than the rock in most of the oxidized zone. An analysis by Ledoux & Co., New York, of the residual soil on basalt near Anse d'Hainault showed that it contains 17 per cent of iron.

A concentrated deposit of particularly rich red clay containing some hematite was found covering a few square meters on the south slopes of the hill. It was probably concentrated by leaching and by the sorting action of running water.

The area of less oxidized ferruginous soil includes possibly several square kilometers but contains no ore of commercial quality.

Other exposures of basalt that break down into similar red hematite-bearing earth were noted in sea cliffs between Chardonnières and Les Anglais and west of Les Anglais. More promising deposits may perhaps be found in some of the areas of basaltic rocks.

RESIDUAL DEPOSITS ON LIMESTONE BETWEEN JÉRÉMIE AND BARADÈRES.

The other type of deposit also is residual but is found in areas of massive upper Eocene limestone, particularly in the region between Jérémie and Baradères. The limestone breaks down first into a soil that is colored red by ferric oxide. An analysis by Ledoux & Co., New York, of this residual soil on limestone about 10 kilometers west of Baradères showed that it contains 16.80 per cent of iron.

Further action on this soil by percolating water produces here and there lumpy concretions of hard brown limonite or hematite. Most of the lumps are less than 2 centimeters in diameter but some are much larger. A few lumps about 10 centimeters long were seen. Running water frequently washes away the loose red soil and concentrates deposits of little limonite pebbles in the gullies. Such deposits are of no commercial value. It is barely possible that material concentrated as cave breccia in the numerous sink holes might be of better grade.

NONMETALS.

By John S. Brown and Wendell P. Woodring.

LIGNITE.

The Republic of Haiti contains probably the most extensive deposits of lignite in the West Indies proper. The largest potential lignite field is in the northwestern part of the Central Plain near Maïssade, but there are other deposits near Camp Perrin, in the arrondissement of Les Cayes. Beds of impure lignite and carbonaceous clay in the Asile Valley are mentioned on page 229. Beds of black chert in upper Eocene limestone (see p. 134) and pieces of carbonized wood in Miocene beds have led to reports of deposits of lignite. The Miocene deposits are the only ones in the Republic that were laid down under conditions favorable for the accumulation of vegetable débris. Miocene rocks in regions not explored during the reconnaissance may possibly contain beds of lignite. It is not likely that coal of higher rank than lignite will be found anywhere in the Republic.

Lignite Near Maïssade.

Several accounts of the deposits of lignite in the northwestern part of the Central Plain have been published, but the report by Tippenhauer[1] is the only one that has been examined.

The beds of lignite are confined to the Maïssade tongue of the Thomonde formation. The area containing lignite probably coincides with the area floored by Maïssade rocks, embracing about 100 square kilometers. (See Pl. XXXVI.) This estimate is based on the assumption that the beds of lignite extend across the trough of the Central Plain syncline, where they are concealed by younger beds of the Maïssade tongue. The outcrop of the lignite-bearing beds on the northeast limb of the syncline is also concealed by stream deposits.

The lithology and stratigraphic relations of the Maïssade tongue are discussed on pages 168-173.

Most of the beds of lignite occur in the middle part of the Maïssade tongue, interbedded with sandstone, siltstone, and clay containing a mixture of marine and brackish-water mollusks or only brackish-water mollusks. The lithology and fossils show that these beds were laid down in a coastal swamp. The part of the Maïssade tongue containing lignite was examined on Rivière Frio south of Maïssade, and on Rivière Fond Gras, Rivière Fond Bleu, and Rivière Blanche northwest of Maïssade. At all these localities the beds dip at angles of 45° to 70° northeastward, toward the trough of the Central Plain syncline, which extends northwestward approximately through Maïssade. Farther to the northeast the beds flatten rather abruptly and dip at angles of 2° to 6° toward the trough of the syncline. The beds of lignite were not examined in this region, where they dip gently.

Sections showing the thickness of the beds of lignite are given on pages 170-173. The section on page 173, measured on the right bank of Rivière Frio about 100 meters above the crossing of the road from Maïssade to Hinche, shows two beds of lignite. The lower bed, containing many dirty streaks, is 2.5 meters thick. The upper bed is 1.47 meters thick, but it contains two benches of lignite 14 and 17 centimeters thick, separated by carbonaceous clay. Sample No. 2 of the table of analyses on page 482 was obtained from a channel of uniform width across the entire thickness of the upper bed. Sample No. 1 was obtained from the upper bench of lignite in the upper bed. The section measured on Rivière Fond Gras a short distance above its confluence with Rivière Canot (see p. 172) shows four

[1] Tippenhauer, L. G., Beiträge zur Geologie Haïtis; VI, Das Lignitlager von Maïssade und der Aufsteig zum Zentralplateau von Gonaïves und von Norden aus: Petermanns Mitt., Band 47, pp. 193-199, pls. 15 and 16 (map and sections), 1901.

beds of lignite having a thickness of 9, 67, 93, and 22 centimeters in ascending order. The thick beds contain partings and benches of dirty lignite or carbonaceous clay. A bed of lignite 17 centimeters thick was measured in the section of beds in the lower part of the Maïssade tongue as exposed on Rivière Fond Bleu. Five beds of lignite having a thickness of 5, 54, 75, 125, and 48 centimeters in ascending order are shown in the section on page 171, measured on Rivière Blanche. All the beds contain partings of impure lignite and clay.

