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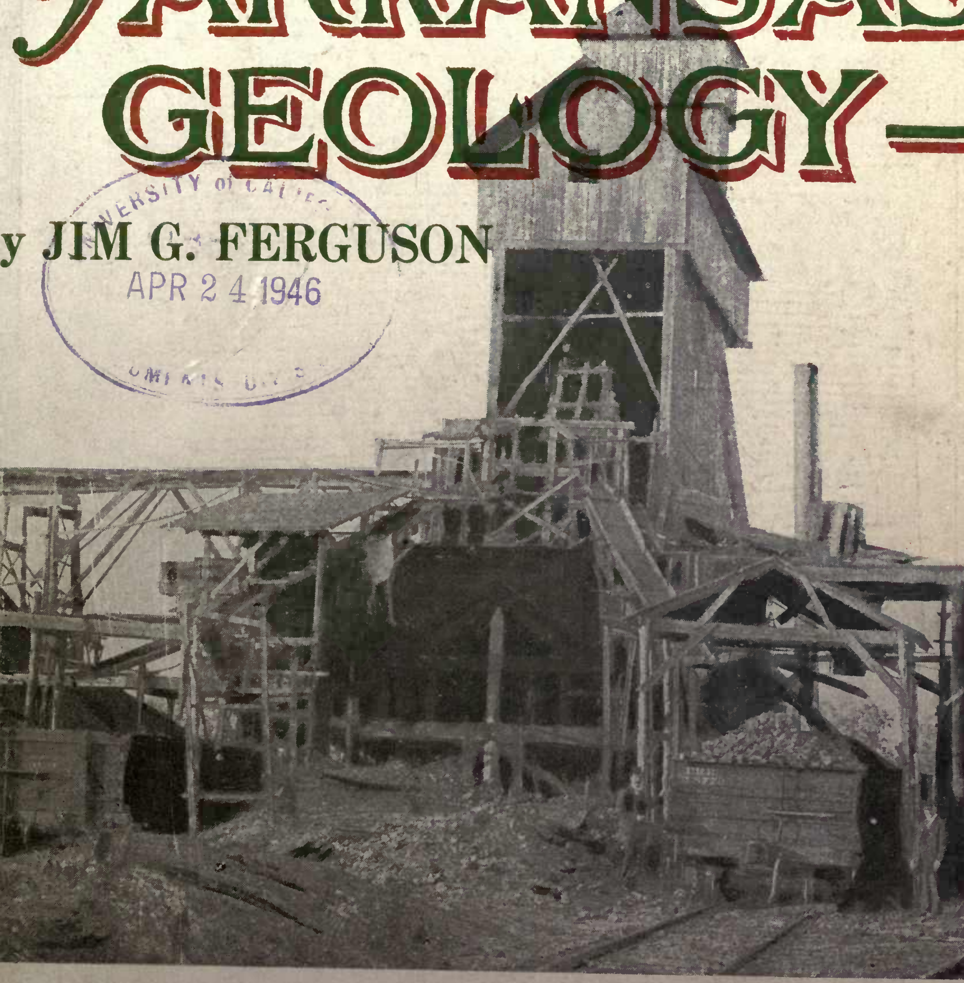

Published by the State Bureau of

Mines, Manufactures and Agriculture

Jim G. Ferguson, Commissioner
Little Rock, Arkansas

GEOLOGIC MAP OF ARKANSAS

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U. S. Geology Survey Bulletin No. 351, "The Clays of
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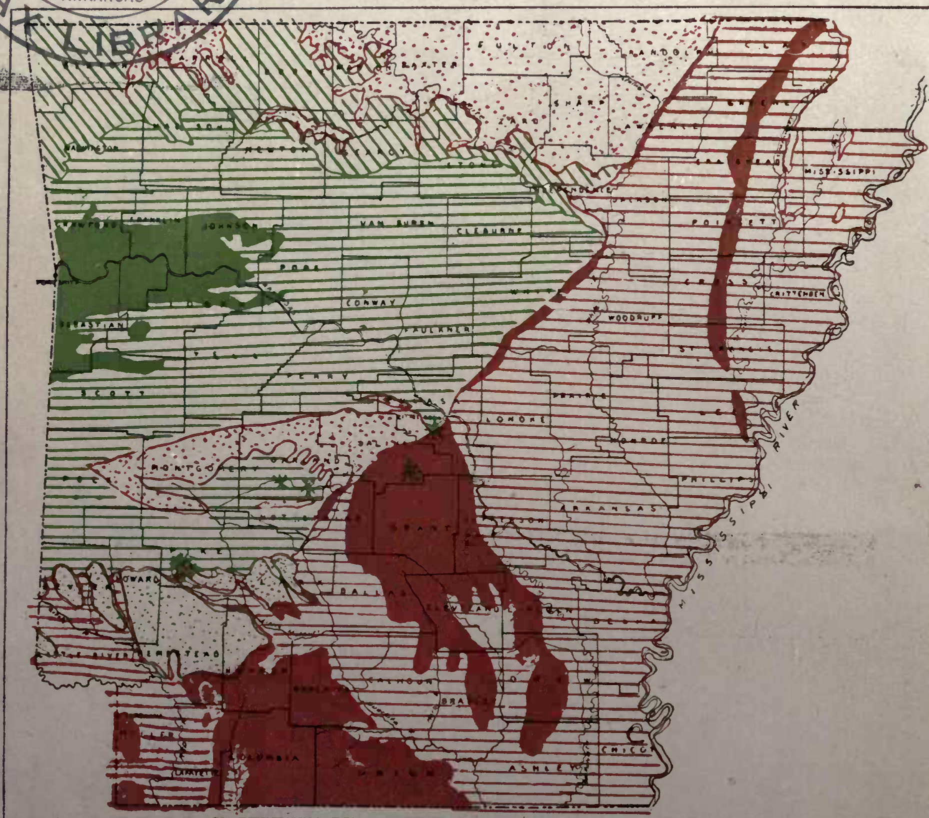

LEGEND

QUATERNARY

TERTIARY

Cambrian, Ordovician, Silurian, and Devonian

CARBONIFEROUS

Pennsylvanian

Mississippian

Productive Coal Measures

Undifferentiated Sandstones

Underlying Beds of Mississippian

Igneous Rocks

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of the

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of the

STATE OF ARKANSAS

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INTRODUCTION.

REVIEW OF THE HISTORY OF ARKANSAS GEOLOGICAL SURVEYS.

Until the State Legislature deems it expedient to authorize a further survey of our mineral resources, a work that has been neglected for a good many years and for the lack of which Arkansas has been seriously hindered in its material progress, use must be made of such literature as has resulted from the splendid labors of earlier surveys, and the records of private and government researches, if our knowledge of the geology of the state is to be refreshed either for practical purposes or for our mental edification.

The subject of a state geological survey of Arkansas was first brought to public attention by Governor Elias N. Conway in his message to the Legislature in 1856. On his recommendation the first geological survey of the state was begun under an act passed January 4, 1857. Dr. David Dale Owen, then State Geologist of Kentucky, was appointed State Geologist of Arkansas and entered upon his duties October 1, 1857. The results of the work done in 1857 and 1858 are given in Owen's "First Report of a Geological Reconnaissance of the Northern Counties of Arkansas," Little Rock, 1858.

The bill providing for the continuation of the survey passed in February, 1859. Under this act Doctor Owen was again appointed State Geologist. Before the next Legislature convened Doctor Owen died (Nov. 3, 1860), and his "Second Report of a Geological Reconnaissance," was edited by his brother, Doctor Richard Owen, and Prof. J. P. Lesley, and was printed in Philadelphia in 1862. Both of the Owens reports are now out of print.

The Civil War followed shortly after the publication of Doctor Owen's second report, and all such work was necessarily suspended in the Southern States. No steps were taken to finish the geological survey of Arkansas until after the close of the war.

In the General Assembly of 1866 a bill was passed by the Senate providing for a geological survey of the state, but it was rejected by the Lower House. In the Legislature of 1871 a survey bill was passed, and approved May 28, 1871. Under this act Governor O. A. Hadley appointed W. F. Roberts, Sr., of Pennsylvania, State Geologist. Dr. George Haddock, then of Arkadelphia, was, upon Governor Hadley's recommendation, appointed Mr. Roberts' assistant and went with him through the western part of the state. Mr. Roberts' report was never delivered to the Governor. A series of articles, however, was subsequently published by Mr. Roberts in the Age of Steel, of St. Louis, Missouri (1887-88), and it is probable that these articles represent his views of the geology of the state and give the results of his work. They are largely a repetition of the results given by Doctor Owen.

In 1873 Dr. George Haddock, who had been Mr. Roberts' assistant, published at Little Rock a pamphlet of 66 pages, entitled "Report of a Geological Reconnaissance of a Part of the State of Arkansas Made During the Years 1871-72." This paper gives the only results of the work done under this appropriation. It is of but little or no importance and adds nothing to the work done by Doctor Owen. The paper is out of print.

The General Assembly of 1873 passed a bill for the continuation of the survey. Under this act the following geologists were appointed: George Haddock, appointed May 15, 1873, removed from office January 14, 1874. Mr. Haddock made no report except the one published under a former appropriation and mentioned above. Wm. C. Hazeldine, appointed January 14, 1874, and removed June 29, 1874. As State Geologist he made no report and, so far as can be ascertained, did no field work. Arnold Syberg was appointed June 29, 1874, and remained in office to the end of the term. Mr. Syberg made no report, and the only work he did was to receive and examine specimens sent or brought in from various parts of the state.

The failure of the surveys from 1868 and 1875 to yield any geological results must be attributed to the general demoralization of the state government during the reconstruction period. No further efforts were made to carry on a geological survey until the year 1881, when a bill for such work was defeated in both branches of the General Assembly. In the Assembly of 1883 the only legislation passed relating to geological work was a Senate concurrent resolution "authorizing and directing the Governor to make application to the Secretary of the Interior of the United States for a geological survey of the State of Arkansas." Nothing seems to have come of this effort to obtain help from the national government.

In January, 1887, Governor Simon P. Hughes, in his message to the General Assembly, suggested an appropriation for a geological survey. An act was accordingly passed providing for the appointment of a State Geologist and three assistants. Under this act Dr. J. C. Branner was appointed State Geologist and entered upon the duties of the office June 24, 1887. In the General Assembly of 1889 there was much opposition to the continuance of the survey due chiefly to the fact that the survey had declared fraudulent certain so-called gold mines in the western part of the state. The bill, however, passed and Doctor Branner was reappointed State Geologist. The survey was continued by the General Assembly of 1891, with the understanding that it should be brought to a close by the end of March, 1893. However, the General Assembly of 1893 appropriated $4,000 to complete the publication of reports.

During Doctor Branner's term of office a large number of reports were issued. The annual report of 1888 comprised four volumes, that of 1889 two volumes, 1891, two volumes, 1892, five volumes, and two reports remain unpublished for lack of appropriations. The reports issued are chiefly of an economic nature, although a few are of a more general geologic character. A list of them follows:

Annual Report for 1888.

Vol. I—Gold and Silver, by Theo. B. Comstock, Pp. xxxi, 320, 2 maps.

Vol. II—Mesozoic, by R. T. Hill. Pp. xiv, 319; illustrated; 1 map.

*Vol. III—Coal (preliminary), by Arthur Winslow, Pp. x, 120; illustrated; 1 map.

*Vol. IV—Washington County, by F. W. Simonds; Plant List, by J. C. Branner and F. V. Coville. Pp. xiv, 262; illustrated; 1 map.

Annual Report for 1889.

Vol. I—Clays, Kaolins and Bauxites. Illustrated; maps. By J. C. Branner; illustrated, about 300 pages. (Not published.)

Vol. II—Crowley's Ridge, by R. E. Call. Pp. xix, 283; illustrated; 2 maps.

Annual Report for 1890.

Vol. I—Manganese, by R. A. F. Penrose, Jr. Pp. xxvii, 642; illustrated; 3 maps.

Vol. II—Igneous Rocks, by J. Francis Williams. Pp. xv, 457; illustrated; 6 maps.

Vol. III—Novaculites, by L. S. Griswold. Pp. xx, 443; illustrated; 2 maps.

Vol. IV—Marbles, by T. C. Hopkins. Pp. xxiv, 443; illustrated; atlas of 6 maps.

Annual Report for 1891.

*Vol. I—Mineral Waters, by J. C. Branner. Pp.viii, 144; 1map.

*Vol. II—Miscellaneous Reports:—Benton County, by F. W. Simonds and T. C. Hopkins; Elevations, by J. C. Branner; River Observations, by J. C. Branner; Magnetic Observations, by J. C. Branner; Mollusca, by F. A. Sampson; Myriapoda, by Charles H. Bollman; Fishes, by Seth E. Meek; Dallas County, by C. E. Siebenthal; Bibliography of the Geology of Arkansas, by J. C. Branner. Pp. x, 349; illustrated; 2 maps.

Annual Report for 1892.

*Vol. I—Iron Deposits, by R. A. F. Penrose, Jr. Pp. x, 153; 1 map.

Vol. II—Tertiary, by Gilbert D. Harris. Pp. xiv, 207; illustrated, 1 map.

Vol. III—Coal, final report; illustrated; topographic maps and sections. By Arthur Winslow and others. (Not published.)

Vol. IV—Lower Coal Measures; topographic maps, sections and illustrations, by J. H. Means and Geo. H. Ashley. (Not published.)

* V—The Zinc and Lead Deposits, by J. C. Branner. Pp. xiv, 395; illustrated; atlas of 7 maps.

Relief maps of the State, of the Coal Area and of Magnet Cove were also made under the Branner survey.

I—The Mineral Resources of Arkansas, by J. C. Branner. (About 700 pages, illustrate.) Not published.

II.—Final Report upon the General Geology of Arkansas, by J. C. Branner. (About 500 pages, illustrated.) Not published.

* A few copies are still on hand and may be obtained by forwarding sufficient postage to the Commissioner of Mines, Manufactures and Agriculture, Little Rock, Ark. All other reports are out of print.

In 1907 there was established the Geological Survey of Arkansas in charge of the Geological Commission of Arkansas, composed of the Governor of the State, the President of the University of Arkansas, and the Commissioner of Mines, Manufactures and Agriculture. The members of the commission received no compensation for services rendered for the survey, but were reimbursed for actual necessary expenses. The Professor of Geology of the University of Arkansas was designated as Ex-Officio State Geologist and required to devote 15 per cent of his time to survey work. The assistants included one geologic aid, six engineering aids and one clerk, appointed by the State Geologist with approval of the Commission. These assistants have all been professors or advanced students of the University. Appropriations were made biennially and were partly contingent on cooperation with the U. S. Geological Survey. The Act of 1907 appropriated $1,800 "for a geological survey of the slate deposits in Arkansas in cooperation with the U. S. Geological Survey." The act of 1909 appropriated $5,000 for the purpose of carrying on the work of the survey.

Three reports have been issued by the Survey under Prof. A. H. Purdue: one is on the Slates of the State; another on Coal Mining in the State; and the third is a preliminary report on the Water Powers (White River). The average annual cost of printing reports and maps for the last four years has been $1,300. This was paid from the State printing fund.

New work undertaken by this survey included an investigation of the clay deposits of the state with the view of ascertaining the extent of each deposit and the purpose to which it is best suited; also an investigation of coal mining in the state, for the purpose of conserving the supply and improving the methods of mining. In cooperation with the Federal survey the state survey was to make a study of the water powers of the state.

An appropriation of $7,500 for the Geological Survey was made at the regular session of the General Assembly in 1911, but was vetoed by the Governor, preventing the completion of the clay report, work on which was begun in 1909. Professor A. A. Steel's report on coal was completed at private expense and published in 1912.

Since 1912 there has been no appropriation for further geological work and the Professor of Geology at the State University has carried on the work of answering inquiries as he found time in the conduct of his regular class work.

Fortunately a few of Dr. Branner's reports, unpublished at the time of the abandonment of the Survey, have become available through the generosity of the author in tendering the information to the United States Geological Survey, under whose authority these valuable bulletins have been published. While these are helpful to science, they do not supply the local need of authentic information and the state has been without printed matter of any kind dealing with the important subject of minerals.

So many calls have been made upon the department for specific or general information, which required the searching of authorities and the making of tedious and not always complete replies, that the commissioner concluded to publish a summary of the various reports, issued by the state and obtained from the government, in which the mineral resources of Arkansas are treated, in as convenient a form as the limited allowance for the printing expense would permit.

At the outset of the undertaking it was not hoped to include in the bulletin any new contributions to the geological literature of the state, but as the work progressed much encouragement was received, especially from those high in scientific authority, and as a result there has been obtained information of the greatest value never before published. This new matter includes chapters on Petroleum and Natural Gas, one by Doctor Branner and another by Doctor Drake, the latter being accompanied by a map, showing the favorable and unfavorable areas, such as will prove a useful guide in the future for those who are in search of these minerals.

This material, with the additional matter condensed from the previously published reports, presents enough of the principal facts to give the layman at least a fair idea of the extent, location and probable value of any mineral known to be present in the state, and, fortunately, there has been found room for a bibliography of Arkansas geology that will enable anyone who is sufficiently interested to pursue the study through a considerable list of books and reports.

The collecting and assembly of this material has largely been work of an editorial nature, for the problem was to select the more important features of each report or paper and arrange it in its proper order, and by the addition of photographs and reference notes, to make each subject comprehensive and useful for practical present-day purposes. Care has been taken to quote the authors literally rather than to attempt to summarize in new language the meanings they sought to convey. Geology is one of the most intricate of sciences and it is safest not to tamper with what the great writers have set down.

After the matter had been prepared and carefully checked it was submitted for criticism to Dr. John C. Branner, former state geologist, Dr. N. F. Drake, the present state geologist; and Prof. A. A. Steel, acting professor at the University of Arkansas. A chapter on The Geology and General Topographical Features of Arkansas was prepared with the permission of the Director of the United States Geological Survey, by H. D. Miser, a member of the Survey and one of the ablest authorities on the geology of Arkansas. The cooperation of these trained geologists has enabled the department to present this bulletin in a much more perfect arrangement than would have been possible had the manuscript not had the scrutiny of experts.

It has been thought well to include in this volume, and in fact to make its principal feature, an article recently contributed by Doctor Branner to the Arkansas Gazette, in which a plea is made for a new geological survey of Arkansas and valuable suggestions made for obtaining the substantial means with which to conduct such work.

There is nothing that Arkansas needs so much as a new geological survey. Such information as a new survey would bring forth will serve to attract capital and guide the forces that will develop the mineral resources of the state. It would be a splendid thing if such a survey could be made while the state has the opportunity to obtain the counsel and advice of such eminent men as Doctor Branner and Doctor Drake.

Millions of dollars are being spent in prospecting for oil and gas in Arkansas at the present time. If the state was doing what Oklahoma, Texas and Louisiana are doing it would not only direct these energies to conserve the capital of investors, but it would safe-guard the interests of the commonwealth in these great natural resources, the revelation of which will enrich the state.

The meagre information contained in this synopsis of the geologic lore of the state is the strongest argument for the need of an appropriation of a sum sufficient to establish and maintain a permanent geological corps for the making of a thorough and accurate inventory of the state's mineral wealth, such as would benefit every county in the state. It should be the duty of this survey to collect records of all deep well drillings and to co-operate with the Federal government in completing a soil survey of the State that would be helpful in the agricultural development of Arkansas.

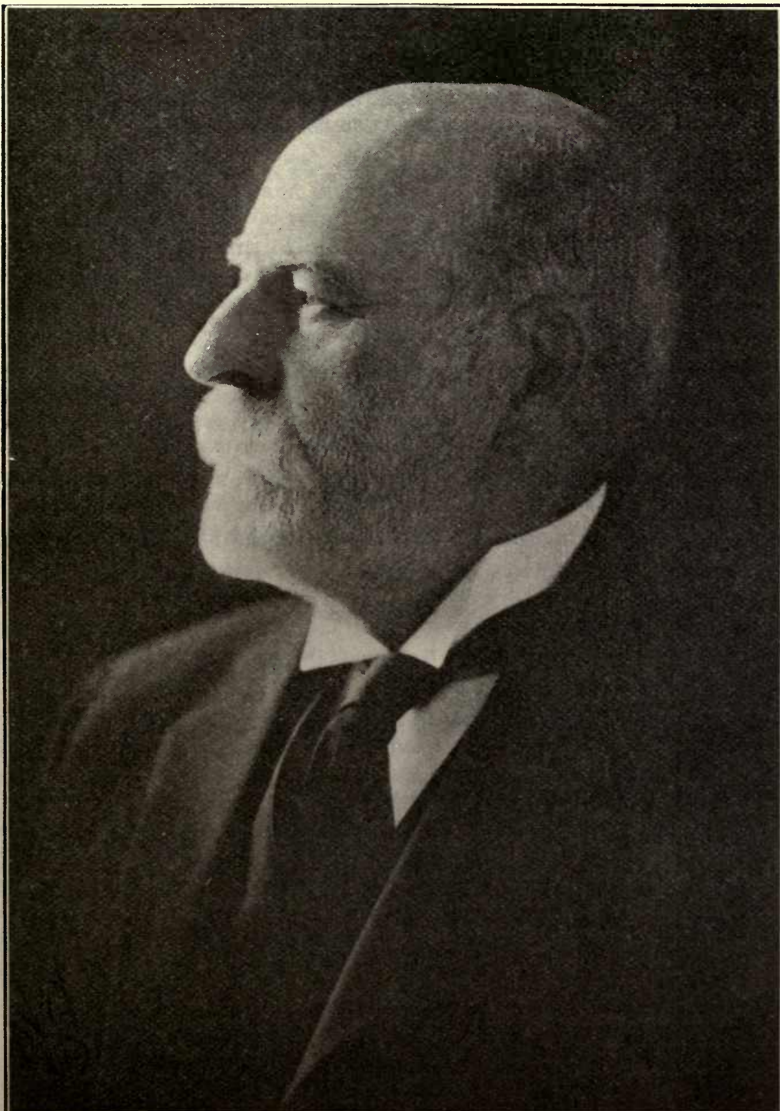
Those who are not familiar with the state's mineral resources may, by a reading of this volume, form a higher estimate of their value for there are vast stores of wealth yet to be uncovered regarding which the people of Arkansas, because of a want of literature on the subject, have had an opportunity to learn very little.

Doctor Branner, Doctor Purdue, Doctor Drake, Professor Steel, Hugh D. Miser and others have laid the foundation for a permanent and useful work. They have pioneered a field rich in possibilities and opened a way to opportunities which the state would be deemed recreant in its duty to the public if it did not take advantage of by the closest study and most persistent research, intelligently conducted by geologists of the future equal in training and ability to those of the past. Upon the work that has been accomplished there can be built greater structures, for Arkansas in mineral resources is one of the richest states and the products of her mines and quarries form no small part of the state's contribution to the material wealth of the nation.

Jim G. Ferguson

Commissioner of Mines, Manufactures and Agriculture.

Little Rock, Ark.,
June 20, 1920.



DOCTOR JOHN C. BRANNER,
President Emeritus, Leland Stanford University, California;
Former State Geologist of Arkansas.

DR. BRANNER OUTLINES WORK FOR NEW GEOLOGICAL SURVEY.

Jim G. Ferguson, Commissioner
Mines, Manufactures and Agriculture

Dear Sir:

I am often asked what remains to be done on the geology of the State of Arkansas. It is quite impossible to answer this question comprehensively in a few words, but it may be worth while to mention here some of the subjects that require first attention:

1. Bring up to date the work on the coal lands and publish the report.

2. Report on the petroleum and natural gas resources.

3. Report on the fertilizers.

4. Report on the soils of the state, their origin, distribution and treatment.

5. Report on the clays, kaolins and fullers earths.

6. Revise and publish the report on the Lower Coal Measures.

7. Report on the structural materials including Portland cement.

8. Report on the state water supply including underground waters.

9. A comprehensive work on the general geology and geologic history of the state.

10. The preparation and publication of a large scale topographic and geologic map of the state.

The work to be done and the order of its doing, however, must depend to some extent on developments as the work progresses.

John C. Branner

Stanford University, California,
June 17, 1920.

INCIDENTS IN THE HISTORY OF THE GEOLOGICAL SURVEY OF ARKANSAS, and SOME CONCLUSIONS TO BE DRAWN THEREFROM.

By John C. Branner, Former State Geologist of Arkansas.

What I may here say stands in great need of indulgence, for my attachment to the people of Arkansas and my interest in the welfare of the state can scarcely turn round in the narrow space allotted to this brief paper.

Thirty-two years ago, I was appointed state geologist of Arkansas by Governor Simon P. Hughes and entered upon the duties of that office June 24, 1887. I was reappointed by Governor Eagle in 1889, and again in 1891, and held the office until 1893. During those six years the survey published eighteen volumes of reports, sixty maps, and 6,365 pages of text, at an expense to the state of about $100,000.

Though the work of the survey was far from complete when the organization was abolished by the legislature in 1893, and though some of the most important of its reports were never published, and still others were never even written, the people of the state seem to think the survey was well worth while, that it was instrumental in directing attention to the valuable mineral resources of the state, in bringing in the capital necessary to the development of several of these resources, and in increasing the value of the taxable property of the state.

At the request, therefore, of the editor of the Arkansas Gazette, I venture to offer the people of the state the benefit of a life's experience in dealing with mineral resources in various parts of the world, in order to point the way to further developments of the resources of Arkansas.

The success of a state geological survey depends upon the cooperation of what may be called two factors, or two sets of muscles. One of these is legislative, the other is executive. To put it differently, the state legislature must provide the laws and make the appropriations necessary for carrying on the work and for publishing the results, while the geologist must do the work and put his results in such shape as to make them available to the public. The first move must, therefore, come from some member or members of the state legislature who are willing and able to give their time and attention to the details of drawing up, introducing, and piloting the necessary bill or bills through the various committees and through both houses of the legislature.

Since the state survey was abolished in 1893 many attempts have been made to revive it, but these efforts have invariably failed, not for lack of cordial moral support, but simply because there was a general impression that such a bill would go through on account of its obvious value and importance. But it never did, and it never will go through in this way.

It is worth while recalling briefly in this connection the history of the former state geological surveys. The first geological survey of the state was made by Dr. David Dale Owen between 1857 and 1860, and Dr. Owen published two volumes of reports, a total of 687 pages. His work was well done and so far as it went, it was found to be perfectly trustworthy, and the cost to the state was $16,800.

In 1871-3 another survey was undertaken with W. F. Roberts, Sr., as state geologist, and George Haddock assistant geologist. The only publication made by these geologists was a pamphlet of 63 pages by George Haddock. The state's appropriation for the work was $15,000.

In 1873-4 the survey was continued under George Haddock, later under W. C. Hazeldine, and still later under Arnold Syberg. Their appropriations amounted to $19,628, but they made no report. It is to be noted regarding these surveys that they cover a period of seven years, that they cost the state $51,428 but that, with the exception of Dr. Owen's reports, the work was of no value. This fable teaches something worth keeping in mind in connection with state geological surveys.

There followed a period of thirteen years in which the state was entirely without a state geologist. In 1886 and 1887 there was great excitement through the western part of the state, especially in Garland and Montgomery counties, in regard to the supposed discovery of gold, and it seems quite probable that the excitement, misleading as it turned out to be, led to the provisions made by the legislature of 1887 for a new state survey. In any case the political credit for the geological work done in Arkansas between 1867 and 1893 belongs to Hon. Elias W. Rector of Hot Springs, a member of the lower house, who not only drew up the bill passed by the legislature of 1887 providing for the survey, but who guided every step of its way through the committees and through both houses.

In the legislature of 1889, and in spite of the most violent opposition from the so-called "gold miners" and from disappointed political hangers-on, Colonel Rector put through amendments that made the survey a permanent state institution, and provided much needed assistance. From the very outset Colonel Rector left nothing to chance or to general interests, but gave his undivided personal attention to the bills at every step of the way. When some one takes up the matter of a revival of the state survey in Arkansas with the same intelligence and the same enthusiasm, the matter will go through, but otherwise it never can and it never will.

While speaking of the indispensible work of the legislature, I venture to refer to a kind of opposition to such work not infrequently met with among its members. There is a natural and proper disposition among members of the legislature to look out for what are usually known as local interests. For example, a representative from the Mississippi river bottoms is liable to feel that his section of the state is not interested in the coal mines of Sebastian county, in the gas wells of Crawford county, in the chalk beds of Little river, or the bauxite beds of Saline and Pulaski. But in reality the interests of a state are as broad as the state itself, and it is as much the duty of the member from Chicot or Phillips county to support a state survey as it is for members from the mineral bearing counties to support the enterprises in which the river bottoms are more directly concerned.

Taking a broad view of such matters, they are all state questions, and deserve to be treated broadly, and with a view to dealing justly with every interest and with every person in the state. Like geology itself, the political problem is a large one, and it needs to be dealt with in a large way.

The executive part of the geological work necessarily rests chiefly in the hands of the state geologist. It goes without saying that he should be a man

THE LATE DOCTOR A. H. PURDUE,
Former State Geologist of Arkansas and at the time of his death State Geologist of Tennessee.

of proper scientific training, of sound judgment, and of upright principles. When given the necessary funds to carry on his work, he should be allowed to do that work in his own way, but he should also be given the cordial moral and official support to which his position entitles him. For one of his first duties is to protect the legitimate interests and the good name of the state itself, and to do that effectively he must have the backing of those who are in a position to give it to him.

When, after careful examination, it was found by the geological survey in 1888 that the hundreds of so-called gold mines of Montgomery and Garland counties were mostly worthless, or even fraudulent, the results were reported to Governor Hughes. It was as disagreeable a piece of work as ever falls to the lot of a governor or a state geologist. Did Governor Hughes hesitate about what was to be done? Not the slightest. He simply asked: "Are you sure of the correctness of your conclusions?" "I am," said I "Then go ahead and publish them; I'll back you," said he, and he did back me against companies and interests capitalized for more than a hundred and thirteen millions of dollars!

Some accounts of these matters were published in the Arkansas Gazette of August 9, 1888, and up to the end of October of that year, and in the Engineering and Mining Journal of New York for August 18 and for October 20, 1888.

But back of the governor and back of the legislature, the people must support their own representatives and their own geologists. To that end they should be reminded that they cannot have the benefit of science without paying for it, any more than they can raise a crop without planting the necessary seed and looking after it. And it is especially important that the work be so done that it will benefit the land owners and the public rather than that it be done for the benefit of a few individuals.

The farmers naturally ask what they are to get out of appropriations for geology, and they are apt to be impatient of the hard words and queer ways of the geologists. One of my assistants, on meeting a farmer on the wooded slopes of the Boston Mountains, was asked by him if he had found any "mineral." The assistant told him quite truthfully that he was not looking for "mineral." The farmer felt not only amazed, but wronged, and asked pointedly: "Well, if you are not looking for mineral, what in blank are you looking for?" Such a question is perfectly frank and honest, and it is entitled to an equally frank and honest answer, which is easily given. The scientific methods used by the geologist do not always permit him to approach his problem directly. Even a man who goes fishing has to spend some of his time in the indirect occupation of finding bait.

The farmers have so often been the victims of selfishness that they are naturally suspicious of devices for getting big state appropriations from which they receive little or no benefit. They are rarely interested in those intangible mineral resources so much talked about in connection with a geological survey, and from which they receive little or no direct benefit; but unfortunately their very suspicions have been turned to their own disadvantage, and to the disadvantage of the entire state in this matter of a geological survey. In many places in Arkansas agricultural lands were found by the state geologist to be of great value for the coal beneath them. In many cases these lands that were worth many thousands of dollars an acre on account of the coal, were sold for ten to twenty dollars an acre because the report of the state geologist on coal was never published. Prospective buyers of such lands put their own experts in the field to ascertain the distribution of the coal, while they (the buyers) joined in the farmers' chorus for economy in state expenditures, and so kept from being published the state report that would have shown the farmers the value of their own lands which they were readily persuaded to sell for a small fraction of their real value.

The duties of the state geologist cannot all be set down in black and white. Some of them are obvious enough, but others are not so easily defined. But too much should not be expected of him.

A geologist cannot find resources that do not exist; he can only point them out when and where they do exist. But while he must devote himself to a broad study, and to the setting forth of the state's available resources, he must necessarily do a good deal of what may be termed dead work, or work of negative value. For it is quite as much his duty to determine what the state has not as it is to determine what it does have. He should also be wise enough to keep the organization and work of the survey out of politics and out of religion, for the day he is expected to provide a position on the survey for any one for any reason besides his fitness to do the work of the survey, the value of the work will begin to decline.

With a single exception the young men who served as assistants during my term of office as state geologist were chosen solely because they were capable of doing the work required of them. That one exception was a political roustabout who was taken on faith, and who was permitted to depart in peace when he was found unable to do his work. Later he came to me for subscriptions to political campaign funds, and when I explained that I was in science, not in politics, he endeavored to prevent my reappointment by Governor Eagle on the ground that I was politically off color. The governor frankly spoke to me about it, but when I told him I didn't know the political opinion of a single man on the survey, and that I was there solely as a geologist, he renewed the appointment without further question.

As a matter of fact I had nothing to fear on the score of politics, but no self-respecting geologist could afford to have his assistants dismissed for views that had no direct bearing on the work they were doing for the state, nor could the state geologist maintain his self-respect or his scientific standing if he had to watch the political skies when there was so much work to be done under his feet.

The question is often asked whether the geological survey of the state should be revived. Some people think the mineral resources of the state can take care of themselves, and that the people's money should not be spent on work that private enterprises and corporations would be glad to do at their own expense. Those who hold such views are both right and wrong; a sharp line is to be drawn between doing work to help private parties and work to help the state in a broad sense.

As a rule capital is disposed to hesitate about investing in a state where there is no information available about its resources, and no way to find out about them except by the expenditure of its own funds. If a state wants to borrow money, it knows that it must open up its books, and if it wants to interest capital in mines or in mineral resources, it must open up its geology. The private corporation that can send its own experts into the field and ascertain the values of lands justly regards the information thus gained as its own private property, and the valuable lands may be bought up without the owners knowing or suspecting what they are disposing of. But when such work is done by the state geologist, the results belong to the state, and the owners of the lands get the benefit of work that they could not afford to have done at their own expense. It is also worth remembering that if a state has mineral resources and doesn't take the trouble to ascertain their extent and importance, the rest of the world is justified in concluding that they are without importance.

The idea that one can advertise what he has, or even what he has not, if he will only shout loud enough and use ink enough, is no longer true of mineral resources. The people of Arkansas have had enough experience of bogus mines to know that precise measurements and exact data are worth vastly more than black-face type and questionable generalizations. And it is hoped that the people will realize that the sound and abundant seed they plant today will bear sound and abundant fruit for many generations to come. If they plant not, neither shall they reap.

Stanford University, California, September 3, 1919.

GEOLOGY AND GENERAL TOPOGRAPHIC FEATURES OF ARKANSAS.

By Hugh D. Miser

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TOPOGRAPHY.

The topographic features of Arkansas reveal considerable diversity and may be grouped into several natural divisions which are briefly described below.

A line passing from a point near the northeast corner of the State in a general southwesterly direction through Little Rock to Arkadelphia, Clark County, and thence nearly due west through De Queen, Sevier County, divides the State into nearly equal parts or halves. The southeast half of the State is a comparatively low plain which is a part of a broad belt of country known as the Gulf Coastal Plain. This plain in Arkansas ranges in elevation from 100 to 700 feet above sea level and is divisible into a series of rolling uplands, lying 200 to 700 feet above sea level, and a series of nearly level to gently rolling valleys and lowlands lying 100 to 300 feet above sea level. Both the uplands and lowlands have a gentle southward slope. Crowleys Ridge is the most prominent physiographic feature in the northeastern part of the State. It is one-half to 12 miles wide and extends from Helena, Phillips County, northward into Missouri, though it is cut in two by gaps at some places. The crest of the ridge is 400 feet above sea level near Helena but it gradually rises northward and is 500 feet above sea level in Clay County.

Most of the northwest half of the State is comparatively elevated, and is divided by the Arkansas River Valley into the Ozark region (including the Boston Mountains) on the north and the Ouachita Mountain region on the south.

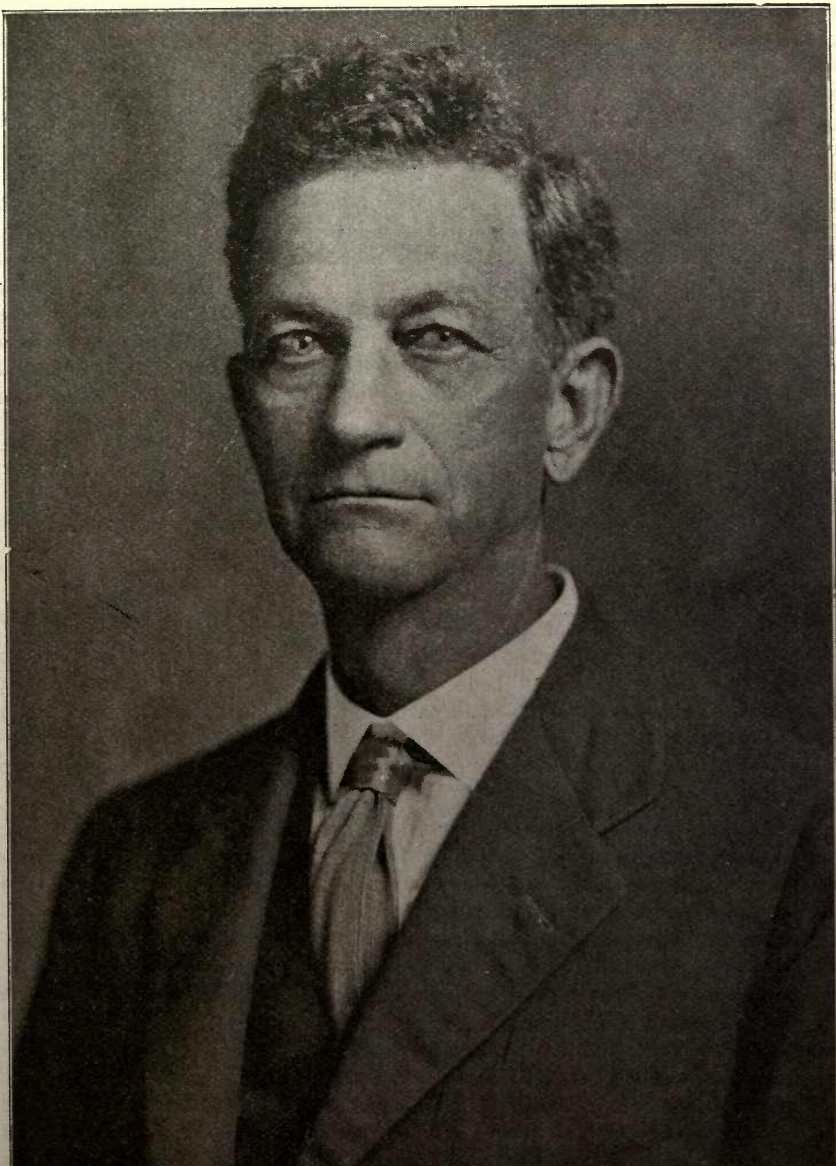
The part of the Ozark region lying north of the Boston Mountains is known as the Ozark Plateau and occupies a belt, about 40 miles wide, along the northern border of the State. This belt is made up of two plateaus. The lowest one of these—the Salem Plateau—is in Ordovician rocks and presents an exceedingly rough topography. It forms a triangle whose apex is near Newport, Jackson County, and whose base lies on the Missouri-Arkansas line from Boone County to the east end of Randolph County, but the basin-like area in which Berryville, Carroll County, is situated is also a part of this plateau.

The next higher plateau, known as the Springfield Plateau, is formed by resistant cherty rocks of Mississippian age, and lies between the above-indicated triangle and the north-facing escarpment of the Boston Mountains. It is separated from the lower plateau by a sinuous escarpment which attains a height of 400 feet near Eureka Springs, Carroll County. Much of this pleateau is a gently rolling country but large parts of it are cut by numerous canyon-like valleys. Most of its surface stands between 1,000 and 1,500 feet above sea level.

The Boston Mountains overlook the Springfield Plateau from an irregular north-facing escarpment 500 to 700 feet in height and many outlying peaks of these mountains stand out on the Springfield Plateau. Most of the southern slope of the mountains is less precipitous and passes off gradually into the Arkansas Valley, though at many places it is marked by abrupt descents and is broken by steep-sided canyon-like valleys. This mountainous region has an average width north and south of about 35 miles, and extends east and west a distance of approximately 200 miles, from the valley of Neosho (Grand) River in Oklahoma eastward to the Coastal Plain near Batesville, Ark. The mountain tops form a greatly dissected tableland, which rises 2,200 feet above sea level and 1,700 feet or more above the flood plain of Arkansas River, though a few remnants along the north side stand 2,300 to 2,400 feet above sea level. The mountains are rather rugged and have steep slopes and sharp projecting spurs separated by narrow ravines, 500 to 1,400 feet deep. The slopes are broken at many places by vertical or nearly vertical cliffs, which are due to the alternation of hard and soft beds of rock. Some of the cliffs are more than 100 feet high.

The Arkansas Valley is 30 to 40 miles wide and extends from the vicinity of Little Rock westward into Oklahoma. It is a nearly level plain, most of which is between 300 and 600 feet above sea level; but rising above it there are a great many ridges and several mountains with a nearly east-west trend. Among the mountains are Sugarloaf, Poteau, Petit Jean, Magazine, Whiteoak, and Big Rock mountains and Maumelle Pinnacle. Of these Magazine Mountain, standing 2,823 feet above sea level and 2,300 feet above the surrounding country, is the highest and is also the highest mountain in Arkansas. The statement is made on page 551 of the Encyclopedia Britannica (Eleventh edition, 1910)) that this mountain is the "highest point between the Alleghenies and the Rockies." A still higher point, as shown on the Winding Stair topographic map of the United States Geological Survey, is the west end of Rich Mountain near Page, Leflore County, Oklahoma; it is between 2,850 and 2,900 feet above sea level.

The Ouachita Mountain region is 50 to 60 miles wide and extends from the vicinity of Little Rock westward into Oklahoma. It is composed of numerous, nearly east-west ridges, several intermontane basins, and a dissected piedmont plateau, 15 miles wide, along its southern border. The ridges are narrow and parallel and have steep slopes and sharp straight even crests. Just west of Little Rock they are low, scarcely exceeding 750 feet above sea level or more than 250 feet above the valleys, but they gradually increase in height to the west and on the western border of the State near Mena, Polk County, some of the highest ridges attain an elevation of 2,750 to 2,800 feet above sea level or about 1,750 feet above the valleys. The intermontane basins are wide valley areas whose upland surfaces range from about 500 to 1250 feet above sea level, being lowest at the east end



DOCTOR N. F. DRAKE,
State Geologist of Arkansas.

of the region and highest near the west border of the state, and they are channeled by both deep and shallow valleys. Mena, in Polk County, Mount Ida, in Montgomery County and the southern part of the city of Hot Springs are located in such basins. The piedmont plateau is known as the Athens plateau, receiving its name from Athens, Howard County. It occupies a belt of country about 15 miles wide, lying between the Ouachita mountains on the north and the Coastal Plain on the south, and extending from near Arkadelphia, Clark County, westward into Oklahoma. When the plateau is viewed from the crests of the mountains to the north is appears to be a practically level plain ending abruptly against the mountains, but when it is crossed very little level country is found; the rest is greatly dissected by narrow crooked valleys of southward-flowing trunk streams and by numerous east-west valleys of small tributary streams. The upland surface of this plateau ranges from 400 to 1,100 feet above sea level, being lowest at its east end and along its south side, and highest on the north side in Pike, Howard, and Polk counties.

GEOLOGY

GENERAL FEATURES.

The several natural divisions of the State differ considerably not only in their surface features but in the character and age of their rocks.

The exposed rocks of the Ozark region consist chiefly of dolomites, limestones, cherts, sandstones, and shales, ranging in age from Ordovician to Pennsylvanian. The rock beds, though lying nearly flat, have a slight southward dip which is disguised in parts of the region by minor folding and by a considerable, though not large, number of faults. The youngest formations of the region occupy the summits of the Boston Mountains and dip southward from these mountains to the Arkansas Valley.

The rocks in the Ouachita Mountain region are all of sedimentary origin with the exception of two small areas of igneous rocks and their associated dikes. One of these areas is at Magnet Cove, Hot Spring County, and the other at Potash Sulphur Springs, Garland County. The igneous rocks are nephelite syenites and related types and were intruded into the sedimentary strata late in the Lower Cretaceous epoch or early in the Upper Cretaceous epoch. Some of the igneous dikes at and near Klondike, Saline County, have been decomposed to a soft earth to a depth of about 200 feet below the surface, and this earth is being mined and marketed as fuller's earth. The sedimentary rocks consist chiefly of cherts, shales, sandstones, and novaculites; they are 24,000 feet or more thick; and they range in age from Cambrian to Pennsylvanian. At or near the close of the Pennsylvanian epoch they were subjected to intense lateral compression movements which have produced numerous parallel, closely compressed, nearly east-west folds and a considerable number of faults. As a result of these movements the strata at most places dip at angles of 40° or more from the horizontal. The structure of the region, taken as a whole, is that of a vast compound anticline, which is known to geologists as an anticlinorium. The principal anticline extends from near Little Rock to the vicinity of Mena. In general the oldest strata are exposed near the middle of this anticline and the youngest northward and southward therefrom, but, on account of the deformation of the strata by folding and faulting much alternation of older and younger beds is found everywhere in going in a northward or southward direction across the region.

