NORTH CAROLINA GEOLOGICAL AND ECONOMIC SURVEY

JOSEPH HYDE PRATT, Director and State Geologist

BULLETIN No. 33

# The Deep River Coal Field of North Carolina

BY

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Prepared by
United States Geological Survey
In Cooperation with the
North Carolina Geological and Economic Survey

## LETTER OF TRANSMITTAL

CHAPEL HILL, N. C., June 1, 1923.

*To His Excellency,* CAMERON MORRISON,

*Governor of North Carolina.*

SIR:—There has just been completed a report on "The Deep River Coal Field of North Carolina," which has been prepared by the State Survey in coöperation with the United States Geological Survey. The investigation of this coal field has aroused a great deal of interest throughout the State in regard to the occurrence of a commercial quantity of coal in North Carolina. There is a very large demand for information regarding this occurrence, and I would submit the report for publication as Bulletin No. 33 of the series of publications of the North Carolina Geological and Economic Survey.

Yours respectfully,

JOSEPH HYDE PRATT, *Director,*

*North Carolina Geological and Economic Survey.*

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# PREFACE

For about one hundred and fifty years coal has been known to occur in North Carolina, and for many years there has been more or less interest aroused amongst our people as to the possibility of developing commercial fields of coal. Considerable prospecting and some mining has been done during this period, but most of the work was a failure due to several causes, chief of which perhaps was lack of capital and having men unfamiliar with coal mining in charge of operations. As a result the public began to consider that either the coal was so poor or the mining conditions so bad that it was doubtful if coal mining could ever be made to pay. This was probably a natural sequence considering what was known of the occurrence of some of the coal which was in very thin seams and obviously could not be worked profitably. Also considerable of the coal that was first used was weathered and did not have the heating properties expected of it. The present investigation was undertaken with the idea that the coal of the Deep River Field is much more valuable than has been generally believed and that it should become a source of fuel, not only for mills and railroads of Eastern North Carolina, but for a domestic use in the form of coke.

There are two areas in the State in which coal occurs: one known as the Deep River Coal Field covering portions of Chatham, Lee and Moore counties, and which is described in detail in this report; and the other, the Dan River Coal Field covering portions of Stokes and Rockingham counties. The coal beds of both these fields occur in sandstones and shales of Triassic age, which outcrop in comparatively narrow belts.

The Dan River Field has been described in detail by Mr. R. W. Stone, Geologist of the United States Geological Survey, in Economic Paper 34, 1914, pages 115-149, of the State Survey's publications; and the conclusion reached in regard to this coal field was that "after a thorough and careful examination of the Triassic beds in the Dan River Field the conclusion is reached that there is no reason to expect to find commercially valuable coal beds in this district." This report substantiated the information that the Survey had regarding this field, and since this report came out there has been no further prospecting or consideration given to this field from a commercial standpoint.

The Deep River Coal Field has been investigated from time to time over a period of nearly one hundred years, but only one of these investigations was more than a superficial examination. This was the report of Dr. H. M. Chance, made in 1884-85 for the North Carolina Department of Agriculture. Dr. Chance's conclusions, which were not particularly favorable and which are discussed in this report, were that in the area described "the prospects are sufficiently encouraging to warrant a thorough exploration of each individual tract by the landowners; that in the area between Farmville and Gulf two beds of coal exist that may be considered workable."

In discussing the subject the authors give a very interesting history of the discovery and development of coal in this field. It seems evident that the coal was discovered at Gulf some time prior to 1775, and from that time to the present there has been considerable uncertainty as to the quantity and quality of the coal in the area.

The geography of the field shows it to extend from a short distance northeast of Cape Fear River in a southwesterly direction to Carthage and in the other direction from Sanford on the southwest to a few miles beyond Gulf on the northwest, embracing portions of Chatham, Lee and Moore counties. It is known and designated as the Deep River Coal Field because almost all the prospecting and developing has been on or near that stream from near Glendon to the point where Deep and Haw rivers unite to form the Cape Fear. The area in which the presence of coal has been demonstrated is only a small part of the area outlined above.

The geologic formations and structure cover a considerable portion of the report and are discussed in great detail. The coal beds are associated with sandstones and shales which are of Triassic age and belong to the Newark group. This Newark group of rocks includes the red sandstones of the Connecticut Valley in Connecticut and Massachusetts, and the red sandstone and shale of Virginia. This Newark group in the Deep River Field consists of three generally recognized parts: a lower formation to which the name Pekin has been given, composed largely of red and brown sandstone; a middle formation of light colored or drab shale, sandstone and coal beds, to which has been given the name Cumnock; and an upper formation called the Sanford, consisting mainly of red conglomerate of great though unknown thickness. This portion of the report also describes the character and location of the dikes cutting through the formations, and faults that were noted; and shows cross-sections of the formation at various places throughout the area. A geologic map of the area also accompanies the report.

In describing the coal, attention is called to the occurrence of two oenches known as the upper and lower. Formerly in speaking of the thickness of the coal beds both benches were included in the width given as seven feet six inches, and it is believed that this entire thickness was originally mined. It is only the upper bench, where the coal varies in thickness from three feet to nearly four feet, that is considered at the present time as commercial coal, although it is believed that under certain conditions this lower bench might be mined and cleaned profitably. The extent of the workable coal and available tonnage is estimated by the geologists as approximately sixty-eight million tons of recoverable coal in the district west of the Deep River fault; and that mining can be carried on profitably to a depth of two thousand feet. The area in which this tonnage is included is about twenty-five square miles, and it is considered reasonable to assume that the coal bed throughout this area averages at least three feet in thickness of recoverable coal. The character and quality of the coal have been very carefully studied and physical and chemical analyses are given of coal taken from various sections of the area. One interesting feature of the chemical composition of the coal is that it contains approximately two per cent of nitrogen, which could be obtained in the form of ammonium sulphate as a by-product in coking the coal, which would give approximately twenty-three pounds per ton of coal. The coking test showed that the coal would make a coke of very good quality in so far as could be determined by a laboratory test and is fairly equal to either Freeport or Pittsburgh cokes. It is believed that one use of the Deep River coal that should be given careful consideration is to coke it, using the coke obtained as a domestic fuel, and the yield of gas for generating electric power for transmission.

The ammonium sulphate, obtained as a by-product, will be of large value for agricultural purposes. There would also be obtained as another by-product approximately twenty-two gallons of tar (dehydrated) per ton of coal. The by-product yield in coking this coal compares very favorably with yields from Freeport coal.

The report also discusses briefly the possibilities of oil in the area, and the conclusions of the geologists are that from a geological point of view all the evidence collected in the field bearing on this question is of a negative character.

The present report has been prepared through the coöperation of the United States Geological Survey and the North Carolina Geological and Economic Survey. Geologists were detailed from the Federal Survey staff to make the investigation. The United States Bureau of Mines also coöperated in the investigation by sampling the coal and making chemical and physical analyses and washing and coking tests of same.

The Director of the Survey, who made several trips into the field during the investigation, wishes to extend the thanks of the Survey and of the geologists making the investigation to the citizens of the community for their kindness and courtesy in assisting in securing data on the mineral resources of the area. Others who were particularly interested in the coal itself were most liberal in giving their services and means at all times, and the Survey desires at this time to express its special thanks to Mr. Charles Reeves of Sanford, Mr. William Hill of Cumnock, Mr. Bion Butler of Southern Pines, Mr. J. S. Cox of the Norfolk Southern Railway, General E. F. Glenn of Glendon, Dr. M. E. Street of Carthage, and Mr. McIver, for these services.

While the history of coal mining operations in this Deep River Field has been one of many failures due to lack of adequate capital to develop a mine under the prevailing mining conditions, to lack of experience in coal mining of those in charge of the work, and to lack of adequate transportation facilities, today, on account of changed conditions of marketing and transportation facilities and the thousands of homes calling for domestic fuel supply, there seems to be no reason why the mining operations should not be reasonably successful. This of course is predestined on there being an adequate supply of coal that can be obtained at moderate cost, the probability of which is discussed in this report.

Joseph Hyde Pratt,
*Director,*
*North Carolina Geological and Economic Survey.*

# The Deep River Coal Field of North Carolina

BY

MARIUS R. CAMPBELL and KENT K. KIMBALL

## INTRODUCTION

### General Statement

The Deep River coal field of North Carolina (see Key map on Pl. 1 in pocket), although it has been known for about 150 years, has had an unfortunate history of failure after failure in attempts to mine and market the coal, until the general public has either forgotten that such a coal field exists, or is strongly imbued with the idea that the coal is so poor and the mining conditions are so bad, that it is doubtful if it ever could be made to pay. The present report contains the results of a recent examination by geologists of the United States Geological Survey coöperating with the North Carolina Geological and Economic Survey, which shows that the coal is of excellent quality; that the mining conditions are fairly good for a rather steeply dipping coal bed; and that the general conditions in the surrounding region are favorable for the development, on a larger scale than has ever been attempted, of that part of the margin of the trough extending from Cumnock (Pl. 1, in pocket) southwestward at least to Carbonton, and possibly from Cumnock for a few miles southeastward toward Colon.

The coal beds of the Deep River Field occur in sandstone and shale of Triassic age, which crop out in a comparatively narrow belt from Oxford near the northern border of the State to the South Carolina line, twelve or fifteen miles west of Pee Dee River. Coal has been reported at many places in this belt, but the only known coal of commercial importance is found on Deep River, west and northwest of Sanford.

It was found necessary, before attempting a study of geologic conditions in the Deep River Field, to make a base map upon which the geologic data could be plotted, as no map of this region, worthy of the name, could be found. The map, shown in Plate 1, is the result of a survey carried on by the junior author assisted by William J. Cox and Lynn J. Adcock, and much of the success of the report is due to the indefatigable work of these men in covering the ground in the appointed time. The survey was made with plane-table and telescopic alidade and distances were determined by stadia measurements. When the major part of the map had been completed it was found that the dikes, which are present in great numbers, are magnetic and have a decided influence on the magnetic needle of the plane-table. As courses were determined by this needle, any local attraction produced by a dike would tend to cause an error in the direction of the line being surveyed. Owing to this source of local attraction many errors will be found in the directions of the roads, and the geographic relations of features shown on the map may be quite different in detail from the relations of the same features on the ground; but, as the local variation due to one dike may be in an opposite direction from that due to another dike, the effect of one tends to neutralize the effect of the other and for that reason the map, taken as a whole, is approximately correct. The public is, however, cautioned against depending, in important matters, solely upon this map for distances and directions of surveyed lines and acreage inclosed by such lines.

In carrying on both the topographic and the geologic work in this field, the writers found the citizens, as a rule, willing and anxious to help in securing data on the mineral resources of the country; and as it is impossible to enumerate individuals who furnished information of this sort, the writers wish to extend their thanks to all for their kindness and courtesy. Those who are most deeply interested in the coal itself contributed in many ways to the success of the work; chief among those who gave their services and means at all times are Mr. Charles Reeves, who assisted very materially by furnishing information regarding coal prospects, maps, and the result of drilling operations of the Carolina Coal Company; Mr. William Hill, then General Manager of the Cumnock Coal Company, who assisted the writers in gathering information concerning the Cumnock mine, the prospecting work that had been done by the Cumnock Coal Company and the logs of deep wells which the company had drilled on its property; Mr. Bion Butler of Southern Pines, who furnished geologic data which has been of great value in solving some of the difficult problems encountered in the field, and without which the writers would have found it impossible to have completed their work in the time alloted for that purpose; and Mr. J. S. Cox, local superintendent of the Norfolk Southern Railroad for a motor car trip over this line from Hemp to Raleigh. General E. F. Glenn, Doctor M. E. Street and Mr. McIver were also helpful in furnishing information regarding general conditions and in assisting the writers in getting about the field.

## History of Discovery and Development

The history of the discovery and development of coal in this field has never been recorded in print, and consequently much of it has been lost, or if preserved, it exists only in tradition.

The first published account of coal that the writers have discovered is contained in a letter written by Professor Olmsted[1] from Chapel Hill in 1820. In this letter he says:

An extensive secondary formation has lately been discovered near us. On the road between this place and Raleigh, traveling eastward, we come to it four miles from the college; but at another point it has been discovered within two miles of us. It is a sandstone formation . . .

It was natural to look for coal here and I have for some time directed the attention of my pupils, and of stonecutters to this object. Two or three days since one of the latter brought me a handful of coal, found in this range, on Deep River, in Chatham County, about 20 miles south of this place. The coal is highly bituminous, and burns with a very clear and bright flame. It is reported that a sufficient quantity has already been found to afford an ample supply for the blacksmiths in the neighborhood.

From the quotation just given, it would seem that the Deep River coal was discovered only a few years before 1820. It is, however, probable that it had been known locally for many years, but had not been brought to the attention of the State Geologist. This view of the case is substantiated by Professor Olmsted's [2] statement in his report of 1824, which is as follows:

In addition to the foregoing presumptions that coal might be found in the district of country under consideration, we have it in our power to say that coal has actually been discovered in this region, and that a bed of considerable extent has been opened not far from the Gulf[3] on Deep River.

It is about 50 years since this coal bed was first discovered. Mr. Wilcox, an enterprising gentleman, proprietor of the Old Iron Works at the Gulf, took some pains to have it opened, and to introduce the coal into use.

Professor Emmons[4] corroborates this statement in his report of 1852 in which he says: "It [the Horton mine at Gulf] was known in the Revolution, and a report made to Congress, respecting it, is still extant." The writers have searched for this report, but have not been able to find it.

It also is probable that the outcrop of the coal beds from Farmville to Carbonton was known and prospected in the early part of the nineteenth century. Chance[5] says:

Coal was dug from open pits for blacksmithing in the Deep River coal field early in this, if not indeed in the last century, but no systematic attempt was

[1]Olmsted, Prof. D., Red sandstone formation of North Carolina, Am. Jour. Sci., vol. 2, page 175, 1820.
[2]See manuscript, page 5.
[3]The name Gulf was given to the settlement at the sharp bend of Deep River, by boatmen who found here an unusually deep portion of the river between shallows formed by the dikes where they cross the stream.
[4]Emmons, Ebenezer, Report of Professor Emmons in his Geological Survey of North Carolina, p. 131, Raleigh, 1852.
[5]Chance, H. M., Report on North Carolina coal fields to the Department of Agriculture, p. 23, Raleigh, 1885.

made to open the field to market until the slackwater improvement of the Deep River. As these improvements were seriously damaged by floods soon after the completion, the people were discouraged from further attempts at that time. The next attempts were made upon the completion of the railroad from Fayetteville to Egypt and the Gulf. Some coal was shipped over this road from the shaft at Egypt, but the cost of transportation to Fayetteville and trans-shipment and towing down the Cape Fear River to Wilmington . . . on a river full of shoals, was doubtless too great to leave any profit. Operations were most actively pushed in the period immediately preceding the [Civil] war. During the war coal was mined at Farmville, Egypt, Gulf, and the Evans' place, and shipped by river to Fayetteville and to Wilmington, where it was used to some extent by blockade runners, but the aggregate amount thus shipped must have been quite small.

From the quotations given above and from information gathered in the field it seems evident to the writers that the coal of this field was discovered at the Gulf some time previous to 1775 and that the Horton coal mine was in operation at that place at least some of the time during the Revolution, but without doubt the mine was operated in a small way to supply local needs.

It is also probable that within the next 50 years after the Horton mine was opened the outcrop of the coal bed had been prospected and was fairly well known from Farmville (now the Carolina coal mine) at least as far as Gulf. Peter Evans, who owned the plantation in the great northward bend of Deep River, including the village now known as Cumnock, began mining coal, it is reported, on his property, then called Egypt[1] in 1830.

In 1851 the Egypt plantation was sold to L. J. Houghton and Brooks Harris. Harris soon acquired the interest of Houghton, and in 1852 sank the Egypt shaft, probably the most important single piece of development work ever undertaken in this coal field. The shaft pierced the principal or Cumnock coal bed at a depth of 430 feet, but was continued to a total depth of 460 feet. The property changed hands frequently, and in 1854 passed into the ownership of the Governors Creek Steam Transportation and Mining Company, which operated the mine until after the Civil War when, by order of the Convention, the name was changed to "The Egypt Company."

The market for this coal was then largely to the east and the great problem was to get it to seacoast cities at a cost that would enable it to be sold at a profit, in competition with coals from other fields. Two lines of outlet for the coal were considered: (1) an all-water

[1]The original name of the settlement on this plantation was LaGrange, but this name was changed by Peter Evans to Egypt, as the result of a facetious remark by one of his neighbors. One day, as the story goes, Evans met Peter Smith, a Scotchman, on the road and asked him where he was going. Smith replied that he was going to the "land of Egypt" to get corn. Evans was so pleased with having his plantation called "The land of Egypt" that he ordered a gift of corn to Peter Smith, and soon thereafter had the name of his plantation and the little settlement changed from LaGrange to Egypt.

route by the establishment of slack-water navigation on Deep and Cape Fear rivers, and (2) by railroad to Fayetteville and then by barges down Cape Fear River from that place to Wilmington. The railroad was the first to be secured, construction beginning at Fayetteville in 1855. Egypt was, during the Civil War, the western terminus of this road and considerable coal mined at Farmville, Egypt and Gulf was shipped to Fayetteville to supply the arsenal at that place or to be transshipped to Wilmington for the use of blockade runners.

The building of locks and dams to secure slack-water navigation between Fayetteville and Carbonton was begun by private parties about the same time as railroad construction was begun, but it resulted in failure and the State took over the project. Just as the locks and dams were completed war broke out and they were forgotten in the stress of wartime conditions, and all of the dams went out, except the Lockville, Gorgas and Gulf dams, which were kept up to supply water-power for grist mills. Upon the termination of the war, attention was again attracted to the need of slack-water navigation on Deep River and the Deep River Navigation Company was organized and began rebuilding the locks and dams, largely for the purpose of transporting iron ore from the vicinity of Buckhorn on Cape Fear River to the Endor furnace on Deep River. This company maintained locks and dams on Cape Fear River at Battles and Buckhorn and on Deep River at Lockville, Gorgas, Endor and Gulf. A dam was also built at Carbonton, but the lock was never used. It is reported that slack-water navigation was carried on in 1873 and for several years thereafter, but eventually the locks and dams were permitted to fall into decay as the iron business declined and finally all were swept out of existence, and slack-water navigation on Deep River was a thing of the past.

The Egypt mine (Pl. III) had a checkered history after the Civil War; ownership changed frequently, but no one seemed to be able to operate at a profit. Finally in 1870 the mine was closed down and it remained flooded until 1888 when it was reopened, but with no better success in mining and marketing the coal than had been attained before. The mine continued in operation until 1902, but owing to several bad explosions of gas and to financial difficulties it was again closed and remained under water until 1915. At the last mentioned date the property passed into the hands of the Norfolk Southern Railroad Company and was rehabilitated under the name of the Cumnock Coal Company, the name Egypt being no longer acceptable on account of the many disastrous explosions that had occurred in the mine when it was operated under that name. From 1915 down to 1922 the entire output of Cumnock mine has been used for railroad purposes, but this has not been great, as the mine has been operated in only a small way. In September, 1922, the property was bought by the Erskine Ramsey Coal Company with the intention of greatly enlarging the mine and increasing its output.

About 1921 the Carolina Coal Company was organized for the purpose of developing a mine at the site of the old village of Farmville in Chatham County, just across the river from the Cumnock mine. The company began the shipment of coal in a small way in the summer of 1922 by trucking the coal to the railroad at Cumnock, but recently grading has been done for a direct connection with the Norfolk Southern Railroad and it is probable that by the time this report goes to press the rails will have been laid and all-rail shipments begun.

The entire history of coal mining operations in the Deep River Field has been one of many failures, due to lack of adequate capital to develop a mine under the mining conditions here prevailing, to lack of experience in coal mining, and to lack of adequate transportation facilities to reach the consumers who were located mostly on the seashore many miles distant. Today conditions of marketing and transportation are very different; the railroads, the cotton mills, and other manufacturing plants are ready and eager for fuel, to say nothing of the thousands of homes that call for a domestic supply, and as the field has now fairly adequate railroad service, there seems to be no reason why mining operations should not be reasonably successful provided there is an adequate supply of coal in the ground that can be obtained at moderate cost.

## The Present Investigation

The present investigation was undertaken with the idea that the coal of the Deep River Field is much more valuable than has been generally believed and that it is a source of fuel for the mills and railroads of Eastern North Carolina if it could be demonstrated that there is large enough tonnage available at a reasonable depth to warrant the investment of capital.

It was fully realized, before systematic work was undertaken, that exposures of coal and the associated rocks are poor and totally inadequate for a minute survey of the field. It was also realized that most of the coal prospects had been opened many years ago and that almost without exception they are now caved so that the coal is as effectually concealed as if mines and prospect pits had never been opened.

To the writers it seemed possible, however, to map the field and determine in a general way whether the coal is lenticular or whether it extends indefinitely along the belt of Triassic rocks as well as across the trough toward the southeast. It also seemed possible, by careful field observation and the plotting of dips to determine with some degree of accuracy the shape of the trough and also the depth of the coal at different points within the trough. The results of the examination herewith presented are far from satisfactory to the writers, but they are about as accurate as it is possible to make them without deep drilling in the interior of the trough.

## GEOGRAPHY OF THE DEEP RIVER COAL FIELD

The Deep River coal field, as outlined on the accompanying map, extends from a short distance northeast of Cape Fear River in a southwesterly direction to Carthage and in the other direction from Sanford on the southeast to a few miles beyond Gulf on the northwest. It embraces parts of Chatham, Lee and Moore counties. It has long been known as the Deep River Coal Field because almost all the prospecting and development has been on or near that stream from near Glendon to the point where Deep and Haw rivers unite to form Cape Fear River, but it should be clearly understood that the presence of coal has been demonstrated in only a small part of the area outlined above.

The field here considered lies mainly in the valley of Deep River and the surface consists of a number of low plateaus or terraces that, near the river and also along its more important tributaries, have been sharply dissected. The altitude ranges from about 165 feet above sea level at Avants Ferry on Cape Fear River to 580 feet on the ridge at Carthage. The latter is the highest land in the field and is a narrow remnant of a plateau that was doubtless once continuous throughout this part of the State, but now has been so dissected by streams that only remnants of its once even surface remain on the inter-stream areas. On the southeastern margin of the field the coal-bearing rocks have been in places deeply covered with white sand which prevents, in large measure, dissection by the streams and consequently this part of the field consists generally, except in the immediate vicinity of the larger streams, of an undissected plain in which the bed rock is effectually concealed by the veneer of white sand.

The area represented by the map is essentially an agricultural country, the principal crops being cotton and tobacco. Recently the raising of fruits of various descriptions has become quite successful in adjacent areas and it seems probable that their cultivation may extend into this district. The river bottoms are particularly fertile, being almost universally cleared and in a high state of cultivation, except a deep fringe of trees, vines, and weeds which line the immediate banks of the rivers, as shown in Pl. 2-A.

The highways generally follow the inter-stream divides, for these, except near the rivers, are generally flat and well suited for highway construction. In building some of the new automobile roads, however, less attention is paid to the surface features and the roads pursue more direct courses than would be possible were they to follow the divide between streams. The railroads, on the contrary, generally follow the minor drainage lines in their courses across the major drainage basins of the region, for in so doing they secure nearly a water grade.

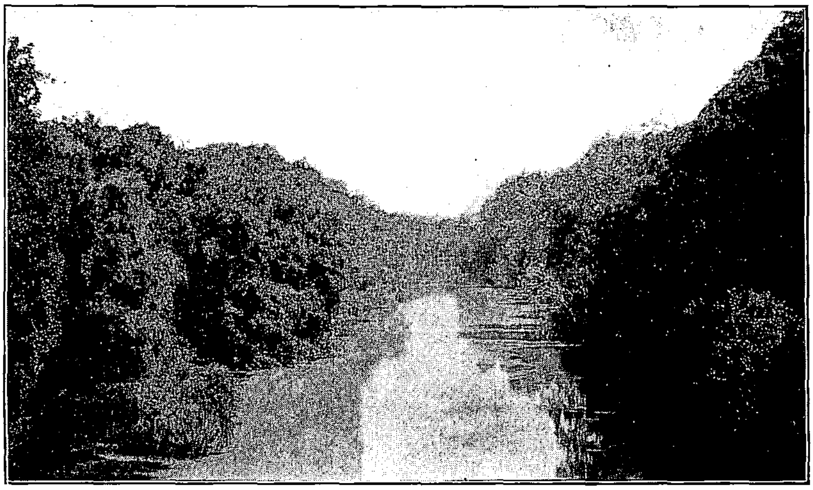
The principal railroad in the field is the main line of the Seaboard Air Line which enters the field from the north near Moncure, passes south through Sanford and leaves the field 1½ miles west of Jonesboro. The Atlantic and Yadkin (a branch of the Southern Railway) extends southeastward from Greensboro to Sanford where it terminates, but through passenger trains are run on to Wilmington over a branch of the Atlantic Coast Line. The Norfolk Southern Railroad has recently acquired or built a line running southwestward from Raleigh to Charlotte. This railroad enters the Deep River Field at Corinth, east of Cape Fear River, traverses the developed coal district about Cumnock and Gulf and leaves the mapped area at Putnam. Two small narrow-gauge lines also serve the field: the Atlantic and Western from Sanford to Broadway and Lillington; and the Randolph and Cumberland through Hallison, Carthage, and Cameron. Formerly a narrow-gauge branch of the Norfolk Southern extended from Carthage to Pinehurst, but train service had been abandoned for some time when the present field examination was made.

