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UNITED STATES
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HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
R. R. SAYERS, DIRECTOR

REPORT OF INVESTIGATIONS

COAL CARBONIZATION: CARBONIZING PROPERTIES OF MEDIUM-VOLATILE COALS OF DIFFERENT TYPES

BY

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D. A. Reynolds[2/] and J. D. Davis[3/]

INTRODUCTION

Investigations by the Bureau of Mines have shown that the carbonizing properties of splint and bright coals may differ greatly. In a study of 55 coal columns selected from representative coals of the Appalachian region, Sprunk and coworkers[10/] compared various chemical and physical properties of splint and associated bright coals. Carbonization tests in the Fischer retort at 932°F. (500°C.) showed that, except for bright coals of high oxygen content, the coke residue from bright coal was much more swollen and cellular than that from splint. With one exception, agglutinating values determined by the Bureau of Mines test, were lower for splint than for associated bright coal.

Because sorting of coal in quantity is tedious and time-consuming, separate types have not been carbonized by the Bureau of Mines-American Gas Association (BM-AGA) test, which requires 85- to 200 pound charges. However, this method has been used to determine the carbonizing properties of samples of bed layers that are composed largely of either splint or bright coal.[4/] In these earlier tests, which were made at high temperatures on layer samples from the Elkhorn bed, Letcher County, Ky., the splint coal yielded more coke than the bright coal, and this coke was slightly stronger than that from the bright coal. The cokes from samples with large proportions of bright coal were more cellular or porous, as were the low-temperature cokes obtained from carbonization of separated samples of bright coal in the Fischer retort.

1/ Paper presented before the Division of Gas and Fuel Chemistry, American Chemical Society, at Atlantic City, N. J. September 8 to 12, 1941. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Report of Investigations 3695."

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PROPERTIES OF COALS TESTED

The results of Bureau of Mines investigations therefore indicate that the carbonizing properties more specifically, the coke-making property of a coal that is predominantly splint will be unlike those of bright coals of similar rank. An opportunity to make this comparison became available during the investigation of the carbonizing properties and petrographic composition of four medium-volatile coals (one of which was predominantly attrital) representing splint, semisplint and cannel types. Chemical and petrographic analyses of these coals, all from the Appalachian region, are given in Tables 1 and 2, respectively. Lower Banner coal (No. 58) contained 36 percent bright coal, 53 percent semisplint, and 11 percent cannel; it contained 66 percent attrital components compared to 35 percent for Sewell and 31 percent for Lower Freeport and Bakerstown coals. The typical appearance of Lower Banner coal is shown by the photographs of representative lumps in figure 1; the columnar structure, steel-gray luster, and absence of banding are characteristic of splint.

The percentages of fixed carbon contained by these coals, on the dry, mineral-matter-free basis, are as follows: Lower Banner, 76.9; Sewell, 77.5; Lower Freeport, 73.4; and Bakerstown, 77.1 Judging from the chemical analysis alone, virtually the same carbonizing properties would be expected for these four coals. Therefore the differences found for the several carbonizing properties of Lower Banner coal as compared with the other coals must be attributed to its particular type, or petrographic composition.

EXPERIMENTAL RESULTS

Lower Banner, Sewell, Lower Freeport, and Bakerstown coals were carbonized by the BM-AGA test method; and the results of these investigations, except for Bakerstown coal, have been published. [3,5,6] The more significant of these results are shown in Table 3. These include the yields of coke, gas, and tar from tests in the 18-inch retort at 1652°F.; apparent specific gravity, 1-1/2 inch shatter index, and 1-inch tumbler index of the coke; plastic properties determined by the Gieseler plastometer; agglutinating values measured by the Bureau of Mines method; expansion in the Bureau of Mines sole-heated oven; and maximum internal gas pressures developed in the BM-AGA tests at 1112° F. and 1652° F.