The Arkansas Valley lies between the southward monoclinal slope of the Boston Mountains to the north and the uplift or anticlinorium of the Ouachita region to the south and is thus a synclinal trough. The rocks of the valley consist of 24,000 feet or more of sandstones and shales which contain workable beds of coal over much of its western part. They are of Pennsylvanian age, though some of the oldest rocks exposed on the south side of the valley are probably of Mississippian age. The strata like those in the Ouachita Mountain region, were compressed at or near the close of the Pennsylvanian epoch into east-west folds and have been faulted to some extent, but the folding has been less intense than that in the Ouachita region. The anticlines are generally narrower and steeper than the synclines; there is a tendency for the anticlines to be steeper on their north sides; and the folding becomes more gentle toward the north. The structure bears a close relation to the topography, the long narrow ridges indicating moderately to highly inclined rocks. Buttelike mountains, such as Poteau, Sugarloaf, and Magazine mountains, indicate practically horizontal rocks in synclinal basins.

The sedimentary strata underlying the surface of the Gulf Coastal Plain are chiefly clays, marls, sands, and gravels, and are of Lower Cretaceous, Upper Cretaceous, Tertiary, and Quaternary ages. They lie in a nearly horizontal position, though they have a general dip of 100 feet or less to the mile to the south and southeast. They were deposited upon a fairly smooth floor of Paleozoic rocks. This floor has been reached in deep wells at Nashville, Howard County, and at other places near the northwestern border of the Coastal Plain, but over most of the southeast half of the State it has been so deeply buried that it has not been reached in wells. The Cretaceous and younger strata overlying it along the east border of the State are more than 2,500 feet thick and those along the south border are more than 3,000 feet thick.

Intrusive igneous rocks occur in the Coastal Plain on and near Fourche Mountain, which is a few miles south of Little Rock, and in small areas near Bryant and Bauxite in Saline County. They consist of pulaskite ("blue granite") and nephelite syenite ("gray granite") and several other related varieties of rock. Associated with the igneous rocks and with the adjacent Tertiary sediments are important deposits of bauxite, the chief ore of aluminum. Other igneous rocks, known as peridotite, occur in four small areas near Murfreesboro, Pike County. The largest of these, so far as known, contains about 75 acres. Much of the peridotite has been decomposed to earth and soft rock to a depth of 200 feet or more, and in this earth and soft rock diamonds have been found. The igneous rocks in the Coastal Plain, like those in the Ouachita Mountain region, were intruded late in the Lower Cretaceous epoch or early in the Upper Cretaceous epoch.

The sedimentary rocks of Arkansas have been carefully studied over much of the State and have been grouped into numerous formations to which names have been applied. By means of the fossils in them, and by the determination of the relations of the strata one to the other, they are assigned to the different geologic systems and series. Some rock formations in the State contain no fossils, so that their age assignment is dependent entirely upon their relations to overlying and underlying rocks whose ages have been determined by means of fossils. There are many minor and major unconformities that break the succession of the rocks; and on account of the geologic events that produced the unconformities many rock formations thin out and are absent over large and small areas. The rocks in each of the natural divisions of the State are briefly described below in the order of their age, with the oldest first and the youngest last.

OZARK REGION.

ORDOVICIAN SYSTEM.

Jefferson City dolomite.—The Jefferson City dolomite is exposed in the northeastern part of Marion County and in other counties farther east, and so far as known is the oldest exposed formation in northern Arkansas. It consists of at least 300 or 400 feet of gray dolomite and chert, in which a few fossils have been found.

Cotter dolomite.—The Cotter dolomite, 500 feet or more thick, is exposed over large areas in many counties in the northern part of the State, but has been studied in greater detail west of Baxter County than it has east of that county. The thickest outcrops are in northern Boone County and other counties farther east. Berryville, Carroll County, and Cotter, Baxter County, from which the formation takes its name, are situated on the dolomite. The formation consists mainly of two kinds of dolomite—a fine-grained earthy, white to buff or gray variety known as "cotton rock," and a more massive medium-grained gray variety whose weathered surfaces are rough and dark. Besides dolomite it contains chert that is sparingly fossiliferous and also contains thin layers of sandstone and shale.

Building stone is quarried from the formation near Beaver, Carroll County. It is compact gray magnesian limestone or dolomite, in beds from 2 to 4 feet thick. The best beds afford durable building stone of pleasing color.

Powell limestone.—The Powell limestone, 0 to 200 feet thick, is widely exposed in Benton, Carroll, Boone, Marion, Newton, and probably other counties farther east, but is absent at some places in the counties here named. It is a fine-grained gray or greenish-gray magnesian limestone, usually free from fossils, but there are a few thin beds of green shale and at some places there is a conglomerate at the base. The name of the formation was taken from the abandoned station of Powell, a short distance southeast of Pyatt, Marion County.

Everton limestone.—The Everton limestone, 0 to 205 feet thick, is widely exposed in Benton, Carroll, Madison, Boone, Newton, Marion, and Searcy counties, and probably others farther east. It is thickest in Boone, Newton, and Marion counties and thins to the north, west, and east. It takes its name from Everton, Boone County, where it is well exposed. The upper part of the formation is 115 feet or less thick and is composed of massive compact dove-colored limestone and some friable white sandstone, but in Marion County much of the limestone contains enough magnesium for it to be classed as a dolomite. The limestone that is free from magnesium is suitable for making lime. The middle part of the formation is a white friable sandstone in massive beds and is known as the Kings River sandstone member, receiving its name from Kings River in Carroll and Madison counties. The sandstone at places is as much as 40 feet thick and is well suited for the manufacture of plate and ordinary glass. The lower part of the formation is a sandy compact dark-drab magnesian limestone, known as the Sneeds limestone lentil, and varies in thickness from a feather edge to 50 feet. It is not as widely distributed as the middle and upper parts of the Everton. The known exposures are in Marion and Newton counties. The limestone receives its name from Sneeds Creek, in Newton County, on which it is exposed.

St. Peter sandstone.—The St. Peter sandstone—a formation which is widely distributed in the upper Mississippi Valley—is exposed over large areas in Carroll County and most of the other counties farther east. It and the Kings River sandstone member of the Everton limestone are described in the reports of the Arkansas Geological Survey as "saccharoidal sandstone." It is massive and friable, is white or cream colored, and varies in thickness from a feather edge to 200 feet, being thickest to the south and east. It is being quarried for glass sand at Guion, Izard County. Outcrops of this sandstone occur in many of the picturesque bluffs along Buffalo and White Rivers.

Joachim limestone.—The Joachim limestone, 0 to 150 feet thick, is exposed in Newton County and all of the counties between it and Lawrence County. It thins to the north and west and is therefore thickest in its most eastern and southern outcrops. It is a drab-colored fine-grained, sparingly fossiliferous magnesian limestone, and at many places it is sandy and contains thin beds of sandstone which usually occur near the base.

Jasper limestone.—The Jasper limestone, 0 to 50 feet thick, is present, so far as known, only in Newton County. It takes its name from Jasper, the county seat, near which most of the exposures occur. It is a compact bluish-gray, slightly fossiliferous limestone suitable for making lime, and it affords a beautiful and durable building stone, as is shown by buildings at Jasper that were constructed with it. A bed of white sandstone, 8 to 20 feet thick, is at the base and at some places there are thinner beds of similar sandstone that are interbedded with the limestone.

Plattin limestone.—The Plattin limestone, 0 to 240 feet thick, is exposed over large areas which comprise parts of Sharp, Independence, Izard, Stone, and Searcy counties, and is thickest in the counties to the east. It is a massive, even-bedded dove-colored or grayish-blue limestone which is comparatively free from fossils and it breaks with a conchoidal fracture. It has been quarried at places for building stone and for making lime, for which it is well suited. Certain layers of the limestone are so fine grained as to suggest that they are lithographic stone of good quality and considerable prospecting has been done for such stone but the search for commercial quantities of it has not been successful. The most promising locality is on West Lafferty Creek in Izard County.

In practically all of the geologic reports on Arkansas the Plattin limestone has been described as the "Izard limestone," but the "Izard," as it was defined, included not only the Plattin but also the Joachim limestone, which has been described above. The Jasper limestone which overlies the Joachim limestone in Newton County was also included in the "Izard limestone," but it is absent in Izard County, from which the "Izard limestone" was named.

Kimmswick limestone.—The Kimmswick limestone, 0 to 55 feet thick, is exposed in Independence, Izard, and Stone counties and so far as known is absent farther west. It is an even-bedded massive light-gray fine-grained slightly fossiliferous limestone, but at places it is coarse grained and at some places its uppermost beds are compact and grayish blue, thus resembling the bulk of the Plattin limestone. Thin lenses and nodules of chert are present at many places but are not sufficiently numerous to prohibit the use of most of the limestone for making lime for which it is probably suitable.

The Kimmswick limestone constituted the lower part of "Polk Bayou limestone" of many of the geologic reports on northern Arkansas, whereas the Fernvale limestone, which overlies the Kimmswick, constituted the upper part of the "Polk Bayou limestone." In some of the earliest reports the Kimmswick limestone was included in what was then called the St. Clair limestone.

Fernvale limestone.—The Fernvale limestone, 0 to 125 feet thick, is exposed over large areas in Independence, Izard, and Stone counties; small outcrops occur near St. Joe, Searcy County; and one small outcrop is on Little Buffalo River, a mile northeast of Jasper. The greatest thickness of the limestone given above is in Penters Bluff near Penters Bluff station, in Izard County, but the usual thickness at other places in the Batesville manganese district, in which Penters Bluff occurs, is about 100 feet. This limestone is coarse grained, massive, cross bedded, and fossiliferous, is dark gray and pinkish gray in color, and would make a valuable building stone. Deposits of manganese ore occur in the Fernvale limestone and in its residual clays in the Batesville manganese district, which comprises parts of Sharp, Izard, and Independence counties, and they have been worked much of the time since 1849.

The Fernvale limestone was included in the so-called St. Clair limestone of some of the earlier geologic reports on northern Arkansas, also in the so-called "St. Clair marble" of some of the reports, and in the upper part of the "Polk Bayou limestone" of the more recent reports. It was first identified by E. O. Ulrich as being the same as the Fernvale limestone of middle Tennessee.

Cason shale.—The Cason shale, 0 to 21 feet thick, is present in comparatively small areas. The largest of these are in Independence, Izard, and Stone counties, but small outcrops occur near Duff, Searcy County, and Jasper, Newton County. It consists of greenish-gray calcareous shale and smaller amounts of sandstone and phosphate, and besides these it contains manganese and iron minerals. Phosphate is widely distributed in the shale and has been mined at a few places near the abandoned village of Phosphate in Independence County. The mines have, however, not been worked for several years. At several places in the Batesville district—notably the Cason mine 3 miles north-northeast of Batesville—parts of the shale contain a large enough quantity of manganese oxides for such parts of the shale to be mixed and shipped as a low-grade manganese ore. The residual clays of the shale also contain workable quantities of manganese ore. Fossils in the Cason shale have been found at very few localities.

SILURIAN SYSTEM.

Brassfield limestone.—The Brassfield limestone so far as known is present at only a few places; these occur between Duff and Tomahawk, Searcy County, where it is several feet thick, but fossils that have been derived from it through weathering occur in residual clays at the Montgomery mine, 5 miles east-northeast of Cushman, Independence County. It is a granular, light-gray fossiliferous limestone and contains a small amount of glauconite. This limestone has heretofore been included in the St. Clair limestone but its lithology, fossils, and stratigraphic relations show that it is of the same age as the Brassfield limestone of Kentucky and Tennessee.

St. Clair limestone.—The typical St. Clair limestone, 0 to 100 feet thick, is exposed at many places in Independence, Izard, and Stone counties. It is a coarse-grained pinkish light-gray, highly fossiliferous limestone and much of it would make a valuable building stone. The greatest thickness, 100 feet, is at the Cason mine.

Lafferty limestone.—The Lafferty limestone, 0 to 85 feet thick, is a thin-bedded compact earthy, sparingly fossiliferous limestone, of which the upper part is gray in color and the lower part red. The only known occurrence is an exposure 1¼ miles north of Penters Bluff station in Izard County. The name of the limestone is taken from West Lafferty Creek which is half a mile east of the exposure.

DEVONIAN SYSTEM.

Penters chert.—The Penters chert, 0 to 91 feet thick, is exposed within two small areas in Independence County, one being near Pfeiffer and the other near Penters Bluff station from which the formation takes its name. It is a compact gray and bluish chert, though the upper part is dark colored at places. No fossils have been discovered in the chert but its lithology and stratigraphic relations indicate that it is of the same age as the Camden chert of west-central Tennessee and the lower part of the Arkansas novaculite of west-central Arkansas and southeastern Oklahoma. The Camden chert, as shown by fossils, is equivalent in age to at least a part of the Oriskany group of the Northern Appalachian region.

The Penters chert has heretofore been considered to be a part of the Boone chert, which is described later.

Clifty limestone.—The only exposure of the Clifty limestone in northern Arkansas is on the East Fork of the Little Clifty Creek in the southeast corner of Benton County. It is a sandy compact light bluish-gray fossiliferous limestone and the greatest thickness that has been observed is 2½ feet.

Chattanooga shale.—The Chattanooga shale is exposed in Washington, Benton, Carroll, Madison, Searcy, and Independence counties. It is either absent or not exposed in the other counties in northern Arkansas. It is a coal black clay shale that splits into thin plates and slabs and gives off the odor of petroleum when struck with a hammer. It is thickest near the western border of the State, where it attains a thickness of 70 feet. The shale is generally underlain by a white to brown sandstone, 0 to 75 feet thick, known as the Sylamore sandstone member, which is also thickest in the western part of the State. At some places the sandstone contains chert pebbles and at some places it is phosphatic.

The Chattanooga shale in the reports of the Arkansas Geological Survey is called "Eureka shale."

CARBONIFEROUS SYSTEM.

Mississippian Series

Boone formation.—The Boone formation, 250 to 400 feet thick, consists in the main of a series of cherty fossiliferous limestones and cherts that has been known as the Boone chert, a name given to the series on account of its wide distribution in Boone County. Below these over a large area in the northern part of the State lies the St. Joe limestone member of the formation, a well-marked bed of gray or pink crystalline limestone, which is the basal Carboniferous bed. It is easily recognized by its color, texture, and its marked contrast with the beds that usually underlie it. This limestone ranges in thickness from a feather edge to 100 feet and forms an almost unbroken, though very sinuous outcrop from the vicinity of Mountain View, Stone County, to the State line near Seligman, Mo., and is exposed in all of the counties between that county and the western boundary of the State.

Where the cherts are interbedded with much limestone they form, on decay, a fertile soil, such as is found over large areas in Boone, Benton, Washington, and Madison counties. When comparatively free from limestone beds the soil is generally too meager for agriculture and forms the "flint hills" of central Independence County, of western Carroll and northern Madison counties and the watersheds north of Marshall and southwest of Rush Creek, in Marion County, and the hilltops about Elixir Springs, Boone County, and Doddsville, Marion County.

The Boone formation affords an abundance of fractured loose chert on the hillslopes, suitable for road building. The limestone in it is used for building stone and for making lime. A quarry at Pfeiffer, Independence County, is producing a high grade of ornamental limestone.

Moorefield shale.—In the vicinity of Batesville there is a bed of shale lying on the Boone formation. It is well exposed around Moorefield, from which place it is named. At and near Batesville it varies in thickness from less than 100 to more than 250 feet. To the west, at Marshall, it is not over 35 feet thick, and evidently it does not extend much farther westward. The shale has a light grayish or bluish color and is very friable. In places it is sandy. A fossiliferous limy phase, several feet thick, at its base has been called "Spring Creek limestone."

Batesville sandstone.—The Batesville sandstone, 0 to 200 feet thick, is so named from the town of Batesville which is built on it. The sandstone is present along the base of the slopes of the isolated hills and mountains north of the Boston Mountains escarpment, in Independence, Stone, Searcy, Newton, Boone, Carroll, Madison, Washington, and Benton counties. It is thickest in its most eastern exposures. The rock is coarse grained, cream-colored to brown, often false bedded, and in some places contains beds of shale interstratified with sandstone. A light sandy soil results from its disintegration. It serves as an excellent reservoir, for the wells that penetrate it usually find in it an abundance of good soft water.

In the part of the State west of Harrison, Boone County, the sandstone is generally underlain by a limestone, 0 to 50 feet thick, known as the Hindsville limestone member. The greatest areal exposure of the member is near Hindsville, Madison County, from which it was named. The limestone is gray, fossiliferous, and oolitic, is interbedded with thin beds of sandstone, and includes at its base a chert-pebble conglomerate. It is suitable for building stone and for making lime. The limestone for the columns at the front entrance of the main building of the University of Arkansas, at Fayetteville, was quarried from this limestone on Brush Creek near Hindsville.

Fayetteville shale.—The Fayetteville shale, 10 to 400 feet thick, consists principally of black or dark-gray carboneous shale, at many places thinly laminated, and in general is thickest to the south. Near its base there is generally a thin bed of hard, dark gray or blue fossiliferous limestone, while its middle part commonly grades from a sandy shale to a true sandstone, and where the sandstone phase predominates this portion of the formation is distinguished as the Wedington sandstone member. The shale is well developed in the valley of West Fork of White River near Fayetteville, from which town it is named, and the Wedington sandstone member is particularly prominent southwest of Fayetteville, in Wedington Mountain, where it attains a thickness of 150 feet—perhaps one-half the total thickness of the formation there. The softness of the shale causes it to erode so easily that its outcrop is usually marked by a valley, or by steep slopes. Where exposed, the shale disintegrates readily and forms a black and fertile soil. The composition of the unweathered shale renders it suitable material for brick making. The shale beds are practically constant from the Oklahoma line to the Gulf Coastal Plain near Batesville, but the sandstone thins out at places.

Pitkin limestone.—The Pitkin limestone, 0 to 100 feet thick, is widely distributed over northern Arkansas, extending along the north side of the Boston Mountains from Independence County to the western boundary of the State. It thins out to the north and is generally thickest in its most southern outcrops. It is exposed along the north face of these mountains and on many of their outliers and in some places it forms a prominent escarpment. It is also exposed on the south side of the Boston Mountains in Franklin, Johnson, and Newton counties. It is composed of massive gray fossiliferous limestone, parts of which are probably pure enough for making lime. In the reports of the Arkansas Geological Survey it is known as the "Archimedes limestone," because of the presence of **Archimedes**, an easily recognized bryozoan, the screwlike stems of which are common on the weathered surface of the rock.

Pennsylvanian Series

Morrow group.—Under the name Morrow group are included several beds of limestone, sandstone, and shale, which vary much in thickness, arrangement, and character, and are of but little topographic prominence. They lie just below the sandstone of the "Millstone grit" of the Arkansas Geological Survey, and, as a rule, form the middle part of the northern escarpment of the Boston Mountains. South of Batesville, near Jamestown, these beds have a total thickness of about 200 feet, while at places farther west they are about 400 feet thick.

To the lower part of the group the name Hale formation has been applied, and to the upper part the name Bloyd shale has been applied. The Hale formation is composed of conglomerate, sandstone, limestone, and shale, and is known to vary in thickness from 80 to 300 feet. The Bloyd shale is composed mainly of black clay shale, but partly of limestone which occurs in two beds, the upper being known as the Kessler limestone member and the lower the Brentwood limestone member. The shale is about 200 feet thick in southern Washington County and northern Crawford County but from this part of the State it thins to the north and east and is known to be absent in parts of Madison, Carroll, Boone, and Newton counties.

A coal bed, as much as 14 inches thick occurs in the Bloyd shale in Washington County and has been worked on a small scale.

Winslow formation.—The Winslow formation makes the summit and southern slopes of the Boston Mountains, except in the deeper ravines where older rocks have been exposed. Rocks of this formation also occur on the tops of the outliers immediately north of the Boston Mountains.

The formation consists of beds of sandstone and shale, with a few thin local layers of limestone. The sandstone beds range in thickness from 3 feet to more than 50 feet. One of these beds, and in places two, near the base of the formation, are conglomeratic, containing waterworn quartz pebbles of small size and form prominent bluffs along the mountain slopes. These gritty beds at and near the base of the Winslow formation were described by the Arkansas Geological Survey in the report on Washington County as the "Millstone grit." The shales, which constitute probably 75 per cent of the formation, are as a rule black and carbonaceous, though less so than the shales of the Morrow group. Coal occurs within this formation but only in beds too thin to be profitably worked. The Winslow formation in the Boston Mountain region extends up to the base of the series of rocks that contain the workable coal beds in the Arkansas coal field. Its total thickness in the southern part of the region where it is greatest is estimated to be more than 1,500 feet.

OUACHITA MOUNTAIN REGION.

CAMBRIAN SYSTEM.

Collier shale.—The Collier shale is exposed in a nearly east-west valley area, 1 to 3 miles wide and about 15 miles long, lying between Womble and Mount Ida, Montgomery County. The entire thickness of the formation is not known as the base is not revealed, but the exposed beds are probably at least 500 feet thick. The formation is composed mostly of bluish-black soft graphitic, intensely crumpled clay shale, but contains some bluish-gray or black limestone and a few thin layers of dark chert. No fossils have been found in the formation. Very little or none of the limestone is suitable for making lime, and none of it is suitable for building stone on account of the fractured condition of the limestone and the occurrence of quartz and calcite veins in it.

ORDOVICIAN SYSTEM.

Crystal Mountain sandstone.—The Crystal Mountain sandstone, 850 feet thick, crops out in Montgomery County and produces high rugged ridges which extend westward from the vicinity of Crystal Springs to a point about 15 miles west of Mount Ida. A group of these ridges south of Mount Ida is known as the Crystal Mountains and from them the sandstone takes its name. The formation is composed of coarse-grained massive gray to brown sandstone but at the base there is a conglomerate with limestone and chert pebbles that have been derived from the Collier shale. Clusters of quartz crystals are found in fissures at numerous places and many are sold at Hot Springs, Garland County, for museum specimens and for use as ornaments. The sandstone is used as a building stone at Mount Ida.

The formation has not yielded any fossils but, for reasons which can not be presented in this short paper, it is tentatively assigned to the Ordovician system.

Mazarn shale.—The Mazarn shale, 1,000 feet thick, takes its name from its occurrence on the headwaters of Mazarn Creek in Montgomery County. It is exposed at other places in this county and outcrops of it are known to extend as far east as Blakely Mountain in Garland County. The outcrops everywhere occur in valleys. The formation consists of shale and of small amounts of limestone and sandstone. The shale is ribboned, consisting of alternating black and green layers that split at an angle with the bedding. Fossil graptolites of Lower Ordovician age have been found at a few places.

Blakely sandstone.—The Blakely sandstone, 0 to 500 feet thick, consists of shale in alternating black and green layers and hard gray sandstone. The shale constitutes 75 per cent of the whole, but the sandstone, which produces high ridges, is the prominent feature. The ridges formed by this sandstone extend in an east-northeastward direction from Womble, Montgomery County, across Garland County, into Saline County. A group of these ridges in Garland County is known as Blakely Mountain and from it the sandstone has been named. The formation is absent at most places west of Womble and at probably all places north of that town. Graptolites of Lower Ordovician age have been found in shale in the formation in Blakely Mountain. Quartz crystals are found in fissures in the sandstone but they are not so numerous as they are in the Crystal Mountain sandstone.

Womble shale.—The Womble shale, 250 to 1,000 feet thick, is exposed in wide and narrow valley areas from the vicinity of Big Fork, Polk County, across Montgomery, Garland, and Saline counties, into Pulaski County. The name for it is taken from the town of Womble, part of which is situated on the base of the shale. The formation consists of black graphitic shale, with thin beds of sandstone near the base and beds of limestone near the top. The shale near the base is composed of black and green layers that split at an angle with the bedding and thus show ribboned cleavage surfaces. Graptolites of Lower Ordovician age are numerous. Some of the limestone has been used for making lime for local use, near Cedar Glades, Garland County, and Black Springs, Montgomery County.

Bigfork chert.—The Bigfork chert is exposed over large and small areas between Shady postoffice, Polk County, and Pulaski County, and in such areas it produces numerous low steep-sided knobs. The formation is estimated to be 700 feet thick in Garland County and other counties farther west, where it has been studied more extensively than elsewhere. It is composed of thin-bedded gray to black, much shattered chert interbedded with thin layers of black shale. The fossils that have been found consist mainly of graptolites. The chert is excellently adapted for road building and is being used for this purpose at Hot Springs.

Polk Creek shale.—The Polk Creek shale, 0 to 200 feet thick, is exposed on steep rocky slopes and in narrow valleys in close association with the outcrops of the Bigfork chert, and so far as known is absent in comparatively small areas. It is a black graphitic shale; in parts it is siliceous and in others clay shale. It has been prospected for roofing slate near Big Fork, Polk County, and near Washita, Montgomery County. Graptolites are abundant in the shale.

SILURIAN SYSTEM.

Blaylock sandstone.—The Blaylock sandstone is exposed in a small area near Bog Springs, Polk County, and in other, though not large. areas as far east as the vicinity of Malvern. Along some of its most southern outcrops it has an estimated thickness of 1,500 feet, but it thins so rapidly to the north that it is not present 3 or 4 miles north of the places where it has the above-estimated thickness. It is composed of fine-grained light-gray to dark-gray or green compact sandstone and buff to dark shale. Its areas of outcrop are very rocky, occurring on mountain slopes and in narrow valleys. One small collection of fossils, consisting entirely of graptolites, has been obtained at the south base of Blaylock Mountain, in the southwest corner of Montgomery County.

Missouri Mountain slate.—The Missouri Mountain slate, 0 to 300 feet thick, is exposed on or near high ridges from Polk County east to Pulaski County, but is absent at places near Mount Ida. It is a red and green clay slate but at places is dark colored. Thus far it has not yielded any fossils. It has been extensively prospected for commercial slate at several places near Hawes and Bear, Garland County, and at many places in Polk and Montgomery counties, and has been quarried for switchboards at Slatington in the last-named county.

DEVONIAN SYSTEM.

Arkansas novaculite.—The Arkansas novaculite is widely exposed in Polk County and the other counties between it and Pulaski County. It is exposed in more or less parallel and nearly eastward-trending belts, whose narrowness is due to the steep dips of the beds. Owing to the narrowness of these belts and to the greater resistance of the novaculite (a variety of chert) to weathering than the adjacent strata above and below, its outcrops stand up as sharp ridges, whereas both the older and younger rocks form valleys. Many rock ledges occur on the crests of the ridges and in the water gaps.

The formation is thickest in its southernmost outcrops, where the thickness at many if not at most places is about 900 feet, but it thins to the north and is absent at places near Mount Ida, and probably at other places. It has been studied more extensively in Garland and Hot Spring counties and the other counties farther west than elsewhere in the State. There it consists of three lithologic divisions—a lower one, made up almost entirely of massive white novaculite; a middle one, consisting mainly of thin layers of dense dark-colored novaculite interbedded with shale; and an upper one consisting chiefly of massive, highly calcareous novaculite. These divisions vary in thickness and character from place to place.

The lower division is commonly from 150 to 300 feet thick, though at some places the thickness is greater. It is made up almost wholly of typical novaculite, whose white color and massiveness make it the most conspicuous part of the formation. In fact, it is this part that usually occupies the crests of the ridges. The beds are from 2 to 10 feet thick and are commonly even bedded. The massive novaculite is usually dense, gritty, fine grained, homogeneous, highly siliceous, translucent on thin edges, and white with a bluish tint, but where unweathered it is bluish gray. It has an uneven to conchoidal fracture and a waxy luster like that of chaledony. Though the bulk of the rock is white, much of it varies in shades of red, gray, green, yellow, and brown, and in many places it is black. These shades are produced by iron and manganese oxides and possibly in some places by carbonaceous matter. The rock contains a little calcite, but exposures of the calcereous stone are not common and have been found only in stream beds. Joints are numerous and run in all directions, but the most prominent joints are normal to the bedding. Many of them are filled by white quartz veins which are usually so thin as to be inconspicuous. Slickensides along both joints and bedding planes are common.

The middle part of the formation consists chiefly of interbedded novaculite and shale. The novaculite is similar to that in the lower massive part of the formation, except that the common color is dark gray to black and that the beds are much thinner, usually between 1 inch and 6 inches thick. A conglomerate at the base of this division was observed at a number of places. It consists of small rounded and subangular pebbles of novaculite in a sandy and dense flinty matrix. The shale ordinarily observed is black, weathering to a buff or brown color, but some of it is red.

The upper part of the formation ranges from about 20 to 125 feet in thickness and is thickest along the southernmost exposures. It consists chiefly of massive, highly calcareous light-gray to bluish-black novaculite which is so resistent that at some places where it and the accompanying beds of the formation are not overturned it produces low ridges or knobs on the slopes of the higher ridges. Some thin beds of ordinary dense chalcedonic novaculite like that so characteristic of the middle and lower parts of the formation are also included. Fine lamination parallel with the bedding is common. On weathering, the more calcareous rock loses its calcium carbonate becomes white or cream-colored and porous and soft enough to receive impressions from the hammer without breaking.

Novaculite from the lower part of the formation is quarried on North Mountain, Indian Mountain, and near Summit, Garland County, for oil stones or whetstones. It is also quarried on North Mountain, Garland County, and near Butterfield, Hot Spring County, for use in concrete. Deposits of tripoli derived from the novaculite have been prospected near Caddo Gap, Montgomery County and near Langley, Pike County. Manganese oxides occur in the novaculite and much prospecting for manganese ore has been done in Pike, Polk, and Montgomery counties.

The lower part of the formation is considered to be of Devonian age; but the middle and upper parts are doubtfully placed in the Devonian system, as there is a possibility that these two parts may be of Mississippian age. The only fossils that have been found in the formation in Arkansas are conodonts, linguloids, sporangites, and fossil wood, all of which were obtained from the middle and upper parts of the formation.

CARBONIFEROUS SYSTEM.

Mississippian Series

Hot Springs sandstone.—The Hot Springs sandstone is exposed on high mountain ridges at and near the city of Hot Springs. It is simply a lenticular formation, and so far as known is not present except near Hot Springs. The maximum thickness is 200 feet. The formation is composed of gray hard quartzitic sandstone, and at the base there is a conglomerate which is as much as 30 feet thick. The pebbles are of all sizes up to 6 inches in diameter and consist mostly of novaculite.

Stanley shale.—The Stanley shale is the surface rock in large and small areas in Polk, Sevier, Howard, Pike, Montgomery, Clark, Hot Spring, and Garland counties, in the southern part of Yell County, in the northern part of Saline County, and in the west-central part of Pulaski County. Some of the largest areas are intermontane basins like the one in which Mena is situated and the one in which the southern part of Hot Springs is situated, whereas the other large areas form a part of the Athens plateau which is south of the Ouachita Mountains. The thickness, as measured near Glenwood, Pike County, is 6,000 feet, and it is perhaps equally as great at all other places.

The formation is composed of bluish-black and black fissile clay shale and fine-grained compact greenish-gray or bluish-gray sandstone. Several tuff beds, as much as 85 feet thick, occur near the base in Polk County. The upper part of the formation in Arkansas has yielded a single collection of plants, including some ferns. Some of the shale at the base has been altered to slate and this has been prospected for commercial slate in Polk, Montgomery, and Garland counties. Quartz veins in the formation contain lead, zinc, and antimony minerals near Gillham, Sevier County.

Jackfork sandstone.—The Jackfork sandstone, 5,000 to 6,600 feet thick, forms broad low nearly east-west ridges on the Athens plateau south of the Ouachita Mountains. These ridges are forested with yellow pine and among them are Grindstone Mountain extending westward from the vicinity of Arkadelphia, Clark County, and several ridges that are south of Kirby, Pike county. Furthermore, the formation is widely exposed in the Ouachita Mountains themselves. In fact, its outcrops form the highest and some of the most rugged mountain ridges of the Ouachitas. Some of these are Black Fork, Rich, Fourche, Mill Creek, and Irons Fork mountains near Mena, Polk County; Muddy Creek Mountain near Washita, Montgomery County; and Blue Mountain near Cedar Glades, Garland County. In the southern exposures of the formation it is composed of massive compact fine-grained to coarse-grained light-gray sandstone with some millstone grit, especially in its basal part, and with a small amount of green shale, whereas in many of its northern exposures the shale forms the greater part of the formation and the sandstone a minor part of it. Indeterminable invertebrate fossils have been found in the millstone grit at the base.

Pennsylvanian Series

Atoka formation.—The Atoka formation is exposed in two narrow east-west belts between Kirby and Murfreesboro, Pike County, and another belt, which is probably one of these, follows the south base of Chalybeate Mountain, 5 miles south of Amity, Clark County. The thickness of the formation in this part of the State is estimated to be 6,000 feet. The Atoka is also exposed in large areas in Scott, Yell, and Perry counties and the west-central part of Pulaski County. Two of the principal ridges formed by it are Dutch Creek and Danville mountains. The formation in Yell County is estimated to be 7,800 feet thick. Here, as elsewhere in the State, it is composed of hard light-gray to brown sandstone and an equal or greater amount of black clay shale.

ARKANSAS VALLEY REGION.

CARBONIFEROUS SYSTEM.

Mississippian Series

Jackfork sandstone.—The Jackfork sandstone, as has been previously stated, is composed of shale and a smaller amount of sandstone in its northernmost outcrops in the Ouachita Mountain region, and it is doubtless represented by similar strata in some areas on the south side of the Arkansas Valley.

Pennsylvanian Series

Atoka formation.—The Atoka formation comprises a considerable part of the thick series of sandstones and shales that underlie the coal-bearing rocks in the Arkansas coal field. This series of rocks was referred to in the publications of the Arkansas Geological Survey as the "Lower or Barren Coal Measures." The uppermost formation in this series is known as the Atoka formation and contains beds which are equivalent to part of the Winslow formation of the Boston Mountains. The Atoka is estimated to be about 7,000 feet thick and is composed of sandstone separated by thick beds of black clay shale. It has not yielded any fossils in Arkansas. The sandstones form ridges and the shales underlie valleys and lowlands. Sandstone beds in the formation supply the gas from the Massard Prairie gas field near Fort Smith, the Coops Prairie gas field near Mansfield, and the Kibler gas field near Van Buren.

Hartshorne sandstone.—The Hartshorne sandstone lies at the base of the productive coal-bearing rocks of the Arkansas coal field. It is known to have a great areal extent, and is found cropping out around the edges of the coal bearing rocks from the east end of the Arkansas coal field westward into Oklahoma. It is 100 to 300 feet thick, and contains minor beds of shale in its central and upper parts. An important coal bed known as the Hartshorne coal rests on the top of the sandstone.

McAlester group.—Above the Hartshorne sandstone there is in the productive coal-bearing rocks a series of shales and sandstones with a number of beds of workable coal. The McAlester group is divisible into three formations—(1) a lower, known as the Spadra shale, consisting of three or more beds of coal and minor strata of sandstone; (2) a middle, called the Fort Smith formation, composed chiefly of sandstone and shaly sandstone beds with one or more workable beds of coal; (3) an upper, described as the Paris shale, consisting partly of beds of sandy shale with some sandstone and one or more workable beds of coal. The Spadra shale is 400 to 500 feet thick, the Fort Smith formation 375 to 425 feet, and the Paris shale 600 to 700 feet. Numerous collections of fossil plants have been obtained from the McAlester group.

Savanna formation.—Overlying the McAlester group there is in the productive coal series a formation consisting of several sandstone members separated by shales. This is known as the Savanna formation. It occurs in Arkansas only in the tops and upper slopes of Poteau, Sugarloaf, Short, and Magazine mountains. That part of the Savanna exposed in Arkansas is estimated not to exceed 1,000 feet, and constitutes approximately the lower two-thirds of the entire formation, which is present farther west in Oklahoma.

The rocks of this formation, as well as the other rocks of the productive coal series, are all more or less folded, so that the shale and sandstone outcrops depend on the character and direction of these folds and can therefore be determined only after a study of the structure of the region. It can be said, however, that the shale outcrops generally lie in the valleys parallel to the ridges which are formed by sandstone.

GULF COASTAL PLAIN.

CRETACEOUS SYSTEM.

Lower Cretaceous Series

Trinity formation.—The Trinity formation is exposed in a belt, a few miles wide, extending from a point near Delight westward across Pike, Howard and Sevier counties and thence into Oklahoma. It has a thickness of over 600 feet at a locality 2 miles north of Center Point, Howard County, and probably has a like thickness farther west in Arkansas, but it thins out near the east border of Pike County. It consists predominantly of clay but includes subordinate beds of sand, gravel, and limestone. The limestone contains fossil oysters and other shells and occurs in two beds, the Dierks limestone lentil and the De Queen limestone member, both of which are exposed in narrow belts. The De Queen limestone, the higher of the two, is near the middle of the formation. It ranges in thickness from a feather edge to 72 feet, and its outcrop extends from Plaster Bluff, near Murfreesboro, westward through De Queen into Oklahoma. It is not present east of Plaster Bluff. The Dierks limestone at some places is 50 feet above the base of the formation and at others is probably 200 feet above the base. Its thickness ranges from a feather edge to 40 feet. Its outcrop extends from a locality about 2 miles north of Delight westward to Cossatot River, where it thins out. The gravel also occurs in two beds that attain a thickness of 100 feet. The lower of the two gravels is at the base of the formation. It is called the Pike gravel member and is exposed in an almost continuous though irregular belt from the west side of the State to the east end of the outcrop of the Trinity. The upper gravel, the Ultima Thule gravel lentil, is above the Dierks limestone and is exposed in an irregular belt extending from Cossatot River westward into Oklahoma. These four lentils and members and the interbedded sands and clays of the Trinity have a slight southward dip. Although the Trinity occupies a nearly horizontal position it rests upon the truncated upturned edges of steeply dipping shales and sandstones of Carboniferous age, which, however, form a smooth floor that has only minor irregularities and undulations. A pronounced unconformity therefore occurs at the base of the Trinity.

The above-mentioned gravels are composed mostly of novaculite pebbles. They are widely distributed and constitute a very large supply of good road material. Gypsum occurs in the De Queen limestone member and has been prospected in a small way near Plaster Bluff. Limestone in this member has been used for rough building stone at De Queen, but neither it nor the Dierks limestone is pure enough for making lime.

Goodland limestone.—The Goodland limestone, 0 to 25 feet thick, is a chalky fossiliferous limestone and is exposed on Little River near Cerro Gordo, Little River County. It is not exposed east of that place.

Washita group.—The Washita group consists of calcareous clays and thin beds of limestone and is exposed over a small area in the northwest corner of Little River County where it has a total thickness of over 250 feet.

Upper Cretaceous Series

Bingen formation.—The Bingen formation receives its name from the village of Bingen, Hempstead County. Its area of outcrop is a belt, narrow to the east and wide to the west, and extends in a west-southwestward direction from the vicinity of Clear Spring, Clark County, across Pike, Hempstead, Howard, and Sevier counties. The formation ranges in thickness from a feather edge to 580 feet, being thickest to the southwest. It is composed of sand, clay, and gravel, and near Tokio and farther east contains beds to which the name Tokio sand member has been applied. This member is in fact the only part of the formation exposed east of Little Missouri River and is the only part that contains beds of quartz sand.

The gravel in the Bingen occurs in several beds. The southward sloping plateau on which Center Point, Howard County, is located and a similar plateau west of Lockesburg, Sevier County, owe their preservation and prominence to these gravels. The thickest and also the most widely distributed bed which is as much as 60 feet thick, is at the base. These different gravel deposits resemble one another as well as those of the Trinity formation and are well adapted for road making. They are composed of partly rounded to well-rounded pebbles usually 1 inch or less in diameter, and most of the pebbles are novaculite.

Among the other kinds of pebbles there are various types of igneous rocks, which are similar to or identical with some of the crystalline rocks of Arkansas. These are found in the basal part of the formation from the vicinity of Murfreesboro westward.

A greenish cross-bedded arkosic sand composed of kaolinized feldspar and a less amount of other minerals is widely distributed west and northwest of Tokio and Highland. Besides the sand just described the formation contains red, light-colored and dark-colored clays and quartz sand. The light-colored clays are in beds reaching a thickness of 5 to 6 feet and consist of plastic ball clays and nonplastic kaolins. A 5-foot bed of kaolin in the NE. ¼ SE. ¼ sec. 24, T. 8 S., R. 25 W., is reported to be fullers earth. Some of the clays contain fossil plants.

Brownstown marl.—The Brownstown marl is the surface formation in a belt a few miles wide extending in an east-northeastward direction from the vicinity of Brownstown, Sevier County, to the vicinity of Hollywood, Clark County. In the western part of the belt where it is thickest it attains a thickness of 650 feet. It is a blue or gray calcareous clay containing many fossil oysters and is characterized by the presence of the large oyster **Exogyra ponderosa,** whence it has sometimes been called the "**Exogyra ponderosa** marl." The soil derived from the formation, when not mixed with surficial deposits, is black and waxy, but the subsoil is yellow.

Austin ("Annona") chalk.—The Austin chalk consists of white chalk, which at White Cliffs, Sevier County, has a thickness of over 100 feet, but thins out rapidly to the east, disappearing entirely before reaching Okolona, Clark County, where it is composed only of chalky marl. To the west outcrops are found at Rocky Comfort, Little River County. The chalk was formerly used in the manufacture of Portland cement at White Cliffs.

Marlbrook marl.—The Marlbrook marl consists of blue, chalky, somewhat glauconitic marls, which are impure chalk at some places. The most extensive outcrops of this formation are along the ridge which extends from Marlbrook, the type locality in Hempstead County, to Saratoga, in southern Howard County. It forms a stiff black soil. About 200 to 300 feet above the base of this formation is a very chalky layer 20 to 50 feet thick, which has been called the "Saratoga chalk marl" or the "Saratoga formation." It is exposed in the Marlbrook-Saratoga region at the town of Okolona, where it is called "cistern rock;" at Dobyville, and on Little and Big Deciper creeks in Clark County. The thickness of the Marlbrook marl ranges from 750 feet at Texarkana to 50 feet or less at Arkadelphia.

Nacatoch sand.—Above the Marlbrook marl is a series of sandy beds which are of vast economic importance to a strip of country along the Missouri Pacific Railway between Arkadelphia and Texarkana, since they are the source of the main water supply of that region. Like the other sandy beds of the Cretaceous, at the outcrop they are distinguished with difficulty from the surficial sands that mantle the region. However, the thousands of wells which have been sunk to this horizon prove conclusively that the outcrop of this bed produces the belt of sandy land which begins on Yellow Creek south of Saratoga and extends, with interruptions of greater or less importance, along the main drainage channels, through Washington, De Ann, Garlandville, Nacatoch Bluff, and Keyton, and finally reaches Ouachita River at High Bluffs above Arkadelphia.

Nacatoch Bluff, on Little Missouri River, in Clark County, from which the sand takes its name, reveals one of the most complete exposures occurring along this belt and shows calcareous and quartzitic rocks which, when encountered in wells, are called "water rocks."

In the western part of this region the sands are rather light in color, although about Hope they are overlain by a very black sandy layer 3 to 15 feet thick, and have an aggregate thickness of about 100 to 160 feet. Toward Arkadelphia the sand grows darker and thinner. In the well of the Arkadelphia Ice and Fuel Co. it appears to extend from 100 to 160 feet, and is therefore about 60 feet thick. In a well at Prescott, it is reported to be 176 feet thick. It is apparently 178 feet thick in a well at Bodcaw, Nevada County, and is at least 185 feet thick in a well near Fulton, Hempstead County.

Marls encountered in wells at Little Rock, at Cabot, Lonoke County, and Beebe, White County, contain a fauna corresponding in age to the fauna of the Nacatoch sand. There are small exposures of beds of Upper Cretaceous age in the vicinity of Newark, Independence County, and the meager fauna found in the beds indicate that they are probably of the same age as the Nacatoch sand.

Arkadelphia clay.—The dark laminated clays which overlie the Nacatoch sand form the "blue dirt" of the well drillers along the line of the Missouri Pacific Railway from Arkadelphia to Texarkana. These beds contain uppermost Cretaceous fossils for 100 to 200 feet above the Nacatoch sands, the fossil-bearing beds being well developed on Yellow Creek 3 to 4 miles northwest of Fulton, 5 to 6 miles north of Hope, north and northwest of Emmet, and at Arkadelphia. Thus far no fossils have been found in the upper portion of this formation, which extends without any apparent break to the Eocene sand beds forming the sandy hills south of the Missouri Pacific Railway. This absence of fossils, together with the fact that the Midway (Eocene) formation, though commonly characterized by limestones, contains dark-colored clays, makes the exact determination of the top of the Cretaceous in this section particularly difficult.

The total thickness of the Arkadelphia clay, excluding the beds which appear to be stratigraphically Eocene, is from 200 to 300 feet at Arkadelphia, 500 feet at Laneburg, 500 to 600 feet at Hope and Spring Hill, and 500 feet at Texarkana.

