759–771.

[9] Daniels, Joseph, The Coal Fields of Pierce County: Washington Geol. Survey Bull. 10, 1915, p. 29.

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DESCRIPTION AND PROPERTIES OF COALS

DESCRIPTION AND SOURCE OF SAMPLES

Table 18 gives the source of the coal samples and the composition of the various blends. All coals and blends were numbered, and these numbers were used instead of the bed or mine name in all other tables. Table 18 is so constructed that it may be unfolded and used to identify the coals or blends of the other tables.

MATANUSKA FIELD, ALASKA

Two coal beds were sampled in the Matanuska Valley, Alaska, during the latter part of May 1949. They were shipped June 1 and were received in Pittsburgh June 30, 1949.

No. 3-bed coal (385) was sampled at the Evan-Jones mine at Jonesville, in Lower Matanuska Valley. One full shovel of run-of-mine coal taken from each mine car prior to dumping made up the sample. Although the carbonizing sample, which was raw coal, contained 21.3 percent ash, the washed coal was reported to contain only 10 to 12 percent ash. At one point in the mine,[10] where the bed was 97 inches thick, the coal thickness was 85 inches.

The M bed (386) was sampled at the Chickaloon mine in the Upper Matanuska Valley. Here the bed, including 5 inches of black shale, was 5 feet 10.8 inches thick. According to the Federal Geological Survey,[11] this coal bed may be M or N.

VANCOUVER ISLAND, BRITISH COLUMBIA

Samples of No. 2-bed coal from two mines in Vancouver Island, B. C., were included in this investigation. Both samples were run-of-mine coal washed at 1.60–1.65 gravity. They were taken June 4, 1949, and received June 24, 1949.

Sample 388 represented the No. 2 bed at No. 8 mine, Cumberland, Comox coal area. At this point the bed dip was northeast 7° to 9°, and the strike was N. 20° W. Twenty-four percent of the sample was rejected in washing.

Sample 389 represented the No. 2 bed at the T' Sable River mine, Union Bay, T' Sable River coal area. The dip was 7° to 9° northeast, and the strike was N. 20° W. Twenty-eight percent of the sample was rejected in washing. At this mine, 90 to 100 percent of the coal is washed.

[10] See footnote 5.
[11] See footnote 6, plate 14.

SOUTHEASTERN DISTRICT, BRITISH COLUMBIA

Eight samples representing seven coal beds in the southeastern British Columbia coal district were included in this investigation.

In the Crowsnest area, four Elk River colliery mines near Fernie, Crowsnest Pass district, were sampled July 4, 1949. Each of these samples, representing full-seam mining, was taken from belt conveyors; 100 cross-sectional cuts were taken from 40 tons. They were received August 11, 1949. No. 9 bed (390) was sampled at No. 9 mine; No. 10 bed (391) was sampled at No. 1 East mine; No. 3 bed (392) was sampled at No. 3 mine; and No. 4 bed (393) was sampled at No. 4 mine. In this locality the beds dip 12° to 23° southeast and the strike is N. 60° E.

Two additional samples (394 and 395) from the Crowsnest area, representing the Michel mine at Michel, represent raw coal from the "A" and "B" beds, respectively. Both beds were sampled from conveyor belts July 6, 1949. In this mine, the beds dip 5° to 30°; the strike is variable, because the mine is in a synclinal basin. At the time the sample was taken, 42 percent of the mine's output was coked, using 228 beehive and 36 Curran-Knowles ovens. These samples were received August 17, 1949.

Two samples were taken in the Upper Elk River coal area at the Aldridge Creek prospect mine, which is 48 miles north of Natal. Channels were cut from the face of each bed at points more than 100 feet from the portal in order to obtain fresh coal. The opening is about 4,300 feet above sea level. The dip is 37° southwest, and the strike is N. 18° W. This prospect is in an area containing a contiguous reserve estimated at 126 million tons. The No. 5 bed (401) represented the entire thickness of the bed, 8 feet 2 inches, and included 4 inches of clay. The No. 4 bed (402) was 10 feet thick, and no part was excluded, although four bands of gumbo totaled 2 inches. The samples were taken July 31 and August 2, 1949, and were received September 12, 1949.

NORTHEASTERN DISTRICT, BRITISH COLUMBIA

One sample (399) was taken from an unnamed bed in the Peace River coal area at an outcrop about 52 miles northwest of Hudson Hope. In this prospect, the exposure was cut by a waterfall; a channel was cut from the face after blasting 5 feet from the exposed coal. The bed was 4 feet 3 inches thick; a 2½-inch parting of carbonaceous shale and 4 inches of underclay were excluded from the sample. The dip was 4° northeast and the strike was N. 10° W. The opening was approximately 4,750 feet above sea level. The sample was taken August 13, 1949, and received September 26, 1949.