The Deep River Coal Field lies near the center of the State, being about 45 miles southwest of Raleigh, 60 miles southeast of Greensboro, 125 miles east of Charlotte, 35 miles northwest of Fayetteville, and 30 miles north of Southern Pines and Pinehurst. Sanford, the principal town, is situated on the main artery of automobile travel from Washington and Richmond to the winter resorts of the South and it also has good automobile roads leading to the more important cities and towns in the surrounding region.

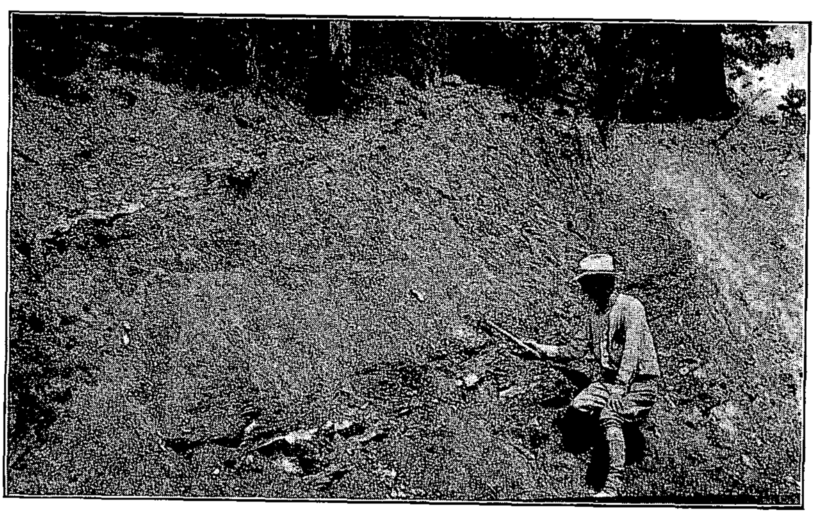
## GEOLOGIC FORMATIONS

### General Statement

The sandstone and shale which are associated with the coal beds in the Deep River Field extend in a narrow belt of outcrop nearly across the State in a north-south direction. This belt begins in a point in



A. Deep River from the Horseshoe Bridge. The bottom on the left is cleared and farmed, except for a fringe of trees and vines on the river bank.



B. Outcrop of the Cumnock coal bed near Gulf. This outcrop, in a recent cut made by the Norfolk Southern Railroad, shows about 4 feet of badly watered coal.

the vicinity of Oxford in Granville County and extends southwestward through the towns of Durham, Sanford, and Carthage, about as shown on Kerr's[1] geologic map of the State to beyond Wadesboro, where it crosses into South Carolina near its southern terminus.

There has been much written on the subject of the geologic age of these rocks, which, according to the fossil remains found in them, appears to have been well determined. The writers, during the course of the present investigation, gave no attention to this phase of the subject, accepting the usage current in geologic literature.

The red sandstone of the Connecticut Valley in Connecticut and Massachusetts; the great belt of red sandstone, shale and trap rock extending from the Hudson River to Culpepper, Virginia; the Richmond, Farmville, and other scattered areas of similar rocks in Virginia; and the rocks of the Dan and Deep River fields of North Carolina all are of Triassic age and belong to what geologists call the Newark group, a name given to them by W. C. Redfield, because of their excellent development in the vicinity of Newark, N. J. Redfield introduced the name as follows:[2]

> I propose the latter designation [Newark group] as a convenient name for these rocks [red sand stones and shales of New Jersey and Eastern Pennsylvania], and those of the Connecticut Valley, with which they are thoroughly identified by foot prints and other fossils, and I would include also the contemporary sandstones of Virginia and North Carolina.

Later I. C. Russell[3] definitely applied the term Newark group to the rocks of both the Dan and the Deep River fields of North Carolina with the idea that possibly future workers might subdivide the group into a number of formations.

In the Deep River Field geologists have recognized certain differences in the rocks, some of the rocks being distinctly red and others being generally drab or gray, but no one, with the exception of Ebenezer Emmons, one of the former State geologists, has definitely attempted to map such distinctions and to give them specific names. Emmons, in his report of 1852 (p. 120), refers to the various divisions of the Newark group as follows:

> The coal seams of Deep River may be described under three grand divisions, proceeding from the inferior to the superior beds:
>
> 1. Inferior conglomerates and sandstones below the green and black slates.
>
> 2. Black slates, with their subordinate beds and seams.
>
> 3. Sandstones, soft and hard, with freestone, grindstone grits, and superior conglomerates.

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[1]Kerr, W. C.: Report of the Geological Survey of North Carolina, vol. 1, Raleigh, 1875.
[2]The name Newark as applied to a geological formation was proposed by W. C. Redfield in a paper, "On the relations of the fossil fishes of the sandstone of Connecticut and other Atlantic States to the Triassic and Oolitic periods." Am. Jour. Sci., 2d series, vol. 22, pp. 357, 1856, and Prac. Am. Asso. Adv. Sci., vol. 10, pp. 181, 1856.
[3]Russell, I. C.: Correlation papers—the Newark system. U. S. Geological Survey, bulletin 85, 1892.

In his report of 1856 (p. 228), Emmons recognizes in his text the three divisions enumerated in his earlier paper, for he says:

A natural division seems to exist when we take into account the physical characters of the formation only; and indeed it would be disregarding important features, were these to be passed by unnoticed. According then to these features, the series should be divided into three great deposits, the lower red sandstone and its conglomerate; the coal measures including slates, shales and drab-colored sandstones, with their subordinates; and lastly, the upper red sandstones and marls.

But on the map accompanying this report he represents four divisions in the Newark group, as follows:

(4) Upper sandstone.
(3) Salines.[1]
(2) Coal slate and coal.
(1) Lower sandstone.

Although Emmons shows the four divisions on his sketch map in the report for 1856, it is doubtful if he could, in the field, generally distinguish the "Coal slate and coal" from the "Salines," the latter being simply drab shale, above the coal in the Cumnock shaft, which, because of the salt that it contains, can there be readily separated from the underlying coal-bearing rocks. The writers made no attempt to differentiate the "Salines" from the "Coal slate and coal," for it seems extremely doubtful if, in the weathered exposures generally found in the field, the two phases could be identified and differentiated.

The Newark group in the Deep River Field consists of three generally recognizable parts, by geologists called formations; a lower formation composed largely of red and brown sandstone, a middle formation of light-colored or drab shale, sandstone and coal beds; and an upper formation of mainly red conglomerate of great, though unknown thickness. In places these formations are clearly marked and easily followed on the surface, but in other places the middle formation disappears, being either faulted out or replaced by red sandstone or conglomerate similar to that in the other formations. As it is desirable to map and describe these formations, it seems best to give them specific names so as to simplify the descriptions and the reference to the formations as much as possible. In accordance with this idea, the name Pekin is selected for the lowest formation, Cumnock for the middle formation, and Sanford for the upper formation. The reasons for the selection of these names will be given under the description of each of the formations. In the following description the formations will be con-

[1]Through an obvious error in preparing the geologic map for this report the "Salines" was placed below the "Coal slate and coal."

sidered in ascending order, beginning with the lowermost one which was laid down probably on a land surface of the ancient crystalline schist and slate.

### Pekin Formation

No specific name has heretofore been applied to the lowermost formation of the Newark group in this field; it has generally been referred to as the "Lower red sandstone." As it is one of the most definite formations of the group, it seems best to propose a geographical name for it. Unfortunately the names of the towns situated on the outcrop of this formation in the Deep River Coal Field are either in current use for other formations in nearby states, or the formation at the particular place does not show in typical form, hence no name within this field is suitable.

At the close of geologic work in the area here considered, the writers made a hurried examination of the Newark formations in Montgomery and Randolph counties. In this reconnaissance the succession of rocks in the group was found to be identical with that observed in the Deep River Field. The lowermost formation is prevailingly red and occupies a belt of outcrop about 2 miles in width on the northwest side of the trough of Newark rocks; this is succeeded by the overlying light and black shales of the Cumnock formation. The best exposure of the lowermost formation was seen on the road running due east from Mt. Gilead. This road crosses Little River 4 miles to the east and on the second terrace about one-half mile east of the river the red sandstone of the Newark appears. The road continues on this rock for a distance of 2 or 2½ miles and then passes onto the characteristic light-colored rocks of the Cumnock formation. In the midst of the lower red rocks is the village of Pekin, and it is proposed to call the lowermost red sandstone and shale Pekin for this place, as the formation here is in typical form.

In the Deep River Coal Field the Pekin formation shows in outcrop in a belt of fairly even width but more or less broken because of inability of the writers to recognize in places the overlying Cumnock formation, from the Carthage-Charlotte road on the southwest to Cumnock, and in a much narrower belt 8 miles or so northeast to Moncure on Deep River. Professor Emmons appears to have been the first person to assign a thickness to the lower sandstone. His original statement (Report of 1852, p. 137) is as follows:

> The inferior mass or that below the slate, is about fifteen hundred [feet] . . .

In his later and more comprehensive report (Report of 1856, p. 231), Emmons revises his figures to some extent, as follows:

> The thickness of the lower red sandstones at the Gulf and Egypt [Cumnock] is at least fifteen hundred feet, and probably nearer two thousand.

Other writers on this field generally give the thickness of these sandstones as 1,500 or 1,600 feet, apparently accepting the estimate of Emmons as given above.

During the course of the present examination almost all roads crossing the Pekin formation were carefully surveyed by plane-table and telescopic alidade, distances being measured by stadia. As the survey progressed most of the outcropping rocks were noted and dips and strikes recorded in their proper positions on the plane-table sheet. Cross-sections of the Pekin formation made up from these data give fairly accordant results, as far as the best sections are concerned, of about 2,000 feet. This thickness was obtained on the new Carthage-Charlotte highway near Calvary Church, on the road running northwestward from Carbonton, and on the road running north from the bridge over Deep River at Cumnock.

In that part of the field north and east of Colon, the upper limit of the Pekin formation was not definitely determined, as the light-colored shale and sandstone which carry coal beds appear to be poorly developed and it was impossible to trace them continuously and determine the contact between them and the Pekin formations, but in a general way as far as Deep River the Pekin formation appears to be much thinner than it is farther south. A rough measure north of Zion Church shows a thickness of about 1,000 feet and a similar thickness seems to be present at Lockville at the crossing of Deep River.

East of Deep River the contact of the Pekin formation and the ancient schist makes a turn toward the northwest nearly at right angles to its previous course, and north of Moncure these beds appear to regain their normal thickness of about 2,000 feet. The reason for this abrupt change in direction of the line of contact was not apparent in the field, but it may be due to great irregularities in the surface on which the Pekin formation was deposited. Emmons in his report of 1856 (pp. 231-232) noted the extreme thinness of the Pekin formation at Jones' Falls (Lockville). He reports less than 40 feet, but he offers no adequate explanation of the anomalous conditions which reduced it to this thickness. He interprets the great mass of conglomerate which the writers saw on the railroad north of Moncure as an overlap of the upper red sandstone across the eroded edge of the light-colored shale, but this can hardly be the case as the belt of outcrop of the light-colored beds is continuous and the rocks are well exposed on the Capital Highway in the north edge of the village.

The most remarkable member of the Pekin formation is a gray conglomerate composed of white quartz pebbles ranging up to 2 inches in diameter. This bed is hard and very resistant and has been extensively quarried in the past for millstones. It is the basal conglomerate of the Pekin formation and was laid down on the eroded edges of the ancient schist and slate which form the basement complex of the region. The pebbles were doubtless derived from quartz veins that are of common occurrence in the underlying rocks. They are well rounded and show by their shape that they have been rolled for a considerable distance by a fairly rapid stream of water. The matrix also consists of the same material reduced to a still finer condition.

The millstone conglomerate is found in its best development on the northwest border of the field from the Carthage-Charlotte highway northeastward to the vicinity of Putnam. It was also noted by the writers on the east side of Deep River southeast of the Carolina coal mine, and fragments were found on the west side of the river north of the coal mine. This rock was in great demand in the early days for the manufacture of millstones, and quarries were opened at many places on its outcrop. The largest operation of this kind, the ruins of which were seen by the writers, was on McCallum Fork of Richland Creek, about 300 feet below the crossing of the highway that connects Calvary Church with Hallison and Putnam. Here there was a large quarry from which the raw material was obtained, and an extensive plant for the shaping of the raw material into the finished product. Trees have completely overgrown the ruined mill and office and water has flooded the quarry, so that little now remains to mark the site of a once flourishing industry.

The quarry noted above is certainly 100 years old, as it is described by Professor Olmsted in his report (p. 15) of 1824, as follows:

> The region of sandstone embraces several beds of that conglomerate rock which is used for millstones. But the most distinguished locality for the millstone grit occurs on Richland Creek in Moore County, near the western limit of the formation. . . . This excellent bed of millstone grit is exposed to view directly on the bank of the creek, forming three horizontal strata or layers, each composed of large tabular masses. The lowest stratum is the best quality for millstones. It consists of a hard grayish red sandstone in which are thickly imbedded water-worn pebbles of white flint or quartz. These millstones are very much valued for grinding corn, and are sought for from distant parts of the State, and bring from $30 to $100 per pair.

Chance in his report of 1885 (p. 24) makes the following statement:

> In Moore County the conglomerate at the base of the formation yields an excellent stone for corn-mills. A factory has recently been established by

the North Carolina Millstone Co., and complete mills ready for the belt are now made and shipped in large numbers.

This conglomerate was also found on the east bank of Deep River where it is cut by the Deep River fault, about a mile east of the old Endor iron furnace. It was not seen northeast of that place, although the base of the Pekin formation was crossed at a number of places.

At Lockville, a coarse conglomerate occurs on both sides of Deep River at what appears to be the same horizon as that of the millstone grit, but here the matrix is a strong red color and the pebbles or rather the boulders—for they range up to at least twelve inches in diameter—are of schist. The rock bears no resemblance to the white quartz conglomerate of the millstone grit, although it seems to be at that horizon. The red conglomerate is well shown in the cuts of the Capital Highway where this road climbs to the upland south of the river and it was also seen in full force on a branch of the Seaboard Air Line Railway which runs due north from Moncure to Pittsboro. Curiously enough, however, this conglomerate does not show on the main automobile road to Pittsboro which turns to the left about one-quarter of a mile beyond Lockport. On this road the schist makes its appearance in less than one-half mile and from that point for about one-quarter of a mile the road runs practically on the contact of the red schist conglomerate and the underlying bed-rock.

Professor Emmons noted (report of 1856, p. 237) this apparent thinning of the Pekin formation at Jones' Falls (now Lockport) and the presence of the red conglomerate noted above, but instead of regarding the conglomerate as the basal member of the Pekin formation, he considered it as belonging to the red sandstones of the Sanford formation. He accounted for its present position as being due to unconformable deposition across the eroded edges of the Cumnock formation. Professor Emmons proved his case, as he supposed, by the discovery of certain fossil plants above the schist conglomerate near Lockville and by the finding on Haw River of the same fossil plants overlying one of the conglomerate beds of the Sanford formation. Whether or not Professor Emmons is correct in attributing the presence of this schist conglomerate in contact with the schist itself as due to overlap the writers cannot affirm or deny, as time did not permit of a close examination of the rocks or of the collecting of fossils from them. In some respects Emmons' theory seems to apply, but in others it is contrary to the observed facts. The writers are not in a position to settle this question, so merely call attention to it as one of the interesting points that future workers may look forward to as a problem worthy of their best efforts.

The other members of the Pekin formation are fairly uniform in character throughout the field and have no striking characteristics that call for comment. Professor Emmons' description of the rocks composing this formation is very good and the writers can add little or nothing to it, except that in places the formation carries considerable hematite which appears to be very pure, and, if it could be found in great quantity, would be extremely valuable as an ore for iron-making. An exposure of this hematite was found in a cut of the Norfolk Southern Railroad about a half a mile northwest of the station of Colon. This occurs as a mass about five feet long and one foot broad and of unknown depth; it is in sandy shale which strikes nearly east-west and dips twenty-six to thirty degrees to the south. Similar masses, though of smaller dimensions, were seen in the clay pit of the brick works at Colon in shale that also appears to dip to the south. If the dip and strike are at all indicative of the general geologic structure, this shale belongs in the Pekin formation and underlies the Cumnock formation which outcrops farther to the south. The iron ore exposed in the vicinity of Colon is doubtless of secondary origin and due to the segregation of iron in the deeply oxidized shale and shaly sandstone. All of the red rocks of the Newark group contain much iron, but until segregation takes place, the iron is too widely disseminated to be of value as an ore.

### Cumnock Formation

*General Statement.* The coal-bearing rocks are not so well exposed as are those belonging to the Pekin formation. In fact, were it not for the section in the mine shaft at Cumnock, geologists would have a very inadequate idea of the composition of the coal-bearing formation in this field. Because the shaft section is regarded as the type of the formation and because the development of the coal has been much more extensive here than at any other place in the field, the name Cumnock is given to the generally light-colored rocks bearing coal or associated with the coal. The Cumnock formation varies greatly in thickness and composition throughout that part of the field examined so that it is doubtful if the section exposed in the Cumnock mine will hold in distant localities.

The Egypt (now Cumnock) shaft, shown on Pl. III, was sunk, according to Captain Charles Wilkes[1] of the United States Navy, by the Governor's Creek Coal and Iron Company, but local information gathered in the field indicates that the shaft was sunk by Brooks Harris in 1852, and that Harris in 1853, disposed of his interest in

[1]Report on the examination of the Deep River district, North Carolina Senate, Doc. 26, 35th Congress, 2d Sess., p. 6, 1859.

the property to Thomas Andrews, who, in the same year organized the Governor's Creek Steam Transportation and Mining Company. The geologic world is greatly indebted to Captain Wilkes for preserving a record of the rocks penetrated by this shaft, for, so far as the writers are aware, his is the only report in which the original section was published and even the present owners of the property have no other record than that given in Captain Wilkes' report.

Emmons' description (Report of 1856, pp. 232-234) of the Cumnock formation and its thickness and component parts is somewhat vague and indefinite and the writers are not satisfied that they have correctly interpreted his statements. He apparently divides the coal measures into two parts: (1) the black and green beds of the bottom and, (2) drab-colored beds at the top. The thickness of the former is given as extending 150 to 200 feet above the top of the Cumnock shaft section and 200 feet below its base. This would give the black and green beds a thickness of about 800 feet. The drab-colored beds he states are 1,200 feet thick on McIver's plantation near Egypt.[1] These measurements give a total thickness of about 2,000 feet, but Emmons states clearly that the formation is probably thicker at Egypt than it is at any other place in the field.

In comparatively recent years four core-drill holes have been put down to the Cumnock coal bed on the Cumnock property, and as one of these holes penetrated the coal bed at a depth of 1,064 feet 7 inches it affords an even better section than that revealed by the Egypt shaft. The logs of these four wells and also the section of the Egypt shaft, as given by Capt. Wilkes, are shown on Figure 1.

In borehole No. 1 the lowest red rock penetrated by the drill is 548 feet above the Cumnock coal bed; in borehole No. 2 it is 561 feet; and in borehole No. 3, 506 feet. The average of these measurements is 538 feet. If all the exposures in the field were as clear as the logs of the boreholes there would seemingly be little difficulty in determining the top of the Cumnock formation, but in deeply weathered rocks it is not always possible to distinguish brown from gray unless both rocks are strongly marked. Judging from the experience of the writers in the field, it seems highly probable that the brown sandstones and shales noted in logs, 1, 2, and 3 (see Fig. 1) are in reality included in the Cumnock formation, and that as so constituted, it extends 800-850 feet above the Cumnock coal bed and from 100 to 150 feet below that bed. On this assumption the Cumnock formation at the Cumnock mine is about 1,000 feet thick, instead of 2,000 feet, as determined by Emmons.

[1]It is possible that Emmons intended this measurement of 1,200 feet to include the rocks showing in the Egypt shaft. If so, it would represent the full thickness of the Cumnock formation, and would be more nearly in accord with, but still thicker than, thicknesses determined in surrounding acres. The statements, however, are too vague to be taken seriously.

The writers endeavored to apply the Cumnock shaft section to the same belt of rocks observed in other parts of the field, but there seems to be little or no agreement in the thickness of either the formation as a whole, or its various members. In fact in several places the formation appears to be lacking, either faulted out or replaced by red conglomerate similar to that which constitutes the major part of the Sanford formation overlying the coals.

Emmons, in his report of 1856, states that he experienced difficulty in tracing the belt of drab sandstone and shale which constitute the

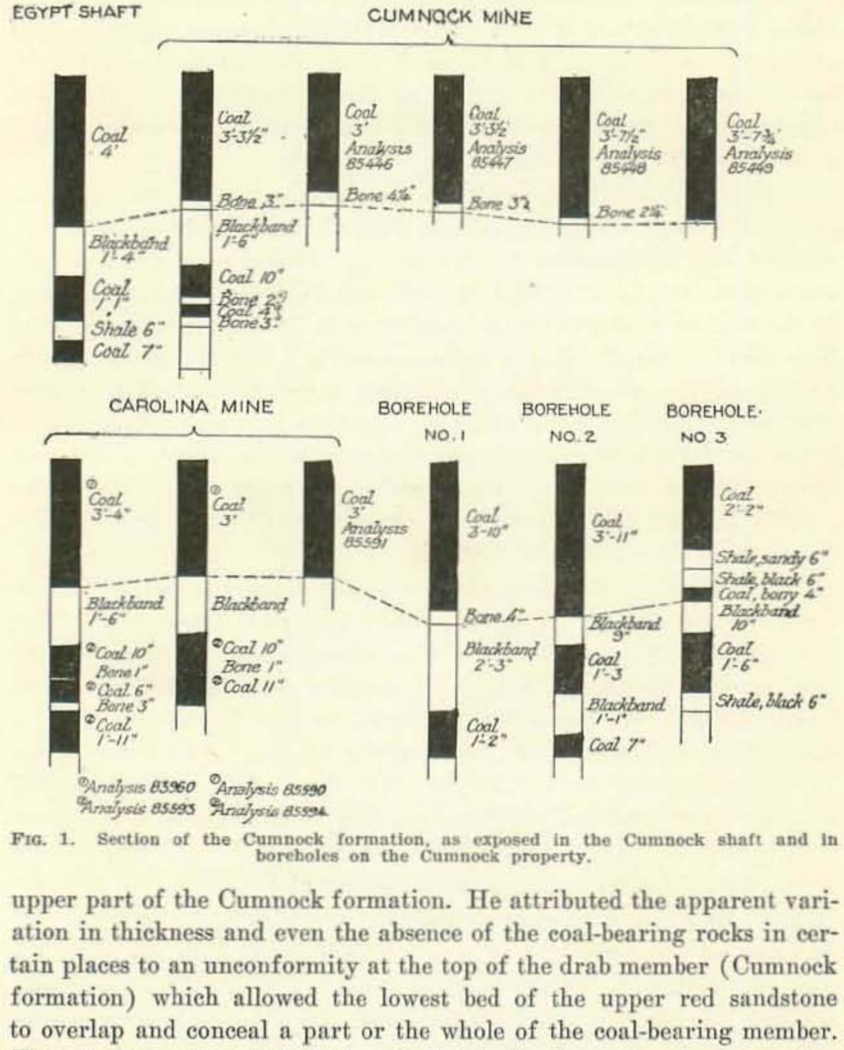
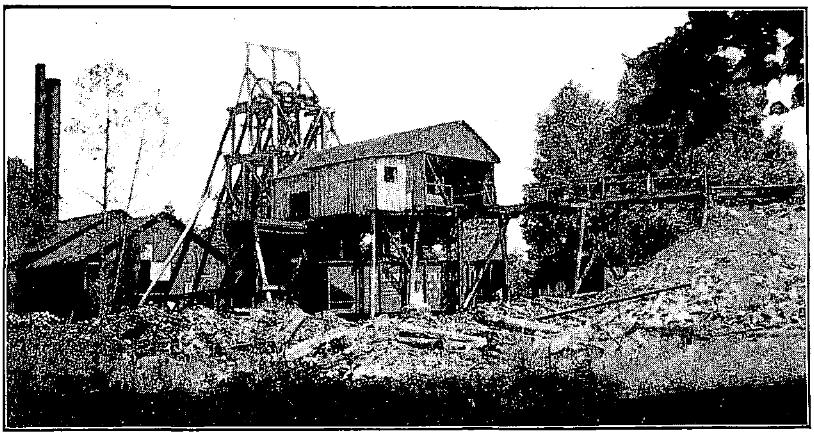



FIG. 1. Section of the Cumnock formation, as exposed in the Cumnock shaft and in boreholes on the Cumnock property.