TERTIARY SYSTEM.

Eocene Series

Eocene deposits, including in ascending order the Midway, Wilcox, Claiborne, and Jackson formations, 1,000 feet or more in aggregate thickness, form the core of Crowleys Ridge; they are exposed in the uplands which occupy much of south-central Arkansas, south of Little Rock; and they are exposed in small areas along the western margin of the Coastal Plain from Little Rock northeastward to the southern part of Independence County. The formations of Eocene age are more or less similar in character, and comprise sands, clays, marls, and some limestones and workable beds of lignite. These beds dip gently to the southeast; they are all more or less sandy; and but few of them are hard and consolidated. At the lignite mines of Ouachita County, however, some of the sands are indurated to very compact sandstones, and at some places in Crowleys Ridge they form the hardest of quartzites. At and near Piggott in Clay County, Benton in Saline County, Malvern in Hot Spring County, Fordyce in Dallas County, Lester in Ouachita County, and other places there are valuable deposits of potter's clay and fire clay.

Pliocene (?) Series

Gravels and sands, possibly of Pliocene age, occur in Crowleys Ridge and cover the foothills of Lawrence, Independence, and probably other counties.

QUATERNARY SYSTEM.

A sheet of sedimentary materials, 200 feet or less thick, which consist of sands, clays, and gravels, cover the Tertiary area of the State and some of the adjacent Palezoic rocks and yield large quantities of water which is extensively used in the culture of rice. The country lying north of Arkansas River and east of the Palezoic hills belongs mostly to the Quaternary. The lowest strata exposed in Crowleys Ridge belong to the Eocene. All the river bottoms are of recent origin, while the loess, 140 feet or less thick, which caps Crowleys Ridge and likewise the river terraces and second bottoms of all the important streams belong to the Pleistocene.

Bibliography.

The list of reports given below includes only those that were used in the preparation of the above chapter on the topography and geology of Arkansas. These represent a very small percentage of the total number of publications on the geology of the State. A complete bibliography of the geology of the State by J. C. Branner was published in 1894 in Volume 2 of the Annual Report of the Arkansas Geological Survey for 1891, and a second bibliography by him, listing all of the titles up to 1909, was published by the same Survey.

Published Reports.

1891.* Williams, J. F., The igneous rocks of Arkansas: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 2.

1892. Griswold, L. S., Whetstones and the novaculites of Arkansas. Arkansas Geol. Survey Ann. Rept. for 1890, vol. 3.

1893. Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 4.

1900. Branner, J. C., The lead and zinc region of north Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 5.

1904. Adams, G. I., Purdue, A. H., and Burchard, E. F., Zinc and lead deposits of northern Arkansas: U. S. Geol. Survey Prof. Paper 24. (Out of print.)

Ulrich, E. O., Determination and correlation of formations [of northern Arkansas]: U. S. Geol. Survey Prof. Paper 24, pp. 90-113. (Out of print.)

1905. Adams, G. I. and Ulrich, E. O., Description of the Fayetteville quadrangle: U. S. Geol. Survey, Geol. Atlas, Fayetteville folio (No. 119).

1906. Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46. (Out of print.)

1907. Purdue, A. H., Description of the Winslow quadrangle: U. S. Geol. Survey, Geol. Atlas, Winslow folio (No. 154). (Out of print.)

——————, Developed phosphate deposits of northern Arkansas: U. S. Geol. Survey Bull. 315, pp. 463-473. (Out of print.)

Collier, A. J., The Arkansas coal field: U. S. Geol. Survey Bull. 326.

1908. Branner, J. C., The clays of Arkansas: U. S. Geol. Survey Bull. 351.

1909. Purdue, A. H., The slates of Arkansas: Arkansas Geol. Survey.

1913. Eckel, E. C., Portland cement materials and industry in the United States: U. S. Geol. Survey Bull. 522.

1914. Smith, C. D., Structure of the Fort Smith-Poteau gas field, Arkansas and Oklahoma: U. S. Geol. Survey Bull. 541, pp. 23-33. (Out of print.)

1915. Siebenthal, C. E., Origin of the zinc and lead deposits of the Joplin region, Missouri, Kansas, and Oklahoma: U. S. Geol. Survey Bull. 606.

Mead, W. J., Occurrence and origin of the bauxite deposits of Arkansas: Econ. Geology, vol. 10, pp. 28-54.

1916. Stephenson, L. W., and Crider, A. F., Geology and ground waters of northeastern Arkansas: U. S. Geol. Survey Water Supply Paper 399.

Purdue, A. H., and Miser, H. D., Description of the Eureka Springs and Harrison quadrangles: U. S. Geol. Survey, Geol. Atlas, Eureka Springs-Harrison folio (No. 202).

1917. Miser, H. D., Manganese deposits of the Caddo Gap and De Queen quadrangles, Arkansas: U. S. Geol. Survey Bull. 660, pp. 59-122.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624.

1918. Stephenson, L. W., and Miser, H. D., Camp Pike and the adjacent country: Text on back of topographic map. Little Rock quadrangle, U. S. Geol. Survey.

Miser, H. D., and Purdue, A. H., Gravel deposits of the Caddo Gap and De Queen quadrangles, Arkansas: U. S. Geol. Survey Bull. 690, pp. 15-29.

——————, Asphalt deposits and oil conditions in southwestern Arkansas: U. S. Geol. Survey Bull. 691, pp. 271-292.

Unpublished Reports

Miser, H. D., Diamond-bearing peridotite in Arkansas: U. S. Geol. Survey Bull. (Manuscript not completed.)

——————, Manganese ore deposits of the Batesville district, Arkansas: U. S. Geol. Survey Bull. (Preliminary report in press and detailed report almost ready for press.)

Purdue, A. H., and Miser, H. D., Description of the De Queen and Caddo Gap quadrangles: U. S. Geol. Survey, Geol. Atlas, De Queen-Caddo Gap folio. (In course of preparation.)

——————, Description of the Hot Springs special quadrangle: U. S. Geol. Survey, Geol. Atlas, Hot Springs folio. (In course of preparation.)

Ulrich, E. O., Description of the Yellville quadrangle: U. S. Geol. Survey, Geol. Atlas, Yellville folio. (In course of preparation.)

*The numbers in this column are the dates of the publication of the reports.

MINERALS AND ECONOMIC PRODUCTS.

METALLIFEROUS MINERALS.

Antimony

Since 1873 antimony has been mined intermittently in Sevier and Howard counties, near Antimony and Gillham. This field is believed to extend westward into Oklahoma. With refernce to the antimony deposits John T. Fuller, in a special report to the Bureau of Mines, Manufactures and Agriculture in 1913, made the following statement:

"The rocks of the antimony region are alternating thinly bedded sandstones and sandy or muddy shales, of Pennsylvanian and Mississippian age. They are of a light-yellowish or drab color where exposed, and dark gray to black where unweathered. The rocks have been thrown into very regular parallel folds running a trifle north of east. The folds are so close that in many places the dip of the rocks approaches perpendicularity, and so regular that the strike of the rocks is sometimes used to tell direction.

"The original minerals found in the veins are quartz, stibnite, jamesonite, zinkenite, galena, sphalerite, pyrite, chalcopyrite, siderite, and calcite. Traces are found of arsenic, bismuth, cadmium, cobalt (?), silver and minutely and rarely, gold. Cervantite and bindheimite occur as oxidation products of stibnite and jamesonite, respectively.

"The ores have been mostly rather pure oxide and sulphide of antimony, or lead ores, in many places silver bearing, for 40 to 115 feet from the surface, below which sphalerite and other impurities begin to come in. The ores which are easily oxidizable, or those whose oxidation products are readily soluble, have been more or less completely leached from the upper portions of the veins to the depth mentioned, which probably corresponds to the lower limit of variation of the ground-water surface.

"The minerals occurring in the veins are deposited upon the faces of the quartz crystals forming the combs, and are therefore younger than most of the quartz, although a certain amount of quartz has been deposited later with the metallic minerals.

"There is a central area through which the veins predominantly carry stibnite; elsewhere either the other minerals preponderate or no stibnite is present. This area runs northeastward from the Otto mine to the May—a distance of about 8 miles in a direct line, and is perhaps 2 miles wide.

"The ore bodies occur in thin lenticular masses whose longest dimension approaches verticality and may reach more than 100 feet. The width may be from 3 or 4 feet to 20 or even 40 feet; the thickness ranges from a "feather-edge" to 2½ feet."

Bauxite Mining in the Arkansas Field. The bauxite is all mined from open pits.

REFERENCES.

Comstock, T. B.—Annual Report, Geol. Surv. of Ark., 1888, Vol. I, pp. 136, 140, 142, 144-145.

Wang, C. Y.—Antimony: its history, chemistry, etc. Philadelphia, 1909. (Contains bibliography.)

Hess, F. L.—The Arkansas antimony deposits. Bulletin No. 340, U. S. Geol. Surv., Washington, 1908.

Williams, Charles P.—Occurrence of antimony in Arkansas. Transactions of the American Institute of Mining Engineers, Vol. III, May, 1874.

Dunnington, F. P.—Antimony ores in Sevier County, Arkansas. Proceedings of the American Association for the Advancement of Science for 1887, Vol. XXVI, Salem, 1878.

Santos, J. R.—Analysis of native antimony ore from Sevier County, Arkansas. Chemical News, Vol. XXXVI, London, October, 1877.

Wait, Charles E.—The antimony deposits of Arkansas. Amer. Chem. Soc., Vol. I, Pamphlet.

Shriver, Ellsworth H.—Antimony deposits of Arkansas. Min. & Sci. Press, Vol. 114, pp. 920-922.

Bauxite

HISTORICAL FOREWORD BY DOCTOR BRANNER.

The Arkansas bauxite deposits were discovered by me the last week in June, 1887, at several places where they were then exposed along the turnpike running south from Little Rock to Sweet Home, and a little more than one mile south of where the road crosses Fourche Bayou. It is not to be understood that the material was not known before that date. As a matter of fact the bed of the turnpike near Sweet Home was mostly made of bauxite, and one gentleman afterwards informed me that he and his brother had driven oxen over "that stuff" forty years before.

There is an old report on Fourche Cove, by Dr. W. Byrd Powell, published at Little Rock in 1842, which mentions what the author called "an extensive amygdaloid formation within the cove and also upon the eastern side of it. * * * * At one locality the amygdaloids are small, resembling a mass of peas." It is quite evident that this refers to the pisolitic bauxite, though the writer did not recognize it as such, and he thought some of it was jasper.

Dr. Owen, who was state geologist of Arkansas from 1857 to 1860, also refers to "ferruginous amygdaloid of rather peculiar character," and says that "the amygdules are very globular, so that the rock has much the appearance of peastone," but though there is no doubt that he refers to the bauxite, there is no evidence that either he or Dr. Powell suspected the true nature of the material. At the time of these writers bauxite was very little known even in Europe, and it was not known at all in America.

But no announcement was made and none could be made of the discovery of the nature of these deposits until the matter had been placed beyond reasonable doubt. Much work had to be done both in the field and in the laboratory before the discovery could be confirmed and made known. Meanwhile the state geologist had many other duties that demanded his attention. It was not until January 7, 1891, that enough work had been done to warrant the announcement of the discovery. On that day a preliminary report was addressed to Governor Eagle, giving chemical analyses of the bauxite, the approximate location of the deposits that had been determined up to that time, and some general information about its uses. This original report to

Governor Eagle was first published in the Arkansas Gazette and in the Arkansas Democrat of January 8, 1891. It was also reproduced in the third and forth biennial reports of the Commission of Mines in 1894 and in 1896, and abstracts of it were published in New York, Philadelphia and London.

I was a hopeful young man in those days, and I felt sure that the world would want these valuable deposits, for I knew they were the first considerable one of the kind to be found in America up to that time. But the world went about its business the next day very much as usual. Evidently bauxite didn't interest people. It was somewhat disappointing, especially as there was considerable opposition to the continuation of the work of the State Geological Survey, and it was hoped that the announcement of the importance of the bauxite deposits might lead the Legislature to have more confidence in the practical value of the survey's work. The opposition grinned, and remarked that Branner had discovered a mare's nest. What the Legislature thought about it I never knew.

Assuming that it would only require a remainder to some of the chemical manufacturing companies to get them interested, I wrote to the Pittsburg Reduction Works calling their attention to the deposits of bauxite awaiting development in Arkansas. The subject did not interest them. I then went to Syracuse, New York, and personally spoke to the superintendent of the Solvay Process Company about the matter. I pointed out the character of the material, the extent and accessibility of the deposits, and the low price at which the lands could probably be had at that time. If I offered to sell him a gold brick he could not have been less interested.

Meanwhile the world was turning round, and there was much work to be done on the geology of Arkansas. Requests were received occasionally for specimens or for information, and these were referred to the Little Rock Board of Trade, or to the banks, or to the Commissioner of Mines. Meanwhile the news of the existence of the deposits spread slowly through the northern states and in Europe. I have never followed the history of the development of the industry. Nor did I ever find time to prepare a full report on the geology. Only two brief papers were published by me on the subject in the scientific journals: one in the American Geologist for March 1891, pp. 181-183, and the other in the Journal of Geology, Vol. V. April-May, 1897, pp. 263-289. The latter contains the first published bibliography of bauxite.

The earliest published statistics of production do not show exactly when the shipment of bauxite from the state began. The first year for which figures have been published is 1899. when 5045 tons were shipped. The business seems to have been well on its feet by 1903 when the shipment amounted to 25,713 tons. In 1909 it had reached 106,874 tons; from that time on the statistics are given in the following table.

Stanford University, California, JOHN C. BRANNER.
June 18, 1920.

Rapid Growth of the Bauxite Mining Industry.

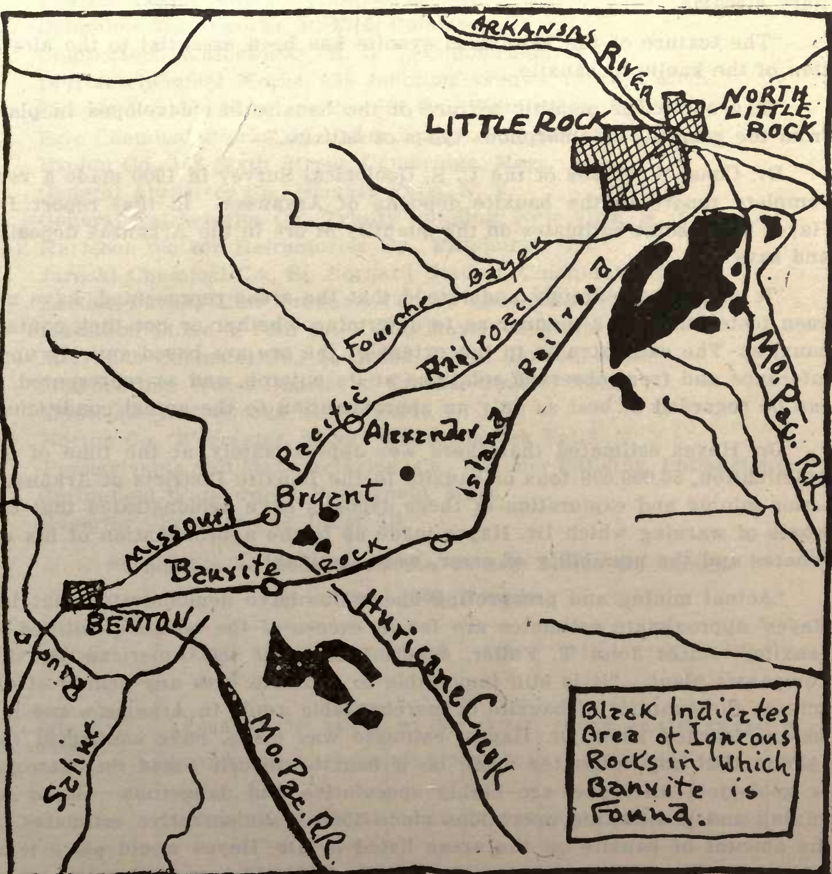
Arkansas' bauxite production has increased so rapidly that since 1910 the State has produced over 80 per cent of the bauxite mined in this country.

In 1915 the output was more than 90 per cent of the total and has continued at this rate to the present time.

The only operators of importance in 1920 are the Republic Mining and Manufacturing Company of Little Rock; the American Bauxite Company of Bauxite; the Globe Bauxite Company of Chemical Spur; and the Du Pont Chemical Company of Wilmington, Delaware.

From a report on the "Occurrence and Origin of the Bauxite Deposits of Arkansas," by W. J. Mead, published in Economic Geology, Vol. X, No. I, January, 1915, is quoted the following:

"The major part of the production comes from what is known as the Bauxite District, sometimes called the Bryant District, lying about 18 miles



Map of the Arkansas Bauxite Area.

southwest of the city of Little Rock and covering an area of about 12 square miles in Bryant township of Saline county. The second and less important district is known as the Fourche Mountain District, lying immediately south of the city limits of Little Rock in Pulaski county and embracing an area somewhat larger than the Bauxite District. The two areas are about 14 miles apart.

"A study of the general geology, chemistry and mineralogy of the deposits has lead to the following conclusions:

"The bauxite and associated clays are the products of surface weathering of the syenite by normal processes of rock decomposition, and are in no sense chemical sediments.

"Bauxite deposits occurring on the syenite surface have developed in situ from the syenite.

"The deposits developed in situ from the syenite show evidence of downward secondary concentration of alumina.

"Bauxite lenses occurring interstratified with the tertiary sediments consist of material which has been removed from its place of origin by tertiary streams.

"The texture of the kaolinized syenite has been essential to the alteration of the kaolin in bauxite.

"The oolitic, or pisolitic texture of the bauxite has developed in place from the granitic, or amorphous types of bauxite."

Dr. Chas. W. Hayes of the U. S. Geological Survey in 1900 made a very complete report on the bauxite deposits of Arkansas. In that report Dr. Hayes made some estimates on the quantity of ore in the Arkansas deposits, and says:

"It should be definitely understood that the areas represented, have not been tested in such a manner as to determine whether or not they contain bauxite. The estimates as to the extent of the ore are based entirely upon inference and from observed relations at its outcrop, and as represented, it can be regarded at best as only an approximation to the actual conditions."

Dr. Hayes estimated that there was approximately, at the time of his examination, 50,000,000 tons of bauxite in the Bauxite Districts of Arkansas. Later mining and exploration of these deposits have demonstrated that the words of warning which Dr. Hayes made as to the approximation of his estimates and the possibility of error, were justifiable.

"Actual mining and prospecting operations have demonstrated that Dr. Hayes' approximate estimates are far in excess of the actual quantities of bauxite," states John T. Fuller, superintendent of the American Bauxite Company's plant. "It is still impossible to estimate with any degree of exactness the quantity of bauxite of merchantable grade in Arkansas, and the lessons learned since Dr. Hayes' estimate was made, have confirmed the opinion that any estimates made on a bauxite deposit based on outcrops, or geological inference, are highly speculative and dangerous. Based on mining and prospecting operations since 1900, a conservative estimates of the amount of bauxite on the areas listed by Dr. Hayes would place it at 1-10 of Dr. Hayes' figures, or approximately 5,000,000 tons from which must be deducted the bauxite mined since 1900."

Each bauxite deposit opened up shows several different qualities of ore and the quality of ore exposed in the mining faces varies considerably from time to time, according to Mr. Fuller. It is necessary to have constant analyses made of the mine facies in order that only ore of pure enough quality is shipped to the consumers. The range in quality of the merchantable ore is shown by the following analyses, which may be taken as average analyses of any of the mine facies.

Al_2O_3	Fe_2O_3	SiO_2	TiO_2	Loss on Ign.	Moisture
57,14	3.86	7.15	2.26	29.59	1.63
57.14	3.86	7.15	2.26	30.77	9.81
59.75	2.37	4.78	2.25	30.85	1.50

Users of Bauxite

Aluminum Co. of America, Pittsburgh, Pa.
Booth Chemical Co., P. O. Box 203, Elizabeth, N. J.
Carborundum Co., Niagara Falls, N. Y.
Charles Lennig & Co. (Inc.), 112 South Front Street, Philadelphia, Pa.
Charles Taylor Sons Co., Cincinnati, O.
Columbus Waterworks, R. F. 5, Columbus, O.
Cumberland Waterworks, R. D. 3, Cumberland, Md.
Detroit Chemical Works, 238 Junction Avenue, Detroit, Mich.
E. I. du Pont de Nemours Powder Co., Wilmington, Del.
Erie Chemical Works, 31 Union Square, W., New York, N. Y.
Exolon Co., 156 Sixth Street, Cambridge, Mass.
General Abrasives Co., Niagara Falls, N. Y.
General Refractories Co., Trinity Building, New York, N. Y.
Harbison-Walker Refractories Co., Pittsburgh, Pa.
Jarecki Chemical Co., St. Bernard Station, Cincinnati, Ohio.
Laclede-Christy Clay Products Co., St. Louis, Mo.
Massillon Stone & Fire Brick Co., Massillon, Ohio.
Merrimac Chemical Co., 33 Broad Street, Boston, Mass.
Metropolitan Water District of Omaha, Omaha, Neb.
Montclair Waterworks, Little Falls, N. J.
Norton Co., Worcester, Mass. (also Niagara Falls, N. Y.)
Pennsylvania Salt Manufácturing Co., Widener Building, Philadelphia, Pa.
Springfield Waterworks, Springfield, Mass.
Superior Chemical Co., Joliet, Ill.

Production of Bauxite in the United States By States.
(In Tons 2240 Pounds.)

States	1910	1911	1912	1913	1914	1915	1916	1917	1918
Alabama			19,587						
Georgia	33,096	30,170	14,173	27,409	18,547	25,008	46,410	62,134	37,000
Tennessee									
Arkansas	115,836	125,448	126,105	182,832	200,771	272,033	378,949	506,556	532,000
Total	148,932	155,618	159,865	210,241	219,318	297,041	425,359	568,690	569,000

REFERENCES.

Ashley, G. H.—Bauxite mining in Tennessee; The Resources of Tennessee, Vol. 1, No. 6, 1911, pp. 211-219.

Aubrey, J. A.—The Refractory uses of bauxite. Eng. and Min. Jour., Feb. 3d, 1906, pp. 217-218.

Branner, J. C.—A preliminary report upon the bauxite deposits of Arkansas with locations and analyses. Arkansas Gazette, Little Rock, Jan. 8, 1891. (This was the original announcement of the discovery of the deposits.)

Berger, W. F. B.—Bauxite in Arkansas. Eng. and Min. Jour, Apr. 14, 1904, pp. 606-607.

Branner, J. C.—The Bauxite deposits of Arkansas. Jour. Geology, Vol. 5, 1897, pp. 263-289. (Contains a bibliography of bauxite.)

Day, David T.—Arkansas (bauxite) 21st Annual Report, U. S. Geol. Surv., Part VI, 1901.

Engineering and Mining Journal.—Bauxite brick. Issue for January 19, 1905, p. 154.

Hayes, C. W.—Bauxite. Mineral Resources, U. S. for 1893, U. S. Geol. Surv., 1894, pp. 159-167.

————. The geological relations of the southern Appalachian bauxite deposits. Trans. Am. Inst. Min. Eng., Vol. 24, 1895, 243-254.

————. Bauxite, its occurrence, geology, origin, economic value. Sixteenth Ann. Rept. U. S. Geol. Surv., pt. 3, 1895, pp. 547-597.

————. The Arkansas bauxite deposits. Twenty-first Ann. Rept. U. S. Geol. Surv., pt. 3, 1901, pp. 435-472.

Holland, T. H.—The occurrence of bauxite in India. Records Geol. Surv., India, Vol. 32, pt. 2, 1905, pp. 175-184.

Horton, J.—The manufacture of aluminum. Trans. Eng. Soc. School of Prac. Sci., Toronto, No. 18, 1905, pp. 113-123.

Hill, James M.—Bauxite and aluminum in 1917, U. S. Geol. Surv., Mineral Resources of the U. S. Part I, 1917.

Hunt, Alfred E.—Aluminum (and bauxite). Mineral Resources U. S. for 1892, U. S. Geol. Surv., 1893, pp. 227-254.

————. Bauxite. Trans. Am. Inst. Min. Eng., Vol. 24, 1895, pp. 855-861. Mineral Resources of the U. S., U. S. Geol. Surv.

————. Aluminum, Aluminum Co. of America, Pittsburgh, Pa., 1904, 268 pages.

Institution of Mechanical Engineers.—Minutes of meeting, alloys of aluminum and copper. Engineering, Mar. 8, 1907, pp. 299-307.

Judd, Edward K.—Aluminum. Mineral Industry during 1905, pp. 11-22.

————. The bauxite industry of the South. Eng. and Min. Jour., Mar. 23, 1907, pp. 574-575.

————. Bauxite. Mineral Industry, Vol. 16, 1908, pp. 97-102.

McCalley, H.—Bauxite. The valley regions of Alabama, pt. 2, Alabama Geol. Surv., 1897, pp. 79-84; also descriptions of Calhoun and Cherokee counties.

McCallie, S. W.—Bauxite deposits of southern Georgia. Eng. and Min. Jour., May 27, 1911, p. 1050.

Mead, W. J.—Occurrence and Origin of the bauxite deposits of Arkansas, Economic Geology, Vol. 10, No. 1, January, 1915.

Minet, Adolphe.—(Translated with additions by Leonard Waldo), The productions of aluminum and its industrial use, 1st edition, John Wiley & Sons, New York, 1905, 266 pages.

Packard, R. L.—Aluminum (and bauxite). Mineral Resources U. S. for 1891, U. S. Geol. Surv., 1892, pp. 147-163.

————. Aluminum. Sixteenth Ann. Rept. U. S. Geol. Surv., pt. 3, 1895, pp. 539-546.

Parker, E. W.—Arkansas Bauxite Deposits. Mines and Minerals, Vol. XX, Scranton, 1900.

Paint, Oil and Drug Review.—Aluminum paints. Issue for Aug. 15, 1906, p. 30.

Phalen, W. C.—Bauxite and aluminum. Mineral Resources U. S. for 1909, pt. 1, U. S. Geol. Surv., 1911, pp. 561-572.

Phalen, W. C.—Bauxite and aluminum. Mineral Resources U. S. for 1910, pt. 1, U. S. Geol. Surv., 1911, pp. 711-723.

Phillips, Wm. B., and Hancock, David.—The commercial analysis of bauxite. Jour. Am. Chem. Soc., Vol. 20, 1898, pp. 209-225.

Richards, Joseph W.—Aluminum, its history, occurrence, properties, metallurgy, and applications, including its alloys, 3d ed., Baird & Co., Philadelphia, 1896.

————. The metallurgy of aluminum in 1906. Mineral Industry, Vol. 15, 1906, pp. 12-17; Eng. and Min. Journal, June 8, 1907, pp. 1083-1086; Eng. and Min. Jour., June 15, 1907, pp. 1147-1149.

Schnatterback, C. C.—Aluminum and bauxite. Mineral Resources U. S. for 1904, U. S. Geol. Surv., 1905, pp. 285-294.

Spencer, J. W.—Bauxite (the Paleozoic group). Georgia Geol. Surv., 1893, pp. 214-239.

Spurr, J. E.—Alum deposits near Silver Peak, Esmeralda County, Nev. Bull. U. S. Geol. Surv., No. 225, 1904, pp. 501-502.

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Stacy-Jones, J. E.—Light aluminum alloys. Indust. World, May 11, 1907, pp. 593-596.

Struthers, Joseph.—Aluminum and bauxite. Mineral Resources U. S. for 1903, U. S. Geol. Surv., 1904, pp. 265-279.

Sutherland, James.—The preparation of aluminum from bauxite. Eng. and Min. Jour., Oct. 3, 1896, pp. 320-322.

Veatch, Otto.—Report on the bauxite deposits, Wilkinson County, Ga. Bull, Georgia Geol. Surv., No. 18, Appendix D. 1909, pp. 430-447.

Watson, T. L.—The Georgia bauxite deposits, their chemical constituents and genesis. Am. Geologist, Vol. 28, 1901, pp. 25-45.

——————. Bauxite deposits of Georgia. Bull. Georgia Geol. Surv., No. 11, 1904.

Wetherell, E. W.—Laterite in Mysore. Mysore Geol. Dept. Memoirs, Vol. 3, pt. 1, p. 27.

Copper

"There is no record of copper ore production in Arkansas. although scattering deposits have been discovered in several places and mined on a small scale, principally in north Arkansas, at one place in Pulaski County and in Polk County."—John T. Fuller, Mineralogist, State Bureau of Mines, Manufactures and Agriculture, 1913.

Purdue reported the presence of chalcocite of steel-gray or blackish type from Carroll county, and at the time of the compilation of this bulletin it is reported that ore is being mined near Eureka Springs. Chrysocolla is frequently found in cavities at the zinc mines. Aurichalcite is also common at many of the zinc mines, but always in small quantities.

Bright green earthy and crystalline masses of malachite (hydrous copper carbonate) are found in the Tomahawk copper mines, Searcy county. Two assays of malachite from this locality gave 39.48 and 39.57 per cent of metallic copper. Small quantities of the same material were shipped from the Big Bear mine near Ferndale, Pulaski County, but the mining of these ores did not prove profitable.

Theo. B. Comstock has the following to say with regard to the copper deposits of the State with special reference to Polk County (Arkansas Geological Survey Annual Report, 1888, Vol. I. p. 245.

"The only economic source of copper as yet made manifest is the mineral chalcopyrite, or copper pyrites, which is intimately associated with galena in nearly all of the known occurrences of that mineral. (In Pulaski, Polk, Howard, Sevier, and Montgomery counties.)

"Incrustations of azurite, the blue copper carbonate, are common in the black shales, but these are of no commercial importance. In connection with these, in rare instances, a very little native copper in minute scales, in black shale, and, at times, small crystals of blue vitrol (chalcanthite) have been observed.

"These all deserve mention here, chiefly because, in the eyes of many, their striking contrasts with the surrounding rock are taken as evidence of richness out of all proportion with the facts. The azurite incrustations upon quartz in the Silver World mine, in Polk County, and in other places upon the shales, will coat a knife blade with a thin film of copper if only rubbed across it.

"The amount of this mineral which is present in a ton of the rock mined is too small to have any commercial significance. One ton of the pure mineral might be worth, say, $90, but the market value of one ton of the incrusted rock and mineral together, as saved in the form of ore at the mine would be nothing, as the valuable portion could not begin to pay the cost of separation. The copper product of this and similar mines has cut no great figure in the claims made for its resources, but as all the other material saved upon the dumps are worthless, some pains have been taken to determine the amount of this metal contained in the copper-bearing portions.

"As indicating the presence of metallic substances somewhere in the neighborhood, the development of these Polk County mines has been useful. Traces of gold and silver, nickel, cobalt, zinc and tin have been found in the Silver World product and all these, except tin, in one or other of the Worthington group of prospects. In the Silver World considerable manganese also occurs. There is, therefore, reason to believe that some kind of an ore belt runs through the region. From other indications and from observations through the district, it is the writer's opinion that this is a manganese tract worthy of further investigation. That there are, in the region examined, any deposits of copper ore which can be worked profitably for themselves alone, is, however, very improbable. Traces of copper in quartz and other rocks may mean little or nothing, as pyrite often contains very small percentages of this metal, and that mineral is widespread."

REFERENCES.

Branner, John C.—Report Arkansas Geological Survey, Vol. V, 1892, pp. 252-253.

Gold

"For many years there has been a vague but persistent faith in the existence of gold in paying quantities in Arkansas. From time to time repeated discoveries of this metal have caused much excitement in different localities. One by one the successive "finds" have proven barren when thoroughly tested. The little known portions of the mountainous country have always been regarded curiously and the reported discovery in those regions have received more ready credence, perhaps, because of the supposed existence of granite rocks. Nowhere in this state, at any period of mining activity, has so much energy been shown, or so much real faith in the value of discoveries, as in Montgomery County. * * * Large expenditures of money in the erection of mills, and in the opening of shafts by men claiming to be competent judges, have been regarded by many as adequate evidence of the permanency of this district as a gold mining area. There can be no question of the honesty of these opinions, supported as they have been, in not a few instances, by the investment of all their available capital on the part of those who have held them."—Report Ark. Geol. Surv., Vol. 1, 1888.

"The conclusions of Dr. Branner's reports are as follows:

"First—The various agencies which have been at work in Arkansas have not had access to any important supply of gold.

"Second—The processes of deposition have often acted too rapidly to accumulate the gold in workable deposits.

"Third—The auriferous deposition, if any has taken place, has been spread over such vast areas as to dilute the whole to a condition of extreme poverty.

"Fourth—There have been no special accumulations, even in cases where such must have been formed, if gold had been present in the solutions from which other metallic ores have been locally deposited.

"Fifth—At the time of the formation of the deposits in which gold is being sought, the structural conditions were unfavorable to its accumulation.

"Sixth—The proper mechanical, physical and chemical conditions have often been present, yet gold is absent from those situations in which all of these conditions have been most favorable to its retention.

"Seventh—There is one more reason for the unfavorable opinion expressed regarding the future of the gold mining industry in Arkansas. It is the invariable absence of gold in the "float" and the sands and gravels, as well as in the large number of secondary deposits, which have resulted from the decomposition and degradation of the original accumulations. In some of these, at least, the chances should be best of all, but in none of them has gold been found in workable quantities."

REFERENCES.

Branner, John C.—Annual Report of the Geological Survey of Arkansas for 1888, Vol. I, Report upon the geology of western central Arkansas, with especial reference to gold and silver, by Theo. B. Comstock, Little Rock, 1888.

The so-called gold and silver mines of Arkansas. An official report to Gov. S. P. Hughes. Arkansas Gazette, August 9, 1888.

Arkansas Gold and silver mines. An official report to Gov. S. P. Hughes in reply to certain charges. Arkansas Gazette, October 18, 1888. Arkansas Democrat, Ortober 18, 1888. Engineering and Mining Journal, New York, October 20, 1888.

Iron

"The result of the survey's investigation of the iron deposits of the state have not met the expectations and hopes of their commercial value, with which the work was begun. The number of places at which iron deposits occur throughout the state is almost endless, but the examination of these deposits and the chemical analyses of the ores show that most of them are either too limited in extent, or that they are too low in grade to admit of their being worked. The deposits of Lawrence and Sharp counties are the only ones that merit attention, and whether these deposits can be worked now must depend on economic conditions—transportation, markets and competition."—Report Arkansas Geological Survey, Vol. I, 1892.

"Limonite, small quantities in nearly every county; has been mined near Berryville in Carroll County, and in Lawrence and Sharp counties."—Bulletin 624, U. S. Geol. Surv.

"Magnetite, magnetic iron ore, Hot Spring County, in loose fragments at Magnet Cove; not mined."—Bulletin 624, U. S. Geol. Surv.

"Hematite, Pulaski, Saline, Garland, Montgomery, Pike, Scott, and Franklin counties, occurs in beds of hematite shale."—J. C. Branner.

"Siderite, about Chalybeate Springs, at Kellogg mine, Pulaski County; at Magnet Cove and in the higher sandstones of coal measures in Scott and Franklin counties."—J. C. Branner.

Turgite and goethite are also mentioned in the list of iron minerals, their presence being noted in the manganese and iron belts.

REFERENCES.

Branner, John C.—Annual Report of the Geol. Surv. of Arkansas for 1892, Vol. I. The iron deposits of Arkansas, by R. A. F. Penrose, Jr., Little Rock, 1892.

Penrose, R. A. F. Jr.—The Tertiary iron ores of Arkansas and Texas. Bulletin Geol. Soc., 1891, Vol. III, pp. 44-50.

Swank, James M.—History of the manufacture of iron in all ages, and particularly in the United States, for three hundred years, from 1585 to 1885, p. 258, Philadelphia, 1884.

On the Meteoric iron which fell in Johnson County, Arkansas, March 27, 1886, by G. F. Kunz. American Journal of Science, Vol CXXXIII, third series, New Haven, 1887.

Iron Pyrites.

The constantly increasing use of pyrites in the manufacture of sulphuric acid may make available in the future the deposits which occur on the south slope of West Mountain, two miles west of Hot Springs, Garland County; in southern Polk county and at Golden City, in Logan County.

Pyrite ("fool's gold," "mundic," iron disulphide; sulphur, 53.4; iron, 46.6 per cent; brass yellow, often in cubes, sometimes massive). found in small quantities at a few of the zinc mines in north Arkansas; notably hard.

On Kelling's place, Tomahawk Creek, Searcy County, there is a bed of iron pyrites at the contact between the Silurian and Carboniferous rocks from 3 to 10 inches thick. It is a valuable ore when found in quantity, but it is regarded as a detriment to zinc when mixed with its ores.

Marcasite ("mundic," iron disulphide: sulphur, 53.4; iron, 46.6), is very like pyrites; bronze yellow color; decomposing more readily than pyrites; it is occasionally found in the zinc mines in the form of small stalactites. Also reported at Rabbit Foot mine, Saline County, carrying some nickle.

Cne of the most important commercial deposits of iron pyrites is in the south slope of West Mountain, two miles west of Hot Springs in Garland County. Samples from this deposit are said to have analyzed 50 per cent sulphur. The property is owned by Tennessee capitalists and has been prospected for use in the manufacture of sulphuric acid but at this time is not being mined.

Lead

"Galena (lead sulphide)—the principal lead ore mineral—has been mined in limited quantities in Baxter, Benton, Carroll, Boone, Marion, Newton, Washington, and other counties of northern Arkansas. In western Arkansas it has been found sparingly and mined occasionally in Garland County, near Blakely Creek; Hot Spring County, at Point Cedar; Montgomery county, at Rubicon, near Virginia City, and at Minnesota, Montezuma, Walnut and Waterloo mines; Pulaski County, Kellogg and McRae mines; Sevier County, at Bellah mine, in Gulch shaft, New Discovery shaft, near Conboy and elsewhere. Cerusite (lead carbonate) occurs in Howard, Montgomery, Newton and other counties, with galena and coating it in mines in northern Arkansas."—Bulletin 624, U. S. Geol. Surv., Useful Minerals of the United States.

Approximately 1,000,000 pounds of galena were shipped from the north Arkansas field in the record year of 1917, as compared with a production of 48,000,000 pounds of zinc from the same mines.

Mine Production of Lead in Arkansas, 1907-1918*.

(Report U. S. Geol. Surv.)

	QUANTITY, (SHORT TONS)		VALUE	
Year	Ores	Metal	Ores	Metal
1918	155	120	$13,594	$173,082
1917	474	282	47,593	1,364,964
1916	339	272	28,097	1,826,420
1915	79	63	4,961	795,832
1914	52	41	2,408	62,016
1913	23	18	1,179	53,536
1912	39	31	2,180	103,224
1911	80	64	4,321	75,696
1910	80	63	3,714	107,352
1909	30	24	1,800	52,080
1908	18	15	985	56,870
1907	15	12	800	55,932

*No allowance made for smelting loss. Value given for ore is that actually received by the producer, whereas the value of the metal is calculated from the average sales price of all grades.

Tenor of Arkansas Lead and Zinc Ore and Concentrates.

(Report U. S. Geol. Surv.)

	1917	1918
Total crude ore, short tons	203,600	37,000
Total concentrates in crude ore, per cent:		
Lead	0.23	0.42
Zinc	8.82	6.62
Metal contents of crude ore, per cent:		
Lead	.19	.32
Zinc	3.70	2.86
Average lead content of galena concentrates	80.5	77.4
Average zinc content of sphalerite concentrates*	58.4	59.0
Average zinc content of zinc silicate and carbonate*	40.5	40.6
Average value per ton:		
Galena concentrates	$100.41	$87.70
Sphalerite concentrates	63.13	53.07
Zinc silicate and carbonate	38.15	37.70

*Includes some mixed carbonate and sphalerite.

Manganese Mining in Independence County.

The ores are galena, sphalerite and smithsonite and the concentrates produced are generally of high grade and free from or very low in iron or lime. The sphalerite has frequently assayed 2 to 3 per cent above the price basis of 60 per cent, metallic zinc content. The sphalerite and smithsonite are shown by analysis to contain appreciable quantities of cadmium, especially in a yellow variety of smithsonite, known locally as turkey fat, which shows as high as 0.8 per cent of cadmium.

REFERENCES.

Winslow, Arthur.—Lead and zinc deposits, Mo. Geol. Surv., VI and VII, Jefferson City, 1894. (Contains bibliography.)

John C. Branner.—Annual Report Arkansas Geological Survey, Vol. V, 1892. Zinc and Lead.

Manganese

Manganese ores occur in two different parts of Arkansas, one in the Batesville region, mostly in Independence and Izard counties, in the northeastern part of the state; the other in the southwestern part of the state, in the region extending from Pulaski County on the east to Polk County and the Oklahoma border on the west. In the former region considerable mining has been done; in the latter the amount of work has been limited. The two regions approach, in their nearest parts, within about 90 miles of each other, the southern extension of the Batesville region being about that distance northeast of the manganese area of Pulaski County, while it is over 150 miles northeast of the manganese area of Polk County.

During the world war when the supply of imported Brazilian manganese was curtailed by a lack of shipping facilities and when increasing quantities were needed by the government, H. D. Miser of the U. S. Geological Survey was assigned to make a special report on the manganese deposits of the Batesville region in Arkansas. From Mr. Miser's report the following is quoted:

"The developed manganese deposits lie in a belt 20 miles long by 4 to 8 miles wide, which extends westward through Independence, Sharp, and Izard counties, in the northeastern part of the State, but are mainly in Independence county. Manganese is not likely to be found in every part of this belt, but the deposits, which differ greatly in size, are extensive. One hundred and eighty mines and prospects, most of which have produced ore, were visited.

"The ores are manganese oxides, chiefly psilomelane, hausmannite, and braunite. Wad and manganite also occur in minable quantity and the ores in places include pyrolusite. Although these minerals may be found separately, two or more are generally mixed in the same deposit and at a few places they are associated with ferruginous manganese ores and with small quantities of brown and red iron oxides. At some places the ferruginous manganese ores predominate.

"The manganese has been derived from the Cason shale, in which it has been concentrated in the form of oxides into deposits of minable size by ordinary groundwater perhaps recently. Much of the ore has been concentrated in shale itself, but most of it is now in the residual clays of the limestones below the shale. The ore now in these clays was originally carried downward in solution by groundwater from the shale and deposited in the Fernvale limestone. As this limestone has been carried away in solution boulders and fine particles of ore have been freed, and as erosion in the region has proceeded the ore has settled by gravity or has been carried by streams down the hillslopes until much of it now rests upon limestones that are lower than the Fernvale.

"The high-grade manganese ores generally contain 45 to 52 per cent of manganese though some of the ore shipped contains as much as 60 per cent of manganese. Most of the ores contain from 3 to 8 per cent of iron, 0.15 to 0.30 per cent of phosphorus, and 2 to 8 per cent of silicia. Some of the ore shipped contains more than 0.30 per cent of phosphorus and a very little contains 0.40 to 0.50 per cent of phosphorus. Most of the ferruginous manganese ores contain 20 to 40 per cent of manganese, 8 to 20 per cent of iron, and 5 to 26 per cent of silica. The phosphorus content is about the same as that of the higher grade ores.

"An estimate of the quantity of available manganese ore of all grades in this region, where mining is not preceded by systematic prospecting, is difficult to make. Of the 180 deposits examined about half contain an estimated available reserve of 200 tons or less. Only about one-third contains about 1,000 or more tons and only a few contain more than 5,000 tons, though certain of these, contain many thousand tons. A small number of prospects and mines, however, were not visited, and these and the unexplored deposits may increase considerably the reserve. The deposits of the region perhaps include at least 250,000 tons of available ore containing 40 per cent or more manganese and 170,000 tons available ore containing less than 40 per rent manganese.

"The ores from the Batesville region are used for making ferromanganese, spiegeleisen, and high-manganese pig iron. Very little, if any, has been found suitable for chemical uses.

"The consumers of ore from this region are as follows:
"Tennessee Coal, Iron, & Railroad Co., Birmingham, Ala.
"Miami Metals Co., Tower Bldg., Chicago, Ill.
"American Steel Foundries, McCormick Bldg., Chicago, Ill.
"Southern Manganese Corporation, Anniston, Ala.
"Mississippi Valley Iron Co., 6500 Broadway, St. Louis, Mo.
"Sloss-Sheffield Steel & Iron Co., Birmingham, Ala.
"Central Iron & Coal Co., Holt, Ala.
"Sligo Furnace Co., 915 Olive St., St. Louis, Mo.
"The larger producers in the region are as follows:
'W. H. Denison, Cushman.
"R. S. Handford, Cushman.
"Eureka Manganese & Mining Co., Cushman.
"Marqua Mining Co., Cushman.
"Cushman Manganese Co., Cushman.
"Manganese Development Co., Cushman.
"N. A. Adler, Batesville.
"Independence Mining Co., Batesville.
"Ozark Mining Co., Batesville.
"Vance Mining Co., Batesville.
"J. F. Barksdale, Anderson.
"Shepherd & Wilson, Batesville.

"Besides these there are many small operators who work on their own or leased land, or on contracts with the larger operators, and who sell their ore to the larger operators."

