The Geological Survey

OF

ARKANSAS

1909

The Slates of Arkansas

BY

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WITH A

Bibliography of the Geology of Arkansas

BY

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LETTER OF TRANSMITTAL

To the President, Governor George W. Donaghey, and Members of the Geological Commission of Arkansas:

Gentlemen: I have the honor to transmit to you herewith, the report on the Slates of Arkansas, made in compliance with an Act of the Thirty-sixth General Assembly of the State of Arkansas, together with the Bibliography of the Geology of Arkansas, by Dr. J. C. Branner, ex-State Geologist of Arkansas.

Your Obedient Servant,

A. H. PURDUE.

University of Arkansas,
Fayetteville, Ark.
March 29, 1909.

THE GEOLOGICAL COMMISSION

HIS EXCELLENCY, GEORGE W. DONAGHEY,

GOVERNOR OF ARKANSAS.

PRESIDENT JOHN N. TILLMAN,

UNIVERSITY OF ARKANSAS.

HON. GUY TUCKER,

COMMISSIONER OF MINES, MANUFACTURES AND AGRICULTURE.

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PREFACE

The attention the slate deposits of Arkansas have attracted in recent years from prospectors and operators, as well as the favorable comments made by the very few geologists who had examined them, sufficiently justified the Thirty-sixth General Assembly of Arkansas in making an appropriation for their somewhat exhaustive examination. The results of this examination will be found in the report that follows.

The field work for this report was done in the summers of 1907 and 1908 under an arrangement for co-operative work between the United States Geological Survey and the Geological Survey of Arkansas. As associates with the writer in the field work, were Messrs. R. D. Mesler and H. D. Miser, recently students in the department of Geology, University of Arkansas. Whatever value there may be in this report is largely due to the efficient work of these two gentlemen, who never shrank from the arduous task of constant, difficult mountain climbing beneath the hot rays of the summer sun.

Within the time and with the means at command, it was not practicable to carefully cover the entire slate area of the State. Especially was this true, because good maps as a base were not available except for a limited portion of the area. It so happened, however, that this portion included that part of the slate area that had received most attention and had been most developed. This map had been prepared by the U. S. Geological Survey, and was the topographic sheet of the area between the meridians 93° 30′ and 94° 00′ and the parallels 34° 00′ and 34° 30′. The northern part of this map covers a considerable portion of the slate area in Polk and Montgomery counties. This area was carefully mapped and is published herewith. This map will be of value, not only in showing the structure and areal geology of the region it covers, but also in judging of the geology in the areas both to the east and west, for they all are similar. While it was not practicable to map the slate outcrops to the east and west of the region mentioned, those parts were covered by reconnaissance and the results will be found in chapter V.

The following is a brief history of the geological work done in the area, previous to that embodied in the present report: In 1834 G. W. Featherstonhaugh was sent out by the topographic bureau of the Department of War, in compliance with an act of Congress of June 28th of that year, as U. S. Geologist. Results of his observations were published in 1835 as a geological report of an examination made in 1834, of the elevated country between the Missouri and the Red River. The work done by Featherstonhaugh was of the nature of a reconnaissance from St. Louis to Red River. His course took him over the western part of the highlands of Arkansas, and through what was then a small village on the present site of Hot Springs. He describes the rocks of this, as of those of other areas over which he passed, only in a general way, and but incidentally refers to the slate as "grauwacke slate," or simply as "slate."*

In 1859 and 1860, David Dale Owen, then State Geologist of Arkansas, made a reconnaissance survey including the area in which slates occur, the results of which are published in the "Second Report of a Geological Reconnaissance of the Middle and Southern Counties of Arkansas." In this report, Owen makes frequent mention of slate, and expresses the opinion that some of the slate observed by him is of excellent quality.

*Geological Report of an examination made in 1834, of the elevated country between the Missouri and Red Rivers. By G. W. Featherstonhaugh.

In 1890, Mr. L. S. Griswold, under the direction of Dr. J. C. Branner, then State Geologist of Arkansas, made a survey covering practically the entire slate area of the State, in doing the field work for his report on "Whetstones and the Novaculites of Arkansas." The result of this survey is published in Volume III of the annual reports of the Geological Surveys of Arkansas for 1890. The object of the work of Mr. Griswold was such as to preclude the careful observations of all economic products except novaculite, but he has the following to say covering slates: The shales commonly found in the valley parts of the area in different degrees of hardness and various colors are commonly called slates. These have been quarried in several places west of Little Rock for roofing slates, and near Hot Springs for flagging. They seem to lack the toughness of good slates and soon wear out. When sheltered from weather, however, they are fairly durable. The rocks of the area have been so completely crushed that it often is difficult to obtain the stone in large slabs, so the waste in quarrying is great. Some of the red varieties have pretty colors, and may find some use where the wear will not be so great as it is in the pavements.*

In 1903, T. Nelson Dale published the results of a microscopic examination of a half dozen specimens of slate from Polk County, Arkansas. The specimens examined were black, red and green. As a result of the examination Mr. Dale says: The remarkably fine cleavage and the absence of calcium and magnesium carbonate in the black (1) and green (6) render them exceptionally good. The reddish slate (4) is good and (3) may prove equally so. If (1) and (6) occurred in a populous region they would doubtless be in great demand.†

Later Mr. E. C. Eckel of the U. S. Geological Survey

*Geol. Surv. of Ark., Vol. III, 1890, p. 390.
†Bulletin No. 225, U. S. Geol. Surv., p. 416.

made a reconnaissance trip through the slate area of Arkansas, the results of which are published in Bulletin No. 275 of the U. S. Geological Survey, 1906. In this Mr. Eckel described the slate of some of the openings and gave the analyses of seven different specimens. His report is supplemented by several microscopic analyses by T. Nelson Dale.

The chapter on the bibliography of the geology of Arkansas was gratuitously furnished by Dr. J. C. Branner, ex-State Geologist of Arkansas, and represents his careful compilation of the literature on this subject for many years.

The writer desires to take this opportunity of expressing his appreciation of the uniformly courteous treatment from the people living within the area covered by this report. Especially is he under obligations to Mr. S. Higham of the Southwestern Slate Company, at Slatington, Arkansas, to Messrs. M. W. Jones and G. W. Heath of Big Fork, Arkansas; to Mr. A. G. Jones, of Alamo, and to Mr. J. M. Jones, of Plata.

A. H. PURDUE,
STATE GEOLOGIST.

THE SLATES OF ARKANSAS

BY A. H. PURDUE, State Geologist

CHAPTER I.

HISTORIC DATA RELATING TO THE SLATE INDUSTRY

THE INDUSTRY IN EUROPE.

The time at which slate came into use for roofing purposes seems undetermined. Probably, as in the case of many other products of nature, its adoption for the uses of man extends far back into the darkness of history. According to accounts, the locality where it was first used was western Wales, where it is said to have been utilized in the construction of buildings prior to the Norman conquest,* which took place in the latter part of the eleventh century. Some of the old castles of north Wales, built during the twelfth century, were covered with slate† from the quarries near by. In the centuries that followed, the slate industry of Wales developed until slate was shipped in large amounts to all parts of Great Britain as well as to the Continent and the United States. It appears, also, that slate for roofing purposes came into early use at Angers, France.

As early as the first part of the seventeenth century,‡ slate was extensively produced at the De la Bole quarries, Cornwall. The development of the slate industry, however, is more closely associated with Wales than with any other region, and it is from there that the best quarrymen have been secured in the development of the business in the United States.

*16th An. Rep. U. S. G. S., Pt. IV., p. 481.
†Slate and Slate Quarrying, Fourth Ed., p. 161. By D. C. Davies, London.
‡Loc. Cit.

CORRECTIONS.

Page XI, line 7, for *Surveys* read *Survey*.

Page 46, line 14, after *p.* add *31*.

Page 76, line 15, for *26 W.* read *25 W.*

Page 80, line 26, strike out *Fig. 2*.

Page 80, line 27, for *V* read *VII*.

THE INDUSTRY IN THE UNITED STATES.

Data upon the history of the slate industry in the United States seems rather meagre, but the following brief statement is quoted from Mr. George P. Merril:*

"The quarrying of slate for roofing purposes is an industry of comparative recent origin in the United States.........The earliest opened and systematically worked [quarries] are believed to have been those at West Bangor, Pa., which date back to 1835.

"The abundance of slate tombstones in many of our old churchyards, however, would seem to prove that for other purposes than roofing these stones have been quarried from a much earlier period. It is stated, moreover, that as early as 1721 a cargo of 20 tons of split slate was brought to Boston from Hangman's Island, in Braintree Bay, which may have been used in part for roofing purposes; but the greater part of the material for this purpose was imported directly from Wales. It is also stated that slates were quarried at Lancaster, Massachusetts, as early as 1750 or 1753, and were extensively used in Boston soon after the close of the Revolution. The old Hancock house on Beacon street...........was covered with slate from these quarries, as was also the old State House and several other buildings. This quarry was worked more or less for fifty years and formed at one time quite an important industry, but which finally became unprofitable, and about 1825 or 1830 the works were discontinued, not to be again started till about 1877.

"The first quarry opened in what is now the chief slate-producing region of the United States was that of Mr. J. W. Williams, situated about a mile northwest of Slateford, in Pennsylvania. This dates back to the year 1812."

The slate quarries of Pennsylvania are located in the vicinity of Bangor and Pen Argyl, in Northampton County; Slatington, Lehigh County; and in York County. The latter includes a part of the Peachbottom district, which lies partly in Pennsylvania and partly in Maryland.

The early history of the slate industry in Maryland is obscure, but it appears that slate was quarried for local use

*An. Rep., Smithsonian Institution, 1886, Pt. II, p. 291.

as early as 1750.* The counties that produce slate are Harford, Montgomery and Frederick.

Relating to the early history of the slate industry in Vermont, the following is quoted.†

"In 1845, Hon. Alansan Allen,...........commenced working the slate of that [Fairhaven] region, and for two years limited his operations to the manufacture of school slates...........At first the enterprise promised a fair remuneration for the outlay, but in consequence of a rapid decline in the price of school slates in the market the enterprise was abandoned, and in 1847 the first effort at manufacturing roofing slate was made in Fairhaven by Mr. Allen. During that season he manufactured and sold about two hundred squares ....and in 1849 the amount reached five hundred squares; but the too prevalent custom of people to purchase a *foreign* article in preference to home productions, materially affected his sales, and almost compelled him to abandon the enterprise. But in 1850-51 a new impetus was given to the slate business. Intelligent Welchmen, accustomed to working slate, emigrated to Fairhaven, Castleton and Poultney, and made purchases of land and opened quarries, or were employed by others who had opened them; and such was the character of the slate that the prejudice which had existed against Vermont slate in the cities, disappeared as soon as its valuable properties were fully understood. The result was that in 1855—eight years after the first effort at manufacturing roofing slate was made—from that vicinity alone there were produced forty-five thousand squares of slate, or nearly twice the whole amount of slate imported from foreign countries that year...........

"The 'West Castleton Railroad and Slate Co.' in 1853, commenced sawing and planing slate for black-boards, billiard-beds, etc., and in 1855 the successful experiment of enameling slate was made by this company, under the supervision of E. S. Chapman, Esq., since which the manufacture of enameled mantel pieces, bracket-shelves, table tops, etc., has steadily increased and now [1861] thousands of these articles, are annually manufactured and sold by this company........

"At the time of our visit [in 1858] there were employed about the works one hundred men, fifteen of whom were engaged at the quarry. From fifteen thousand to sixteen thousand feet of slate were sawed and polished per month, and of this, a large proportion was manufactured into chimney-pieces, pier-slabs, table and bureau-tops, map-boards, bracket-shelves, etc., and marbleized; and in addition to

*Maryland Geol. Surv., Vol. VI., p. 189.
†Rep. on the Geol. of Vt., Vol. II., 1861, p. 796.

this amount, there were also manufactured about one hundred and fifty squares of roofing slate per month."

The most important slate district of Vermont is in Rutland County, the principal quarries being located near Castleton, Fairhaven, Poultney and Pawlet; but the counties of Windham, Orange, Caledonia and Washington also produce slate.

No data is at hand upon the history of the slate industry of New York. Most of the slate from this state is produced in Washington County, the deposits there being a continuation of those in Rutland County, Vermont.

A small amount of slate quarrying has been done in northern New Jersey, in the continuation of the Bangor-Slatington belt of Pennsylvania.

In Virginia, slate is produced at Arvonia, Buckingham County; Snowden, Amherst County; Warrenton, Fauquier County, and Fluvanna County. No data is at hand on the history of the industry in that state, but according to tradition of the quarrymen, the Williams quarry, the oldest at Arvonia, has been operated since 1832.

In Maine, slate is produced in Piscatoquis County, at the towns of Monson, Blanchard, and Brownville.

In Georgia, slate is worked to some extent at Rockmast, Polk County.

A small amount of slate is produced in eastern Tennessee, in Blount County.

Other states in which slate is known to occur are Arizona, California, Utah, Minnesota, and Michigan.

The principal slate-producing states of the United States are Pennsylvania, Vermont, Maine, Maryland, and Virginia. Among these Pennsylvania takes the lead with Vermont second and Maine third.

The slate of Pennsylvania is produced in Northampton and Lehigh Counties, in the central-eastern part of the state. This area is known as the Bangor-Slatington slate belt. It extends eastward into the northern part of New Jersey, and it is from the latter locality that the slate of New Jersey is produced. There is another slate-producing area in the southeastern part of Pennsylvania, in Lancaster and York counties. This area extends into Harford County, Md., and it is here that most of the slate from the latter state is produced. The total length of this area in both Pennsylvania and Maryland is only about 10 miles, and its width does not exceed one-half mile. The slate from this area is what is known in the market as Peach Bottom slate. A small amount of slate has been produced from time to time in Frederick and Montgomery counties.

Most of the slate of Vermont and that of New York comes from one area, which is about twelve miles wide and thirty miles long, extending practically north and south, and is located in the central-eastern part of New York and the southwestern part of Vermont.

The slate from Maine is produced near the center of the state, in the southern part of Piscatoquis County.

The slate of Virginia occurs in Amherst, Buckingham and Fluvanna counties, near the central part of the state, and in Fauquier County in the northern part. The principal quarries are at Arvonia, a few miles south of James River in Buckingham County.

The following is the value of the slate annually produced in the United States, for all purposes, since the year 1900.*

*Statistics from the U. S. Geological Survey.

Year.	Value.	Year.	Value.
1900	$4,240,466	1904	$5,617,195
1901	4,787,525	1905	5,496,207
1902	5,696,051	1906	5,668,346
1903	6,256,885	1907	6,019,220

The following table shows the production of slate in Arkansas, since 1902.*

	Roofing slate squares.	Value.	Milled stock value.	Total value.
1902	500	$ 4,000	.....	$ 4,000
1903	118	709	$4,000	4,709
1904	1,750	10,300	4,000	14,300
1905	50	350	9,650	10,000
1906	....	......	5,000	5,000
1907	....	......	8,500	8,500

Most of the slate produced in the United States is used for roofing purposes. For example, the roofing slate produced in 1906 was reported as 1,214,742 squares, valued at $4,448,786, while the value of all other stock in the same year was $1,219,560.

THE INDUSTRY IN ARKANSAS.

The Eastern Part of the Slate Area. As early as 1859, a slate quarry was opened northwest of Little Rock.† A company was formed to quarry this slate for roofing purposes, but it was found incapable of standing the weather. Many years ago a quarry was opened near the mouth of Glazierpeau Creek, twelve miles northwest of Hot Springs, but no reliable report of this slate having been utilized has been secured. From 1885 to 1908, several quarries were opened up in the western part of Pulaski County and the eastern part of Saline County, and from some of these, a small amount of roofing slate has been shipped.

The Southwestern Slate and Manufacturing Company. In 1902* the Southwestern Slate and Manufacturing Company was organized to operate in Polk and Montgomery counties, Arkansas. Title was acquired to land to the extent of about 1,600 acres. A large amount of money was subscribed for the development of the property, particularly at Slatington, Montgomery County. The money was expended in building roads, erecting buildings, installing machinery and in various other improvements necessary for conducting an extensive business when transportation possibilities, which were soon expected, could be had. Disappointment in securing transportation and the large outlay of money, resulted in the re-organization of the company in 1905. In this re-organization, the name was changed to the Southwestern Slate Company, which succeeded to all the property of the first company, and purchased about 320 acres more land. This company is capitalized at $500,000, the issued portion representing the actual cash invested. The operating plant contains one saw, one planer, and one rubbing-bed. To the present time (1908), only milling slate has been produced, a considerable amount of this having been put on the market, principally for use in electrical purposes.

*Compiled from statistics of the U. S. Geological Survey.

†Second Report of Geol. Recon. of Ark., by D. D. Owen, p. 73.

The work of the Southwestern Slate and Manufacturing Company, and its successor, gave an impetus to slate prospecting, and a large number of titles were acquired to slate lands, and more or less prospecting done on many of them, among which the following are mentioned:

The Altus Slate Company. In 1900 the Altus Slate Company opened a quarry in Polk County in Section 11, 3 N., 23 W., about seven miles west of Big Fork Postoffice. After working for about a year it was discontinued.

The writer is informed that no slate was shipped from this quarry. Near by is another quarry that was owned

*For the history of this company, the writer is indebted to Mr. J. M. Slyke, Sec. of the Southwestern Slate Company.

by the Standard Slate Company. After working for some time this company went into bankruptcy, and the property was sold.

Subsequently the Gulf Slate Company of Indianapolis, Indiana, opened a quarry in Sec. 12, 3 N., 29 W. Some buildings were erected and a good deal of work was done here but no slate was shipped. Nothing was being done at the time of the writer's visit in the summer of 1907.

In the neighborhood of Big Fork Postoffice, there are numerous smaller openings made by more or less pretentious individuals and companies, most of which were made from 1900 to 1906.

The J. R. Crowe Coal and Mining Company. In 1904 the J. R. Crowe Coal and Mining Company opened small quarries in Sec. 36, 3 S., 26 and 27 W. At the same time small buildings were erected for tenant houses, and a larger one for a hotel. At the time of the writer's visit (1907), no work was being done, and no slate had been shipped from this place.

The Ozark Slate Company. In the winter of 1902 the Ozark Slate Company began operations in Garland County, about twelve miles west of Hot Springs. A plant was erected consisting of a hoisting engine, two wire trams, each about 500 feet long, and a few buildings. The most important of these contained the boiler and engine, two saws, one planer, one hand saw, one rubbing-bed and six slate trimmers. A great deal of work in the way of quarrying was done here. At the time of the writer's visit to this place, the plant was in charge of the quarry foreman, but no work was being done.

Other Prospects. From 1900 to 1905, a large number of slate prospects were made in the neighborhood of Crystal Springs in Montgomery and Garland counties. About the same time several prospects were opened up farther west, in the vicinity of Plata and Alamo, Montgomery County, but no slate has been shipped from any of these.

CHAPTER II.

GENERAL CONSIDERATIONS RELATING TO SLATE

DEFINITION AND CHARACTERISTICS OF SLATE.

Slate may be defined as any rock that has the property of parting along parallel planes developed to such an extent that it may be split into thin plates with even surfaces. This property of parting is called cleavage.

There are two classes of rock which are very unlike, but both somewhat resemble slate. These are schist and shale. In most cases slate is a rock intermediate between the two. Schist, like slate, will split along planes that are more or less parallel, but the surfaces thus produced are rough and wavy. It usually is harder, more inflexible, crystalline and stony than slate. Shale is not unlike slate in general appearance and composition, but there are differences which may be discovered by either the geologist or the layman in the field, and others which can be determined only by the aid of the microscope. Of the former class, the following are some of the more common: (1) Shale occurs in layers or laminae, and when quarried these fall apart and break up into thin leaves or sheets; slate is taken from the quarry in blocks, and comes to be in sheets only by artificial splitting. (2) Shale usually has less strength than slate, and is softer and more earthy to the touch and smell. (3) When suspended in air (as when supported on the ends of the fingers) and struck a light blow, shale will produce a dull, dead sound; slate, when so struck, usually will have a somewhat metallic ring.

The microscope shows that slate contains a greater variety of minerals than shale and that particles composing the slate are more or less flattened and have their longer axes in the same general direction, neither of which is markedly true of shale.

Slate is nearly always metamorphosed shale. Schist may be, and often is metamorphosed shale, the alteration having gone further than in slate. Probably in all cases where the question comes to be a practical one, it is easy to determine in the field whether a rock is a shale or a slate on the one hand, or a slate or a schist on the other. Slate, to have economic importance as such, would be recognized. But there are cases in which the classification from the scientific point of view, might become difficult; for there are all grades from shales into slates and slates into schists.

Many of the mineral particles of slate are secondary. That is, they are not original constituents of the rock but have been formed in the process of alteration from a shale to a slate. The most common of these minerals is mica, which occurs as small scales. Those rocks in which these scales are sufficiently abundant to produce a lustrous appearance are known as phyllite, or mica slate. Slate in which mica is not thus developed and which is without lustre, is known as clay slate.

THE ORIGIN OF SLATE.

As stated above, slate is of secondary origin. That is, its slaty properties have been induced in some parent rock, by alteration or metamorphism of that rock. Only rocks of very fine grain are capable of thus being altered. Most slate has been derived from the alteration of beds of shale, and this in turn was formed from the consolidation of mud or clay put down under water, layer upon layer. Such beds were derived from former land areas and were carried by streams and spread out over the beds of the sea, just as streams are now carrying material from the present land

areas and spreading it out over the beds of the present seas. And, as at the present time, coarse material, consisting of sand and gravel, is put down along and near the coast line and the fine material usually some distance from the coast, so it must have been in former times. At the present time there are parts of the coast, such as bays, in which the water is comparatively quiet and in which mud and clay are now being deposited. Such, doubtless, were the conditions in past time. So that the material of most of the slate beds was put down partly in the deep water some distance from shore and partly in the quiet, shallow water near the shore. A very small amount of slate has been derived from fine grained rock of igneous origin.