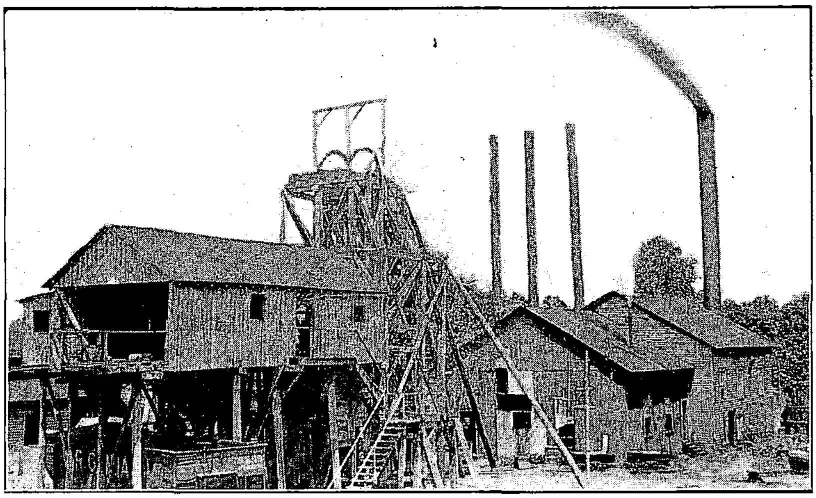
upper part of the Cumnock formation. He attributed the apparent variation in thickness and even the absence of the coal-bearing rocks in certain places to an unconformity at the top of the drab member (Cumnock formation) which allowed the lowest bed of the upper red sandstone to overlap and conceal a part or the whole of the coal-bearing member. The present writers looked in vain for indications of such an overlap, but none was found, and they came to the conclusion that the apparent thinning and even disappearance of the Cumnock formation could be explained in another way which seems to agree with observed facts better than does the theory that Emmons advanced. The theory adopted by the present writers is that the difference in the formation is due in large part, if not wholly, to variations in sedimentation and consequently, red shale, sandstone or even conglomerate may have been laid down in one part of the field at the same time that drab shale or even shale containing much black carbonaceous matter was being deposited in another part. In fact it seems much more reasonable and in accord with observed facts to assume that coal-forming swamps were of local occurrence in Triassic time in much the same manner as they are limited today and that a swamp extensive enough to cover North Carolina from north to south is much less probable than one five, ten, or even twenty miles in extent.

In order to present some of the evidence regarding the variation of the Cumnock formation in this field it will first be necessary to describe the distribution of the outcrop. Before beginning such a description it is well to explain that, although the territory covered by the writers, as shown on the map, extends from Carthage to beyond Haw River, much of this area was examined in a reconnaissance manner only, in order to determine the general structure and that detailed examination was limited to localities where the prospect of finding coal in commercial quantity is more promising than it is in most of the area represented on the map. The description begins at the southwest extremity of the area and extends northeastward to the farthest point examined in the vicinity of Moncure.

*In the Carthage Trough.* On the new-cut highway which extends northwestward from Carthage the rocks are excellently exposed from a point about 1½ miles west of the courthouse at Carthage to the northwestern margin of the field. The rocks as far as the crossing of Richland Creek are prevailingly red and as they dip continuously to the southeast, they without doubt belong to the Sanford formation. The red rocks continue beyond the creek for a distance of about 400 feet where they rest conformably upon light-colored rocks of the Cumnock formation. These rocks extend along the highway, except where they are cut by a large dike near the middle of the belt, for a distance of 2,200 feet, and to all appearances they are conformable and the full thickness of the formation is present. The rocks near the dike are somewhat disturbed, but beyond its influence they dip with considerable regularity sixteen degrees to the southeast. This dip, if it were regular throughout the entire formation would indicate a thickness of only



A. The Cumnock coal mine.



B. The Cumnock coal mine.

600 feet. As this measurement is much less than that obtained a few miles to the north, as explained on another page, one is forced to the conclusion that either the Cumnock formation is here unusually thin or that it has been cut by a fault and part of the formation has disappeared in the process. The fault-hypothesis seems hardly tenable as in other longitudinal faults of considerable magnitude in this region the movement has been such as to duplicate a part or all of the outcrop and thus give it a greater width and the formation an apparently greater thickness than it normally has rather than to reduce the width of its outcrop.

The rocks exposed are principally gray sandstone and drab shale, but near the dike the shale has been baked to a dark, almost black color resembling black carbonaceous shale. No sign of coal was observed but reports are current that coal has been seen in Richland Creek somewhere in this vicinity. It is possible that coal is present here, for it is only eight and one-half miles in a direct line to the old coal mine on the Jones' farm east of Glendon, but whether or not the coal is of workable thickness here is another problem that can be solved only by prospecting with pick and shovel, or with a core drill.

The next line of observation is along the public road from Mooshaunee to Friendship Church. As this road has never been improved there are few exposures, but so far as the surface indications go, there is no evidence that the Cumnock formation crosses this road. The same condition holds on all of the roads crossing the territory west of McLennon's Creek and for a distance of five miles northeast of the Randolph and Cumberland Railroad. This country was crossed on the road leading to the southeast from Putnam, also on the road running in a similar direction from Cool Springs Church, and on a road intermediate between the two. On all these roads the only rocks that were seen are red rocks which in all probability belong to the Pekin formation.

The next line across the field on which traces of the Cumnock formation were found is the Carthage-Glendon road. As far north as Cole's Mill the roads both to the south and the west of the main road gave no indication of the light-colored rocks of the Cumnock formation; in fact, there seems to be no possibility of the northeastward extension of the belt of outcrop of the Cumnock formation, showing on the Charlotte road northwest of Carthage, for the road from Carthage to Mooshaunee and also the road from Carthage to Cole's Mill shows nothing but red rocks which, unless the Cumnock formation changes in color in this locality, cannot belong to that formation. Likewise the road from Cole's mill to Mooshaunee is on red rocks from one of these places to the other.

On the west side of the Glendon road, about one and one-half miles north of Cole's Mill, the Cumnock formation suddenly appears in full force, for its outcrop extends from the Carthage-Glendon road for fully one-half mile to the west. From this place northward the light-colored rocks were seen at a number of places as also were the bands of black shale which are a characteristic feature of the formation. The black shale is particularly well exposed and prominent by the side of the road near the forks where the road to the Horseshoe bridge turns off to the right from the regular Glendon road. The Cumnock formation was also seen on all the roads turning to the northwest from the main Carthage-Glendon road toward Putnam and Cool Springs Church. On the main Glendon road nearly the full width of outcrop was seen on the slope northward toward McLennon's Creek, and the contact between the light-colored rocks of the Cumnock formation and the red beds, which are supposedly of the Pekin formation, were crossed three-quarters of a mile from the point where the road forks and the right hand fork leads to Horseshoe Bridge. Between that point and the creek and also on the northwest side of the creek for some distance no rocks but those which are red were seen, but at a fork of the road about one mile north of the creek, with one branch turning to the left toward Cool Springs Church and the other turning off the main road to the right toward the old coal mine on the Jones property, the light-colored rocks of the Cumnock formation appear in outcrop. This band of outcrop is only 900 feet wide, being about one-third of the normal width of outcrop of the entire formation. The dip of the Cumnock formation could not be determined here as the rocks are soft and massive and no bedding planes could be detected. North of this narrow band of outcrop the rocks are universally red as far as the bridge across Deep River north of Glendon where the red beds of the Pekin formation rest upon the crystalline schist.

The two bands of outcrop of the Cumnock formation, mentioned above, can be traced northeastward until they unite two miles southwest of Carbonton. Thus there is a main band of outcrop of the Cumnock formation from a short distance north of Cole's Mill northeastward through the Horseshoe Bend of Deep River and on to Carbonton which appears to be the normal outcrop on the northwestern limb of the Carthage trough; and a second band of outcrop which begins in a sharp point one-half mile southwest of the Carthage-Glendon road, increases in width to 900 feet where it crosses the road just mentioned, and gaining the full width of outcrop soon after it crosses Deep River and before it reaches the village of Haw Branch. This belt of outcrop continues northeastward to the vicinity of Carbonton where it appears to blend with or unite in some manner with the other band of outcrop lying to the south.

There are therefore two problems here that call for an explanation: (1) The failure of the outcrop of the Cumnock formation on the Carthage-Charlotte road to connect with the outcrop of the same formation north of Cole's Mill, and (2) the bifurcation of the outcrop of the Cumnock formation between Carbonton and Haw Branch.

Several explanations might be offered for the solution of problem No. 1, but each one is open to some objection which, in the light of the evidence at hand, appears to be fatal. The possible explanations that should be considered by any geologist working in this field in the future are as follows:

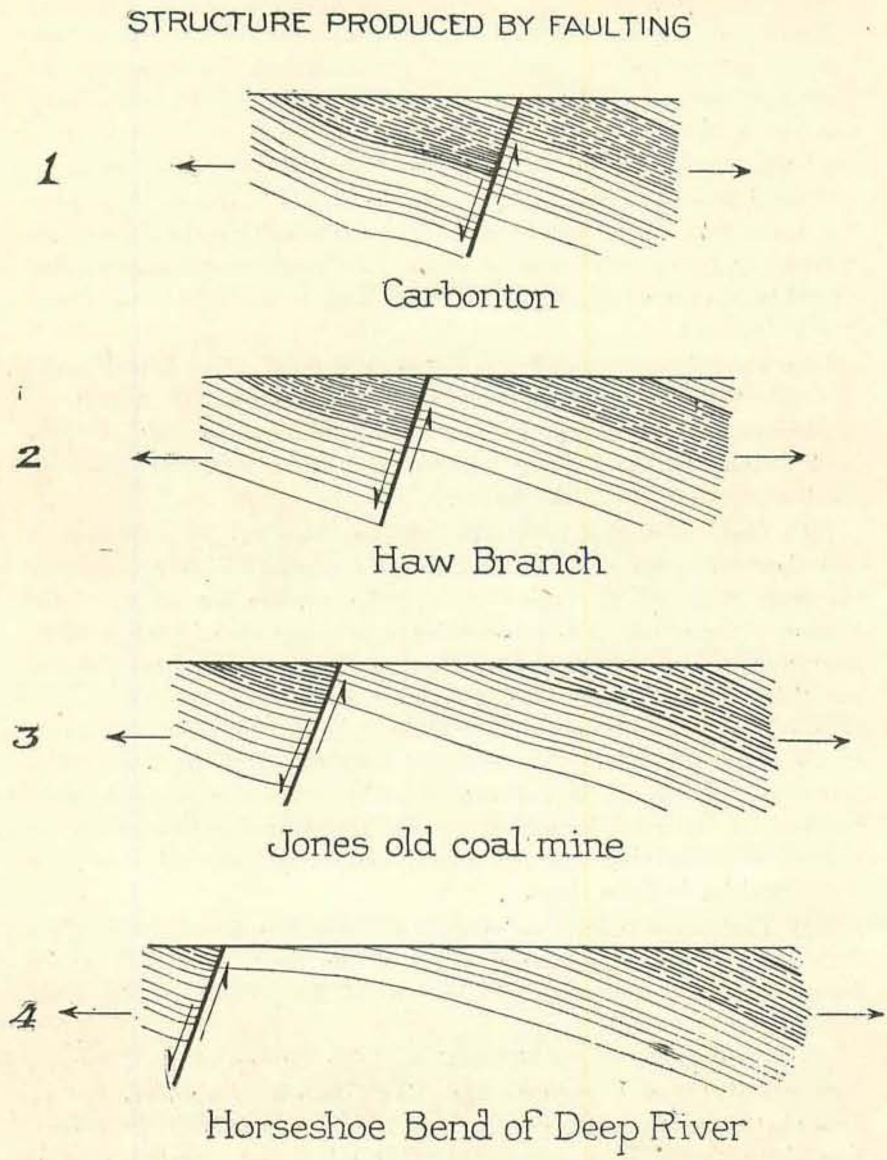
(A) That the outcrop of the Cumnock formation, as known north of Cole's Mill, really swings to the west and connects with the outcrop of the same formation on the Carthage-Charlotte road west of Richland Creek, and that, owing to poor exposures, it was not observed north or northwest of Mooshaunee.

(B) That the Carthage trough here has been cut by a cross-fault and the part south of the fault has been dropped with reference to the part north of the fault. This might explain the offset of the Cumnock formation, but it is difficult to conceive of such a fault occurring without leaving some offset in the line of contact between the Pekin formation and the underlying schist.

(C) That the disappearance of the typical Cumnock formation in the region between Cole's Mill and the Carthage-Charlotte road is due to a local change in sedimentation, by which the generally drab rocks of the Cumnock formation are displaced by red sediments similar to both the overlying and the underlying formations and hence are indistinguishable from them.

(D) That there is here an overlap of the red rocks of the Sanford formation across the upturned edges of the rocks of the Cumnock formation, which conceals all indications of the presence of the latter formation.

(2) The question of the bifurcation of the outcrop of the Cumnock formation between Carbonton and Haw Branch is simpler, but of somewhat greater economic importance, because it affects the formation where it possibly contains a workable bed of coal. Such a bifurcation, as that shown on the map, could have occurred in only one of two ways: being the result of either a low fold or wrinkle on the side of the large trough, or of a normal fault which has dropped the block




Geologic Structures

of rock on the northwest side or raised the one on the southeast side, so that the outcrop of the Cumnock formation is repeated for a distance of about three and one-half miles. The fold hypothesis is the simpler one and, in regions in which the rocks are subject to such disturbances, it would be accepted without much question, but in this trough folds in the rocks are almost unknown and normal faults are the rule, hence in all probability the bifurcation of the outcrop of the Cumnock formation is due to a fault which cuts the outcrop at a slight angle, as shown in Figure 2 and described more fully under the subject of Geologic Structure.

The trace of this fault follows the southern margin of the belt of outcrop that passes through Haw Branch and, if it extends northeastward as it probably does, it must pass somewhere to the southeast of Carbonton, but its position was not determined, for at the time of the field examination the presence of this fault was not realized. The wide floodplain of Deep River about Carbonton makes the collection of data bearing on the position of the fault difficult, but it seems probable that if search were made in the vicinity of the site of the old village some evidence of the inter-fingering of the light-colored rocks of the Cumnock formation and the red rocks of the Sanford formation would be found. The representation of the fault on the map as well as the outcrop of the formations southeast of Carbonton are largely hypothetical, but they serve to express the idea that the writers hold that probably there is at this place a fault which separates an upraised block of the earth's crust on the southeast from a dropped block on the northwest, and the junction of the two belts of outcrop of the Cumnock formation in the vicinity of Carbonton merely means that here the fault passes across the Cumnock formation and farther northeast lies entirely within the Sanford formation, or at least is in this position for a number of miles. On this assumption the belt of outcrop of the Cumnock formation which extended into this area from the Horseshoe Bend of Deep River comes to an end in a sharp point somewhere in the vicinity of Carbonton, and the belt lying to the northwest and passing through Haw Branch continues on to the northeast through the present village of Carbonton to Gulf. No direct measurement of the thickness of the Cumnock formation was made in the vicinity of Carbonton, but in constructing the cross-sections shown in Fig. 2 it was found that, according to observed dips and details of distribution of outcrop, the formation must be at least 1,000 feet thick.

From Carbonton to Gulf the base of the Cumnock formation is quite well marked on the ground and its position in a number of places was accurately determined. This line is nearly straight, the only irregularities being those due to the influences of dikes which are very abundant and seemingly cut the coal nearly parallel to the outcrop. The upper limit of the formation was not nearly so well determined as the lower limit, for it follows in a general way the floodplain of Deep River, and this floodplain is so broad that it was not thought practical to seek for evidence regarding the exact position of the upper limit of the formation.

East of Gulf the writers, when in the field, were puzzled by the apparent lack of parallelism between the line marking the lower limit of the Cumnock formation and the line marking the upper limit. No attempt was made to actually follow the lower boundary of the formation from Gulf to the Cumnock bridge, but it was assumed that it is regular and conformable in its curve and direction with the line marking the base of the Pekin formation nearly two miles to the north. Considerable data were obtained on the upper boundary of the Cumnock formation and it was found not to be conformable with the line marking the base of the Pekin formation, but to offset decidedly to the south at a distance of about a mile from Gulf. A careful study of the compiled map shows at once that the point here in question lies almost on the continuation of the supposed Carbonton fault and that if it were granted that this fault might continue as far to the northeastward as this place, it would account for the irregularity in the upper boundary of the Cumnock formation.

All of the facts in the hands of the writers indicate that the line marking the top of the Cumnock formation crosses Deep River about 700 feet below the bridge at the old mill directly south of Gulf. This does not agree with the statement made by Chance (pages 13-14) that at the old coal mine which was once opened west of the village, and which was abandoned because in a short distance a large dike was encountered, red sandstone appears directly south of this great dike. It is also well known that deep drilling was done here years ago, but no authentic account of the results could be obtained; there is, however, a vague rumor that a well near the river bank found the coal at a considerable depth and that most of the rocks penetrated near the surface are the red rocks of the overlying formation. If these rumors are correct, the geology about Gulf is very complicated and different from that which is represented on the present map, but the writers, while not making a special examination of this particular locality, have no hesitation in saying that the evidence collected in the surrounding territory does not agree with such an interpretation as would have to be made if the rumor mentioned above were correct, and hence they are inclined to class this hearsay evidence as too vague and indefinite to be seriously considered, unless it were substantiated by a detailed examination.

As stated before, the writers believe that the line marking the top of the Cumnock formation crosses Deep River a short distance below the bridge, but this line if projected to the east would not include a great mass of light-colored sandstone which shows still farther down the river and at an old quarry about half way between the river and the line of the Southern Railway, about a mile southeast of Gulf. As this apparent offset in the upper boundary of the Cumnock formation is on the prolongation of the Carbonton fault, it is suggested that perhaps this fault is longer than has been supposed and really is responsible for this offset as well as the much larger offset of the same formation southwest of Carbonton. This idea of the extension of the fault is offered more in the nature of a suggestion than as an established fact and should be considered by any coal operator who is interested in the development of this part of the field. As the evidence in the vicinity of Haw Branch shows that the fault which is supposed to be responsible for the offsets in the Cumnock formation is diminishing in throw or magnitude northeastward, it is probable that south of Gulf it may not have lifted the coal bed more than 100 feet and it probably dies out before it reaches the schist at the northern point of the syncline. As the movement on the fault plane was such as to cause the block of rock on the southeast side of the fault to move upward with respect to the block on the northwest side, both the upper and the lower boundary of the Cumnock formation will be found to offset to the southwest, but for only about 1,500 feet for the lower boundary and 4,000 feet for the upper boundary, the difference being caused by the increasing magnitude of the fault toward the southwest and the different angle at which the fault cuts the boundary line.

From the offset just described to Cumnock and the Carolina mine the outcrop of the Cumnock formation appears to be exceedingly regular and without offsets of any kind. It is possible, however, that if it could be followed in detail, small offsets would be found for some small faults have been encountered in the mines which would doubtless produce such features where they come to the surface, but they are so small that it would be almost impossible to detect them.

*As Offset by the Deep River Fault.*—East of Cumnock and the Carolina mine the outcrop of the Cumnock formation is more complicated than it is at any other point seen by the writers. As those working in the coal of this region are in doubt about the continuation of the beds the writers spent considerable time tracing the outcrop between the points at which the coal has been prospected in the vicinity of the

Carolina mine and the Capital Highway north of Sanford. Professor Emmons, in his report of 1856, gives a colored geologic map of the Cumnock formation from the present village of Carbonton to Cape Fear River. One of the most interesting features of the map is the great bend which he supposed the outcrop of the formation to make just east of Farmville (now the Carolina mine) and the swing to the southwestward across the river some distance east of the old Endor iron furnace below the mouth of Buffalo Creek. The outcrop of the Cumnock formation is represented as continuing in this direction to beyond the house of Evander McIver where it turns abruptly to the southeast, paralleling approximately the line marking the contact of the Pekin formation and the underlying crystalline schist. Emmons gives no facts in support of his conception of the great bend in the outcrop of this formation, merely stating in the text (p. 244) that, "The outcrop crosses the river between Evander McIver's and the Hornville property, thence by Farmville, it crosses the river obliquely at Egypt, and soon recrosses it again near the fish-trap, and passes into the Taylor plantation." Naturally the writers made a very detailed examination of this part of the field, for the interpretation of the structure necessarily has an important bearing upon any conclusion regarding the area and tonnage of available coal.

The position of the outcrop of the Cumnock coal bed from Gulf to the Carolina coal mine (Farmville of the old reports), barring a hypothetical offset, is quite well known and the writers were able by means of prospect pits to continue the tracing southeastward beyond the Carolina mine to the edge of the flood plain, about 1,300 feet from Deep River at the bend where the course of the river changes from nearly due east by the mouth of Pretty Creek to a northward course toward Woodard's Bridge. As the outcrop of the coal bed shows no trace of irregularity save a gentle curve toward the south, one would scarcely expect in a distance of 1,300 feet a decided change in direction of the outcrop of the formation. When, however, one tramps from Woodard's Bridge up the river bank on the southeast side he finds high hills of schist opposite the mouth of George's Creek and even further south, and when he reaches a point in strike with the outcrop of the coal at the last prospect pit, he finds equally high rugged hills made of a white quartz conglomerate, in all respects similar to the millstone grit exposed on McCallum Creek. As this conglomerate strikes N. 35° E. and dips 15° southeast, it will be seen at once that it is out of harmony with the coal outcrop and also with Emmons' hypothesis that the outcrop of the coal swings abruptly to the southwest across Deep River.

In order to test Emmons' hypothesis still further, the rocks, showing on the south side of the river from the mouth of Buffalo Creek down stream to the bend mentioned above, were carefully examined as to their character and attitude, but nothing was found that would in any way support it. The rocks throughout this stretch of river are prevailingly red and do not belong to the Cumnock formation. The strike of the rocks from the mouth of Buffalo Creek to the mouth of Pretty Creek are parallel with the outcrop of the coal bed from the Carolina mine to the river flood plain, and as the dip is to the southwest in conformity with that of the coal, it is apparent that the red sandstone at the site of the old Endor iron furnace overlies the coal bed and hence belongs to the Sanford formation. East of the mouth of Pretty Creek the rocks are nearly horizontal, red sandy shale. As these in all probability overlie the quartz conglomerate noted above in the river bluff, a few hundred feet to the north, they must belong to the Pekin formation.

From all the evidence collected in the field, it seems certain that the Cumnock formation, including the workable coal bed of the same name comes to an end suddenly near the last coal prospect mentioned above. The reasons for this conclusion may be summarized as follows: (1) If the coal were assumed to cross the river on its regular course it would strike at right angles the basal conglomerate of the Pekin formation, which of course, without the intervention of a fault, is impossible; (2) if the coal bed swings, as supposed by Emmons, to the southwest, it would come in contact, in the vicinity of the site of the old Endor furnace, at right angles with the red sandstone of the Sanford formation. As each of these assumptions results in an absurdity, they cannot be regarded seriously.

The only theory that fits the known facts is that the Cumnock formation, including the coal bed, is cut by a normal fault near the first coal prospect pit, west of Deep River. The movement on this fault plane, which probably is nearly vertical, has been such as to raise the rocks on the east relative to those on the west, or to drop those on the west relative to those on the east about 2,500 feet so that the Cumnock coal bed comes in contact on this fault plane with the base of the Pekin formation or with the underlying schist on the east side of the fault. The fault swings somewhat to the southwest and crosses Deep River at or near the mouth of Pretty Creek. The real test of the fault-hypothesis is whether or not boundaries other than those of the Cumnock formation are offset in a similar manner and to a like amount.

The first boundary line to be tested is that marking the base of the Pekin formation or the contact between that formation and the underlying schist. This boundary was located on the road running nearly north from the bridge across Deep River at Cumnock, as shown on the accompanying map. It was also determined on the road from west of the Carolina coal mine to the Sanford-Pittsboro road. This also is shown on the map. The base of the Pekin formation as represented by these points is roughly parallel to the outcrop of the coal bed and at the last mentioned place the boundary swings to the southeast in almost exact conformity to that of the coal bed. As the outcrop of the coal bed could not be followed to the supposed fault-line, it was essential to trace the contact of the Pekin formation and the schist southeastward from this road as far as it extends. This line was crossed almost due south of the point where the road from the Carolina mine intersects the Pittsboro road. When platted this point proved to be on the extension of the contact line from the west and afforded no indication of being near the end of the Pekin formation. Again the contact was crossed near Deep River where the stream turns from due north to almost east, a course that it follows to Woodard's Bridge. Here at a point 800 feet north of the river the contact was again found, or at least fragments of a quartz conglomerate, which undoubtedly is the basal conglomerate of the Pekin formation, were found on schist. North of this point nothing but schist fragments appear on the surface and south of the point nothing was seen on the surface but fragments of conglomerate and brown sandstone. It was found that this point is in line with the other points to the west in indicating a gently southward curving boundary line similar to that marking the outcrop of the coal bed. West of this point all indications point to perfectly normal relationships, but east of the point there was nothing to be found but schist and it was found that this schist extends south to the river where it shows as a ledge projecting into the north side of the stream. Here, as further north, brown sandstone fragments are abundant to the west of the schist so that it is concluded, and seemingly without the possibility of error, that this line of contact between fragments of sandstone and conglomerate on the west and schist on the east marks the line of the fault.

From the point described above southward (up stream) all the rocks exposed on the west side of the river belong to the Newark group, but all those on the east, as determined by a foot-traverse along the river bank, are schist up to the next great bend in the course of the river where it turns from an easterly to a northerly course. As the rocks on the west are Newark and on the east schist it is obvious that the fault follows closely the flood plain of the river and consequently its exact position cannot be determined. Where the fault crosses the river east of the mouth of Pretty Creek it is in the midst of red rocks and here its position can only be inferred.

As shown on the map, the line marking the base of the Pekin formation is offset to the south by this fault one and one-half miles. It seemed probable, therefore, that the coal outcrop would be found on the east side of the fault about one and one-half miles to the south of the last pit noted southeast of the Carolina mine.

Professor Emmons in his report of 1856 mentions the occurrence of coal near the house of Evander McIver and at Martin Dyer's, although he does not give the thickness of the coal bed at either place, except to say that a boring at Martin Dyer's disclosed 10 inches of coal. The Martin Dyer farm is on the main Capital Highway two and one-half miles from Sanford and about one-quarter of a mile south of the "Old Cumnock" road. Evander McIver lived on this road a little more than two miles from the Capital Highway and about three-quarters of a mile from the crossing of the Southern Railway.