The Southwestern Arkansas Field.

Frequent attempts have been made to work the manganese deposits of southwestern Arkansas, in Pulaski, Saline, Garland, Hot Spring, Montgomery, Pike and Polk counties, the last efforts at development being made during the world war, but mining has not proved permanently profitable. Branner's map of the Arkansas manganese deposits shows this field as "unworkable." From Vol. I, Annual Report, Arkansas Geological Survey 1890, the following is quoted.

"The aggregate amount of manganese in the region is undoubtedly large, but it is distributed over an extensive area, and in almost all places it is hopelessly scattered through the rock in small nests and seams. If these nests and seams were in sufficient quantities the rock might be crushed and the ore concentrated by washing but the pockets containing them are too small to permit the expense of machinery. It is a popular idea that the ore will increase in quantity at a depth, but there is absolutely no reason to expect this, as such deposits are just as likely, and sometimes even more likely, to become poorer at a depth than to improve. * * * *

"The value of the small quantities of ore that might be mined in Montgomery and Polk counties, would be in the considerable percentage of peroxide of manganese, or pyrolusite, that many of them contain. * * * * The ores of Montgomery and Polk counties are generally, though not always, too high in phosphorous, so far as the analyses at hand show, to be desirable as a source of spiegeleisen and ferro-manganese."

REFERENCES.

Branner, John C.—Annual Report of the Geol. Surv. of Arkansas for 1890, Vol. I, Manganese: Its uses, ores and deposits, by R. A. F. Penrose, Jr. Includes notes on the paleontology of the Batesville region, by Henry S. Williams.

Harder, E. C.—Manganese deposits of the U. S., Bul. 427, U. S. Geol. Surv., 1910. (Contains bibliography.)

Penrose, R. A. F.—The origin of the manganese ores of northern Arkansas and its effect on the associated strata. Proceedings of the American Association for the Advancement of Science, Vol. XXXIX, Salem, 1891.

Williams, Henry S.—On the age of the manganese beds of the Batesville region of Arkansas. American Journal of Science, Vol. CXLVIII, New Haven, 1895.

Hewett, D. F.—Manganese and manganiferous ores in 1916. U. S. Geol. Surv., Mineral Resources of the United States, 1916, Part I.

Miser, H. D.—Manganese deposits of the Caddo Gap and De Queen Quadrangles, Arkansas. U. S. Geol. Surv., Bulletin 660, 1917.

Joslin, G. A.—Manganese in west central Arkansas, Min. & Sci. Press, Vol. 113, 1916.

Batesville Board of Trade. Pamphlet descriptive of the Batesville-Cushman Manganese Field, 1919.

Silver

"There are deposits of argentiferous ores in the state, some of which are deserving of thorough examinations, although none of these have been, as yet, extensively developed. Cn the other hand, a considerable amount of mining work in a small way has been done in situations where there is no possible chance of success, while assays of questionable value have induced many to excavate in rocks which are even more certain to yield no silver than to prove barren in gold. * * *

"What is most needed in the silver areas is exploration to greater depths; in other words, development. Let us hope that this rather than the opening of numerous new 'prospects' may characterize the near future. The successful outcome of work in the deeper portions of two or three properties, that will probably reward diligent prospectors, if the ore-bodies be clearly followed, will give a greater impetus to mining industry than the uncovering and exhausting of a large number of surface 'bonanzas.'

"The mining for silver in Pulaski County has been fitful, and thus far, not profitable, but, as might be expected in the neighborhood of Little Rock, the explorations have been somewhat thorough. There are in the county three districts, the immediate environs of Little Rock, the Kellogg mining area and the region about the McRae mine.

"There are two districts in Saline County where prospecting has been done but in neither of the areas have silver ores been actually mined, and there is much uncertainty concerning their occurrence. Unsuccessful prospecting also has been done in Garland and Hot Spring counties. Extensive operations have been carried on in Montgomery County, especially about Silver City, but without profit to the miners.

"The district in Pike County which is included in this review is not promising as a prospective field for silver, chiefly because the tough grits and the thick post-Tertiary deposits cover the shales so deeply that the mineral bodies, if they exist, do not appear frequently at the surface. In Howard County the environment is even less favorable, but here erosion has been more serviceable to the prospector in certain localities.

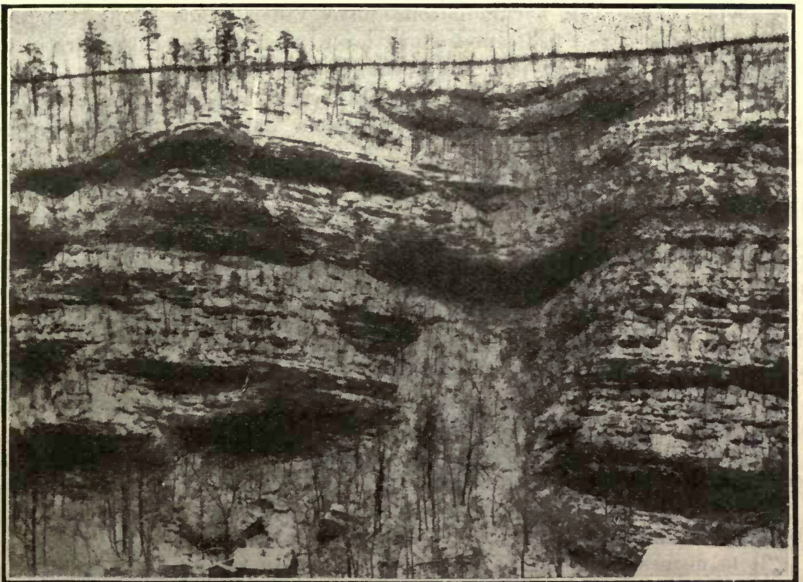
"Sevier County.—The product of the antimony mines, where they carry galena, may eventually yield the precious metal, but there is not a high percentage of it in the ore that has been mined. * * * The Silver Hill district, if carefully explored, may yield good returns but deep workings directly upon the ore body will be requisite for development. There is a very enticing field for prospectors northeast of the Bellah and Davis mines, as far as Silver City, along a narrow belt, and in a southeastward continuation of the same belt indefinitely into Oklahoma."—Report Ark. Geol. Surv., Vol. I, 1888.

REFERENCES.

Branner, John C.—Annual Report of the Geol. Surv. of Arkansas for 1888, Vol. I, report upon the geology of western Arkansas with special reference to Gold and Silver, by Theo. B. Comstock.

Conrad, C. P.—Silver in Arkansas. Engineering and Mining Journal, Vol. XXX. New York, 1880.

Mather, W. W.—Argentiferous galena from Arkansas. American Journal of Science, Vol. LXV, second series, 1853.



Silver Hollow Bluff on Buffalo River, Marion County.

Zinc

"The zinc ores of North Arkansas are found for the most part in rocks of Ordovician age. This area is shown upon the geological map—not that it is meant that it is all ore bearing, but that it is all worthy of attention in this connection. The ores in the order of their importance, are sphalerite (zinc sulphide), popularly called "jack," "rosin jack," etc.; smithsonite (zinc carbonate), and calamine (zinc silicate). In addition to these, there are several minerals of zinc that are more or less abundant, but they do not occur in sufficient quantities to entitle them to be looked upon as ores. The following conclusions seem to be warranted:

"The zinc was originally deposited in sedimentary beds, mostly of organic origin, in which much of it is still found.

"The growth of the crystals in the original bedded deposits took place prior to the hardening of the enclosing silts.

"The position of the ores in the beds has been changed more or less since they were originally deposited.

"The changes have been going on ever since the original deposition and are still in progress.

"By means of such changes vertical and other fissures have been filled with ores brought into them by circulating waters from above, from below and from the sides.

"The position of the ores in the secondary deposits has been determined largely by those structural features that have guided the underground waters in their passage through the rocks.

"In some cases the accumulations have taken place along synclinal troughs, in other cases, in fissures along fault lines, and in still others in the breccias formed along ancient underground water courses.

"The subterranean waterways have in many instances been closed by the deposition of mineral matter and the water has been forced into other channels.

"The carbonates and silicates are produced by the alteration of sulphide ores mostly in place.

"Much of the prospecting in the zinc regions has been done as intelligently as it is possible to have it done. The people doing the work have studied the rocks and the ores and have followed nature—the best possible guide in such matters. In other instances the prospectors have come into this region with long and valuable experience found elsewhere that would have been of the greatest value where the experience was obtained, but here it was simply misleading. The results have been unfortunate for every one concerned.

"Many drill holes have been put down in the zinc region, but many of the records are of no importance because the holes have been bored regardless of the fact that the rocks penetrated are all exposed in the sides of the hills near at hand.

"It is necessary to say a word here in regard to what is called 'going down'—a much mooted question in this region. The theory that zinc ore is to be looked for at considerable depths may be a perfectly correct one in some regions. Whether it is correct in this north Arkansas region depends on the precise location and the details of its geology.

"Inquiries are often made in regard to certain so-called rules laid down a few years ago for the guidance of the miners of this region. One of these rules is 'to follow the more prominent vertical fissures in the search for ore.' Another statement, though not given in the form of a rule, is of far-reaching importance, if it is true. It is that 'all workable deposits of ore occur in direct association with faulting fissures traversing the strata, and with zones or beds of crushed and brecciated rock, produced by movements of disturbance the undisturbed rocks are everywhere barren of ore.

"No fault is to be found with the statement that important ore bodies do occur in fissures, but to say that the ores occur only in fissures, and that 'the undisturbed rocks are everywhere barren of ore,' is to overlook many of the most important deposits of north Arkansas, that is the bedded ones. Over a large part of the zinc region these ore beds can be traced as certainly as a coal bed in western Pennsylvania.

"In regard to these so-called rules, it is enough to say that the miners will do well to get their directions from the geology of the region in which they are working and not from the geology of some other state or some other country."—Report Arkansas, Geological Survey, Vol. V. 1892.

Below is a detailed report of production collected from the various lead and zinc mines of north Arkansas for the year 1917, by J. H. Hand, of Yellville, Arkansas:

MARION COUNTY.

Name of Shipper.	No. Pounds.
J. C. Shepherd M. Co	8,372,000
Morning Star M. Co	3,415,000
Yellow Rose M. Co	1,820,000

Edith M. Co	1,485,000
Kennedy M. Co	330,000
Bonanza M. Co	270,000
Silver Hollow M. Co	180,000
Fox Den M. Co	300,000
Omeara M. Co	240,000
Crooked Creek M. Co	123,000
Onwata M. Co	180,000
Seawel Brothers	180,000
Arkansas & S. C. M. Co	70,000
J. B. Rowden	70,000
W. N. North	60,000
Boone County M. Co.	60,000
Monkey Hill M. Co	60,000
Beaty M. Co	60,000
Bank of Yellville	60,000
Pyatt M. Co	120,000
W. O. Headley	60,000
Paradis & Worth	50,000
Bear Hill M. Co	60,000
North Star M. Co	120,000
Miscellaneous Shipments	480,000
Total	18,175,000

SEARCY COUNTY.

J. C. Shepherd M. Co	8,800,000
Lucky Dog M. Co	1,104,000
N. W. Redwine M. Co	560,000
Howard M. Co	1,210,000
Jack Pot M. Co	130,000
Wallace M. Co	120.000
Madden M. Co	60.000
Churchill-Evening Star	80,000
Lost Mountain M. Co	50,000
Total	12,434,000

BOONE COUNTY.

Gloria M. Co	1,376,000
L. L. Brown	1,347,000
Markle & McCurry	772,000
J. P. Harvey	438,000
D. G. & B. M. Co	670,000
Cantrell & French	214,000
Clear Creek M. Co	350,000
E. Q. Boone	839,000
Harrison M. Co	290,000
Saylors & Lewis	167,000
Zara M. Co	128,000
Doolin & Lawhorn	150,000
Marlin & Osenbaum	140,000
Jackson M. Co	140,000
Estes Zinc Co	130,000

Era M. Co	197,000
Madison M. Co	48,000
W. J. Horsley	58,000
Madison M. Co	70,000
Barham Brothers	110,000
C. E. Morris	33,000
L. T. Westrich	60,000
Arkansas M. Co	60,000
J. E. Potts	60,000
Alberta M. Co	50,000
Polk Kendall	70,000
G. W. Capps	70,000
Total	7,726,000

NEWTON COUNTY.

North Slope M. Co	1,745,000
Bald Hill M. Co	410,000
Hamilton & White	228,000
Eleventh Hour M. Co	460,000
Van Sicklen	214,000
Victor Primrose	890,000
Cook & McCoy	490,000
E. R. Springer	160,000
W. N. North	100,000
L. E. Lake	60,000
H. G. Moss	280,000
W. E. Luke	120,000
Hamilton & Young	60,000
Miscellaneous	1,510,000
Total	5,417,000
Total Shipments from Field	44,615,000
Ore in Docks December 31	3,800,000
Total 1917 Production	48,415,000

Two zinc smelters have been established, one at Fort Smith and one at Van Buren, near the natural gas fields, and Arkansas ore is now smelted with Arkansas gas.

Mine Production of Zinc in Arkansas, 1907-1918*.

(Report U. S. Geol. Surv.)

	SPHALERITE		SILICATE-CARBONATE		METAL CONTENT	
Year	Short tons	Value	Short tons	Value	Tons	Value
1918	310	$16,450	2,156	$68,333	951	$173,082
1917	916	57,824	17,053	650,585	6,691	1,364,964
1916	1,670	112,726	16,609	940,224	6,815	1,826,420
1915	606	41,341	7,925	408,079	3,209	795,832
1914	743	19,406	1,143	25,187	608	62,016
1913	594	16,916	680	15,050	478	53,536
1912	1,419	56,235	462	11,231	748	103,224
1911	1,407	40,425	183	4,239	664	75,696
1910	1,857	74,136	128	2,641	994	107,352
1909	896	33,948	98	2,736	510	52,080
1908	516	18,270	939	21,469	605	56,870
1907	538	15,233	663	16,210	474	55,932

*Allowance made for smelting loss. Value given for ore is that actually received by the producer. Value of the metal is caluculated from the average sales price reported by the smelters.

Tenor of Arkansas Lead and Zinc Ore and Concentrates.

(Report U. S. Geol. Surv.)

	1917	1918
Total Crude Ore, Short Tons	203,600	37,000
Total Concentrates in Crude Ore, per cent:		
Lead	0.23	0.42
Zinc	8.82	6.62
Metal Content of Crude Ore, per cent:		
Lead	.19	.32
Zinc	3.70	2.86
Average Lead Content of Galena Concentrates	80.5	77.4
Average Zinc Content of Sphalerite Concentrates,*	58.4	59.0
Average Zinc Content of Zinc Silicate and Carbonate,*	40.5	40.6
Average Value per ton:		
Galena Concentrates	$100.41	$87.70
Sphalerite Concentrates	63.13	53.07
Zinc Silicate and Carbonate	38.15	37.70

*Includes some mixed carbonate and sphalerite.

The ores are galena, sphalerite and smithsonite and the concentrates produced are generally of high grade and free from or very low in iron or lime. The sphalerite has frequently assayed 2 to 3 per cent above the price basis of 60 per cent. metallic zinc content. The sphalerite and smithsonite are shown by analysis to contain appreciable quantities of cadmium, especially in a yellow variety of smithsonite, known locally as turkey fat, which shows as high as 0.8 per cent of cadmium.

REFERENCES.

Branner, J. C.—Annual Report of the Geol. Surv. of Arkansas for 1892, Vol. V. The Zinc and lead region of north Arkansas, Little Rock, 1900.

The Missouri and Arkansas zinc region. Discussion of Eric Hedburg's paper on the Missouri and Arkansas Zinc Mines. Transactions of the American Institute of Mining Engineers, Vol. XXXI, New York, 1902.

Chance, H. M.—The Rush Creek zinc district. Transactions of the American Institute of Mining Engineers, Vol. XVIII, New York, 1890.

Schmitz, E. J.—Notes of a reconnaissance from Springfield, Missouri, into Arkansas. Transactions of the American Institute of Mining Engineers, 1898, Vol. XXVIII.

Phillips, Wm. B.—The zinc-lead deposits of southwest Arkansas. Engineering and Mining Journal, April 6, 1901, Vol. LXXI.

The removal of iron from zinc blende. Engineering and Mining Journal, November 30, 1901. Vol. LXXII, New York, 1901. (Treatment for the zinc ores of southwest Arkansas.)

Adams, Geo. I.—Zinc and lead deposits of northern Arkansas. U. S. Geol. Surv., Bulletin No. 213, Washington, 1903. Transactions of the American Institute of Mining Engineers, 1903, Vol. XXXIV, New York, 1904.

Winslow, Arthur.—The lead and zinc deposits of Missouri. Geol. Survey of Missouri VI and VII., Jefferson City, 1894. (Contains a bibliography of lead and zinc.)

Adams, Purdue and Burchard.—Zinc and lead deposits of northern Arkansas. U. S. Geol. Surv., Professional Paper 24. Washington, 1904.

Siebenthal, C. E.—Zinc and lead deposits of the Joplin region. Bul. 909. American Institute of Mining Engineers, 1257-1266. New York, Sept. 1917.

NON-METALLIFEROUS MINERALS AND ECONOMIC PRODUCTS.

Arkansite.

One of the rare minerals found in Magnet Cove, which has attracted wide attention among students of geology, is Arkansite (Titanic acid or Brookite). It is in the form of thick black crystals and is much sought after by collectors of mineral specimens, but has no particular commercial value. Its characteristics and geological significance is discussed in numerous papers and publications of a scientific nature.

REFERENCES.

Shepard, Charles Upham.—On three new mineral species from Arkansas. American Journal of Science, second series, Vol. LII. Arkansite, Ozarkite and Schloromite, New Haven, 1846.

Whitney, J. D.—Examination of three new mineralogical species, proposed by Rev. C. U. Shepard. American Journal of Science, Vol. LVII, New Haven, 1849. Describes briefly Arkansite, Schloromite (with analysis) and Ozarkite.

(Arkansite, Ozarkite and Schloromite). Proceedings of the Boston Society of Natural Science, Vol. III, Boston, 1851.

Farther account of the Arkansite, American Journal of Science, Second series. Vol. LVI. Chemical experiments upon Arkansite, New Haven, 1847.

Asphalt.

"Seven asphalt deposits, three of which are in Pike County, and four in Sevier County. in southwestern Arkansas, were examined by the writers. * * * The asphalt deposits in Pike County are near Pike, Delight, and Murfreesboro. The deposits in Sevier county are between Dierks and DeQueen, near the village of Lebanon.

"The asphalt impregnates nearly horizonal beds of loose sand in the basal part of the Dierks limestone lentil or still lower in the Trinity formation. The deposits thus consist of asphaltic sand except at one place where the asphalt impregnates the Pike gravel member at the base of the formation. The layers containing the asphalt range from an inch to 12 feet in thickness.

"The asphalt deposit near Pike is the only one from which asphalt has been shipped in commercial quantity. The asphaltic sand mined at that locality from 1903 to 1906 by the Arkansas Asphalt Company is said to have amounted to 4,815 tons, valued at $22,368. It was used in Little Rock in paving West Markham Street from Main to Cross streets, a distance of 12 blocks, and in paving part of Center Street. A 2-inch surface of the asphalt was laid upon a 5-inch concrete base, which rested upon clay. Owing to improper preparation of the asphalt the paving was not entirely satisfactory.

"The asphalt deposit near Delight is thin, the reported thickness being 3 to 6 feet. If the deposit is later proved to maintain that thickness under a considerable area, it might be profitably worked, but the overburden is so thick, 30 to 35 feet or more, that under-ground mining would probably be necessary. The asphalt exposed at the other localities is not thick enough to be mined and probably is no thicker away from the outcrops."—Extracts from U. S. Geological Survey Bulletin 691-J, by Hugh D. Miser and A. H. Purdue.

REFERENCES.

Hayes, C. W.—The asphalt deposits of Pike County, Arkansas. Engineering and Mining Journal, Dec. 13, 1902, Vol. LXXIV; also Bulletin No. 213, U. S. Geol. Surv., Washington, 1903. Abstract, Mineral Industry, Vol. XI, New York, 1903.

Miser, Hugh D. and Purdue, A. H.—Asphalt deposits and oil conditions in southwest Arkansas. U. S. Geol. Surv. Bulletin 691-J, 1918.

Agricultural Marls and Chalk.

(Annual Report Ark. Geol. Surv., Vol. II, 1888.)

"No region of the world is more plentifully and conveniently endowed with such valuable natural marls and chalks than Arkansas, nor is there any region which could be so greatly benefited by their use. We have here large areas of soil especially deficient in the very ingredients which are so plentifully stored up in our marls. Many farmers endeavor to cultivate soils which are pure commercial marls, in which there is entirely too much lime, as in some of the black land regions, while others cultivate land utterly deficient in lime, potash, etc., which might readily be supplied by using the natural marls. Large tracts like the prairies east of the Missouri Pacific Railway, * * * might be made the most fertile and profitable lands of the state.

"It is very remarkable that in Arkansas, within a small triangular area of thirty miles square between Washington and Murfreesboro and the White Cliffs of Little River we have abundant supplies of at least four of these valuable kinds of marl, greensand, lime, chalk and gypsum with the reasonable expectation that another year's investigation would reveal the phosphates. These facts alone, if properly utilized, will be of greater value to the state than all the gold dug within the bounds of California has been to that state.

Cretaceous Marls.

(Annual Report Ark. Geol. Surv., Vol. II, 1888.)

"These marls are very siliceous, and the lime and greensand occur in local horizons or beds. Their chief value, if used for mixing, would be to loosen and supply phosphoric acid, iron and potash to sandy and sticky clay lands. * * * * The potash in these marls is 3.06 parts in the 100. The lime can be regulated by selecting the fossiliferous or non-fossiliferous portions. The chief point of occurrence of these greensands is in the valley of Town Creek at Washington, Hempstead County, where the greensand occurs in varying degrees of purity, accompanied or unaccompanied by shell beds, which are useful in case lime is also needed. The same greensands occur in Clark County at many places, but as far as the writer's limited observations extend, in no case, so pure as those at Washington. The sandy surface residual soils of these marls, occupying an intermittent and limited strip from Arkadelphia to Columbus, are, no doubt, the finest soils possible for fruit trees and especially valuable for growing peaches. In this connection it is interesting to note that they present the same physical condition and occupy the same geologic horizon as the celebrated peach growing regions of New Jersey.

Chalky or Lime Marls.

(Annual Report Ark. Geol. Surv., Vol. II, 1888.)

"The lime marls of the middle beds of the upper Cretaceous in Clark, Hempstead, southern Howard and Sevier counties are of great variety in composition, inexhaustible in quantity, and must be a source of great wealth to the agricultural industries of this part of the state in the future. The principal geologic horizons of these marls are the beds between Washington greensands and the White Cliffs chalk, including the Big Deciper, Gryphaea vesicularis and Exogyra ponderosa marls, at innumerable places wherever these are the surface formations. The noted cretaceous black lands are without exception, the immediate residue, or but slightly transported debris, of these formations.

"'The essential ingredients in all of these lime marls are calcium carbonate, usually in a chalky state of division, phosphoric acid and potash; the accessory ingredients, which would be noted in comparison with the soil to be treated, are sand and clay. Greensand is usually more or less abundant throughout. In general, these lime marls possess, in addition to all the virtues of greensand marls above described, a large and valuable percentage of the form of lime known as calcium carbonate."

Gypseous Marls in Greene county and Calcareous and shell marls in Jefferson, Lonoke and St. Francis counties, in addition to the two localities already named, are reported in Bull. 624, U. S. Geol, Surv.

Building Stone.

See Granite.
See Marble and Limestone.
See Sandstone.

Clays.

Ball or Paper Clay.

Pike county.

Brick Clay.

Arkansas county, common brick made from red surface clay at Stuttgart.

Ashley county, alluvial buckshot clay used for common brick at Hamburg.

Benton county, pits in residual red-clay used for common brick at Bentonville, Rogers and Siloam Springs.

Boone county, at Harrison.

Bradley county, at Warren.

Carroll county, common brick made from residual clays at Berryville and Green Forest.

Clark county, common brick made from alluvial clay at Arkadelphia and Gurdon, common brick, fire brick and draintile from Tertiary clay at Whelen Springs.

Clay county, common brick made from red clay on Crowley's Ridge at Rector, Piggott and Pratt.

Cleburne county, alluvial clay used for common brick at Heber Springs.

Cleveland county, pressed brick made at Kingsland.

Columbia county, surface clays used for common brick at Magnolia and Waldo.

Craighead county, common and pressed brick made from clays of Crowley's Ridge at Jonesboro.

Cross county, loess and surface clay on Crowley's Ridge used at Wynne.

Drew county, alluvial and leached buckshot clays used near Monticello for common brick.

Faulkner county, buckshot clays used at Conway.

Garland county, alluvial and residual clays and Carboniferous shales used for common red brick at Hot Springs.

Greene county, pressed and common brick made from reworked loess at Paragould, and from loess at Gainesville.

Hempstead county, surface clay used at Hope, Doyle and Spring Hill.

Hot Spring county, alluvial clay used for common and pressed brick at Malvern; white plastic clay for white front and paving brick at Malvern.

Howard county, common brick clay at Nashville.

Independence county, red surface clay for common brick at Batesville.

Jefferson county, alluvial and surface clays used at Pine Bluff and Redfield.

Lawrence county, surface clay used for common brick at Walnut Ridge; yellow or reddish clay at Black Rock; residual clay at Imboden.

Lee county, red brick from loess of Crowley's Ridge, at Marianna.

Lincoln county, yellow surface clay used for common brick at Palmyra.

Lonoke county, at Lonoke and Cabot, red surface clay for common brick.

Miller county, Tertiary clays used at Texarkana for pressed and common brick.

Mississippi county, yellow alluvial clay used for common brick and draintile at Blytheville.

Monroe county, at Brinkley.

Nevada county, at Emmet and Prescott, common brick and building tile.

Phillips county, common brick made from mixture of surface clay and loess at Helena.

Poinsett county, reworked or eroded loess used at Harrisburg for common brick and draintile.

Polk county, common brick made from residual clay at Mena.

Pope county, residual clay and shale used at Atkins.

Prairie county, red surface clay used at DeValls Bluff.

Pulaski county, surface clay used for common brick at Little Rock.

Randolph county, at Pocahontas, common and front brick.

St. Francis County, brick clay and yellow loess on and near Crowley's Ridge, burns uniform red; used at Forrest City.

Saline county, surface clays used at Benton.

Searcy county, residual clays used for common brick at Marshall and Leslie.

Sebastian County, Carboniferous shales used at Fort Smith and Mansfield for common and paving brick; alluvial clay near Fort Smith burns light red, soft brick, re-pressed for front brick, uniform good color.

Sevier county, surface clay used for common brick near Delmar.

Union county, red surface clay used at Felsenthal.

Washington county, at Prairie Grove, common brick and draintile.

White county, argilliceous shales of Round Mountain suitable for sewer-pipe and paving brick; surface clay mined at Beebe, Searcy and Judsonia for common brick.

Woodruff county, surface clay used at Cotton Plant; common brick and draintile, made from buckshot clay at New Augusta.

Yell county, alluvial and surface clay mined at Dardanelle.

Fire Clay.

Clark county, fire brick made from Tertiary clay at Whelen Springs.

Crawford county, disintegrated Carboniferous shales in vicinity of Van Buren makes good yellow ware; used to line kilns at Fayetteville.

Hot Spring county, fire brick made at Malvern and Perla from Tertiary clays.

Ouachita county, at or near Lester, * * * high grade clay which burns gray to reddish brown. The clay is used in place of imported German pottery for crucibles, tank blocks and the like refractory vessels for glass works.

Saline county, Tertiary clays used for fire brick at Benton.

Occurs also in Conway, Dallas, Franklin, Garland, Hempstead, Johnson, Logan, Pike, Sebastian, White and other counties.

Kaolin.

Dallas County white kaolin of fair refractoriness outcrops in the Tertiary strata in the SE¼ section 10, T. 7 S., R. 17 W. and on Little Cypress Creek.

Garland county.

Hot Spring county.

Lawrence county, at Black Rock and Annieville.

Ouachita county, in large quantity in Tertiary strata on Sandy Branch.

Pike county, beds of variable color in the Upper Cretaceous (Bingen sand) outcrop at several places on Saline, Vaughan and Clear Creeks near Delight.

Pulaski county, white pisolitic kaolin in places in Fourche Mountain region, burns white and glazes well.

Saline county, nearly white kaolin, residual from nephelite syenite at Bauxite.

Pottery Clays.

Ashley county, Tertiary clays suitable for common pottery, near Hamburg.

Bradley county, Tertiary clays at Banks, Alga Bluff, Crawford's Bluff; clay at Johnsonville formerly used.

Calhoun county, supply on Champagnolle Creek, Moro Creek and large streams.

Clark county, Tertiary clays on Copeland Ridge and at Berringer mine near Whelen Springs.

Clay county, Tertiary clays on Crowley's Ridge near Piggott and Greenway.

Cleveland county, near New Edinburg, Mount Elba and other places.

Columbia county, near Mount Holly and Magnolia.

Conway county.

Crawford county.

Dallas county, Tertiary clays abundant and of excellent quality along streams.

Drew county.

Faulkner county, buckshot clays abundant over flood plains of streams.

Franklin county, strong dark-red earthenware residual clays abundant.

Garland county, residual clays from Paleozoic shales at Hot Springs and on Cedar Mountain formerly used for pottery.

Grant county.

Greene county, Tertiary clays on Crowley's Ridge at Gainesville, formerly used.

Hempstead county, Tertiary clays used for jug ware, etc., at Spring Hill.

Hot Spring county, at Perla Switch, near Malvern, burns light-cream colored common pottery.

Independence county, residual clays from Moorefield shale and Boone limestone near Sulphur Rock and Newark, formerly used.

Jefferson county, White Bluff on Arkansas River.

Johnson county, soft shale sagger clay in Felker mine, Coal Hill.

LaFayette county, leached pottery clays along Red River.

Logan county, Pennsylvanian clay abundant.

Miller county, Tertiary clays used at Texarkana for jugs, churns and jars; burns solid cream color.

Montgomery county, alluvial clay along Ouachita River used for stoneware near Story.

Nevada county.

Ouachita county, abundant along Ouachita Valley.

Pulaski county, red and yellow surface clay used for making flower pots.

Saline county, Tertiary clays used for jugs, crocks, jars, art pottery and other clay ware at Benton; Burns solid cream color.

Sebastian county, red and blue, has been mined in NE¼ section 20, T. 10 N., R. 26 W.; abundant at Fort Smith and elsewhere; light yellowish surface clay used at Comby's pottery.

Union county, abundant.

Yell county, Carboniferous shale formerly used in SE¼ section 12, T. 6 N., R. 21 W.

The above discussion of the clays is taken from Bulletin 624, U. S. Geol. Surv., Useful Minerals of the United States, 1917.

Tertiary Clays.

(U. S. Geol. Surv., Bulletin No. 351, by John C. Branner.)

"The Tertiary clays are the most important in the state. With their accompanying sands, marls and organic deposits, they underlie a large part of the state east and south of the Missouri Pacific Railway, south of Arkansas River. North of this and east of the Paleozoic hills the sediments are chiefly Quarternary deposits, except Crowley's Ridge, the lowest part of which is Tertiary.

"Limonite hardpan, or buckshot, is found all over the low country for 50 miles or more west of Crowley's Ridge. On the east of the ridge it is but a narrow fringe along its base below Poinsett county ,but north of this county it spreads over the whole region as a subsoil, in places rising to the surface and varying in depth from 3 to 7 feet. It extends eastward to the alluvial bottoms of the St. Francis. Along the Cache River in Greene and Clay counties much of the land is made up of these slashes or buckshot soil.

"In the low, flat lands, commonly known as "slashes," thin beds of plastic clays are found at places where acidulated waters have leached the iron from the soil. Some small potteries get their clays from such places. The supply of available clays of this kind is uncertain, and most of the areas covered by them are small. Such clays occur in the flat lands of the Cretaceous, Tertiary and Quarternary areas of the state. which, are not alluvial lands, properly speaking."

Clays For Drain Tiles.

(U. S. Geol. Surv., Bulletin No. 351, by John C. Branner.)

"There is no lack of clay in this state available for the manufacture of good drain tiles. The light-blue clays through the country lying between Beebe and Kensett and thence to Judsonia, and between Kensett and West Point, in White county, are available for the manufacture of tiles. The clays about Brinkley, Monroe county, are well adapted to tile making. Along the western base of Crowley's Ridge in Phillips, Lee and St. Francis counties, and on both sides of the ridge in Cross, Poinsett, Craighead, Greene and Clay counties, these clays are abundant and of excellent quality. They abound also along Bradshaw and Terre Noir creeks in Clark county.

"In the counties south and southeast of Little Rock, clays available for tile making occur both as surface soils in the valleys (not alluvial) and in the widespread stratified Tertiary beds of the region."

Fort Smith Clays.

(U. S. Geol. Surv., Bulletin No. 351, by John C. Branner.)

"Sebastian county is among the leading counties of the state in the development of its clay industries. Clay shales of the coal-bearing rocks are used in the manufacture of paving bricks. An analysis is here given of the Fort Smith clay shales, and for the purpose of comparison analyses of the well-known Carboniferous shales of Akron, Ohio, and Cheltenham, Missouri, are added:

	Ft. Smith	Akron, O.	Cheltenham, Mo.
Silica ($Si O_2$)	58.43	60.05	54.92
Alumina ($Al_2 O_3$)	22.50	20.00	22.71
Iron ($Fe_2 O_3$)	8.36	6.82	9.81
Lime ($Ca O$)	.32	.52	.52
Magnesia ($Mg O$)	1.14	.45	2.59
Potash ($K_2 O$)	2.18	1.79	3.16
Soda	1.03	1.60	.62
Sulphur	.16	1.95	——
Loss on Ignition	6.87	6.96	5.88
	100.20	100.99	100.21
Sand	25.72	29.12	2.04
Water at 110° — 115° C.	3.37	1.25	2.69

"The clay shales of Sebastian county are wide-spread and the beds are of great thickness. The shales of this region break up or decompose under the influence of the weather, forming plastic clays. Such clays are available for the manufacture not only of paving brick, but of sewer pipe and pottery.

"The abundance of excellent raw materials, the proximity of the deposits to the coal and gas fields and ample transportation facilities have encouraged development, giving the county high rank in the output of clay products."

Loess For Brick-Making.

(U. S. Geol. Surv., Bulletin No. 351, by John C. Branner.)

"The loess constitutes the upper 30 to 90 feet of the higher portions of Crowley's Ridge from Dee postoffice, in Craighead county, southward to Helena, in Phillips county. At Helena it attains its maximum thickness. This loess is especially suited to the manufacture of superior grades of brick. Care is necessary in its preparation for molding, however, and discrimination is required in respect to the mixture of soils from the neighboring hills. Where the soils of the hillsides are largely made up of sands and gravels derived from local outcrops of the Tertiary strata, as they are in some places about Jonesboro, Harrisburg, Gainesville and Wynne, they are unsuited to the manufacture of good brick. At other localities, notably near Marianna, at Forrest City, and at La Grange, the slopes of the hills, along their lower margin contain many small nodules of limonite, which render the soils less valuable for brick manufacture. If these nodules be removed by screening, the soils can be used successfully in brick manufacture. But at all these localities there are abundant deposits of clean loess that furnish unlimited opportunities for brickmaking. The bricks made from the Crowley's Ridge loess usually burn to a good color—cherry—red for hard, and a lighter shade of red for the soft burned ones."

Fire Clay.

(U. S. Geol. Surv., Bulletin No. 351, by John C. Branner.)

"Fire clays occur under nearly all the beds of lignite wherever they have been found in Crowley's Ridge. At the base of the great beds on Bolivar Creek in Poinsett county, are found clays rich in alumina and which might be valuable for the manufacture of press bricks, fire bricks, sewer pipes and similar uses. The clay is light gray in color and contains but little grit. The analysis is as follows:

Silica	61.76 per cent
Alumina	22.91 per cent
Iron (ferric) oxide	3.32 per cent
Lime	0.75 per cent
Magnesia	0.90 per cent
Potash	0.62 per cent
Phosphoric Acid	Trace
Loss on Ignition	8.75 per cent
Total	99.39

Pottery Clays.

(U. S. Geol. Surv., Bulletin No. 351, by John C. Branner.)

"The common pottery clays of Pulaski, Hot Springs. Saline, Clark, Hempstead and Miller counties, and those in other of the southeastern and eastern counties of the state, are all of sedimentary origin and of Eocene or lower Tertiary age. They were laid down in nearly horizontal beds, which generally dip toward the southeast at a low angle, so that beds that outcrop at or near the Paleozoic highlands lie at depths that become greater toward the southeast. In nature these Tertiary deposits vary from coarse sands through earthy marls to fine plastic clays. Many of the clay beds contain impressions of fossil leaves and small sticks of wood—materials that evidently sank, with the clays that inclose them, to the bottom of the swamps or lagoons that once covered this region. While the pottery clays dip to the southeast and gradually descend to greater depths beneath the surface, the beds do not preserve throughout the characters they may display at a single exposure."

Bauxite Clays.

(U. S. Geol. Surv., Bulletin No. 351, by John C. Branner.)

"The pisolitic clays and kaolins associated with the bauxite of Arkansas, in so far as their origin is understood, do not appear to fall under any of the foregoing classes. Their composition varies from that of an iron ore carrying 55 per cent of metallic iron to that of a true kaolin with but little or no iron. In some places they pass by gradual transition into true bauxite—that is, a hydrated oxide of alumina; in others they are a true kaolin, a hydrous silicate or alumina. In Arkansas, as in southern France and in Ireland, where similar deposits occur, they are associated more or less intimately with eruptive rocks. They occur in pockety deposits of uncertain distribution, with a tendency to form horizontal lenticular beds varying greatly in thickness as well as in character."

Shale.

(U. S. Geol. Surv., Bulletin No. 351, by John C. Branner.)

Over the most of the slate-bearing area, south of the Arkansas River and west of the Missouri Pacific Railroad, shale is common and much of it is of good quality. In northern Arkansas the Eureka shale is present in large quantities."

Kaolin.

Deposits of kaolin occur at many places and in a variety of formations. The best known deposits are those of Saline county, near Benton from which the famous Niloak (a reversed spelling of kaolin) pottery is made. The beauty and popularity of these wares is due as much to the skill of the artists as to the quality of the material from which the pottery is made, though the texture of the clay and its colors are important factors in ceramic art. No two pieces of this pottery are alike in arrangement of color. Two or more shades are employed, usually a blue and a brown, in interesting rotation and accidental pattern. No less attractive are the truly artistic designs by which the clay is shaped into vases, bowls, urns and all manner of nick-nacks, such as ornament the library table or mantle.

Doctor Branner in his report says:

"The kaolins found in Saline county are of three varieties: (1) a compact variety, derived from the feldspathic rocks by decomposition, (2) a pisolitic variety, found associated more or less intimately with the bauxite deposits, and (3) a clay-like variety of sedimentary origin, found at Benton." The report indicates extensive deposits in this locality.

In the same report Doctor Branner speaks of the extensive deposits of kaolin in Pike county as follows: "The Pike county kaolin is different in physical characters from any other kaolin thus far found in the state. * * * The largest area found in any one body covered about 10 acres. No exposures of feldspathic rock are within 50 miles of the deposit. * * * * The greatest depth at which the kaolin was found was 25 feet. * * * An analysis of a sample of kaolin from Vaughan Creek shows:

Silica (Si 0_2) 48.87; alumina (Al $_2$ 0_3) 36.51; iron (ferric) oxide (Fe $_2$ 0_3) .98; lime (Ca 0) .19; magnesia (Mg 0) .25; water 13.29. * * * It occurs in white, pink and brown colors. * * * It should be looked for at places where it will have a covering thick enough to protect it from infiltration of iron-charged waters from the surface. * * * The analysis of this kaolin shows that except for the stains referred to it is sufficiently pure for the manufacture of fine porcelain ware. It seems to be well adapted also for paper finishing. It also has high refractory properties and in case it can not be found free from impurities that would injure it as a china clay, it is still available for the manufacture of a high grade of fire proof articles."

In the Fourche Mountain district, where the igneous rocks are much weathered, there are beds and local deposits of kaolin or kaolinite, frequently impure from siliceous or ferruginous admixtures. Halloysite, a hydrous alumina silicate, allied to kaolinite is found in the western part of Pulaski County and at the Montezuma mine in Garland County.

A white kaolin of fair refractoriness outcrops on the Kilmer land in Dallas County and a quantity is reported on Sandy Branch in Ouachita County. Of the latter deposit Doctor Branner says: "After the sand is removed by washing it is available for the manufacture of pottery and also as a refractory material. The quantity seems to be very large." The kaolin deposits in Magnet Cove are not considered of commercial importance.

During the latter part of 1909 and the early part of 1910, under the direction of the State Geological Survey, H. D. Miser, began the work of collecting samples of clay and making the necessary observations as to the thickness, extent, covering, character, etc., of the deposits for the publication of a complete report. Eighty-seven samples were collected from the different parts of the state and transported to the University of Arkansas but these samples were never tested and further work on the clay report was suspended due to the veto, by the Governor, of the appropriation made by the Legislature of 1911 for the maintenance of the survey.

REFERENCES.

Branner, John C.—The Clays of Arkansas. Bulletin No. 351 of the U. S. Geol. Surv., and geological map of Arkansas, Washington, 1908.

Branner, John C.—A bibliography of clays and the Ceramic Arts, 451 pages, published by the American Ceramic Society, Columbus, Ohio, 1906.

Clays for paving bricks at Fort Smith. Fort Smith, 1889.

Analyses of Fort Smith clay shales. Brick, Tile and Pottery Gazette, Vol. X, No. 3, June, 1889.

Chatard, J. M.—Analysis of "Tallow clay," from Arkansas. Bulletin No. 90, U. S. Geol. Surv., Washington, 1892.

Eckel, E. C.—Clays of Garland County, Arkansas. Bulletin No. 285, U. S. Geol. Surv., 1905, Washington, 1906.

Eakin, L. G.—Analysis of kaolin from Garland County, Arkansas, 14 miles from Hot Springs. Bulletin No. 78, U. S. Geol. Surv., Washington, 1891.

Purdue, A. H.—Possibilities of the Clay Industry of Arkansas, published by the Arkansas Brickmakers' Association, Little Rock, 1910.

Cement Materials.

"Inasmuch as clays occur in almost every part of the state in greater or less abundance, it is assumed that the location of the chalk, at White Cliffs, must determine the site of a possible cement factory. A special effort has therefore been made to ascertain whether the clays at and near the chalk deposits are available for the production of cement. Little River and Sevier county clays are intimately associated with the post-tertiary gravels, and cover large portions, not of Little River and Sevier counties alone but of several of the adjoining counties in the southwestern part of the state."—Report Arkansas Geological Survey, Vol. II, 1888.

The proximity of the natural gas field of northwest Louisiana to the White Cliffs chalk deposits affords an additional advantage for the utilization of the abundant supply of materials in southwest Arkansas for the manufacture of cement and at the time of the publication of this bulletin it is reported that a large cement plant is to be installed, natural gas promising to solve the troublesome fuel problem.

"Limestone suitable for Portland cement occurs in many counties in the northwestern part of the state."—U. S. Geol. Surv. Bull. 624.

REFERENCES.

Branner, John C.—On the manufacture of Portland cement. Annual Report of the Geol. Surv. of Arkansas for 1888, Vol. II, Little Rock, 1888. Contains tables of analyses of Arkansas chalks and clays.

"The Cement Materials of Southwest Arkansas." Transactions of the American Institute of Mining Engineers, 1897, Vol. XXVII. 5 cuts and map.

Reply to criticism of R. T. Hill, on "The Cement Deposits of Arkansas." Transactions American Institute of Mining Engineers, Vol. XXVII, New York, 1897.

Eckel, E. C.—Portland Cement Resources of Arkansas. Bulletin No. 243, U. S. Geol. Surv., Washington, 1905.

Fitzhugh, G. D.—The Portland cement materials of southwestern Arkansas. Engineering Association of the South. Transactions, Vol. XV, 1905.

Hill, Robt. T.—Criticism of the paper of J. C. Branner on "Cement Deposits of Arkansas." Transactions of the American Institute of Mining Engineers, Vol. XXVII.

Chalk.

(See Limestone for Lime, Cement Materials and Agricultural Marls.)

"The chalk deposits of the state, so far at least as the Geological Survey has been able to outline them, are confined to Little River county. It is highly probable, however, that similar or more or less modified deposits may be yet found in adjacent counties along the northeastern extension of the outcrop. The chalk is exposed at and about the village of Rocky Comfort and at and about White Cliffs Landing on Little River. The most extensive exposures are those about Rocky Comfort where the chalk and black soil derived from its decomposition cover an area of about twenty square miles. The chalk and the chalky limestones extend further north and further east than they are represented, * * * but they are covered in those directions by superficial post-tertiary deposits of clay, gravel and sands to depths which would probably render their handling unprofitable. Even the derived black soil is itself too thick in many places to admit of removal. The area over which the chalk is actually exposed and without covering about Rocky Comfort is estimated to be only about 900 acres.