Not enough field work was done to determine the number and continuity of the lignite beds. The section on Rivière Blanche, which includes the greater part of the lignite-bearing series, shows five beds. The beds probably are lenticular.

The lignite was examined only on weathered outcrops. Most of it is dark brown and has a woody texture and dull luster, but some of it is black and harder and has a shining luster. The black, shining lignite may occur in lenses in the dull, dark-brown lignite or it may make up entire beds. The surface of the dark-brown lignite shows a network of cracks due to loss of moisture by evaporation. The black lignite shows fewer cracks.

The following table gives the results of analyses of two samples collected on Rivière Frio:

Analyses of lignite from Maïssade.

[Made at the Pittsburgh laboratory of the United States Bureau of Mines; H. M. Cooper, chemist.]

Form of sample analyzed.	Proximate analysis.				Ultimate analysis—sulphur.	Heating value (calories).
	Moisture.	Volatile. matter.	Fixed carbon.	Ash.		
Sample 1:						
As received	31.55	29.91	28.79	9.75	3.89	3,737
Air dried	21.50	34.30	33.02	11.18	4.46	4,285
Moisture free	....	43.70	42.06	14.24	5.68	5,459
Moisture and ash free	....	50.96	49.04	....	6.62	6,365
Sample 2:						
As received	26.18	27.55	20.69	25.58	4.15	2,594
Air dried	16.08	31.32	23.52	29.08	4.72	2,949
Moisture free	.....	37.32	28.03	34.65	5.62	3,514
Moisture and ash free	....	57.10	42.09	....	8.60	5,377

The samples were taken by cleaning off the weathered surface to a depth of a few centimeters and cutting a channel about 10 centimeters wide and deep across the bed. The material thus obtained was broken into small pieces, quartered, and placed in a can.

As these samples were collected from the outcrop they contain less moisture than samples from underground workings. The loss of moisture is shown by the numerous cracks in the lignite at the outcrop. Sample No. 2, from a channel across the entire bed, includes dirty lignite and carbonaceous clay, some of which could probably be excluded in mining. The high percentage of ash and low heating value of this sample are due to this incombustible material.

Tippenhauer[1] records the following analysis, but the locality and form of material analyzed are not given:

	Per cent.
Moisture	16.05
Volatile matter	41.30
Fixed carbon	22.65
Ash	20.00
Sulphur	3.19
Heating value in calories	3,829

This analysis represents a picked sample, as the heating value is relatively high. The percentage of moisture is lower and the ratio of fixed carbon to volatile matter is much lower than in the analyses on page 482.

The relative value of the Maïssade lignite is discussed on pages 485-487.

Lignite near Camp Perrin.

It has long been known that lignite beds crop out near Camp Perrin, in the arrondissement of Les Cayes. Eugène Nau[2] published an official report on this lignite in 1859-60, and Thomasset[3] described it in 1898.

The lignite-bearing beds were examined on La Ravine du Sud and on La Rivière. They are of Miocene age and were deposited in lakes, fresh-water swamps, and deltas. Their lithology and structure are described on pages 232-236.

The lignite beds are of unknown extent, but they undoubtedly underlie several square kilometers and probably lie beneath all the dissected lowland near Camp Perrin except a small part near the northern border. They are concealed by alluvium except along some of the streams and ravines.

In the section exposed on La Ravine du Sud (see p. 234) there are at least three or four beds of lignite that are fairly free from partings of impure lignite and clay, ranging from 50 centimeters to 1 meter in thickness. The other beds contain so much incombustible material that they are worthless. Other beds higher in the section might be found by exploring the gravel-covered region to the south. The thickest well-exposed bed is 90 centimeters in thickness. Another poorly exposed bed seems to be nearly a meter thick. On La Rivière there are at least three

[1] Tippenhauer, L. G., op. cit., p. 195, 1901.

[2] Nau, Eugène, one of several articles on the mineral deposits of the Republic in Le Moniteur, 1859-1860. Published also in La République, 1859-1860. These reports were not examined.