Slaty Cleavage. The conspicuous and important result of the alterations of rock into slate is the development of the property known as slaty cleavage. The value of a slate deposit depends largely upon the perfection and ease with which it will split and this is dependent upon the perfection of the cleavage.

Relation of Cleavage to Bedding. The direction of slaty cleavage usually is oblique to the bedding planes, though not always so. An idea of the common relation of cleavage to bedding may be obtained from Fig. 1.

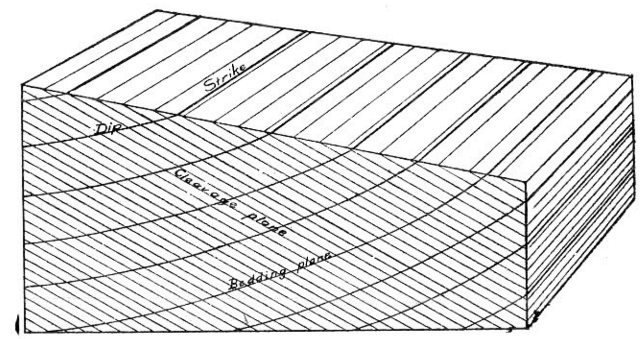


Fig. 1. Diagramatic illustration showing the common relation of cleavage to the bedding planes.

The angle between the bedding planes and the cleavage planes may vary from a very small one to a large one. If the sedimentary material from which the slate is derived consisted of layers of different color, composition or texture, the relation of the cleavage to the bedding can be easily seen. It frequently happens that the shale from which the slate was derived consisted of differently colored layers; or it may have contained thin beds of some other sedimentary material. In such cases the original differences in color of the slate are likely to be preserved, and the layers of different material will have the cleavage undeveloped or poorly developed, depending upon the size and other physical characters of the constituent grains. In either case the banded effect of the original sedimentary material will be preserved, and the relation of the cleavage to the bedding will be evident.

If the original material was of uniform color, composition and texture, the relation of the cleavage to the bedding may not be an easy matter to determine, for under such conditions, all traces of bedding are likely to have been removed. In such cases, to determine the angle between the cleavage planes and the bedding planes it is necessary to have the contact with beds which are above or below the slates, and in which the cleavage is not developed. In some cases the cleavage is parallel with the bedding planes, which, however, are then obliterated in those parts where the cleavage is developed.

Along any line parallel with the strike of the rock, the angle between the cleavage and the bedding may be quite uniform throughout considerable distances. But along lines at right angles to the strike, or with the dip of the rock, this angle varies. The variation is caused by the cleavage planes being parallel, while the dip of the beds changes from point to point according to the location in the field. This will be understood by referring to Fig. 1.

The Development of Slaty Cleavage. The development of slaty cleavage is a matter that has received a great amount of attention from geologists. While there is not complete agreement as to the exact nature of the process that produces it, all agree that the essential agent is lateral pressure. The sedimentary rocks, including of course the beds of shale from which most slates have been derived, were put down in water in practically horizontal positions. Neglecting the cause of lateral pressure and passing at once to its results, we note that because of the enormous pressure thus applied to the outer rocks of the earth, these rocks suffer great compression, from which they are gradually bent into folds. Thus are produced the anticlines and synclines—the arches and the troughs—and therein lies the cause of the parallel ridges of most mountainous regions. Folded regions are expressions of lateral pressure over those parts of the earth where the pressure has effectually exerted itself. And as lateral pressure is necessary to the development of slaty cleavage, it follows that slate could not reasonably be expected to occur outside of folded regions.

The process of folding, however, is not of itself necessary to the development of slaty cleavage. It is one of the results of strong lateral pressure. Slaty cleavage is another. Necessary conditions for the development of slaty cleavage to the extent necessary for commercial slates, are deposits of fine-grained material such as clay, and great pressure.

The main features in the process by which slaty cleavage is induced may be understood from the following conditions: The mineral grains and fragments constituting sedimentary rocks were put down under water with their longest axes approximating a horizontal direction. Much of this material consisted of beds composed mainly of clay and extremely fine-grained sand. This subsequently became buried under many hundred feet of other material, the weight of which tended to force the longer axes of the grains in the same common horizontal position that they were disposed to assume during deposition. Also the weight of the superincumbent material tended to weld the grains together into coherent layers, thus producing shales, the rock from which most slate is derived.

The alteration or metamorphism of shale into slate involves a series of complicated processes, the consideration of which cannot be exhaustively entered into here, but will be briefly discussed under the heads of *mechanical processes* and *chemical processes.**

Mechanical Processes. The force of the mechanical processes is pressure. The exertion of the pressure is usually supposed to be in approximately horizontal planes, and doubtless in most cases in which rocks have been deformed by this force it has so acted. In such cases the force is spoken of as lateral pressure because it acts in one direction or in two opposite directions in or near a horizontal plane.†

Because of the great number of factors entering into the stress usually spoken of as lateral pressure, this probably acts in a perfectly horizontal direction only locally and for only comparatively short periods. But for the sake of simplicity it may be conceived as acting in parallel horizontal planes, and consequently in the initial stage, as approximately parallel to the bedding, and to the planes in which the longest axes of the mineral grains are located. Like all other dynamic forces of the earth, this pressure is gradually induced and acts gradually throughout the whole period of its exertion. It will increase in intensity until a maximum is reached and then decrease until it eventually dies out. During the stage of increase, there may come a time when the force exerted upon the rock beds from lateral pressure will be greater than that exerted by the weight of the superincumbent rocks. The difference between the two would be the differential pressure.

*For full treatment of this subject, the reader is referred to the following:

Rock Cleavage. By C. K. Leith, Bull. U. S. Geol. Surv., No. 239.

Deformation of Rocks—III. *Cleavage and Fisility.* By C. R. Van Hise. Journal of Geology, Vol. IV., pp. 449-483.

Schistosity and Slaty Cleavage. George F. Becker, Journal of Geology, Vol. IV., pp. 429-443. Also Bull. Geol. Soc. Am. Vol. IV., 1891, pp. 13-90.

†It seems not unreasonable to suppose that when stratified rocks are buried, as they frequently have been, under thousands of feet of rock, the pressure resulting from the weight of the superincumbent rock might be sufficient to induce slaty cleavage to at least a slight degree, as in the case of brick moulded in a hydraulic press under excessive pressure.

As a result of this, the rock beds are shortened and the mineral particles constituting them, are gradually changed in form and position until their longest axes occupy planes at a high angle to the direction of the lateral pressure. This change involves in part a rotation of the mineral particles, accompanied by flattening, and in part only flattening. In any case the final position of the longest diameters of the grains after rotation and flattening is normal or nearly so to the direction of pressure and likely is in planes at a high angle to the bedding.

If the lateral force were parallel to the bedding, the rotation and flattening of the mineral particles would bring their longest axes in planes normal to the bedding planes. But the lateral force is seldom parallel to the bedding, so that the longest axes of the mineral particles after rotation and compression usually occupy planes more or less oblique to the bedding planes.

The thickening of the beds is due to the rotation and flattening of the mineral particles. The maximum thickening would follow when the lateral force acts parallel with the bedding. This would decrease with change of direction of the lateral force, and when this force is normal to the bedding planes there would be no thickening and probably thinning would ensue. But as the lateral pressure can act perpendicular to the bedding planes only when the latter dip at a high angle, it follows that cases of thinning from this cause would be very exceptional.

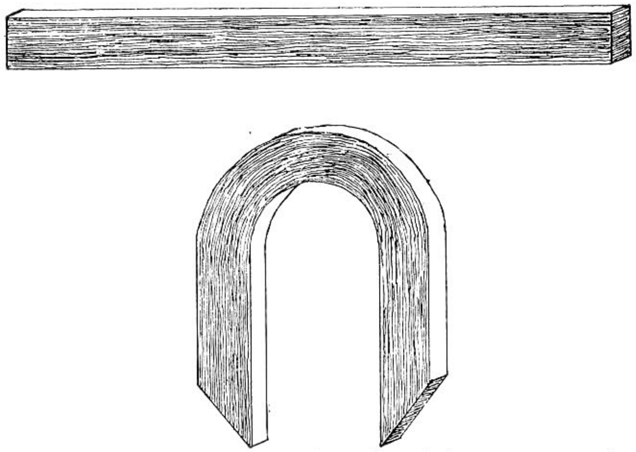
That the rotation of the mineral particles and their flattening in parallel planes is one of the important causes of slaty cleavage is evidenced in the fact that such cleavage is parallel to the planes in which the flattening has taken place, *i. e.*, the planes in which are located the longest and mean diameters of the mineral grains;* and by the further fact that the excellence of the cleavage is proportional to the degree of arrangement of the mineral particles with their axes in common planes and the amount of flattening that has taken place.†

It follows that the perfection of the cleavage is dependent upon all those factors that determine the amount of rotation and flattening. Among these are the strength of the differential pressure, the period of time during which it was exerted, and the hardness of the mineral particles. The grains of shale are composed of soft, easily compressed material and it doubtless is for this reason that such deposits are capable of acquiring the excellence of cleavage necessary for commercial slate; for it often occurs that over- and under-lying beds composed of harder material have cleavage imperfectly developed or wholly undeveloped.

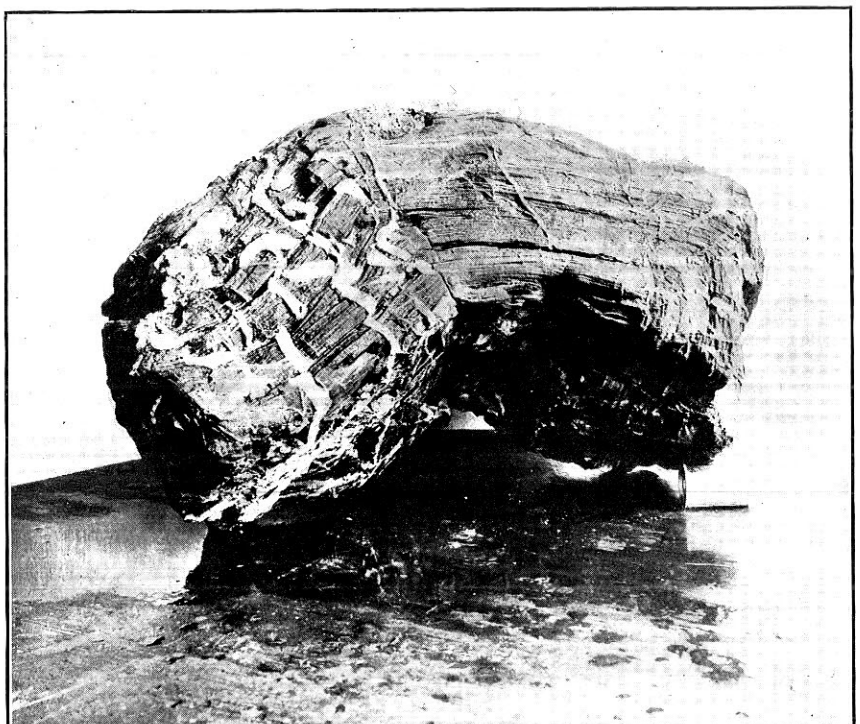
Attention already has been directed to the folding of rocks under pressure,and the association of cleavage with folded areas. Among the mechanical processes accompanying folding is that of shearing. This movement involves the slipping of different rock layers upon each other and may be illustrated by folding the leaves of a book and noticing

*Secondary cleavage may be produced in the planes of the longest and shortest diameters, or normal to the main cleavage. This is known in slate as the "grain."

PLATE I.



1. Diagram illustrating the shearing of rock layers over each other in the process of folding.



2. An example of the shearing of rock layers over each other in the process of folding. The shearing is shown by the displacement

how the edges change from an angle normal to the page to one oblique to the page. Figure 1 of Plate 1 will further illustrate this process, and figure 2 is a photograph of a rock, the layers of which have sheared over each other, in folding. The amount of shearing is shown by the displacement of the quartz veins, which had been formed before the folding took place.

Van Hise has called attention to the fact that this shearing process, in soft beds, causes the cleavage to accord more nearly with the bedding than if the rocks did not suffer from it.* It will be seen that this movement in the case of soft beds is along numerous planes parallel with the bedding and would tend to shift the longest axes of the mineral grains from any position oblique to the bedding, to one parallel with it.

Chemical Processes. The chemical processes that are a part of metamorphism are thought by investigators to be an important cause of slaty cleavage. These consist in the development and crystallization of new minerals and the recrystallization of the old ones. In this process the newly formed minerals tend to take a position with their longer dimensional axes parallel with those of the mineral grains. The process doubtless goes on simultaneously with the rotation and flattening of the mineral grains, and possibly is continued afterwards. Those minerals that are formed while pressure is active, rotate and flatten in the same direction as the original mineral grains; and the parallelism of these newly formed minerals with the original grains facilitates cleavage.

But minerals themselves possess cleavage. In some this property is well developed, in others poorly developed. Among those in which it is well developed is mica, and it so happens that in the process of metamorphism resulting in slate, mica is much more abundantly developed than any

*Deformation of Rocks, Jour. of Geol., Vol II, pp. 472-473.

of the secondary minerals. Also the cleavage planes of mica are usually parallel with the longest axes of the mineral particles, so that the cleavage of this mineral coincides with that of the rock and comes to be an important cause of the slaty cleavage. Other minerals of secondary importance, because they are not so common in slate as mica, and because their cleavage planes do not so frequently take the general parallel direction of the constituent grains, are chlorite and hornblende.

The cause of the chemical reactions resulting in the formation of secondary minerals probably rests in the frictional heat developed during the process of rotation and flattening under lateral stress, aided by the presence of the moisture in the original shales. The new minerals are formed by the breaking up and the recombination of the elements of the older ones, especially those of clay, feldspar and iron. These new minerals are mainly the micas, (muscovite and biotite), hornblende and chlorite. Both the micas occur in very thin scales. Muscovite is a silicate of aluminum and potash and is usually colorless though it may be tinged with yellow, brown, green or violet. Biotite, which is not nearly so common in slate as muscovite, is a silicate of aluminum, potash, magnesium and iron. It is black to dark green in color.

Hornblende is a silicate of aluminum, calcium, magnesium and iron. It is quite hard and varies in color from green to black. In slate it occurs in small, usually microscopic crystals.

Chlorite is a silicate of aluminum, magnesium and iron, containing water. It usually is of green color, is soft and smooth and unctuous to the feel.

The development of new minerals consists in the breaking up and rearrangement of the elements of the minerals present before metamorphism. While certain elements

of the shale may be removed in small quantity by the underground water, and others introduced in small quantity by the same agent, but little difference in composition would be expected between slate and the shale from which it was derived.

In order to make a comparison between the two, the following table of partial analyses has been compiled from complete analyses of shale and slate by the U. S. Geological Survey.* The analysis of shale was made from a composite of fifty-one samples of Paleozoic shale; that of slate is the average of several analyses of slates of Cambrian age from Vermont. The minerals are arranged in the order of their quantitative importance.

Table of Analyses of Shale and Slate.

	Shale	Slate
SiO_2	60.15	60.92[1]
Al_2O_3	16.45	18.28
Fe_2O_3	4.04	1.91
FeO	2.90	4.92
H_2O	4.71	3.24[2]
K_2O	3.60	4.16
MgO	2.34	2.72
Na_2O	1.01	1.34
CO_2	1.46	.81[3]
TiO_2	.76	.76
CaO	1.41	.76
P_2O_5	.15	.12
MnO	trace	.16
BaO	.04	.06[3]
C	.88	.26[4]

[1]Unless otherwise stated, amount given is the average of the analyses of 11 samples, the total number analyzed.

[2]Includes moisture and water of crystallization.

[3]Average of the analyses of 9 samples.

[4]Average of the analyses of 4 samples. The other 7 contained none.

When it is remembered that original differences of composition must be considered, the similarity of the two

*Bulletin No. 168, pp. 17 and 278-280.

columns is striking. The greatest differences is in the relative amounts of ferric and ferrous iron, the ferric being most abundant in the shale and the latter in the slate, the proportion being in the reverse order. This doubtless is attributable to the reduction of the ferric to the ferrous iron by the carbonaceous matter of the shale. It will be noted that the amount of carbon in the shale is greater than in the slate. The relative combined amounts of the ferric and the ferrous iron in the shale and slate respectively are 6.94 and 6.83.

Of course it is understood that while the chemical analyses so closely resemble, the petrographic or microscopic analyses would be quite different, as the latter would indicate the mineral occurring in the slate and not found in the shale.

VARIETIES OF SLATE.

Slate may be divided into classes on the basis of either color, mineral properties, or uses.

As to color, slate may be black, purple, red or green. Black slate, like black shale, owes its color to finely divided carbonaceous matter deposited with the shale from which the slate was derived; purple slate to a mixture of iron oxide, Fe_2O_3 and chlorite; red slate to the presence of iron oxide; and green slate probably to the presence of a large amount of chlorite.

As to mineral properties, slate is commonly divided into clay slate and phyllite or mica slate. The difference in the two classes is in the degree of metamorphism, that process having gone much farther in the mica slate than in the clay slate. The mica slates are more compact than the clay slates, as a rule are more sonorous, and have mica scales developed in sufficient amount to give them more or less of a metallic lustre.

As to use, slate may be divided into roofing slates and milling slates. As the name suggests, roofing slates are those suitable for roofing purposes. The properties for good roofing slate will be considered later. Milling slate is slate that is suitable for any commercial purpose to which slate is put other than for roofing. It is so called because before being placed on the market, it must go through the factory where it is sawed, planed and polished. Some slates are suitable only for milling purposes, others for roofing, while still others can be used for either.

USES AND QUALITIES OF SLATE.

Most of the slate quarried is sold for roofing, though a large amount is used for other purposes, such as flooring, blackboards, school slates, electric switch-boards, table tops, wainscoting and vats. Probably the greatest demand at present, aside from roofing purposes, is for switch-boards.

Among the qualities to be considered in roofing slate are color, cleavability, strength and ability to withstand attacks of atmospheric agencies.

The things to be considered in selecting the color of a roofing slate are the requirements of harmony with the colors in the walls of the building on which it is to be used, and the ability of the color to endure the weathering agents without fading. If a slate has been long in use, the endurance of its color can be tested by comparing a piece fresh from the quarry with another that has been in service for several years; if not, it may be tested by comparing a piece fresh from the quarry with natural exposures of the bed from which it is taken. Discoloration is due to the chemical reactions of the constituent minerals, consequently the stability of a color depends upon whether the minerals are stable or unstable. Of the different slates, green is the most likely to discolor.

Roofing slate should be sufficiently cleavable to split readily in plates a quarter of an inch or less in thickness, with smooth surfaces. The smooth surface is desired because it adds to the appearance of the roof, prevents the collecting of dust, and by the equal distribution of any strain that may come upon them, avoids the breakage of overlapping shingles. "Ribbons" are undesirable because the cleavage over them is usually uneven, because they often produce lines of weakness and because the variety of color mars the appearance of the roof.

The strength of roofing slate should be suffiicent to withstand the strains of shipping and service, with small loss from breakage. The strains of service come from those produced by workmen in laying and making repairs, the impact of hailstones, objects thrown on the roof, and the expansion of such freezing water as may be able, by the clogging of gutters or otherwise, to collect under the shingles or in the joints between them.

The ability of a slate to withstand the attacks of atmospheric agencies depends chiefly upon the mineral constituents and the degree of metamorphism. Porosity doubtless is a factor in determining the life of a slate, but those used for roofing purposes are so compact that this probably can be neglected.

The common minerals that are more or less injurious to slate, are lime and the sulphides of iron, especially marcasite. Lime being easily attacked by the acids of the atmosphere, is disposed to cause the disintegration of slate, if present in considerable quantities. Iron sulphide is oxidized by the atmosphere to sulphate, which being soluble, causes disintegration. Clay slate may be so slightly metamorphosed that it will soon go to pieces under the influence of changes of temperature, and absorption and evaporation of moisture.

Milling slate includes all slate that may be manufactured and placed on the market for flooring, wainscoting, mantels, lavatories, blackboards, switchboads, laundry tubs, etc. Such slate, on being taken from the quarry, is first sawed into blocks of the desired size, then split and planed to the desired thickness, after which it is put on the rubbing bed and polished. It is not necessary that slate for milling purposes have the perfect cleavage required for roofing slate, but it must be free from sand, nodules of iron sulphide and other hard material that would injure the saw or planer, or prevent polishing. The strength should be sufficient to permit of shipping, handling, and the necessary drilling, sizing, etc., required by the final use to which it is put, with but little loss from breakage. An essential requirement for switchboards is that the material be practically a nonconductor. It follows that for this purpose, metalliferous veins are detrimental, as is any considerable amount of magnetite, pyrite or other metallic sulphide, distributed throughout the slate. Hematite is so poor a conductor that its presence does not materially interfere with the use of slate for electrical purposes.