"The value of this chalk is hardly appreciated at the present time. When we consider that chalk is a very soft rock ,and therefore, does not require grinding as do the compact limestones, and further the greater ease with which it can be burnt to lime, its superiority over other limestones may be seen. The fact that this bed is the only one known to exist in the United States may increase its value. * * These cliffs which long have been a landmark of the region, are about 150 feet high, perpendicular, and as white and almost as pure as the celebrated chalk cliffs of Dover, England. * * * The following analyses show how closely it agrees in composition with the chalk of Medway, England, which has been so long used in the manufacture of Portland cement:

	Medway, Eng.	Rocky Comfort	White Cliffs
Carbonate of Lime	88.50	88.48	90.32
Carbonate of Magnesia	——	——	Trace
Iron Oxide	1.05	1.25	6.85
Alumina	2.82	1.25	1.30
Alkalies	2.61	——	None
Silica	5.45	9.77	6.85

—Report Arkansas Geological Survey, Vol. II, 1888.

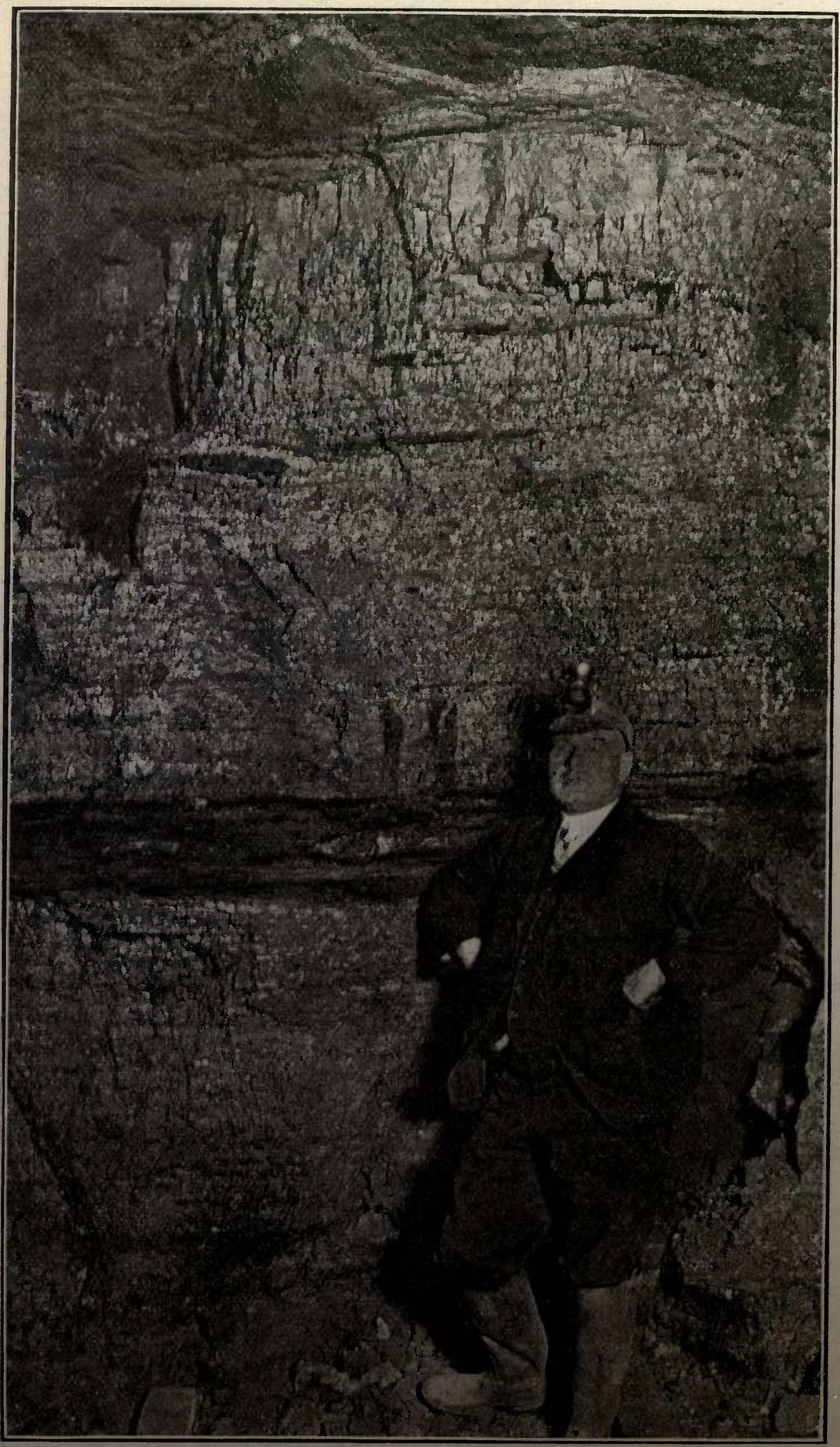
REFERENCES.

Branner, John C.—Reports Arkansas Geological Survey, Vol. II, 1888, and Vol. IV, 1890.

Marcou and Belknap.—Jura, Neocomian and Chalk of Arkansas. American Geologist, Vol. IV, pp. 357-367, December, 1889.

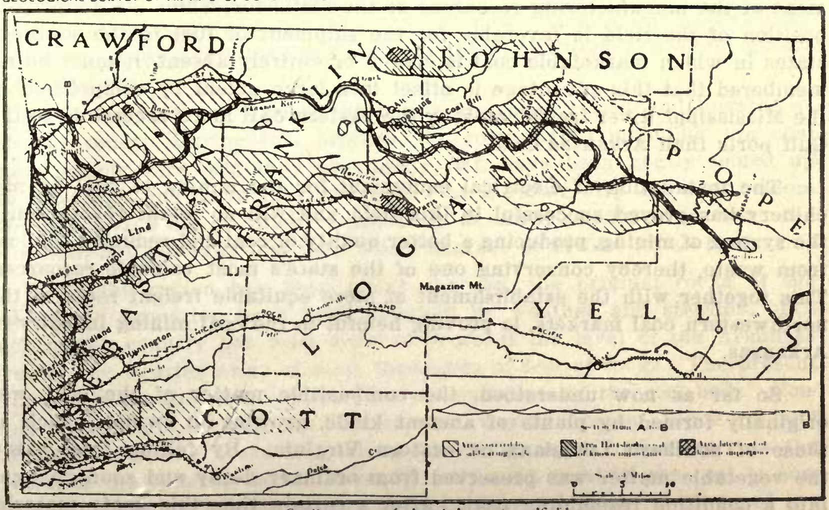
Anonymous.—Chalk of southwestern Arkansas. Stone, April, 1902, Vol. XXIV, New York, 1902.

Taff, J. A.—Chalk of southwestern Arkansas, with notes on its adaptability to the manufacture of hydraulic cement. Twenty-second Annual Report of the U. S. Geol. Surv., Part III, Washington, 1902.



Ten-foot Vein of Coal in a Sebastian County Mine.

GEOLOGICAL SURVEY OF ARKANSAS. COAL MINING. PLATE I



Outline map of the Arkansas coalfield.

Coal.

Beneath the beds of the Arkansas River, extending westward from Russellville to the state line there are extensive deposits of coal. The law provides that all mineral deposits under the bed of the stream belong to the state and, in a case from Ft. Smith, involving the right of certain persons to take sand from the river without compensation to the state, this law was upheld by the United States Supreme Court thus permanently establishing the state's title to mineral deposits underlying the Arkansas River. Dr. John C. Branner, former State Geologist, reported these river bed coal lands in a letter to the Governor on July 29, 1895.

From the reports of John C. Branner, A. H. Purdue, and A. A. Steel, and from other official publications ,the following facts are quoted:

The coal-bearing area of the state is 1584 square miles in extent. The field reaches from Russellville on the east through Pope, Johnson, Logan, Yell, Franklin, Crawford, Sebastian and Scott counties to and beyond the Oklahoma border.

About Clarksville and Russellville in the eastern part of the field, the product is a high-grade semi-anthracite and in the western part of the field is produced a high-grade semi-bituminous coal of almost smokeless quality.

Varying widely in character, the Arkansas coals will prove of their greatest utility, when the differences of quality are more properly emphasized in the trade and employed for the specific uses to which each type of fuel is especially adapted, for a coal that is remarkably well adapted to one purpose may be ill-fitted for another. The semi-anthracite is preferable for domestic use, because of its cleanliness, and the semi-bituminous is more suited to steaming purposes in locomotives or factory furnaces, because of its high-heat-producing qualities.

The most promising opportunities for the development of Arkansas' coal trade lies in the increase of home consumption by the more fuller development of the manufacturing resources of the state, for, while the geographic position of the field is favorable for the shipment of fuel to the southern states in which marketable coal is scarce or entirely absent, it must be remembered that this advantage is offset to a large extent by competition of the Mississippi River traffic, making the eastern coal more accessible to the Gulf ports than Arkansas coal.

The installation of electrical equipment for the mining of coal by machinery has proved successful in this field and will no doubt revolutionize the system of mining, producing a better quality of coal and reducing the loss from waste, thereby conserving one of the state's most valuable resources. This together with the establishment of more equitable freight rates to the northwestern coal markets, is proving helpful to the coal mining industry in Arkansas.

So far as now understood, the combustible matter of the coal was originally formed by plants of ancient kinds, growing in swamps, such as those of southern Louisiana or eastern Virginia. By falling into water, the vegetable matter was preserved from ordinary decay and soon changed into a condition resembling peat. After a certain time this peaty material was covered, generally by mud, as sometimes now happens to similar deposits in the delta of the Mississippi. Additional sediment was washed in as the country was more or less gradually submerged, until the original vegetable matter of the Arkansas coal was covered by some thousands of feet of mud and sand. This mud and sand in the course of time changed respectively to shale, which the miner calls 'slate,' and to sandstone. While covered in this way, the peat also changed to coal.

Since the original swamp was not everywhere equally deep, and since the vegetation grew more rapidly or decayed less in some parts than in others, the thickness of the coal is far from uniform over the entire field. The swamp also shifted its position at different times, and the growth of vegetation ceased occasionally, while thin layers of mud were washed in. Therefore, no one bed of coal is continuous over the whole coal-bearing area, and there are often one or more partings of dirt or rock known as 'middle band' or 'band rock' between the parts or 'benches' of the thicker seams. At least a thin bed of coal was formed over most of the Arkansas coal-area just after the sand which now forms the Hartshorne sandstone was put down, at which time the sea became shallow and filled with mud and vegetable matter. This Hartshorne sandstone is a thick, easily recognized stratum of rock, and indicates the most favorable place for prospecting, because the greater part of the coal in the state is just above it. This bed is known at Hartshorne coal. Smaller swamps were formed at two or three levels or 'horizons' above this, with as much as 1,000 to 1,200 feet of shale and sandstone between the resulting coal seams. In outlying parts of the main coal field, and as far away as the northwest part of the state, thin beds of coal ,mined for local use, were deposited considerably before the Hartshorne coal, and as much as 2,000 feet beneath its horizon.

All of the Arkansas true coal was deposited during the great coal-forming period called by geologists the Pennsylvanian period. Much later in Tertiary time, there were extensive peat swamps over much of that part of the state which is now low and flat. This material, however, has not been completely changed to coal, but has only reached the stage of lignite, which contains so much water that it is not now commercially valuable for direct burning, although the beds are very thick, and used to a slight extent for making gas.

Since the coal was buried, the region has been raised and lowered at different times. During this process, the rock layers including the coal seams, which were originally practically flat, have been gently folded up into anticlines and down into synclines. As a result they are now seldom level, but have a dip or 'pitch' occasionally as much as 18 degrees from the horizontal, but generally less than 6 or 7 degrees or 10 feet in 100 feet.

While the region has been above the sea, the original rocks of the coal-bearing formation have been attacked by weather and streams, until much of the country has been reduced to about the level of the Arkansas River by the wearing away of some thousands of feet of rocks. The present surface is below the higher part of the old anticlines of the coal beds. Consequently, much of the coal has been carried away by erosion. Since the land surface is hilly, the broad line, along which the main coal seam cuts the surface, or the 'outcrop' is very irregular, although most of the coal is now in the synclines or 'basins' as they are called by the miners. Some of the highest mountains in the field, such as Sugarloaf, Poteau and Magazine, are immediately over these basins.

Extent of the Coal Supply.

The Arkansas coal field lies in the valley of the Arkansas River between the western border of the state and Russellville.* It has roughly the shape of a Roman capital L with its base along the Oklahoma line. It is about 33 miles wide and 60 miles long, but it is only in the eastern and western parts of this area that the Hartshorne coal is probably thick enough or sufficiently free from partings to be of economic importance. Still, some 300 to 320 square miles will probably contain coal which may be mined. In places, the coal is over 8 feet thick, and when clean and of good quality, it has been mined where no thicker than 18 inches. The Hartshorne seam will probably average about 3 feet thick, and assuming this thickness over 310 square miles, that part of this bed which lies in Arkansas once contained something like a billion and a quarter tons of coal. The small amount of coal above and below the Hartshorne horizon may be nearly equivalent to that already mined, which was about 46,800,000 tons up to the end of 1919. At an average 'recovery' of 80 per cent in mining, the state will therefore yield only about 850,000,000 tons, but at the present rate of mining, this will last for 350 years. The rate of mining will probably increase.

Upon the accompanying map is indicated the area in which the Hartshorne coal is of known importance. Coal can not be mined from every acre of this area because there are many small tracts in it that contain only faulty or thin coal. They are often too small to map, and the exact location of many of them will not be known until all of the good coal has been mined. This faulty coal occupies a considerable proportion of the areas of the mines already opened. Since the best part of the coal seam is opened first, there will be a larger proportion of faulty coal in the remaining parts of

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*See Collier's report for partial description of the field and geology:

the Hartshorne seam. The amount of this faulty coal has been guessed at in placing the ultimate recovery of the coal at the low figure of 80 per cent.

Attention should be called to the fact that the largest part of the unmined area of thick Hartshorne coal lies beneath Sugarloaf and Poteau mountains. These tracts constitute by far the largest portion of the Arkansas coal reserves, estimated above. Unfortunately, most of this coal is under from 1,000 to 3,000 feet of rock and can not be profitably mined until the price of coal is largely increased.

Heating Value of Arkansas Coal.

The coals in the eastern part of the field have about seven to nine times as much fixed carbon as volatile combustible matter, and are rated as semi-anthracite. These are sold for domestic use at but little below the price of the Pennsylvania anthracite. Those in the western part of the field contain but three to six, generally five, times as much fixed carbon as volatile combustible, and the coals are bituminous. They are less smoky than most bituminous or soft coals.

The heating value of the coal, which lies between 13,700 and 14,700 British thermal units, and its specific gravity (average 1.35) place it among the best coals in the United States. Its moisture and ash are also low, but it contains a little more sulphur than other high grade coals. This sulphur, combined with iron as pyrite or 'fool's gold' often occurs as large nodules or layers, which the miners call 'sulphur balls' or 'sulphur bands.' These are noticeably heavier than the coal, and can be easily picked out by the careful miners. The Arkansas coal is probably a little softer than similar coals from some other fields.

List of Arkansas Coal Operators.

Sebastian County.

Western Coal & Mining Company	Jenny Lind
Conroy Coal Company	Hartford
Central Coal & Coke Company	Huntington
Central Coal & Coke Company	Hartford
Central Coal & Coke Company	Prairie Creek
Mammoth Vein Coal Company	Prairie Creek
Hartford Coal Company	Hartford
Katy Coal Company	Midland
New Coronado Coal Company	Arkoal
National Coal Mining Company	Hackett
American Smokeless Coal Company	Greenwood
Greenwood Coal Company	Greenwood
Arkansas Coal Mining Company	Hartford
Woodson Bar Coal Company	Bonanza
Woodson Coal Company	Hartford
Hartford Smokeless Coal Company	Hartford
Bolen Darnall Coal Company	Hartford
Harbottle Coal Company	Hartford
Rush Coal Company	Hartford
Hackett Smokeless Coal Company	Excelsior

Arkansas Valley Coal Company	Hackett
Backbone Coal Company	Excelsior
Crescent Coal Company	Hackett
Phoenix Coal Company	Arkoal
Bonanza Smokeless Coal Company	Bonanza
C. C. Woodson Coal Company	Montreal
Greenwood Ridge Coal Company	Montreal
Jim Lee Coal Company	Montreal
G. W. Jackson Coal Company	Midland
Mama Coal Company	Jenny Lind
Turnipseed Coal Company	Midland
Trantham Coal Company	Midland
W. C. McCormack Coal Company	Burma
Robinson Coal Company	Midland
Security Coal Company	Burma
Dave Moody Coal Company	Burma
John Mantell	Prairie Creek
Martin-Rains Coal Company	Hartford
Price & Wilson Coal Company	Huntington
J. F. Looper Coal Company	Huntington
Hackett-Excelsior Coal Company	Ft. Smith
Peacock Coal Company	Jenny Lind
W. H. Meillmier Coal Company	Hartford
S. A. McAdoo Coal Company	Barling
Graham-Hall Coal Company	Huntington
Co-Operative Coal Company	Burma
Jim Fork Coal Company	Midland
Hartford Valley Fuel Company	Hartford
McGehee & Urquhart Coal Company	Jenny Lind
Litchford Coal Company	Huntington
Border Coal Company	Hackett
Fax Coal Company	Huntington
F. H. Schwearjohnn Coal Company	Hartford
Basinger Coal Company	Excelsior
Bargibend Coal Company	Excelsior
Davis Coal Company	Prairie Creek
George Wilkinson	Prairie Creek
Roughley Coal Company	Hartford
M. Clayton	Hartford
T. H. Bunch Coal Company	Hackett
Great Western Coal Company	Hartford
Pruett Coal Company	Hackett
Gibson & Rice Coal Company	R. F. D., Charleston
Tom Hoopengarner Coal Company	Huntington
Thatch & Graham	Montreal
Smokeless Fuel Company	Montreal
Woodson & Abernathy	Montreal
Williamson Strip Pit	Montreal
Sun Coal Company	Hackett

Franklin County.

Western Coal & Mining Company	Denning
Geo. E. Dodson Coal Company	Alix
Wallis McKinney Coal Company	Alix
Denning Coal Company	Denning
Schmidt Blakely Coal Company	Alix
Semi-Anthracite Fuel Company	Alix
Altus Black Diamond Coal Company	Altus
Haskell Coal Company	Charleston
Douglass Coal Company	Denning
Douglas Coal Company	Alix
Lewis & Whittle	Alix
Moomaw Coal Company	Ozark
Denning Domestic Coal Company	Alix
Liberty Coal Company	Denning
Ozark Coal & Mining Company	Ozark
Jones Mine	Ozark
Carpenter Coal Company	Charleston
Smith Brothers Coal Company	Ozark
Altus Coal Company	Denning

Johnson County.

Sterling Anthracite Coal Company	Clarksville
Fernwood Mining Company	Clarksville
Fernwood Mining Company	Montana
Spadra Creek Coal Company	Spadra
Luca Mardis Coal Company	Spadra
McWilliams Ward & Company	Spadra
Johnson King & Company	Montana
McKinney Bros. Coal Company	Montana
Clark McWilliams Coal Company	Williams Spur
Scranton Anthracite Coal Company	Montana
Collier-Dunlap Coal Company	Hartman
Duncan Coal Company	Hartman
Hoing Coal Company	Coal Hill
Gaelic Coal Company	Coal Hill
Rafter Coal Company	Coal Hill
Douglas Brothers Coal Company	Coal Hill
I. H. Mitchell	Coal Hill
Douglass & Sons	Coal Hill
Smokeless Anthracite Coal Company	Spadra
Consolidated Coal Company	Spadra
W. A. Hill Coal Company	Coal Hill
J. V. Herring	Montana
Eustice Coal Company	Montana

Pope County.

Southern Anthracite Coal Company	Russellville
Ouita Anthracite Coal Company	Ouita
H. K. Vines Mine	Russellville
Claude Humphrey	Russellville

Logan County.

Short Mountain Coal Company	Paris
Goldsworthy Brothers	Paris
Grand Coal Company	Paris
Dennis Coal Company	Paris
Paris Coal Company	Paris
New Union Coal Company	Paris
J. R. Remy Coal Company	Paris
Davis Coal Company	Paris
Schmalz Bros. Coal Company	Paris
Liberty Coal Company	Paris
Gunter Coal Company	Scranton
George Daly & Company	Prairie View
Simon Gagaway	Paris

Scott County.

Hodge Coal Company	Bates
Liles Coal Company	Coaldale
Harper Coal & Coke Company	Bates
Bates Smokeless Coal Company	Bates
Bethel Coal Company	Mansfield

Crawford County.

John Owens	Alma

Yell County.

Cornelius King	Chickalah
N. Goodier	Dardanelle

Washington County.

J. W. Turnsill	Baldwin
J. R. Stanberry	Baldwin
H. M. Reed	Baldwin
W. M. Edwards & Son	Baldwin

REFERENCES.

Allen, Thomas.—Semi-anthracite coal 100 miles west of Little Rock. Transactions of the American Institute of Mining Engineers, Vol. III, New York, 1874.

Anonymous.—Arkansas anthracite coal. Engineering and Mining Journal, Feb. 22, 1902, Vol. LXXIII.

Branner, John C.—Annual Report of the Geological Survey of Arkansas for 1888, Vol. III. The geology of the coal regions; a preliminary report upon a portion of the coal regions of Arkansas, by Arthur Winslow, map, Little Rock, 1888.

Branner, John C.—A preliminary statement of the distribution of coal over the area examined by the Geological Survey (of Arkansas). Arkansas Gazette, Little Rock, Feb. 13, 1889.

Branner, John C.—"The Coal Fields of Arkansas." Mineral Resources of the United States, Washington, 1893.

Bain, H. F.—The Bonanza, Arkansas, coal mines. Engineering and Mining Journal, Nov. 12, 1898, Vol. LXVI, pp. 579-580.

Bache, F.—The Arkansas-Indian Territory coal field. Engineering and Mining Journal, Vol. LXXVI, New York, Sept. 12, 1903.

Claghorn, Clarence R.—The preparation of Bernice anthracite coal. Annual Report of the Geol. Surv. of Arkansas for 1888, Vol. III, Little Rock, 1888.

Chance, H. M.—Geology of the Choctaw coal fields. Transactions of the American Institute of Mining Engineers, Vol. XVIII, New York, 1890. Contains notes on Arkansas coals.

Collier, Arthur J.—The Arkansas coal field. Bulletin No. 316, U. S. Geol. Surv., Washington, 1907; also Bulletin No. 326, U. S. Geol. Surv., 1907.

Campbell, M. B.—The classification of coals. Bi-monthly Bulletin of the American Institute of Mining Engineers, No. 5, New York, Sept., 1905. (Includes Arkansas coals.)

Crane, W. R.—Coal mining in Arkansas. Engineering and Mining Journal, Oct. 28, 1905.

Drake, N. F.—A geological reconnaissance of the coal fields of the Indian Territory. Proceedings of the American Philosophical Society, Vol. XXXVI, with ills. and maps. Reference to Arkansas geology. A reprint published as No. XIV of "Contributions to Biology from the Hopkins Seaside Laboratory," Palo Alto, 1898.

Keyes, C. R.—Horizons of Arkansas and Indian Territory coals compared with those of other trans-Mississippian coals. Engineering and Mining Journal, June 1, 1901, Vol. LXXI.

Lawrence, B.—Coal in Arkansas. De Bow's Review, Vol. II, New Orleans, 1851.

McFarlane, James.—The coal regions of America; their topography, geology and development, New York, 1873. (General description of Arkansas coal fields.)

Pumpelly, Raphael.—Production of bituminous coal in Johnson, Pope, Sebastion, and Washington counties. Tenth Census U. S., Vol. XV.

Purdue, A. H.—Coal Mining in Arkansas. Arkansas Geol. Surv., Part I, 1910.

Prime, Fred, Jr.—Notes on the Arkansas coal field and statistics of production. Tenth Census U. S., Part II, Vol. V.

Potter, Wm. B.—Semi-bituminous coal of Johnson county with analyses. Transactions of the American Institute of Mining Engineers, Vol. III, 1874, Philadelphia, 1875.

Steel, A. A.—Arkansas Geol. Surv., A. H. Purdue, State Geologist, 1912.

Saward, Frederick E.—The Coal Trade, 1890; Arkansas coal statistics and analyses.

Stevenson, J. J.—Anthracite of Arkansas. Bulletin of the Geological Society of America, Vol. V, Rochester, 1894.

Taff, J. A.—The southwestern coal field. Extract from the 22nd Annual Report of the U. S. Geol. Surv., Part III, Washington, 1902.

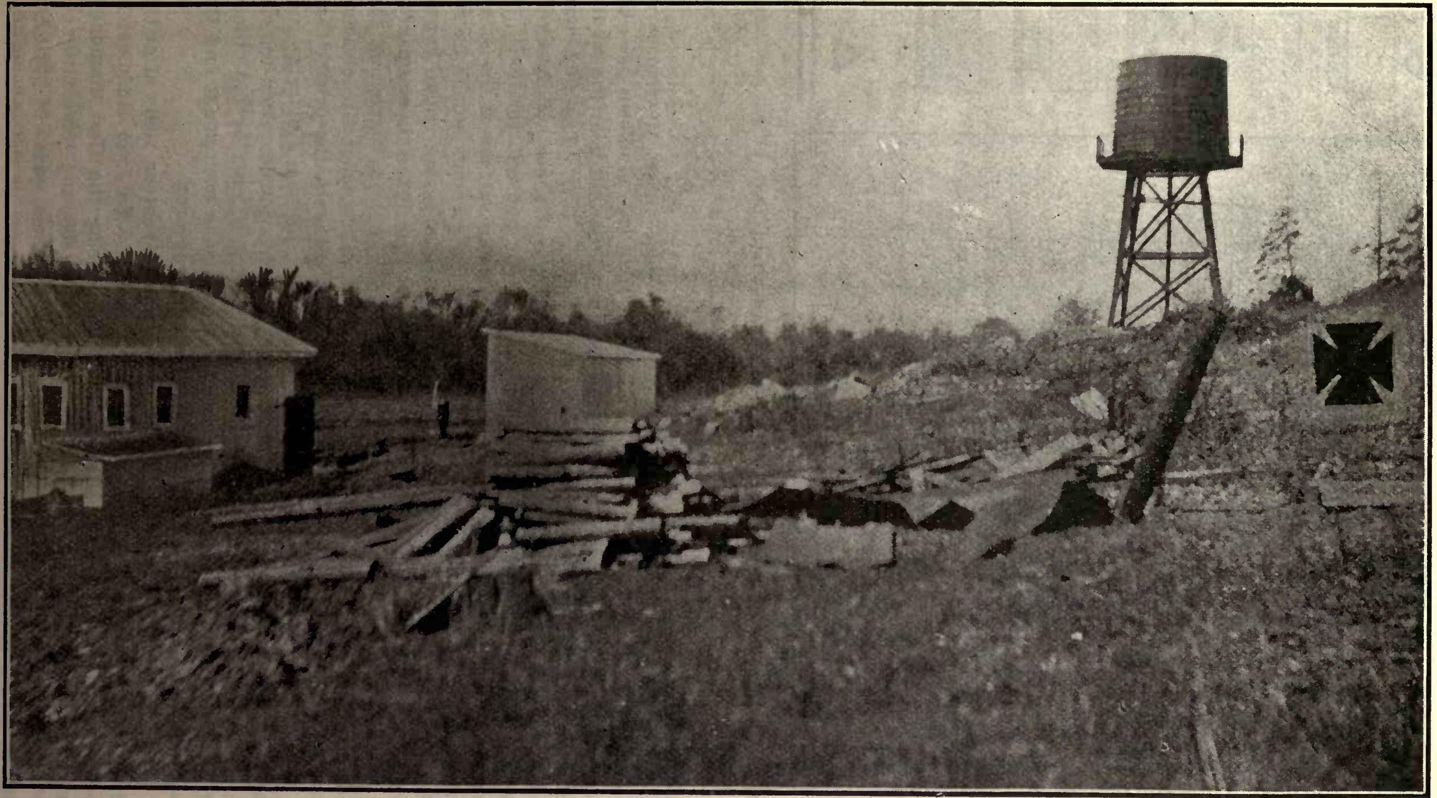
Taff, J. A.—The Camden coal fields of southwestern Arkansas, XXI Annual Report. U. S. Geol. Surv., part II, pp. 313-329, 1900.

Winslow, Arthur.—A preliminary report on a portion of the coal region of Arkansas. Annual Report of the Geol. Surv. of Arkansas for 1888, Vol. III, map, Little Rock, 1888.

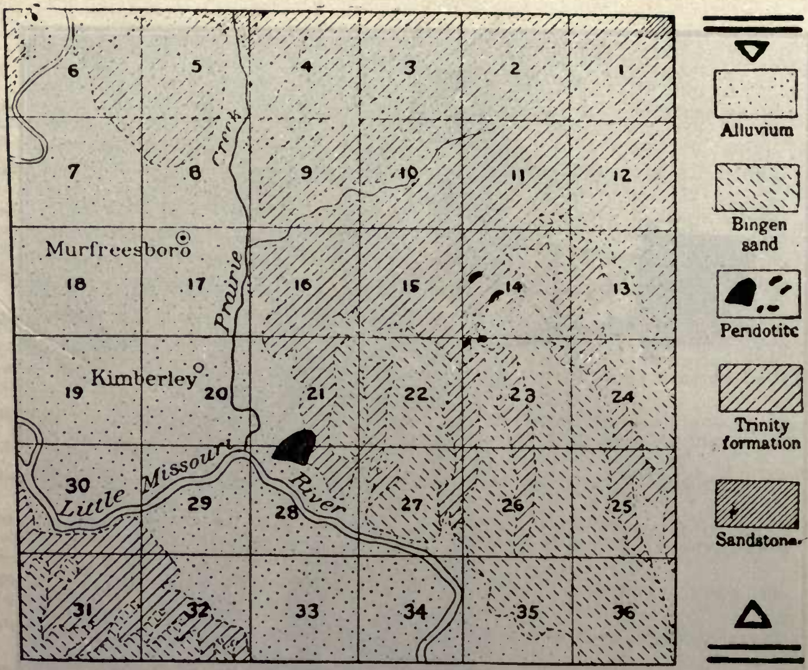
Chert.

Under the heading "Road Making Materials" Doctor Branner calls attention to the value of the hard, flinty chert belonging to the Mississippian series of the Carboniferous system and to the Ordovician system of rocks, widely distributed in all the counties north of the Boston Mountains, as a material especially suited for the building of highways.

"The chert of the Boone limestone is left in large quantity on the surface as a residual product. Under climatic influences it is broken up into small fragments that make admirable road material. In many places the fragments have collected in enormous quantities as talus at the base of the slopes, where the material could be easily loaded on wagons with a steam shovel."—Folio 202, U. S. Geological Survey.



Scene at the Arkansas Diamond Mine June, 1920. Cross Marks Spot where 18 Carat Diamond was Found.



U. S. Geol. Surv   **Map of Arkansas Diamond Field.**

Diamonds.

Four areas of peridotite (diamond-bearing rock) near Murfressboro, Pike county, are described in a report by Hugh D. Miser, (Bulletin 540—U) published by the U. S. Geol. Surv. in 1913. One of these, that near the mouth of Prairie Creek, has been known to geologists since 1842. The rock was not known, however, to be peridotite until 1889, when Branner and Brackett studied and described the nature of the rock and its geologic relations. It is said that Dr. Branner spent half a day searching the surface of the small area for diamond specimens. Not finding any of the precious stones he refrained from making a sensational announcement or arousing undue hopes, but published his discovery in a conservative report that at the time attracted the attention of the scientists more for its importance in suggesting the time and character of the disturbing influences, which about the close of the Cretaceous sank the greater part of Arkansas beneath the ocean, than for its value in disclosing a new diamond field. Dr. Branner's extreme caution. displayed in this matter, was due no doubt to his consideration for the public mind which, at about that time, had been disappointed by the failure to find gold in the same region, following a tremendous excitement and the loss of many millions of dollars in unwise mining ventures.

The first diamonds were actually found in 1906, seventeen years after the visit of Doctor Branner to the Prairie Creek district. To John Huddleston, now of Arkadelphia, belongs the credit of discovering the first diamonds. These rough stones were sent to a Little Rock jeweler and were later cut by Tiffany in New York, being pronounced perfect gems, equal in purity to those of South Africa. Thus the public came to know of the presence of diamonds in Arkansas. The lands containing the deposits were purchased, the town of Kimberly was established and mining operations were begun by several companies.

According to the best information that is available at least 5000 diamonds were found up to the end of 1919. These included white, brown and yellow stones and a canary-colored octahedron weighing 17.85 carts and a clear flat stone of 11 carats. Only one company has operated in the field since 1913, and that upon a small scale. However, it is said that sufficient diamonds have been found to defray the small maintenance expenses. None of the Arkansas diamonds are offered for sale.

Sam W. Reyburn of New York, President of the Arkansas Diamond Corporation, recently announced that the necessary capital had been raised to install a modern reduction plant and that operations would be resumed by June, 1920, with equipment necessary to wash 100,000 tons of dirt and determine whether Arkansas has a real diamond field.

Dr. Branner observed that the peridotite cuts across the Trinity formation of lower Cretaceous age, and lately H. D. Miser, of the U. S. Geol. Survey, has described a sedimentary deposit containing pebbles from the peridotite near the base of the Bingen formation (upper Cretaceous.) This fixes the age of the peridotite and probably all the other igneous rocks of Arkansas in the interval between the upper and lower Cretaceous periods.

REFERENCES.

Branner, John C., and Brackett, Richard N.—The Peridotite of Pike County, Arkansas. American Journal of Science, Vol. XXXVIII, 1889. The same is reproduced in the Annual Report of the Geological Survey of Arkansas, for 1890, Vol. II.

Branner, John C.—Some facts and corrections regarding the diamond region of Arkansas. Engineering and Mining Journal, Vol. LXXXVII, New York, Feb. 13, 1909.

Glenn, L. C.—Arkansas Diamond-bearing Peridotite Area. Bulletin Geol. Society America, Vol. 23, 1912.

Kunz, Geo. F., and Washington, Henry S.—Diamonds in Arkansas. Bimonthly Bulletin of the American Institute of Mining Engineers No. 20, New York, 1908. Engineering and Mining Journal, Aug. 10, 1907.

Notes of the forms of Arkansas diamonds. American Journal of Science, Vol. CLXXIV, New Haven, September, 1907.

Schneider, P. F.—A preliminary report of the Arkansas diamond field. Bureau of Mines, Manufactures and Agriculture, 16 pp., Little Rock, 1907.

Sterrett, D. B.—Diamonds in Arkansas, Mineral Resources U. S., for 1909, U. S. Geol. Surv., 1910.

Purdue, A. H.—A new discovery of peridotite in Arkansas. Economic Geology, Vol. III, August-September, 1918, III.

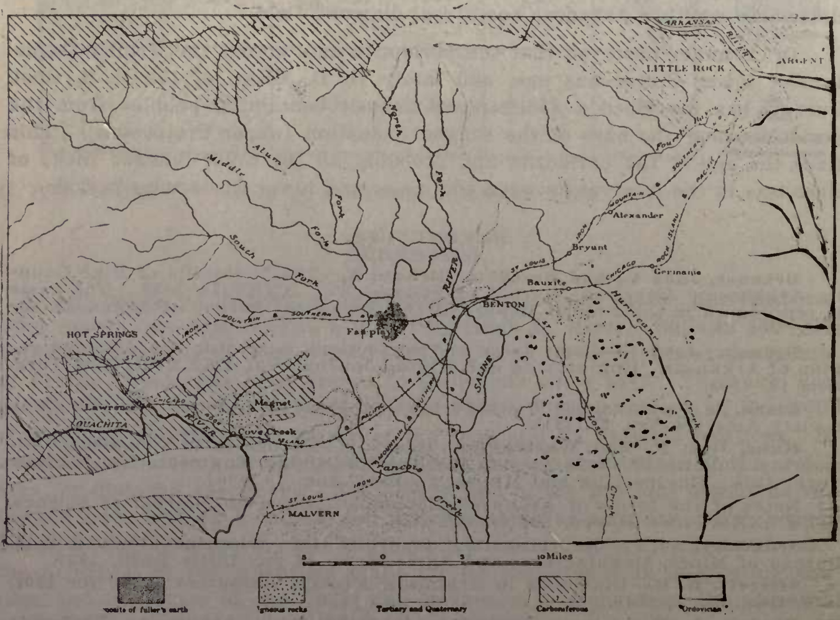
Fuller, John T.—Diamond mine in Pike County, Arkansas. Engineering and Mining Journal, Vol. LXXXVII, New York, Janary 16, 1909; Mar. 20, 1909.

Miser, H. D.—New Areas of diamond-bearing peridotite in Arkansas. U. S. Geol. Surv., Bulletin 540.

Fuller's Earth.

While fuller's earth is now being produced in five or more different states, the presence of this mineral in the United States was first discovered in Arkansas, near Alexander, and is mentioned in a special paper by Doctor Branner who made an analysis from specimens presented to him by John Olsen in 1890.

The material was used for a time for the clarifying of oil in the plant of the Southern Cotton Oil Company. Of this experiment Doctor Branner says: "This fuller's earth is the weathered portions of nearly horizontal beds of tertiary clays that come through the low hills over a large area in the region south and southwest of Little Rock. According to the miner's preconceived notion that ore must "improve with depth" it was expected that after the weathered edges of the clays had been passed the fuller's earth must likewise improve. I remember also that when Mr. Littlejohn (manager of the oil mill) thought the earth was going to be a great success, the miners began to congratulate themselves that the stuff was looking "good enough to eat" and consequently that it must be improving. Almost immediately Mr. Littlejohn reported that it was not working well. To me the reason seemed very clear; the quarymen had left the weathered zone behind and had entered the unaltered clays."
U. S. Geol. Surv.



Location of Fuller's Earth Deposits.

In his report, "The Clays of Arkansas," Doctor Branner mentions the Arkadelphia shale as a probable source of fuller's earth.

Of later developments in the mining of fuller's earth in Arkansas, Hugh D. Miser in United States Geological Survey Bulletin, 530—Q, Developed Deposits of Fuller's Earth in Arkansas, says:

"The developed deposits of fuller's earth in Arkansas occur in an area of about three square miles which lies between Hot Springs and Benton. The Missouri Pacific railroad passes through this area about seven miles west of Benton. * * * * These deposits were discovered in 1897 by John Olsen of Benton. Mr. Olsen at first shipped the crude earth to the Fairbanks Packing Company, St. Louis, by which it was milled and used. He later erected at Klondyke station a plant for milling the crude earth. At present the other operators owning plants within the area are the Fuller's Earth Union (Ltd.) of London, England; the Fuller's Earth Company, General, of Wilmington, Delaware and Fred Rossner, of Little Rock.

(More recently it is reported to the Bureau that a new company has been formed to take over the Olsen interests and that mining, which has been suspended for some time, is to be resumed on a much larger scale.)

"The Arkansas earth is used for bleaching cottonseed oil, hog leaf lard, beef tallow and stearine. When the right kind of crude earth and the proper method of manufacture are used, a satisfactory earth is produced. Yet because of lack of experience in this industry some poor grades of earth have been put on the market. The production of this inferior earth has retarded to some extent the introduction of the Arkansas earth to displace the English earth, which is used mainly by American cotton-oil companies and packers. * * * *

"Arkansas was the second largest producer of fuller's earth in the United States from 1904 to 1907, Florida being first in amount of production. During 1909, 1910 and 1911 Arkansas was third in output and value, Florida being in first place and Georgia second. The amount of fuller's earth produced in Arkansas in 1909 was 2,314 short tons, valued at $18,313.00; in 1910 it was 2,563 short tons, valued at $29,137,00.'"

REFERENCES.

Middleton, Jefferson.—Fuller's Earth in 1917, U. S. Geol, Surv., Mineral Resources of the U. S., 1917, Part II.

Branner, John C.—The Clays of Arkansas, Bulletin 351, U. S. Geol. Surv.

Branner, John C.—An Early Discovery of Fuller's Earth in Arkansas, Transactions of the American Institute of Mining Engineers, New York, 1912.

Miser, H. D.—Developed Deposits of Fuller's Earth in Arkansas, Bulletin 530—Q, U. S. Geol. Surv.

Gas.

See Natural Gas.

"Granite" (Syenite.)

"The total area of igneous rock exposed within the boundaries of the State of Arkansas does not exceed thirteen or fourteen square miles, but the value of these rocks as building and paving materials gives them great economic importance. Their formation and mode of occurrence are of especial scientific interest on account of their relation to the geologic history of the state at large; while their relations to each other are of even more importance from a purely petrographic standpoint, since they illustrate the relative positions of certain groups of igneous rocks whose mutual relations have been as yet but little studied.

"Character of the Rocks:—The igneous rocks of Arkansas all belong to the eleolite syenites and their associated dike rocks. They are of the abyssal and intrusive classes, as distinguished from the metamorphic gneisses and schists and the true effusives. It has not been absolutely proved that some of the rocks did not form true eruptive masses, but on the other hand no proof that they did occur as such has been found, and since their crystalline structure points to a non-effusive origin, it may well be assumed that they all belong to the abyssal and intrusive rocks.

"**Geologic and Geographic Position.**—The larger masses of igneous rocks occur on the southeastern side of the much disturbed and folded area known as the Ouachita uplift, which extends from the central portion of the state in a nearly due west direction to and across the Oklahoma boundary. The smaller dikes of intrusive rock are scattered here and there throughout the eastern half of the uplift and appear to be independent of the folds and ridges, which were formed long before the intrusion of the igneous masses.

"The larger masses of igneous rock are, however, all situated in or near the main anticlinal axis of the uplift and it is probable that they were forced through at points, where, by reason of the folding, the strata were somewhat weakened. It is probable that the greater part of the erosion which has modified the topography of this region to such an enormous extent had practically been completed before the intrusion of the igneous rocks.

"**Division of the eleolite syenites of Arkansas into areas:**—The eleolite syenites were probably all produced from one magma, but since they occur in four well defined areas, and as the rocks which form these various areas differ greatly in their mineralogic independent groups, which can hardly be sufficiently correlated with the others to allow of their all being described together.

These four regions are:

1. The Fourche Mountain or Pulaski county region.
2. The Saline county region.
3. The Magnet Cove region.
4. The Potash Sulphur Springs region.

"Outside of these four typical regions there are many dikes of igneous rock which as far as their petrographic characteristics are concerned might be associated, as well with one group as with another, and which are, as a matter of fact, probably directly connected with none of them, although formed from the same magma from which they all derived their material.

"The differences in structure and mineralogic composition observed in the rocks of the four regions are due to differentiations in the original magma from which they were formed, and are attributable in many cases directly to the conditions under which they solidified.—Report Arkansas Geol. Surv., Vol. II, 1891.

(In addition to the masses described by Williams there are four masses of peridotite near Murfreesboro, Pike County, together with a number of related dikes. A study of these masses has proved that these igneous rocks of Arkansas were all probably formed during the land interval separating the upper and lower Cretaceous periods.)

REFERENCES.

Branner, John C.—Annual Report of the Geol. Surv. of Arkansas for 1890, Vol. II, The igneus rocks of Arkansas, by J. Francis Williams, Little Rock, 1891.

Washington, H. S.—The igneous complex of Magnet Cove, Arkansas. Abstract, Science, March 16, 1900, Vol. XI, Bulletin Geological Society of America, Vol. XI, Rochester, 1900. Review, American Naturalist, Vol. XXXV, May 1901. Review, Technology Quarterly, Vol. VII.

Glass Sand.

Since the establishment of glass factories at Fort Smith and Texarkana, where these industries have access to natural gas, the cheapest and best of fuels, a more convenient market is afforded for the valuable glass sands of the state. It is said that the Fort Smith plant uses 1,000 tons of sand a month and that the Arkansas sands are preferred, but because of an inability to get cars for the shorter haul the material at present is brought from Pacific, Missouri.

The glass sands of the saccharodial sandstone, (St. Peter) quarried at Guion, Izard County, are probably the purest and most extensive in the state. This sand is so pure that it is not even stained. It is quite as good as the best glass sands of Missouri, but is of finer grain.

Glass sands are found in the St. Peter sandstone in north Arkansas from Batesville to Fayetteville.

At Whitlock Spur, near Bryant, Saline County, there is an extensive deposit of high grade glass sand.

Purdue says: "The novaculite of the Ouachita Mountains probably would produce glass of fine quality."

A deposit of glass sand is reported in Jefferson County near Pine Bluff.

With reference to the glass sands of Crowley's Ridge, in Greene County, the following is quoted from the report of the Arkansas Geological Survey, Vol. II, 1889:

"The sand is white. * * * It would make an excellent bottle glass sand, or even the cheaper grades of window glass could be made from it. Its product would be green in color, but less deep than the common green bottle glass, owing to the small amount of iron present. With soda and lime added it would make a fairly good window glass."

REFERENCES.

Burchard, E. F.—Glass Sands of the Middle Mississippi Basin, Bulletin No. 285, U. S. Geol. Surv.

Gravel.