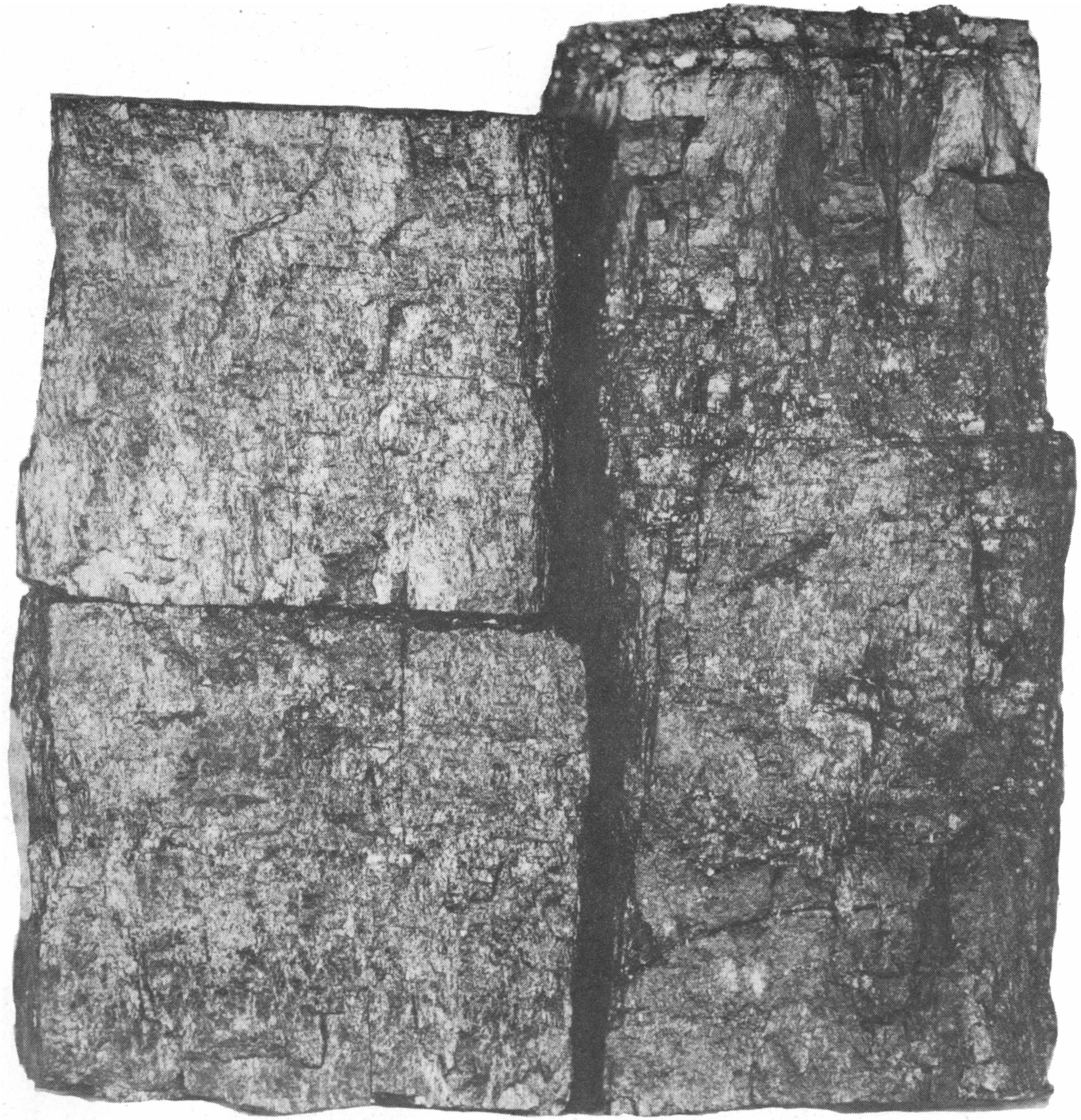

FIGURE 1.- Typical appearance of lumps from column of Lower Banner-bed coal. Note columnar structure, steel-gray luster, and absence of banding.