According to local reports the coal was mined quite extensively during the Civil War in Pretty Creek north of the McIver house. These old mines were located by the writers and the belt of light-colored Cumnock rocks was followed, as indicated on the map, southeastward to the Capital Highway. In the opposite direction the rocks are poorly exposed, but light-colored shale associated with fine fissile black shale was found in a cut on the Southern Railway nearly a mile south of the crossing of the "Old Cumnock" road. As cuts on the railroad just south of this crossing are in thick-bedded red sandstone, it seems probable that the outcrop of the Cumnock formation trends nearly due west from the McIver house to the valley of Buffalo Creek. As all of the rocks in the upland west of this creek are red, the belt of Cumnock formation must be cut off suddenly somewhere in the valley of Buffalo Creek by a fault which brings the Cumnock formation on the east side in contact with red sandstone and shale of the Sanford formation on the west. In other words, this is the same fault as that which was discovered north of Deep River, and the offset of the principal coal bed is about one and one-half miles, or the same as the offset of the base of the Pekin formation.

The evidence in this part of the field is perfectly clear that the geographic distribution of the Cumnock formation, as noted by Professor Emmons and as found by the writers, is the result of a normal or nearly vertical fault or break in the rocks which has affected not only the sandstone, shale, and conglomerate of the Newark group, but also the underlying crystalline schist. It is impossible on account of the similarity of the schist on the two sides of the fault, to trace the fault far beyond the outer boundary of the Pekin formation and in the other direction it is equally difficult to trace it far into the interior of the Carthage trough, because here it is entirely within the Sanford formation and the red sandstone, shale and conglomerate in one part of this formation are so like those in another part that they are indistinguishable.

On the map the fault is shown for only a few miles south of the Evander McIver house, but with a displacement at the river of at least 2,500 feet, it seems probable that it extends much further, possibly as far as to the vicinity of Carthage.

East of the Deep River fault the tracing of the outcrop of the Cumnock formation is extremely unsatisfactory because of the blanket of quartz pebbles on the higher land, the heavy forest which prevails over most of the country in this region, and the probable complicated structure which seemingly has resulted in the dislocation of the band of outcrop into a number of isolated areas.

The first of these isolated areas of the Cumnock formation extends southeastward from the Deep River fault to something more than a mile east of the Sanford-Colon Highway. The coal beds in this formation have been prospected in the valley of the upper part of Pretty Creek just north of the "Old Cumnock" road. The outcrop of the formation follows this road from a short distance east of the Atlantic and Yadkin (Southern) Railway to the Capital Highway, two and three-fourths miles north of Sanford. The light-colored rocks of the formation are well exposed in a cut on the Seaboard Air Line Railway about the same distance from Sanford where they strike N. 60° E. and dip 30° to the southeast. Fragments of the light-colored rocks marking the southern boundary of the Cumnock formation may be seen on the road from Sanford to Colon at a distance of one and three-fourths miles from the main street leading nearly due east from the center of Sanford. From the last mentioned place the outcrop of light buff sandstone was traced continuously nearly due east through the forest for a distance of one and one-half miles to the zone of dikes which passes a little north of west through the village of Colon on the Seaboard Air Line and the Norfolk Southern railroads.

East of the Sanford-Colon Highway the belt of light-colored rocks appears to grow narrower and narrower towards the east until it disappears as stated above, in the zone of dikes. It is probable that other bands of light-colored rocks may extend into this forest-covered region, but, if so, they are separated by red conglomerate which probably interfingers with the light-colored sandstone and shale. The writers are strongly of the opinion that, as the southeastern margin of the trough is approached, the Cumnock formation is split up by layers of red rocks which increase in number and thickness until possibly the light-colored rocks of the formation are entirely replaced by red sandstone, shale, and conglomerate that cannot be differentiated from the overlying and underlying rocks. If the northeastward termination of the Carthage trough as explained later under the heading "Geologic Structure," is due to the formation of a cross-anticline in the vicinity of Colon, then the outcrop of the Cumnock formation should, if it were unbroken, extend in general eastward south of Colon until it reaches the axis of the cross-anticline and then it should loop back to the northwest in a line nearly parallel with, but departing more and more to the northward from the outcrop already described, until it reaches the point where it turns northeastward along the rim of the Corinth trough.

The writers examined this part of the field with considerable care in order to determine whether or not the outcrop does swing back on the north side of the Colon anticline, but no trace of it could be found. As the outcrop extends only as far east as the dikes mentioned before it seems probable that the formation is cut off by a fault which follows the course of the dikes and possibly passes through and is responsible for the sharp angle in the line marking the base of the Pekin formation near the Capital Highway and the Norfolk Southern Railroad. The reason for this supposition will be more fully considered under the heading "Geologic Structure."

*In the Corinth Trough.*—From Colon northeastward to Zion Church a careful examination was made for any drab shale or light-colored sandstone that might indicate the presence of the Cumnock formation, but none was found. In most cases the outcrops are so poor that one cannot be certain that light-colored rocks are not present, but one section was found that shows almost continuous exposures of red rocks from near the Capital Highway on the northwest to the Osgood-Zion Church road on the southeast. This section is on a road which leaves the Capital Highway at Jones Chapel and intersects the Osgood-Zion Church road about a mile north of Osgood and the rocks dip continuously to the southeast throughout practically the whole of this section. Here apparently is a line across which the outcrop of the Cumnock formation does not pass, unless its rocks are different from those which are generally recognized as typical.

Although the Cumnock formation is absent in the section just mentioned, it comes in suddenly, and with its characteristic light drab color, only a mile or so to the northeast, as shown by a coal prospect and associated light-colored rocks in the proper position to be in the Cumnock formation. One-half mile north of Zion Church a thin layer of coal, only a few inches thick has been exposed in a pit dug on the farm of Morris Holt. Here adjacent bands of gray sandstone lying both above and below the coal bed and also the debris of light-colored sandy shale that cumbers the hillsides in the vicinity, all point to the fact that a belt of light-colored rocks strikes parallel with the boundary of the field and dips normally to the southeast at an angle of 25 degrees. The width of this belt of outcrop was not determined, but where the belt is crossed by a small stream near the coal pit, the light-colored rocks were seen for a distance of several hundred feet on either side of the pit.

The coal prospect noted above on the Holt farm, appears to be the same as that mentioned by Professor Emmons in his report of 1856 (p. 244) as occurred on the Rhiney Wicker (Ellington) property. He notes that the coal bed here is less than three inches thick, and this agrees exactly with the statement of Morris Holt, who a few years ago sunk a pit to the coal bed. Professor Emmons, however, does not regard this belt of coal-bearing rocks as occurring in the Cumnock formation, but thinks that it is associated with the upper red sandstones and conglomerates (Sanford formation) and not the same as the rocks exposed in the Cumnock shaft. His conclusions were based on the proximity of a fossil plant-bearing shale to the coal and sandstone. It is true that, although the succession of strata from the schist upward is practically the same as it is at Cumnock, the thickness of the Pekin and the Cumnock formations is very much less. The data at hand do not permit of an accurate measurement of these formations at the Morris Holt farm, but the Pekin formation is probably about 1,000 feet and the Cumnock formation not more than 800 feet thick at this place. The present writers have carefully considered all of these points, and, though they regard Professor Emmons' conclusions as possible, the succession of beds strongly suggests that the formations are the same as those that have been observed farther west.

Although the writers believe that the coal on the Morris Holt farm is in the Cumnock formation they must admit their inability to explain the disappearance of this formation in the district about Colon. Here then is a case of disappearance of the Cumnock formation, very similar to the disappearance of the same rocks in the vicinity of Mooshaunee which was described on another page. The only difference in the two cases is that south of Colon there is positive evidence that the formation changes in character by the occurrence in it of beds of red conglomerate which cannot be distinguished from the red conglomerate of the Sanford formation, and it is possible that, if the outcrop of the formation could be followed to the southwest from the Morris Holt farm, it likewise would be found to split and become red by the introduction of red conglomerate between the layers of drab or gray sandstone and shale.

From the farm of Morris Holt the outcrop of the Cumnock formation probably extends continuously northeastward beyond the limit of the territory represented by the map accompanying this report, but it is not well shown at any point visited by the writers. Light-colored rocks were seen on the southwest side of Deep River on the road from Osgood to Lockville and on the northeast side of Deep River in the vicinity of Moncure. Various rumors were heard in the village of Moncure about coal having been struck in bored wells in the village and also in pits sunk for the foundations of the water tank near the railroad station, but the accuracy of these reports is subject to question. In drilling a water-well in the village the drill is said to have passed through a few inches of black material which may have been coal or black shale. The report that coal was exposed when the foundations of the water tank were laid could not be confirmed by the records in the office of the Chief Engineer of the Seaboard Air Line Railway; therefore the writers conclude that the evidence regarding the presence of coal at Moncure is of very doubtful value and at best does not seem to indicate a thickness of more than a very few inches.

### Sanford Formation

The rocks above the Cumnock formation are almost universally red, being composed largely of conglomerate, sandstone and shale in a monotonous succession, which crops out across the trough from the upper limit of the Cumnock formation to the Jonesboro fault. As these red beds are present under and around the town of Sanford that name is proposed for the formation which includes all rocks of Triassic age above the Cumnock formation.

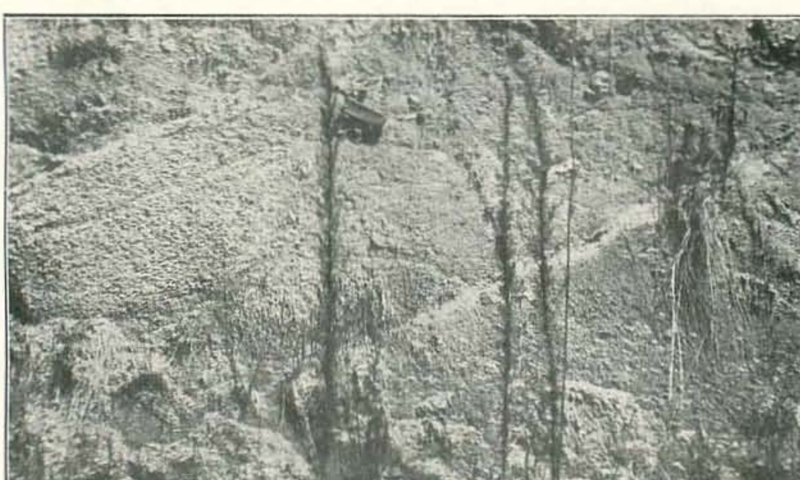
The Sanford formation has little of interest to one seeking for coal, for, so far as known, there are no coal beds in it, and, in fact, very little except red rocks. These consist of red conglomerate, which apparently varies in coarseness according to its nearness to the southeastern border of the field, for from this direction came most, if not all, of the materials composing it. The pebbles, cobbles, and boulders found in the formation were largely derived from the crystalline schist and slate (Pl. IV-A), but the largest boulders observed are of granite (Pl. IV-B), a large mass of which apparently was intruded into the schist just east of the present boundary of the Newark rocks on the east side of Cape Fear River.

The cuts made in grading for the Norfolk Southern Railroad between Colon and Corinth offer the best field for a study of the characteristics of the Sanford formation. In the cuts directly east of Colon the material is relatively fine, few of the individual cobbles being more than six inches in diameter, but near Corinth the material is much coarser, one boulder of granite (Pl. IV-B) near the Jonesboro fault measuring four feet in its longer diameter. A few hundred yards beyond the point where this boulder is exposed in the railroad cut the Sanford formation rests directly against a mass of granite from which the boulder doubtless was derived.

The thickness of the Sanford formation is evidently very great, but no geologist so far has secured sufficient data to make a very reliable estimate. In 1852 Professor Emmons, in discussing this matter, arrived at the conclusion (p. 137) that the thickness of the upper red sandstones (Sanford formation) is 3,000 feet, but confessed that his estimate was vague and of little value, except as a minimum measure, which he thought might be very materially increased, if adequate data were available. At the present time the outline of the field is much better known than it was in 1852 and it is possible to make a better estimate, but even today there are many unknown or variable factors in the problem which render the result only approximately correct.

In making an estimate of the total thickness of rocks in the Deep River Coal Field, it is evident that the field is naturally divisible into two parts; the line of separation being in the vicinity of Colon, three miles northeast of Sanford. The trough southwest of Colon is broader and seemingly shallower than the trough to the northeast of that place, hence it seems probable that a greater thickness of rocks is involved in the latter than in the former trough. Although the trough southwest of Colon is shallower, it is more irregular in structure and is not well adapted to a measurement of thicknesses, particularly when it is remembered that all its eastern part is largely obscured by white sand which mantles the hard rocks and almost completely conceals them. For this reason the southwestern trough has been disregarded. The trough northeast of Colon is narrower, but the dips are much more constant across it from one margin to the other; consequently it offers decidedly better opportunities to obtain a reasonably accurate estimate of the thickness of rocks involved, unless it is cut by longitudinal faults which duplicate the measures. The best estimate that can be made at the present time is that the Sanford formation is probably 4,000 or 5,000 feet thick. If this thickness is correct then the entire Newark group has a probable thickness of 7,000 to 8,000 feet and the crystalline schist lies at approximately that

A. Boulders of schist in the Sanford formation. View in cut of the Norfolk Southern Railroad east of Corinth. The boulders are badly decayed, but range in diameter up to 16 inches.



B. Boulder of granite in the Sanford formation. This boulder, 4 feet in diameter, shows in a cut of the Norfolk Southern Railroad nearly three miles east of Corinth.

depth below the surface in the vicinity of Corinth on the Norfolk Southern Railroad, east of Cape Fear River.

### Igneous Dikes

The rocks of the Newark group, as well as the underlying crystalline schist in the Deep River Field are cut by numerous dikes of diabase, but their outcrops are so greatly obscured by sand, gravel and the forest that the writers made little effort to map them in detail; they were, however, carefully noted wherever they crossed the highways and other lines of travel where their outcrops are plainly visible. An effort was made in a small area northwest of Sanford to trace and map several dikes off the highways, but after one day's experience in tracing the dikes through cultivated fields, woodlands and swamps, it was given up as impracticable.

The dikes, although somewhat irregular in their trend, seem to belong to a great system which in general trends N. 20 degrees W. They are probably fairly evenly distributed throughout the territory, although they are not so represented on the map. This seeming irregularity in occurrence is due in part to the greater number of routes traversed in certain parts of the field than in others, and in part to the better exposures near the river and the larger creeks than there are on the upland, where the blanket of sand and gravel is unusually thick. Although the dikes are present in almost every part of the field, close examination shows that in certain places they are much more numerous than they are in others, and in certain large areas they seem to be absent. When one makes an examination of the outcrop of the Cumnock formation from Haw Branch to Gulf, he is impressed with the frequency with which he encounters dikes or the boulders resulting from the decay of dikes. They seem to follow the outcrop of the coal beds, for they are present at almost every prospect that has been opened for coal in this part of the trough. The parallelism of the dikes and the coal outcrops is certainly true for a distance of a mile or two in the vicinity of Carbonton, but north of Indian Creek there does not appear to be such a close agreement in direction as there is south of that creek. The prevalence of dikes on the outcrop of the coal beds about Carbonton has had a decidedly detrimental effect on the commercial development of the coal. When one compares the general absence of dikes on the ridge which the Sanford-Cumnock road follows for three or four miles south of Cumnock, with their abundance about Carbonton, he is decidedly impressed with the irregularity rather than the regularity of their occurrence.

The composition of the dikes, as shown by a sample collected near the point where the Carthage-Charlotte Highway crosses Richland

Creek and another from a cut of the Norfolk Southern Railroad a short distance southwest of Gulf, is that of a typical diabase with only a very little magnetite. This seems strange, as the dikes had such a disastrous effect on the magnetic needle during the present survey, but it is probable that the magnetic attraction is due to the polarization of the dike material rather than to the composition of the rock.

In general the dikes cut the country rock in an almost vertical direction, and in most cases where their bounding walls can be seen they are extremely regular and the thickness of the dike varies but little. In some railroad cuts where the dikes are visible for ten to twenty feet it was found that they are approximately vertical, that they frequently cut through the bedded rocks without causing any deformation, but here and there the sandstone beds on one or the other side of the dike are pushed up out of their normal position as much as twenty degrees, showing that the igneous material was forced up under great pressure and that in places it lifted the country rock out of its normal attitude. One of the best examples of tilting caused by a dike was seen in a deep cut of the Norfolk Southern Railroad on the southwest bank of Cape Fear River in the eastern part of the field. The photograph of this dike is reproduced as Pl. V-B. As shown by the plate, the dike stands about vertical, but the sandstone on the left which normally outcrops in a nearly horizontal line is tilted or lifted up about twenty-five degrees. The beds on the right are not clearly shown in the cut, but at the time the picture was taken, they were studied with some care and no sign of a corresponding dip was detected.

Although the dikes generally have regular and parallel bounding walls, there are apparently some exceptions to this rule. The most notable case that was seen is a dike cutting the Cumnock formation at the north end of the dam of the Sand Hill Power Company at Carbonton. A part of this dike is shown in Pl. VI-B. The exposure occurs at the end of the dam shown in Pl. VI-A; in fact the camera was resting on the dike when the picture of the dam was taken. On Pl. VI-B the left edge of the dike is indicated by the camera case and the hammers. At this point it comes in contact with the cut edges of the dark indurated shale of the Cumnock formation which here dips to the northwest or away from the observer about ten degrees. The contact of the dike and the shale rises and curves to the right until it reaches the main mass of the dike perhaps eight or ten feet to the right of the rock showing in Pl. VI-B. This contact is sharp and irregular showing that the shale has been broken away by blocks and there is no suggestion of the country rock having been fused by the heat of the molten mass of the dike. This is one of the best exposures of the walls of a dike that was seen.

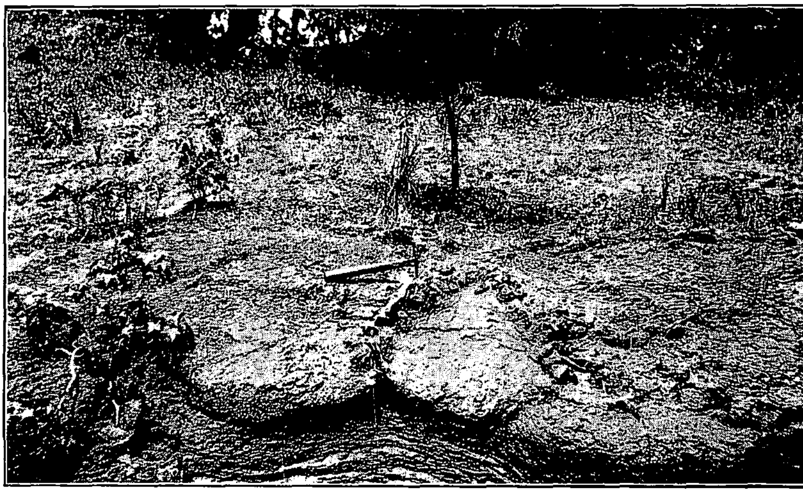
The dikes range in thickness from a few inches to about 100 feet, and it is not thought that any dike in this field has a greater thickness than that just given. Some very minute dikes were observed in a homogeneous red sandstone by the roadside just west of McLennon's Creek on the road leading from Carthage to Mooshaunee. Some of these dikelets are no thicker than a knife blade and none exceeds a quarter of an inch in thickness. They radiate in all directions, following a system of minute fissures that doubtless was developed in the sandstone before the intrusion occurred. These dikelets are shown on Pl. V-A.

It is interesting to note that the dikes have a very decided effect on the circulation of underground water and that this fact is utilized in the field. Thus the inhabitants have learned, through long experience, that water can be secured much more readily by sinking wells near a dike than it can in the country rock where there is no dike. From this fact it is evident that the dike serves as a barrier to the circulation of liquids through the rocks and that next to the barrier a pool is formed. If there were any petroleum in the rocks it is probable that it would be affected in a similar manner and consequently any test wells that are put down should be drilled near the dikes or at least so they would strike the porous reservoir near the point where it is cut by a dike. This phase of the subject will be considered at greater length on another page.

From the standpoint of the coal operator, the most important question concerning the dikes is their effect upon the quality of the coal and upon the cost of mining. It is obvious that if a molten mass from 50 to 100 feet thick comes in contact with coal, the coal will suffer considerable change. If a coking coal, such as that in the Deep River Field, is cut by a large dike, it may be changed into any of the following substances: if the coal is near the surface where oxygen is abundant, the coal is liable to be entirely consumed, leaving in its place only a bed of ashes; if less oxygen is available, the coal may be converted into coke; and if the supply of oxygen be very limited the coal may be so baked that it is converted into anthracite. In general, it may be said that these processes go on at different depths beneath the surface of the ground, for it may be assumed that the supply of oxygen in the rocks decreases as the depth below the surface increases, but this increase is doubtless irregular, depending upon many conditions that, from the surface, cannot be foretold. Although it is obvious that the supply of oxygen decreases with depth, it is impossible to say at what depth anthracite is produced or at what depth the coal is converted into coke.

In the Deep River Field, as far as the writers have observed, the coal has been converted into anthracite wherever it has been cut by a dike; therefore, it seems probable that when the intrusions took place the coal that now shows at the surface was buried beneath hundreds, if not thousands, of feet of other rocks belonging to the Newark group, which have been removed in the general erosion of the region. As erosion progresses so slowly that a man can seldom see in his lifetime any appreciable change in the earth's surface, due to this agency, the intrusion must have taken place millions of years ago and probably soon after the rock-making materials were deposited.

As the dikes may not only affect the quality of the coal in a narrow belt on either side, but may also in places tilt the coal bed, as the sandstone bed is tilted in Pl. V-B, they may seriously affect the mining of the coal. Every operator, therefore, who is contemplating the opening of a mine should carefully study and map the dikes, as they show at the surface, so that he may have some idea of what he is liable to encounter at a depth in the mine, and he should also study them with the object of obtaining more data than is at present available to the writers, regarding the attitude of the dikes and the points at which they are likely to intersect the coal bed. If the dikes are vertical, as the writers have been led to suppose, then they should cut the coal bed directly below their exposure on the surface, no matter at what depth the coal may be, but if the dikes are not vertical, then they will not cut the coal directly beneath the point where they show at the surface, but to the right or left, depending upon the inclination of the dike and the depth of the coal bed. It is possible, however, that a dike, which in general has regular walls and which stands vertically at the surface, may suddenly cut across the beds in such an irregular way that its position at a given depth below the surface cannot be predicted with any assurance whatever. The only case of this kind that was observed by the writers is that already described at the dam of the Sand Hill Power Company at Carbonton, but those who are familiar with the habits of dikes know full well that though they may be in general extremely regular in trend and in attitude, they will sooner or later change their courses suddenly seemingly without reason and pursue a totally different course from that followed by the general system. Such eccentricities are to be expected and the operator should watch carefully for them in order to predict where the dikes may be encountered in the mine. Those who conduct drilling operations or who examine drill cores for the purpose of determining the character



A. Minute dikes cutting red sandstone. These dikes which range in thickness from that of a knife-blade up to a quarter of an inch are exposed on the Carthage-Mooshaunee road a short distance west of McLennons Creek.

B. Sandstone tilted by a dike. This view in a cut of the Norfolk Southern Railroad on the southwest bank of Cape Fear River shows how a dike has tilted a bed of sandstone that a short distance away is horizontal.

of the rock penetrated by the drill, should watch carefully for indications of dike material, as it seems probable that many times such material has not been recognized in drill cores and thus only a part of the information which the core should have yielded has been utilized.

## GEOLOGIC STRUCTURES

### General Statement

In almost the earliest reports on this region the Newark group is reported as lying in a trough or syncline. Professor Emmons, in his report of 1852 (page 119) refers to it as follows:

> The Deep River Coal Field is in the form of a trough. In this coal field, the uplift has been made upon the northwest side. Its line of demarcation is distinct; while, upon the southeast side, there is no outcrop.

In the course of the present examination the idea of the trough-like form of the sedimentary rocks was confirmed in the region represented by the map (Pl. I), and also in a rapid reconnaissance which was made near the southern boundary of the State.

On the line between Richmond and Montgomery counties the Newark sandstone, shale, and conglomerate show in nearly typical form, the three formations described in previous pages of this report being easily recognized. The belt of outcrop has a width of 5 or 6 miles and lies about 4 miles east of Mount Gilead in Montgomery County. The southeastern border of the belt is clearly marked by Pea Ridge which is formed of the crystalline schist and igneous rocks. The boundary line marking the base of the Pekin formation passes through the village of Covington which is shown on most maps. In travelling from Mount Gilead southeastward, one first crosses a belt of red sandstone and shale of the Pekin formation, then a rather narrow belt of the Cumnock formation in which coal is reported, but such reports could not be verified, except locally in pockets in the gray sandstone, then a belt of red sandstone and conglomerate of the Sanford formation. Continuing southeastward one then crosses the formations enumerated above in reverse order. This indicates clearly that the trough is fairly complete, and dips show that it is in the form of an open syncline. The dips on the northwest side are very slight and the width of the outcrop is correspondingly great, but on the southeast side the dips are somewhat steeper, though rather obscure, and the outcrop correspondingly narrow. It is possible that there is a small normal fault on this side of the syncline along the northwest base of Pea Ridge, but if so, it is of small displacement.

No attempt was made to follow the formations northeast of Pekin and Covington, and in fact the outcrops on the divide between the main drainage lines are so badly obscured by sand and gravel that it is extremely doubtful whether this can be done until many drill holes have been put down to bedrock. In some places on this divide the bedrock is deeply covered, as for instance at Pinehurst, a well which was drilled for water encountered bedrock at a depth of 195 feet. The red rocks of the Newark group were seen at Jackson Springs and on the headwaters of Little River north of Pinehurst, and from these occurrences it is assumed that the synclinal structure which shows so clearly at Pekin and Covington is continuous with that at Carthage, as shown on the map accompanying this report.