GRAHAM ISLAND, BRITISH COLUMBIA

An unnamed bed (400) was sampled at the Robertson mine, Camp Robertson, which is 11 miles northwest of Queen Charlotte City, Graham Island, Queen Charlotte Islands. This mine had been closed since 1916 and the sample was dug from an old dump—presumably the coal was weathered. The sample was taken August 28, 1949, and received October 10, 1949.

WASHINGTON

Samples of three Washington coal beds furnished by the Northwest Improvement Co. were tested. The No. 5-bed coal (398) represented washed coal from the Roslyn No. 3 mine in Kittitas County. Beds 3 and 2 (446 and 447) were sampled at the Wilkeson mine, Wilkeson, Pierce County, and were floated at 1.50 specific gravity by the Northwest Experiment Station, Seattle, Wash., to simulate washing. These two samples were taken at the outcrop of beds 2 and 3 and hence may have been oxidized to some extent. Results of BM–AGA tests of No. 2- and No. 5-bed coals made in 1941 were reported in Technical Paper 649, Carbonizing Properties and Petrographic Composition of No. 2-Bed Coal from Bartoy Mine and No. 5-Bed Coal from Wilkeson-Miller Mine, Wilkeson, Pierce County, Wash., by J. D. Davis, D. A. Reynolds, G. C. Sprunk, C. R. Holmes, and J. T. McCartney, 1942, 46 pp.

LOWER SUNNYSIDE BED, UTAH

Lower Sunnyside-bed coal (423) from the Geneva mine, Horse Canyon, Emery County, Utah, was sampled at the coke plant of the Geneva Steel Co. The sample, weighing about 2 tons, was received February 14, 1950.

OKLAHOMA BLENDING COAL

The low-volatile Oklahoma (424) that was being blended with Lower Sunnyside commercially was sampled at the coke plant. The exact source of this coal is unknown.

WEST VIRGINIA BLENDING COAL

The West Virginia low-volatile blending coal (75) was obtained from the Pocahontas No. 3 bed, Carswell mine, Kimball, McDowell County, W. Va. This coal is used extensively in the coking industry.

PITCH

Most of the blends contained 3 percent pitch, which was derived from coal tar. Its melting point was 137° C.

All coal samples were shipped in steel drums with closely fitting covers. The shipments arrived in excellent condition; apparently none deteriorated during the interim between sampling and delivery in Pittsburgh.

CHEMICAL ANALYSES OF COALS

Table 1 gives chemical analyses of the coals on the as-carbonized basis, heating values, softening temperatures of ash, sulfur forms, free-swelling indexes, agglutinating values, and real specific gravities.

No. 3-bed Alaska coal (385) contained 5.1 percent moisture, 36.8 percent volatile matter, 21.3 percent ash as carbonized, and 51.5 percent fixed carbon on the dry, mineral-matter-free basis. The oxygen content (15.0 percent) was high. The rank, which is not definitely fixed because the heating value was not determined, probably is the same as another sample from this bed and mine that ranked as high-volatile B bituminous.[12] M-bed Alaska coal (386) contained 2.6 percent moisture, 20.8 percent volatile matter, 63.9 percent fixed carbon, and 12.7 percent ash. This was a low-oxygen (5.8 percent), low-sulfur (0.5 percent) coal. It contained 76.6 percent fixed carbon on the dry, mineral-matter-free basis; it ranks, therefore, as medium-volatile bituminous.

Two samples (388 and 389) from the No. 2 bed, Vancouver Island, were of similar composition. Although both were washed at 1.60 to 1.65 gravity, they contained 11.9 and 14.3 percent ash and 2.1 and 1.8 percent sulfur, respectively. They ranked as high-volatile A bituminous. Softening temperatures of the ashes were 2,260° and 2,460° F. The carbon dioxide contents of both samples (1.28 and 1.61 percent) were exceptionally high.

The four Elk River coals (390, 391, 392, 393) were of similar rank (medium volatile), but they differed markedly in their proportions of ash. Ranges in their proximate analysis were: Moisture, 1.3 to 1.6 percent; volatile matter, 18.8 to 25.6 percent; fixed carbon, 55.8 to 63.0 percent; and ash, 10.1 to 23.8 percent. They contained only 0.3 or 0.4 percent sulfur, 70 percent or more of which was organic. Their contents of dry, mineral-matter-free fixed carbon ranged from 72.0 to 77.6 percent. The softening temperatures of their ashes ranged from 2,340° to 2,870° F.

[12] Bureau of Mines, Analyses of Alaska Coals: Tech. Paper 682, 1946, 114 pp. (See p. 94.)