CHAPTER III

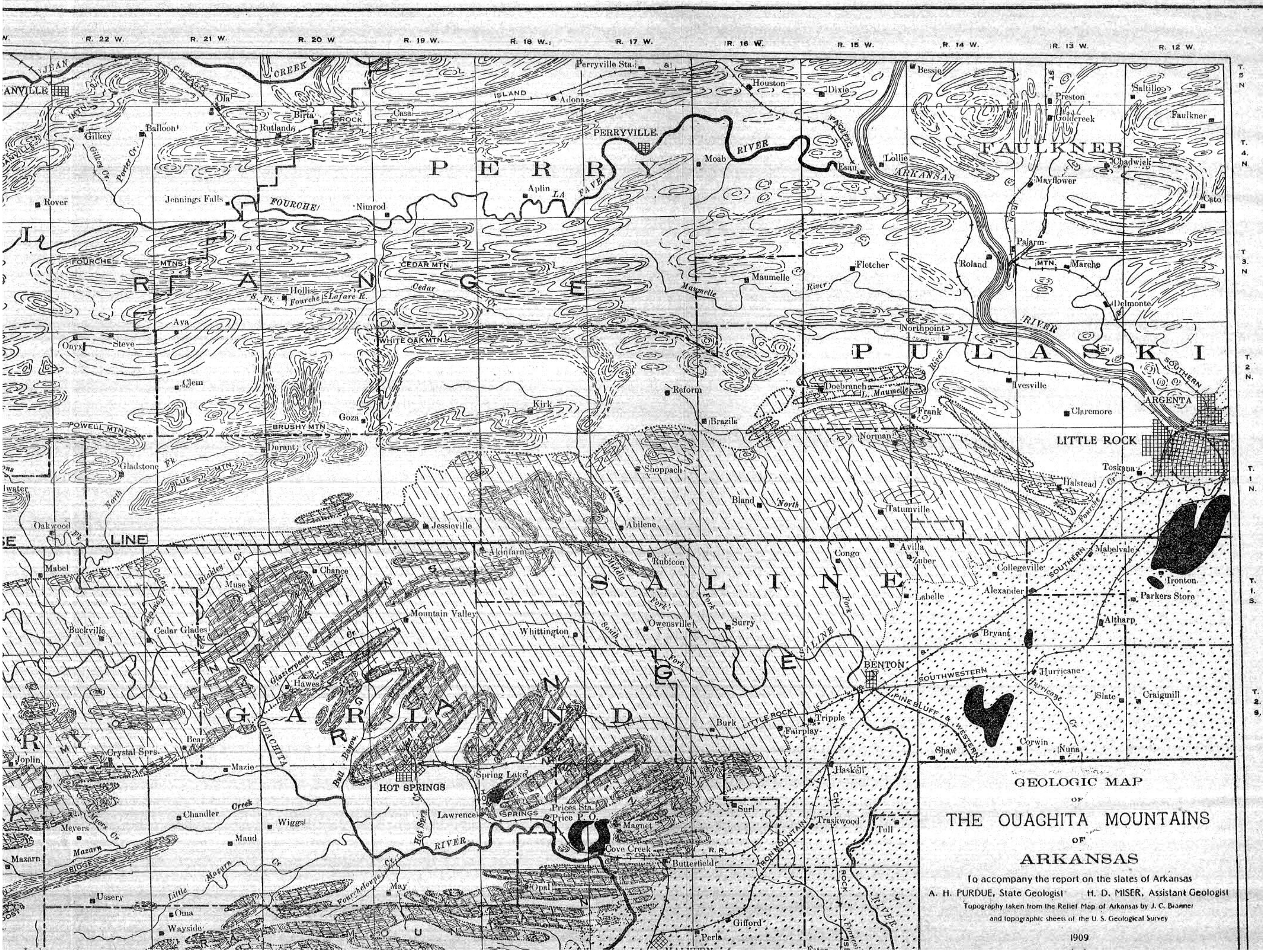
GEOLOGY OF THE ARKANSAS SLATE AREA.

LOCATION AND EXTENT OF THE ARKANSAS SLATE AREA.

The area in which the known slate deposits of Arkansas occur is located in the central-western part of the State. From reading that part of this report that relates to the origin of slaty cleavage, it will be seen that slate can be expected only in those regions where the rocks are more or less intensely folded; and as such conditions of rock structure in Arkansas occur only in the highlands south of the Arkansas River and west of the St. Louis, Iron Mountain & Southern Railroad, it is useless to search for slate elsewhere within the State.

Nor can slate be expected within all parts of the area named; for not only is it necessary for dynamic agencies to so act upon the rocks as to compress and throw them into folds, but it is necessary for the originally deposited material from which the rocks were formed to be mechanically and chemically suited to undergo metamorphism into slate. Most slate has been derived from metamorphosed shale. While shale is common over all parts of the area above outlined, and while folding in many parts has been so intense as to cause the strata to stand on edge or even to be overturned, slate is confined to a comparatively limited area; because within that area only were the shales of such a nature as to permit of their alteration into slate.

The area in which the slates of Arkansas are located includes a part of the Ouachita Mountains and extends from near Little Rock westward to near Mena. Its length



GEOLOGIC MAP
OF
THE OUACHITA MOUNTAINS
OF
ARKANSAS
To accompany the report on the slates of Arkansas
A. H. PURDUE, State Geologist H. D. MISER, Assistant Geologist
Topography taken from the Relief Map of Arkansas by J. C. Branner
and topographic sheets of the U. S. Geological Survey
1909


R. 32 W.
R. 31 W.
R. 30 W.
R. 29 W.
R. 28 W.
R. 27 W.
R. 26 W.
R. 25 W.
R. 24 W.
R. 23 W.
T. 5. N.
T. 4. N.
T. 3. N.
T. 2. N.
T. 1. N.
T. 1 S.
T. 2 S.
T. 3. S.
T. 4.
OKLAHOMA
SEBASTIAN
LOGAN
SCOTT
FOURCHE
YELL
POLK
MONTGOMERY
Sugarloaf
SUGAR LOAF MTNS.
Huntington
Mansfield
Farmer
Belva
Carolan
Golden City
Sugargrove
Patsie
Riley
Manning
Boothe
Tate
Peoria
Hartford
PILOT KNOB
ROUND MTN.
WHITE OAK MTN.
Walnut Tree
Shark
POTEAU MTN.
Poteau
WESTERN
Cauthron
CHALYBEATE MTN.
WALDRON
Cardiff
Greenridge
Olio
Blueball
Wing
Briggsville
Bluffton
Gipson
Winfield
Stringer
Nebraska
Gravelly
Harvey
Brawley
WALKER MTN.
Parks
Cedarcreek
Chula
Aly
Blansett
Boles
Sullivan
Blackfork
MILL CR.
Buck Knob
BLACK FK. MTN.
Gate
Story
Howard
Rich Mountain
RICH MTN.
Harris
Rock Quarry
Mountainfork
Quito
IRONS FK. MTN.
Acorn
Oden
Sims
Washita
Egger
Waters
Ink
ROUND MTN.
MENA
Rocky
Potter
SOUTHERN
MOUNT IDA
Bulger
Dallas
Board Camp
Silver
Gann P. O.
Rust Sta.
Nichols
Pryors
Hatfield
Bigfork
Black Springs
Womble
Alamo
Plata
Shady
Slatington
Ophir
Caddo Gap
Rock Crusher
Cove
Buffalo
Hickory Sta.
OUACHITA
CRYSTAL

15 miles. It includes parts of Saline, Garland, Montgomery and Polk counties. The St. Louis, Iron Mountain and Southern Railroad runs near the eastern border, and the Kansas City Southern Railroad near the western border. A branch of the Choctaw, Oklahoma and Gulf Railroad from Little Rock to Hot Springs passes over a portion of the area most of the way from Benton to Hot Springs. The St. Louis, Iron Mountain and Southern Railroad has a branch road from Malvern to Hot Springs, and the Gurdon and Ft. Smith Railroad is completed from the former place on the St. Louis, Iron Mountain and Southern Railroad to Womble, a new town two and one-half miles southeast of Black Springs in Montgomery County.

TOPOGRAPHY.

The Piedmont plain. The central parts of Clark, Pike, Howard and Sevier counties have a topography consisting of low east-west, rather even crested ridges of practically uniform height, with comparatively broad, intervening valleys. It is this area, with its extension westward into Oklahoma, that forms the southern border of the Ouachita Mountain System, and in this report is known as the Piedmont plain. A plane tangent to the crests of the ridges would slope southward at a low angle, passing beneath the level Cretaceous plain that occupies the southern part of the counties named. Northward, it would intersect the base of the southern ranges of the Ouachita Mountains, which rise abruptly above it.

This rather low area, forming the southern boundary of the Ouachita Mountains, is of the type known to geologists as a dissected peneplain. Its complete history would require more space than can here be devoted to it, for it is long and intricate; but the essential facts in the history are as follows: The rocks of the area are of sedimentary origin and have been so intensely folded that they stand for the most part on edge. During the process of folding, they were lifted out of the sea, converting the area they occupy, not only into land, but into one of high mountains. In the long period that followed, these mountains were worn down to a quite level plain by the atmospheric agencies and running water, leaving the truncated edges of the rocks at the surface. These rocks consisted of belts of rather hard sandstone with intervening belts of soft shale. Neglecting minor changes of level, there was subsequently a period of elevation that brought the rocks to about their present altitude. During the time following this elevation the belts of soft rock have undergone denudation more rapidly than those of the hard ones, with the result that the former are now occupied by valleys and the latter stand up as ridges.

The Arkansas Valley. The history of the Arkansas Valley to the north of the Ouachita System, is similar to that of the area to the south, in that erosion over the area occupied by it has been great. However, this area has not suffered the complete planation of the one to the south, but there are left here and there large portions of the former rock beds, constituting such mountains as Sugar Loaf, in Sebastian County; Magazine, in Logan County; Mount Nebo, in Yell County; and Petit Jean Mountain, in Perry County.

The Ouachita Mountain System. The Ouachita Mountain System extends from Little Rock to Atoka, Oklahoma, a distance of about 200 miles and is limited on the south by the Piedmont plain, and on the north by the Arkansas Valley. Its width is about 50 miles. In Arkansas, the Ouachita System* is divided into a northern and a southern part. The term Ouachita Range is applied to the southern part, but no name has yet been adopted for the aggregate

*The term "Ouachita System" was first applied in the Reports of the Geol. Surv. of Ark., 1888, Vol. II., p. 10; and 1890, Vol. III., p. 196, to those east-west ridges that contain the novaculites, or Arkansas whetstone rocks. But in late years, the term has been extended to include the important group of mountains to the north and *Ouachita Range* is here used in the sense of the original term "Ouachita System."

of the several high mountain ridges constituting the northern part. The prominence of these mountains in the State, and in fact on the continent, entitles them to a name. For that reason, and also as a matter of convenience, they are here designated the Fourche Range, that being the name applied to one of the highest mountains of the area, as well as to another ridge of lesser importance.

The Ouachita Range. The Ouachita Range consists of a large number of parallel ridges that run for the most part east and west. These ridges are narrow, with steep slopes and sharp, straight, barren crests. The highest mountains of the area are in the western and central parts, where many of the ridges are 1800 feet or more above sea-level, with here and there prominent peaks mounting up to over 2000 feet above sea-level or more than 1000 feet above the streams at their bases. The steep slopes and crests are covered with large amounts of rock debris, rendering climbing extremely slow and difficult. This range is divided by basins into several more or less distinct parts to which the following names have been applied:

The Zigzags* in Garland County; the Cystal Mountains in Garland and Montgomery counties; the Trap Mountains, in Hot Spring and Garland counties; the Caddo Mountains in Polk and Montgomery counties; and the Cossatot Mountains in Polk, Montgomery, and Pike counties.

The basins above referred to are located as follows: The Caddo basin is a small area in Montgomery County at the western end of the Crystal Mountains and north of the Caddo Mountains. The town of Black Springs is located in this basin. It is drained by the Caddo River, which leaves it through Caddo Gap, one of the principal water-

*These names are used in the Rep. of the Geol. Surv. of Ark., 1890, Vol. III., pp. 196-200.

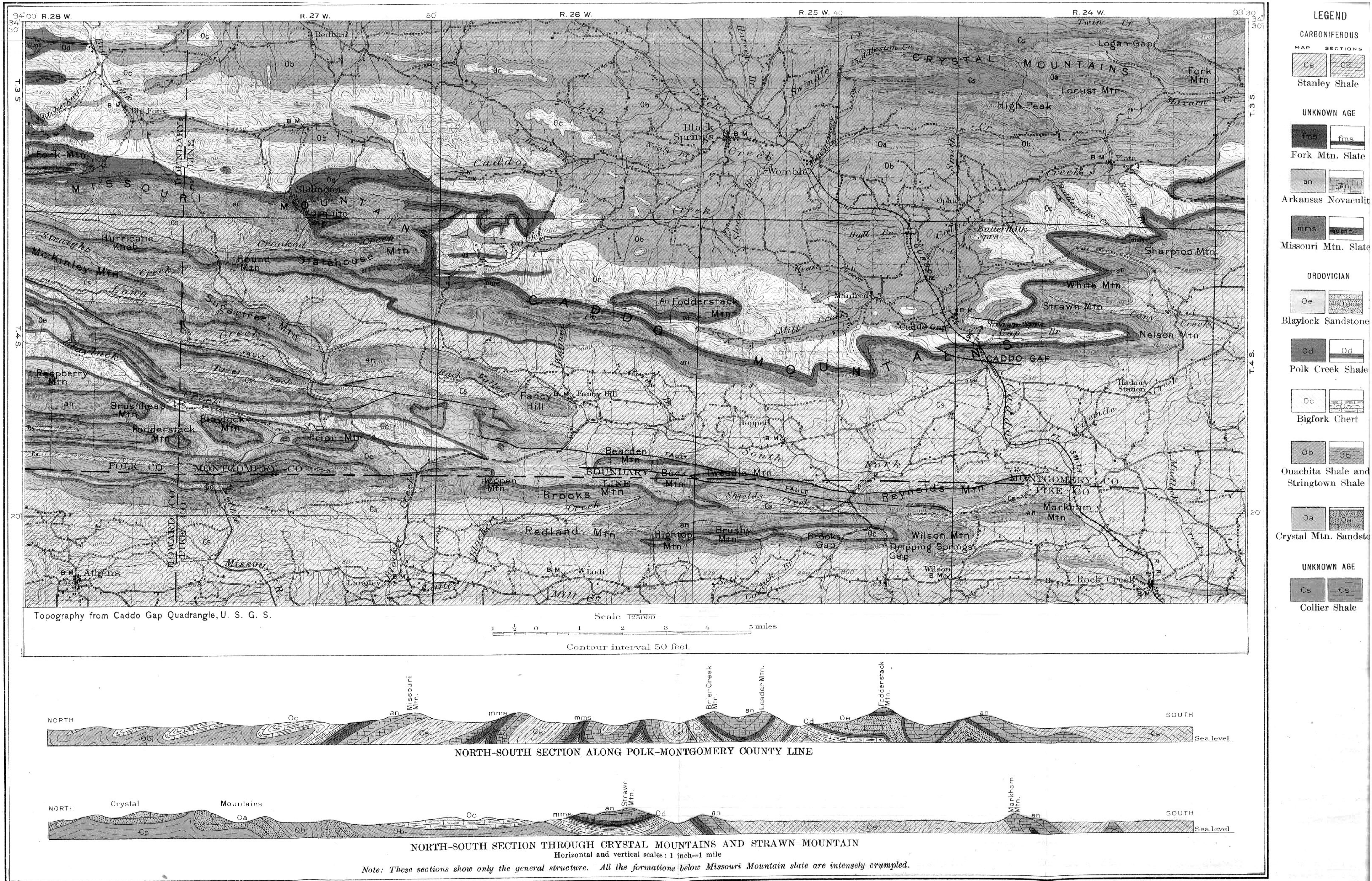
gaps of the area, located at the southeastern corner of the basin.

The Ouachita basin is a basin about 30 miles long and from 5 to 8 miles wide, lying in Montgomery County between the Crystal Mountains and the Fourche Range, and drained by the Ouachita River.

Mazarn basin is about 25 miles long and 5 to 8 miles wide, and is situated in Garland County south of the Caddo and Zigzag mountains, and north of the Trap Mountains. It is drained by the Ouachita River, which receives Mazarn Creek from the west.

A narrow extension of the Mazarn basin runs westward for about 24 miles into Montgomery County. This lies between Caddo Mountain on the north, and Reynolds, Tweedle, Bearden and other mountains on the south.

The Fourche Range. The mountains of the Fourche Range are on the whole of greater magnitude than those of the Ouachita Range. The ridges, like those of the Ouachita Range are parallel, with a general east-west course, but they are larger and higher than those of the Ouachita Range, and are separated by wider valleys. In a general way, it is divided into two parts by the valley of the Fourche la Fave River. In the northern division are Poteau Mountain in Sebastian and Scott counties; Petit Jean Mountain in Logan, Scott and Yell counties; and Danville and Fourche Mountains in Yell County. In the southern division are Rich and Irons Fork mountains in Polk County; Black Fork and Fourche mountains in Polk and Scott counties; Blue Mountain in Garland County; and White Oak Mountain in Saline County.



GEOLOGIC MAP, WITH SECTIONS, OF PORTIONS OF MONTGOMERY, POLK, PIKE, AND HOWARD COUNTIES, ARKANSAS

A. H. PURDUE,
State Geologist
R. D. MESLER,
H. D. MISER,

ROCKS OF THE SLATE AREA.

Igneous Rocks. The surface rocks in which the slates of Arkansas occur are practically all of sedimentary origin. In the eastern part of the slate region, there is a small area of igneous rock at Potash Sulphur Springs in Garland County, and a larger one at Magnet Cove, Hot Spring County. A short distance beyond the eastern border of the slate region, there are two small areas of igneous rock, one in Saline County, about six miles east of Benton, and one in Pulaski County a short distance south of Little Rock. These igneous rocks are much younger than the sedimentary rocks of the slate area, the flows that produced them having occurred about Cretaceous times.

In numerous places throughout the eastern part of the slate area, from the town of Crystal Springs eastward, dikes of igneous rock are reported.* The dikes doubtless are the same age as the larger areas of igneous rocks, with which there is every reason to suppose they are connected beneath the surface rocks. While exposed in a large number of places, their actual area is so small and their effect upon the sedimentary rocks so little, that for the purpose of the present report they may be neglected.

Sedimentary Rocks. The sedimentary rocks of the area consist of shales and slates, chert, novaculite, sandstone, and a small amount of limestone. Of these the shales and slates occur in the greatest quantity and the relative amounts of the others in the order named. The following table presents the different rocks that occur in the area in the order of their ages with the oldest at the bottom:

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*Geol. Surv. of Ark., Vol. II., 1890, pp. 409-427.

Carboniferous......	Stanley shale....................		6,000 ft.
	UNCONFORMITY.		
Age unknown.......	Fork Mountain slate............	100 ft.	
	Arkansas novaculite............	800 ft.	
	Missouri Mountain slate.........	300 ft.	
	PROBABLE UNCONFORMITY.		
Ordovician.........	Blaylock sandstone..............	1500 ft.	
	Polk Creek shale................	100 ft.	
	Bigfork chert...................	700 ft.	
	Stringtown shale	100 ft.	
	UNCONFORMITY.		
	Ouachita shale	900 ft.	
	Crystal Mountain sandstone.....	700 ft.	
	PROBABLE UNCONFORMITY.		
Age unknown.......	Collier shale (observed thickness)	200 ft.	5,400 ft.
	Total...........................		11,400 ft.

ROCKS OF UNKNOWN AGE.

Under this heading there is but one formation, which is here called the Collier shale, beneath the rocks of known Ordovician age. This, with the other older rocks of the Ouachita region, was considered by the Geological Survey of Arkansas as of Lower Silurian (Ordovician) age*. As will be seen later, some of the older rocks above this shale are certainly of Ordovician age, as is shown by the fossils they contain; and the Crystal Mountain sandstone, the formation immediately above, is considered Ordovician on lithologic ground. But careful search has failed to reveal any fossils in the Collier shale, nor has it any lithologic characters that would give it claim to an age classification with the overlying rocks. On the other hand, it is quite different from the rocks above, and at its top there is at least locally a conglomerate which future study may determine to be widespread. For these reasons, it is thought best not to even provisionally place this with the Ordovician. It may be Cambrian. If so, these are the oldest outcropping rocks

*Geol. Surv. of Ark., Vol. III., 1890.

in the State. The following is a description of the Collier shale:

The Collier shale. This shale is named from Collier Creek along the head waters of which it was first observed, in the western part of the Crystal Mountains. It is stratigraphically the lowest, and consequently the oldest of the rocks of the region. Its total thickness was not ascertained, but this certainly is several hundred feet. About 200 feet is exposed in the area above mentioned. This shale is the surface rock north of the western end of the Crystal Mountains, but its areal extent is not yet known. It is a dark, soft, graphitic, clay shale, containing widely-separated thin beds of dense, black and intensely fractured chert. As a result of the severe squeezing and shearing it has undergone practically all traces of bedding have disappeared. It is intensely crumpled and is full of glossy, slicken-sided surfaces. In places, slaty cleavage may be observed. The upper 100 feet or more is quite calcareous, limestone occurring in dark colored, crystalline lenses and layers one-half inch or more in thickness, distributed through the shale. In other parts, the limestone is several feet in thickness, and occurs in much contorted layers from a few inches to more than two feet thick, interbedded with thin seams of graphitic shale. In such cases, the limestone is dark and compact, is much jointed and on long exposure weathers in very uneven surfaces.

In Sec. 3, 3 N., 25 W., the northeast quarter, the limestone of this shale is reported by Mr. H. D. Miser to be in the neighborhood of 100 feet thick, and is described by him as made up of layers from one-half inch to two feet thick, interbedded with black shale, the thickest being at the top. The color of this limestone varies from a light steel gray to bluish gray or black, the former predominating at the top and the latter near the base. The upper part of the limestone is conglomeratic, containing large numbers of rounded quartz grains the size of peas and smaller, and rounded masses of bluish limestone and black chert as much as six inches in diameter. The limestone, on weathering, has the characteristics of a coarse, soft, porous, brown sandstone. Mr. Miser, who observed the conglomerate in several places, thinks there is no doubt but that the chert bowlders were derived from the chert of the shale beneath. No fossils have been found in either the limestone or the shale.

ORDOVICIAN

The rocks of known Ordovician age within the Ouachita Range include five formations, which are here known as the Crystal Mountain sandstone, the Ouachita shale, the Stringtown shale, the Bigfork chert, the Polk Creek shale, and the Blaylock sandstone.