### Carthage Trough

*General Description.*—At Carthage the east limb of the trough is lacking, having been cut off by the Jonesboro fault, as explained later, but the synclinal form is plainly apparent in the rather steeply sloping northwest side of the trough and the relatively flat bottom which is indicated by the slight dips recorded on the Carthage-Sanford road.

From Carthage northeastward the trough is continuous and of approximately the same shape and width to the vicinity of Sanford, Cumnock and Gulf, where it is nearly cut off by a cross-anticline here called the Colon anticline, which corresponds in position and direction with a line connecting Woodard's Bridge and the Sanford Waterworks on the headwaters of Lick Creek, about three miles east of Sanford. The synclinal character of this end of the trough is shown by the semicircular shape of its northern extremity. With the exception of the offset in the outcrop of the formations caused by the Deep River fault, which has already been described, the formations crop out in semicircular belts from Gulf on the northwestern side, through Cumnock to Sanford on the southeastern side. The outcrop of the Cumnock formation, as previously explained, does not complete the semicircle, as it pursues an easterly direction beyond the Capital Highway and is lost to view in a disturbance of the rocks south of Colon. But, although the Cumnock formation does not complete the semicircle, the structure is complete, as shown by dips of the overlying rocks in the vicinity of Sanford; these dips clearly indicate that the semicircular structure prevails entirely across the trough and is terminated only where it is cut off by the great Jonesboro fault which bounds the Newark rocks on the southeast. The synclinal structure about Sanford is shown by westerly and southwesterly dips for one and one-half miles west of town; by westerly dips on the Carthage road a little north of Buffalo Church; by westerly dips in cuts on the Seaboard Air Line Railway, one and one-half miles south of Sanford; by westerly dips in cuts on the Atlantic Coast Line Railroad in the vicinity of the Lee County courthouse; by southwestward dips on the Osgood road two to two and one-half miles from town; by southwestward dips on the Poplar Springs Church road two and one-half miles east of Sanford; and by dips in the same direction just north of the Sanford Waterworks on Lick Creek nearly due east of town. The agreement of these dips and strikes indicates beyond question that the general structure in the vicinity of Sanford is synclinal and that the trough has a very symmetrical end at its northeastern extremity. Some persons may object to this conclusion on the grounds that, by the writers' own statement, the synclinal point or spoon is very much broken and disturbed by the Deep River and possibly other faults, and consequently there may be grave doubts about it ever having been a complete synclinal end. To those who may consider offering such a suggestion, it may be said that the presence of the longitudinal faults does not in any way enter into the question, for it is perfectly clear that these faults were produced after the bowing up of the Colon anticline and consequently after the formation of the spoon-shaped point to the syncline.

East of the Seaboard Air Line Railway the outcrop of the Cumnock formation trends nearly due east for one and one-half miles, and comes to an end, as far as surface indications are concerned, in a group of dikes trending N. 20° W. The original form of the outcrop between the point where it now ends on Lick Creek and the point where it reappears on Little Lick Creek probably will never be known, but it is likely that in its original form it may have turned back toward the northwest slightly and then pursued a regular northeastward course approximately parallel with the northwestern margin of the field as it is today.

*Minor Structures.*—The general synclinal structure of the Carthage trough is quite clear and unmistakable, but some of its subordinate structural features are extremely puzzling. The most pronounced of these minor structures is the Deep River fault which has been partly described on a previous page. This fault is easily recognized where it offsets the contact of the Pekin formation and the underlying crystalline schist and also where it causes a corresponding offset in the outcrop of the Cumnock formation in the valleys of Deep River and Buffalo Creek, but beyond these recognizable features either to the north in the crystalline schist or to the south in the interior of the Carthage trough it is probably impossible to trace it, as it simply offsets the beds within a single formation, and those lying on one side of the fault are so like those on the other side that they are indistinguishable. It is barely possible that the fault extends into the trough only a few miles, as represented on the map, but it is more likely to extend a much greater distance, possibly to the southern boundary of the territory represented by the map. The fault is of the normal or tension type, for no other kind of fault would produce such offsets in the outcrops of the formations, as have been described here. It is the same type as that of the great Jonesboro fault which bounds the Newark rocks on the southeast and probably it was produced at the same time and by the same force that produced the larger fault. The character of the fault and its effect upon the adjacent rocks are shown in Fig. 4.

The minor structures on the rim of the Carthage trough in the vicinity of Carbonton and Haw Branch are not so well marked as the Deep River fault and consequently the exact character of the deformation is a matter of conjecture. The surface evidence of some irregularity in the structure here, as described on a previous page, consists of the bifurcation of the outcrop of the Cumnock formation a short distance west of Carbonton and the termination in a point a short distance southwest of Glendon of the northernmost of these bands of outcrop. This peculiar configuration of the outcrop, as explained on another page, can be accounted for on the assumption that there is here either a minor fold on the rim of the larger trough or that the rim is cut by a normal fault. As the stresses in the earth's crust in this region were such as to give rise to faults rather than to folds, the first assumption as to the character of the disturbance that produced this bifurcation of outcrop will not be considered further and the features showing at the surface will be attributed entirely to faulting.

The actual existence of this fault has been demonstrated for only a short distance—from Carbonton to the Carthage road south of Glendon—but in order to explain several other irregularities in the boundaries of formations, it has been hypothetically extended from near Putnam to the northern point of the syncline between Gulf and Cumnock. The fault attains its greatest magnitude, in this district, in the vicinity of Putnam where the displacement is probably 1,700 feet (4, Fig. 2). It appears to decrease gradually in magnitude toward the northeast, until it dies out probably before it reaches the outer margin of the Pekin formation east of Gulf. The effect of this movement on the outcrop of the various formations involved is shown graphically by a number of sections in Figure 2 which are supposed to represent the rocks as they would appear in deep trenches cut directly across the course of the fault at several places between Horseshoe Bend of Deep River and Carbonton. In considering the effect of this fault on actual mining conditions in the field it should be clearly understood that northeast of Carbonton the existence of a fault as well as its location are almost entirely hypothetical and may or may not be correct. As this fault passes through the site of the old village of Carbonton, it will be called the Carbonton fault.

As shown in the various cross-sections of the fault, the stresses which produced it acted at right angles to the course of the fault and resulted in stretching this part of the crust of the earth. In this stretching process the stresses accumulated until they reached the elastic limit of the rocks and then a fault ensued and the movement on the fault plane (indicated by arrows) was such as to cause the rocks to occupy a wider belt than they did before the break occurred. This widening of the belt of outcrop was accomplished by the upward movement along the inclined plane of the fault of the block of the earth's crust on the southeast, with respect to the block on the northwest side of the break.

It is probable that there are faults in this field other than those shown on the map, but if so they are doubtless of a lower order of magnitude. Several small faults have been reported as having been encountered in mining, but these faults generally have a displacement of only a few feet. Faults of this magnitude are serious obstacles in mining but they are difficult to recognize at the surface. All of these faults are of the normal variety, but they do not, according to report, offset the rocks in all cases in the same direction and to the same amount. Faults that are due to the stretching of the earth's crust do not always

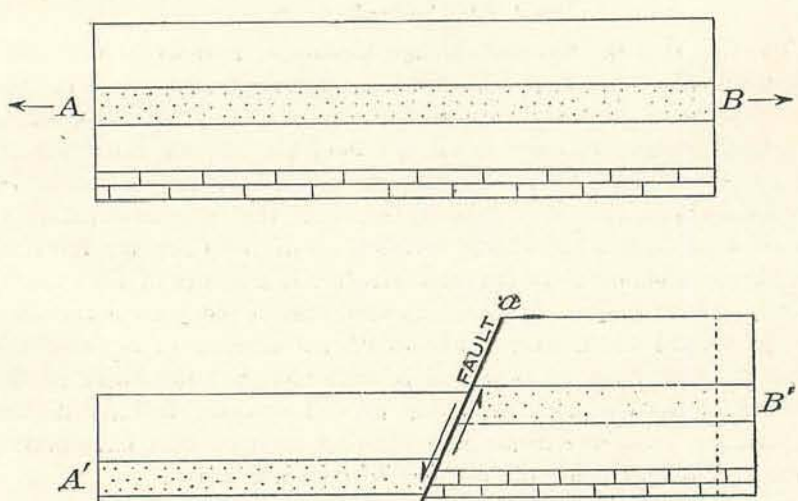



FIG. 3. Diagram showing various forms that normal fault may assume.

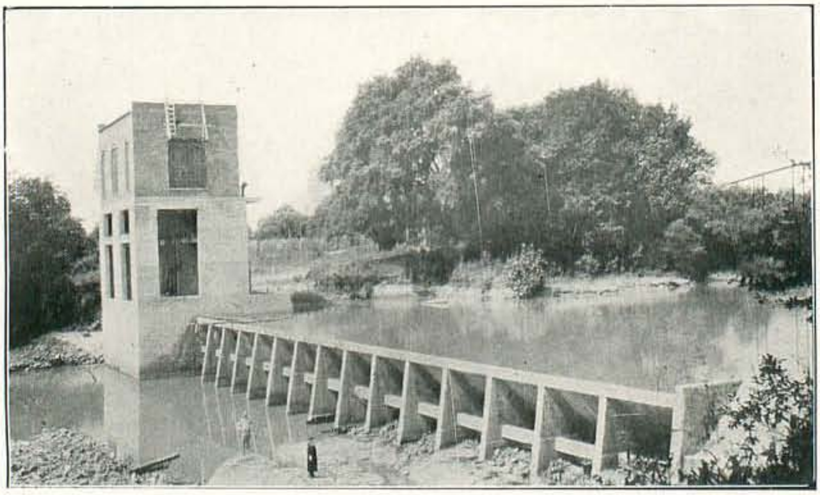
have the upraised side on the southeast; it may be on the northwest, but in that case the plane of the fault will incline in the same direction, so that when the movement is completed the rocks will occupy a greater width of outcrop than they did before. The diagram in Fig. 3 shows how faults of this type may slope in either direction, but the direction of movement will always be the same with regard to the inclination of the fault plane.

There are some slight irregularities in the coal bed shown in the Cumnock and Carolina mines. In the former the dip ranges from about 22 degrees near the outcrop to about sixteen degrees in the lowest workings which, of course, are approaching the bottom of the trough. The coal bed in the Carolina mine has not been mined far enough to reveal much regarding the structure of the coal bed, but there is one thing that stands out very prominently, and that is that the dip in the main entry is only about ten degrees. There seems to be no indication on the surface of a lighter dip of the coal bed as a dip of twenty degrees was measured in a cliff about half a mile southwest of the mine and all of the observed dips in the surrounding rocks agree with this observation. The only explanation that seems at all reasonable is that the mine has been opened in a gentle flexure in which the dip is only ten degrees, but that on driving the entries beyond this small fold, the regional dip of about twenty degrees will be encountered.

### The Colon Cross-Structure

The fact that the Carthage trough terminates abruptly a few miles northeast of Cumnock and Sanford, as previously described, implies the presence of some sort of a cross-structure at this place, because a synclinal trough can come to an end suddenly only by being cut off by a fault or raised by a cross-anticline which effectually destroys the synclinal character. It is evident, therefore, that a cross-structure is required to explain the abrupt termination of the Carthage syncline, but the exact character of the cross-structure is a matter of some doubt. If one were to judge only by the spooning-out of the general synclinal trough toward the northeast, one would not hesitate to say that the cross-structure must be anticlinal in character, but the break in the outcrop of the Cumnock formation as well as other features of less importance, seem to indicate that faulting must at least have played some part in producing the features that we find today.

The outcrop of the Cumnock formation, as described on a previous page, does not indicate an anticline entirely across the trough, as all trace of this formation was last seen at the system of dikes crossing Lick Creek about a mile south of Colon. From Cumnock to the dikes



A. Hydro-electric plant at Carbonton. The dark shale below the dam dips slightly to the right or northwest. Camera rests on the dike shown below.

B. Dike cutting shale irregularly. The dike is exposed in the river bank near the end of the dam shown above.

mentioned above, the Cumnock formation pursues a fairly direct course and dips to the south, as it should if it formed the southwestern limit of a cross-anticline, but the absence of a nearly parallel band of outcrop a short distance to the northeast shows that the anticline is not complete, or possibly that it has been complicated by faulting. The basis for the assumption of a cross-fault is as follows:

(1) The disappearance of the Cumnock formation when it reaches the system of dikes, shown on the map, two and three-quarter miles east of Sanford.

(2) The curious coincidence of the trend of these dikes directly toward the sharp angle in the lower boundary of the Pekin formation, where it turns from a northwest-southeast to a northeast-southwest direction.

(3) The discordance in the dip and strike of the rocks on the two sides of the belt of dikes, the dips on the northeast side being at right angles to those on the southwest side.

(4) The apparent offset in the outcrop of the Cumnock formation from the point already described about one mile south of Colon to the prolongation of the belt of outcrop extending from Lockville southwestward parallel with and about one and one-half miles distant from the line marking the base of the Pekin formation.

From the statements just made it must be evident to all readers that the writers are not in possession of sufficient evidence to determine the form and character of the cross-structure at Colon, but that the evidence at hand points to an anticline that has subsequently been cut longitudinally by a fault.

*The Corinth Trough.*—The structure of the trough east and north of Colon, as far as the evidence obtained by the writers is concerned, is comparatively simple, consisting of a trough of syncline of folding or deposition, which later has been cut near its middle by a longitudinal normal fault. The resultant structure is that of a monoclinal block of the earth's crust in which the dips are fairly constant in amount and uniformly toward the southeast across the entire remaining part of the trough. There are some minor complications on the northwest side of the trough, in the vicinity of Deep River, but at the present time these are not well enough known to permit of an explanation.

*Jonesboro Fault.*—One of the most prominent structural features of the Deep River coal field is the great fault which bounds the field on the southeast side. As this fault does not, in the territory examined by the writers, pass through any town, there is some difficulty in finding an appropriate name, but as it passes through the northern outskirts of Jonesboro and is, therefore, named the Jonesboro fault. Another reason for applying this name is that the fault is exceptionally well exposed in a cut of the Atlantic Coast Line Railroad a few hundred feet southeast of the Lee County courthouse which is located midway between Jonesboro and Sanford.

The actual contact of the Newark sandstones and the schist on the southeast side of the trough can be seen in very few places in this field, but in the railroad cut mentioned above it is as well exposed as one could expect in rocks as soft and friable as either the weathered schist or the sandstone. This contact is shown in Pl. VII. As usual in such faults, there is not a clean-cut line of contact, but the contact can be located within a very few feet. On Pl. VII the nearly horizontal red sandstone can be seen on the left, extending to about the middle of the plate where it is cut off by the fault, but, as previously stated, the break is not a clean one and some fragments of sandstone may be found to the right of this line. The right half of the plate shows crushed and contorted schist which evidently has suffered greatly when the faulting took place and in recent time as been deeply affected by the weather. This zone of crushed and weathered schist has a width of about eighty feet, but at the southern end of the cut grades into fresh schist.

The Jonesboro fault was next seen southwest of the type locality at the point where it crosses the Seaboard Air Line Railway. This occurs in a cut about 1,000 feet north of the highway bridge over the railroad on the Jonesboro-Tramway road. In the cuts at and north of the bridge the schist is so deeply weathered that it has lost its schistose character and it is quite difficult to determine the exact position of the fault, but the presence of a great mass of quartz on the west side of the track makes it certain that the schist extends at least 900 feet from the bridge. On this basis and also on the basis of red sandstone and shale a little farther north, the line was drawn as shown on the map and it is probably correct to within fifty feet.

Southwest of the place where the fault crosses the Seaboard Air Line Railway the country is deeply covered with white sand and no trace of the fault could be found for a distance of nine miles, although its supposed position was crossed at a number of places, but the sand is so deep and the dissection by the streams so slight, that no exposure of bedrock could be found. The fault was approximately located, however, on a road leading southeast from Lamms Grove Church at a distance of about one mile. Here the blanket of sand is removed for a short distance, leaving the schist quite well exposed. No red sandstone was seen, so the line as drawn on the map should be regarded only as a provisional location, and the actual position may be somewhat farther to the northwest.

The actual position of the Jonesboro fault was determined a few miles farther southwest on the Carthage-Cameron road which leaves the main Sanford road three and one-half miles southwest of Lamms Grove Church. On this road at a distance of one and one-half miles from the Sanford road the actual contact of the shale of the Newark group and the schist can be plainly seen by the side of the road. The contact here is as definite as that which has already been described in the cut of the Atlantic Coast Line Railway, north of Jonesboro.

Southwest of the Cameron road no exposures of the Jonesboro fault could be found within the limits of the territory represented by the map, although search for it was carefully made as far to the southwest as the Carthage-Vass road. The Newark rocks are exposed just west of the Carthage-Pinehurst road, but southeast of that road the sand covers everything and no bedrock could be found.

East of Jonesboro the position of the fault is much more easily determined than it was possible to do west of that place. The fault was first located east of Jonesboro near the Sanford Waterworks on the headwaters of Lick Creek. The exact contact was not seen here, but rocks associated with the schist show at the creek crossing a few hundred feet north of the waterworks and a short distance beyond the creek red sandstone of the Newark group is well exposed. This gives the position of the fault with a possible error of less than 100 feet.

East of the waterworks the trace of the fault was not crossed until it reached Poplar Springs Church. On the Sanford road leading to this church the bedrock east of the crossing of Lick Creek is greatly obscured especially on the upland by quartz gravel which is so abundant that it conceals all other kind of rock. This condition prevails to the road crossing within a few hundred feet of the church. Here the gravel is replaced by a deep red soil which at first was taken by the writers to be the residual soil left from the decay of red shale, but on close examination a small quartz vein was found in a gulley about 300 feet northeast of the church. This definitely fixes the red clay as being derived from the schist instead of from clay of the Newark group and consequently the trace of the fault must be at or somewhat to the north of the road crossing mentioned. The distance from the red clay to the fault is entirely hypothetical, but judging from the position of the fault both to the west and the east of this place, it probably is only a short distance north of the road crossing, as shown on the map.

The fault was next located approximately on a country road leading almost directly south from Ross Siding on the Norfolk Southern Railroad. The fault crosses this road about one and one-half miles north of the main road from Jonesboro to Avent's Ferry across Cape Fear River.

The Jonesboro fault is clearly marked where it crosses the Jonesboro-Avent's Ferry road, about a mile northeast of Salem Church. The crystalline schist is here in contact with a bed of conglomerate in the Sanford formation, which contains boulders of schist up to 16 inches in diameter. The approximate position of the fault was also obtained at a point about one and one-quarter miles to the northeast of the point where it crosses the road to Avent's Ferry. At least, schist was found in place, as marked on the map; hence the fault must be to the northwest of this point.

No attempt was made to determine accurately the place where the fault crosses Cape Fear River, but its position was quite definitely fixed where it crosses the Norfolk Southern Railroad about three miles northeast of the river. Here between two cuts almost exactly one mile east of Corinth, the fault must pass, as the cut to the west discloses only a coarse boulder conglomerate, whereas the cut to the east shows only granite in place, with a distance between the cuts of scarcely 500 feet. The beds of conglomerate dip towards the fault about twenty degrees, and as southeast dips are continuous across the trough, it is supposed that the beds here exposed are about the highest beds that the writers saw in the Sanford formation. The boulders (Pl. IV-B) in the conglomerate are all granite, having been derived, in all probability from the great mass of granite to the southeast, a part of which is shown in place in the cut directly east of the fault.

The trace of the Jonesboro fault, as it is indicated on the map, is remarkably regular and without offsets or sharp bends of any kind. This apparently is different from the conception of the fault held by other writers. Thus on Kerr's[1] geologic map of North Carolina the southeastern boundary of the belt of Triassic rocks is represented as extremely irregular, making many sinuous bends that seem to have more relation to the surface configuration than they do to the geologic structure. The writers do not understand how this boundary was located by previous writers, but it was possibly drawn through points at which the red rocks were seen to pass beneath the mantle of sand. The present writers followed the same plan at first, until they discovered that the actual contact of the red rocks of the Newark group and the schist is in places several miles southeast of the point where the Newark

[1]Kerr, W. C.: Report of the Geological Survey of North Carolina, vol. 1, Physical Geography, resumé, Economical Geology, Raleigh, 1875.

rocks pass under the cover of sand. After that experience the sand was regarded as entirely a surface feature and as having no relation to the real structure of the region.

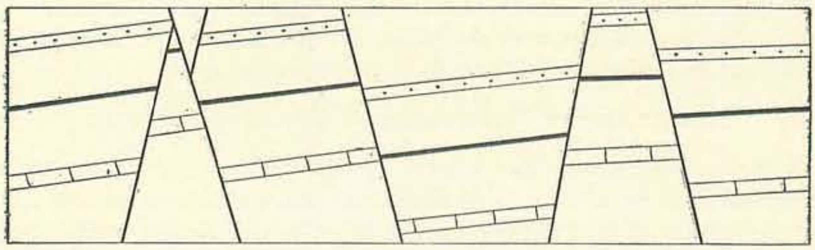


FIG. 4. Diagram showing the character of the Jonesboro fault.

The Jonesboro fault is what geologists generally call a normal fault, or a fault which has been produced by the stretching of the earth's crust in a direction at right angles to the trend of the fault trace until the stress on the rocks was more than they could stand and they are forced to break—this break is the fault. In the present case the pull came from the southeast or the northwest and it accumulated until it was strong enough to rend the rocks of the Newark group, several thousand feet in thickness and also the underlying schist to an unknown distance, but probably to as great if not a greater distance than the thickness of the Newark group. As nature abhors a vacuum, the movement of the rocks on the plane of a fault of this kind is in such a direction as will produce no open spaces within the earth's crust, but will keep the outer shell intact, even though that shell has actually a greater circumference after the faulting than it had before. The manner in which this is accomplished is shown in Fig. 4. A B represents a block of the earth's crust which is subject to tension, as indicated by the arrows at each end. The effect of this tensional stress is to stretch the rocks composing the block to their elastic limit and when that is reached there will occur a break, as the rocks can no longer withstand the pull. In block A'B', the break has occurred along the line *ab* and the block on the right has moved up with reference to the block on the left, or the block on the left has moved down. As the plane of the fault inclines from the perpendicular toward the right at the top and the left at the bottom it naturally follows that a movement such as is indicated by the arrows in block AB will tend to lengthen the block as the distance from A' to B' is manifestly greater than that from A to B. If the fault plane had inclined to the left at the top and the right at the bottom then movement such as has been described would have been due to compression rather than tension and the result of a break would be to shorten the earth's crust. As there is little indication of compressive stresses having been operative it is evident that the Jonesboro as well as the Deep River fault are of the type represented in Fig. 4, the fault plane in each case inclining at the top toward the upraised block, but the indications in the field are that the inclination of these fault planes is not great.

## History of the Development of Geologic Structure

*General Statement.*—The writers are not prepared to outline the complete history of the development of the geologic structure, but certain phases of that history seem to be quite well shown in the Deep River Field, and others are suggested which seem to be worth stating. In departing to a certain extent from the accepted opinions regarding the manner of deposition of the Newark group and the stresses that subsequently have developed in the rocks and have deformed them, the writers are aware that they are entering a field in which other geologists have worked much more extensively and have arrived at very different conclusions, still the structural features here are such as seem to call for a different explanation. The writers merely offer the explanation that is the simplest and still at the same time the one that seems to be adequate to account for the features in question.

It is impossible to visualize the conditions under which the Newark materials were deposited. Many geologists have regarded the present structural features as due to subsidence during deposition, either in the form of a synclinal trough or as a tilted and faulted block. The writers are not prepared to deny that such movements have occurred, but the field relations are such that it seems absolutely certain that the formation of the Jonesboro fault was the last episode in the history of the development of the structure of this region, for the fault cuts all of the other structures; this it could not do were it not the latest feature to have been produced. If the formation of the Jonesboro fault is later than the formation of the other features, it is obvious that it cannot have influenced in any way the erosion of the adjacent region and the transportation of the coarse material to the scene of deposition in the Newark trough.

According to the data accumulated during the study of the Deep River Coal Field, the development of the present structural features may be divided roughly into three separate and distinctive episodes, as follows:

(1) *Deformation accompanying sedimentation.*—Geologists who have studied the Newark group in the Appalachian region generally believe

Jonesboro fault in railroad cut. This exposure is in a cut of the Atlantic Coast Line near the Lee County Courthouse. The fault brings red sandstone of the Sanford formation on the left in contact with badly decomposed and contorted schist on the right.

that these formations were deposited on a subsiding surface and that as time progressed the subsidence became more and more pronounced and at the same time the land surface on either side was elevated more and more, enabling erosion to furnish not only more material to be deposited, but much coarser material, consisting generally of boulders several feet in diameter. Authorities are divided in their opinions, some holding that the subsidence took the form of a syncline of deposition, and some that the subsidence was due to the dropping or the tilting of blocks of the earth's crust which had been separated from one another by great faults.

The writers believe that similar movements accompanied the deposition of the various formations constituting the Newark group in the Deep River Field, but the problem is whether the subsidence was of the nature of a syncline or of tilted and depressed blocks. If it were the latter then some trace of the faults which accompanied and made possible the tilting of the blocks should be found. The only fault that has affected the trough throughout its entire extent is the Jonesboro fault, but it has been shown that this fault truncates some of the important structures of the field and consequently it must have occurred long after the rocks were laid down and after they were deformed in certain ways. In the light of this evidence the writers have concluded that faulting did not play an important part in the original deepening of the troughs. Even with this point settled there is still considerable uncertainty in the minds of the writers as to whether the troughs are the result of simple downward pressure or whether they are the result of horizontal compression. As there is little if any evidence concerning this phase of the subject, it will be dismissed as one of those questions which at the present time are unanswerable.