(See Roadmaking Materials.)

Several thick deposits of gravel are widely distributed along the north edge of the Gulf Costal Plain. The gravels are of Lower Cretaceous, Upper Cretaceous and Quarternary age and are composed mainly of pebbles of novaculite (a variety of chert) derived from the Arkansas novaculite exposed in the Ouachita Mountain region. They are used in making concrete, in ballasting railroads and in the construction of wagon roads. The Pike gravel is the thickest and most persistent gravel bed in the area and has a larger surface distribution than any other. The thickness is rather uniform, being in most places between 20 and 50 feet, but it apparently attains 100 feet near Pike. This gravel consists of pebbles usually less than half an inch in diameter but it contains many larger ones and also many cobbles as much as ten inches in diameter. These pebbles have not been used in tube mills, ,but they are of such a character that it is believed well selected pebbles may be suited for this purpose.

Crowley's Ridge Gravels.

The gravel beds of Crowley's Ridge in northeast Arkansas are of varying thickness, being deposited on a surface which indicates very considerable erosion at a period prior to their deposition. The gravels are made up mainly of a light-colored chert, are generally well rounded or waterworn, rarely angular and always well polished. When in place they are always rudely assorted, cross-bedded and mingled with more or less sand. The gravel is considerably above the general level of the country, reaching often to the very tops of the highest hills. Deposits occur at various points along the ridge from the Missouri border to Helena.

Arkansas River Gravels.

In the bed of the Arkansas River throughout its course in Arkansas and in the beds of many of its tributaries, are gravel bars containing larger quantities of material suitable for road-building.

Gravels on the Higher Ridges

On the higher hills about Little Rock and northwest of that city are quantities of surface gravel. Similar ridges occur in Saline, Grant and Dallas counties and in other parts of southwest Arkansas.

"Gravels (road metal). Along Crowley's Ridge, in Clay, Green, Craighead, Poinsett, Cross, and St. Francis counties. On and near the border of the highlands in Randolph, Lawrence, Independence, Jackson, White, Pulaski, Saline, Hot Spring and Clark counties, and in Bradley, Calhoun, Dallas, Drew, Howard, Jefferson, Lafayette, Pike and Sevier counties. These gravels consist almost entirely of chert, quartz and novaculite pebbles and range in age from Lower Cretaceous to Quarternary."—Bulletin 624, U. S. Geol. Surv.

REFERENCES.

Miser, H. D., and Purdue, A. H.—Gravel Deposits of the Caddo Gap and De Queen Quadrangles, Arkansas, U. S. Geol. Surv., Bulletin 690—B.

Branner, John C.—Crowley's Ridge, Annual Report Arkansas Geological Survey, Vol. II, 1889.

————. Road-Making Materials of Arkansas, published elsewhere in this volume.

Graphite.

Graphite is abundant and pure in many localities in the Trap Mountains in Hot Spring County. It occurs also in the form of graphitic shale in Garland and Montgomery counties. Some of this material is of excellent quality, while some of it occurs in streaks of pockets only, and much is mixed with earthy matter. The impure varieties are available for paints.

Purdue says: "Possibly the most promising outcrop is in the bed of Collier Creek at Buttermilk Springs, northeast of Caddo Gap in Montgomery County.

Gypsum.

"The Trinity formation (of southwest Arkansas) is rich in gypsum and gypsiferous marls ,the latter too impure for the arts, but suitable for an agricultural fertilizer or land plaster. At the gypsum bluff, or "Plaster Bluff," as it is familiarly called, two and one-half miles south of Murfreesboro, in Pike County, there are strata of pure saccharoidal alabaster, from 6 inches to 6 feet in thickness, with seams of satin spar. This gypsum is sufficiently pure to make plaster of paris, as well as fertilizer, and will no doubt be a source of much wealth to the country some day. The same geologic horizon as that contained the gypsum beds on Little Missouri River outcrops sparingly at many points along the southern scarp of the Fort Towson road valley."—Report Arkansas Geol. Surv., Vol. II, 1888.

Prof. A. H. Purdue mentions the presence of gypsum on Messers Creek, north of Center Point, in Howard County.

Gypsum, or "satin spar," occurs in broad crystals, fibrous and earthy, in the zinc and lead districts of north Arkansas. This mineral also has been observed in parts of Saline County where pyrite and limestone are found.

REFERENCES.

Hill, Robt. T.—The Neozoic Geology of Arkansas, Vol. II, Report, Geological Survey of Arkansas, 1888.

Branner, J. C.—Report Arkansas Geol. Surv., Vol. V, 1892.

Lignite.

Camden, or Ouachita Deposit.

Extending northwestward from Camden, is a small area of typical brown subcannel coal, which has been tested for oil and gas production with very favorable results. The coal bed had been traced from about 2 miles northwest of Camden for 13 miles to the northwest and has been opened and mined in a small way at a number of places. The coal ranges from 3 to 6 feet in thickness.

Physically the Camden coal, as it comes from the mine is brownish black and compact and has a generally uniform even texture and structure. Occasonally fragments of lignite with clearly marked woody structure may be seen. It has an uneven conchoidal fracture. It is soft but not friable, that is, it may be easily mined with the pick and may be cut with a knife as readily as compact dry clay, but will not crumble between the fingers. When cut or scratched with a knife it shows a shiny or oily streak. Upon being exposed to dry air, the coal contracts and cracks both along the bedding and at right angles to it so that fragments may be broken by the hand, but the mass does not fall to pieces. The coal is then blacker and harder than when fresh and the streak or powder is more nearly black. On being exposed for a short time to the repeated action of rain, dew, and snow, however, it will disintegrate into small particles.

From this description the coal is evidently of lignite rank, but so far as tested it appears to give a higher candlepower gas than other lignites. Chemically, as shown by the analyses it contains from 32 to 38 per cent of water when fresh. In dry air the moisture will be reduced to 9 to 11 per cent, but this will be reincreased to 20 to 22½ per cent if the coal is submitted to saturated air. The volatile matter in the fresh coal is 32 to 36 per cent and 44 to 46 per cent in the air-dried coal; and the fixed carbon in the fresh coal is 17 to 23 per cent in the air-dried coal. The ash remains from 7.5 to 11 per cent in the fresh coal and and sulphur 0.5 per cent or less in the fresh material.

This coal was tested by the Pittsburgh Testing Laboratory. The average result of 10 tests, at a temperature of 1,800 to 2,000 degrees F., was a yield of 11.386 cubic feet of 22.3 candlepower gas.

David White, who visited the field, described as follows the two stills that were in operation:

The commercial utilization of the lignite from the Camden field is somewhat unique, for although it is employed to a limited extent for local steam-boiler fuel and on the locomotives of the branch railroads coming to the sawmills and mines about Lester, the principal use of the coal appears to be for its distillation products. The best massive brown lignite, essentially "amorphous" and free from bedding, is that most sought for distillation. Such lignite is said to yield as high as 38 gallons of oil per ton, though the average oil production from the lignite as it is mined and distilled approximates 25 gallons per ton. Occasionally lignite which yields as low as 10 gallons per ton is dug at some of the mines in the field. At the time of the field examinations of the fuel by the writer the methods of distillation were still in an experimental stage. A small distillery or "oil mill" was in operation at the town of Camden and another one near Lester. The former had seven horizontal retorts, whereas the latter had only five in an inclined position and farther above the grate. The Lester mill had a capacity of two tons in 24 hours. For three or four hours the lignite in the retort was subjected for a time to a temperature of about 400 degrees after which it was advanced for a time to a temperature of about 700 degrees and finally to 1,200 or 1,300 degrees F., eight or nine hours being required for the complete run. Some of the oil is given off at a temperature of about 400 degrees F., different oils being yielded at different temperatures, those distilling later at the higher temperatures being regarded as best. Likewise, the higher temperatures appear to yield by-products more tarlike and differing in other respects. The brown canneloid is said to yield a lighter-colored oil.

The distillates are said to be used in the rubber industry, in soap making, in paints, and in various proprietary preparations. The residual cinder can hardly be called coke, although often on withdrawing the charge there appears to be a recondensation at the back end of the retort which results in small pieces of completely fused coke, silvery in luster and stalactytic in sculpture, though spongy and friable. The higher grade carbon or cinder derived from the more typical canneloid lignite, after having been ground at the mill, has been shipped to one of the eastern cities, where it was experimentally tried in the manufacture of paint. The small pieces of wood and stem are occasionally found with structure preserved, as charcoal among the lumps of lignitic cinder.

Lignite of Crowley's Ridge.

The lignites of the Crowley's Ridge region are all of Tertiary age. * * * They occur in the form of outcrops along the streams and in gullies with an occasional bed appearing in wells. The thickness of these lignite beds is exceedingly variable. Usually they are less than five feet thick, though the Bolivar Creek beds in Poinsett County are seven feet or more in thickness. It is also noticeable that the vertical distribution of the several beds is irregular, some of them occurring high up in the hills, while others are at their base or below it. So far as traced all these beds are independent of each other, having been formed at different times, and they are generally in lenticular shapes, most of which cover but a few acres and many of them but a few hundred square yards. Their chemical analyses show that the Bolivar Creek and the Clay County lignites are the best. The poorest is that found in St. Francis County, 4 N., 4 E., on section 26. This latter has been analysed with the following result:

Water	10.215	per cent
Volatile Matter	40.70	" "
Fixed Carbon	21.50	" "
Ash (gray)	25.65	" "
Sulphur	2.00	" "

The analysis shows it to have but little or no value for commercial purposes.—Report Arkansas Geological Survey, Vol. II, 1889.

Lignite Elsewhere.

Tertiary lignites occur in most of the counties of southern Arkansas. Probably the deposits nearest approaching in value those of the Camden district are in Pike and Clark counties, but no use has yet been made of this fuel. The location of the lignite is more interesting as indicating the character of the associated clays.

REFERENCES.

Taff, J. A.—Preliminary report on the Camden coal field of southwestern Arkansas. Twenty-first Annual Report of the U. S. Geol. Surv., 1899-1900, Part II, Washington, 1900.

Britton, J. Blodgett.—Lignite near Camden, along the Ouachita River. Transactions of the American Institute of Mining Engineers, Vol. I, New York, 1872.

Ashley, Geo. H.—Cannel coal in the United States, .U S. Geol. Surv., Bull. 659, 1918.

Branner, John C.—Clays of Arkansas. U. S. Geol. Surv., Bull. 351, 1908.

Limestone For Lime.

(Extracts from Annual Report Arkansas Geological Survey, Vol. IV, 1893, by T. C. Hopkins.)

In spite of the abundance of limestone in Arkansas suitable for lime burning, the state imports lime instead of exporting it. As the limestone region of north Arkansas becomes traversed by railways the burning of lime should become one of the most important industries. There are limestones in the Tertiary and Cretaceous areas of the central and southwestern portions of the state, yet the Paleozoic limestones of the north part of the state are so superior for lime burning that it is to them the state must look for its lime supply. The chalk beds will no doubt become valuable in the manufacture of Portland cement, but for common lime it cannot compete with the Paleozoic limestones.

While in north Arkansas there are not less than seven distinct beds of limestone persistent over large areas, and others of more limited extent, it is noteworthy that nearly all the lime that has been burnt has come from a single bed—the limestone in the Boone Chert. It has a greater areal extent than any of the other beds, yet others of large extent would make equally as good lime.

Following is the analysis of limestone from the Boone chert formation in Independence County:

	Per Cent.
Carbonate of Lime	98.43
Carbonate of Magnesia	.95
Insoluble Residue	.28

Without taking into account the proximity to transportation, the different beds of limestone considered solely in the light of their value for making lime, would rank about as follows:

First, Izard limestone.
Second, Boone chert limestone.
Third, St. Joe marble.
Fourth, St. Clair marble.
Fifth, Archimedes limestone.
Sixth, Pentremital limestone.
Seventh, Magnesian limestone.

Besides these there are local occurrences of good limestone among the magnesian beds in the Silurian.

The advantage for lime burning of the Izard limestone over the Boone Chert is the ease with which it is broken, its freedom from chert and the greater ease of burning.

The St. Joe marble is properly a part of the Boone chert series but it differs essentially from the gray limestone higher in the series in being more compact and crystalline and in requiring more burning to reduce it.

The St. Clair marble makes a pure lime, but its toughness makes it expensive to prepare for the kiln and its higher crystallization makes it hard to burn.

The Archimedes and Pentremital limestones are often too impure to make a valuable building lime, yet in many places a good lime can be obtained from them, and in nearly all places they would make a lime good for fertilizing.

It is difficult to compare the magnesian limestone with the others as its value depends on whether a magnesian lime is wanted.

A good stone for lime occurs locally in the Silurian rocks, notably on Clear Creek, Searcy County, and at various points in Marion County.

Carboniferous Limestones.

The limestones on the south side of Boston Mountains have the same lithologic characteristics as those on the north, with the possible exception that they seem to be somewhat more siliceous. In some cases they thin out southward. It is quite apparent, from their relation to the overlying rocks, from a casual examination of their fossils and from their lithologic characters, that their occurrences south of the mountains is a continuation of the beds which outcrop on the north side, and described as the Kessler, Pentremital and Archimedes limestones. For the most part limestone occurs south of the principal range of Boston Mountains only in the deepest valleys and ravines, where the streams have eroded the overlying shales and sandstones, leaving the underlying strata exposed.

Trinity Limestones.

In the southwest part of this state, in Pike, Howard and Sevier counties, along the northern border of the Lower Cretaceous area, is an outcrop of limestone designated by Prof. Robt .Hill of the Survey as the Trinity limestone, and described by him as follows: "In general it is a series of calcareous, gypsiferous, argillaceous sands, alternating with numerous thin strata of firm yellow crystalline bands of limestone, which vary from one inch to one foot in thickness."

Tertiary Limestones.

As compared with those of the Lower Carboniferous, the Tertiary limestones of the state are of but little importance. Their location, however, sometimes give them local value. Gilbert D. Harris, Assistant State Geologist, mentions their occurrence as follows:

"The few exposures that are known are chiefly confined to the western border of the Tertiary area. At Grand Glaise in Jackson County fossilferous Tertiary limestones with some arenaceous layers are exposed in beds about 50 feet thick a few rods south of the railway station. Limestone ledges outcrop at Russell station on the Missouri Pacific Railway. At Little Rock Tertiary limestone is found in sinking wells on Capitol Hill.

Ouachita Mountain Region.

Some curbstones have been quarried from limestone beds in the novaculite area, nine miles northwest of Hot Springs and lime has been burned at the same locality. A black crystalline limestons in lenticular masses, six to eight inches thick, is reported to occur at fifteen miles west of Little Rock. This and the limestones of the novaculite area of the state are all of Ordovician age. In Magnet Cove, Hot Spring County, there are several outcrops of a coarsely crystalline limestone which forms in one place a bluff 20 to 30 feet high.

It will thus be seen that while limestone is widely distributed in the state, all that is suitable for building purposes occurs north of the Boston Mountains, and all the rocks of any considerable importance for lime-burning occur in the same place. The chalk beds of southwestern Arkansas are the only lime deposits south of the Boston Mountains which are likely to have any great commercial value.

REFERENCES.

Branner, John C.—Value of lime as a fertilizer and discussion of deposits at White Cliffs. Arkansas Geol. Surv. of 1888, Vol. II.

Hopkins, T. C.—Lime Industry of Arkansas. Annual Report, Arkansas Geol. Surv., 1890, Vol. IV, Little Rock, 1893.

Means, J. H.—Carboniferous limestones on the south side of the Boston Mountains. Annual Report of the Geol. Surv., of Arkansas for 1890, Vol. IV, Little Rock, 1893.

Harris, Gilbert D., Assistant Geologist.—Annual Report Arkansas Geol. Surv. for 1892, Vol. II.

Marble Quarry Near Batesville, Arkansas.

UNIVERSITY OF ARKANSAS

Limestone—Building.

(See Marbles.)

"The marbles and limestones belong to the Mississippian and Pennsylvanian series of the Carboniferous system and to the Ordovician and Silurian systems of rocks. Gray (Boone limestone), finest quality in Boone, Marion, Newton and Searcy counties; coarsely crystalline; good polish. St. Clair, light gray to chocolate brown, highly crystalline, from Independence County to Newton County; valuable building stone. St. Joe, widely distributed in north Arkansas, length of outcrop is about 3500 miles; light pink to dark chocolate, spotted white, gray or pea green, varies in texture; small quarry at St. Joe.

Benton County, quarried at Monte Ne and Gravette.

Boone County, at Alpena and Keener.

Carroll County, limestone quarried at Eureka Springs; dolomite at Beaver.

Independence County, ornamental limestone is quarried at Pfeiffer, near Batesville.

Izard County, quarried at Guion.

Lawrence County, at Imboden for building and crushed stone.

Sharp County, at Williford.

Washington County, at Johnson.—Bulletin 624, U. S. Geol. Surv.

REFERENCES.

Branner, John C.—Report Arkansas Geol. Surv., Vol. IV, 1890.

Marbles.

(See Limestone, Onyx, Sandstone.)

"The marble region of Arkansas is in the north and northwest part of the state. It includes Marion, Boone, Benton, and parts of Independence, Izard, Stone, Baxter, Searcy, Newton, Madison and Washington counties, and extends north into the State of Missouri.

"The entire region is north of the Boston Mountains, and with the exception of portions of Washington and Benton counties is in the upper White River Valley. It is commonly known as North Arkansas, the Boston Mountains forming a natural barrier between it and the remainder of the state on the south, while the flood-plains of the Black River bound it on the east.

"Comparatively little work has been done to develop the marbles and bring them into the market. Probably the first piece of marble shipped out of the state was the one sent to the Washington Monument in 1836, the year in which the state was admitted to the Union. The block, weighing 9,000 pounds, was taken from near Marble City, Newton County, then known as Beller's Mill. It was obtained by Mr. Beller and Elijah, Samuel and William Harp. By drilling and wedging they separated the block from a ledge four feet thick. It was then put on a log wagon and with ten yoke of cattle these four men took the stone a distance of 60 miles or more over exceedingly rough and tortuous roads across the Boston Mountains to the Arkansas River near Clarksville, whence it was shipped by boat.

(The exterior walls of the New State Capitol at Little Rock were constructed of Batesville marble, quarried at Pfeiffer.)

"The marbles of Arkansas all belong to the list of colored marbles; although some of them are very light colored, all are more or less stained with metallic oxides or with carbonaceous matter. On a stratigraphic basis all the numerous varieties of marbles in Arkansas are, with very few exceptions, included in three classes: The St. Clair; the St. Joe; and the gray marble of the Boone chert formation. The first of these, the St. Clair marble, occurs over the eastern and south central part of the area, and is of Silurian age. The St. Joe and gray marbles, occurring over the entire area, are at the base of the Lower Carboniferous rocks. The few varieties which do not occur in any of these classes are the black, yellow, "onyx," and Archimedes marbles."—Annual Report, Arkansas Geological Survey, Vol. IV, 1890, by T. C. Hopkins; John C. Branner, State Geologist.

Purdue says: "Marble of red, gray and pink colors outcrop at numerous places along White River and its tributaries. Black marble occurs near Marshall, Searcy County, and Jamestown, Independence County.

REFERENCES.

Branner, John C.—Annual Report of the Geol. Surv. of Arkansas for 1890, Vol. IV, Marbles and other limestones, by T. C. Hopkins, Little Rock, 1893.

The building stones of Arkansas, by John C. Branner. Stone, Vol. II, Indianapolis, October, 1889.

Hopkins, T. C.—Topographic features of Arkansas marble. Proceedings of the American Association for the Advancement of Science. Vol. XXXIX, Salem, 1891.

Anonymous.—Batesville oolitic marble. Stone, Vol. XXIX, pp. 345-346. Illustrated, New York, January, 1909.

Novaculite (Whetstones.)

The Arkansas stone is a true novaculite, satisfying all the necessary conditions regarding homegeneity, grittiness, finely granular structure and siliceous composition; it is translucent on the edges and has a marked conchoidal fracture. It occurs associated with shales into which it grades through opaque flinty layers. It is the only true novaculite quarried in quantity in this country.

Novaculite is very like chert, both in composition and in its behavior as a road-making material. It occurs only in the hilly region lying south of the Coal Measures, where it forms the Zigzag Mountains about Hot Springs and the great Ouachita Mountain system south of the Ouachita River, extending from Rockport, Hot Spring County, nearly to Oklahoma, west of Dallas, Polk County.

REFERENCES.

Branner, John C.—Annual Report of the Geol. Surv. of Arkansas for 1890, Vol. III. Whetstones and the novaculites of Arkansas, by L. S. Griswold, Little Rock, 1892.

Branner, John C. and Derby, O. A.—On the origin of certain silicious rocks (novaculites). Journal of Geology, 1898, Vol. VI.

Griswold, L. S.—Indian quarries in Arkansas. Proceedings Boston Society of Natural History, Vol. XXVI, Boston, 1895.

Hull, Edward.—Origin of novaculites of Arkansas. Quarterly Journal of the Geological Society of London, Vol. I, London, 1894.

Rutley, Frank.—On the origin of certain novaculites and quartzites. Quar. Jour. Geol. Soc., Vol. I, London, 1894. Abstract American Geologist, Vol. XIV.

Sutton, J. J.—Oilstones. Third Biennial Report from the Bureau of Mines, Manufactures and Agriculture of Arkansas for 1893-1894.

Burning Gas Well in the Fort Smith District

Oil and Gas Geology as Viewed by Dr. John C. Branner.

There are two and possibly three geologic areas in the State of Arkansas in which petroleum and natural gas may reasonably be expected. One of these fields, that in the western part of the state, is already known, in part, at least; another is the eastern and south-eastern part of the State, while the third is probably unsuspected and may be omitted for the present. The gas fields about Fort Smith are geologically a part of the oil and gas fields of Oklahoma, while the extension of the geology of Northern Louisiana into southeastern Arkansas naturally leads to the inference that that part of the state may likewise contain oil and gas. In the Carboniferous area of western Arkansas the geology is open to direct inspection, and the structure can be worked out satisfactorily and in detail, so that there need be no doubt about where the wells should be located or what rocks may reasonably be expected at various depths.

In the southeastern part of the state, however, the geology in its relation to oil and natural gas, is of a very different type, is much more difficult to deal with and can be successfully handled only by geologists and paleontologists of thorough training.

The nature of the problem that confronts the geologist in southern and eastern Arkansas can be readily understood from a brief statement of the history of the whole region.

In Cretaceous times salt water covered all of eastern Texas, all of Louisiana and Mississippi, and extended as far north as the mouth of the Ohio River. The western shore of this body of water was a little west of the line of the Missouri Pacific Railway from where it enters the state of Arkansas on the north, to Arkadelphia, and from there it ran nearly due west to the Oklahoma line at Ultima Thule.

All of Arkansas east and south of that shore line was beneath this great open bay, and the mud and sediments washed down by streams and the remains of animals and plants living in those waters sank and spread over the sea bottom and gradually built up the sandstones, limestones and clays that form what are now known as the Cretaceous rocks. Later, during Tertiary times, the waters became shallower, and the Tertiary sands and clays were deposited on top of the Cretaceous beds. Finally the whole area was raised far enough to cause the salt water to withdraw entirely from the northern part of this ancient bay region. As soon as the sediments were lifted from beneath the water, streams began to cut gullies and to wash away the upper beds; and this process of erosion and denundation has gone on until hundreds of feet of sediment, perhaps thousands of feet, have been stripped away. The edges of the old sedimentary beds laid down in Cretaceous times are now exposed in Arkansas about Arkadelphia, Okolona, Washington, Saratoga, White Cliffs, Brownstown, Rocky Comfort and Ultima Thule. Almost everywhere else in the state these Cretaceous beds are concealed by the overlying Tertiary sediments.

In Louisiana and Texas petroleum and gas are found both in Cretaceous and in the overlying Tertiary rocks. It is a natural inference that the same rocks may be expected to contain petroleum and natural gas in the state of Arkansas. But though the inference is natural enough, it may not be correct. The problem of the petroleum geologist is not so simple as that. There is nothing we are more certain of today than the fact that the occurrence of petroleum at a certain geologic horizon in one place is not to be accepted as evidence of its existence at the same horizon somewhere else. It is impossible to enter into a detailed discussion here of the many problems that must be dealt with in connection with the subject. The accumulation of petroleum and gas is controlled by certain structural features which are not now open to direct observation in the area in question. Those features are covered by hundreds of feet of overlying sediments and even the structure of the Tertiary beds is now much observed by the wide river bottoms and by the deposits of sands, gravels and clays spread out by the floods that swept over them at the close of the glacial epoch.

After groping about in the dark for years the exploring companies have finally reached the reasonable conclusion that the location of prospecting wells is the work of the trained geologist and paleontologist. One of the great difficulties about the petroleum and gas question in eastern and southeastern Arkansas is that the problems are too large and too expensive to be handled by the land owners, or by individuals. Only strong financial organizations can afford to take the risks involved in such ventures. But while such organizations must be guided by the geologist, no competent geologist can guarantee the finding of petroleum at any particular place. All he can do is to get his geology right, and thus reduce the risk to be run by the exploring companies. If the companies are not prepared to take the risks they should keep out of it entirely. And if the oil is not there, not even the geologist can find it.

Stanford University, California, JOHN C. BRANNER.
June, 18, 1920.

Natural Gas.

The first gas well was drilled in Arkansas on the Massard Prairie, south of Fort Smith in 1901. The producing field at present extends north and south of the Arkansas River, from near Alma on the east to Poteau, Oklahoma, embracing parts of Crawford, Sebastian and Scott counties. The production of natural gas in this field from wells drilled in 1919 exceeded 200,000,000 cubic feet a day. One well has a record of 24,000,000 cubic feet a day and is rated as one of the largest in the Southwest.

Gas is found at depths of from 750 to 3175 feet. There are seven distinct producing sands, each from 40 to 280 feet thick. The product is dry, clean and odorless. Under government test this gas shows a heating record of 1057 British thermal units, which is considerably higher that the tests made by most gases from the Southwestern field.

Five companies are operating in the Arkansas field and pipe lines are laid from the wells to nearby cities for distribution to more than 100 industries and thousands of private homes. The public utilities of Fort Smith and Van Buren, and coal mines nearby, are operated with power generated by natural gas.

Carl D. Sm.th, in U. S. Geol. Surv., Bulletin 541, 1912, says:

"The question as to the probability of striking oil at some point down the dip of the strata below the gas has been asked. It is not known, of course, whether the gas is underlain down the slope of the sand by oil or water, nor how far down the slope the contact of the water and gas or oil and gas would be found, but toward Sugarloaf and Cavanal mountains the strata dip at the rate of 200 to 300 feet to the mile; hence to reach a given bed it would be necessary to drill deeper and deeper as either of these mountains is approached. It is estimated that the top of the Hartshorne sandstone lies at a depth of 3,000 to 3,500 feet below the town of Poteau.

"It seems that, if other things are equal, the chances of striking gas are better in the upward folds or anticlines than in other localities. Of course, if a porous medium be not present in the anticline, then the chances there are no better than elsewhere; but as the presence or absence of the porous medium can not be foretold, that chance must be taken as a part of the risk of drilling."

The late Dr. A. H. Purdue, former State Geologist, expressed the belief that indications were favorable for the extension of the gas field through the Arkansas Valley as far east as Little Rock and recommended the drilling of wells, wherever anticlines occurred in that territory.

Gas is found in small quantities in Washington County, near Fayetteville, and in Independence County, near Batesville, but has not been commercially developed in either locality. The presence of seepage gas has led to the drilling of a prospect well 12 miles south of Little Rock, in Saline County.

At the time this report was prepared a strong flow of gas was obtained in a prospect oil well, drilled by the Constantin Company, near El Dorado, Union County. The heavy flow from this well seems to warrant the belief that a new gas field, if not an oil and gas field, will be developed in south-central Arkansas.

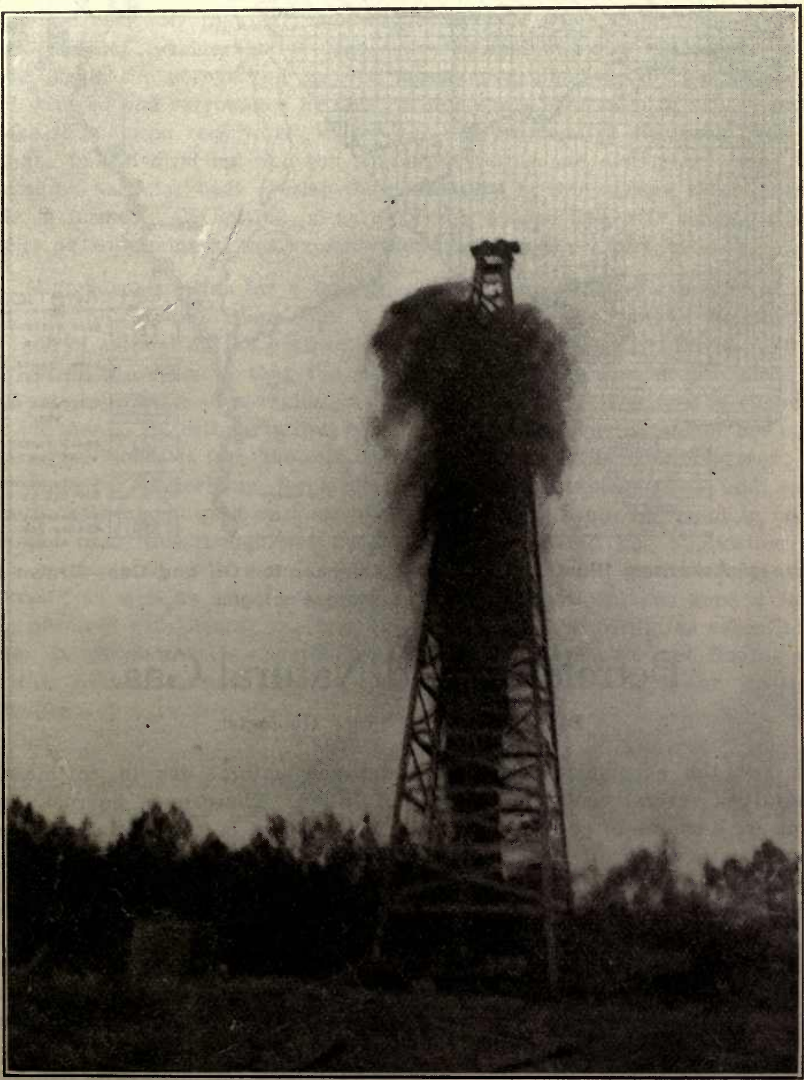
An examination of the stratigraphy, with reference to the oil and gas possibilities near Batesville was made in 1919 by H. M. Robinson and the same year a report was made by E. W. Shaw, on the Natural Gas Resources Available to Little Rock, but these reports have not yet been published.

REFERENCES.

Harris, G. D.—Oil and Gas in Louisiana and Adjacent States. U. S. Geol. Surv., Bulletin 429, 1910.

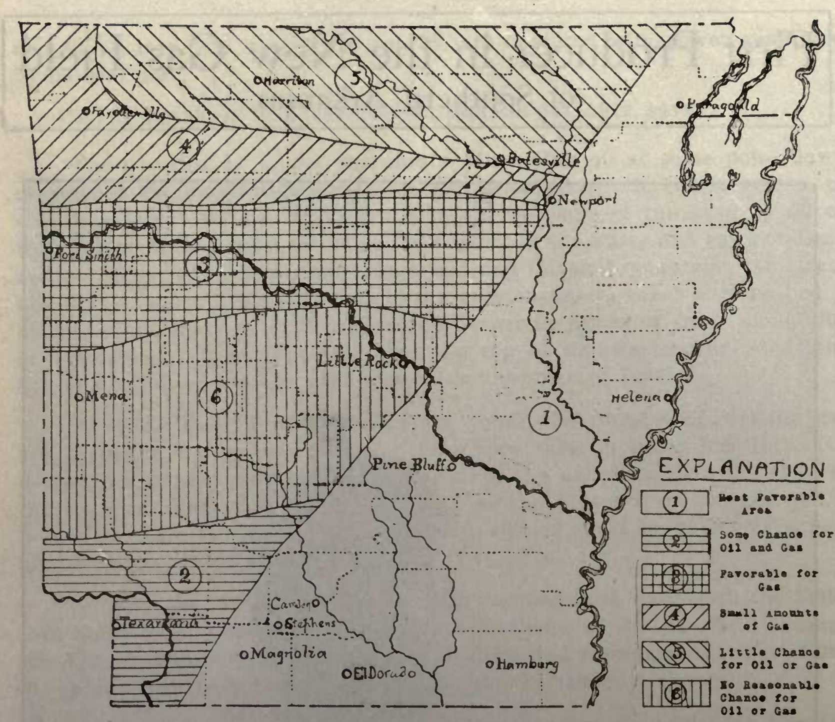
Smith, C. D.—Structure of the Fort Smith-Poteau Gas Field, Arkansas-Oklahoma. U. S. Geol. Surv., Bulletin 541.

First Producer in the New Gas Field
of Southern Arkansas



Constantin Gas Well Near El Dorado

Government geologists report favorable structure in the vicinity of this well for the presence of petroleum, for which the drillers were in search when the well began producing natural gas.



Map of Arkansas, Illustrating Relative Chances for Oil and Gas—Drawn by Dr. N. F. Drake, State Geologist

Petroleum and Natural Gas.

By N. F. Drake, State Geologist.

For the accumulation of petroleum and natural gas in commercial quantities several conditions must be fulfilled. There must be rock beds that are a source of petroleum and gas; there must be rock beds with open spaces into which oil and gas may accumulate; the porous rock bed must be so enclosed by impervious beds as to prevent the escape of the oil and gas; and finally metamorphic action in the region must have been slight, otherwise the oil and gas would have been destroyed.

Geologists are in practical agreement that petroleum and natural gas originate from organic matter deposited with clays and to a lesser extent with limestones. Estauries, lagoons, and more or less stagnant areas of the sea bottom near coast lines seem to have been the most favorable locations for the accumulation of the organic matter that later was converted into petroleum and natural gas. It appears that both animal and plant remains enter into the formation of oil and gas by the aid of bacteria working on the organic matter while it is accumulating and soon after it is buried in the sediments. As the oil bearing sediments become more deeply buried by other sediments the oil is driven out of the beds in which it originated into adjacent porous beds. Whether the oil will then remain in the porous beds largely depends on whether it is enclosed by impervious beds, such as clay beds, in such a way as to prevent the further migration of the oil. There are a number of ways in which the porous beds may become enclosed reservoirs. Upward folds of the rock beds forming anticlines and domes, or in other words inverted basins, often prevent leakage from the reservoir rock. This is especially true when impervious clay or shale beds of considerable thickness overlie and underlie the porous rock bed. Again the porous bed may be lens-shaped, pinching out at the sides and covered and surrounded by clay or clay shale beds in such a way as to make it a closed reservoir. Where the dip or slope of the rock beds is regular in one direction and the porous bed thins and disappears going up the slope, and clay beds overlap the porous bed at this edge, a closed reservoir is formed. Cementing of parts of the porous bed with asphaltic deposits or with mineral matter may also result in reservoirs.

Metamorphism has for a long time been recognized as a means of destroying oil accumulations but it was only recently that a quantative method of estimating the destruction has been proposed. Dr. David White* developed the formula that the degree of metamorphism of the coal or carboniferous shale of a region gave a standard for estimating the chances for oil there. He estimates that where the fixed carbon content of the coal (pure coal basis) is 65% the oils which may formerly have been present in the same or underlying formations, have mostly disappeared and that where the coal shows a carbon ratio of 70% oil will not be found in commercial quantities though gas pools may still persist. The application of this principle to such extensive and varying oil fields as Oklahoma and Texas** as well as many other oil fields over the world has gone a long way towards establishing the formula given by Doctor White as essentially true. It offers what is apparently the best explanation for not finding oil in the Kibler, Massard Prairie and neighboring gas fields of western Arkansas.

Taking into account all the conditions enumerated above as essential, to the formation and retention of oil pools we may now apply them to different sections of the state and see what predictions they lead to in reference to petroleum and natural gas.

The accompanying map presents a rough outline showing different areas into which the state may be divided with reference to different degrees of fitness for petroleum and natural gas. There is more or less variation within each of these areas and usually each area, in its geological features, graduates into the adjoining areas but as a whole each area as mapped forms a fairly distinct group.

Area VI.—The area marked "6" and by vertical lining includes the Ouachita Mountain system in which the rock beds are severely folded into numerous anticlinal and synclinal folds extending almost east by west, the whole forming an upward bent fold or an anticlinorium. The tops of these

*Jour. Wash. Acad. Vol. V. p. 189. Also Bull. Geol. Soc. Amer. Vol. XXVIII p. 733.

**Econ. Geol. Vol. XIV, p. 536. Also Econ. Geol. Vol. XV, p. 225.

folds have been eroded so that now the numerous parallel ridges stand at almost the same elevation. This means that the center of the anticlinorium has been eroded more than at the sides so that now we have exposed at the surface along the central portion of the area the oldest rock beds. Going either northwards or southwards from the central oldest rocks one passes over successively younger rocks as he approaches the border of this area, except that in places severe folding has caused the complete overturning of some of the beds. In age the rocks of this area extend from the Cambrian at the base, through the Ordovician, Silurian, Devonian and into the Carboniferous at the top. The whole gives a thickness of 15,000 to 20,000 feet of shales, sandstones, and some cherts and limestones. The whole area is rather highly metamorphosed so that a large part of the shales are graphitic and often the sandstones have been changed to quartzites. Much of the original pore spaces in these rocks have been filled by silica and lime carbonate. Igneous rocks in small areas, outcrop at a number of places. The severe metamorphism of the rocks in this area at once condemns it as a field for oil and gas.

Area V.—The area marked "5" in the north central part of the state is a part of the Ozark Plateau and its exposed rock beds are mainly Ordovician dolomites and sandstones but overlying these beds in regular order are Silurian, Devonian and Mississippian beds, the total giving something like 2000 feet of outcropping rock beds within this area. Limestones, sandstone and some carbonaceous shale are found in the upper part of these beds. The rock beds are broken or faulted at many places and show some gentle folds but in the main the beds lie almost horizontal or dip slightly to the south. While metamorphic action in this area has not been severe, it has been considerable so that many of the limestones are more or less crystaline. In quarying rocks over the area a little petroleum has been found in small cavities in some of the limestones and dolomites at a number of places. This has led some people to suspect that oil in commercial quantities might be found there. It seems very doubtful whether there is present, at sufficient depth, rock beds capable of giving origin to oil. The Chattanooga shale along the south and southwest border of the area is too near the surface for any oil it might have produced to have been retained in the rocks. The deep seated beds are mainly dolomites and sandstones. Metamorphic action here has almost assuredly been great enough to have destroyed oil accumulations even had they at one time existed. Furthermore test wells in this area and in the same rock beds nearby in Missouri have failed to give encouragement for oil and gas.

Area IV.—The area marked "4" on the map includes the south and southwest border of the Ozark Plateau. Here the rock beds lie almost horizontal but in general have a dip of one to two degrees to the south and southwest. At places this dip increases to five or six degrees or even more. Some gentle folding and faulting occurs over the area and heavy faulting with the downthrow on the south side of the fault planes, occurs along the south border of the area. As one goes northward over this area he reaches successively lower and older rock beds. Along the north border of the area the outcropping rocks are mainly Mississippian while on the south border they are Pennsylvanian. Wells drilled 300 to 500 feet deep near the north border, or 500 to 2000 feet deep near the south border, would pass into the Silurian or Ordovician limestones, dolomites and sandstones. Over those beds lies the Chattanooga shale, which is usually 25 to 40 feet thick. It is highly carbonaceous and is oil and gas-producing. About 350 feet of chert with some limestone overlies the Chattanooga shale. The chert in turn is overlain by 200 to 400 feet of highly carbonaceous shale, the Fayetteville shale, that is also oil and gas-producing. Oil and gas within this area would naturally be expected to have been derived from those shale beds.

We have then in this area beds of rock favorable for the production of oil and gas, porous sandstones suitable for reservoir rock and some gentle folding giving inverted basins that might trap the oil and gas in their upward migrations. In the northern portion of the area the covering over the oil-gas producing shales is not sufficient to prevent leakage but in the southern portion the covering should be ample.

A well a little over 300 feet deep about five miles northwest of Fayetteville has, for about three years, furnished enough gas fuel for cooking and heating at a farm house. This gas was struck in sandstone immediately underlying the Chattanooga shale. Without any reasonable doubt this gas came from the shale. The covering over the shale is nearly 300 feet of Boone chert which would allow gas to escape to the surface and be lost while the shale itself is nearly impervious and gas collecting under the shale would be retained.

A number of other wells widely distributed over this area have given small flows of natural gas but commercial flows have not yet been obtained. It is rather difficult to estimate the degree of alteration or metamorphism that exists over the area. The following coal analysis by G. O. Burr of the University of Arkansas, from a sample of coal taken from the Baldwin mine, situated about seven miles east of Fayetteville, probably gives a fair average for the condition of the area as a whole:

Moisture	0.87%
Volatile Combustible Matter	30.75%
Fixed Carbon	60.30%
Ash	8.13%
Sulphur	2.42%

This analysis gives a carbon ratio for the coal of 66.74% which shows too high a carbon ratio for commercial pools of oil but still permits gas pools of value. It is possible that some local places within this area may have a lower alteration of the rock beds and in that case oil might be found, but the chances are against the existence of such conditions. The southern portions of this area with a better covering over the oil-gas producing shales offers good chances for commercial gas where structural conditions are favorable.

Area III.—The area marked "3" and by horizontal and vertical lining is practically all the area between the Ozark Plateau and the Ouachita Mountain system. The outcropping rock beds here belong to the Pennsylvanian series and consist of carbonaceous clay shales, sandstones, and in the western part some workable coal beds. These beds thicken to the southward, probably being four times as thick in the southern part of the area as in the northern part. According to Branner* the Pennsylvanian sediments of the state reach a total thickness of 23,780 feet. The strata of this area are folded into many folds and the whole series forms a downwarp or synclinorium. As a rule the folds are gentle near the northern border and increase in intensity southward until in places along and near the south border some of the beds stand almost or quite vertical. Metamorphism or alteration of the rock beds has very much kept pace with the intensity of folding. As a rule the highest alteration of the rocks is to the southward and southeastward but near the heavy faulting, as in the southern part of Scott county, the metamorphism may be somewhat less. Coal analyses are not available for the whole field but the following analyses will give a fair idea of the alteration that has taken place and the way it is distributed:

Locality.	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Carbon Ratio	Analyzed by
Near Bates, Scott Co.	3.39	24.44	66.40	5.79	0.87	73	U. S. G. S.
Near Fort Smith	2.19	14.00	72.15	11.66	2.06	84	U. S. G. S
Hackett	0.85	14.91	73.86	9.03	1.32	83	Brackett
Huntington	1.02	17.88	73.61	7.49	1.10	80	U. S. G. S.
Coal Hill	1.52	14.76	76.91	6.95	1.52	84	U. S. G. S.
Spadra	2.15	10.82	76.87	10.16	2.30	88	U. S. G. S.
Near Russellville	2.33	10.16	77.67	9.40	1.81	88	U. S. G. S.

Many other analyses covering the same territory might be given but they would tell the same story. There are no analyses available covering the eastern or the northern borders of the area but bituminous coals are known to be in those localities, and they may show a less degree of alteration. It is not likely, however, that they will prove sufficiently high in volatile matter to give conditions favorable for oil in commercial quantities. As is well known, this area, in its western part, is already a heavy producer of gas. It is likely that the producing areas may be extended farther eastward along the northern part of the field even to the extreme east border of this area.

Area II.—The area marked "2" on the accompanying map is a part of the gulf coastal plains. The northern part of the area is Cretaceous and the southern Tertiary in age. The Cretaceous rock beds comprise clays and marls more or less carbonaceous and sandstone, gravel beds, limestone, and chalk, altogether totaling over 2000 feet in thickness as shown by outcrops. The Tertiary beds are about 1000 feet thick and consist of sands, clays and marls. Both the Cretaceous and the Tertiary beds dip gently to

*Amer. Jour. Sci. Vol. II p. 236.

the southeastward. Both carry beds containing organic matter and porous sandstone beds. Metamorphic action has not altered the beds to a degree that would destroy oil accumulations. It appears then that the thing most needed for insuring the existence of oil accumulations here is good structural features that would entrap the oil in its upward migrations.

The asphalt deposits in Pike and in Sevier counties show oil leakage along the northern border of the area. This oil must have moved northwards up the slopes of the Cretaceous rock beds. So far as known there are no folds within this area but it is possible that there may be some small folds and furthermore some of the porous beds thru which the oil migrates may, in their upward reaches, either thin out and disappear or else become close textured so as to entrap the oil as it moves up the slope of the rock bed.

These last noted conditions can only be proven by the very expensive method of drilling test wells. It is safe to say that oil-bearing areas, under such conditions as exist in this area,, must necessarily be small in comparison with the barren areas. The wells that have been drilled in and near this area have indicated a regularity of the dip to the south and southeast and have given no special encouragement for further prospecting.