The Crystal Mountain sandstone. This formation is named from the mountains in which it occurs, and consists of two parts, a lower massive one composed wholly of sandstone, 300 feet thick; and an upper part consisting of rather massive layers of sandstone interbedded with black to gray shale, 400 feet thick. The shale is in places altered to ribboned slate, like the lower part of the Ouachita shale, presently to be described. The lower part is the main rock of the Crystal Mountains, which owe their existence to this massive, slow-weathering formation. It is a coarse-grained, white sandstone, composed of well rounded grains, and commonly weathers to the color of brown sugar. In many parts, it is thickly set with a net-work of quartz veins from the thickness of a knife blade to several inches. In other parts there are fissures from several inches to several feet in width, the walls of which are lined with magnificent clusters of quartz crystal. It is the common occurrence of such crystals, that gave the name to the mountains, and it is from this sandstone that the large number of quartz crystals, sold at Hot Springs for museum and ornamental purposes, are secured.

Erosion has removed the upper part of the formation from the highest parts of the Crystal Mountains, but it occurs in the ridge to the south, extending from the town of Womble, Montgomery County, eastward for several miles.

This formation has not to the present time produced any fossils, and it is considered of Ordovician age wholly on lithologic ground. The sandstone passes gradually into the Ouachita shale above, and the close resemblance of the included shale beds to the Ouachita shale, seem to the observer in the field conclusive evidence that the two are of the same age.

The Ouachita shale. The Ouachita shale is so named because of its geological importance in the Ouachita Mountain area. It is the next formation above the Crystal Mountain sandstone, into which it passes by gradual increase of sandy layers. It is the surface rock over most of the area north of Missouri and Caddo mountains and west of the Crystal Mountains. A tongue of the exposure passes around the southern border of the Crystal Mountains and extends eastward into Garland County. Fine exposures are to be found almost everywhere within the area described. The formation is intensely crumpled, and for that reason its thickness has not definitely been made out, but it probably is not less than 900 feet.

For the most part this is a dark colored clay shale, but not uncommonly the dark layers alternate with green ones. In many places, slaty cleavage is developed, when the alternating layers of dark and green produce ribboned slate. Somewhere in the lower portion there are thin layers of limestone, interbedded with the shale. Such layers may be seen along Collier Creek, in the east part of Sec. 22, 3 S., 24 W. Quartz veins and thin layers of hard flinty material are common, and fragments of quartz frequently occur on the ground where this is the surface rock. The shale is frequently dissected by straight, well defined joints. Graptolites, while not so common as in the shales above, are frequently to be found.

The Stringtown shale. The Stringtown shale is so named by Mr. J. A. Taff* of the U. S. Geological Survey, who first described the formation as it occurs near Stringtown, Oklahoma. In Arkansas it rests uncomformably upon the Ouachita shale, and is from 75 to 150 feet thick. It consists of two parts, a lower calcareous part and an upper shaley part. The lower part of the formation contains lenses of bluish, compact, brittle limestone, usually thickly set with calcite veins. The basal portion of this is sometimes conglomeratic, the pebbles ranging from the size of peas to two inches in diameter, and are sub-angular. They consist of shale, very fine-grained brown sandstone, and limestone. This conglomerate may be seen in Montgomery County, Sec. 26, 3 N., 26 W., on the hillside to the east of the road, and about 200 yards southeast of the schoolhouse.

The maximum observed thickness of the limestone lenses is about 75 feet. They are made up of layers from a few inches to two feet in thickness and they may thin down to a few feet or entirely disappear, within very short distances. The rapid thickening and thinning of the limestone, its sporadic occurrence, the conglomerate it contains, and the lithologic difference between the shale of the formation and that beneath, led to the conclusion in the field that there is an unconformity between the two formations, which afterward was confirmed on paleontologic evidence, by Mr. E. O. Ulrich. The irregular occurrence of the limestone is due to its having been put down in the valleys of the old land surface, and the pebbles of the conglomerate at the base of

*Atoka Folio, (No. 79) U. S. Geol. Surv., p. 4,

the limestone doubtless were carried in by the streams flowing over that surface.

The upper or shale portion of the formation usually is from 50 to 75 feet thick. It is a very black shale and is soft enough to soil the fingers in handling, qualities due to the presence of a large per cent of finely disseminated graphite. In places, the graphite is conspicuous, and occurs in thin, wavy sheets. While most of this part of the formation is shale, there sometimes occur in it, especially near the top, thin beds of dark colored chert, very similar to the Bigfork chert, next to be described, as well as thin layers of limestone. Some of the shale layers are quite calcareous, and when the lime is dissolved out from these, there remains a gray to pink colored porous, spongy shale, fragments of which are frequent on the slopes. Fossil graptolites abound in the shale of this formation and occur sparingly in the limestone.

The Bigfork chert. The Bigfork chert is so named from Big Fork Postoffice, in Montgomery County, about which this formation extensively occurs. However, it is not limited to this area, but is found in many parts of the Ouachita Range.

It is a very close textured, even-bedded, silicious rock, in layers from one to eighteen inches thick, but the most common thickness is from three to six inches. The color varies from a slate to a dark gray, the former being most common. It is very brittle, and under the blows of the hammer, flies into small pieces. The fracture is angular, in some of the layers approaching conchoidal. In places, it is thickly set with a net-work of fine quartz veins. It is along these veins that the stone breaks when struck with a hammer, and so numerous are they that it often is difficult to secure a hand specimen with fresh surfaces. Straight joints several inches in length with remarkably smooth surfaces, are common. Weathered portions have the appearance of fine-grained, gray, weather sandstone. Usually the layers are crumpled to an astonishing degree, and it probably was the strain accompanying this intense folding that caused the net-work of thin joints, which subsequently were filled with quartz, forming the veins above described. Its thickness is about 700 feet.

This formation is mapped by the Geological Survey of Arkansas* as novaculite, but it differs materially from the true novaculite of the area, in being of a coarser texture, darker color, thinner bedded, not translucent, older, and in having a much more complex structure.

The Polk Creek shale. The Polk Creek shale is so named from Polk Creek, in Montgomery County. It overlies the Bigfork chert, with which it is conformable, and outcrops along the bases of many of the ridges in the Ouachita Range. In color, hardness, and texture, this shale is much like the Ouachita shale. It resembles that also in containing a large number of quartz veins, and locally in having slaty cleavage well developed. In this, as in the Ouachita shale, graptolites abound. It differs from that shale in containing no sandy or calcareous layers, and in being only about 100 feet thick. In places it appears to be absent.

The Blaylock sandstone. This formation is named from Blaylock Mountain, on the Little Missouri River, in Montgomery County. The formation is well exposed at the eastern end of the mountain where the Little Missouri River cuts across the exposed edges. Like the other formations described, it is extremely crumpled. The repetition of beds resulting from the crumpling renders its thickness difficult to determine, but this is thought to be about 1500 feet in the thickest part. Apparently it is conformable with the Polk Creek shale beneath. In parts, through a hundred feet or more, it consists almost wholly of sandstone, while in other

*1890, Vol. III.

parts it is made up of alternating beds of sandstone and shale. The sandstone is in layers that usually are from one to six inches thick, and the bedding is very even. Some of the layers are quite quartzitic, and contain numerous thin quartz veins. Others of the thin layers closely resemble chert. It is fine-grained to medium-grained, and varies from dove-colored to dark-gray or green. Graptolites occur in it rather sparingly. The interbedded shale is dark colored, often black, and fissile. In places, it contains large numbers of graptolites.

The exact stratigraphic relations of this formation are not at present understood. The only area in which it has been carefully studied is in the southern part of Mortgomery and Polk counties, where it outcrops over an east-west belt about three miles wide, and from which it thins northward until it is only a few inches to a few feet thick where it outcrops on the north slope of Caddo Mountain. That the formation is absent north of Caddo Mountain is known, for the horizon at which it occurs is widely exposed. Whether the sudden appearance and rapid thickening as we pass southward, is due to its having been put down in a trough, or to an erosion interval during which that part to the north was removed, will require further field work to determine; but its much contorted condition, and its relations to the overlying formation, later to be described, impress one with the strong conviction that it probably is due to an erosion interval.

ROCKS OF UNKNOWN AGE.

Under this head are three formations, which are here called the Missouri Mountain slate, the Arkansas novaculite, and the Fork Mountain slate. The reasons for considering the age of these rocks unknown are given on p. 45.

The Missouri Mountain slate. This formation is named from Missouri Mountain, in Polk and Montgomery counties, in which it is well developed. It is widespread and, where the Blaylock sandstone is present, rests upon that formation; where that is absent, it rests upon the Polk Creek shale, at all points where contacts were observed. While it partakes of the large and comparatively gentle folds of the area, it appears not to enter into the minute crumpling of the Blaylock sandstone and lower formations, but on the contrary to rest upon their upturned and what seems to be eroded edges. Whether it does or not, has thus far eluded all efforts to determine, on account of the great amount of débris nearly always present on the slopes where the contact between the two formations would otherwise be exposed.

This formation varies from 50 feet and less to 300 feet in thickness the thinnest part being, so far as observed, along the southern border of the Ouachita Range. The formation is a clay slate. A few feet of the basal portion usually is green. Locally, this lower portion is somewhat sandy and such parts contain small crystals of iron sulphide. The remainder, above the basal portion, varies from a blood red to a dark red, containing patches and streaks of green. The green at the base may be the original color, but that above is secondary. On either side of joints that have been followed by water, the color is green, passing through purple into the red of the mass, the effect, on exposed surfaces, being that of a ribbon-like streak an inch or two wide. The red color, which is that of much the larger portion of this slate, is due to a high state of oxidation of the iron that is uniformly distributed through it; the green color to the reduction of the iron to a lower oxide by the ground-water, as it moves through the joints; the purple, which gradually passes into the green on one side and the red on the other, is produced by only a partial reduction of the iron oxide. Where the slate is much fractured, and the ground-water has had free access, considerable masses have been altered from red to green. Small, circular spots of green are quite common in portions that are not otherwise altered.

The Arkansas novaculite. The Arkansas novaculite is the principal formation of the Ouachita Range. This is the rock of the region that is constantly before the eye, and which, on account of its ability to withstand the weathering agents, forms the crests of the mountains. Owing to an unconformity at the top, its thickness is quite variable, but the maximum observed is about 800 feet. The character of the formation varies from the base to the top, as well as in different parts of the same horizon. In a general way, it may be described as consisting of a lower, heavy-bedded, silicious part that is wholly novaculite, and an upper, thin-bedded part of the same material, interpolated with thin layers of black, soft shale. In places, there is an intervening portion containing sandstone.

The lower portion is about 300 feet thick and consists of massive beds from two to ten feet thick, with large ripple-marks showing along the bedding planes. This part of the formation furnishes the abrasives that are known in the markets as the Ouachita and Arkansas stone. It is a very close-textured rock, the grains being of microscopic size. The common color is a very light-gray, but bluish tints, and pink, black, and dove-colored spots are quite common in the lower 50 to 75 feet. The fracture is uneven to conchoidal, and it is very brittle. In lustre it is often waxy, and thin edges frequently are translucent. The bedding is quite irregular, small lenses between the beds being very common. It is profoundly jointed, the joints running in all directions, but the most prominent are perpendicular to the bedding. In many places it is so thoroughly broken up by the joints that it could be quarried with a pick.

The upper portion, in those parts where it is all present, is much thicker than the lower. It consists of layers of novaculite the most common thickness of which is from one to six inches, interpolated by layers of shale that is very black and soft when unaltered. When weathered, this shale is brown to green in color, producing a banded effect. The novacuilte layers usually are dark to black, but lithologically are not otherwise very different from the massive novaculite beds of the lower part of the formation. This part of the formation is frequently and sometimes wholly removed, as a result of an unconformity between it and the Carboniferous rocks that rest upon it.

The Fork Mountain slate. The Fork Mountain slate, when present, lies at the top of the Arkansas novaculite, and is about 125 feet thick. On account of the unconformity above mentioned, it is only locally present, having in many places been removed by erosion. It is present on Fork Mountain, in the eastern part of Polk County, from which it is named. Also, it is known to occur on the south slopes of Missouri and Caddo mountains, along the creek in Sections 25, 26, and 27, 4 S., 28 W., and in Garland County in or near Sec. 24, 2 S., 21 W.

This formation consists of gray to greenish and chocolate colored slates, containing thin layers of quartzite in the lower part. It is much jointed, but withstands weathering and usually forms a bluff where it outcrops on the mountain side. The talus material from this slate occurs in long, prismatic blocks, produced by the intersection of numerous strike and dip joints.

CARBONIFEROUS

The Stanley shale. The Fork Mountain slate is overlain by the Stanley shale, which is of Carboniferous age, and probably is the only formation of that age within the Ouachita Range. It was named by Mr. J. A. Taff, of the U. S. Geological Survey, from the town of Stanley in Oklahoma, where it occurs and has been studied by that

PLATE IV.

Period	Formation name	Columnar section	Thickness in feet	Character of rocks
Carboniferous (Pennsylvanian?)	Stanley shale		6000	Greenish clay shale, locally black slate near the base, and greenish quartzitic sandstone.
Age unknown	Fork Mountain slate		0-125	Gray slate with thin beds of siliceous material.
	Arkansas novaculite		0-800	Massive white and variegated novaculite with alternating flint and shale layers in the upper half.
	Missouri mountain slate		75-300	Mainly red slate with green slate in the basal portion.
Ordovician	Blaylock sandstone		0-1500	Greenish quartzitic sandstone alternating with brownish black shale layers.
	Polk Creek shale		0(?)-100	Black fissile and sandy graptolitic shale.
	Bigfork chert		700	Gray to black chert interstratified with black shale layers at the top.
	Stringtown shale Ouachita shale		900-1000	Black graphitic shale, with slaty cleavage, containing sandstone and limestone layers near the base and patches of blue limestone locally conglomeratic near the top.
	Crystal Mountain sandstone		700	Sandstone interstratified with black shale. Massive, white, coarse-grained sandstone.
Age unknown	Collier shale		200+	Black, graphitic clay shale, containing blue conglomeratic limestone near the top.

Columnar Section of the Ouachita Area.

writer. This formation rests unconformably upon the Fork Mountain slate and the Arkansas novaculite. At its base there frequently is to be found a conglomerate composed of small rounded to subangular pebbles of novaculite. A small per cent. of these pebbles is from light colored Arkansas novaculite, but most of them are dark and have been derived from the upper portion of that formation.

The total thickness of the Stanley shale is about 6000 feet, but so far as known, it is not all represented in the slate area of the State. The full thickness of the formation appears, however, immediately south of the Ouachita Range, in Pike, Hempstead, Howard and Sevier counties. Within the slate area, it occurs in many of the synclinal valleys, such as the one between Missouri and Statehouse mountains, the one south of Statehouse and Caddo mountains, and those traversed by Long and Brier Creeks, all in Montgomery County.

The formation is composed mainly of shale, though the lower part contains a large percentage of sandstone and beds of sandstone occur at intervals throughout the section. Thin beds of dark chert also occur. The shale is carbonaceous, clay shale, and in places within the Ouachita Range is sufficiently indurated to form slate. Fragments of fossil wood are common in it. The sandstone is fine-grained, usually of green color, contains fragments of fossil wood, is frequently permeated by quartz veins, and is rather soft. It usually weathers down on a level with the shale and does not form ridges.

STRUCTURE OF THE OUACHITA RANGE.

Folding. Attention has been directed (p. 29) to the fact that most of the rocks of the slate area are of sedimentary origin, and for our present purpose they may all be so considered. That is to say, these rocks were put down in the bed of a former sea, and near its borders, as clay, mud, etc., in a practically horizontal position. Later, through the powerful dynamic forces within the earth, the area was gradually lifted from beneath the sea. These forces acted in such a way as to involve a shortening of this portion of the earth's circumference, north and south. The rocks, which in the meantime had been formed from the hardening of the clay, sand, etc., in order to adjust themselves to the circumferential contraction, were thrown into east-west folds.

Within the Ouachita Mountain System there was produced one master anticline, or upward fold, known as the Ouachita Anticline*. The highest part of this Anticline lies between Black Springs in Montgomery County, and the Ouachita River in Garland County, passing north of the town of Crystal Springs. While in the vicinity of Black Springs this anticline pitches to the west, it remains a marked feature of the structure to the longitude of Mena, near the west border of the State. Upon the north and south slopes of this anticline are numerous small anticlines and synclines (downward folds), the whole structure forming a compound arch or anticlinorium. An idea of the structure of the south slope can be had from Plate III.

The minor anticlines and synclines are comparatively narrow. So intense were the dynamic forces (which appear to have been exerted from the south) that these folds, which at first were open, came at last to be very closely compressed, so that the rocks nearly all stand at a high angle, and many of them are practically on edge. Indeed it is the rule of the region, that the rock layers, not only have been lifted from the horizontal to the vertical position, involving a movement through an arc of 90 degrees, but have been shoved over beyond the vertical position, or in terms of geological language, have been overturned. This

*Geol. Surv. of Ark., Vol. III., 1890, 273 et seq.

may be plainly seen by reference to the geological sections, Plate III. The overturning and compression are so complete that the rock layers on either side of the axes of the folds, whether they be anticlines or synclines, usually are parallel, forming what is known to geologists as isoclines. This repetition of the rock layers is very confusing to one not familiar with the structure of the area, but must be taken into account by all who intelligently prospect the region for economic geologic products of whatever nature.

The detailed structure of the area has not yet been studied widely enough to state what the rule is relating to the direction of the overturning, but in Montgomery County it is both to the north and to the south. There is in this county, a comparatively broad syncline south of Statehouse and Caddo mountains, and north of Sugartree, Fancy Hill, Bearden, Tweedle, and Reynolds mountains. South of this syncline, nearly all the overturns are to the north, and north of it, they are to the south. That is to say, the axial planes of the overturns on either side of the syncline dip away from it.

An idea of the intensity of the folding in the region may be secured from Fig. 2. The nature of these folds by

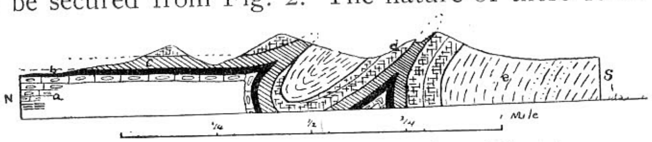


Fig. 2. North-south section through Missouri and Statehouse mountains, one mile east of Slatington.
a. Bigfork chert. *b*. Polk Creek shale. *c*. Missouri Mountain slate. d. Arkansas novaculite. e. Stanley shale.

no means remains constant along their axes, but changes within short distances, so that two cross sections only a mile apart would in many cases be very different. In other words, within short distances the dip of the rock may change greatly. A single anticline may break up into two, a symmetrical anticline may pass into an overturn, or an anticline or syncline may rapidly pitch or plunge. It is a common feature of the structure for two anticlines to overlap each other laterally, plunging in opposite directions. This common structural feature aided by erosion and the resistant hard beds, produces the zigzag topography so common in the eastern part of the slate area. The origin of this topography will be understood by reference to Fig. 3.

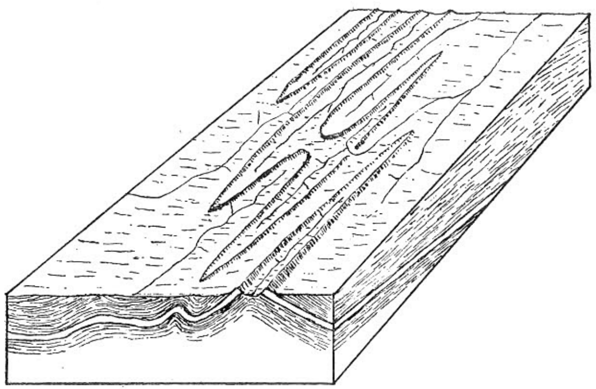


Fig. 3. Diagram showing the origin of zigzag topography by the erosion of overlapping, plunging anticlines and synclines.

Faulting. As would be expected, the rocks of the region could not everywhere, by folding, adjust themselves to the great dynamic force exerted upon them, so that faulting is quite common. The direction of the faults is in the main east and west, or parallel with the ridges, and so far as observed, they all are thrust faults with the exception of one small normal fault which is in the southwest quarter of Sec. 31, 3 S., 27 W. In some cases, the throw is several hundred feet. An idea of the nature and extent of these faults may be had from Plate III. These faults have not been worked out in detail over the entire slate area, but among them are several which occur in a general line of faulting extending from the valley of Long Creek, south of McKinley Mountain, in Polk County, south of eastward, passing south of Fancy Hill and on eastward along the south side of the valley in which the South Fork of the

Caddo is located, apparently terminating near the main branch of Caddo Creek. In Polk County and the western part of Montgomery County this is a single fault, but in the eastern part of Range 27, it breaks up into three, and along the line of Bearden, Tweedle, and Reynolds mountains, there are two parallel faults.

GEOLOGICAL HISTORY OF THE SLATE REGION.

Age of the Rocks. As already has been stated (p. 30) the age of the Collier shale, the oldest of the exposed rocks of the slate area, is not yet determined. It may be of Ordovician age, and it may be older. The Crystal Mountain sandstone, Ouachita shale, Stringtown shale, Bigfork chert, Polk Creek shale and Blaylock sandstone are of Ordovician age (see table p. 30). The age of these has been definitely determined by the fossil graptolites that occur in them. A former publication of the Geological Survey of Arkansas*, in which light was first thrown on the age of these rocks, classed as Ordovician, all the rocks of the area below those of Carboniferous age. From recent work it appears that the age of the Missouri Mountain slate, the Arkansas novaculite, and the Fork Mountain slate can not yet be determind, for no fossils have been found in them† by recent workers in the area. They may be of Ordovician age, they may be Silurian, and they may be Carboniferous. Their lithologic character is so very different from the nearest rocks of Devonian age, (coarse-grained sandstones and black shales) which occur in northern Arkansas, that the possibility of their being of that age is scarcely entertained. On the other hand, their silicious character might easily

*Vol. III., 1890.