(2) *Torsional stresses resulting in cross-structures.*—The next episode of a structural character that followed the close of sedimentation in this trough was a movement that produced the cross-structures that are observable today. The most pronounced structure of this character is the Colon cross-anticline which seemingly is responsible for the northeast spoon-shaped termination of the Carthage trough. As explained before, synclinal structure is visible from the northwest side of the trough at Carbonton to the Jonesboro fault south of Sanford. It is inconceivable that a syncline of deposition could have such a symmetrical end, unless it terminated the area of deposition, but here it occurs near the middle of the length of the original trough, without leaving any evidence that could be interpreted as indicating a difference in the character or amount of material deposited in one part of the trough from that deposited in another.

With the cross-structures must be classed also the dikes of the region which in general trend north twenty degrees west. Along most of the dikes there is no indication of movement in the adjacent rocks, except such slight disturbances as have already been described under the heading Igneous Rocks. Although there is little evidence of movement on the planes of the dikes, the great regularity of their trend and their close parallelism in certain zones indicate that there has been some controlling condition that determined their direction. The writers can suggest no such controlling condition, unless it be incipient fissures which the dikes have followed. If the presence of such fissures before the intrusion of the igneous material be granted, then the origin of the fissures remains to be explained. The only suggestion is that possibly they were the result of torsional stresses which twisted this part of the earth's crust and produced the incipient openings that later were filled with the molten material forming the dikes. It is impossible to fix the relative date of the igneous intrusions, except that they may possibly have occurred simultaneously with the production of the Colon cross-anticline and before the movement began that resulted in the Jonesboro fault.

It seems highly probable that the Colon cross-anticline and the system of fissures which were followed by the dikes are both the result of torsional stresses which resulted from the crowding to the westward of the north end of the trough holding the Newark rocks. This twisting motion resulted in the formation of the incipient cracks followed by the dikes, a buckling of the northwestern rim of the trough, which produced the Colon cross-anticline that is nothing more than a cross wrinkle caused by the westward movement of the northern part of the trough, and possibly the faulting of this anticline which resulted from the same movement.

In the buckling movement just described and the formation of incipient cracks, a line of weakness was formed across the trough passing through the present site of Colon and Woodard's Bridge and as the rocks to the north were crowded westward it seems altogether reasonable to suppose that a fault occurred along this line, allowing the rocks on the north to move to the westward as compared with the rocks on the south of the fault. The amount of this westward movement is measured by the offset of the formation and this probably amounts to about two and one-half miles.

(3) *Normal faulting in a longitudinal direction.*—The last episode in this succession of events was the development of the Jonesboro, Deep River, Carbonton and all other faults of the normal type that

may be found cutting the Newark rocks in a direction roughly parallel with the trend of the troughs.

The Jonesboro is the best example of this type of fault as it extends throughout the territory represented by the map and is the most pronounced displacement that is known in the region. So far as can be determined from the few exposures at which this fault has been seen, it is a nearly vertical break which allowed the rocks on the southeast side to move upward with reference to those on the northwest side, or the rocks on the northwest side to move downward with reference to those on the southeast side. This movement is evident when one considers the results produced by it. All the evidence in the field goes to show that the trough in which the sediments of Triassic age were deposited was once much wider than it is at the present time. Before erosion had removed the rocks they doubtless extended farther to the northwest and it is certain that the Jonesboro fault has cut a strip of unknown width off the southeast side, for the offset in the Carthage and the Corinth basins is not reflected in the course of the fault as it should be if the fault were a normal boundary, and the structures developed in the Carthage trough ran squarely against the fault at right angles which they would not do were the fault at the original margin of the trough of deposition. In view of these facts we must conclude that previous to the faulting the troughs were wider than they are at the present time and that the part to the southeast of the fault has been lifted high above the other part and has been eroded long ago, so that now no trace of it remains; or the trough on the northwest side has been depressed several thousand feet and normal erosion has removed the remnant of the Newark rocks on the southeast side. Either movement would have produced the same result, namely, that the schist on the southeast side is brought into contact with the highest beds of the Sanford formation. The amount of displacement of the formations cannot be told accurately, but it must at least have been sufficient to bring all of the Newark rocks above the present surface on the southeast side of the fault and possibly a considerable thickness of schist hence the movement on the fault plane must have been not less than the thickness of the Newark group which on a previous page has been estimated at 7,000 or 8,000 feet.

The character of the fault and the movement which has taken place on the fault plane is illustrated in Fig. 4. Such a break as that here illustrated, if it took place suddenly, might have produced a ridge on the southeast side of the fault of mountainous proportions. Geologists are now generally agreed, however, that all such movements have been very slow, in fact so slow that, had man been upon the globe at that time, he might not have been aware that great crustal movements were in progress, as the only disturbance he may have felt was an occasional earthquake shock of not very great intensity. If the faulting took place as slowly as indicated above, it is probable that the action of streams and the weather wore down the surface of the uprising mass as fast or even faster than it moved, and consequently no mountains were produced, although the aggregate displacement, due to the faulting, is many thousands of feet.

## THE COAL

### Thickness of the Coal Beds

In the present examination of the Deep River Field very little coal was seen. A great amount of prospecting and even mining was done in the early days but the old prospect pits and the mines have generally fallen shut, so that the coal is not visible at the present time. Here and there on the public roads or in gullies in the fields, some coal may be seen, but generally not enough to enable one to pass judgment as to its quality or workability.

The Cumnock mine, being the most extensive operation in the field, naturally presents the best opportunity to study the character and thickness of the coal beds. In the section of the Egypt shaft, published by Captain Wilkes[1] in 1858, the thickness of the coal beds is given as follows:

SECTION OF COAL BEDS IN THE EGYPT SHAFT

| | *Ft.* | *In.* |
|---|---|---|
| Coal | 4 | 0 |
| Blackband | 1 | 4 |
| Coal | 1 | 1 |
| Shale | | 6 |
| Coal | | 7 |
| Shale, black and iron balls | 8 | 0 |
| Sandstone, gray and clay | 16 | 0 |
| Blackband | 1 | 5 |
| Coal | 1 | 0 |

In the early days, it is believed that the entire thickness of the Cumnock or upper coal bed amounting, in this section, to seven feet six inches, was mined. Whether or not the blackband (carbonate of iron) was utilized in the manufacture of iron, the writers have not been able to determine, but it seems possible that the builders of the old Endor furnace had in mind, when they chose this location, not only the nearness to a supply of fuel, but also of a moderate supply of low

[1]Report of the examination of the Deep River district, North Carolina. Report of the Secretary of the Navy, 35th Congress, 2d Session, Senate Doc. 36, 1858.

grade ore from the Egypt and other mines of the district. Even if the ore were tried in this furnace it must have soon been discovered that it was not suitable for the manufacture of iron as it is associated with and probably largely impregnated with phosphate of iron which occurs in nodules in the associated shale.

The bad reputation which this coal had in the early days is probably due to the fact that both benches of the coal were mined and it is equally probable that some of the tests which are reported to have resulted disastrously were made on coal from the lower bench, as this coal, as shown in the table of analyses, has an ash content of 30 or more per cent.

The present writers measured the coal bed in a room in the Cumnock mine directly above Slope No. 1; at one place it has a thickness of three feet five inches and at another, three feet seven inches. These measurements are of the entire upper bench, including at the bottom some coal which is more bony than that which overlies it. Mr. J. J. Forbes,[1] of the U. S. Bureau of Mines, gives the following as the type section of the two benches of coal in the Cumnock mine:

TYPE SECTION OF THE COAL BED IN THE CUMNOCK MINE

(J. J. FORBES)

| | *Ft.* | *In.* |
|---|---|---|
| Coal | 3 | 3½ |
| Bone | | 3 |
| Blackband | 1 | 6 |
| Coal | | 10 |
| Bone | | 2 |
| Coal | | 4 |
| Bone | | 3 |
| Coal with thin layers of shale | 1 | 0 |
| Total bed | 7 | 7½ |
| Total coal | 5 | 5½ |

In cutting the samples of coal in this mine for analysis, Mr. Forbes measured the following section of the upper bench of the coal bed (see Fig. 5): Coal 3 feet (analysis No. 85446), underlain by 4½ inches of bone, in room 1, off No. 1 rise; coal 3 feet 3½ inches (analysis No. 85447) underlain by 3 inches of bone, in room 10, off right side of No. 1 slope; coal 3 feet 7½ inches (analysis No. 85448), underlain by 2¼ inches of bone, in room 13, off No. 1 slope; coal 3 feet 7¾ inches (analysis No. 85449), underlain by 1 inch of bone, in room 8, off No. 1 slope.

[1]Unpublished report by the Bureau of Mines to Col. Joseph Hyde Pratt, State Geologist.

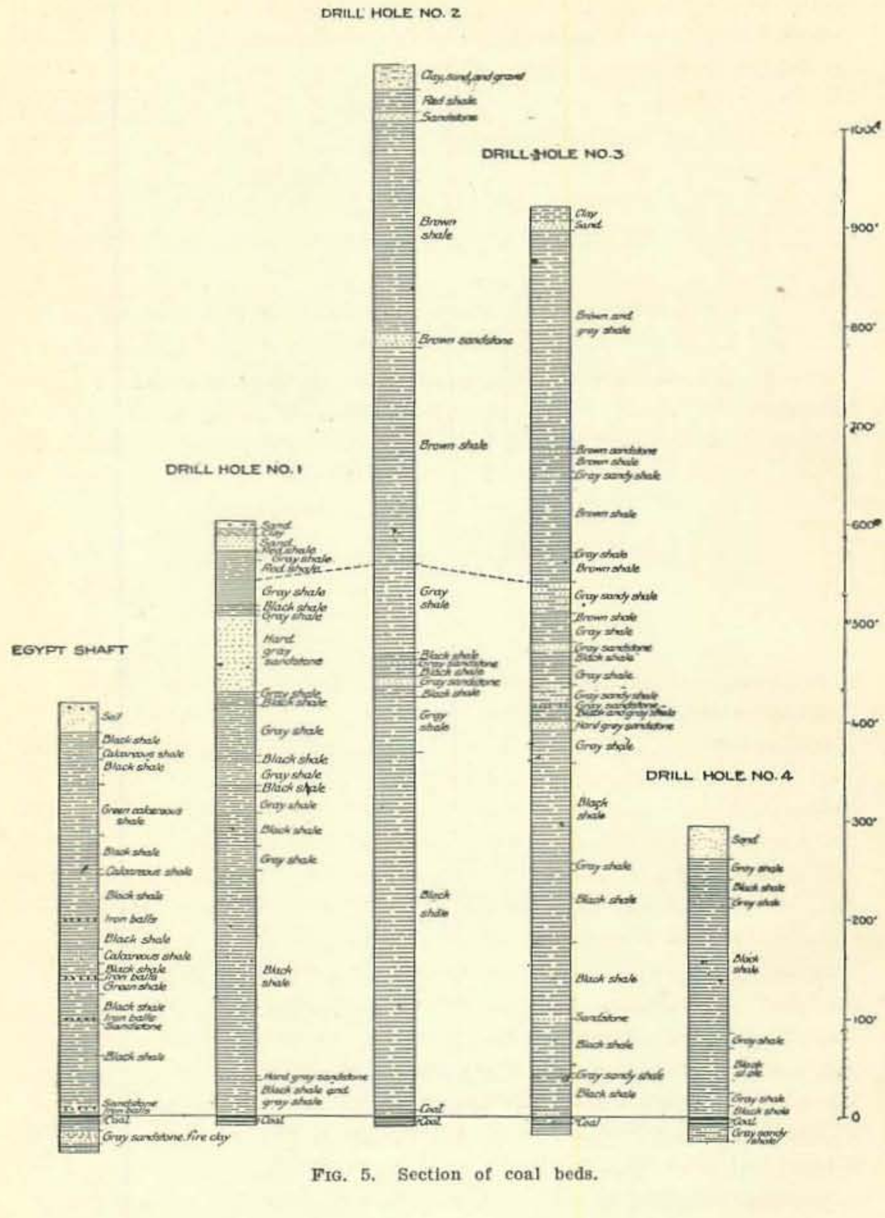



FIG. 5. Section of coal beds.

In the mine of the Carolina Coal Company the upper bench of the Cumnock coal bed, according to one measurement made by the senior writer at the face of 1 left entry, 75 feet from the foot of the slope, is 3 feet 4 inches thick. In sampling this bed for analysis 1 inch of coal at the top was inadvertently excluded from the sample. The analysis of the remaining 3 feet 3 inches of coal is shown as analysis No. 83960 in the table on p. 96. Mr. J. J. Forbes, of the Bureau of Mines, also obtained samples in this mine and his measurements at the points sampled are as follows (Fig. 5): coal 3 feet (analysis No. 85590), on 1 rib of left air-course, 700 feet from the mouth of the mine; coal 3 feet (analysis No. 85591), in No. 1 cross-entry, in by slope air-course. Mr. Forbes also took samples for analysis and made measurements of the lower bench of the coal bed in the Carolina mine as follows:

SECTIONS OF LOWER BENCH OF COAL IN CAROLINA MINE

| A | *Ft.* | *In.* | B | *Ft.* | *In.* |
|---|---|---|---|---|---|
| Coal[1] | | 10 | Coal[2] | | 10 |
| Bone | | 1 | Bone | | 1 |
| Coal[1] | | 6 | Coal[2] | | 11 |
| Bone | | 3 | | — | — |
| Coal[1] | 1 | 1 | | 1 | 10 |
| | — | — | | | |
| | 2 | 9 | | | |

Sections A and B were measured in 1 left entry, off main slope.

In 1884 H. M. Chance prospected the coal beds in the vicinity of Farmville (the Carolina coal mine) quite thoroughly, sinking in all twenty-two shafts in order to determine the character and thickness of workable beds. In one of these shafts he found the upper bench of the Cumnock coal bed to have a thickness of 3 feet, but in all others it was very much thinner or wanting altogether. His final decision was that the upper bench of this coal bed—the one now being mined on the property by the Carolina Coal Company—is of no value. The conditions which led to this decision were probably due to the fact that the many prospectors who had preceded Chance in this part of the field, had mined out most of the coal along the crop and what remained had been affected by caving or the metamorphosing action of dikes and consequently did not show the full thickness of the bed.

Finding, as he supposed, that the Cumnock bed was here worthless, Chance directed his attention to the Gulf coal bed which lies about 30 feet below the Cumnock bed. His section of these beds and the intervening measures is as follows:

[1]Sampled for analysis No. 85593.
[2]Sampled for analysis No. 85594.

SECTION OF COAL BEDS AT FARMVILLE

BY H. M. CHANCE

| | | Feet | In. |
|---|---|---|---|
| Coal | Cumnock bed | 1 | 0 |
| Shale and blackband | | 1 | 6 |
| Clay and shale (estimated) | | 10 | 0 |
| Shale | | 5 | 0 |
| Coal | | | 4 |
| Shale and clay | | 6 | 0 |
| Coal | | 1 | 0 |
| Shale and clay | | 4 | 0 |
| Coal | | 1 | 2 |
| Shale and clay | | 3 | 6 |
| Coal, shaly | Gulf bed | | 8 |
| Coal | | 2 | 0 |
| Shale in blocks | | | 4 |
| Clay | | 4 | 0 |

Chance concluded that the Gulf coal bed is more regular in thickness and consequently more reliable than the Cumnock bed and hence he concentrated his operations on this bed and mined more than 100 tons which were shipped to Raleigh for the use of the Raleigh State Exposition. The character of this coal is shown by an analysis which is supposed to be of a sample representing about 60 tons of coal from the Gulf bed. The analysis is as follows: moisture, 2.1; volatile matter, 28.9; fixed carbon, 52.6; sulphur, 3.7; and ash, 12.7. It is easy now, with the data at present available, to understand that Chance was entirely mistaken in the relative values of the Cumnock and Gulf coal beds, both as regards thickness of beds and quality of the coal.

In addition to the information which the Cumnock and the Carolina mines afford regarding the coal beds there are the logs of four deep drill-holes which have been put down on the Cumnock property. These sections are shown in Fig. 1. The coal beds penetrated by the drill are as follows (Fig. 5):

SECTIONS OF COAL BEDS IN DRILL-HOLES ON CUMNOCK PROPERTY

| *Borehole No. 1* | *Ft.* | *In.* | *Borehole No. 2* | *Ft.* | *In.* |
|---|---|---|---|---|---|
| Coal | 3 | 10 | Coal | 3 | 11 |
| Bone | | 4 | Blackband | | 9 |
| Blackband | 2 | 3 | Coal | 1 | 3 |
| Coal | 1 | 2 | Blackband | 1 | 1 |
| Coal | 5 | 0 | Coal | | 7 |
| Bed | 7 | 7 | Coal | 5 | 9 |
| | | | Bed | 7 | 7 |

| *Borehole No. 3* | *Ft.* | *In.* |
|---|---|---|
| Coal | 2 | 2 |
| Shale, sandy | 0 | 6 |
| Shale, black | 0 | 6 |
| Coal, bony | | 4 |
| Blackband | | 10 |
| Coal | 1 | 6 |
| Shale, black | | 6 |
| Coal, bony | | 3 |
| Coal | 4 | 3 |
| Bed | 6 | 7 |

| *Borehole No. 4* | *Ft.* | *In.* |
|---|---|---|
| Coal and coke | 4 | 0 |
| Blackband | 1 | 4 |
| Coal | 2 | 0 |
| Coal | 6 | 0 |
| Bed | 7 | 4 |

It must be admitted that different measurements obtained on the upper bench of the Cumnock bed in the boreholes might be interpreted as confirming Chance's opinion that this bed is too irregular in thickness to be successfully mined, but when all of the data on thickness available at Cumnock and the Carolina mines are considered, then one cannot help being impressed with the apparent regularity of the upper bench, running on the average about 3 feet 3 inches in thickness and that those sections which depart from this assumed normal section are distinctly different and possibly are to be explained by the disturbing influence of dikes. Usually the cores obtained in drilling are regarded as the final word regarding coal beds, but in this field the core may be seriously affected by a dike and hence every such record needs interpretation by a competent geologist.

On the outcrop southwest of Cumnock there are a few exposures of the coal beds where measurements can be obtained and a number of caved prospects regarding which there was obtained some information that is considered reliable. Some few years ago a slope was sunk on the principal coal bed from a point on the outcrop about 1½ miles nearly due west of the Cumnock mine by William Hill, then General Manager of the Cumnock property. According to Mr. Hill the slope was carried down in coal 4 feet 2 inches thick to a point 150 feet from the mouth of the slope at which the coal bed is offset by a fault. After considerable money had been spent in a fruitless search for the coal bed, the project was abandoned.

In the vicinity of Gulf many prospect pits and so-called mines have been opened on the Cumnock coal bed, but these have not been kept open and the result is that the pits have caved to such an extent that the coal cannot be seen. The only place at which coal is exposed at the present time in this locality is in a recent cut (Pl. II-B) of the Norfolk Southern Railroad, about 2,000 feet southwest of the railroad station at Gulf. The coal bed here is badly crushed and weathered, but it has the appearance of being about 4 feet thick.

Chance gives some data regarding the coal beds at Gulf. At the time of his examination (1884) the remains of two old slopes were found near the boundary line between the Taylor and the Gulf properties from which apparently considerable coal had been mined. The slope on the Taylor farm was not open so that the coal could be seen, so Chance sunk a shaft nearby which struck the upper bench of the Cumnock bed below water level. In this shaft the coal bed measures "almost exactly 3 feet of good clean coal with a slate roof and black-band floor." The analysis of an "average sample" taken from a ton of mined coal, as reported by the State Chemist, is as follows: moisture, 1.7; volatile matter, 35.4; fixed carbon, 55.4; sulphur, 2.0; and ash, 5.5. This analysis is almost identical with some given on page 108 of samples from the upper bench of coal in the Cumnock mine, except that the percentage of ash is less than that shown in recent sampling. This small percentage of ash is probably due to the fact that the sample was picked coal, although intended to be of average quality.

The coal bed opened on the eastern edge of the Gulf property, as reported by Mr. Williams, has the following average section:

SECTION OF COAL BED ON GULF PROPERTY

| | *Ft.* | *In.* | | *Ft.* | *In.* |
|---|---|---|---|---|---|
| Coal . . . . . . | 2 | 0 | to | 2 | 6 |
| Shale . . . . . | | 4 | to | | 6 |
| Coal . . . . . | | 5 | to | | 6 |

A sample of coal from this bed, taken from a pile of about 400 tons gave the following analysis: moisture, 1.9; volatile matter, 32.8; fixed carbon, 59.9; sulphur, 1.4; and ash, 4.0. Chance, however, believes that this analysis is not representative and that the coal contains much more ash and sulphur than the analysis indicates. This bed is correlated by Chance with the bed which he mined at Farmville and which lies about 30 feet below the Cumnock bed. As the coal appears to be quite well developed here it will be called the Gulf coal bed.

From the vicinity of Gulf to the old Black Diamond mine on Indian Creek, there is apparently little information regarding the condition of the coal beds at the crop line or indeed back from the outcrop, as no records of diamond drill-holes have been obtained.

The most recent report on this part of the field is that of Chance (p. 43) which is as follows:

> Explorations made in the past upon the western part of the Gulf property near the Tyson place evidently failed to find the coal in good condition. Two or three slopes were sunk here at which considerable work was evidently done,

but the reports not being favorable and the appearance of the openings and the dumps being extremely unfavorable, I did not consider it necessary to reopen these pits, especially, as much work has recently been done on this property by northern capitalists, and as they did not open at these places the inference that the prospect was not favorable enough to justify further work received additional and forcible support. Moreover as the property is now being thoroughly prospected by the present owners (Metropolitan Bank of Boston), with a diamond drill, at a cost of probably three or four times as much as was appropriated for this exploration of both the Deep and Dan river coal fields, the results so obtained will doubtless determine the value of this property independently of any work that might be done by that State.

Explorations on the Tyson and Palmer places had also evidently failed to disclose the existence of coal of workable quality and thickness, if we may place any faith in the recollections of the residents (and in this I think we may), and as the opening made on the Evans place at the old workings, were of such a discouraging character, I did not feel justified in making any opening on these intermediate plantations, i.e., between the Gulf property and the Evans place.

It is very unfortunate that the results of drilling operations in the vicinity of Gulf, and from that place southwestward to the old Black Diamond mine have never been made public. Under ordinary conditions Chance's conclusions regarding the character of the coal bed would be entirely justifiable, but, owing to the apparently abnormal conditions in this field, the writers are not fully satisfied that, because, one man or one group of men, not thoroughly acquainted with the geologic conditions of the field, saw fit to advise no further operations in 1885, that the field is entirely without merit in 1923. We do not think it entirely safe to come to such a conclusion without more evidence, and consequently the condition of the coal bed in this part of the trough will remain unknown until core-drilling is done here or in adjacent areas.

The Cumnock coal bed has been mined quite extensively near the point where the wagon road from Gulf to Carbonton crosses Indian Creek. This mine is known as the Black Diamond mine, but by whom it was developed and operated the writers do not know. It was evidently in operation many years ago as the old openings have largely fallen shut and the mine dump has been almost completely covered by a rank forest growth. No satisfactory measurement of the thickness of the coal bed could be made, but Chance, in 1884, made some reëxcavations here which throws some light on the condition of the coal bed. At the old shaft Chance reports the following section:

SECTION OF COAL BED IN THE SHAFT OF THE BLACK DIAMOND MINE

| | Ft. | In. |
|---|---|---|
| Shale, clay, and decomposed shale | 32 | 4 |
| Coal, with some shale | 1 | 6 |
| Shale and blackband | 1 | 6 |
| Coal | 2 | 8 |

Chance makes the following comment:

In the airway I found the workings were also upon the lower bench, but the coal was not quite so thick here as at the shaft near the old slope. The coal appeared to be somewhat variable and it was difficult to select a place to make a measurement. The coal may be considered to average as follows:

| | Ft. | In. | | Ft. | In. |
|---|---|---|---|---|---|
| Shale and coal | | 6 | to | | 10 |
| Coal | 1 | 8 | to | 2 | 0 |

Part of the coal is poor and slaty and, if the measurement included only the good coal, the figures would be much smaller. The whole bed, therefore, may be considered as showing an average measurement:

| | Ft. | In. | | Ft. | In. |
|---|---|---|---|---|---|
| Coal (bench not worked) | 1 | 2 | to | 1 | 6 |
| Shale and blackband | 1 | 6 | to | 1 | 6 |
| Shale with some coal | | 6 | to | | 10 |
| Coal (lower bench) | 1 | 6 | to | 2 | 0 |

This bed is doubtless identical with the "Big" bed at the Gulf, Egypt, and Farmville, but in a sadly deteriorated condition. The upper bench, which at these localities carries the best coal, is here too thin to be worked, and the low bench is not only thin but of poor quality, yielding very little good coal.