[3] Thomasset, Henri, Rapport sur les gisements de charbon de l'Asile et du Camp-Perrin (addressé à Monsieur le Secrétaire d'État des Travaux Publics) : Le Moniteur, 53[e] Année, No. 46, pp. 358-359, Port-au-Prince, 8 juin, 1898.

beds, and possibly more. The thickest is 2 meters thick but contains many partings of clay. In one bed 40 centimeters of pure lignite was found. The beds appear to change abruptly in thickness and grade along the strike.

The lignite is black and has a bright luster. It contains many joints, and the joint faces are smooth and shining. Samples taken from outcropping ledges, unlike samples of lignite taken from the Central Plain, contain few cracks, and the material breaks up along joint planes. It has the appearance of a coal of subbituminous rank. The analyses given below show that this appearance is deceptive. The apparent high rank is due primarily to the folding of the beds, as the jointing is the result of crumpling.

The following table gives the results of analysis of two samples. Sample 1 was collected from bed 33 of the section measured on La Ravine du Sud (p. 234); sample 2 was collected from the best bed, about 40 centimeters in thickness, exposed on La Rivière. The samples were collected as described on page 482, except that two channels were cut for sample 1, and three channels for sample 2. The channels were spaced at intervals approximately equal to the thickness of the beds. No effort was made to exclude partings of impure lignite or carbonaceous clay, such as would have to be taken in mining.

Analyses of lignite from Camp Perrin.

[Made at the Pittsburgh laboratory of the United States Bureau of Mines; H. M. Cooper, chemist.]

Form of material analyzed.	Proximate analysis.				Ultimate analysis—sulphur.	Heating value (calories).
	Moisture.	Volatile matter.	Fixed carbon.	Ash.		
Sample 1:						
As received	23.51	22.90	16.53	37.06	0.73	2,270
Air dried	15.95	25.17	18.15	40.73	.80	2,494
Moisture free	....	29.94	21.61	48.45	.95	2,968
Moisture and ash free	....	58.08	41.92	....	1.84	5,758
Sample 2:						
As received	22.08	21.87	12.98	43.07	1.42	1,905
Air dried	14.80	23.92	14.18	47.10	1.55	2,083
Moisture free	....	28.07	16.66	55.27	1.82	2,445
Moisture and ash free	....	62.75	37.25	....	4.07	5,466

The analyses show a lower percentage of moisture than that in the Maïssade lignite. If the lignite in both regions were mined samples from underground workings would contain a higher percentage of moisture, although the amounts of moisture in weathered samples are probably comparable. The lignite from Camp Perrin has a much lower ratio of fixed carbon to volatile matter than the Maïssade lignite, indicating that it probably is an undeveloped cannel coal. It contains a high percentage of ash and has low heating value, which is due principally to the large amount of incombustible material in the partings.

Thomasset[1] recorded the following two analyses, which were made in Paris:

Analyses of Camp Perrin lignite.

	1	2
Moisture	27.74	24.10
Volatile matter	27.06	31.90
Fixed carbon	27.98	31.83
Ash	17.22	12.17
Heating value in calories (not dried)	3,466	4,200
Heating value in calories (dried)	5,050	5,660

In the ratio of fixed carbon to volatile matter these analyses are different from those given on page 484. The samples may have come from other beds of different composition. Their high heating value indicates that they were picked samples, free from impurities. Thomasset states that about 2 tons of this lignite was shipped to Port-au-Prince and burned in the workshop of the street railway company, where it readily produced steam.

Relative Heating Value.

The relative value of fuels is shown by their heating value. The only industrial establishments in the Republic that use large quantities of fuel are the electric light plants, ice factories, sugar mills, and railroads. Wood is the only fuel now used except the small amounts of coal used in the railroad shops. Most of the wood used in Port-au-Prince is that of the leguminous tree called bayahonde, which grows in the Cul-de-Sac Plain. So far as known no tests have been made to determine the heating value of bayahonde wood. The heating value of the lignite of Maïssade and Camp Perrin as compared to wood is graphically shown in Figure 31.

In this graph the wood burned as fuel in the Republic is given an arbitrary heating value of 3,000 calories for dry wood and 2,250 calories for green wood.[2] The heating value of some coals from the United States is given in the same graph.

At the present time wood for fuel in Port-au-Prince costs 95 cents per cubic meter delivered, weighing about 385 kilograms, or $2.47 per metric ton.[3] If it is assumed that this wood is green and has a heating value of 2,250 calories the heating value of the wood as compared to the heating value of the better grade of lignite of Maïssade (sample No. 1 of

[1] Thomasset, Henri, op. cit., p. 359, 1898.

[2] These figures are based on conversions of the heating value of several woods from the United States given in The use of wood for fuel: U. S. Dept. Agr. Bull. 753, pp. 28-30, 1919.

[3] Based on the cost of wood purchased by the electric company of Port-au-Prince. Information supplied by the Engineer-in-Chief.

analysis on p. 482) is as 2,250 is to 3,737; or, if wood costs $2.47 per metric ton, consumers in Port-au-Prince could afford to pay $4.14 per metric ton for this lignite.