Table 1. Analyses of medium-volatile coals carbonized by BM-AGA test.1/

Coal No.	Bed	Dry mineral-matter free fixed carbon, percent	Proximate, percent2/			Ultimate, percent2/					
			Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur
58	Lower Banner	76.9	2.5	21.4	67.8	8.3	4.7	79.5	1.2	4.8	1.5
55	Sewell	77.5	1.6	21.8	73.7	2.9	4.9	85.8	1.4	4.3	.7
60	Lower Freeport	73.4	2.0	24.9	66.7	6.4	5.1	81.2	1.3	5.3	.7
64	Bakerstown	77.1	2.2	21.6	70.5	5.7	4.8	82.1	1.6	4.8	1.0
58	Column sample (all cannel excluded)	76.8	.5	22.1	70.1	7.3	4.7	81.8	1.3	3.6	1.3
58	Cannel coal (low-ash)	79.1	.6	20.0	72.9	6.5	4.6	83.6	1.2	3.4	.7

1/ Analyses by H. M. Cooper, Chemist, Bureau of Mines
2/ As-carbonized basis.

Table 2. Petrographic analyses of medium-volatile coals carbonized by BM-AGA test.1/

Coal No.	Bed	Types				Components			
		Bright	Semi-splint	Splint	Cannel	Anthraxylon	Translucent attritus	Opaque attritus	Fusain
58	Lower Banner	36	53	--	11	30	49	19	2
55	Sewell	81	15	4	--	60	23	12	5
60	Lower Freeport	93	5	2	--	68	24	7	1
64	Bakerstown	91	3	6	--	67	21	10	2

1/ Petrographic analyses by G. C. Sprunk, associate microscopist, Bureau of Mines.

Table 3. Carbonizing characteristics of Lower Banner, Sewell, Lower Freeport, and Bakerstown coals.

Coal No.	Yields at 900°C. in 18-inch retort percent			Physical tests 900°C. cokes, 18-inch retort			Agglutinating value, Kg.[2]	Plastic properties measured by the Gieseler plastometer[3]									Internal gas pressures in BM-AGA tests, lb./sq. in.		Expansion in sole-heated oven, percent[4]
								Initial softening temp. at 0.1 dial div.		Fusion temp. at 5.0 dial div. per min.		Maximum, fluidity, maximum pointer movement			Solidification 5.0 dial divisions per min.				
	Coke	Gas	Tar	Apparent sp. gravity	1 1/2-inch shatter index[1]	1-inch tumbler index[1]		°C.	°F.	°C.	°F.	°C.	°F.	Div per min.	°C.	°F.	600°C. test, 13-in. retort	900°C. test, 18-in. retort	
58	79.2	11.8	3.2	0.95	82.6	65.4	5.3	389	732	430	806	467	873	290	491	916	0.2	0.1	-6.2
55	80.0	11.8	3.4	.88	85.7	68.9	6.8	386	727	435	815	461	862	89	482	900	43.0	6.0	16.0
60	76.5	12.3	5.0	.80	88.9	69.8	6.7	359	678	---	---	421	790	36	428	802	25.0	11.0	19.0
64	78.6	11.9	3.8	.87	88.0	72.3	7.5	375	707	423	793	449	840	84	479	894	30.	5.0	9.8

1/ Averages of 4 to 6 determinations.
2/ Agglutinating value tests by W. H. Ode, assistant chemist, Bureau of Mines. Ration of silicon carbide to coal is 15:1.
3/ Gieseler plastometer tests by R. E. Brewer, associate chemist, Bureau of Mines.
4/ Expansion tests by H. S. Auvil, junior chemist, Bureau of Mines.

The yields of coke, gas, and tar from Lower Banner coal do not differ significantly from those for the other coals. The coke from Lower Banner coal has the highest apparent specific gravity and is the weakest by the results of both the shatter and tumbler tests. The agglutinating value, which affords some indication of the coking property, is lowest for Lower Banner coal and is approximately proportional to the 1-inch tumbler index for the cokes from the four coals. The fact that Lower Banner coke is the weakest is probably related to other anomalous characteristics of this coal that are discussed below.