†Professor L. S. Griswold, in the Report of the Geological Survey of Arkansas, 1890, Vol. III., pp. 404-407, names several localities in which graptolites were supposedly obtained from above the novaculites. Several of these localities were visited by Mr. H. D. Miser, who reports that in each case the graptolites occur above the Bigfork chert, instead of above the novaculite.

permit them to be considered contemporaneous with either the Ordovician limestones of the Ozark region, which contain a great deal of chert, or with the Boone formation (Mississippian) of that region, which is largely and in parts entirely chert. The representative of the Silurian in northern Arkansas is the St. Clair limestone which contains no chert.

Unconformity at the base of the Crystal Mountain sandstone. While the observed evidence of an unconformity between the Crystal Mountain sandstone and the Collier shale is not conclusive, it indicates the probability of such. This is found in the uneven thickness of the limestone at this horizon, and the conglomeratic nature of this limestone described on p. .

Unconformity at the base of the Stringtown shale. The unconformity between the Stringtown shale and the Ouachita shale was determined in the field from the lithologic difference in the two formations, the sporadic occurrence of the limestone at this horizon, and the local conglomeratic nature of the limestone. Subsequently, from paleontologic evidence, Mr. E. O. Ulrich of the U. S. Geological Survey, in a letter to the writer, confirms the field observations.

Unconformity at the base of the Missouri Mountain slate. As already has been stated, there is strong evidence of an unconformity at the top of the Blaylock sandstone, though such has not yet been actually observed. The evidence referred to is a structural one though the occurrence of conglomerate at this horizon is corroberative. While all the rocks of the entire region are much folded, those below the Missouri Mountain slate have suffered more intense folding than that formation and those above. The Blaylock sandstone and Bigfork chert are folded and crumpled almost to the extent of rendering the determination of their exact structure impossible, while the folds of the rocks

above are comparatively simple. This indicates that the older rocks were intensely folded, the area eroded and the younger ones were put down upon their upturned edges. The great amount of débris on the slopes renders the securing of contacts, which is necessary to settle the question, a difficult matter.

The other possible explanation of the structure is that the beds so intensely crumpled were less competent to withstand the pressure than those above. But while the Arkansas novacuilte is a competent bed it would appear that the Missouri Mountain slate would be much less competent than the Blaylock sandstone, and so far as has been observed the former does not partake of the intricate folding of the latter. Besides, the great amount of buckling these beds have suffered, reduced their length and increased their thickness. How such could have taken place beneath the enormous superincumbent weight of almost 20,000 feet of rock, is scarcely conceivable.

Unconformity at the base of the Stanley shale. Whatever may be the age of the Arkansas novaculite, there was, subsequent to its deposition, an elevation of the region by which it was lifted above sea-level and became a land area. During the time it was land, the area suffered greatly by stream erosion, by which process valleys were formed over the surface, some of which were several hundred feet deep. This is plainly to be seen in the numerous cases of local and sudden thinning and thickening of the novaculite, which was the surface rock at the time and which suffered but little or no folding in the elevation. Such unconformities may be seen in the overturned anticlines of Missouri Mountain, in the western part of Sec. 3, 4 S., 27 W., and in Round Mountain, Sec. 8, of the same township and range; numerous other places where the unconformity is less pronounced might be cited.

This period of erosion was followed by one of subsidence, which brought the area beneath the sea, again returning the conditions for deposition. This was during Carboniferous times and the rocks then deposited are of Carboniferous age*. This period of deposition was a long one, for during the time about 18,600 feet of rocks consisting of sandstone and shale were put down. These rocks are now exposed, and one passes over their truncated edges in traveling either northward or southward in the northern part of Pike, Howard, and Sevier counties, over a part of which area they have been carefully studied and mapped, for publication by the U. S. Geological Survey. The names† of these formations are given below, with their thickness in Arkansas.

Atoka sandstone	6,000 feet
Jackfork sandstone	6,600 feet
Stanley shale	6,000 feet
Total	18,600 feet

Oscillations and geographic changes of the area. An unconformity is produced when a land area subsides beneath the sea, and has new deposits put down upon it. In such a case the former land surface, slightly modified by the action of the waves of the advancing shore-line, separates the older rocks beneath from the newer ones above, and becomes a surface of unconformity. Such a surface is always more or less uneven, due chiefly to the work of streams in cutting out valleys while the area was land. An established unconformity, then, is conclusive evidence of crustal oscillation. The above mentioned established unconformities mean that after the Ouachita shale was put down in the sea, the area was elevated into land, suffered erosion, and was again depressed beneath the sea. The same processes were repeated after the deposition of the Fork Mountain slate. The probable unconformities at the base of the Crystal Mountain sandstone and the Missouri Mountain slate, indicate two other probable periods of elevation, erosion and depression. The extent of the area involved in these crustal movements is not yet known.

*According to a verbal statement from Mr. E. O. Ulrich, of the U. S. Geological Survey, he considers these rocks as of Pennsylvanian, or Upper Carboniferous age.

†These names were first used by Mr. J. A. Taff, of the U. S. Geological Survey, in Oklahoma, into which state the formations extend.

After the subsidence that brought in the Carboniferous sea, the area seems to have remained under water most of the time that the 18,600 feet of Carboniferous rocks were being put down. At or near the close of Carboniferous times the area again became land. It was during this elevation that an intense folding of the region took place*. Subsequent oscillations occurred during Cretaceous and Tertiary times, causing the sea to advance and recede, but the full extent of these is not known. Certain it is that during Cretaceous times the sea advanced well toward the present south base of the Ouachita Mountains, and it may have entirely covered that area.

Post-Carboniferous erosion. After the deposition of the Carboniferous rocks, the region was again lifted above sea-level, the movement being accompanied by the formation of a large anticline, whose axis is along the Crystal Mountains, with small folds forming anticlines and synclines on each slope, as already described on p. 42. No sooner was the region again lifted above sea-level than the erosive agencies again began their work of degradation, which may have continued unbroken up to the present time. In this work, all the Carboniferous rocks have been removed over the Ouachita Range, except in the lowest parts of some of the deepest synclinal folds. In addition to this,

*The indications are that there was a previous period of intense folding, that took place at the close of the deposition of the Blaylock sandstone.

a great deal of those formations below the Carboniferous rocks have been removed.

As has already been stated, the thickness of the Carboniferous rocks is about 18,600 feet. The amount eroded from the subjacent rocks is in places more than 1,600 feet, making a total erosion of over 19,600 feet or almost 3.7 miles. The altitude of the highest mountains at present somewhat exceeds 2,000 feet. So that the height of the mountains of the area, had no erosion taken place, would exceed 21,000 feet. However, it must not be understood that the mountains of the region ever reached so great a height, for the rate of elevation, like all great geological processes, was extremely slow, and erosion was constantly going on from the time the area emerged from the sea.

While these mountains probably have stood several hundred feet above their present altitude, it is not necessary to suppose they ever reached magnificent heights. The Carboniferous rocks that overlay the area consisted of shales and sandstone. The former are always easily eroded, and under favorable conditions are rapidly removed. It happens that in this case, the sandstone was also of such a nature as to be easily eroded, so that the denuding processes over the area probably were from the first comparatively rapid.

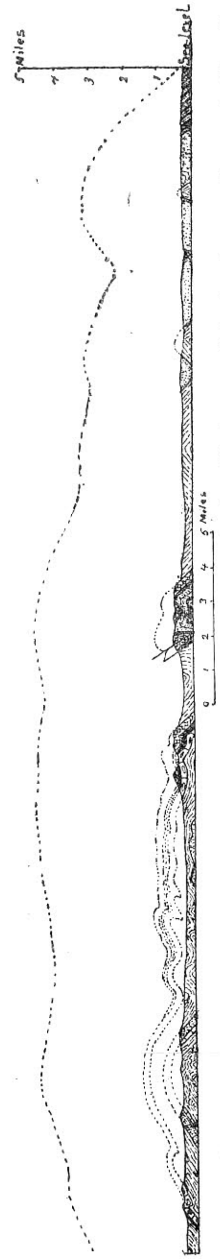


Fig. 4. General north-south section across the Ouachita Range, and the Piedmont plain to the south, one-half mile west of Black Springs, showing the probable amount of erosion from the area.

The Stanley shale, the lowermost of the Carboniferous formations is about 6,000 feet thick, and immediately overlies the hard, silicious Arkansas novaculite. When this shale was eroded down to the hard novaculite, the latter, because of it's ability to withstand weathering and erosion and because of its folded structure, formed ridges parallel with the folds. In parts this formation has been wholly removed, in which case ridges have been formed by other hard rocks, either the Bigfork chert or the Crystal Mountain sandstone, lower down in the section. The ridges thus formed are of different types, some of which are anticlinal, some synclinal, and some monoclinal. The zigzag topography, so common in the eastern half of the area, as already explained, is caused by the erosion of numerous plunging anticlines and synclines overlapping each other laterally.

Drainage. The main stream of the area is the Ouachita River, which rises near the western border of the State and flows eastward to the western part of Garland County, a distance of more than 70 miles, where it turns southeastward. Along its course, it receives Board Camp Creek, Big Fork Creek, South Fork of the Ouachita, Big Mazarn Creek, Little Mazarn Creek, and others of smaller size, from the Ouachita Range.

Heading within the Ouachita Range, and flowing in the main southward, are five very interesting streams, which, named in the order from the west are: Rolling Fork, Cossatot River, Saline River, Little Missouri River, and Caddo Creek. The peculiar interest of these streams, especially the first four, lies in the fact that they take a course transverse to that of the ridges, cutting through them and forming numerous water-gaps. These water-gaps are always narrow, and constitute one of the important topographic features of the area. The water passes through them as cataracts and falls, some of which possess water power that must in time be utilized.

Why it is that these streams should have assumed a direction across ridges of hard rock, when in many cases it appears they could more easily have taken courses around the ridges, is a physiographic question that has not yet been satisfactorily answered. Professor L. S. Griswold is of the opinion that they are of the type known to geologists as superimposed streams*. It is his belief that the region was base-leveled during post-Carboniferous times; that it subsequently subsided beneath sea-level and received a heavy cover of new material during Cretaceous times; and that it again emerged from the sea, the streams taking southward courses over the new deposits, which courses were maintained across the ridges as erosion went on and the beds were lowered.

*Geol. Surv. of Ark., 1890, Vol. III., pp. 215-223.

CHAPTER IV

DESCRIPTION OF THE ARKANSAS SLATES.

The slates of Arkansas are confined to the Ouachita Range, the extent of which may be learned by reference to the map, Plate II. It must not be understood that the entire area of this range is covered with slate deposits. In part of the range it occupies considerable areas, in other parts it out-crops only in belts, usually along the mountain sides, while in other parts there is none.

For reasons stated in the preface, it was possible to map in detail only a small area, which is located partly in Polk and partly in Montgomery counties. This area however, is typical, so that the probable location of slate in other areas can be anticipated after a careful study of this map. Especially is this true of the Missouri Mountain slate, which will be associated with the ridges, and the slate of the Stanley shale, which can be expected only in the synclinal valleys.

There are five of the formations of the Ouachita Range that contain slate. These are the Ouachita shale, the Polk Creek shale, the Missouri Mountain slate, the Fork Mountain slate and the Stanley shale. Only the three last named have been prospected to any extent, and most of the prospecting and developing has been done in the Missouri Mountain slate.

The Ouachita shale. The Ouachita shale is the surface rock about Black Springs and elsewhere in the Caddo Basin, Montgomery County. Its area over the Ouachita Range is not known, but it is greater than the area of all the other slate formations combined. As its name implies, it is mainly a shale, there being usually no indication of slaty cleavage; but in places slaty cleavage is well developed, and in such parts is conspicuous in the stream beds, by the road side, and in other places where the formation is exposed. The cleavage usually is at a high angle to the bedding and as it appears to be best developed in those parts of the formation where the layers are of different color, "ribbons" are very common in it. These consist of alternating green and blue bands from one-fourth to two inches thick, and are due to the original differences in the color of the shale from which the slate was formed. In places this slate is sufficiently indurated for roofing slate, but usually it is too soft to long withstand the weathering agencies. Also, it is in all places where observed so closely jointed as to prevent the quarrying of blocks of commercial size. Besides, its banded or "ribbon" structure would prevent its being desirable commercial slate, even though it possessed all the other requisite qualities.

The Polk Creek shale. The Polk Creek shale is only about 100 feet thick, and this, with the folded nature of the region, causes it to outcrop as narrow belts, which usually are found along the bases of the mountains. This, like the formation above described, is commonly a shale, though locally slaty cleavage is well developed in it. In places this slate is banded, but in others it is of a uniform black color, hard, possessing a high metallic ring and containing large numbers of graptolite fossils. Jointing is very common in this, in both the shale and the slate. On account of the comparatively small amount of this formation in which slaty cleavage is well developed, and the frequency of the joints, it does not give much promise as a producer of commercial slate, though there may be parts from which such could be secured.

The Missouri Mountain slate. This is the formation in Arkansas that has been most prospected for slate. While it does not enter into the minor folding of the region, as does the Polk Creek shale, it, like the formations above, partakes of the principal folding. It is widespread over the area, and often outcrops near the mountain bases, though it may be found high up on the slopes, or even in notches of the crests of the ridges. A study of the map,

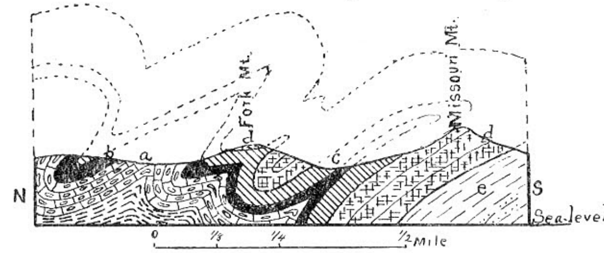


Fig. 5. North-south section through Fork Mt., 3 S, 28 W., showing the folded nature of the Missouri Mt. slate.

a. Bigfork chert. *b.* Polk Creek shale. *c.* Missouri Mountain slate. *d.* Arkansas novaculite. *e.* Stanley shale.

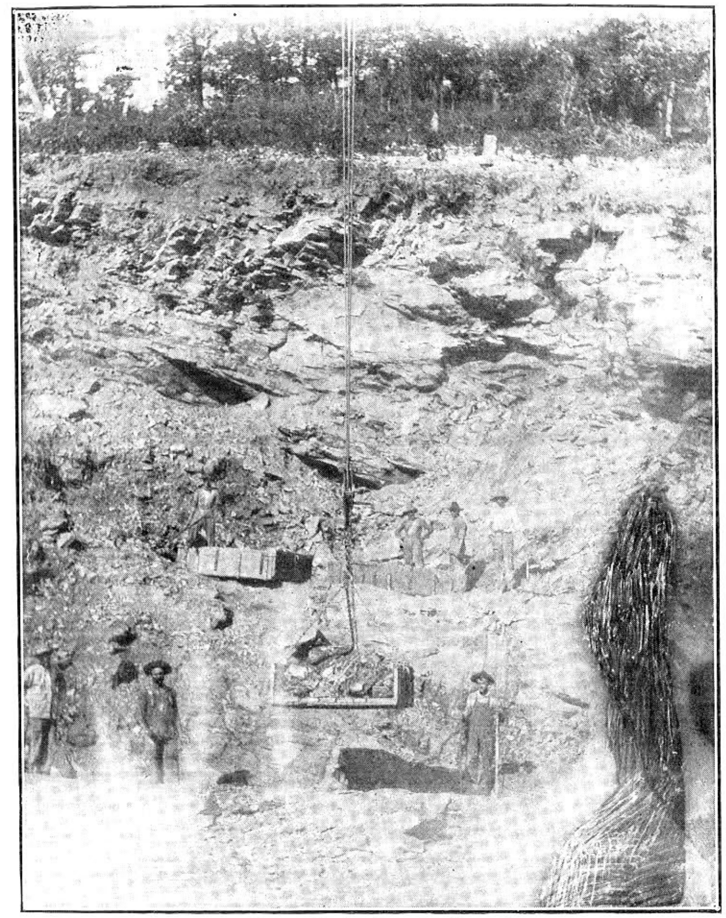
Plate III, will show the distribution of this slate in parts of Polk and Montgomery counties, which is typical of the entire region.

This slate has been rather extensively prospected all the way from Board Camp Creek in Polk County eastward to the Ouachita River, in Garland County. The point at which it has been most extensively worked is Slatington, Montgomery County, though there are other prospects in it of considerable magnitude. The wide extent to which it has been prospected is due, not only to the promise it has given as a source of commercial slate but to the favorable location and nature of its outcrops, which usually are in bluffs, and well up on the mountain slopes. As the slate is exposed in the face of the bluffs, there is no labor and expense of removing surface material, imposed upon the prospector, and the height of the outcrop on the slope permits all waste material to be easily dumped. It varies in thickness from a maximum of about 300 feet to a minimum of 50 feet or less. The thickest portion is along the central line of the Ouachita Range, from which it thins out southward, and probably northward. In the closely compressed anticlines it sometimes is folded over upon itself, when its thickness appears to be double what it actually is. Such is the case in that part of Caddo Mountain that lies south of Wagner Creek, in Sec. 15, 4 S., 26 W., where the slate is exposed over a distance of 600 feet, lying between heavy walls of the Arkansas novaculite.

That this formation produces both red and green slate has already been mentioned on page 38. Though both kinds may and often do occur in the same quarry, the red is predominant. It is a clay slate of remarkable homogeneity, sandy or other impure layers being absent. In color it varies from a scarlet to a dark red, but that of any particular quarry is likely to be uniform. In exposed surfaces it presents a rich, usually pleasing appearance. On account of its homogeneous nature, no traces of the original bedding are to be seen. This, together with its great thickness, makes it impracticable in most cases to determine the direction of the cleavage with reference to the bedding planes. In some cases where it is near the overlying Arkansas novaculite, it is plainly parallel with the bedding, in others oblique. As it has in nearly all cases suffered rather intense folding, it is probable that in most cases the cleavage is oblique to the bedding.

In most parts this slate is intersected by numerous joints that run in all directions, but if favorable places are selected, these are not so common as to prevent the quarrying of large blocks. The slate cleaves with fairly even surfaces and can readily be split into sheets a quarter of an inch thick and less. Some parts of it have a semi-metallic ring, but most of it produces a dull sound when struck. In many places, the intense folding of the region has produced short, wave-like wrinkles in the slate, which quarrymen call "curl" and which are avoided in prospecting. Any quarry showing a considerable amount of this had as well

PLATE V.



2. One of the South Quarries.
SOUTHWESTERN SLATE CO., SLATINGTON.

be abandoned. In other parts two sets of cleavage planes are locally developed. These may be detected by the splitting up of the slate on exposed surfaces into small prisms after the manner of shoe-pegs. Such exposures as this should be avoided by the prospector.

It is seldom that sheets of any considerable size are found on the slopes, from which it appears that this slate weathers quite readily. If this inference is correct, it could not be used for roofing purposes. It is hoped, however, that this statement will not deter any one from experimenting with it by putting it into actual use, as this alone can determine its fitness for such purposes. In the only instance that has come to the writer's attention, where shingles of this slate were used for roofing purposes, they went to pieces after a few years' service. But the result of this one trial should not be taken as final, for slate from another quarry might last for many years. The best way to test it is for the people of the slate area to use it on small and temporary outbuildings. Such a test should be made of the slate of every quarry that will produce shingles; for the beautiful color of this slate, if it be discovered with lasting qualities, would at once put it in great demand, especially for buildings with gray walls or gray trimmings.

It will be remembered that at the present time slate is in demand for inside work, such as laundry tubs, wainscoting, lavatories, switchboards, floor-tile, etc. This slate is too soft for the last purpose named, but is well adapted for all the other purposes, and especially for switchboards, for which practically all the product from the quarries at Slatington has been used. Several samples of this slate were submitted to Professor W. N. Gladson, of the department of Electrical Engineering of the University of Arkansas, who tested its conductivity, the result of which is published elsewhere in this report.

Because of its softness and homogeneity, this is altogether a desirable slate to work. It splits, saws and planes easily, and soon takes a polish on the rubbing-bed. But in the process of drying, after having been taken from the rubbing-bed, it is liable to check, and the amount thus lost greatly reduces the profit of working it. This checking is sometimes at right angles to the cleavage and sometimes parallel with it. That is to say, the worked pieces may crack either perpendicular to their faces, or they may split apart. If some method of working can be devised that will avoid this checking, the slate industry of the state will become an important and paying one.

The Fork Mountain slate. This slate lies normally above the Arkansas novaculite, but, due to overturning, it frequently occurs beneath that formation on the mountain slopes. If, on one side of a valley or a ridge it occurs above the novaculite, on the opposite side it most likely will occur below. On account of an unconformity at its top the formation is not everywhere present, and for the same reason it varies greatly in thickness at the different places where it is known to occur. Its maximum thickness has not yet been ascertained, but in Sec. 5, 4 S., 27 W., where it outcrops well upon the mountain slope, it is known to exceed 100 feet. When the formation dips into the mountain it can easily be detected, for it then forms bluffs, but if it dips with the mountain slope it may be overlooked.

This is a hard slate, usually gray in color, though portions of it on weathered surfaces are green or chocolate. Thin, sandy or quartzitic layers are quite frequent. The cleavage usually is well developed and occurs at all angles to the bedding planes. "Ribbons" not infrequently occur. It has great strength and toughness and is highly sonorous. In most places jointing is so frequent as to render the slate worthless, but it must not yet be concluded that exploiting will find it universally so. Prospectors should not neglect this slate. While it certainly never would do for milling purposes, if found sufficiently free from joints and sandy seams, it would make shingles of exceptional quality.