Chance's condemnation of the coal bed at this mine is based largely on a question of thickness of the coal bed. The question now arises, was he justified in his conclusions? The coal in the shaft of this old mine is a high-rank anthracite, as shown by samples collected by him and analyzed by the State chemist. The analysis is as follows:

ANALYSIS OF COAL FROM THE BLACK DIAMOND MINE

| | Per cent |
|---|---|
| Water at 115 C. | 4.3 |
| Volatile matter | 4.9 |
| Fixed carbon | 74.6 |
| Sulphur | 2.1 |
| Ash | 14.1 |

As the coal in this field is generally of a bituminous character, it is evident that the anthracite, disclosed by this analysis, is due to local metamorphism by the heat of a dike which cuts the coal bed practically at the point where the old mine was situated. This inference was verified by the writers who found many blocks of excellent anthracite on the mine dump and the dike itself is visible on the surface all about the old workings. If, therefore, the coal bed, after being converted into anthracite has a thickness of 1 foot 2 inches to 2 feet, as quoted above, is it not reasonable to assume that the coal bed, before it was metamorphosed by the dike was considerably thicker? If this is a reasonable assumption, can these measurements, which are the only ones available, be used to predict the thickness of the bed at some distance from the dike or in the interior of the trough? Fortunately there is considerable data at hand bearing on the shrinkage of a coal bed when it is converted from bituminous coal to anthracite, and the writers believe that the data are in such concrete form that they may be applied directly to this case.

In the Cerrillos coal field of New Mexico, a coal normally of bituminous rank has been locally converted into high-rank anthracite by the heat of a volcanic sill which has been injected into the rocks a few feet above the coal bed. Where the coal has been converted into anthracite it has shrunken from 4 feet 6 inches to 2 feet 10 inches in thickness. A similar case is known in Routt County, Colorado, where a volcanic sill has changed a bituminous coal 11 feet thick into anthracite 6 feet 6 inches thick. The percentage of reduction in thickness in these two cases is nearly the same, but to apply the results to the coal of the Deep River Field it is necessary to know the percentage of increase from anthracite to bituminous. In the New Mexico coal it amounts to 60 per cent and in the Colorado coal to 69 per cent. The average of these two is 65 per cent.

If this rate of increase is applied to the measurements given by Chance, his figures would be changed as follows:

1 foot 6 inches multiplied by 1.65=2 feet 5¾ inches.
2 feet multiplied by 1.65=3 feet 3½ inches.
2 feet 8 inches multiplied by 1.65=4 feet 4¾ inches.

On this basis it seems quite probable that away from the dikes the coal in the Carbonton region will be found thick enough to work, at least in the vicinity of the outcrop. What its thickness may be in the interior of the trough can be told only by deep drilling.

The next point at which some information was obtained regarding the coal is an old prospect or mine, generally known as the Gardner mine. This prospect is in a ravine on the southeast side of the road leading from Carbonton to Horseshoe Bend of Deep River and about 2¼ miles from the railroad station at Carbonton. Here again the prospect has been opened where the coal bed is cut by a dike and the heat has changed the coal into anthracite. An analysis by the State chemist of a sample of the best coal from this prospect, collected by Chance (p. 40), is as follows:

ANALYSIS OF COAL FROM THE GARDNER MINE

| | Per Cent |
|---|---|
| Water at 115 degrees C. | 1.7 |
| Volatile matter | 6.4 |
| Fixed carbon | 80.0 |
| Sulphur | 2.8 |
| Ash | 9.1 |

The old prospect is still open, exposing the coal bed which, according to the writers' measurements, is as follows:

SECTION OF COAL BED IN THE GARDNER MINE

| | Ft. | In. |
|---|---|---|
| Coal | | 11½ |
| Shale, black | | 4 |
| Coal | 1 | 3 |
| | 2 | 6½ |

As the analysis, quoted above, shows this to be a good grade of anthracite, the thickness should be increased as follows:

CORRECTED SECTION OF THE COAL BED IN THE GARDNER MINE

| | Ft. | In. |
|---|---|---|
| Coal | 1 | 7 |
| Shale, black | | 4 |
| Coal | 2 | 0¾ |
| | 4 | 1¾ |

The section of the coal bed in this mine, as reported by Chance, is different from that measured by the writers. Chance's statement (p. 47) is as follows:

> The total thickness of the bed, as exposed by this drift, is about 2 feet 8 inches [4 feet 4¾ inches, expanded measurement] with a few inches of very slaty coal on top and two (sometimes three) slate partings from ¼ inch to 1 inch thick dividing the coal into benches of very nearly equal size. The lower part of the bed is evidently high in ash; the coal between the slate partings is clean and good, there being two such layers respectively 5 and 7 inches thick.

There are many old prospects on the northwestern line of the coal outcrop from the vicinity of Haw Branch village southwestward for a distance of two miles, but no new data on the condition of the coal bed in this part of the field was obtained by the writers. Chance states that he opened some of these old pits on the Murchison farm, probably a short distance west of Haw Branch station. Here he found 6 to 8 inches of "slaty worthless coal" overlying 26 to 30 inches of "coal with several thin slaty seams." Judging from the analysis given by Chance, it is apparent that the coal here has been only slightly metamorphosed to a semibituminous coal. In the pits on the southwest side of Deep River, on what is now the Jones farm, he reports the coal bed as containing more shale than coal and in general a worthless bed.

Although it seems possible that the coal may be successfully mined as far to the southwest as the Gardner mine, the evidence seems to be conclusive that the bed is deteriorating in this direction and that somewhere near the place where it crosses Deep River is the limit of workable coal. There are many rumors of coal farther to the southwest, but the writers were unable to verify them and they very much doubt the presence of coal thick enough to work in the territory drained by McLennon's Creek.

East of the Deep River fault, but little is known of the coal. On Pretty Creek just north of the old McIver homestead, coal was mined rather extensively about Civil War times, but the mines have slumped shut and at present no coal can be seen. According to report, Charles Reeves reopened some of these mines a few years ago and found a coal bed 2 feet thick. As there are no dikes known in the vicinity, it is probable that the thickness reported by Mr. Reeves is the maximum thickness than can be expected in this region. An ambitious attempt was made just before the Civil War to develop the coal east of this fault, by a two-compartment shaft, located nearly a mile due west of the point where the Old Cumnock road branches off the Capital Highway, 2¾ miles north of Sanford. There is a vague report current that this shaft is 400 feet deep, but it is now full of water and that rumor could not be verified. No trace of coal or even black shale was found on the dump so it seems probable that the project, which was abandoned on the breaking out of hostilities, had not been carried to completion and a workable bed discovered. It seems incredible that any company would expend money enough to sink such a shaft without preliminary drilling to establish the presence of a workable bed of coal, but the writers could not find any one who knew of such drilling having been done or even were aware of the names of the parties who sunk the shaft.

Professor Emmons, as stated on another page, reports that a 10-inch bed of coal was pentrated by the drill at a shallow depth on the farm of Martin Dyer, near the junction of the old Cumnock road with the Capital Highway. So far as known to the writers this constitutes all of the data on the coal west of the Capital Highway. It is manifestly inadequate as a basis for a prediction as to the tonnage available and the extent of the field, but it is given in detail so as to show clearly how meager the information is and how necessary, before new mining enterprises are inaugurated, to drill back of the outcrop so as to know definitely the thickness and character of the coal beds and their depth below the surface of the ground.

East of the Capital Highway and as far northeastward at least as Haw River no coal more than 3 inches in thickness has been reported on what is regarded as reliable authority. In view of this fact it is highly probable that coal of workable thickness does not occur in this region.

### Extent of Workable Coal and the Available Tonnage

From the evidence just given regarding the conditions of the coal beds on the outcrop and in mines and drill-holes, there seems to be little question that one bed, at least, is of workable thickness along the outcrop from the Deep River fault to Haw Branch, a distance of 11 miles. East of the Deep River fault the evidence is so meager regarding the presence of workable coal that one does not seem justified in including any of this territory in a probable coal field, until the presence of such coal has been demonstrated by extensive prospecting with pick and shovel or better, with a core drill.

The amount of available coal in this field depends upon several factors, some of which are known with some degree of certainty and others are unknown or are so little known that any statement regarding them must partake more or less of the character of a guess. One of the greatest of the unknown factors is the shape and depth of the trough holding the Newark rocks. Some have assumed, but on what grounds the writers have never found out, that the basin at Cumnock is nearly circular in shape and some manuscript maps are extant on which the circular outlines are represented and even the center of the basin indicated. As stated under the heading Geologic Structure, the writers considered themselves fairly successful in determining the shape and depth of the Carthage trough. Fortunately for those wishing to develop coal mines, this trough seems to be comparatively shallow and with a nearly flat bottom. This means that the coal beds, as well as the associated rocks are but slightly disturbed by folds and faults and consequently that mining conditions, even at a depth are fairly good. The shallowness of the trough also means that much more of the coal is accessible than would be the case were the dips steep and regular from the rim to the axial line and consequently much more of the coal is within mining distance of the surface than otherwise would be the case.

The questions which the operator or the prospective operator wishes to have answered are these:

(1) How deep can successful mining be carried? (2) How far will one have to go from the outcrop to reach this depth? (3) Does the coal bed hold a workable thickness as far as it is within mining distance of the surface?

The first is an engineering question and can be answered better by a mining engineer of experience than by a geologist. Nevertheless certain things are apparent in the mines already in operation which may throw some light on the possibility of conducting deeper operations farther within the trough. In the first place the black band forming the parting between the two benches of the coal bed in the Cumnock mine makes an excellent floor that will not heave under pressure from the pillars. Also the roof is excellent, doubtless being able, when properly supported to withstand the load of many hundreds if not thousands of feet of strata. The question of the depth to which mining can be carried in this trough is largely one of cost; it seems probable, however, that mining can be carried to a depth of 2,000 feet, without great difficulty. The writers have based their conclusions largely upon this assumption. If it proves to be erroneous, some reduction will have to be made in the estimated tonnage of coal available.

The determination of the location of the points at which the coal reaches a depth of 2,000 feet is based largely upon cross-sections made up from observed dips along the line of the section. As surface observations on the dip of the beds are not entirely reliable, owing to the lack of distinctive bedding planes in the more massive rocks and to the disturbed condition of the rocks in the presence of dikes, the determination of the true dip is very difficult indeed. Cross-sections constructed under such conditions must be regarded as provisional only and to be replaced as soon as more reliable data are available.

Another factor that must be taken into account in determining the extent of workable coal within the trough is the probability that the coal bed thins southeastward in conformity with the thinning noticed on the outcrop. Judging by the facts at present available, one is justified in the conclusion that the coal bed does not retain a workable thickness to the southeast beyond the old prospects near the McIver homestead, east of the Deep River fault. He is also justified in assuming that the bed is not workable much beyond Haw Branch. Of course no one knows whether the line marking the limit of workability in the interior of the trough is straight between these two points, or whether it pursues a circuitous course. In the absence of evidence to the contrary, it is reasonable to assume the simpler condition rather than a more complicated one, therefore, one is justified in assuming that this line is nearly straight between the points specified above, and the conclusions arrived at by the writers are based accordingly.

An estimate of the tonnage of coal available, based on such data is of course very inaccurate, but it has a certain value, as being under present conditions, the best guess that can be made, but it should be remembered that it is only a guess. In making this guess or estimate, great reliance was placed on the section along the Sanford-Cumnock road for a distance of about three miles from the village of Cumnock. On this section the writers had as a basis the data from the Cumnock mine, which shows the coal at a depth of about 600 feet below the surface, and the log of drill-hole No. 3, which recorded the bed at a depth of a little more than 900 feet below the surface. From bore-hole No. 3 southward the section was based solely upon dips measured at the surface, and as these are generally slight and directed to various points of the compass, the coal bed descends very slowly toward the south and it is estimated that at a distance of 3½ miles from the outcrop, it is only about 2,000 feet below the surface.

Similar sections have been constructed from the south end of this section to Gulf and to Carbonton, and the sections have been made to harmonize at their common meeting point. The points on these sections at which the coal is estimated to be at a depth of 2,000 feet have been connected on the map by the line Y Z, but in using this line it should be remembered that its position is only vaguely determined and that in reality its place may be changed considerably when deep drilling has been done. In the meantime this line is intended to mark the lower limit of workable coal as indicated by all of the evidence available at the present time.

All territory lying between the line Y Z and the outcrop of the coal bed and extending from the Deep River fault to the Gardner mine near Haw Branch is regarded provisionally as coal territory, in which the coal is accessible, providing mining can be carried to a depth of 2,000 feet. The area included within the lines mentioned above is about 25 square miles, and it seems reasonable to assume that the coal bed throughout this territory averages at least 3 feet in thickness of recoverable coal. The weight of coal necessarily depends upon its specific gravity, and it is assumed that the Deep River coal has a specific gravity of about 1.3. This is an assumed figure, as no specific gravity determinations of the coal, as far as the writers are aware, have been made, but it is based on many determinations of the specific gravity of various coals of the country. As the weight of a cubic foot of water weighs 62.5 pounds, and the weight of coal is 1.3 times that of water, it follows that the weight of a cubic foot of coal, as it lies in the ground, is 62.5 by $1.3 = 81.25$ pounds. The number of cubic feet in a coal bed 1 foot thick and one acre in extent is 208.7 by 208.7 by 1 = 43,556 cubic feet, and as the weight of one cubic foot is 81.25 pounds the weight of the whole is 43,556 by 81.25 = 3,538,925 pounds or roughly 1,770 short tons. If the coal bed is 3 feet thick then the tonnage per acre would be 1,770 by 3 = 5,310 tons. If the territory underlain by a 3-foot bed is 25 square miles or 16,000 acres, then the total coal in the ground was originally 5,310 by 16,000 = 84,960,000 short tons.

The figures given above are supposed to represent the total coal in the coal bed, but not the amount that could be recovered in actual mining. In order to determine the amount that actually could be recovered, it is necessary to allow for pillars that cannot be removed, for partings that may come into the bed and replace good coal, and for the amount of coal lost by dikes and faults cutting the coal bed. As there are little or no data available in this field regarding the factors mentioned above, an accurate estimate is not possible, but, if the mining conditions, as developed in the Cumnock mine, hold throughout the territory included between the outcrop of the coal bed and the line Y Z it is probable that 80 per cent of the coal in the bed can be recovered. Eighty per cent of 84,960,000 tons is 67,968,000 tons or the estimated tonnage of recoverable coal in this field west of the Deep River fault. The amount of coal east of this fault cannot be estimated at the present time, for there is little or no positive evidence, that the coal is more than 2 feet thick in any part of this territory and a bed of this thickness can hardly be considered workable at a depth under present conditions. If drilling in the territory east of the fault should reveal a coal bed more than 2 feet in thickness, it would be worth considering in a commercial way, but until drilling is done it is useless to speculate whether or not there is a supply of workable coal east of this fault.

Similarly there may be workable coal southwest of Haw Branch, but the surface indications are not favorable and additional data can be obtained only by prospecting with pick and shovel or preferably with a core drill.

### Character of the Coal

The coal of the upper bench of the Cumnock bed is known only in the Cumnock and Carolina mines where it is a jet black coal with few, if any, dull bands. In other parts of the field, particularly toward the southwest, the coal bed is broken up by layers of shale which detract greatly from its value. In the mine mentioned above the coal is fairly homogeneous in texture and quality throughout.

Cleavage is highly developed in the coal, the principal cleavage planes being at right angles to the strike of the bed. The cleavage is so marked that, on a face of coal parallel with these planes, the coal cleaves off in thin layers, ranging in thickness from about one-eighth to one-half inch. One can, with the hand, peel these thin laminæ off the face to an almost indefinite depth. Naturally a coal so highly cleaved as this coal is, will produce a very small percentage of lump when mined and hence the coal in its raw state is not well adapted to domestic use. In the run-of-mine form there are few fragments larger than one's hand, and even fragments of this size are liable to be broken much finer in handling and shipping.

Very great ignorance prevails, even in the Deep River Field itself, regarding the quality of the coal now being mined there, and outside the limits of the field, few persons know anything about it. The writers have been assured that the coal is worthless; that locomotive tests have been attempted in times past with this coal, but that it was so poor that the locomotive went "dead" on the road, the coal being of such a quality that it would not produce enough steam to run a light engine. The writers do not question the reports that such tests were made, but they do maintain that, if such tests were made and resulted as disastrously as reported, the material used was not the best nor even the average coal of the upper bench, or if it came from this bed it was outcrop coal which had weathered to such an extent that it had lost most if not all of its heating value. It is possible, of course, that these tests were made on coal from the lower bench, and, if that were the case, the failure could be easily explained for the heating value of this coal compared with that of coal from the upper bench, is as 10,400 to 13,700, or only 76 per cent as efficient in the production of heat.

For the seven years prior to 1922 the Cumnock mine has been owned and operated by the Norfolk Southern Railroad Company, and practically the entire output of the mine has been used by that company for locomotive fuel and for stationary steam plants along the right-of-way. If the coal were as poor as some have believed, it could not have been used in this manner.

In order to determine the true value of the coal, the writers cut one sample in the mine of the Carolina Coal Company for analysis and Mr. J. J. Forbes of the United States Bureau of Mines cut several samples in both the Carolina and the Cumnock mine for the same purpose. The results of the analysis of these samples in the Pittsburgh laboratory of the Bureau of Mines are given in the following table, together with the analyses of other coals of the Appalachian region with which the Deep River coal may come in competition. Each analysis, as a matter of convenience, for various users, is presented in three forms, marked A, B, and C. Form A represents the coal in the same condition as it was in the mine before the sample was cut for sampling, the coal sent to the laboratory, was sealed air-tight in a galvanized-iron can so that it reached the laboratory without taking on or giving off moisture; form B represents theoretically dry coal; and form C represents the theoretical condition of the coal after all moisture and ash have been eliminated. The percentage given in form A are the ones that should be used in the comparison of coals and in the study of a coal with respect to its adaptability to certain uses, for this form more nearly represents the coal that is actually shipped and fed into the furnace than are those given in either form B or form C. Form B is the one most used by mechanical engineers, because it is a more stable form of fuel than is form A, and the mechanical engineer is more concerned in the testing of apparatus than he is in testing coal. Form C is used only when it is desirable to compare the coal substance itself of one coal with another, regardless of impurities, or when the relation of the volatile matter to the fixed carbon is the all essential consideration. The forms B and C are adapted for special purposes only and should not be used by the ordinary operator, purchaser, or consumer of the coal.

## ANALYSES OF COAL SAMPLES FROM THE DEEP RIVER COAL FIELD

| | Location | Analysis No. | Form of Analysis | Proximate | | | | Ultimate | | | | | Heating value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Moisture | Volatile matter | Fixed carbon | Ash | Sulphur | Hydrogen | Carbon | Nitrogen | Oxygen | B. t. u. |
| Cumnock Coal Mine J. J. Forbes, Collector April 14, 1922 | Room 1. off No. 1 rise | 85446 | A | 2.5 | 31.0 | 56.6 | 9.9 | 2.9 | ------- | ------- | ------- | ------- | 13,240 |
| | | | B | ------- | 31.7 | 58.1 | 10.2 | 3.0 | ------- | ------- | ------- | ------- | 13,570 |
| | | | C | ------- | 35.3 | 64.7 | ------- | 3.3 | ------- | ------- | ------- | ------- | 15,110 |
| | Room 10 on right side of No. 1 slope | 85447 | A | 1.8 | 32.2 | 59.6 | 6.4 | 1.8 | ------- | ------- | ------- | ------- | 14,030 |
| | | | B | ------- | 32.8 | 60.6 | 6.6 | 1.8 | ------- | ------- | ------- | ------- | 14,280 |
| | | | C | ------- | 35.1 | 64.9 | ------- | 1.9 | ------- | ------- | ------- | ------- | 15,280 |
| | Room 13, off No. 1 slope | 85448 | A | 4.2 | 31.9 | 54.9 | 9.0 | 1.9 | ------- | ------- | ------- | ------- | 13,250 |
| | | | B | ------- | 33.3 | 57.3 | 9.4 | 2.0 | ------- | ------- | ------- | ------- | 13,830 |
| | | | C | ------- | 36.7 | 63.3 | ------- | 2.2 | ------- | ------- | ------- | ------- | 15,260 |
| | Room 8, off No. 1 slope | 85449 | A | 1.7 | 34.1 | 56.6 | 7.6 | 1.8 | ------- | ------- | ------- | ------- | 13,770 |
| | | | B | ------- | 34.7 | 57.6 | 7.7 | 1.9 | ------- | ------- | ------- | ------- | 14,010 |
| | | | C | ------- | 37.6 | 62.4 | ------- | 2.0 | ------- | ------- | ------- | ------- | 15,170 |
| Composite of mine samples 85446, 85447, 85448, and 85449 | | 85450 | A | 2.5 | 32.0 | 57.3 | 8.2 | 2.0 | 5.3 | 75.5 | 2.0 | 7.0 | 13,620 |
| | | | B | ------- | 32.9 | 58.7 | 8.4 | 2.1 | 5.1 | 77.5 | 2.0 | 4.9 | 13,970 |
| | | | C | ------- | 35.9 | 64.1 | ------- | 2.3 | 5.6 | 84.6 | 2.2 | 5.3 | 15,260 |
| Carolina Coal Mine M. R. Campbell, Collector Jan. 21, 1922 | Face of No. 1 left entry, 75 feet from foot of main slope | 83960 | A | 1.8 | 32.5 | 58.8 | 6.9 | 2.4 | 5.2 | 77.1 | 2.1 | 6.3 | 13,890 |
| | | | B | ------- | 33.1 | 59.9 | 7.0 | 2.4 | 5.1 | 78.5 | 2.1 | 4.9 | 14,140 |
| | | | C | ------- | 35.6 | 64.4 | ------- | 2.6 | 5.5 | 84.4 | 2.3 | 5.2 | 15,200 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Carolina Coal Mine<br>J. J. Forbes, Collector<br>April 17, 1922 | Rib of left air-course, 700 feet from the mine mouth | 85590 | A | 2.3 | 32.4 | 57.2 | 8.1 | 2.2 | ------- | ------- | ------- | ------- | 13,630 |
| | | | B | ------- | 33.2 | 58.5 | 8.3 | 2.3 | ------- | ------- | ------- | ------- | 13,950 |
| | | | C | ------- | 36.2 | 63.8 | ------- | 2.5 | ------- | ------- | ------- | ------- | 15,210 |
| | No. 1 cross entry, 100 feet in, by slope air-course | 85591 | A | 1.7 | 32.2 | 58.4 | 7.7 | 2.5 | ------- | ------- | ------- | ------- | 13,790 |
| | | | B | ------- | 32.8 | 59.4 | 7.8 | 2.5 | ------- | ------- | ------- | ------- | 14,030 |
| | | | C | ------- | 35.5 | 64.5 | ------- | 2.8 | ------- | ------- | ------- | ------- | 15,220 |
| Carolina Coal Mine<br>J. J. Forbes, Collector<br>April 17, 1922 | Main slope, 100 feet out by face and 750 feet from mine mouth | 85605 | A | 1.9 | 32.1 | 58.8 | 7.2 | 2.2 | ------- | ------- | ------- | ------- | 13,930 |
| | | | B | ------- | 32.7 | 59.9 | 7.4 | 2.2 | ------- | ------- | ------- | ------- | 14,190 |
| | | | C | ------- | 35.3 | 64.7 | ------- | 2.4 | ------- | ------- | ------- | ------- | 15,330 |
| Composite of mine samples 85590, 85591, and 85605 | | 85592 | A | 2.0 | 32.4 | 58.1 | 7.5 | 2.3 | 5.1 | 76.5 | 1.9 | 6.7 | 13,810 |
| | | | B | ------- | 33.0 | 59.3 | 7.7 | 2.3 | 5.0 | 78.0 | 1.9 | 5.1 | 14,090 |
| | | | C | ------- | 35.8 | 64.2 | ------- | 2.5 | 5.4 | 84.5 | 2.1 | 5.5 | 15,260 |
| Composite of two mine samples of lower bed | | 85595 | A | 1.8 | 29.0 | 40.2 | 29.0 | 2.9 | 4.4 | 57.2 | 1.7 | 4.8 | 10,450 |
| | | | B | ------- | 29.5 | 40.9 | 29.6 | 3.0 | 4.2 | 58.3 | 1.7 | 3.2 | 10,650 |
| | | | C | ------- | 41.9 | 58.1 | ------- | 4.3 | 6.0 | 82.7 | 2.4 | 4.6 | 15,120 |

ANALYSES OF COAL SAMPLES FROM OTHER FIELDS, WITH WHICH THE DEEP RIVER COAL MAY HAVE TO COMPETE

| | Form of Analysis | Proximate | | | | Ultimate | | | | | Heating Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Moisture | Volatile matter | Fixed carbon | Ash | Sulphur | Hydrogen | Carbon | Nitrogen | Oxygen | B. t. u. |
| Pocahontas field, W. Va.—Best coal | A | 1.7 | 16.5 | 76.0 | 5.8 | .5 | 4.3 | 84.2 | 1.1 | 4.1 | 14,490 |
| New River field, W. Va.—Best coal | A | 2.1 | 21.6 | 71.9 | 4.4 | 1.5 | 4.7 | 83.1 | 1.6 | 4.7 | 14,540 |
| Dante field, Va.—Best coal | A | 2.4 | 34.7 | 55.8 | 7.1 | .6 | 5.3 | 78.2 | 1.5 | 7.3 | 13,930 |
| Toms Creek, Va.—Best coal | A | 2.2 | 32.4 | 59.2 | 6.2 | .6 | 5.2 | 79.7 | 1.6 | 6.7 | 14,130 |
| Big Stone Gap field, Va.—Best coal | A | 2.2 | 33.7 | 56.4 | 7.7 | .8 | 5.1 | 77.2 | 1.5 | 7.7 | 13,790 |
| Morgan Co., Tennessee—Best coal | A | 2.1 | 37.2 | 54.7 | 6.0 | 2.7 | 5.5 | 76.5 | 1.8 | 7.5 | 13,880 |
| Claiborne Co., Tennessee—Best coal | A | 3.7 | 36.5 | 57.0 | 2.8 | 1.0 | 5.5 | 78.2 | 1.9 | 10.6 | 13,980 |
| Claiborne Co., Tennessee Medium coal | A | 5.2 | 31.7 | 55.1 | 8.0 | .9 | 5.0 | 72.6 | 1.8 | 11.7 | 12,790 |

In using the figures given in the table of analyses it should be remembered that the sampler is much more careful in excluding impurities than is the miner or even the operator in time of great scarcity of coal, and consequently the coal that reached the market from these mines is liable to contain much more ash than that shown in the analysis of the mine samples.