Photo of Hunter Well Near Stephens Just After Showing of Oil Occurred

Arkansas' first production of oil in commercial quantities was from the Hunter Well, which, with several thousand acres of leases, has been taken over by the Standard Oil Company. It is understood the field is now to be thoroughly prospected.

Area I.—The area marked "1" comprises nearly all that part of the state lying east and south of the Missouri Pacific Railroad. This area is also a part of the gulf coastal plains. The outcropping rocks are Tertiary and Quaternary in age. The Quaternary beds form a thin covering of alluvial materials lying on the Tertiary beds, along the flood plains of the river bottoms. The Tertiary beds consist of clays, and marls more or less carbonaceous and sandstone and some lignite beds. The strata dip gently towards the southeast. Going eastward over the area one passes over beds that are successively higher and younger geologically and the series becomes thicker until in the southeast part of the state these beds are probably 2000 feet or more in thickness. Under these beds the Cretaceous beds above noted extend apparently without any breaks.

During Tertiary times the Gulf of Mexico extended over this area in an embayment that reached northward to the southern point of Illinois and it extended to the east of the Mississippi River into Tennessee and Mississippi about as far as it extends westward from the Mississippi River over Arkansas. The underlying and older Cretaceous embayment was somewhat broader but did not extend quite so far northwards. The embayments gave good conditions for the accumulation of organic matter of the sea and neighboring land areas. Over this area also, with the possible exception of a part of Crowley's Ridge, the rocks have not been altered to a degree that would injure oil accumulations. **The conditions are then favorable for oil and gas wherever structural conditions exist to catch and hold the oil and gas.**

Since the Tertiary rocks are practically all soft and friable they easily go to pieces where exposed at the surface. So a deep soil usually covers the underlying beds and one cannot, except in rare cases, determine from surface examinations how the underlying rock beds lie. Where the top exposed beds lie parallel to the underlying beds and the top beds are well exposed it is a simple process to determine the underground structure so far as folding is concerned. Over this area the rock beds are usually covered and often not well marked when exposed and in places the topmost and the lower beds are not parallel or conformable so it is difficult to determine the structure here.

There is some fairly good evidence of a gentle anticlinal fold extending northeast by southwest through the central part of Cleveland county. Should this prove to be true the fold may be expected to extend farther to the northeast and southwest beyond Cleveland county.

While the area marked "1" offers the best chances for finding oil in the state, and while so many of the essential conditions for oil are favorable it should be remembered that sediments laid down along a shore line retreating seaward with a slowly subsiding sea bottom and a rising adjoining land area, as was likely the case, would give rise to beds dipping regularly and not to folds or structural features favorable to entrapping oil. Favorable structural areas may therefore be expected to form only a small part of the total area. As shown by the conditions enumerated the favorable places are difficult to locate until more data bearing on the subject is collected.

The log of every deep well drilled in this area should be accurately recorded as these records would furnish one of the best means of determining the most favorable places to locate future test wells.

Petroleum

(See preceding chapters under heading of Natural Gas and Oil)

The discovery of immense oil fields in three neighboring states, Louisiana, Texas and Oklahoma, has attracted attention to the possibilities of oil development in Arkansas. Land has been leased in different counties, and it is reported that 100 prospect wells were being drilled in 1920, several in Union and Ouachita counties, one in Hot Spring County, one in White County, one in Franklin County, one in Washington County, one in Pulaski County, one in Columbia County, one in Yell County and quite a number in different parts of Benton County. In the gas fields of Crawford, Sebastian and Scott counties drilling is being extended into the deeper sands with the hope of finding oil at 4,000 or more feet.

A company with the highest grade of technical advisers are sinking a well at Winslow on what they admit is a remote chance of striking oil in a favorable anticline in the Chattanooga shale. At this well there is also a chance of striking a little oil in the much higher Wedington sandstone or the Fayetteville shale, but the well is considered too near the outcrop.

Another company is testing a well located anticline at Ozark where there are possibilities of oil in the lower part of the Pennsylvanian of the Carboniferous formation, including the full thickness of the Atoka formation, and the probable extension of the Fayetteville shale. They also plan to test another anticline at Jethro in the northern part of Franklin County where the formations are similar but higher and containing less shale.

In the United States Geological Survey Bulletin No. 429, G. D. Harris has the following to say under the heading, "Oil and Gas in Louisiana, with a Brief Summary of their Occurrence in Adjacent States:"

"As oil and gas occur in southern Louisiana and southeastern Texas in commercial quantities in the vicinity of Saline domes, a few hundred acres in extent, most of such localities being separated by barren regions scores of miles wide, it is highly important for future development that the manner of occurrence of these salines should be carefully studied, so that probably productive territory may be separated from territory in which the discovery of oil or gas is unlikely. * * * In the opinion of the writer, all the saline domes are located along lines of fracture in the deep-lying Mesozoic and Paleozoic rocks, and in general their location seems to be at the crossing of such lines. * * * * The large amounts of gas and oil found in the Caddo field, Louisiana, appear to be simply following east and north slopes of a great uplift, and concentrating or reconcentrating along slight anticlinal ridges. * * * Hopes may be entertained of finding oil and gas so entrapped in wells sunk in various places near the Eocene--Cretaceous contact from Arkadelphia and to beyond San Antonio (Texas).'

(Aside from the salt domes of Louisiana other oil fields, such as the Caddo and Homer fields, have been found in connection with minor anticlines along the northern edge of the Sabine uplift of Louisiana. These rocks also occur widely in southeast Arkansas and are likely to contain oil. Unfortunately they are north of the Sabine uplift and will be some 600 feet deeper. If oil is found it is reasonable to expect that the pressure will be correspondingly increased.—Paranthetical information verbally supplied to the editor by Prof. A. A. Steel, Acting State Geologist.)

Asphalt and Petroleum in Southwestern Arkansas.

From the report of Hugh D. Miser and A. H. Purdue, "Asphalt Deposits and Oil Conditions in Southwestern Arkansas," U. S. Geol. Surv. Bulletin No. 691—J., the following is taken:

"The Trinity formation contains petroleum and asphalt at many places in northern Texas and southeastern Oklahoma. The asphalt in these two states and in Arkansas, as in other regions, is doubtless a residue of crude petroleum, whose lighter and more volatile parts have escaped by evaporation. The petroleum yielding the asphalt in Arkansas is believed by the writers to have been derived from the Carboniferous rocks underlying the Trinity formation, near the base of which the asphalt is found. In support of this belief is the fact that there are small amounts of asphalt in the sandstone of the Atoka formation, of Carboniferous age, which crops out in two narrow belts with a north of east trend in Pike County, a few miles north of Pike and Murfreesboro.

"Asphalt is also found in Carboniferous and older rocks near Mena, Arkansas, and in southeastern Oklahoma. The Carboniferous rocks pass beneath the Trinity formation, and the beds are tilted in such a manner that their edges project against the base of the Trinity. Any oil in the Carboniferous beds would, in the course of time, work its way upward into the Trinity. It could not go higher than the lower limestone of the Trinity, because of the impervious character of this limestone and the associated clays. As the Trinity has a gentle dip to the south, the oil would be conveyed up the dip to the surface. There is, however, no direct proof that some or all of the petroleum did not originate in the basal part of the Trinity formation, which contains some fossiliferous limestone.

"On the assumption that the petroleum yielding the asphalt herein described originated either in the Trinity or in the underlying rocks, the petroleum has probably migrated northward. There is, however, a possibility that it came upward from the Paleozoic strata immediately subjacent to the areas containing the asphalt deposits.

"The Cretaceous rocks in southwestern Arkansas have a southward dip of about 100 feet to the mile, and although they have been slightly warped, no pronounced anticlines or synclines occur in Pike, Howard and Sevier counties. Thus, if petroleum occurs in the region south of the asphalt deposits, its accumulation into quantities of possible commercial importance would probably be controlled by terrace structure, lenticular character of sands, or irregularities in the Cretaceous floor.

"The peridotite masses near Murfreesboro may have lifted the Trinity so as to produce structure favorable for the accumulation of oil about them, just as volcanic necks or plugs have done in Mexico and probably in Texas, but such phenomena have not been observed around the peridotite masses.

"There is no possibility that either oil in commercial quantities or gas in large pools will be found in the Ouachita Mountain region of west-central Arkansas or in most of this region in Oklahoma... The Carboniferous and older rocks have been so highly tilted and so much fractured and metamorphosed that if oil or gas were ever present in them the gas and much of the oil would have made their escape to the surface and the remainder of the oil would have been distilled to asphalt."

Oil Geology Around Fayetteville.

From the Annual Report of the Arkansas Geological Survey, Vol. IV, 1888, the following is taken:

"The occurrence of oil and gas in the vicinity of Fayetteville has led many to the expectation that something substantial might be realized from it. But the oil indications are based solely upon the occurrence of petroleum in small quantities in the Fayetteville shale, and the gas thus far discovered is evidently from the same source, and likewise of small quantity. Oil may occur in the rocks of any geological horizon, and the mere fact of its presence is not, as many suppose, prima facie evidence of the existence of petroleum in paying quantities. The Fayetteville shale has been pretty thoroughly explored, and there is no substantial reason for expecting it to prove a source of oil.

"There was more or less excitement a few years ago about oil found on Cove Creek, 13 N., 32 W., Section 24. The locality, though not a promising one, has been examined by the Geological Survey. It is known locally as "the oil spring."

"'It may be well in this connection to correct an error in regard to the relations of the structural geology of this part of the state to this oil-saturated rock on Cove Creek. It has been thought that the rocks in the Boston Mountains dipped north, forming a basin in the central or northern part of Washington County, and that the oil-bearing rocks exposed on Cove Creek would therefore be found at a considerable depth in Benton County and in northern Washington County, and rich in oil. This is a grave mistake. The general dip of the rocks through the Boston Mountains is to the south, though there are many local dips in other directions. Everything in the general geology of Washington County points to the fact that the sandstone in which this oil occurs is cut off along the north face of the Boston Mountains and that the rocks through the central and northern parts of the county all lie below it.

"It should be added, moreover, in regard to the Cove Creek oil-bearing sandstone, that it is not a rock from which oil can be expected to flow. It does not contain enough oil to thoroughly saturate it; it cannot, therefore, be expected to yield flowing wells of oil."

Outlook in North Central Arkansas.

In a description of the Eureka Springs and Harrison quadrangles, by A. H. Purdue and H. D. Miser, published by the U. S. Geological Survey, the following statement is made with reference to oil development possibilities in north central Arkansas:

"Considerable money has been spent in northern Arkansas in drilling wells with the hope of finding oil or gas, but neither has yet been found in commercial quantity north of Crawford and Franklin counties. Furthermore, the character of the rocks does not indicate that either oil or gas will be found in commercial quantity in the quadrangles under discussion or in the adjoining parts of northern Arkansas and southern Missouri. However, any wells that are put down should be sunk on the domes. Oil may perhaps be distilled from the Chattanooga shale.

In his report, "The Underground Waters of Northern Louisiana and Southern Arkansas," A. C. Veatch says:

"All of Louisiana and that part of Arkansas south of the Arkansas River and the mountains, has the same general structure as the Great American Coastal Plain of which it forms a part. The land is higher towards the old plateau and mountain region, and the beds are for the most part unconsolidated; they succeed one another more or less regularly, range in age from the Cretaceous on the one hand to the recent shore deposits on the other, and dip in a general way coastward at a rate greater than that of the land surface. * * * In the older beds there is, in addition to the slope toward the coast, a slope toward the Mississippi Valley. Some of these older beds are very much disturbed, forming peculiar, sharp, cone-shaped domes, and as these layers often contain artesian salt water, and are frequently broken by the high folding, the salt water is free to pass into the sands of the surrounding younger formations. * * * *

Natural Mounds.

In many parts of Arkansas the presence of low circular mounds, 20 to 100 feet in diameter and one to four feet high, give rise to a supposition that oil or gas may underlie the country where this curious topography appears, the theory being that the mounds are extinct vents, formed by the blowing out of sand and earth with escaping fumes or fluids. Geologists have explored and studied the little hummocks but they offer no suggestion for solving the mystery surrounding the origin of the mounds. Their uniformly circular shape is believed to preclude the possibility of their having been formed by wind or by ants or burrowing animals. No such mounds are known to be in process of formation at the present time. The occurence of the mounds in various topographic positions and on geologic formations of all ages would seem to render the spring or gas-vent theories untenable. They have been observed in Pulaski, Jefferson, Lonoke, White, Jackson, Independence, Lawrence and Clay counties. These geologic curios are discussed by L. W. Stephenson and A. F. Crider in Water Supply paper No. 399, U. S. Geol. Surv. 1916, and by M. R. Campbell in the Journal of Geology, XIV, 708-717, 1916. The letter contains a bibliography.

Oil Shales.

"Petroleum occurs in small quantities in the Fayetteville shale of Washington County. Everything in the general geology of this section points to the fact that the sandstone in which this oil occurs is cut off along the north face of the Boston Mountains and that the rocks through the central and northern parts of the county all lie below it. The rock does not contain enough oil to thoroughly saturate it."—Annual Report of the Arkansas Geological Survey, Vol. IV, 1888.

"Oil may perhaps be distilled from the Chattanooga shale (of northwest Arkansas) which is sufficiently bituminous to give off the odor of petroleum when struck with a hammer, but such distillation will be profitable only after the prices of petroleum and its products become higher."—A. H. Purdue and H. D. Miser.—Eureka Springs-Harrison Folio, No. 202, U. S. Geol. Surv. Among the shale rocks of northwestern Arkansas, H. D. Miser of the U. S. Geol. Survey, includes the Bloyd shale.

REFERENCES.

Miser, Hugh D. and Purdue, A. H.—Asphalt Deposits and Oil Conditions in Southwestern Arkansas. U. S. Geol. Surv., Bulletin 691—J, 1918.

Harris, G. D.—Oil and gas Louisiana and Adjacent States. U. S. Geol. Surv., Bulletin 429, 1910.

Veatch, A. C.—Geology and Underground Water Resources of Northern Louisiana and Southern Arkansas, U. S. Geol. Surv., Prof. Paper 46, 1906.

Ochre.

Ochre is used as a coloring matter for tinted paints, and paints made with it as a base are often used for forming coats. It finds its most extensive use, however, as a filler in the manufacture of linoleum.—Mineral Resources of the United States, Part II, 1912.

Ochre of a deep red color occurs abundantly near Wittsburg on Crowley's Ridge. An analysis suggests no valuable use to which this clay could be put. It is used locally for painting barns.—Report Arkansas Geological Survey, Vol. II, 1889.

Deposits of yellow ochre occur near Monticello, Drew County, and Piggott, Clay County.—A. H. Purdue.

Brown ochre, or limonite, occurs in many parts of the state, but it is usually contaminated with clays. * * * Red ochre, Fourche Mountain and suburbs of Little Rock, usually impure from admixture with silica and clay. —J. C. Branner.

Onyx.

Argonite or Mexican onyx (Carbon dioxide, 44 per cent; lime 54 per cent) occurs in large quantities in some of the zinc mines of north Arkansas. Doctor Branner says, "We have seen beautiful pieces of this rock that would have brought high prices in the market wantonly destroyed, partly because the owners were not aware of its value, and partly because this is a zinc mine—not a stone quarry."

From the report of T. C. Hopkins on the Marbles of Arkansas, the following facts are taken:

"None of the onyx marbles of Arkansas are quite as translucent or as brightly banded as the finest qualities of Mexican stone, yet much of it is very handsome, works easily, takes a brilliant polish and will no doubt command a good price. Further research may show even finer qualities."

Slabs containing several square feet of "Eureka onyx" have been recovered from caves near Eureka Springs and made into paper weights, clocks, scarf-pins, pen holders, etc. Large quantities of stone are exposed in a cave near Dodd City. It occurs in white, cream, red and yellowish brown colors. Apparently slabs four or five feet square or even larger could readily be obtained. It is a beautiful stone.

REFERENCES.

Report Arkansas Geological Survey, Vol. IV, 1890.

Paint Minerals.

There are some seams or pockets of a very good quality of barytes in many places in Montgomery County, between the Broken Rock and Blue

Mountain axes, and generally speaking along the whole length of that belt. Some of the barytes is white and of high value. Ground shale and impure graphite which abound in southwestern Arkansas, especially in Montgomery County, are useful materials as fillers for paints. Red ochre (hematite) and "reddle," or a kind of red chalk, are abundant in many localities in southwestern Arkansas. Use might be made of these in paint manufacture. The yellow and brown ochreous earths (limonite) may in some cases be useful for similar purposes. The quantity of such ore, particularly in Pulaski County, south and west of Little Rock, is enormous and easily mined.

Pearls.

Precious pears are procured from the fresh water mollusca of White and Black Rivers in north Arkansas and occasionally from Little River in southwest Arkansas. The Arkansas pearls are of rare quality in color and an unusually high per centage are perfectly shaped. Frequently gems are found that bring from $300 to $2500 each.

The pearl-bearing shells are extensively used in the manufacture of pearl buttons, being dredged from the bottom of the streams by specially designed boats manned by expert fishermen. Tons of these mollusca are marketed annually at Black Rock, Newport, DeValls Bluff and Clarendon, where there are plants for the production of the pearl buttons of commerce.

Phosphates.

Northern Arkansas.

In the United States Geological Survey Bulletin No. 351, Prof. A. H Purdue, former State Geologist of Arkansas under the title "Developed Phosphate Deposits of Northern Arkansas," published in 1906, says:

"The developed phosphate deposits of Arkansas are on Lafferty Creek, on the western edge of Independence County. The only point at which the beds are now worked is about three fourths of a mile east of White River and the same distance from the White River branch of the Missouri Pacific R. R. Although this is the only locality at which the deposits have been developed, they have a wide east-west extent, reaching from the town of Hickory Valley, ten miles northeast of Batesville, westward at least as far as St. Joe, in Searcy County, a distance of more than 80 miles. A phosphate bed, which is practically horizontal, outcrops in a winding line on the hillsides and in other places between the points mentioned. A phosphoric horizon can be traced to the westward border of the state, but at no point west of St. Joe have phosphate rocks, in considerable amount, attracted the attention of geologists. Thin layers of phosphatic sandstone are found in the Devonian shales in the western part of Carroll County, on War Eagle Creek.

"In the area over which the phosphate rocks occur nothing but sedimentary rock is exposed at the surface. The ages, relations, and names of the formations in the eastern part of the area are given as follows:

Carboniferous
 Boone chert, including St. Joe marble.
Devonian
 Chattanooga shale and Sylamore sandstone.
Silurian
 St. Clair limestone.
Ordovician
 Cason shale
 Polk Bayou limestone.
 Ozark limestone.

In June, 1900, a company was organized under the name of the Arkansas Phosphate company, for the purpose of developing the phosphate beds along Lafferty Creek. After several months of prospect work it was found that the phosphates exist in sufficient quantities to justify extensive mining operations. A mining and milling plant was erected, several miles of railway spurs were laid and mining was begun. After only a few months of active operation the plant was destroyed by fire, which stopped the work.

The following analyses of specimens of the rock were made in the laboratory of the United States Geological Survey.

	Phosphoric Acid (P_2O_5)	Equivalent in Calcium Phosphate ($Ca_3(PO_4)_2$)
Four inches from top of bed	25.86	56.45
Middle of bed	27.24	59.46
Eight inches from bottom of bed	27.40	59.81
Black phosphate	32.60	71.06
Composite sample	29.18	63.70
From lower bed	13.46	29.38

"The aggregate thickness of the two beds at the quarries is from 8½ to 10 feet.

The geological formations of the vicinity of the developed deposits from below upward are: The Izard limestone, the Polk Bayou limestone, the Cason shale, the St. Clair limestone, the St. Joe marble and the Boone chert. The developed deposits occur between the Polk Bayou limestone and the St. Clair marble, consequently at the horizon of the Cason shale, which is thought to be of Ordovician age. The phosphate rock is of sedimentary origin and where developed is light grey, homogenous, and conglomeratic, the pebbles being the size of peas and smaller. The beds probably were laid down near the shore as the sea advanced landward. Their phosphatic nature is thought to be due mainly to the fragments of organic matter that constitute so large a portion of their mass, though it may be due in part to the droppings of marine animals.

"As the phosphatic rocks of Northern Arkansas are usually covered by soil where they outcrop on the hillside, a few suggestions to prospectors in search of these beds may be of advantage.

"As one passes up the hillside of the deeper valleys in western Independence County he goes first over a compact, gray to dove colored, brittle limestone, that breaks easily under the blows of the hammer. This is the Izard limestone. Above this is a coarsely crystalline limestone, light gray at the bottom, but growing darker toward the top, until the upper portion is at some places almost chocolate colored. This is the Polk Bayou limestone. It is at the top of this limestone that the phosphate of the locality occurs. In case the St. Clair limestone is present it will be found above the phosphate; if not the Boone chert (possibly the St. Joe marble) will be found above it. It is useless to look for phosphate above the base of the Boone chert or above the top of the Polk Bayou limestone. Fragments of manganese ore, which are easily recognized and always conspicuous when present, are good indications of the phosphate horizon, as the two are closely associated. Of course it must be remembered that loose material works its way down hill, so that only the upper limit of the material here described marks the position of the phosphate beds."

Other Deposits of Phosphate.

From Bulletin No. 74, Arkansas Agricultural Experiment Station, 1902, by John C. Branner and J. F. Newsom, the following is quoted:

"The second region in which phosphate rocks occur in the State of Arkansas has been indicated as the Cretaceous area of the southwestern part of the State. But little is known of the exact extent, thickness or richness of the phosphate beds in this part of the state. In some of the beds there are bands of black pebbles which were formerly regarded as chert of quartz; a chemical examination of these pebbles, however, show that many of them are phosphate nodules. Such bands may be seen in the rocks exposed on Deciper Creek, west of Arkadelphia, in Clark county. These pebbles have not been seen in quantities sufficiently abundant to make the deposits valuable, but an examination of the Cretaceous rocks with these facts in view may lead to the discovery of such deposits.

"Another possible source of phosphates in the Cretaceous area of southwest Arkansas is to be found in the green sands marls. Some of these marls are very like those of New Jersey, and are, in all probability, available for the same purposes as those for which they have long been so extensively and successfully used in New Jersey, namely, for direct application as fertilizers to the soil. No thorough practical test, however, has been made of the Arkansas greensands.

"Conglomerate beds are known in the Ouachita uplift, which bear so striking a resemblance to the Sylamore sandstone that they are scarcely to be distinguished in hand-specimens. The only apparent difference is that the Ouachita uplift specimens appear to be a little more crystalline or metamorphosed. On account of the crushing of the rocks throughout this southern area this was to be expected. Owing to the folded, faulted and metamorphosed condition of the rocks in this region and the almost total absence of fossils, it cannot be positively stated whether or not these conglomerates are the equivalents of the Sylamore sandstone of North Arkansas.

"Specimens of this conglomerate have been seen from several places north and south of the city of Hot Springs, but an analysis of one of these specimens did not show it to be rich enough in phosphoric acid to have any value.

"In the region of the Lower Coal Measures rocks in the vicinity of Amity, Clark county, a conglomerate found by Dr. George H. Ashley, resembles the phosphate rock somewhat; but a chemical examination of one sample of it showed it to contain only about 9 per cent of calcium phosphate. Further search in the neighborhood of Amity may lead to the discovery of richer deposits.

"The whole area over which the phosphate beds occur or are to be expected, has not been examined, and it is not known, therefore, how much the materials vary in character and composition. Judging from what is already known it seems reasonable to suppose that better deposits than any thus far found may yet be discovered."

"The point, however, to which we would direct especial attention," says Doctor Branner, is that all of these rocks, even those running high in iron and aluminia, may be used directly as fertilizers. This is a fact of the first importance to the owners of phosphate lands and to the farmers of the south."

REFERENCES.

Branner, John C.—Lead and Zinc. Annual Report Arkansas Geol. Survey, 1892, Vol. V.

Branner, John C. and Newsom, J. F.—The phosphate rocks of Arkansas. Bulletin No. 74, Arkansas Agricultural Experiment Station 1902; Review, Engineering and Mining Journal, Abstract 25.

The phosphate deposits of Arkansas. Transactions of American Institute of Mining Engineers, 1896, Vol. XXVI, 1896.

Arkansas phosphate rocks. Arkansas Democrat, semi-weekly, Little Rock, November 3, 1901; Harrison Times, Harrison, Arkansas, January 18, 1902.

Purdue, A. H.—Developed phosphate deposits of northern Arkansas. Bulletin No. 315, U. S. Geol. Surv., Washington, 1907.

Memminger, C. G.—Phosphate rock in Arkansas. Mineral Industry, Vol. XI, New York, 1903.

Stone, Ralph W.—Phosphate Rock in 1918. U. S. Geol. Surv., Mineral Resources of the United States, 1918.

Waggaman, Wm. H.—A report on the natural phosphates of Tennessee, Kentucky, and Arkansas. Bulletin No. 81, United States Department of Agriculture, Bureau of Soils, Washington, 1912.

Owen, David Dale.—First Report of a Geol. Reconnaissance in the northern counties of Arkansas, 1858.

Penrose, R. A. F., Jr.—Nature and origin of deposits of phosphate of lime. Bul. 46, U. S. Geol. Surv., Washington, 1886. (Contains bibliography).

Hopkins, T. C.—Marbles. Annual Report Arkansas Geol. Survey, 1890, Vol. IV.

Ulrich, E. O.—Zinc and Lead. Prof. Paper, U. S. Geol. Survey, No. 24, 1904.

Potash From Leucite Rock.

During the world war F. C. Calkins of the U. S. Geol. Survey, examined the deposits of leucite rock in the Magnet Cove district of Arkansas with special reference to their possible utilization as a source of potash, but with the cessation of hostilities the European supply again became available and no development work was undertaken. The leucite rock is one of the many sources of potash which can be made use of in this country, but the difficulty of recovering the potash from this material renders it of little economic value in competition with the richer and more easily obtained potash of Germany and France on our markets.

Precious Stones.

Besides diamonds, pearls and quartz crystals, which are treated under separate headings, the Arkansas list of precious stones includes amethysts, rare but found occasionally in Montgomery and Yell counties; turquois or variscite, found in veins of quartz and in concretionary patches in dolomites in Montgomery county; garnets, in Magnet Cove; false topaz, Hot Spring County; sunstone, pink or gray, in Magnet Cove; wavelite, the latter found also in Magnet Cove; opal, about the ancient hot springs in Saline and Hot Spring counties; jasper of various colors, in Montgomery and Polk counties; and agate, finely variegated, in Montgomery county.

REFERENCES.

Kunz, George Frederick.—Gems and precious stones of North America. Second edition, New York, 1892. Quartz crystals, pp. 110-111; novaculite, 122; lodestone, 192; titanite, 194; Arkansite, 194.

Quartz Crystals.

Quartz crystals of wonderful lustre and form are found in many parts of Arkansas, notably in the vicinity of Hot Springs, in the Crystal Mountains, which it is said has furnished some of the largest and most beautiful quartz crystals in the world. Cavities in the rocks are beautifully coated with these sparkling gems, many of them of rare color and shape; some of them with liquid cavities. They are non-mineral bearing and are valuable chiefly as curios or ornaments, being known as "Hot Springs Diamonds" because of their manufacture into trinkets and jewelry for sale as souvenirs to visitors at Arkansas' famous health resort. Clear, limpid specimens are found at Delaney in Madison County and in Crystal Mountain near Womble, Montgomery county.

REFERENCES.

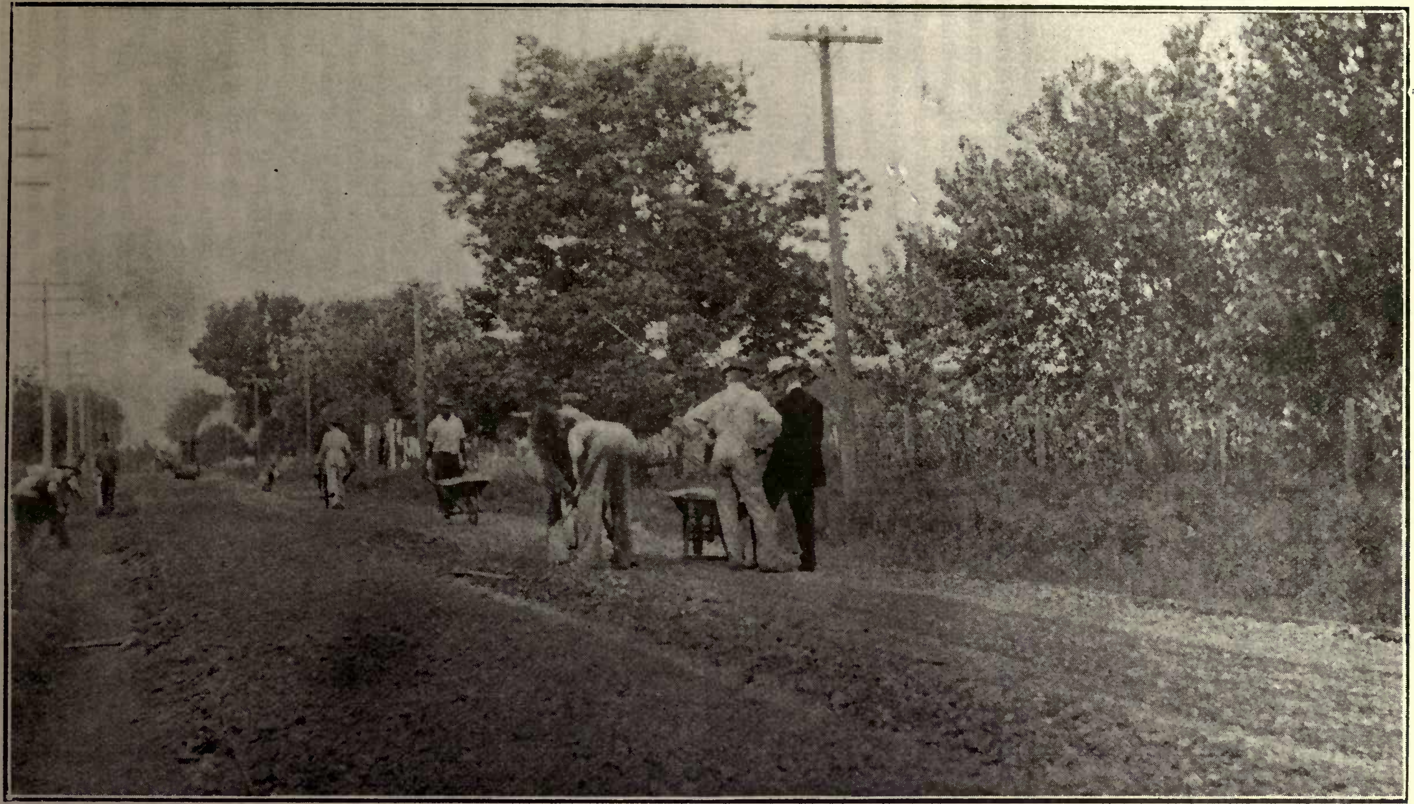
Report Arkansas Geological Survey, Vol. I. 1882. pp. 113, 128, 289.

Rectorite.

A peculiar form of kaolinite, to which the name rectorite has been given, is found in Saline County. This material is tough and leathery, but it has the smooth soap feel so characteristic of the kaolins and of steatite. It occurs in association with the Carboniferous sandstones of the region, but the deposits, so far as is known, are only about a foot thick.

Rectorite, as it comes from the ground, ranges in color from pure white to reddish brown. The sheets are very flexible but entirely without elasticity. It is infusible before the blow pipe, but when heated in the flame of a Bunsen burner it loses water and becomes brittle. Specimens were sent to the ceramic works to be tested practically, and the following report was made on the results by Homer Laughlin of East Liverpool, Ohio:

"The sample of what you call kaolinite sent me was duly received and carefully examined and tested under fire. The mineral is neither kaolin nor kaolinite, but just what it should be called, I am unable to say, never in all my experience having seen any mineral of this kind. Unlike kaolin, it will not dissolve in water. It burns a white color and becomes very vitreous and strong. It cannot be finished with a smooth face or skin, but roughs



Road Building Scene in Arkansas.

up like a blotting pad. It is certainly a very interesting and curious mineral, but I think of no use for it in ceramic manufacture unless it could, after experiments, be made into novel ornaments."

References

Branner, John C.—The Clays of Arkansas. Bulletin 315, U. S. Geological Survey.

Brackett, R. N. and Williams, J. F.—Newtonite and Rectorite. Amer. Jour. Sci., CXLII, 11-21, 1891.

Road Making Materials In Arkansas.

By John C. Branner,

It is not my object to point out the importance of good roads; but simply to call attention to the materials that should be avoided and the materials that should be used when we come to the actual work of road construction. It is also assumed that whenever road building is taken up seriously, properly informed road engineers will have the laying out of the routes and the determination of the details of grades, curves, drainage. cross section and methods of construction, for unless these details be looked after by those whose business it is to know about and to attend to them, no attempt at road building is likely to be satisfactory or more than half successful.

The rocks of the State are the State's road making materials. In some places these rocks lie in their original unbroken beds, in others they are more or less shattered or broken up into talus or gravels, or they have been rolled in the beds of streams and worn into more or less round pebbles. But the gravels and pebbles are derived directly from the beds of hard rocks, and therefore had the same general distribution as the strata from which they are derived. This distribution of road-making materials therefore depends upon the distribution of the various kinds of rocks, and this depends upon the geology of the State, so that a map showing in detail the distribution of the various kinds of road-making materials would be, to a certain extent, a geological map.

The road builder often has to make his roads of whatever he finds at hand, but it often happens that there are several kinds of rock equally convenient, and that he can use one just as well as the other. It is of great importance in such cases that he should know which to choose, for, as I shall point out, some rocks are altogether unfit for such use, and it is just as important to avoid poor materials as it is to use good ones.

It is intended to speak in this paper, however, only of the materials adapted to making the surface or top dressing, or "metal", as it is often called, of common roads or turnpikes. Many elements of course go to making up a good road, but even with the proper drainage, cross section, foundation and grade, without a proper surface the road must always be a poor one, besides being expensive to maintain. When the Telford system is used almost any hard rock will answer for the bed rock of the roadway, but only a few kinds of rock are fit to be used as dressing or road metal.

It is proposed, therefore, to point out the advantages of the materials of the State that might be utilized for such purposes, and to call attention to other materials that have been, or are liable to be used, but which are judged to be objectionable.

Inferior Materials

For top dressing of turnpikes or road metal any and all materials that grind up quickly under traffic, forming dust in dry weather or mud in wet weather, must be regarded as objectionable. Such materials have certain advantages for first construction in being more easily prepared, and there is therefore so much more reason for guarding against them. Materials to be avoided for such purposes are:

1. The argillaceous or clay shales.
2. Limestones,
3. Syenites or "granites."
4. Clean sandstone.

1. **Argillaceous Shales.** The term shale is unfortunately not in common use among the people; what geologists call shale is often known as "slate" or "soapstone." The rock is made of clay and hardened; when the clay is pure the rock is known as argillaceous shale, and when it contains considerable sand it is known as arenaceous or sandy shale. These shales vary somewhat in color; some of them are very black, others are gray and others are of reddish color.

For road building purposes the shales may be divided into two classes—clay shales and sandy shales.

The clay shales are entirely unfit for such purposes; the sandy shales are the only ones that should be used for the top dressing. The reason of this is that sooner or latter the rocks are crushed and ground up, and that which is made of clay only forms a fine dust when dry and a pasty sticky mud when wet. The arenaceous or sandy shales, on the other hand, contain so much grit that they usually pack hard and make a firm roadbed.

The argillaceous shales are not confined to any particular geologic horizon, but may occur with the rocks of any age from the Silurian to the Tertiary. In the northern part of the State the formation that I have called the Eureka shale is a black or green clay shale. In and south of the Boston Mountains, and throughout the Coal Measures area of the State such shales are common, and they also abound in the Silurian area about Hot Springs, and between Hot Springs and Dallas, Polk county, though they by no means form the only, or even the greatest part of the rocks of the area mentioned.

2. **Limestone.** Limestone was formerly regarded as one of the best rocks for top dressing, and it has been extensively used for such purposes, but it has proved very unsatisfactory in the long run, and in many parts of the country the limestone macadamized roads are being taken up and reconstructed of more satisfactory materials. The rock wears easy into an impalpable powder when dry and forms a sticky paste when wet. Hard limestone makes an excellent roadbed,but it should never be used for surface dressing. There is a temptation to use limestone for such purposes because they are easily broken and pack readily on account of their friability. But they wear out with equal readiness, and soon require repairing. The limestones of the state are most abundant in the region north of the Boston Mountains and west of the St. Louis, Iron Mountain and Southern Railway. There are a few patches of limestone in ravines heading on the south side of the Boston Mountains and in Garland and Montgomery counties, and some in Clark, Hempstead, Sevier and Little River counties.

The soft chalky limestones found in Hempstead and Little River counties are especially objectionable for road-making.

3. **Syenite or "Granite."** It has been inferred that because the Little Rock syenite makes good paving blocks and excellent building stone it must make good surface metal when crushed. This, however, is not altogether true. About 80 per cent of the Little Rock syenite is feldspar. When this feldspar decays, or when it is finely powdered, it forms clay or kaolin. Now everyone knows that clay should not be used as a top dressing for roads, for when dry it forms a fine dust and when wet it forms mud, both of which are objectionable both on their own account and because they mark the beginning of the destruction of the roadway. While, therefore, syenite may make a good dressing for a short time, it must of necessity soon break down into objectionable decay. It is a good rock, however, for roadbed. The area of feldspathic rocks in the state covers about thirteen square miles altogether. They are confined to Pulaski, Saline and Hot Spring counties, with a few small dikes in Garland, Montgomery and a few other counties.

4. **Sandstone.** As a rule sandstone is not a good road-making rock, but if road builders will observe the behavior of sandstones of different varieties they will find that some of them make fairly good roadbeds, while others do not. This difference is due to the absence or presence of a binding material, and no more specific directions can be suggested than that clean, sandstone, or sandstones containing no binding materials, such as lime, clay or iron. should not be used for surface metals.

Superior Metals.

What kind of rock makes the best road metal? Road engineers generally seek the hardest rock they can find, and the principle is generally, but not always a correct one. The object to be sought is a hard, smooth road surface, that will not grind or cut readily under wheels so as to make dust or mud. But one of our hardest Arkansas rocks, the so-called granite, is not as good for such purposes as the softer argillaceous shales, because the feldspar which makes the great bulk of the granite, soon breaks down into kaolin—one of the stickiest kinds of mud. In the main, however, the method of seeking the hardest rock is the correct one. In North Arkansas, for example, there are four great classes of rocks: The limestones, sandstones, shales and cherts. Of these the chert (commonly known as flint) is by far the hardest and the best for road making.

It is sometimes said that all rocks harden when exposed to the weather. This is far from being true of all rocks, though it is true of some of them. Syenite, for example, decomposes when exposed, as do many other rocks which contain soluble constituents.

It should, moreover, never be forgotten by those who undertake to make good roads that the arrangement of the materials is of as much importance as the materials themselves. An authority on this subject covers the case exactly when he says that "a common gravel sieve often constitutes the principal instrument whose judicious use will make a good road out of a miserable string of ruts and cobbly elevations. It would be only necessary to sift out and separate the soil under the road to a sufficient depth into cobbles, coarse gravel, fine gravel and sand; then replace them in the order named, and with the proper thickness of layers of each; wet down and roll, and the result will be a good road.

The materials best adapted for road making, and having anything like a wide distribution in Arkansas, are:

A. Arenaceous shales.
B. Chert, of "flint rock."
C. Novaculite.
D. Gravels.

The useful materials mentioned above belong to different geologic formations, and are to be looked for only within the areas covered by the formations to which they are confined, or where such materials have been carried by streams into adjacent areas.

A. **Arenaceous of Sandy Shales.** The arenaceous shales abound in the Lower Coal Measures of the state in the region south of the north face of the Boston Mountains, north of the Fourche and Petit Jean Mountains, and west of the St. Louis, Iron Mountain and Southern Railway. This region contains sandstones and clay shales as well as sandy shales, but as a rule the sandy shales are very widespread through it. One needs to guard against the clay shales in this region, for they are about as abundant as the sandy shales, and the two often grade into each other imperceptibly. The difference between clay shale and sandy shale is that the former is comparatively free from sand or grit, while the latter is a mixture of sand with a certain amount of clay. They can be readily distinguished by cutting with a knife. A knife will cut clay shale as readily and smoothly as if it were a piece of soap or stearine, but when a sandy shale is cut the knife blade catches and grates disagreeably upon sand grains.

In some of the counties within the Coal Measures sandy shales predominate, while in others the shales are chiefly argillaceous. In Cleburne county, for example, the sandy shales cover a large part of the uplands of the county, and good road-building materials are abundant and convenient almost all over the county. These shales are often more or less micaceous, and for this reason they have been regarded as gold and silver-bearing, and some prospecting has been done upon them. It is hardly necessary to say that these sandstones and shales contain neither gold nor silver. If properly utilized, however, they may yet prove of great value to the people of that county as a road-making material. These shales usually occur imbedded with sandstones. In the process of weathering the shales break down first, leaving the sandstones as the topographic prominences, forming sharp ridges or capping flat-topped mountains or hills. In regions where the rocks are horizontally bedded the shales may therefore be looked for below the ledges of sandstone; but in regions in which the rocks have been folded the sandstone will be found to form the crests of ridges, while the shales will be found in the valleys. Some of the sandy shales contain a considerable percentage of lime or iron, and either of these substances acts as a cement, and makes a hard, smooth roadway. In order to prepare this material for top dressing it has to be quarried out and crushed. It is comparatively soft, however, and not nearly so hard to crush as syenite or sandstone.

B. **The Chert or "Flint Rock."** Chert or flint is one of the hardest of rocks, but it doesn't usually occur in considerable quantities in its original beds, but is everywhere mixed with more or less lime, so that beds of pure chert often grade into pure limestones or marbles. The cherts (in place) in this state are confined to the area lying north of the Boston Mountains and west of the Iron Mountain Railway. Not all of this area, however, contains chert beds. There are two horizons at which it occurs in large quantities—the first is that of the Boone chert and cherty limestone lying at or near the base of the Carboniferous series of rocks; the second is the great chert bed lying far below the Boone chert, geologically speaking, and exposed in the counties through which the upper White River flows. The Boone chert (in place) begins in Independence county, just west of the Black River, and near Dota post office, about five miles northeast of Sulphur Rock. It forms a belt of ragged edges from five to fifteen miles wide, crossing the state from this point past Cushman, Mountain View, Marshall, St. Joe, Harrison and Eureka Springs, and forming the greater part of the surface of Benton county. Without a large map it is impossible to show the precise distribution of this Boone chert through the northern part of the state. Nothing more can be attempted here, therefore, than call attention to the material and its general distribution. The Boone chert, as a geological horizon, is made up of both cherts and limestones, and these elements mingle in the formations in various proportions. When the chert is exposed to the weather, it decomposes slightly, the lime in it being dissolved out, sometimes leaving the chert rather spongy. The "Ridge roads" through all the chert region of the state bear witness to the great value of this chert as a road-making material. These roads, though seldom or never repaired, are hard, compact, dry and free from mud and dust all the year round. The gravelly roads on the hills about Eureka Springs are all of this Boone chert. The best roads in Benton, Carroll, Boone, Marion and Searcy counties are on this same formation. All through these chert regions the beds of the streams are filled in places to a depth of fifteen feet with the accumulated small fragments of chert, most of which is in a suitable condition for immediate use for road building.

The chert beds that occur in the Silurian rocks of north Arkansas are geologically much lower than the Boone chert, and lie to the north of the Boone chert area. They crop out along the stream bluffs through Randolph, Sharp, Fulton, Izard and Baxter counties, and large quantities of the broken fragments accumulate in the beds of streams where they are often in excellent condition for road material.

In connection with the subject of chert it may be well to call attention to the extensive and increasing use of this material for road making in southwest Missouri, the refuse from the zinc mines of Jasper county being utilized for such purposes.

C. **Novaculite.** Novaculite is very like chert, both in composition and in its behavior as a road-making material. It occurs, however, only in the hilly region lying south of the Coal Measures, where it forms the Zigzag Mountains about Hot Springs and the great Ouachita Mountain system south of the Ouachita River, extending from Rockport, Hot Spring county, nearly to Oklahoma west of Dallas, Polk county. It is from this series of rocks that the famous Arkansas whetstones come.

The novaculite is usually much shattered and fractured as it lies, and, being for the most part a brittle rock, it may readily be broken when it is not already small enough to be used without crushing. Like the chert, it accumulates in vast quantities in the beds of streams and in narrow valleys, and it is from these local accumulations that the materials can be had most conveniently for road making.

D. **The Gravels.** Siliceous gravels have always been regarded as one of the best kinds of road-making materials. They have this considerable advantage over prepared macadam that they require no crushing, and are therefore cheaper, while they have been partially sorted by the waters which transported them to where they are found. In many of the northern states the gravel beds of the glacial drift have furnished excellent road-making materials for the entire states. Here in Arkansas there is no glacial drift, properly speaking, but there are extensive and widespread beds of gravel that are equally good. These gravel beds occur at various places along the immediate valley of the Arkansas River from Fort Smith to Pine Bluff. They are often at a considerable elevation above the present river (at Dublin, Logan county, they are 160 feet; at Little Rock they rise to a height of 140 feet above the river), but they never reach the highest hills. The gravels found along the river are generally mixed with more or less clay, but they may be looked for washed clean of such clay in the streams across the gravel bed, while some cheap method of washing and screening the gravelly clays will yield large quantities of excellent road metal at Little Rock and in many other parts of the state.