The Stanley shale. This formation, as the name implies, is almost everywhere a shale, no slaty cleavage having been developed in it. But in some parts of the closely folded synclines of the Ouachita Range, it is altered into true slate. This slate has been rather extensively prospected near Slatington, and at several places in the southeastern part of Polk County. It is blue to black in color, and where the cleavage is best developed this is remarkably fine, permitting the slate to split into very thin sheets with smooth, beautiful surfaces. With the exception of the quarry near Slatington, and one east of Bear, belonging to the Ozark Slate Company, none of any size has been opened in this formation. Nor has any of it, so far as is known to the writer, been used for roofing purposes. From the general observations in the field, it appears that this formation does not give much promise of producing commercial slate. Though the formation is a thick one, only a small portion of it had been altered to slate, and this, where observed, is not sufficiently indurated to last long on a roof.

TESTS OF ARKANSAS SLATE.

Electrical tests. Six pieces of red slate from Slatington, Arkansas, were submitted to W. N. Gladson, Professor of Electrical Engineering in the University of Arkansas, who reported the following electrical tests:

Prof. A. H. Purdue, University of Arkansas.

Dear Sir: I respectfully submit the following report of a test of the electrical resistance of six pieces of red slate from Slatington, Ark.

These pieces of slate were tested in comparison with three pieces of gray slate taken at random from old switch bases in the University electrical laboratory. A piece one centimeter cube was cut from each sample and these numbered consecutively from 1 to 9 inclusive, Nos. 1, 3, and 4 being gray slate. In preparing the cubes, metallic particles were found in samples 4 and 6, while Nos. 5 and 6 were so easily split that it was difficult to obtain a centimeter cube.

The pieces of Slatington slate as received were smooth blocks 4 x 5 x ⅝ inches, unvarnished or in any way filled. They are of red or reddish-brown color, much softer than the gray slate and split much more readily. All samples tested were dry and appeared to be seasoned. The method of measuring the resistance of these centimeter cubes was as follows:

A block of paraffin wax was attached to the center of a glass plate, which in turn was thoroughly insulated from the table by glass strips piled across each other. In the top of the paraffin block an opening was cut one centimeter square and about 3 mm. deep. In the bottom of the cavity thus formed four copper supports were embedded so that their top surfaces were in the same plane about 1 mm. below the top of the paraffin cup. A drop of mercury coming about flush with copper supports in this cavity formed one terminal for making electrical connection to the slate cube. Contact with the opposite face was made by placing a well amalgamated zinc plate 1 cm. square, on top of the cube. This arrangement insured equal contact with each slate cube under test.

The galvanometer used was of the D'Arsonval type and had a working constant of 70,533 millimeters on a scale one meter distant through one megohm resistance. The electro-motive force was furnished by storage cells and kept constant at 42 volts during the experiment.

The connections were made as shown in Fig. 6.

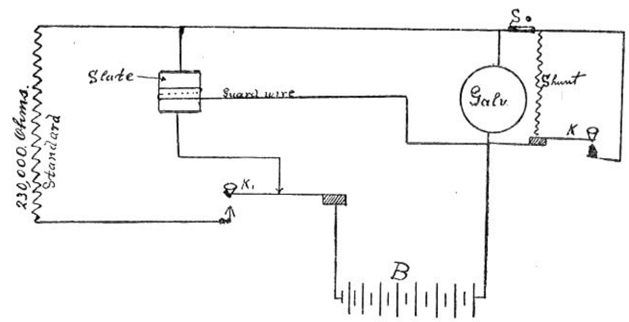


Fig. 6. Showing connections made in testing slate.

To avoid leakage over the surface of the slate a guard wire was connected as shown. All readings were taken after the deflections became constant, which in some cases require a half hour after electrification.

The results of the test are shown in the following table, from which we find the average resistance of all samples to be 1224.2 megohms per cu. cm. The average resistance of the three gray samples was 1180, and of the six red slate samples, 1267.8 megohms per cu. cm. Each piece tested, except No. 7, shows a different resistance between opposite parallel faces, which seems to depend on the plane of cleavage. The gray slate samples show a decidedly higher resistance between faces of cube perpendicular to cleavage planes, but in individual samples the distribution of resistance would be greatly affected by the presence of foreign conducting particles or seams which are liable to occur in all slate.

Sample	Galvanometer scale deflections, millimeters.			Resistance in Megohms.		
	Perpendicular to cleavage planes	Parallel to cleavage planes				
	D	D′	D″	R*	R′	R″
1	39	40	44	1808.5	1763.3	1603.0
2	98	174	625	719.7	405.3	67.1
3	171	185	283	414.9	381.2	249.2
4	35	94	43	2015.3	750.4	1640.3
5	104	47.7	39.9	678.2	1476.3	1767.1
6	338.9	28	88	208.1	2519.0	801.5
7	91	91	48	775.0	775.0	1469.4
8	47	51	27	1500.7	1383.0	2612.3
9	45	33	36	1567.4	2137.3	1959.2

*R, R′ and R″ correspond to the directions D, D′ and D″ respectively.

Average of Nos. 1, 3 and 4 =1180.6 gray slate.
Average of Nos. 2, 5, 6, 7, 8 and 9 =1267.8 red slate.
Average of all samples =1224.2 megohms per cen cube.

PHYSICAL TESTS.

The following specimens were collected and submitted to the Structural Materials Testing Laboratories of the U. S. Geological Survey at Forest Park, St. Louis, for transverse pressure, absorption, and physical tests, and for chemical analyses. The results are herewith published.

No.	*Owner.*	*Location.*	*Color.*
1	Southwestern Slate Co..	E. line of N. E. ¼, S. E. ¼, Sec. 33, 3 S., 27 W..	Red
2	Southwestern Slate Co..	E. line of N. E. ¼ of S. E. ¼ of Sec. 33, 3 S., 27 W..	Green
3	M. J. Harrington.......	Sec. 24, 3 S., 29 W.......	Black
4	Southwestern Slate Co..	S. E. ¼, S. E. ¼, Sec. 33, 3 S., 27 W.............	Red
5	M. J. Harrington.......	Sec. 24, 3 S., 29 W.......	Black
6	M. W. Jones...........	Sec. 24, 3 S., 29 W.......	Green
7	M. W. Jones...........	Sec. 24, 3 S., 29 W.......	Green
8	M. W. Jones...........	Sec. 24, 3 S., 29 W.......	Red
9	M. W. Jones...........	Sec. 24, 3 S., 29 W.......	Reddish Brown
10	M. W. Jones...........	Sec. 24, 3 S., 29 W.......	Red
11	C. B. Baker............	N. E. ¼, Sec. 18, 3 S., 28 W.	Buff
13	M. W. Jones............	Sec. 24, 3 S., 29 W.......	Red

Results of Tests on Arkansas Slate*

Field Number	Register Number	Individual Specimen No.	Transverse Tests: Demensions: Width (Inches)	Demensions: Depth (Inches)	Span (Ins.)	Conditions at Maximum Load: Load Center (Lbs.)	Deflection Center (Ins.)	Modulus of Rupture #/□"= Lbs. per sq. in.	Modulus of Elasticity (Constant up to nearly Max.)	Absorption Tests: Weight Ratio of Absorption: 30 Min.	Weight Ratio: 24 Hours	Weight Ratio: 48 Hours	Volume Ratio of Absorption: 30 Min.	Volume Ratio: 24 Hours	Volume Ratio: 48 Hours	Physical Tests: Specific Gravity: True	Specific Gravity: Apparent	Absolute Porosity 1 - A.S.G./T.S.G.	Weight Per Cu. Ft. (Lbs.)
		1	2.00	0.95	9	322	.0190	2,410	2,100,000	.0017	.0189	.0189	.0047	.0511	.0513	2.863	2.714	.....	169.1
1	Misc. 141	2	1.98	0.97	do.	674	.0148	4,880	4,640,000	.0005	.0175	.0193	.0014	.0475	.0523	2.859	2.712	.....	169.0
		3	1.98	0.98	do.	854	.0196	6,060	4,250,000	.0011	.0164	.0786	.0031	.0439	.0500	.....	2.689	.....	167.5
Average								4,450	3,660,000	.0011	.0176	.0189	.0031	.0475	.0512	2.861	2.705	.0545	168.5
		1	1.94	1.00	9	920	.0134	6,400	6,430,000	.0004	.0089	.0105	.0010	.0243	.0286	2.813	2.738	.....	170.6
2	Misc. 142	2	1.97	0.98	do.	959	.0150	6,840	6,040,000	.0004	.0075	.0095	.0012	.0205	.0260	2.816	2.747	.....	171.1
		3	1.99	0.97	do.	920	.0170	6,630	5,470,000	.0003	.0087	.0101	.0009	.0238	.0276	.....	2.744	.....	171.0
Average								6,620	5,980,000	.0004	.0084	.0100	.0010	.0229	.0274	2.815	2.743	.0256	170.9
		1	1.98	0.28	12	59	.0430	6,840	13,420,000	.0037	.0160	.0189	.0094	.0409	.0481	2.696	2.550	.....	158.9
3	Misc. 143	2	1.95	0.26	do.	56	.0790	7,640	8,820,000	.0012	.0114	.0146	.0031	.0293	.0375	2.702	2.564	.....	159.7
		3	2.05	0.27	do.	80	.0855	9,640	11,030,000	.0041	.0167	.0201	.0105	.0425	.0512	.....	2.544	.....	158.5
Average								8,040	11,090,000	.0030	.0147	.0179	.0077	.0376	.0456	2.699	2.553	.0541	159.0
		1	2.07	0.30	12	93	.0600	8,990	11,820,000	.0026	.0113	.0121	.0072	.0310	.0332	2.862	2.748	.....	171.2
4	Misc. 144	2	1.98	0.27	do.	64	.0560	7,980	12,420,000	.0009	.0087	.0114	.0025	.0241	.0315	2.857	2.776	.....	173.0
		3	1.99	0.29	do.	80	.0615	8,600	11,570,000	.0013	.0112	.0122	.0036	.0307	.0334	.....	2.741	.....	170.8
Average								8,520	11,940,000	.0016	.0104	.0119	.0044	.0286	.0327	2.860	2.755	.0367	171.7
		1	1.94	0.85	12	210	.....	2,700	2,900,000	.0023	.0120	.0157	.0058	.0305	.0402	2.705	2.557	.....	159.3
5	Misc. 145	2	2.04	0.77	do.	279	.0405	4,150	3,150,000	.0033	.0153	.0193	.0083	.0390	.0491	2.704	2.544	.....	158.5
		3	1.94	0.78	do.	388	.0335	5,920	6,010,000	.0024	.0121	.0156	.0062	.0309	.0397	.....	2.553	.....	159.1
Average								4,260	4,020,000	.0027	.0131	.0169	.0068	.0335	.0430	2.705	2.551	.0570	159.0
		1	2.04	1.09	12	400	.0252	2,970	2,620,000	.0014	.0076	.0114	.0040	.0210	.0314	2.860	2.771	.....	172.6
6	Misc. 146	2	2.03	1.02	do.	318	.0134	2,710	4,810,000	.0010	.0081	.0093	.0027	.0225	.0257	2.854	2.767	.....	172.4
		3	2.03	1.01	do.	791	.0233	6,880	6,920,000	.0015	.0080	.0093	.0041	.0221	.0257	.....	2.769	.....	172.5
Average								4,190	4,780,000	.0013	.0079	.0100	.0036	.0219	.0276	2.857	2.769	.0308	172.5
		1	2.03	0.24	12	35	.0660	5,390	9,240,000	.0010	.0089	.0109	.0028	.0243	.0300	2.805	2.739	.....	170.6
7	Misc. 147	2	2.07	0.23	do.	57	.....	9,370	10,290,000	.0013	.0089	.0107	.....	.....	.....	2.810	.....	.....	.....
		3	1.96	0.24	do.	40	.0740	6,380	8,060,000	.0011	.0090	.0113	.0029	.0246	.0310	.....	2.733	.....	170.3
Average								7,050	9,200,000	.0011	.0089	.0110	.0029	.0245	.0305	2.808	2.736	.0256	170.5
		1	1.99	0.17	7	48	.0317	8,760	13,150,000	.0010	.0073	.0088	.0029	.0203	.0244	2.849	2.764	.....	172.2
9	Misc. 149	2	2.00	0.14	do.	47	.0358	12,590	19,530,000	.0010	.0081	.0091	.0029	.0227	.0256	2.845	2.806	.....	174.8
		3	2.00	0.22	4	120	.....	7,440	....	.0009	.0082	.0091	.0026	.0229	.0255	.....	2.789	.....	173.8
Average								9,600	16,340,000	.0010	.0079	.0090	.0028	.0220	.0252	2.847	2.786	.0214	173.6
		1	1.97	0.53	9	139	.0181	3,390	4,720,000	.0183	.0410	.0410	.0467	.1045	.1045	2.828	2.552	.....	159.0
11	Misc. 150	2	1.94	0.51	do.	155	.0181	4,150	6,090,000	.0185	.0402	.0404	.0471	.1023	.1029	2.830	2.546	.....	158.6
		3	1.93	0.52	do.	140	.0206	3,620	4,500,000	.0084	.0365	.0365	.0216	.0941	.0941	.....	2.576	.....	160.5
Average								3,720	5,100,000	.0151	.0392	.0393	.0385	.1003	.1005	2.829	2.558	.0958	159.4
		1	1.94	0.15	7	20	.0265	4,810	9,820,000	.0016	.0094	.0101	.0045	.0263	.0283	2.863	2.801	.....	174.5
8	Misc. 148	2	2.04	0.17	do.	36	.0330	6,410	9,410,000	.0010	.0081	.0096	.0028	.0227	.0272	2.866	2.822	.....	175.8
		3	2.02	0.17	do.	32	.0250	5,760	15,810,000	.0010	.0089	.0098	.0027	.0252	.0279	.....	2.838	.....	176.8
Average								5,660	11,680,000	.0012	.0088	.0098	.0033	.0247	.0278	2.865	2.820	.0157	175.7
		1	1.99	0.12	7	9.75	.0430	3,570	5,730,000	.0088	.0251	.....	.....	.....	.....	2.854	.....	.....	.....
10	Misc. 148	2	1.93	0.13	do.	8	.0378	2,570	4,250,000	.0072	.0257	.0257	.0194	.0689	.0689	2.857	2.682	.....	167.1
		3	1.97	0.14	do.	18	.0440	4,890	6,340,000	.0067	.0251	.0253	.0180	.0672	.0677	.....	2.676	.....	166.7
Average								3,680	5,440,000	.0076	.0253	.0255	.0187	.0681	.0683	2.856	2.679	.0620	166.9
		1	2.03	0.15	6	20	.0440	3,940	3,550,000	.0046	.0228	.0229	.0124	.0613	.0617	2.862	2.691	.....	167.6
13	Misc. 148	2	2.00	0.16	do.	20	.0300	3,520	4,420,000	.0062	.0243	.0243	.0167	.0652	.0652	2.860	2.683	.....	167.1
		3	1.93	0.18	do.	24	.0180	3,450	6,480,000	.0061	.0241	.0244	.0163	.0640	.0648	.....	2.658	.....	165.6
Average								3,640	4,820,000	.0056	.0237	.0239	.0151	.0635	.0639	2.861	2.677	.0643	166.8

*These tests were made at the Structural Materials Testing Laboratories of the U. S. Geological Survey, St. Louis, Mo.

CHEMICAL ANALYSES.

Field No.	1	2	3	4	5
Reg. No.	*Misc.* 141	*Misc.* 142	*Misc.* 143	*Misc.* 144	*Misc.* 145
Silica	53.81	54.83	68.90	57.79	69.76
Alumina	25.40	23.53	14.03	22.92	14.16
Ferric Oxide	6.17	5.06	*	5.19	*
Manganese Oxide..	.06	.14	.02	.07	.04
Lime	.31	.28	.37	.23	.38
Magnesia	1.74	3.05	1.11	1.97	1.32
Sulphuric Anhydride.	Trace	.26	.56	.08	.07
Ferrous Oxide.....	2.75	3.41	4.65	2.62	4.58
Sodium Oxide ...	.49	.21	.05	.12	.13
Potassium Oxide..	4.27	3.21	2.14	4.66	1.94
Water at 100° C...	.66	.43	.66	.48	.54
Ignition loss	4.62	6.01	7.69	4.13	7.44
Total	100.28	100.42	100.18	100.26	100.36

Field No.	6	7	8, 10, 13	9	11
Reg. No.	*Misc.* 145	*Misc.* 147	*Misc.* 148	*Misc.* 149	*Misc.* 150
Silica	52.50	55.71	53.23	52.35	52.79
Alumina	26.31	25.20	26.29	26.16	24.96
Ferric Oxide......	3.98	2.46	3.81	5.81	6.27
Manganese Oxide..	.11	.11	.06	.10	.06
Lime	.28	.26	.31	.29	.28
Magnesia	2.27	1.74	1.87	2.29	1.69
Sulphuric Anhydride	.22	Trace	Trace	Trace	Trace
Ferrous Oxide....	5.34	3.97	4.21	3.16	3.81
Sodium Oxide	.04	.22	Trace	.16	.03
Potassium Oxide..	3.32	4.51	3.58	3.82	3.52
Water at 100° C...	.47	.53	.59	.57	.72
Ignition loss	5.33	5.13	5.82	5.19	5.79
Total	100.17	99.84	99.77	99.90	99.92

*Owing to the large amount of volatile organic material it is impossible to determine the ferrous oxide—consequently all iron has been assumed as being present in the lowest state and calculated as such.

CHAPTER V.

NOTES ON QUARRIES, PROSPECTS AND OUT-CROPS.

The following is a detailed description of the quarries and prospects examined in the course of the field work on the slate deposits. Several of the prospects are described as occurring in the Stanley shale. It must be understood that this name refers to the geological formation and not to the character of the material taken from it. By reference to the description of the Stanley shale (p. 41) it will be seen that this formation, which is mainly shale, is in places altered into slate. For the geological name, *Missouri Mountain slate,* the name *red slate* is commonly used in these notes, partly as a matter of convenience and partly because that is the term by which the formation is known among the quarrymen and prospectors.

RANGE 13 WEST

The Hull property. In Sec. 8, 1 N., 13 W., in the southeast corner of the northwest quarter of the southwest quarter, Mr. Alonzo Hull opened up the black slate in the Stanley shale formation in 1885. The workable slate is about four feet thick in this quarry and the dip is 70 degrees north, 15 degrees west. The quarry is about 30 feet long, 20 feet wide and 70 feet deep. The slate is a bluish black, has a clear ring and is very hard. It splits into shingles of good thickness and has a smooth cleavage surface. The slate contains small crystals of iron pyrites.

The quarry is on rather level ground and is near the base of the Stanley shale. Mr. Hull used the slate for roofing purposes. His home and several out buildings were covered with the slate in 1885. Also some buildings in

Little Rock were covered with it. All these roofs are still in good repair.

(R. D. Mesler).

RANGE 15 WEST

The T. H. White property. In Sec. 34, 2 N., 15 W., Mr. T. H. White began work in what appears to be the Stanley shale about 1888. He, with Mr. Chas. Gugerty, opened up the quarry in the southwest corner of the northwest quarter of the southeast quarter of Sec. 34, and later formed the Arkansas Slate Co. This quarry was worked two or three years and several car loads of roofing slate were shipped from Bryant, Arkansas, to St. Louis.

The quarry is about 30 feet square and 50 feet deep. The slate is very hard and has a clear ring, and splits into good roofing shingles. The joints are far enough apart to get out blocks five to six feet in diameter. Small crystals of iron pyrites are scattered through the slate. Some of the roofing shingles now at the quarry said to have been made in 1888 and 1889 are unaltered.

(R. D. Mesler).

In Sec. 32, 2 N., 15 W., a quarry was opened by Mr. T. H. White of St. Louis. The quarry is near the centre of the section and is in the Stanley shale. The horizon and quality of the slate are about the same as that just east in Sec. 34. Nothing further than prospecting was done here.

(R. D. Mesler).

The Marysville Slate Company's property. Along the Hot Springs and Little Rock road in the southwest corner of the northeast quarter of Sec. 16, 1 N., 15 W., Mr. T. H. White of St. Louis did some prospecting in 1891. Several quarries were opened here in the Stringtown shale (below the Bigfork chert) and the Marysville Slate Company was organized. The main quarry near the road is about 70 feet long, 40 feet wide and 30 feet deep. Several car loads of shingles were made between 1891 and 1894 and shipped from Bryant to St. Louis.

The slate is a bluish black, with a good clear ring, but contains numerous crystals of iron pyrites. It splits well and is very hard and free from shale and clay. It has an extremely smooth cleavage surface and does not check on being exposed to the air. The dip and strike joints are eight inches to two feet apart but do not interfere with the slate for shingle material.

(R. D. Mesler).

RANGE 20 WEST

The King Dunklee and Woods property. Between 1897 and 1908 considerable prospecting was done and several openings were made in the southeast quarter of Sec. 2, 2 S., 20 W., to determine the location and quality of the slate. The dip is 30 degrees north, 40 degrees west and the slate is about of the same quality as that just south in Sec. 11. The black slate splits into good shingles that are sonorous. The jointing does not interfere in quarrying the slate out in large blocks. Crystals of iron pyrites are scattered through the slate.

(R. D. Mesler).

The James Dunklee property. In the northwest quarter of the northeast quarter of Sec. 11, 2 S., 20 W., are several openings in the black, red, and gray slate made by Mr. James Dunklee in the summer of 1908. The black and red slate openings are on the north side of the hill and the dip of the slate is 35 degrees north, 40 degrees west, and about the same as the slope of the hill. The openings are small, none being over four or five feet deep. The slate is not crushed or crumpled and is comparatively free from jointing.

The opening of the gray slate is on the south side of the hill and about one hundred and fifty feet from the base of the hill. The opening here is small, not over four feet deep but the slate has a very good ring and splits well.

(R. D. Mesler).