A comparison of results obtained on mine samples and on railroad car samples shows that on the average the ash in the car sample may be from 30 to 50 per cent greater than it is in the mine sample. Thus coal which shows 6 per cent ash in the mine sample is likely in the car sample to run from 7.8 per cent to 9 per cent, but if the increase exceeds 50 per cent, it indicates gross carelessness in mining the coal or preparing it for the market.

The composition of the mine sample may be regarded as the ideal toward which the commercial coal of the mine approaches more and more closely as better methods and more care is exercised in mining, and commercial coal will agree with the mine sample when the best methods are used and every employee coöperates with the management in excluding impurities from the output of the mine.

As the most important point in the consideration of the value of a coal for ordinary purposes is its heat-producing power, the column headed B. t. u.[1] in the table of analysis is worthy of most careful consideration. As a direct comparison of figures is not easy to make, the graph, shown in Fig. 6, has been prepared to show the comparative heating values of the coals listed in the table of analyses. It is apparent from the graph that Cumnock coal is somewhat inferior in heating value to the best Pocahontas and New River coals, and that it is about the same as the coal mined at Dante, Toms Creek, and Big Stone Gap, Virginia, and Oliver Springs and Jellico, Tennessee, but is considerably better than the poorer coals mined in most of these districts.

The table of analyses shows that the Cumnock coal is relatively high in sulphur, averaging in eight mine samples, 2.2 per cent, as against an average of 1.1 per cent in the other coals listed in the table. The difference between 1.1 and 2.2 is not serious, unless the coal were used for the manufacture of metallurgical coke, where difference of 1.1 per cent would be a rather important matter. In steam-raising the percentage of sulphur in the Cumnock coal will probably have little

[1]B. t. u. is an abbreviation of the term British thermal unit. This unit is the one by which heat is generally measured and expressed in English speaking countries. The heat-producing value of a coal is determined in the laboratory by exploding a small amount of coal within a steel bomb and carefully measuring, by a delicately graduated thermometer the increase in temperature. The amount of heat thus generated is expressed in British thermal units, one of these units being the amount of heat required to raise one pound of water one degree Fahrenheit, the water being at the temperature of maximum density, 39.1 degrees F.

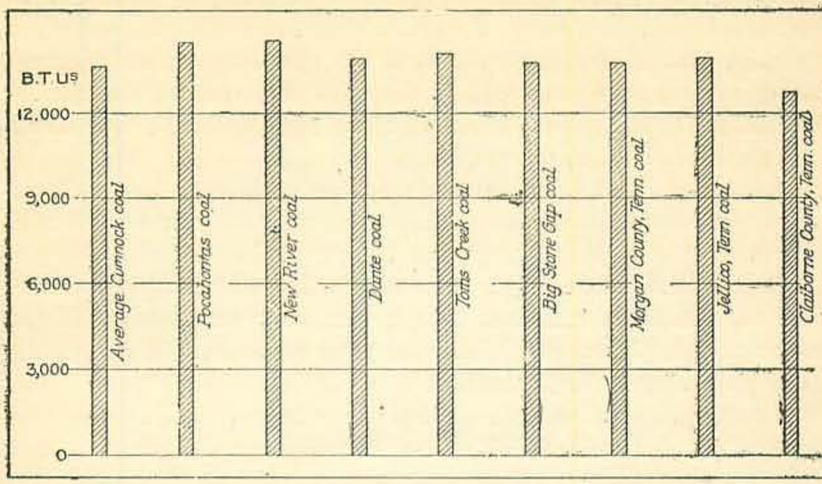



FIG. 6. Graph illustrating comparative heating values of competing coals.

or no effect, except that the sulphur will tend to corrode the grate bars more rapidly than pure coal. It should be remembered by operators, however, that the sulphur in the coal as shipped to market is liable to be much greater than that shown in the mine samples. This is an imminent danger, for in places the coal contains many "sulphur" balls from 1 inch to 2 or more inches in diameter. In mine sampling these nodules of pyrite were excluded from the samples on the theory that in actual mining it is possible to remove them if the coal is properly hand-picked, and no careful operator who is at all mindful of the reputation of his output, will allow such material to remain in the commercial coal.

### Tests by the Bureau of Mines

The Deep River coal is generally regarded as a coking coal, but up to the time of the present examination, no reliable test of its coking properties had been made, or if made, the writers were not aware of the fact. The coal has been noted since its earliest exploitation as a fine smithing coal and this in itself is an indication of its coking quality, as one of the prime requisites of a smithing coal is that it will coke and thus make a "hollow" fire.

At the request of Col. Joseph Hyde Pratt, State Geologist, the United States Bureau of Mines has recently made tests of the coking quality of the Deep River coal and of its adaptability to washing as a means of reducing the sulphur and ash so as to make it suitable for the manufacture of metallurgical coke. Through the courtesy of the

Director of the Bureau of Mines the essential features of these tests are given herewith.

A large sample of washed coal from the top bench in the Cumnock mine was tested at the Experiment Station of the United States Bureau of Mines at Pittsburgh, Pennsylvania, for its coking properties and for the by-products which it would yield in the operation. The sample of washed coal which was to be tested had the following composition:

PROXIMATE AND ULTIMATE ANALYSES OF WASHED COAL AND COKE

| | *Coal* *Per Cent* | *Coke* *Per Cent* |
|---|---|---|
| Moisture | 1.0 | 0.5 |
| Volatile matter | 33.0 | 3.8 |
| Fixed carbon | 59.6 | 87.2 |
| Ash | 6.4 | 8.5 |
| Hydrogen | 5.2 | 1.2 |
| Carbon | 78.9 | 86.0 |
| Nitrogen | 2.1 | 2.0 |
| Oxygen | 5.8 | 1.0 |
| Sulphur | 1.6 | 1.3 |
| B. t. u. | 14220 | 13350 |

The results of the laboratory coking tests on the washed coal is as follows:

| | |
|---|---|
| Final coking temperatures | 775° to 800° C. |
| Weight of charge | 15 pounds. |
| Coke yield | 75 per cent of charge. |
| Gas yield | 8,000 cu. ft. per ton of coal. |
| Ammonium sulphate | 23 pounds per ton of coal. |
| Tar (dehydrated) | 13.9 per cent of coal charged or 22 gallons per ton. |

The report of the Bureau of Mines on this test is as follows:

"The by-product yield of this coal is entirely satisfactory and compares favorably with yields from Freeport, Pa. coal. It is felt that with a full cooking temperature (950°C.) and 18 hours time, it would be reasonable to expect a 70 per cent yield of matallurgical coke, 10,000 to 12,000 cubic feet of good gas, 11 gallons of tar, and 25 to 27 pounds of ammonium sulphate. In general, the coke, as far as it can be judged by a laboratory scale test, is of very good quality fully equal in all respects to Freeport or Pittsburg cokes. The sulphur in the coke is somewhat high (1.3 per cent), but this could be cut down by admixture of a low-sulphur steam coal. Such a mixture of coal is now considered to be good by-product practice."

This test seems to establish the coking quality of the Deep River coal and also the fact that even by washing, the sulphur is too high to yield a metallurgical coke without the admixture of a coal containing less sulphur. As there is probably little or no demand for this kind of coke in North Carolina, the relatively high percentage of sulphur is not an important matter. It seems probable that the best market in the State for coke is for domestic use as a substitute for anthracite, and for this use the sulphur is not excessive. In an agricultural country, such as central North Carolina, it is probable that the ammonium sulphate is a very important, if not the most important, by-product of the coking process. In using the figures given in such a report, it should be understood that the results of a general test are significant only in suggesting what may be secured in actual practice, but the actual yield of any by-product depends largely upon the method used, and the method best suited to produce a large quantity of a certain constituent is not the one best suited to obtain a large yield of another constituent.

The results of the Bureau of Mines test show that, if the coal is coked in by-product ovens, a good quality of coke may be secured for domestic or manufacturing purposes, a normal amount of gas, a rather large yield of ammonium sulphate for the cotton and tobacco fields, and a medium amount of tar.

As the two coal beds in the vicinity of Cumnock are only 18 inches apart, they may easily be regarded as two benches of a single coal bed, but there is no advantage in so considering them unless the coal contained in the lower bench, as well as the black band (iron carbonate) between them, can be utilized. As shown by the analyses of the coal from the lower bench that are given in the table (p. 83), the coal in the raw state contains too much ash to be salable in competition with better coals, therefore if it is to be utilized, some way of improving its condition must be devised. In order to determine the possibility of reducing, by washing, the percentage of ash in the lower bench from about 30 per cent to 6 or 8 per cent, a washing test was made by the United States Bureau of Mines. In order to make a thorough test about 1,150 pounds of coal was sent to the Bureau of Mines testing laboratory at Urbana, Illinois, and elaborate float-and-sink test were made with liquids ranging in specific gravity from 1.3 to 1.8. Tests were also made in washing the coal in jigs and on tables, but without very satisfactory results.

The conclusions arrived at by the Bureau of Mines experts are as follows:

> The sample of coal received at the laboratory representing the bottom bench of the Cumnock bed from the Farmville (Carolina Coal Company's) mine, consists very largely of bony coal and carbonaceous shale. Only a small amount of coal low in ash content is present. It is, therefore, impossible to treat this coal successfully by the usual coal-washing methods to secure a reasonable yield of coal as low in ash content as the coal of the top bench (8 to 10 per cent, of the bed). The treatment of this coal at ¼ inch minimum size on

either jigs or tables would probably yield 50 to 70 per cent of washed coal with an ash content in the neighborhood of 24 per cent.

As stated before, this test shows that washing will probably not improve the coal of the lower bench sufficiently to justify the erection of a washery and therefore some other method must be sought, if this bench of the coal is to be utilized at the same time that the upper bench is being mined.

As the sulphur content of the upper bench of the Cumnock coal bed is too great for the manufacture of metallurgical coke, a washing test of this coal was also made by the United States Bureau of Mines at its Urbana, Illinois plant to see if it were possible by ordinary washing methods to materially reduce this element. Elaborate tests were made by float-and-sink methods, by washing in jigs, and by washing on tables.

The coal to be tested was crushed to different sizes and subjected to a float-and-sink test on liquids of various densities with the result that it appears to be entirely feasible to reduce both the sulphur and ash by washing processes. The float-and-sink test showed that with a solution whose specific gravity is 1.5 the ash could be reduced from 12.7 to 6.5 per cent; the sulphur could be reduced from 2.32 to 1.76 per cent; with a consequent loss of the sample tested of 9.4 per cent.

After this preliminary test had been made the raw coal was washed in a jig. This test yielded 87.6 per cent of washed coal, having 7.1 per cent of ash and 1.85 per cent of sulphur. The results of this test are very satisfactory, as far as the ash is concerned, but rather disappointing as the percentage of sulphur was not materially reduced. A table test showed a yield of washed coal of 87.6 per cent, having an ash content of 7.1 per cent, and a sulphur content of 1.79 per cent. A table test of coal crushed finer than that noted above, yielded 90.0 per cent of washed coal, having 6.8 per cent of ash and 1.82 per cent of sulphur.

As these various tests agree very closely, it may be said that, as far as a single test on a small scale will determine, the coal from the upper bench of the Cumnock bed, if subjected to washing in a jig, would have its percentage of ash materially reduced, but that, as far as the sulphur is concerned, the results hardly justify the expense of the operation.

The failure to greatly reduce the content of sulphur is explained as follows:

The general sample representing the entire lot of coal contained 1.52 per cent of pyritic sulphur and 0.80 per cent of organic sulphur. The total sulphur content amounted to 2.32 per cent, of which 34.5 per cent was present as organic sulphur and 65.5 per cent as pyritic sulphur. Sulphate sulphur was not determined as the analysis made at the Pittsburg station of the mine samples showed a maximum value of only 0.026 per cent. . . . This condition is favorable for a good sulphur reduction, but it is counterbalanced by the finely disseminated nature of the pyritic sulphur present in the coal.

*Ash reduction by Trent process.*—A final attempt to reduce the percentage of ash in the coal of the lower bench of the Cumnock coal bed was made by the Trent process—a patented process which, in certain coals, will reduce the ash very materially indeed. The test was made at the works of the company in Alexandria, Virginia.

The Trent process for reducing ash in coal, consists in dry pulverizing the coal so that it will go through 100-mesh sieve; wetting of the pulverized material with water from the tap; and then the addition of a small percentage of standard Navy fuel oil. The oil tends to unite with the carbon, freeing the earthy matter which settles to the bottom.

The sample to be tested, which consisted of run-of-mine coal from the lower bench in the Carolina mine, had the following composition: moisture, 1.4; volatile matter 29.4; fixed carbon 42.0; ash, 27.2. The so-called "amalgam" resulting from the combination of the oil and carbon had the following composition: volatile matter, 48.5; fixed carbon, 38.1; ash, 13.4. If this amalgam is then subjected to low temperature distillation until the oil that has been added is driven off, the resultant purified coal contains 17.1 per cent of ash.

If the coal were treated by this process, the result would be the so-called amalgam which contains about 21.6 per cent of fuel oil in addition to the finely divided carbon and ash, or if the oil were distilled it would leave only the finely divided carbon and ash. In either form the product can be used as a fuel—if in the amalgam form with a content of ash of 13.4 per cent and if in the form of dry purified coal with an ash content of 17.1 per cent.

The reduction of the ash by this process is rather disappointing and is said to be due to the fact that the earthy material is present in a very finely divided condition and this means that to reach the carbon itself, the crushing would have to be possibly to 200 mesh which would be quite expensive.

There is no question about the effectiveness of this process, but in certain cases the reduction in the ash is not nearly so marked as in others. The operator considering this process should calculate closely the cost of separating this bench of coal from the upper bench, its crushing down to the required degree of fineness and finally the marketing of the product, either in the form of oil-amalgam, powdered fuel, or briquettes made from the powdered material.

## POSSIBILITIES OF PETROLEUM IN THE DEEP RIVER FIELD

Much speculation has been indulged in here as well as in other States crossed by the belt of rocks of Triassic age as to the possibility of obtaining oil or gas from the sandstone which forms such a large proportion of their bulk. Many reports are current regarding so-called oil seeps and gas is supposed to bubble up through the water in many of the streams. The writers examined a number of these localities supposed to show signs of oil, but none was seen, though the oxide of iron which generally forms an iridescent scum on stagnant water was seen at a number of places. Persons finding such an iridescent scum on water may easily test it by stirring the water with a stick. If the scum can be drawn out and stirred into whorls without breaking, it is probably oil of some kind, but if it is brittle and breaks when stirred, it is oxide of iron and worthless.

As there are apparently no signs of petroleum at the surface, the next step in the investigation is to study the rocks of the region to see if the conditions, which by long experience geologists have come to regard as essential, are present or not, for in many of the well known oil fields there were absolutely no surface indications of the presence of oil or gas before drilling began. In conducting the geologic study of the possibility of oil pools there are four elements that enter into the problem. These are: (1) the presence of rocks of such a character that they may have served as the place of origin or source of oil or gas; (2) porous sandstones or limestones into which the oil when formed, can collect; (3) a geologic structure or fold of such a character that it will trap the oil and gas as they migrate through the porous rock; and (4) a nonporous shale or clay above the sandstone to seal in its oily contents and prevent their escape.

(1) As petroleum has been derived largely, if not wholly, from organic remains which were buried in the mud or sand that now form the country rock, it will be necessary to find a fairly thick formation which contains fossil remains in abundance. All of the Newark rocks of the Deep River Field appear to have been laid down in fresh water or on the land, hence they do not contain a marine fauna from which the oil could have been derived. The presence of beds of coal and some black shale are indications of abundant vegetal growth, but in all except the Cumnock formation the materials are so coarse that air could easily have reached the enclosed vegetal matter and cause its destruction. The black shale and coal of the Cumnock formation would probably supply some material for the formation of oil, but the volume of such shale and coal is so small that the amount of oil that may have been produced from them in the past is negligible. It is true that

some layers of the shale are quite rich in bituminous material, and that at one time there was a manufacturing plant in operation at Farmville for the distillation of oil from the shale and coal, but, as described on a previous page, the Cumnock formation is in many parts of the field apparently thin and in places is apparently replaced by red conglomerate, and consequently the volume of possible oil-producing shale is small. On account of this replacement toward the southeast, the part of the field most promising, as a source of oil, is about Cumnock and Gulf where the formation is thickest and contains the most bituminous material. But here erosion has cut deeply into the formation without exposing any trace of the coveted substances.

(2) There are many beds of porous sandstone in the Cumnock formation, where it is well developed, that might serve as reservoirs for oil or gas, and even in the overlying Sanford formation there are coarse brown sandstones that might serve a similar purpose, if other conditions were favorable.

(3) Wide experience of petroleum geologists all over the world has demonstrated that about 90 per cent of the oil is found in anticlines or arches in the rocks, hence the first thing the oil geologist does is to look for such structures. As stated previously there are few known anticlines in this field. In general the rocks have been depressed into basins or troughs rather than raised into anticlines or arches. Thus the Carthage and the Corinth troughs are both essentially synclinal in structure, although in each case the scycline is not complete because of the great fault along the southeast side. On account of this structure neither basin nor trough can be considered a favorable place to drill for oil. As described previously these troughs are united by a cross-anticline at Colon, but this fold has raised the formation so high that the Cumnock formation crops out at the surface as far east as Colon, hence there are scarcely any rocks below the surface on this anticline that might be considered as sources of oil or gas. Another disturbing factor in this anticline is the possibility, if not probability that it is broken along its crest, by a fault which follows the system of dikes north to Colon and there turns to the northwestward to the margin of the field. Altogether the Colon cross-anticline does not seem promising from a geological point of view.

In referring to anticlines as the most favorable rock structures for holding accumulations of oil or gas, it must be understood that this statement applies only to rocks that are saturated with water and that in dry rocks the oil accumulates, if it accumulates at all, in very different places. This is illustrated by Fig. 7, which is supposed to be a cross-section representing the rocks as they would appear in the side of

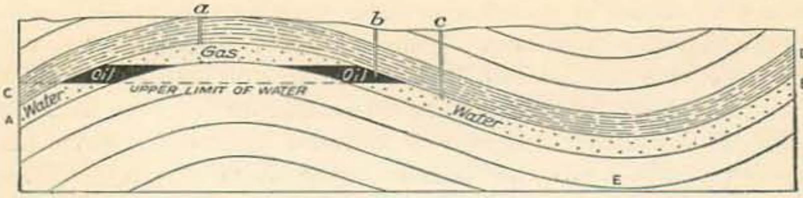



FIG. 7. Diagram showing form of oil pools in an anticline.

a deep trench cutting an anticline and a syncline. A B represents a moderately coarse porous sandstone which is the reservoir rock. C D is the overlying impervious shale which serves as a blanket and retains any fluid that may be in the reservoir rock. As water is heavier than oil and as both of these substances are heavier than gas, the three will arrange themselves, under the influence of gravity, in the order shown in the figure, gas at the top, oil next lower in the anticline, and then water occupying almost all of the synclinal fold. If a well is drilled at *a* it will encounter gas; at *b*, oil; and at *c*, water. In some cases there is little or no gas and then the oil is forced into the crown of the arch and a well drilled at *a* would strike oil.

If the rocks are not saturated with water, then there is no force to drive the hydrocarbons into the anticline, and, under the pull of gravity, the oil would tend to migrate toward the bottom of the syncline at E. Such cases are seldom met with, but some of the oil pools in western Pennsylvania are in dry rocks and the oil, though much disseminated in the reservoir rocks, appears to be slowly migrating downward, but is arrested locally by denser portions of the sandstone and small pools on the limbs of the syncline are of common occurrence. If the oil is not trapped by barriers of dense rock, it finally reached the bottom of the syncline, but a pool in such a situation is rare indeed.

(4) The different beds of the formations in this field are not well enough known to enable one to say positively that any given porous sandstone is overlain by a nonporous shale, but generally the succession of shale and sandstone is the rule and it is probable that most porous sandstones have a shale cap. So far as this element of the problem is concerned, it may be taken for granted that it is favorable.

In addition to the elements of the oil problem enumerated above, geologists are now coming to acknowledge a fifth element in the degree of metamorphism which has affected the rocks and which is apparently all important in determining in advance of drilling or even geologic investigation whether or not there is a possibility of obtaining oil if a well were drilled. Metamorphism means change and changes in the rocks are induced by crustal movements, probably accompanied by the development of sensible heat. When rocks have been squeezed to such an extent as to produce heat, their condition and character have been changed so that the geologist has little difficulty in recognizing the marks of this change and he can pronounce at once on the general question of whether or not the rocks are liable to contain oil. Thus the crystalline schist and slate underlying the Newark rocks bear all the ear-marks of having been greatly metamorphosed and no geologist would consider for a moment the possibility of their containing oil, except possibly very locally, where oil may have recently migrated into them from some adjacent oil-sand. The Newark rocks, on the other hand, on casual inspection, show no signs of having been affected by heat or pressure, but such a test is not always satisfactory, because in the incipient stages of change there is little outward effect apparent. The most satisfactory indication of metamorphism is the condition of the coal as shown by a chemical analysis (pp. 82 and 83). The comparison of many coal analyses in the Appalachian region shows that the great oil pools are found where the fixed carbon in the coal in the C form (see table of analyses) is less than 60 and that little if any oil is found where the fixed carbon is more than 65 per cent. The fixed carbon in the Deep River coals ranges in the C form from 62.4 to 64.9, hence the rocks are metamorphosed to such an extent that it is doubtful if any oil remains, granting that it formerly existed in the rocks. It seems certain that no oil pool of consequence would ever be found in these rocks, but the chance for finding natural gas is much better than that for finding oil.

The relation of the dikes to the possible occurrence of oil has already been mentioned (p. 48), but it is worth repeating here for the benefit of those who may be tempted to drill test wells in this field. The dikes act as barriers to the circulation of water and the inhabitants have long ago learned that the most favorable place to find a supply of water is near a dike. If the dike serves as a barrier to the circulation of water, it doubtless would serve the same purpose to the circulation of oil, and hence, if there is any oil in the rocks, it would be liable to accumulate near the dike and a well located in such a position as to penetrate the oil sand near a dike would be much more likely to be successful than would one located at a distance from a dike. As many of the dikes are doubtless inclined one way or the other, it would be impossible to determine the exact distance from the dike on the surface at which a well should be located so as to penetrate a given sand close to the dike, but an attempt should be made to secure this sort of a location.

*Conclusions.*—From a geological point of view, the writers have no hesitation in saying that all of the evidence they were able to collect in the field, bearing on this question, is of a negative character. The thinness of strata bearing organic material and its apparent restriction to the northwestern margin of the troughs makes it impossible to conceive of it as a possible source of a commercial quantity of oil. But even if we grant that at some time in the past, oil may have been distilled from the organic material entombed in the rocks, there are few, if any, anticlines in which it may have accumulated, and without such structures the volatile constituents of the oil have had ample opportunity to escape through the coarse conglomerate which composes most of the Newark group.

As, however, many of the citizens of this field would like to see a deep well drilled so as to settle the question regarding the presence or absence of petroleum, the writers were on the lookout throughout the time spent in the field for a location that might be considered the best, from a geological point of view, to drill a test well, but after mature consideration of all of the facts that were obtained they regard all locations as unfavorable and are unable to say that any one location is more favorable than another. No one, even the most experienced geologist can say positively that oil does not occur in these rocks, but they can say that all of the facts obtainable are of a negative character, and that in their opinion it is not worth spending time or money in prospecting where conditions appear to be so unfavorable.

Sometimes the drilling of a test well will satisfy public opinion regarding the presence or absence of petroleum much better than the opinion of the most eminent geologist, but in such a case as the Deep River Coal Field, where there is no pronounced anticline, one well would test only the possibilities in its immediate vicinity, but would tell nothing about oil possibilities in the territory surrounding the well. Under such conditions, it would require many wells, unless the driller were fortunate enough to strike oil in his first or second venture. Altogether the adequate testing of this field might prove to be very expensive, with no returns, and in such an event it would have been much better to spend the money in building good roads or in improving the soil, or in some enterprise that would redound to the benefit of the entire community, rather than in a hole in the ground that yielded nothing.

ERRATA - Bull. 33, N.C.G. and E. Survey
Figure 2 is on page 32.
The diagrams shown as figures 3 and 4 should be reversed.


# MAP OF THE DEEP RIVER COAL FIELD IN LEE, CHATHAM, AND MOORE COUNTIES NORTH CAROLINA

BY MARIUS R. CAMPBELL AND KENT K. KIMBALL

1923

Main roads were surveyed by planetable and stadia; secondary roads, by foot-traverse, except roads in Moore County, which were taken from a map made by the Bureau of Soils.

Direction of surveyed lines, and also areas enclosed by them, owing to local attraction of the dikes, are not accurately represented and the map should not be used in determining acreage of coal lands or distances between points; the map, however, because of the tendency of errors to compensate one another, is a fairly accurate representation of the country.