The results of the Gieseler plastometer test indicate that the maximum fluidity of Lower Banner coal is much higher than that of the other coals; the maximum pointer movements, in divisions per minute, are as follows: Lower Banner, 290; Sewell, 89; Lower Freeport, 36; and Bakerstown, 84. The internal gas pressures, or pressures within the uncarbonized part of the charge, were measured in the BM-AGA tests by a method previously described.[8] Lower Banner coal developed maximum internal gas pressures of 0.2 and 0.1 pound per square inch at 1112°F. (600°C.) and 1652°F. (900°C.) respectively, compared with 25 to 43 pounds at 1112°F. (600°C.) and 5 to 11 pounds at 1652°F. (900°C.) for the other coals. These results indicate that the gases and vapors escape through the plastic Lower Banner coal much more easily than through the other medium-volatile coals; therefore, since the escape of these volatile carbonization products depends on the permeability of the plastic layer (which in the BM-AGA test forms a continuous envelope surrounding the uncarbonized part of the charge) plastic Lower Banner coal must be more permeable than the other coals. The expanding property was measured in the Bureau of Mines sole heated oven[1] at a charge density of 55.5 pounds per cubic foot, with the heated wall (or sole) maintained at 1742°F. (950°C.) and under a constant pressure of 2.2 pounds per square inch. Table 3 shows that, under these conditions, Lower Banner coal contracted 6.2 percent whereas the other coals expanded 9.8 to 19.0 percent. Lower Banner coal contains 76.9 percent fixed carbon on the dry, mineral-matter-free basis, which ranks it well within the range of coals that may be expected to expand during carbonization. As coal expands because the escape of volatile decomposition products from the plastic layer is retarded, it follows that a contracting coal like Lower Banner offers slight resistance to evolution of these volatile products.

The fact that the carbonizing properties of Lower Banner coal differ appreciably from those of three medium-volatile coals in respect to agglutinating value, internal gas pressure, and expansion could be explained by the higher fluidity of Lower Banner coal, as indicated by the Gieseler test. High-volatile coals, which are contracting, generally are highly fluid by the Gieseler method of testing, whereas medium- and low-volatile coals, which are frequently expanding, are much less fluid. It seems probable that high fluidity (or low viscosity) permits gases and vapors to escape from the plastic layer easily so that the charge does not expand and no significant gaseous pressures develop. This hypothesis has been suggested by Russell[9] to explain the contracting property of high-volatile coking coals which generally show high fluidity by the Gieseler tests; however, it must be recognized that factors other than high fluidity may cause coals to possess the properties that characterize Lower Banner coal and differentiate it from other medium-volatile coals. Oxidation of coal effectively lowers the agglutinating value, the maximum internal gas pressures, and the expansion; and similar effects may be produced by blending with inerts, such as fusain or coke breeze. Obviously, Lower Banner coal was not oxidized, because one of the primary effects of oxidation is lowering of the maximum fluidity shown by the Gieseler test; neither was any inert added to the sample. Although splint cannot be considered an inert in the carbonization of coal, it is possible that, if present in large proportions, it may cause the effects obtained by blending inerts with coking coals. Mott and Wheeler[7] have noted that durain (the British equivalent of American splint) is a valuable constituent of coking slacks in concentrations as high as 40 percent, but because it lowers the swelling power of a mixture, it may cause poor agglomeration if present in higher concentrations.

SUMMARY AND CONCLUSION

Lower Banner coal differs from three medium-volatile Appalachian coals in that it yields weaker coke and contracts during carbonization. This difference is believed to be due to the dissimilar plastic properties of Lower Banner coal, which permit its volatile decomposition products to escape through the plastic layer easily and at relatively low pressures. Lower Banner coal is predominantly splint, whereas the others are bright coals and this difference in petrographic composition probably accounts for the unlike carbonizing properties. Although the data are too limited to warrant a conclusion on the manner whereby this modification of the plastic property is effected, two explanations are indicated:

1. Splint and cannel constituents increase the fluidity of plastic coal.

2. Splint and cannel constituents reduce the agglomeration, or cohesive property, below that necessary to retard the escape of volatile products.

The latter explanation is more plausible because splint and cannel are less fusible than other types of coal and therefore would not be expected to increase the fluidity of plastic coal.

It is apparent from these results that certain carbonizing properties of medium-volatile coal are not predictable from chemical analyses and that petrographic composition may modify these properties more than has been recognized generally.

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