The Hot Springs Slate Company's property. In the southeast quarter of the southwest quarter of Sec. 11, 2 S., 20 W., the red slate was opened up by the Hot Springs Slate Company in 1902. The quarry is on the north side of the hill and the dip of the slate is parallel to the slope, being about 30 degrees north, 38 degrees west. The opening is about 40 to 50 feet long, 20 feet wide and 7 to 10 feet deep. The joints are 4 inches to six feet apart and blocks of large size can be gotten out. The slate splits well and can be sawed into thick blocks. The ring is about the same as in the red slate at other places in this locality. This is by far the best opening for red slate observed in the region on account of lack of crumpling and jointing. It is much more easily quarried than at most places where the red slate is prospected. It is reported that this slate does not check on exposure to the air. No slate has been shipped from this locality.

(R. D. Mesler).

The Hot Springs Slate Company's property. Near the center of the northeast quarter of the northwest quarter of Sec. 11, 2 S., 20 W., quite a good many shingles have been made from black slate. Here the black slate, as well as the red slate in the same locality, is overturned. The quarry is about 20 feet square and 50 feet deep. The dip is 30 degrees north, 38 degrees west.

The slate has a good ring and splits into thin shingles with smooth cleavage surfaces. Large blocks can be quarried, as the joints are few. There is less crumpling and jointing than at most localities, but the slate contains crystals of iron pyrites. About 8,000 to 10,000 roofing shingles were made from this quarry between 1902 and 1906 but none have been shipped away.

(R. D. Mesler).

The Jake Kempner property. In Sec. 19, 2 S., 20 W., about a quarter of a mile southeast of the mouth of Glazierpeau Creek, the black slate of the Stanley formation was opened up shortly before the war. It is reported that some slaves were brought up the Ouachita River and worked here. According to this report, the slate was taken down the river in small boats. The opening is 15 by 20 feet and 30 feet deep. The quarry could not be examined on account of its being full of water at the time visited.

For several years after the slate was first opened, the people in the neighborhood hauled the blocks of slate away for building chimneys and foundations.

(R. D. Mesler).

RANGE 21 WEST

The Ozark Slate Company's property. In Sections 23 and 24, 2 S., 21 W., there are several openings made by the Ozark Slate Company. These occur in the red slate, the Fork Mountain slate, and the Stanley shale. A well equipped plant has been erected for milling slate.

The openings in the red slate consist of three small prospects and one of considerable size. The color of this slate is a uniform, dark-red. The cleavage is only fair, though sufficiently good for milling purposes. The bedding was not determined, so that the relation of the cleavage to the bedding is uncertain. The jointing is considerable and in the present stage of development prevents the quarrying of large blocks.

No attempt has been made to utilize the slate taken from the red slate quarries, either for milling stock or for shingles. The material on the oldest dumps, which are said to have been made four or five years, is rapidly disintegrating.

In Sec. 24, the northwest quarter, on the north slope of a hill, there is a prospect in the Fork Mountain slate 30 feet square, and 10 feet deep. The dip is 9 degrees north, 10 degrees east, and is with the slope. The color of this slate

is a uniform, pleasing, bluish gray. The cleavage, which is parallel with the bedding, is excellent, permitting the slate to split in sheets of any thickness, and producing even, smooth surfaces. It has unusual flexibility and strength, and is highly sonorous. It is a superior slate. Both dip and strike joints occur, but these are not frequent, and slabs 2 by 6 feet could be quarried. Some of the layers, which are from one-fourth to one inch thick are hard and sandy, but these could be sorted out in quarrying.

The hill-slope above the quarry is mostly covered with soil but such outcropping rocks as there are, indicate that much the same material as that described in the quarry extends to the top of the hill and 50 feet down the south slope.

Whether or not this is a valuable slate deposit depends wholly upon the waste that would come from the hard beds. The prospect well deserves further development. Inasmuch as the dip is with the slope, the slate lies to the best possible advantage for quarrying.

The main quarry of the Ozark Slate Company is in the Stanley shale. It is 100 by 50 feet, and is 65 feet deep. At the time of the writer's visit, the pit was filled with water to the depth of 50 feet. That part that could be seen is little else than a dark colored, Carboniferous shale. The dip is about 15 degrees north, and the cleavage which is poorly developed at the top, is parallel with the bedding. The material from the upper part of the pit will not split in blocks less than an inch in thickness, but that near the bottom will split thin enough for shingles though the cleavage is a little "wild," and shingles made from it do not run even in thickness. A small shed roof made from these shingles has been in use three years, and most of the shingles are in good condition.

About 200 feet northeast of the main opening is another, 50 feet up and down the slope, 10 feet wide, and 4 feet deep, including 18 inches of soil at the top. The slate is in the Stanley shale, is bluish-gray in color, and dips 15 degrees north, 20 degrees west, and with the hill slope. Both dip and strike joints are well defined. Blocks 2 by 4 feet could easily be quarried. The cleavage is with the bedding and is very good down to the thickness of one inch. The strength is not very great, and it is not sonorous.

(A. H. Purdue).

RANGE 22 WEST

The George Everett property. In Sec. 3, 3 S., 22 W., the north half, there is a prospect on the north slope of the hill. The opening is 35 feet long, 8 feet wide and 5 feet deep. The dip is 45 degrees north, 15 degrees east. Most of the quarried part consists of weathered material from near the surface. The slate is red. Strike and dip joints are well developed and do not appear to be very frequent. With further development blocks of good size could be quarried. The sonorousness and hardness are about the average of red slate, and the cleavage is fair.

About 500 feet east of the above named opening there is another of similar size. The dip is 30 degrees north, 15 degrees east, and is with the slope. The characteristics of the slate are the same as of that above described.

(A. H. Purdue).

The Eli Bolinger property. A little over a quarter east of the last named prospect is a small opening 8 by 25 feet. The cleavage is good, and it appears that blocks of considerable size could be quarried if the prospect were developed. The work was done about four years before the time visited, and the slabs on the dump were rapidly falling to pieces. The opening is in the red slate.

(A. H. Purdue).

The Peter Henan property. In Sec. 5, 3 S., 22 W., the south half, there is a prospect in a small ravine about

50 feet above the base of the hill. The opening is 100 feet long and 10 to 15 feet wide, with a face 4 to 6 feet high. The dip is 16 degrees north, 30 degrees west, and with the slope. The color is a deep red with streaks of green along the joints. Both dip and strike joints are well defined, and besides there are numerous irregular joints, so that, as the prospect now shows, only small blocks can be quarried. The cleavage is better than is common in the red slate, and is with the bedding. It is but slightly sonorous.

(A. H. Purdue).

The Davis porperty. East of, and on the opposite side of the ravine from the last mentioned prospect, and distant from it about 150 feet, there is a prospect consisting of two openings. One of these is 10 by 40 feet, with a face of 6 to 8 feet, and was about six years old at the time visited. The other, more recently opened, is about 15 feet higher on the slope, and is 100 feet long with the inner face 8 to 10 feet. The slate is dark red, with a few green streaks along the joints. While it is much fractured by jointing blocks 4 by 6 feet could be quarried, though most of the material would be in smaller blocks. The color is deep red, the cleavage is above the average for the red slate, and is parallel with the bedding. It is slightly sonorous. Much of the slate of the upper opening is "lumpy," from small accumulations of iron pyrites. That portion that is free from lumps would make good milling slate if it does not check on drying. The cleavage is nearly horizontal, and the slate lies well for quarrying.

(A. H. Purdue).

The Crawford property. On the point of the mountain, in the northeast corner of Sec. 7, or the southeast corner of Sec. 6, 3 S., 22 W., there is a prospect consisting of two openings about 75 and 100 feet long respectively. These openings extend into the hill only a few feet. The dip is

20 degrees north, 70 degrees west. The slate is of a dark red color, is "curly" and the cleavage is poor.

(A. H. Purdue).

RANGE 23 WEST

The Fordyce property. In Sec. 29, 3 S., 23 W., well upon the west mountain slope, there is a prospect in red slate. This slate is not sonorous. Its cleavage is poor, and on weathering it falls to pieces in shoe-peg fashion. Iron sulphide and other minerals are absent. Joints are numerous and there is no regularity about their occurrence.

(H. D. Miser).

Name of owner unknown. In Sec. 10, 3 S., 23 W., the east part, on the south slope of a mountain and near the top, there is a prospect in the red slate. The prospect consists of a stripped surface 40 by 60 feet. The dip is north, or into the mountain. The slate is of a beautiful red color and is somewhat sonorous. The cleavage promises to be good with greater depth. The thickness at this point appears to be about 125 feet. This is one of a number of claims known as "The Horse-shoe Group."

(A. H. Purdue).

RANGE 24 WEST

The Bill Jones property. Near the line between Secs. 2 and 3, 4 S., 24 W., in the head of a ravine on the northwest slope of Sharptop Mountain, there is a prospect in red slate. The general dip is 30 degrees north, 50 degrees east. This slate has a dead ring. It splits only into thick pieces. The cleavage surface transversely cuts numerous small slicken sides, which give the glossy surfaces the resemblance of polished walnut wood. The slate is so much jointed as to render it worthless.

(H. D. Miser).

The Bonanza property. In the northwest corner of Sec. 36, 3 S., 24 W., on the north slope of the mountain, there is a prospect in the red slate. It is on the east side of a small ravine, and uncovers the slate over an area 35 feet square. The dip is 32 degrees south, 40 degrees west. The slate splits easily with rather rough surfaces, is of a deep red color, and is somewhat sonorous. The jointing is irregular, but not so frequent as to prevent the quarrying of large blocks. It is reported that blocks 4 by 6 feet have been taken from this prospect.

While the dip in this prospect and the one mentioned above is into the hill, the slate could be quarried with comparative ease, as the slope is gradual. The slate could be quarried to the best advantage by beginning on the upper side and working downward.

(A. H. Purdue).

The J. M. Jones property. In Sec. 35, 3 S., 24 W., the northeast quarter, there is a prospect in a ravine on the north slope of the mountain, at an elevation of 1150 feet. The opening is about 35 feet north and south, with an inner face of 10 feet. The dip is 30 degrees south, 10 degrees east, and into the mountain. The slate is of a bright red color, of about the average hardness of the red slate, and is not sonorous. Near the north end of the quarry, there is a streak of yellow slate, due to weathering of the red. Blocks of almost any size could be quarried here, and some two and a half by five feet have been taken out. The jointing appears to be irregular, but is not frequent.

(A. H. Purdue).

RANGE 25 WEST

The Perkins property. In the southwest quarter, Sec. 3, 5 S., 25 W., at the base of a steep mountain slope and a few feet north of Shields Creek, there is a prospect in red slate which occurs near the top of the flinty shales of the

Arkansas novaculite*. This red slate deposit is about 20 feet thick and has a very high dip to the south. This slate has a fairly good ring and is readily split into pieces one-fourth of an inch thick and thicker. The cleavage surface is even and from glossy to dull. Almost the entire thickness of this deposit contains numerous small cavities, the size of a pin head, filled with a white to yellow powder which is most likely derived from some other mineral, possibly iron sulphide. Two sets of parallel joints are present and these joints are from a few inches to two or three feet apart.

(H. D. Miser).

RANGE 26 WEST

Name of owner unknown. Near the southeast corner of Sec. 7, 4 S., 26 W., on the east end of Fodderstack Mountain, there are several prospects in the red slate. From each, the slate can be taken out in large blocks which split well, but it has no ring. The slate is lacking in hardness in this locality.

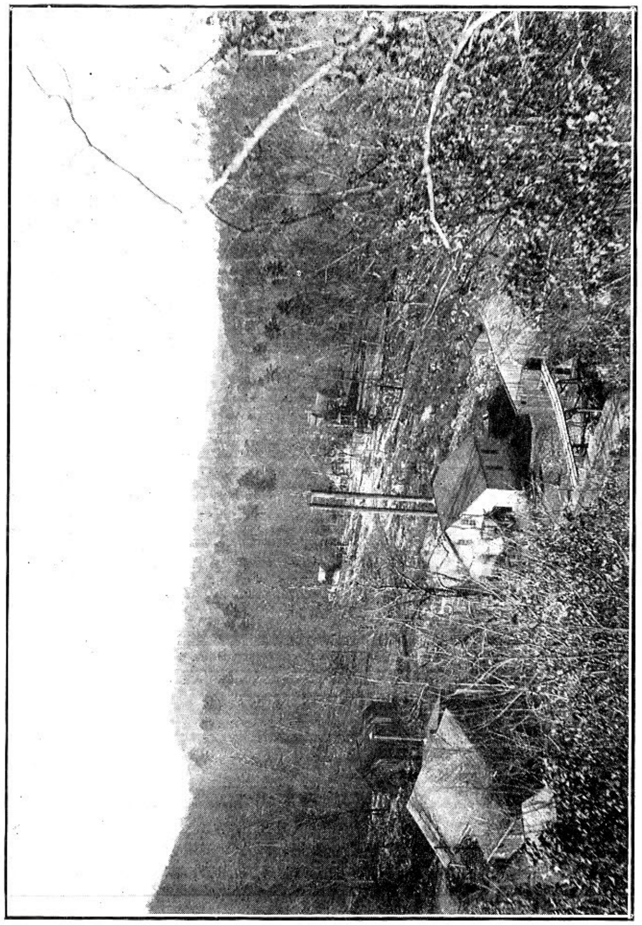
(R. D. Mesler).

Name of owner unknown. In 3 S., 26 W., in the northeast corner of the southeast quarter of Sec. 9, and in the northwest corner of the southwest quarter of Sec. 10, there is a good exposure of green slate which is very hard and has a clear ring. It is exposed on the surface of the ground and does not become soft on exposed surfaces. It is divided into rather large blocks by jointing, splits well and is entirely free from crumpling. No openings have been made at this locality. The dip is low to the southwest. This slate is in either the Ouachita or Stringtown shale.

(R. D. Mesler).

*This is the only slate prospect observed at this horizon.

PLATE VI.



1. Plant of the Southwestern Slate Company, Slatington, Ark.

Name of owner unknown. Near the southeast corner of Sec. 7 on the east end of Fodderstack Mountain several prospect holes have been sunk in the red slate and at each the slate is taken out in large blocks which split well but the slate has no ring. The slate is lacking in hardness at this locality.

(R. D. Mesler).

RANGE 27 WEST

Name of owner unknown. In the south part of Sec. 23, or north part of Sec. 26, 4 S., 27 W., along the small branch that flows westward, about 75 feet of the red slate is exposed. The exposure is so much weathered that its character could not be determined, but it is possible that prospecting might show well developed cleavage parallel with the bedding. Slabs 5 by 20 inches may be seen on the talus. In places it contains numerous layers of dark chert 1 to 3 inches thick, while in other parts this is rare. Dip and strike joints both are common, the former being most pronounced. The formation lies at this place between the Arkansas novaculite on the hill-slope to the north and Stanley shale on the slope to the south, all dipping south at a high angle.

(A. H. Purdue).

The Southwestern Slate Company's property. The quarries and prospects described in the following paragraphs belong to the Southwestern Slate Company:

On the south side of the mountain, in Sec. 3, 4 S., 27 W., at the height of 1750 feet, there is a ledge of red slate 15 feet high, showing along the mountain side for 125 feet. The prominence of the bluff would indicate that this slate withstands weathering. The cleavage is good, but joints are numerous. Layers of fine-grained sandstone a half inch thick and greater, are common. The color on the weathered surface varies from a beautiful red to green and brown. It doubtless is all red some distance in from the exposed surface.

The Southwestern Slate Company's property. In the east half of Sec. 34, or the west half of Sec. 35, 3 S., 27 W., at the head of a small ravine there is a fine bluff of the red slate. The slate, which is of deep, rich red color, lies practically horizontal, and is but slightly jointed. It cleaves well, with fairly even surfaces, but is not sonorous. This is an excellent milling slate if it will not check on drying.

(A. H. Purdue).

The Southwestern Slate Company's property. In the northern part of Sec. 5, 4 S., 27 W., on the south slope of the Missouri Mountain, at the height of 1800 feet, there is an exposure of slaty material, 180 feet thick. The dip is 17 degrees north, 20 degrees east, and into the mountain. When this was observed, it was not known that the formation in which it occurs ever contained slate, and it was described in the notes as "a thin bedded, greenish to chocolate colored, hard shale, forming a bluff on the mountain side, and containing thin beds of quartzite near the top. About the middle portion, there is a bed of conglomerate two and one-half feet thick."

This belongs to what was afterward named the Fork Mountain slate, which subsequent observations show to be almost everywhere a true slate. It is probable that prospecting would show this to be no exception to the rule, though it should be remembered that usually the slate of the formation is so much jointed as to render it worthless. While this formation occurs normally above the Arkansas novaculite its position is here reversed due to overturning.

(A. H. Purdue).

The Southwestern Slate Company's property. In the north part of Sec. 9, 4 S., 27 W., on the north slope of Statehouse Mountain a quarry was being opened up at the

time of the writer's visit. The slate is in the center of an isoclinal fold, and dips 58 degrees north. The cleavage is with the bedding, or nearly so. Jointing is frequent and in all directions. The effect of the color is that of a beautiful, uniform red, though small green spots are noticeable on close inspection. The best of the slate is quite sonorous and cleaves well, but "curl" is so common as to probably prevent this quarry from being valuable. This quarry is in the red slate.

(A. H. Purdue).

The Southwestern Slate Company's property. In Sec. 3, 4 S., 27 W., the north half, in a ravine on the north slope of the mountain, at the height of 1650 feet, there is a fine exposure of the red slate. The slate dips at a low angle to the north or with the mountain slope. The joints are straight, clean-cut, and not frequent, so that the slate could be quarried in large blocks.

In the small creek that runs along the north side of Sec. 3, there is a bed of green slate lying practically horizontal, with the cleavage parallel to the bedding. This slate can be quaried in large, beautiful slabs, but it contains thin layers of fine, sandy material, which precludes it from milling slate. It might be worked into shingles an inch or more in thickness, should ever such come into use. This is in the basal part of the Missouri Mountain slate.

(A. H. Purdue).

The Southwestern Slate Company's property. In the west part of Sec. 4 or the east part of Sec. 5, 4 S., 27 W. there is a small prospect in the Stanley shale. The opening is 30 feet wide with a face 3 feet high at the inner end. The color is dark blue, and the cleavage poor. On exposure it rapidly disintegrates.

(A. H. Purdue).

The Southwestern Slate Company's property. In Sec. 4, 4 S., 27 W., on the east side of a small branch flowing into Crooked Creek and near the base of the mountain, there is a quarry about 100 feet square and 50 feet deep. The dip of the rocks is north or into the mountain, and the cleavage is parallel with the dip. Both strike and dip joints are numerous, two feet being the usual maximum distance apart. Thin quartz veins are common on the east side of the quarry. The rocks in the upper 10 feet of the quarry are thin-bedded sandstone and shale.

Most of the material taken from the quarry was waste, but several squares of shingles were on the ground at the time of the writer's visit, and appear to have been cut three or four years. These were of two kinds. One a grayish blue, micaceous slate, the other, bluish black and non-micaceous. The former is sonorous, cleaves with a rather rough surface, and has withstood weathering. The latter is not sonorous, cleaves with a smooth, glossy surface, and about 10 per cent. of it has gone to pieces. This quarry is in the Stanley (Carboniferous) shale.

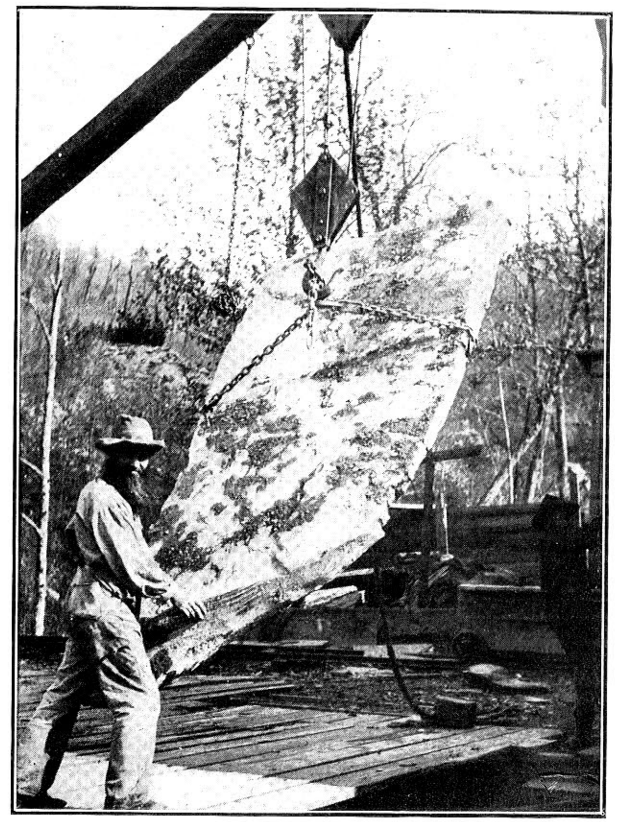
(A. H. Purdue).

The Southwestern Slate Company's property. In Sec. 35, 3 S., 27 W., on the north slope of the mountain, at a height of about 1600 feet, there is a quarry in the red slate, from which has been obtained a good deal of the material that has been worked up into milled stock. This is known as the north quarry. The slate at this point can be quarried in fine large blocks, as is shown by Fig. 2, Plate V.

(A. H. Purdue).

In the same section as that above described, and on the south slope of the mountain, there are three quarries in the red slate. These probably were the first quarries opened up in this part of the slate area, and a large amount of work has been done in them. These quarries have supplied most of the milled stock that has been shipped from Arkansas, but unfortunately the openings were at points where the slate had suffered much from crushing and jointing,

PLATE VII.



2. Block of red slate from North Quarry, Southwestern Slate Company.

and as a consequence the amount of waste was unusually large.

The J. R. Crowe Coal and Mining Company's property. Two openings, one of which appears to be on the east side of Sec. 36, 3 S., 27 W., and the other on the west side of Sec. 31, 3 S., 26 W., occur on the north slope of the mountain at the height of 1380 feet. The dip of the slate is about 32 degrees south, and into the mountain. The first named of the openings exposes a thickness of about 30 feet of slate. The cleavage appears to be with the bedding, but disintegration is so great that this is very poor. Both strike and dip joints are frequent. Most of the slate is green or brown in color, these colors having resulted from the weathering of the red slate to which it belongs.