The present price of semibituminous coal from the United States, such as the coal from the New River field of West Virginia (*m*, in Fig. 31), delivered in Port-au-Prince is not known. During the two months preceding the strike of April, 1922, the average price of such coal delivered at Hampton Roads, Va., was $4.62 per ton (2,000 pounds avoirdupois weight), or $5.09 per metric ton. Freight, dockage charges, and insurance probably would bring the price delivered at Port-au-Prince to about $18 per metric ton.

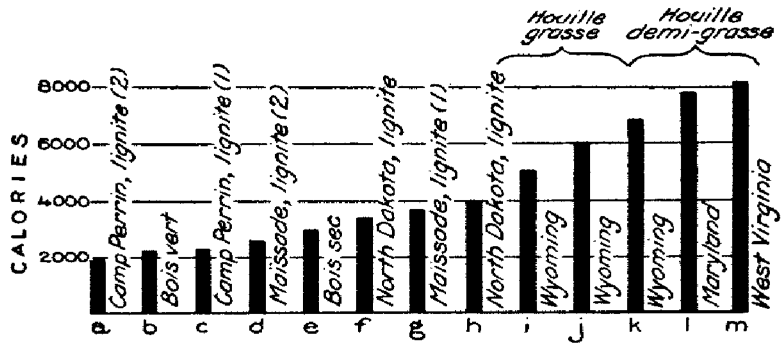

FIGURE 31.—Diagram showing the heating value of Maïssade and Camp Perrin lignite as compared with other coals and wood.

If green wood is worth $2.47 per metric ton and American semi-bituminous coal $18 per metric ton the lignite from Camp Perrin and Maïssade has the following value:

Comparative value of wood, lignite, and coal.

	Green wood at $2.47 per metric ton.	West Virginia semibituminous coal at $18 per metric ton.
Camp Perrin lignite (No. 2)	$2.09	$4.20
Green wood	2.47	4.97
Camp Perrin lignite (No. 1)	2.49	5.01
Maïssade lignite (No. 2)	2.85	5.72
Dry wood	3.29	6.62
Maïssade lignite (No. 1)	4.10	8.24
West Virginia semibituminous coal	8.96	18.00

Although this table is based on some unknown factors it gives an idea of the relative value of the lignite. Coal at $18 per metric ton is too expensive for ordinary industrial uses, as with coal at that price wood is worth twice its present cost.

The Camp Perrin lignite therefore can not compete with wood at the present time. In composition this lignite resembles undeveloped cannel coals of Tertiary age in Texas, but its heating value is lower. Picked samples would show much higher heating values than those given on page 484, but picked samples could not be mined. The beds are steeply inclined and would have to be worked from steeply inclined or vertical shafts. The abrupt change in dip and the faulting would increase the difficulties. The rocks that overlie the lignite beds are soft and could not be supported without extensive timbering. These conditions and the distance to industrial centers prohibit the exploitation of these beds.

Under present conditions of transportation the lignite at Maïssade can hardly be utilized. In composition and heating value the grade of lignite represented by sample 1 in the table on page 482 closely resembles the lignite of Eocene age in Montana and North Dakota. If a railroad could be extended into the Central plain this lignite could compete with wood under favorable conditions of production, even at the present time. There are beds containing enough lignite of this grade to be mined. Near the trough of the Central Plain syncline, where the beds dip gently, the lignite could be mined in open cuts by stripping the overburden. If the demand for fuel increases as the available supply of wood becomes exhausted, these beds should be examined to determine the available tonnage, methods of production, and methods of treatment.

Lignite as mined contains a high percentage of water, which lowers its heating value. When exposed to the air it rapidly loses some of its moisture and "slacks," and is then an unsatisfactory fuel. If the lignite is to be used at a distance from the deposits it would require some treatment in order to obtain from it the maximum amount of heat. In Germany "brown coal" of lower rank than the lignite of Maïssade is successfully briquetted without the use of a binder after being dried. The lignite of North Dakota has not yet been treated on a commercial scale, but the results of tests indicate that the most successful treatment is to carbonize the lignite and briquet the carbonized residue with the aid of a binder.[1] An elaborate series of tests probably would be required to determine the best method of treating the lignite of Maïssade. It is possible that it would not "slack" too rapidly to be used in near-by industrial centers. When brought from the mine small pieces "slack" less rapidly than large pieces. Samples taken from the weathered outcrop on Rivière Frio in February, 1921, were cracked but had not crumbled by September, 1922. Samples from underground workings would, however, contain more moisture and would "slack" more rapidly.

[1] See Babcock, E. J., Economic methods of utilizing western lignites: U. S. Bur. Mines Bull. 89, 1915.