The second opening is about 30 yards to the east of the one described. This opening is 75 feet along the mountain, with a floor 40 feet wide. The bed of promising slate in this quarry is only about 5 feet thick, but it is much less weathered and less jointed than that just described.

About 300 yards further to the east, in Sec. 31, 3 S., 26 W., there are two other openings about the same height, and in the same formation, at the head of a small ravine. The larger of these is 50 feet along the mountain side, and shows 25 feet of red slate of good quality. The joints are few, the beds massive, and the cleavage good. It appears that blocks 8 to 10 feet long could be quarried here.

(A. H. Purdue).

RANGE 28 WEST

The American Slate Company's property. In Sec. 32, 3 S., 28 W., in a small branch which runs north, at the base of a high mountain, there is a prospect in gray (probably Fork Mountain) slate. The slate has a fairly good ring, and can be split into sheets one-eighth inch thick and thicker. The cleavage surfaces usually are rough and wrinkled. Iron sulphide and other minerals are absent. The slate is so much jointed that after searching, a good piece 12 by 24 inches could not be obtained from the dump where the best pieces had been placed.

(H. D. Miser).

Name of owner unknown. In or near Sec. 32, 3 S., 28 W., the northeast quarter, the Fork Mountain slate is exposed in a bluff on the north bank of the head of Big Fork Creek. This exposure should be prospected.

(A. H. Purdue).

Name of owner unknown. In Sec. 32, 3 S., 28 W., the northeast quarter of the northwest quarter, in a small ravine on the north slope of the Missouri Mountain, there is a prospect in the black Stanley (Carboniferous) shale. The dip is to the north, and the cleavage with the dip. The dump contains slabs of sufficient size for large shingles. The cleavage is excellent, and the slate is sonorous and contains numerous small mica scales.

(A. H. Purdue).

Name of owner unknown. In Sec. 32, 3 S., 28 W., there is an opening in the Fork Mountain slate on the south slope of the mountain. The dip of the rocks is into the mountain, and is 32 degrees north, 15 degrees west. The opening is 70 feet long, but extends into the hill only 5 feet. The cleavage is parallel with the bedding, a fact much to the advantage of the slate, should it ever prove valuable. Strike joints are well developed, and if we may judge from the small size of the opening, are some four or five feet apart. The color is gray. The waste from the quarry is much decomposed, but the material probably would grow better were the quarry extended further into the hill, away from the weathered portion.

(A. H. Purdue).

The Danville property. In Sec. 28, 3 S., 28 W., the northeast quarter of the southwest quarter, in a gap of Fork Mountain, there is a prospect 22 feet wide and probably 20 feet deep, in gray slate. The bottom portion was filled with water at the time of the writer's visit, only the upper 10 feet showing. This is what is known as the Fork Mountain slate, the name having been suggested by the location of this quarry. It is of a pleasing dark gray color, cleaves well with fairly even surfaces, has great strength, and is highly sonorous. The cleavage is at a high angle to the bedding and in parts of it, ribbons are pronounced. This would not make milling slate, but would produce shingles of excellent quality if the joints are not so numerous as to prevent its being worked with profit, a thing that can be determined only by further prospecting.

Another prospect on the same property is located in Sec. 29, 3 S., 28 W., on the south slope of the mountain at an elevation of 1450 feet. This small prospect is in the Fork Mountain slate on the south bank of a drain that runs south 40 degrees east, and on a point between the drain and a sag to the south. The cleavage dip is 20 degrees north, 80 degrees west. The bedding was not determined, but ribbons in the slate show that the cleavage is not parallel with it. The master joints are at right angles to the cleavage, and are with the cleavage strike. Such joints as show are from 18 inches to 5 feet apart. This slate cleaves well, is of a gray color, possesses good strength, is sonorous, and lies well for quarrying. It is worthy of further attention.

(A. H. Purdue).

Name of owner unknown. In Sec. 30, 3 S., 28 W., apparently in the northeast quarter, there is an opening in the Stanley shale in an east-west ravine, and at the base of a hill to the north. The cut is 15 feet with the strike with a 10-foot face at the inner end. The slates dip 15 degrees north, 20 degrees west. The rocks exposed are shaly slates containing a layer of quartzite from 1 to 5 inches thick.

The slate is gray, cleaves readily with uneven surfaces, and is quite sonorous.

(A. H. Purdue).

RANGE 29 WEST

The Whisenhunt property. In Sec. 35, 3 S., 29 W., the south half, on a gentle slope to the north and a short distance south of Mine Creek, there is a small prospect in gray (probably Fork Mountain) slate which has a low dip to the north. The slate has a good ring and can be split into pieces of suitable thickness for roofing slate. The cleavage surface is smooth. Iron sulphide, clay and other minerals are absent. The amount and character of the jointing could not be determined, as the opening was small.

(H. D. Miser).

The Whisenhunt property. In Sec. 35, 3 S., 29 W., the south half, on the south bank of Mine Creek, there is a prospect in black (probably Carboniferous) slate. This slate has a low dip to the north. It is free of iron sulphide and other minerals, has a clear sharp ring, and can be split into pieces one-fourth of an inch thick and thicker. The cleavage planes run across the bedding planes, but do not cause ribbons as the eight feet of slate in the opening is of a uniform color. The cleavage surface is smooth and shows no wrinkles. On account of the dynamiting of the prospect, the number of sets and the frequency of the joints could not be determined, yet it is probable that pieces of commercial size can be obtained.

(H. D. Miser).

Name of owner unknown. In Sec. 7, 3 S., 29 W., the northwest quarter of the northwest quarter, there is a small prospect 150 yards west of Board Camp Creek and a quarter of a mile north of Mr. Henry Harrison's house. It is in dark gray shale of the novaculite series, and is closely intersected with irregular joints.

(A. H. Purdue).

The Harrison property. In the same section named above, and in the southeast quarter of the northwest quarter, about a quarter of a mile east of Mr. Harrison's house, there is a small prospect in the Fork Mountain slate, from which only a few cubic yards have been removed. The dip is 26 degrees north, 30 degrees west, and the rock lies so as to be easily quarried. The cleavage surfaces on the few slabs taken out are quite uneven, but this probably would improve with depth. The color is gray, the slate is sonorous, and joints are not numerous. This should be prospected further for roofing slate.

(A. H. Purdue).

Name of owner unknown. In the same section named above, the northwest quarter of the southwest quarter, on the east bank of Board Camp Creek, a half mile south of Mr. Harrison's house, there is a prospect in the upper, thin-bedded part of the Arkansas novaculite. The material sought is shale, which is only a few inches thick between the beds of novaculite. Some are soft, clay shales, others silicious and hard, and all of a dark color. It is not advisable to prospect this further.

(A. H. Purdue).

Name of owner unknown. In Sec. 18, 3 S., 29 W., there is a small opening in the southeast corner, on the north hill slope. The dip is 41 degrees north, 10 degrees west. About 12 feet (stratigraphically) is much weathered, but that beneath appears sound. The joints are irregular, but not so numerous as to prevent the quarrying of large blocks.

(A. H. Purdue).

The Boyer property. In Sec. 20, 3 S., 29 W., the northwest quarter, there are two openings on the north slope of the ridge above described, made 10 years before the writer's visit. The dip is 19 degrees north, 10 degrees west. One of the openings, 20 by 40 feet, was full of water at the time visited. The other is only a stripping but it discloses fine red slate at the surface, an exposure 6 by 10 feet showing no joints. The prospect indicates a fine quality of red slate.

(A. H. Purdue).

Name of owner unknown. In the southwest quarter of the northwest quarter of the above named section, there is an opening on the south slope of the ridge, in the Fork Mountain slate, which, owing to an overturn, lies beneath the Arkansas novaculite. The cleavage is excellent and the slate would be of good quality were it not that the joints are so numerous as to probably destroy its value. Both strike and dip joints occur, but the former are most pronounced.

(A. H. Purdue).

The Spencer-Kelly property. In the southeast quarter of the southwest quarter of the section mentioned above, there is a quarry 100 feet along the strike and 15 feet into the hill, in the bottom of a ravine. It is in red slate, which dips into the hill to the north. The major joints are well developed strike joints, those showing being about 4 feet apart. The minor joints are irregular and quite close together. From present indications, only small blocks could be quarried. The slate cleaves well with fairly smooth surfaces, is of good color, and is somewhat sonorous. The upper 13 feet showing in the quarry is much disintegrated, the promising slate being in the lower part of the quarry. Sheets of slate on the dump 18 inches square and a quarter of an inch thick do not show signs of weathering. They had been out about a year at the time visited. The indications are that this is a superior quality of the red slate.

(A. H. Purdue).

The Gulf Slate Company's property. In or near Sec. 12, 3 S., 29 W., the north part of the southeast quarter, is a quarry 40 by 50 feet. The depth could not be made out, as the quarry was full of water at the time of the writer's visit. It is on the north slope of the same ridge, and the slate belongs to the same formation as in the last two mentioned quarries. The beds dip 35 degrees north, 20 degrees west. Forty feet of the upper part (stratigraphically) is so weathered as to be worthless. The lower part that can be seen above the water appears better, but is intersected by numerous joints oblique to the cleavage. Some fine looking blocks which must have been taken from the bottom, were on the dump.

(A. H. Purdue).

The Atlas Slate Company's property. In Sec. 11, 3 S., 29 W., there is a quarry on the north slope of the hill at an elevation of 1350 feet. The dip is about 45 degrees to the north, the bedding planes forming the inner face of the quarry, which is about 100 feet square. The opening is in the red slate and both red and green slate occur, the latter being along and near large joints into which water had free access. The joints are irregular and so numerous as to preclude the quarrying of large blocks. In both the red and the green slate the cleavage is excellent, but neither is sonorous.

This quarry was opened in 1900 and the work continued for about a year. It is reported that about 40 squares of shingles were produced.

(A. H. Purdue).

The Standard Slate Company's property. Up the hill immediately to the west of the quarry above described, at the height of 1400 feet, there is another quarry 125 feet with the strike and 50 feet wide. It is in red slate. The upper 30 feet (stratigraphically) is much weathered. Below this is about 12 feet of solid red slate intersected with strike and dip joints, but so infrequent as to make it possible to quarry blocks 3 by 4 feet long. The slate is not sonorous, and the cleavage poor, but it is well suited for milling slate, provided it can be worked without loss from checking.

(A. H. Purdue).

The Andrews and Harrington property. In Sec. 15, 3 S., 29 W., the northeast quarter, there is a small opening in a ravine at the height of 1250 feet, and 150 yards north of the public road. The opening is 6 feet with the strike and 30 feet with the dip, which is 26 degrees north, 15 degrees west. Very black slate shows throughout the whole course of the opening, the depth of which does not exceed two feet. Dip and strike joints occur and are so near together as to make it difficult to secure blocks large enough for shingles.

Judging from the dump, this slate is easily cleavable, with comparatively smooth surfaces, is highly sonorous, and has good strength. Certain of the layers are thickly set with graptolite fossils. This slate is closely associated with the Bigfork chert, and is either the Stringtown shale or the upper part of the Ouachita shale. The apparently excellent quality of this slate would justify further prospecting in this vicinity for parts that are not so much jointed.

(A. H. Purdue).

Name of owner unknown. In Sec. 24, 3 S., 29 W., the south half of the southeast quarter, there is an opening in the Stanley shale in a ravine running south from the top of the ridge. The dip is about 18 degrees north, and into the hill. The opening is about 25 feet across the strike with a face of 4 feet showing at the inner end. Both dip and strike joints occur, the latter being most pronounced. The cleavage is splendid, and the slate quite sonorous. Both black and gray slate occur. Slabs that have been on the dump for more than a year, show no signs of disintegration.

(A. H. Purdue).

Name of owner unknown. In Sec. 25, 3 S., 29 W., northwest quarter of the northwest quarter, there is a small prospect in a ravine in the Stanley shale. The slate dips into the hill to the north. It is both gray and black in color. The black is of a uniform color, cleaves with an even surface, is sonorous, and slabs that have been on the dump for two years have not perceptibly weathered. This slate appears to be of good quality but the opening is so small that the amount can not be made out.

(A. H. Purdue).

The Brannon property. In Sec. 25, 3 N., 29 W., the northeast quarter of the northeast quarter, there is a small opening in a ravine, and at the base of the ridge to the north. The rocks dip 30 degrees north, 10 degrees east into the hill. The slate is black and gray in different beds, cleaves well, is sonorous, and appears to withstand weathering, but jointing is so frequent as to make its value doubtful.

(A. H. Purdue).

The South Wales Slate Company's property. In Sec. 24, 3 S., 29 W., in the southwest quarter, there is a small opening in the red slate, at the head of a ravine, and on the north slope of the mountain. The dip of the cleavage is 29 degrees north, 10 degrees west, which appears to be with the bedding. The cleavage is very good, it being possible to split blocks 2 feet square into sheets one-fourth inch thick. There occur remarkably straight dip and strike joints from 2 to 10 feet apart, and it appears that blocks of any size desired could be quarried. The slate in the quarry is of a uniform pea green, though the red occurs in abundance just above the quarry. A few of the layers contain nests of iron sulphide crystals, but these do not appear to be numerous enough to materially injure the slate.

Should it ever become desirable to open up this quarry on a large scale, there is all reason to believe that slate equally good with that now exposed, could be obtained in large quantity in the hill both east and west of the ravine. Fig. 7 shows the structure at this locality.

(A. H. Purdue).

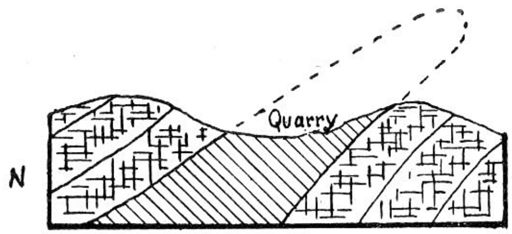


Fig. 7. Showing the structure at the South Wales Slate Company's Quarry.

Name of owner unknown. In Sec. 22, 3 S., 29 W., there are two small openings in the southwest quarter of the southwest quarter, in a small east-west ravine. The rock is black to gray Stanley shale, interbedded with sandstone. Red slate occurs up on the hillside, south of the ravine, and also near the head of the ravine.

(A. H. Purdue).

RANGE 30 WEST

Name of owner unknown. In Sec. 13, 3 S., 30 W., the northeast quarter of the southeast quarter, on the mountain side, at the height of 1400 feet, there is a quarry in the red slate, 30 by 40 feet, and 20 feet deep. A road has been constructed up the mountain at considerable expense. The cleavage is parallel with the dip, which is 45 degrees north. The slate is green, brown and yellowish brown, which are colors derived from the weathering of the red, only a few streaks of which are left. The part sought in quarrying was the green. Slabs of this of the size for large shingles have been left at the quarry for two years without weathering or checking. They are somewhat sonorous, and the cleavage is good. Dip joints are well developed, and are from 10 inches to 2 feet apart. Strike joints are common, and are

oblique to the cleavage. "Curl" is common in many parts of the quarry.

(A. H. Purdue).

RANGE 32 WEST

Name of owner unknown. Near the center of Sec. 2, 8 S., 32 W., about 100 yards south of a small stream in an east-west valley, there is a prospect in grayish black slate which occurs in the Stanley shale. This slate has a dip of about 20 or 30 degrees east of south and is three feet thick. Both above and below the slate there is greenish clay shale. The slate is readily cleavable, if we may judge from the appearance of the thin pieces taken from the opening and scattered about over the surface. The cleavage surface is very smooth. Iron sulphide and other minerals are absent. Both strike and dip joints are developed. The strike joints are 5 and 6 inches apart near the surface, but below the surface the frequency of their occurrence could not be determined on account of water in the opening. The dip joints are 5 and 6 feet apart.

(H. D. Miser).

GLOSSARY OF GEOLOGICAL AND SLATE QUARRY TERMS.*

Anticline. The arch part of a folded bed.

Anticlinorium. A mountain mass arch-shaped in its general internal structure.

Authigenous. Minerals originating chemically within a rock are called authigenous.

Back Joint. Joint plane more or less parallel to the strike of the cleavage and frequently vertical.

Bed. A continuous mass of material deposited under water at about one time.

Blind Joint. Obscure bedding plane.

Bottom Joint. Joint or bedding plane horizontal or nearly so.

Breccia. Rock made up of angular fragments produced by crushing and then recemented by infiltrating mineral matter.

Brecciated. Applied to a rock made up of angular fragments but not transported.

Clastic. Constituted of rocks or minerals which are fragments derived from other rocks.

Cleave. Slaty cleavage.

Conformity. When two beds overlie in parallelism without any disturbance of the crust having affected the first one before the deposition of the second, they are said to be in conformity.

Curl. Small crumples or wrinkles, that split up with the cleavage and the grain into small prisms.

*From Bulletin No. 275, U. S. Geol. Surv. pp. 146-7.

Diagonal Joints. Joints diagonal to the strike of the cleavage.

Dip. The degree and the direction of the inclination of a bed, cleavage plane, joint, etc.

Dip Joints. Vertical joints about parallel to the direction of the cleavage dip.

Dike. Molten material erupted through a narrow fissure.

End Joint. Vertical joint about parallel to direction of the cleavage dip.

Erosion. The "wear" of a rock surface by natural mechanical or chemical agencies.

False Cleavage. A secondary slip cleavage superinduced on slaty cleavage.

Fault. A fracture resulting in a dislocation of the bedding or cleavage, one part sliding up or down, or both changing positions along the fracture.

Flints. A term applied alike to quartz veins or beds or quartzite.

Formation. A larger group of beds possessing some common general characteristics or fossil forms differing from those of the beds above and below.

Grain. An obscure vertical cleavage usually more or less parallel to the end or dip joints.

Hards. Term applied to beds of quartzite or quartzitic slate.

Hogbacks. Shear zones.

Isoclinal. Folds with sides nearly parallel are said to be isoclinal.

Matrix. Term used in microscopic descriptions of slate, etc., to denote the chief substance of the slate itself, apart from the various mineral particles or crystals it may inclose.

Metamorphism. The process, partly physical, partly chemical, by which a rock is altered in the molecular structure of its constituent minerals and frequently in the arrangement of its particles.

Overlap. Where, owing to the depression of a coast and the consequent landward shifting of the shore line, the later marine sediments cover up the extremities of the older ones, there is said to be an overlap.

Pitch. The inclination of the axis of a fold of rock,

Post. A mass of slate traversed by so many joints as to be useless. This term is also used to denote bands of hard rock.

Pseudomorph. A mineral that has assumed the crystal form of a different mineral as the result of the partial or entire alteration or replacement of the original mineral through chemical processes.

Quartzite. A sandstone in which the grains are held together by a silicious (quartz) cement.

Ribbon. A line of bedding or a thin bed appearing on the cleavage surface, sometimes of a different color; or a small bed of quartzose or calcareous material either crossing or parallel to the cleavage. When such ribbons are separated by beds of slate too thin to be worked, the ribbons and the small beds are together designated as "ribbon."

Sculping. Fracturing the slate along the grain, *i. e.*, across the cleavage in the direction of the dip.

Sericite. A ribbon-like or fibrous form of muscovite or potash mica.

Shear Zone. Hogback.

Slant. Longitudinal joint more or less parallel to cleavage and often slickensided.

Slickensides. Surface of bed or joint plane along which the rock has slipped, polishing and grooving the surfaces.

Slip. Occasional joint crossing the cleavage, but of no great continuity. Slips are not infrequently fault planes.

Slip Cleavage. Microscopic folding and fracture, accompanied by slippage; quarrymen's "false cleavage."

Split. Slaty cleavage.

Stock. Useful slate taken from the quarry.

Stratum. A bed.

Stratification. Bedding, in distinction from cleavage.

Strike. Direction at right angles to the inclination of a plane of bedding, cleavage, jointing, etc.

Strike Joint. Joint parallel to the strike of the cleavage.

Sulphur. Iron pyrite.

Syncline. The trough part of a fold of rock.

Synclinorium. A mountain mass, in general internal structure trough shaped.

Thick Joint. Two or more parallel joints between which the slate has been broken up or decomposed.

Top. The weathered surface of a slate mass or the shattered upper part of it.

Unconformity. When the lower one of two contiguous deposits affords evidence of having been exposed to atmospheric erosion before the deposition of the upper one, there is said to be an unconformity between them.

Vein. When correctly used, denotes a more or less irregular, sometimes ramifying, mineral mass, often of quartz, with calcite, etc., within the slate. Such veins are called veins of segregation, to show that they consist of matter collected from the adjacent rock by solvent waters. But, as generally used by slate quarrymen, "vein" is the equivalent of bed or stratum.

Wild Rock. Any rock not fit for commercial slate.

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BY JOHN C. BRANNER

The following authors' list includes nearly all the titles referring to the geology, mineralogy, and paleontology of the State. This list is a second edition of the one published in Vol. II of the Annual Report of the Geological Survey of Arkansas for 1891, Little Rock, 1894. Since the appearance of the first list, a great many new papers have appeared, and some old titles have been found, that were overlooked in making up the first edition.

The names of authors of publications are arranged in alphabetic order. Newspaper articles are not included in the list except those published by W. F. Roberts in the *Age of Steel*, of St. Louis.. Those titles are listed chiefly because Mr. Roberts was at one time State Geologist of Arkansas, and, as he published no official report, the articles are believed to represent his views of the geology of the State. There are included also a few official reports that have been published in newspapers only.

Maps of the United States, on which attempts have been made to show the geology of Arkansas, are not mentioned except in the cases of some of the earlier ones, such as Maclure's, Lyell's, Marcou's, Hitchcock's, Blake's and McGee's. Purely statistical information, such as may be found in census reports, is not attempted.

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