It may prove worth while to seek water-worn gravels in the bed of the Arkansas River at such places where the current is swift enough to carry away the clay and sand. When found at such places they can be dredged just as sand is now dredged at Little Rock. The gravels obtained from the bed of the river, however, are open to the objection that they will not pack so readily or so hard as those taken from the land. The reason for this is that there is enough iron associated with the gravel beds on land to cement them when they are packed on the road, while the same material when found in the bed of the river is comparatively free from the iron and clay, and incapable therefore of packing promptly and firmly unless mixed with some other material. The materials of the river have also generally been brought so far that the softer fragments have been worn out and only the very hard ones remain, and these resist crushing and binding. A little sandy clay mixed with such gravel will generally cause it to bind properly.

The material composing the Arkansas gravels referred to under this head is principally chert. It has been washed down the streams flowing into the Arkansas from northwestern Arkansas and southwestern Missouri, which fact accounts for its being found all along the Arkansas Valley. Its wide distribution across the valley is due to the meanderings and channel changes of the Arkansas River and to the ancient floods of that stream.

Beds of gravel having a similar origin occur along White and Black Rivers in north Arkansas, and follow the flood plains of those streams. Just north of Sulphur Rock, in Independence county, the water-worn materials cap the hills 250 feet above White River. Further up the river these gravel deposits occur here and there as isolated patches on the slopes of the inner curves of the large streams, often high above the present water level.

Through the eastern part of the state the gravels have a wide and even distribution in the geologic sense, though for practical purposes their distribution is local rather than general. Along Crowley's Ridge they are often found concentrated in vast quantities in the beds of streams that flow from the ridge, as for example the Little Crow Creek near Madison, St. Francis county, where they are convenient to railway transportation and offer abundant and excellent material for road building through the eastern part of the state, where such material is scarce, except in those favored localities along Crowley's Ridge.

About Little Rock such gravels are mingled with sands and clays that cover almost all the ground upon which the city is built. In those parts of the state lying southwest of Little Rock these gravels are of novaculite, and were derived from the region of novaculite lying between Little Rock and Dallas, in Polk county. Along what was once the old shore line upon which they were worn, and stretching from Little Rock past Benton, Malvern, Arkadelphia, Murfreesboro, Nashville, Center Point and Lockesburg to Ultima Thule, these gravels form extensive beds, in places twenty feet or more in thickness, while to the south of this line they become gradually finer and less abundant until in the extreme southern portion of the state they occur in patches, and the individual pebbles are of small size. As in other cases, they are often concentrated along small streams and in narrow valleys About Nashville and Center Point, in Howard county, gravels of this type are widely distributed, making good natural roads over much of the higher ground of that and adjoining counties.

In some cases gravel is better than crushed rock; in others the reverse is true; but what this difference is will depend upon the characters of the two kinds of rocks used. Gravel is not fit to be used unless it is sorted or mixed with other binding materials and rolled with clays so as to insure it packing hard and firm. Loose smooth gravels, that slip upon each other and allow the wheels to sink in the roadway, should never be used in that condition.

It will be seen that Arkansas is well supplied with good road materials except in the alluvial bottom lands in the eastern part of the State, and even there gravel available for such purposes may often be found in the stream beds. The road-making materials of the novaculite region and of the chert region of the north are as good as one can reasonably ask for—indeed, they are about as good as materials in their natural condition can be—while the gravels of the central and southwestern parts of the state are excellent and sufficiently abundant. In many parts of the state road-making materials are so good, so abundant, and so widespread that lack of them can never be an excuse for bad roads.

Publications on Road-Building Materials

Gravel Deposits of the Caddo Gap and De Queen Quadrangles, Arkansas, by Hugh D. Miser and A. H. Purdue. U. S. Geol. Survey Bulletin No. 690—B, 1918.

Annual report of the Geological Survey of Arkansas for 1890, Vol. II. Whetstones and the Novaculites of Arkansas, by L. S. Griswold.

Salt.

At present no salt is being produced in Arkansas and it is unlikely that the salines in different parts of the state, from which supplies of salt were obtained before and during the Civil war will ever be active competitors of the salt-bearing sections of Kansas where there exists a plentiful deposit of pure rock salt. There are salt wells in Sevier county, a salt spring in Franklin county and surface deposits of salt in Clark and other counties of the state. Many artesian salt wells have been developed in prospecting for oil in different parts of the State.

REFERENCES.

Van Rensselaer, J.—Salt. American Journal of Science, Vol. VII, New Haven, 1824.

Brackenridge, H. M.—Salines on the Arkansas. Views of Louisiana. Pittsburgh, 1814, Baltimore, 1817.

Phalen, W. C.—Salt in the U. S., Mineral Resources of the U. S. for 1908, part II, 643-657. (Contains bibliography.)

Sandstone.

The Paleozoic area of Arkansas abounds in sandstone, most of which is undeveloped. In the large area of Pennsylvanian rocks, especially in the Boston Mountains, there is much excellent light-brown sandstone, easily quarried, and there is considerable quartzite near Hot Springs. Twenty-four sandstone quarries in eleven counties report production in this state. The largest use is for riprap, with concrete, road-making, railroad ballast and building stone following in order.* * * Sandstone quarries are operated at Carrollton, Heber Springs, Morrilton, Ozark, Hot Springs, Guion, Clarsville, Lamar, Leslie, Ft. Smith, Greenwood, Springdale, Bald Knob, Russell and Searcy.—Mineral Resources of the United States, Vol II, 1912, U. S. Geological Survey.

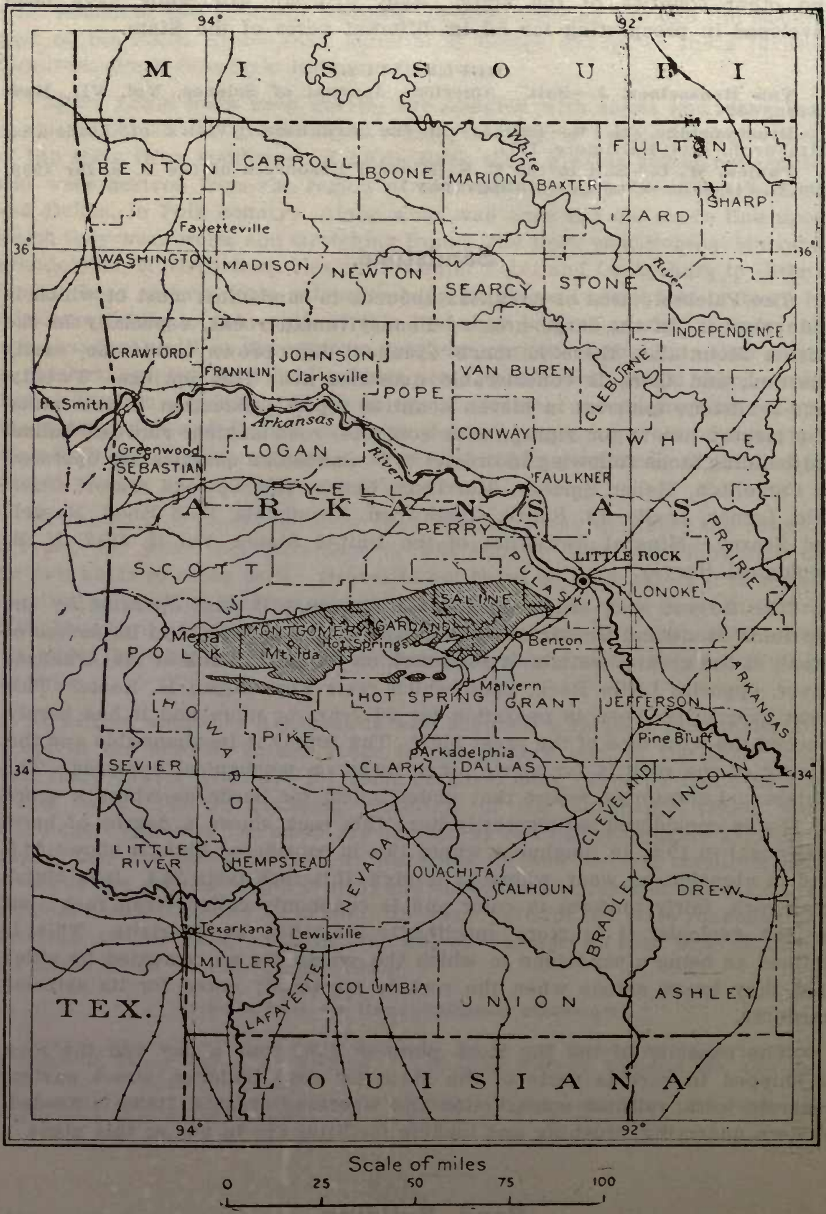
The largest rock crushing plant in Arkansas is that operated by the Big Rock Stone and Construction Company of Little Rock, and its source of supply is the great mountain of solid rock on the north bank of the Arkansas River, opposite Little Rock, upon which rests Fort Logan H. Roots. This great quarry has been in operation for 20 years or more and it has barely touched the west face of the great bluff. The supply is inexhaustible and the quality of the rock is for above other rocks on mechanical analyses. The Pittsburg Labratories report that under a test for hardness where a score of 17-x is considered satisfactorily hard this rock shows a degree of hardness equal to 19.5; in toughness where 19-x is considered high, it shows 24.5 and in abrasion, or wear, where 13 is high, this rock tests 24.1 It is bluish gray rock, fairly uniform in color and is commonly called "trap rock" but by the geologist it is more specifically classified as quartzite. This is defined as being a sandstone in which the grains are so cemented by silica that they break across when the rock is fractured; noted for its extreme hardness.

The capacity of the Big Rock plant is 2,000 tons a day and the rock is shipped to various parts of the state for road building, street paving, concrete work, railroad construction and wherever crushed stone is needed. Modern quarrying, crushing and loading facilities are in use at this plant.

Sand, Building.

This material is dug at many places; Boone county, Harrison; Clark county, Arkadelphia; Green county, Paragould; Izard county, Guion; Jefferson county, Pine Bluff; Pulaski county, Little Rock; Saline county, Benton; and from the bed of the Arkansas River at other points.

U. S. Geol. Survey.



Map Showing the Slate Area in Arkansas.

Sand, Moulding.

A brown sand suitable for moulding sand is found in the vicinity of Coal Hill, Johnson county. The material is also found in Pulaski county at Little Rock.

Slate.

Topography, Geology and Character of Deposits.

A summary from A. H. Purdue's "The Slates of Arkansas," published by U. S. Geological Survey, Bulletin 586, follows:

The slate area of Arkansas covers part of the Ouachita Mountains, which lie south of Arkansas River and have a general east-west trend. The area extends from the vicinity of Little Rock about 100 miles westward nearly to Mena, and has an average width of 15 miles. The rocks include shales, slates, chert, novaculite (a deposit of extremely fine quartz grains), sandstone and a little limestone. The entire sedimentary series is estimated at 11,400 feet in thickness, of which the upper 8,825 feet contains some commercial slate, as shown in table below:

Section in Arkansas Showing the Relations of Slates.

	Feet
Carboniferous:	
Stanley shale: Greenish clay shale, locally black slate near the base, and greenish quartzitic sandstone	6,000
Unconformity.	
Age unknown:	
Fork Mountain slate: Gray slate with thin beds of siliceous material	125
Arkansas novaculite: Massive white and variegated novaculite with alternating flint and shale layers in the upper half	800
Missouri Mountain slate: Mainly red slate with green slate in basal part	75-300
Ordovician:	
Blaylock sandstone: Greenish quartzitic sandstone alternating with brownish-black shale	0-1,500
Polk Creek shale: Black fissile and sandy graptolitic shale	0?-100
Big fork chert.	
	8,825

These strata lie in parallel close folds with the east-west axes which pitch alternately but always together east and west. The folds are either erect or overturned to the north or south. The peculiar topography of the region is due to these parallel pitching folds and to the unequal resistance offered to erosion by the soft shales and slates and by the hard quartzose beds.

Slate of possible economic value occurs in the four formations mentioned below.

The Polk Creek shale passes here and there into a black graptolitic sonorous slate, in places banded. The smallness of the amount of slate and the abundance of joints throughout the formation make the deposit of doubtful economic value.

The Missouri Mountain slate has been extensively prospected and is now quarried at Slatington. It produces both red and green slate, the former predominating. In some places the cleavage is parallel to the bedding; in others it is oblique. The slate is defective in sonorousness and in many places shows two sets of slip cleavage.

This slate is used for mill stock, particularly laundry tubs, lavatories, wainscoting and electric switchboards. In the preparation of millstock there is a certain loss from worked pieces cracking either along or at right angles to the cleavage.

The Fork Mountain slate consists of a hard slate, generally gray but weathering in places green or chocolate color and containing many thin sandy beds. The slate usually has a good cleavage and is ribboned, highly sonorous, strong and tough. So far as prospected it is too much jointed to be of economic value.

The Stanley shale is almost everywhere a shale, rarely a slate. It has been extensively prospected near Slatington and in the southwestern part of Polk county. The color of the slate is blue to black and its cleavage remarkably fine, with very smooth cleavage surfaces. It is not regarded as sufficiently durable for roofing. Two quarries have been opened in it.

Microscopic Analyses of Slates From Arkansas.

Black slate from Mena, near Big Fork. This is a pure black slate, which to the unaided eye has an exceedingly fine texture and a remarkably smooth cleavage surface with a slight luster. It is both carbonaceous (or graphitic) and magnetic; does not effervesce with cold dilute hyrochloric acid, is very sonorous and very fissile. Under the microscope this slate shows a matrix of muscovite (sericite), with a very brilliant aggregate polarization and an unusually fine texture and great homogeneity. Quartz grains are few and not over 0.01 millimeter in diameter. Rutile needles unusually minute. Many opaque particles of irregular shape, some of which are pyrite, others magnetite, and some coaly or graphitic matter. No carbonate. The constituents, arranged in descending order of abundance, appear to be muscovite; carbonaceous or graphitic matter, quartz, pyrite, magnetite and rutile. This is a mica slate, with remarkably fine cleavage and not liable to discolor on exposure, but its strength and its behavior under frost should be tested.

Dark-reddish slate from Mena, near Big Fork. In color this slate is somewhat darker than the "red" slate of New York. To the unaided eye it has a minutely granular texture and roughish, speckled, almost lusterless surface. Contains very little magnetite, does not effervesce with cold dilute hydrochloric acid, is sonorous, splits readily and has some argillaceous odor. Under the microscope it shows a matrix of muscovite (sericite), with brilliant aggregate polarization, quartz grains ranging up to 0.025 millimeter, muscovite and chlorite scales, and abundant hematite in minute dots. There are also rhombs, from 0.1 to 0.2 millimeter, of chlorite and rhodohrosite probably pseudomorphs. No other carbonate. The constituents arranged in descending order of abundance, appear to be muscovite, hematite, kaolin, quartz, chlorite, rhodochrosite (?), and magnetite. This slate compares favorably in texture with the "red" slate of New York.

Reddish slate from the Missouri Mountain ("Mammoth red" and "Lost Hannah" of quarrymen; exact locality not given. Color lighter than above, but not quite so red as the New York slate. To the unaided eye has a fine texture and a fine cleavage surface but no luster. Contains very little magnetite; does not effervesce with cold dilute hydrochloric acid, is sonorous and fissile, has some argillaceous odor. Under the microscope it shows a matrix of muscovite (sericite), with brilliant aggregate polarization, quartz grains up to 0.03 millimeter, muscovite and chlorite scales, abundant hematite pigment and no carbonate. The constituents, arranged in descending order of abundance, appear to be muscovite, hematite, kaolin, quartz, chlorite and magnetite. This is a finer and softer slate than the dark red and should be tested for strength and frost resistance.

Greenish-gray slate from Mena. In color this resembles the sea-green slate of Vermont. To the unaided eye it has a fine texture, a roughish cleavage surface, and a waxy luster; does not show pyrite on sawn edge, contains very little magnetite; does not effervesce with cold dilute hydrochloric acid, and is somewhat sonorous. Under the microscope it shows a matrix of muscovite (sericite), with a brilliant aggregate polarization and is of very fine texture and homogeneity, but the cleavage is crossed at an angle of 13° by a very close bedding foliation and also by an obscure slip or false cleavage at about 40°. Contains very few and very minute quartz grains, no carbonate, several pseudomorphic rhombs of chlorite, 0.08 millimeter, and has a slight argillaceous odor. The constituents, arranged in descending order of abundance, appear to be muscovite, quartz, kaolin, chlorite and magnetite. The two extra foliations are likely to prove to directions of weakness.

Light greenish slate from Missouri Mountain slate ("Mammoth red"), locality not designated. This is more greenish than the above; to the unaided eye has an exceedingly fine texture and a very fine, almost lusterless cleavage surface; shows pyrite on sawn edge; contains a little magnetite; does not effervesce with cold dilute hydrochloric acid, is sonorous, very fissile, and has a slight argillaceous odor. Under the microscope it shows a matrix of muscovite (sericite), with a brilliant aggregate polarization and great eveness of texture. A very minute bed of quartz grains, chlorite and muscovite lies in the cleavage, which is therefore the bedding also. The grain is indicated by the transverse position of some of the muscovite scales. Quartz not very abundant but occurs in grains up to 0.037 millimeter. Rutile needles about from 0.0028 by 0.0009 up to 0.0014 millimeter. Muscovite and chlorite scales occur, the latter producing the green color. There are some opaque granules (limonite? and pyrite), occasional lenses, 0.14 millimeter long, of a central mass (probably rhodochrocite), with secondary muscovite at both ends. No other carbonate. Shows a number of tourmaline prisms up to 0.025 by 0.008 millimeter. The chief constituents, arranged in descending order of abundance, appear to be muscovite, quartz, kaoline, chlorite, rutile, pyrite, magnetite and tourmaline. This mica slate probably possesses more petrographic interest than economic value. Its fissility, freedom from carbonate, and color are very favorable, but it will probably be found too delicate for use on a roof.

Very dark bluish-gray slates from Sec. 25, T. 3 S., R. 29 W. (Specimen collected by E. C. Eckel.) To the unaided eye this slate has a fine texture and a smooth cleavage surface with a little luster, and shows a little pyrite on the sawn edge. It contains very little magnetite, considerable carbonaceous or graphitic matter, does not effervesce with cold dilute hydrochloric-acid, is sonorous, and has a high grade of fissility. Under the microscope it shows a fine-textured matrix of muscovite (sericite) with good aggregate polarization, but somewhat obscured by carbonaceous matter. Quartz is not abundant, the grains measure up to 0.047 by 0.02 millimeter. Pyrite spherules, measuring up to 0.008 millimeter in diameter, number about 120 per square millimeter . There are rutile needles but no carbonate. The chief constituents, arranged in order of decreasing abundance, appear to be muscovite, quartz, pyrite, carbonaceous or graphitic matter and rutile. This slate has absence of carbonate in its favor. It is not so fine or so fissile as the black slate from Mena, but may prove more durable.

Light-gray slate with a slightly greenish tinge from Sec. 30, T. 3 S., R. 28W. (Specimen collected by E. C. Eckel.) To the unaided eye this has a fine texture, but a lusterless, roughish surface, and shows a little pyrite on the sawn edges. It contains an insignificant amount of magnetite but no carbonaceous or graphitic matter, does not effervesce with cold dilute hydrochloric acid, and has an argillaceous odor and a fair degree of fissility and sonorousness. Under the microscope it shows a fine-textured matrix of muscivite (sericite) with brilliant aggregate polarization, containing no abundant quartz grains, measuring up to 0.03 millimeter, scales of chlorite and muscovite transverse to cleavage, some pyrite cubes up to 0.063 millimeter (generally with a rim of secondary quartz), passing into limonite and staining the matrix. Rutile needles abound.

Very dark-gray spangled slate from quarry operated by the Southwestern Slate Manufacturing Co. (Specimen collected by E. C. Eckel.) To the unaided eye this has a coarsish texture and a roughish, almost lusterless surface, spangled with minute scales of mica, shows pyrite on sawn edges, contains very little magnetite and little carbonaceous matter, does not effervesce with cold dilute hydrochloric acid, is somewhat sonorous, tolerably fissile, and has a slight argillaceous odor. Under the microscope it shows a fine-textured matrix of muscovite (sericite) with brilliant aggregate polarization containing roundish and angular grains of quartz of variable and large sizes, up to 0.27 by 0.17 millimeter; also a few of plagioclase feldspar, scales of muscovite and biotite up to 0.2 by 0.1 millimeter, some lenses of carbonate up to 0.4 millimeter long, a few grains of tourmaline, and lenses of secondary quartz. There is a faint incipient slip cleavage, not apparent, however, in the hand specimen. The chief constituents of this slate, arranged in order of decreasing abundance, appear to be muscovite (including sericite), quartz, carbonate, pyrite, carbonaceous matter and kaolin, with accessory biotite, plagioclase, tourmaline and magnetite.

REFERENCES.

Purdue, A. H.—The Slates of Arkansas, the Geol. Surv. of Arkansas, 1909.

Dale, T. Nelson.—Microscopic analyses of Arkansas slate. Bulletin No. 275, U. S. Geol. Surv., Washington, 1906.

Note on Arkansas roofing slates. Bulletin No. 225, U. S. Geol. Surv., Washington, 1904.

Bulletins 275 and 430, U. S. Geological Survey.

Talc—Soapstone.

Talc deposits occur in Saline, Garland, Hot Spring and Montgomery counties and soapstone, the impure form of talc is found in massive beds, underlying slabby sandrock, in Saline county 12 miles northeast of Benton.

The properties of talc which render it useful for many purposes are its foliated or fibrous structure, its softness,its whiteness or light color and luster, its medium weight, its sectile and flexible but not elastic quality, its greasy feel, its low conductivity but high absorption of heat and electricity. The most important use of talc is made in the manufacture of paper. The highest price talc is manufactured into pencils and blanks for insulators and burners.

The qualities which render soapstone useful are its slow conduction of heat and electricity, its difficult fusibility and chemical stability in resisting the action of solvents, as well as its softness. It is used for table tops, acid tanks, laundry tubs, switchboards, stove and furnace lining, laboratory equipment, foot warmers and fireless cookers.—Mineral Resources of the United States, Part II, 1912.

A description of the soapstone at Wallis quarry (Sec. 15, 1 N., 15 W) and elsewhere is given in the report of Arkansas Geological Survey, Vol. I, 1888.

Tripoli.

From the fact that tripoli of no better grade than that to be found in many points of Arkansas is extensively mined in Missouri, it is reasonable to believe that this material might be profitably worked in this state, especially the richer deposits. An excellent grade of tripoli has been found near Butterfield in Hot Springs county, but the extent of the deposit is unknown. This occurence, according to H. D. Miser, United States Geological Survey, is a weathered calcareous siliceous rock, simulating the novaculites. The calcite has been leached out, leaving a pure siliceous residue of fine grain. The novaculite beds at other localities west of Butterfield have also been altered to tripoli.

Deposits of tripoli are reported in Montgomery, Garland, Ouachita, Washington and Independence counties.—Report, Bureau of Mines, Manufactures and Agriculture, 1913.

Purdue reported that samples of good "tripoli" had been received from the vicinity of Farmington in Washington county. The quotation marks would seem to indicate that the tripoli of commerce and not pure tripoli is meant.

"There is a great abundance of this material in the zinc region, but whether or not it has any commercial value is a matter that can be determined only by experiment. It is extensively used for manufacturing polishing powders and water filters."—Report Arkansas Geological Survey. Vol. V, 1892.

Water Resources.

Water Power

Private surveys have been made at a number of points along White River and its tributaries, on the Ouachita and Little Missouri and other streams to locate the available water powers of the State of Arkansas, but the data secured by these surveys are not available.

Under A. H. Purdue in 1911 a survey and preliminary report was made by W. N. Gladson, covering White River from its headwaters to Buffalo Shoals, a part of North Fork of White River and Buffalo Fork of White River. The following table of distance and fall of the streams is taken from the Gladson report.

White River

From	To	Miles	Feet
Habberton	Monte Ne	27.69	59.39
Monte Ne	Jennings Ford,	21.40	63.37
Jennings Ford	Blue Springs,	27.98	71.58
Blue Springs	Beaver Bridge,	7.00	18.60
Beaver Bridge	State Line (Carroll Co.)	3.74	8.20
	Total,	87.71	221.14
	Average fall per mile		2.57
State Line (Boone County	Bradley's Ferry,	21.92	52.24
Bradley's Ferry	Music Creek,	17.42	36.15
Music Creek	Dews Ford	21.18	50.46
Dew's Ford	Cotter Bridge,	15.16	38.18
Cotter Bridge	Head Buffalo Shoal,	11.09	25.72
Warner Creek	Foot Buffalo Shoal	1.73	10.52
	Total,	88.50	213.27
	Average fall per mile		2.41

Buffalo Fork of White River

From	To	Miles	Feet
Boxley	Mouth Cecil's Creek,	20.55	229.66
Cecil's Creek	Mouth Little Buffalo,	12.03	94.29
Little Buffalo	Mouth Richland Creek	22.71	96.98
Richland Creek	Gilbert,	23.00	102.22
Gilbert	West Horseshoe Bend,	25.81	83.26
West Horseshoe Bend	East Horseshoe Bend,	7.08	20.82
East Horseshoe Bend	Mouth Buffalo Fork,	19.42	58.95
	Total,	131.00	686.18
	Average fall per mile		5.23

North Fork of White River

From	To	Miles	Feet
Smith's Ferry	Buzzard Roost Falls,	4.75	21.68
Buzzard Roost Falls	Norfork,	13.95	57.28
	Total,	18.70	78.96
	Average fall per mile		4.24

Commenting upon this report Doctor Purdue said:

"While a large amount of water power is available along the streams included in this report, the inauguration of any large enterprize will necessitate the construction of a series of dams and the utilization of the combined power from all; but as the valley are narrow and but little agricultural land would be flooded by such dams, the cost of developing the power would not be prohibitive."

The United States Geological Survey, in Water Supply Paper No. 234, credited Arkansas with 255 water wheels capable of developing a total maximum of 5868 horsepower.

The largest water power plants in the state are located at Mammoth Spring, on Spring River, and near Russellville, on Illinois River.

From the Gladson report the following is quoted:

"With the present state of development of the art of transmitting electric power long distances with slight losses, the water power of the northern and western part of the state should furnish cheap and abundant power in any quarter of the state for manufacturing and lighting purposes. * * * *A water power plant located on White River at Buffalo City, for instance, could economically furnish water power within a radius of 200 miles, which would reach the most distant point in the state."

At the time of the preparation of this chapter movements were on foot for the establishment of large power plants at Cotter on White River and on Little Red River above Judsonia.

Little Red River Project.

At the time of the publication of this report a company was being promoted by Little Rock and north Arkansas capitalists for the development of water power on Little Red River between Heber Springs and Higden. It is claimed that 55,000 horse power can be obtained by the construction of dams at Higden, Heber Springs, Pangburn and Bee Rock, for which there would be a market in the nearby cities of Searcy, Kensett, Higden, Judsonia and Higginson. Nearly a third of the water shed of Little Red River lies in the Ozark National Forest Reserve. Just above Higden the three forks of the river converge and by the construction of a dam at Higden a lake could be formed one-half to four miles wide and fourteen miles in length.

REFERENCES.

Gladson, W. N.—Water Power. Report Arkansas Geological Survey, 1911.
Water Supply Paper, No. 234. U. S. Geol. Surv.
Water Supply Paper, No. 399. Geology and Ground Waters of Northeast Arkansas. U. S. Geol. Surv.

Mineral Waters.

Arkansas is a well watered state. Hundreds of beautiful, free-flowing springs of excellent water gush from hillsides and valleys in all parts of the state. In the limestone region north of the Boston Mountains, such springs are especially abundant, large and beautiful. They are not mineral waters, properly speaking, but they are more valuable than if they were.

Some of these springs are so big that they are utilized for driving mills, cotton gins and other machinery, and as their discharges are suubject to little or no fluctuations throughout the year, they are free from the dangers of freshets and the risks of droughts. Such are Loster's Spring, six miles west, and "Big Spring," six miles northwest of Batesville; another on Mill Creek, Stone county; one at Marble City, Newton county; another on Rush Creek, Marion county. and one at Silver Spring, Benton county. At Mammoth Spring, in Fulton county, one of the finest water powers in the country is furnished by an enormous clear water spring.

Besides these truly gigantic springs, no one who travels through north Arkansas can fail to be impressed by the great number of large and beautiful springs to be found at every town and village, to say nothing of those at almost every farm house. Especially worthy of mention are the springs at Big Flat, Lone Rock, Harrison, Bellefonte, Valley Springs, Western Grove, Yardell, Marble City, Francis Postoffice (Bear Creek Springs), Berryville, Whitener and Spring Valley.

Fortunately, the Survey has made an analyses of a type of these fine springs—that of Valley Springs, Boone county. That analysis shows the water to contain only 15 grains of mineral matter to the gallon, almost all of which is carbonate of lime.

There is also an abundance of springs whose waters are remarkable for their purity; such are the Crescent Springs at Eureka Springs, Carroll county, and Elixir Spring at Elixir, Boone county. These springs contain less than six grains of mineral matter to the gallon. It should be noted in regard to these two springs in particular, and the same is no doubt true of many other springs in that part of the state, that their waters pass down through cherts, rocks that have but little easily soluble matter in them, and this is no doubt the reason of their great purity.

Running across north Arkansas from Batesville to the Oklahoma line, is a formation spoken of in the Survey's reports as the Batesville sandstone; it is the coarse, yellowish brown sandstone on which and partly of which Batesville is built. Several other towns of north Arkansas are built on this same sandstone; namely, Mountain View, Marshall, St. Joe and Green Forest. The towns mentioned get their water supply from wells dug in this Batesville sandstone; the water is soft, cool and abundant.

It is a popular belief that mineral waters are "nature's remedies," and that as they are good things the more one has of them the better. The analyses of our mineral waters show that some of them contain large quantities of Epsom salt, Glauber's salt, and common salt. Now no one would suppose for a moment that the habitual daily use by a healthy person of large quantities of these salts could be anything else than injurious. Epsom salt is Epsom salt, and its physiological effects are the same whether one takes it from a sparkling spring in the mountain or from the bottles of a drug store. Some of the mineral waters of the state are highly charged with such ingredients; every gallon of the Potash Sulphur water contains 33 grains of Glauber's salt; every gallon of the National Spring water at National, Logan county, contains 33 grains of Glauber's salt and 46 grains of Epsom salt; every gallon of the water from Howard's mineral well at Sharp's Cross Roads, Independence county, contains 160 grains of Glauber's salt and 115 grains of Epsom salt. Such waters should not be used without some reference to what they contain. It is not meant to imply that these and similar waters are dangerous, but simply that they have important medicinal properties, that they should be used as medicines with discrimination, and that those who have no need for such medicines should not use them. It should be remembered also that whether also that whether a water is a good or bad for the general use depends, not on the amount of matter it holds in solution, but rather on the quality of that matter. The waters containing carbonate of lime and the chalybeate waters are generally good ones, but the habitual use of magnesian waters is injurious to most persons, in spite of the fact that they may be beneficial to the same persons at times when they stand in need of such remedies. And because one can advantageously drink large quantities of the waters of Eureka Springs, Elixir Springs and Hot Springs waters containing but little mineral matter in solution—it must not be inferred that he can drink like quantities of strong magnesian waters with similar effects. Rough tests of artesian wells at Camden show that they contain large quantities of calcium chloride, a substance quite unusual in mineral waters.

Ground Waters of Northeast Arkansas

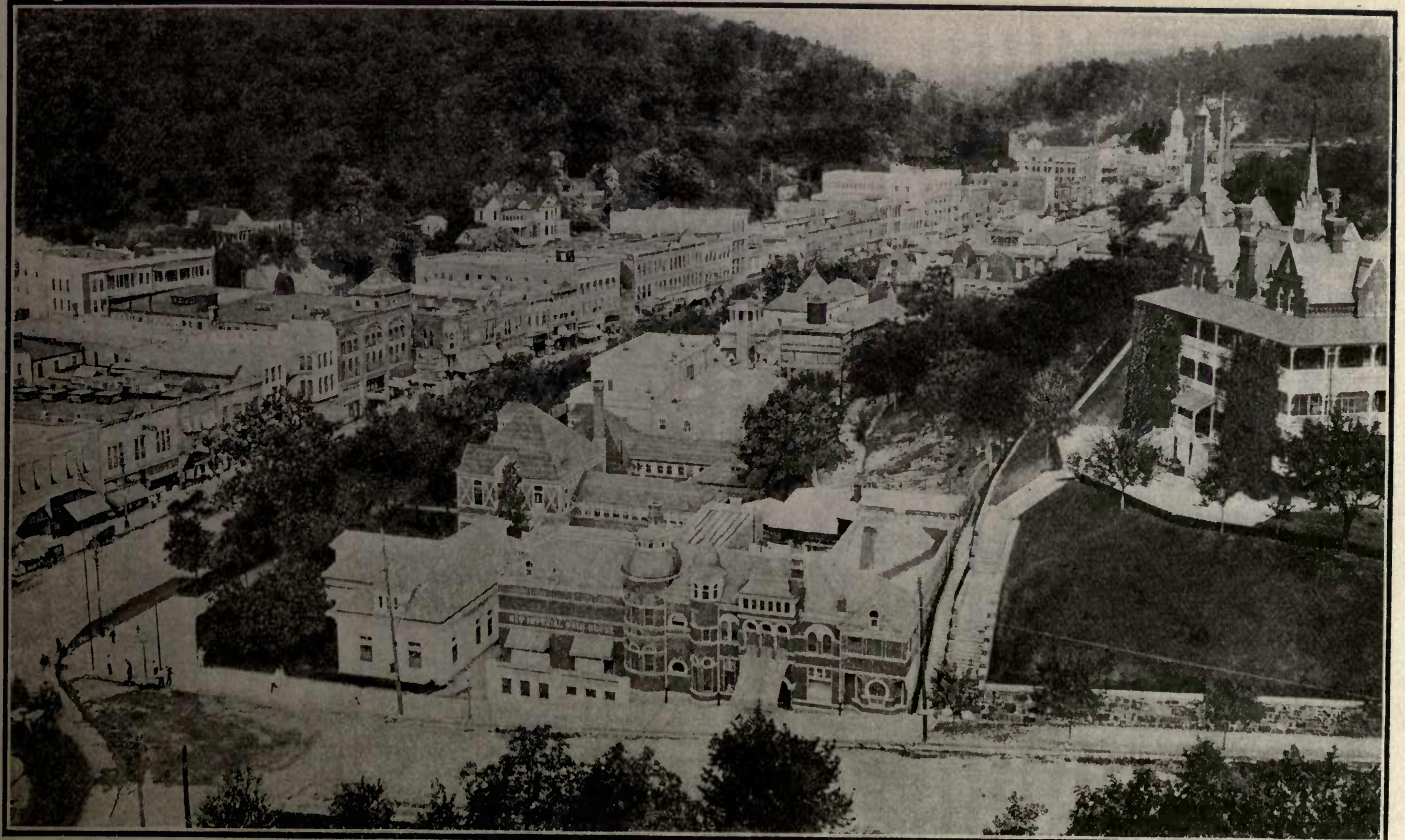
The strata which underlie northeastern Arkansas are saturated with water below level, known as the water table, which ranges from the surface to a depth of 100 feet or more. The water table lies deepest in Crowley's Ridge and shallowest in the lowlands east and west. The water table does not occupy a fixed position at any given place but continually fluctuates, being highest at the end of long period of precipitations and lowest at the end of a long drouth.

Large quantities of water are obtained at depths of 50 to 200 feet throughout the lowlands. Many wells in the rice-growing areas are pumped at rates between 1,000 and 3,000 gallons a minute, or even more without appreciable decrease in the under-ground supplies.

The beds of porous sand which partly compose the buried, Cretaceous deposits of the area constitute an important, though largely undeveloped, source of artsian water. In northeastern Arkansas flowing wells that doubtless tap water-bearing beds of Cretaceous age are in use at Blytheville, (depth 1,448 feet); Burdette, (1,495.5 feet); Wilson, (depth 1,567 feet); and Marked Tree, (depth 2,007 feet). Non-flowing wells that tap beds of this age are located at Jonesboro 1,214 and 1,265 feet, respectively), and at Newport, (depth of Paleozoic rocks, 655 feet).

Water Supply in the Rice Belt

"Water for irrigation is present in great abundance at relatively shallow depths throughout the rice-growing area of Arkansas. * * *Water for irrigating the rice fields is obtained chiefly from the Pleistocene alluvial deposits which underlie the Advance lowland to depths of 100 to 200 feet. Wells 6 to 12 inches in diameter are sunk to the coarse sands and gravels in the lower part of the deposits, which contain large quantities of water. The wells are equipped with powerful pumps, centrifugal pumps being generally used, and yield from 200 to 4,000 gallons a minute.* * * Though wells are the chief source of water for irrigation, lands near streams and bayous might be irrigated with surface water.—Water Supply Paper No. 399, U. S. Geol. Surv., Geology and Ground Waters of Northwestern Arkansas.



Heart of Hot Springs, Arkansas.

The Hot Springs of Arkansas.

The waters of Hot Springs claim the place of first importance in any consideration of the medicinally valuable waters of the state. For a great many years these waters have been used by people from all parts of the country with results that merit the serious attention of everyone, and strike the ordinary observer as nothing short of marvelous.

Doctor Branner in his report on Mineral Waters says:

"There is naturally much curiosity on the part of visitors of Hot Springs regarding the cause of the high temperature of the waters. In the Yellowstone National Park where hot waters abound, the activity of igneous agencies offer a ready answer to such questions, but in Arkansas, where nearly all the rocks to be seen are of sedimentary origin, there is no evidence of recent volcanic activity, and such an explanation of temperature is not therefore so readily accepted. Some of the theories advanced to explain the hot waters are interesting only as curiosities and are not mentioned here as having other value. For example; it has been suggested that the heat comes from coal burning beneath the surface of the ground. It is perhaps enough to say that coal measures, to which coal is confined in Arkansas, lie far to the north of Hot Springs, and that the hot waters come up through Ordovician rocks which contain no coal. Of the theory that the heat may be produced by chemical action, it may be said that the water itself gives no evidence of its having received its temperature in this way, its chief constituent being carbonate of lime. So far as the geology of the region is concerned, if there were no hot waters in the vicinity none would have been anticipated on geologic ground alone. But the water being hot it seems most probable that its heat is derived from coming in contact with masses of hot rocks, the cold edges of which may or may not be exposed at the surface."

Source of the Hot Waters.

Dr. A. H. Purdue, in a paper read before the 25th anniversary meeting of the Indiana Academy of Science, 1909, discussing the Hot Springs of Arkansas and the source of their high temperature, said in part:

"The collecting area must be in the near vicinity of the Springs, and a study of the topography, stratigraphy and structure thereabout locates it with reasonable certainty. A glance at the section (Fig. 2) from Sugarloaf Mountain southeastward through Hot Springs Mountain will indicate the collecting area. The surface of the overturned, anticlinal valley between Sugarloaf and North Mountains, is higher than the level of emergence of the springs. * * * The considerable thickness of the Big Fork Chert, its much fractured nature and the thin layers of which it is composed, all combine to make it a water-bearing formation of universal importance. * * * The exact location of the springs is attributed to the southwestern plunge of the Hot Springs anticline. * * * The areas of igneous rock at Potash Sulphur Springs, Magnet Cove and other places, force the suggestion upon one that the waters of the springs owe their temperature to passing over hot rocks or the vapor from such in some part of their underground course. (Doctor Branner has already called attention to this as the probable source of the heat. See Geol. Surv. of Ark., Report on Mineral Waters, pp. 9 and 10.)

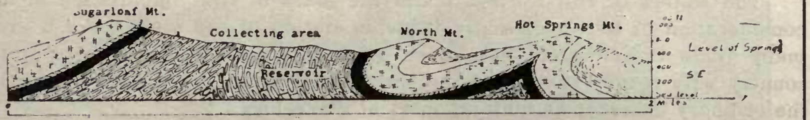


Fig. 2. Northwest-southeast section at Hot Springs.

1. Bigfork chert.
2. Polk Creek shale.
3. Missouri Mountain slate.
4. Arkansas novaculite.
5. Hot Springs sandstone.
6. Stanley shale

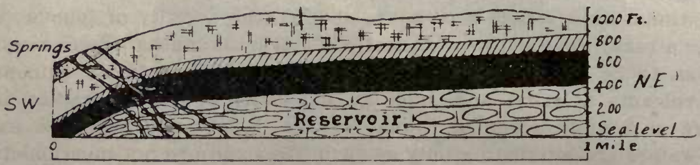


Fig. 3. Northeast-southwest (longitudinal) section of Hot Springs Mountain, showing the hypothetical water conduit at the plunging end of the anticline. Symbols same as in Fig. 2.

Map Explaining Source of the Hot Waters.

The fact that these are practically the only hot springs within the Ouachita area (recently a spring said to have a temperature of 98° to 100° F., has been discovered issuing from the Arkansas novaculite in the bed of the Caddo River at Caddo Gap, Montgomery County), though there are scores of cold springs issuing from the same formations and under practically the same geologic relations, gives this suggestion great weight; but inasmuch as some of the springs are said to be unusually radio-active, there is the alternative suggestion that atomic decomposition in igneous rocks (which may have lost their magmatic heat) is the source of the high temperature of the water."

The waters of the hot springs are very pure. On an average the several spring waters contain 12.94 grains of material in solution to the gallon. Of this material nearly 60 per cent is carbonate of lime, over 21 per cent is silica, 9 percent is carbonate of magnesia, while the remainder is chiefly choloride of sodium (common salt), sulphate of soda (Glauber's salt) and sulphate of potash. There is but little difference in the composition of the waters of the various springs. The positive therapeutic qualities of these waters are due to physical rather than to chemical properties, their virtue being due to radio activity, which is very marked in some of the springs.

Million Gallon Flow Daily.

There are 44 hot springs, flowing 1,000,000 gallons a day. The average temperature of the waters is 135 degrees Fahrenheit. The springs are owned and controlled by the United States and in 1832 were set apart as a National Sanitarium for all time, dedicated to the people of the United States to be forever free from sale or alienation. There are 24 bath houses connected with the springs some of these being of palatial architecture and magnificently equipped. The operation of the baths and charges are regulated by the government through a superintendent of the reservation appointed by the Secretary of the Interior. The government has spent large sums on the building of roads and parkways and otherwise beautifying the resort, which is visited annually by upwards of 100,000 people from many parts of the world who come here for rest, recreation and treatment. Some of the world's finest resort hotels are located at Hot Springs and there are housing facilities for caring for the large number of visitors.

Action of Waters.

The immediate effect of a bath at 98° F. of this water as compared to a bath of ordinary water of the same temperature, is that it is very much more stimulating, exhilarating and eliminant, all secretory organs becoming roused into greater activity and the effect of the continued use of the baths are remarkably great in alterative action, correcting retrograde metamorphosis, equalizing and moderating nervous excitability, increased action of the absorbent system, increased disintegration of tissue, great increase of assimilation and reparation, and greater activity of all excretory organs elminating blood poisons rapidly, and all effete and poisonous products of the disintegration of tissue by the kidneys and skin. The hot water drank while in the bath keeps up a constant current through the blood vessels from within outward, the water drank in the bath supplying that lost by the blood in sweating.

Briefly stated, the use of the Hot Springs waters opens the pores and channels for the expulsion of the matters injurious to health, arouses torpid and sluggish secretions, stimulates the circulation, the muscles, the skin, the nerves, the internal organs, and purifies the blood, removes all aches and pains, restores the exhausted, revives the debilitated and helps build up and renew the entire system. They are administered in the treatment of the sick internally and externally, being drunk in large quantities and applied in all the different forms of baths.

The opinion of resident physicians of marked ability and experience, based on years of observation in connection with the regular medical treatment, is that the following list of diseases are successfully treated by the use of the baths and the internal administration of the hot waters; Gout, rheumatism, stiff joints, skin diseases, scrofula, syphillis, nervous affections, paralysis spinal disease, sciatica, catarrh, specific locomotor ataxia, dyspepsia, uterine diseases (especially sterility and lucorrhea), malaria, blood diseases of chronic character and alcoholism. Gout rheumatism, muscular contraction, diseases of the skin and affections of the nervous system, are especially greatly benefitted by the baths. The hot waters are valuable aid in surgical treatments and highly efficient as an uric acid eliminant.

In his circular for the guidance of the officers of the army in sending sick here, the surgeon general of the United States army enumerates the ailments for which the sick should be sent to the Army and Navy Hospital at the Hot Springs of Arkansas. It says:

"Relief may reasonably be expected at the Hot Springs in the following conditions: In the various forms of gout and rheumatism, after the acute or inflamatory stage; neuralgia, especially when depending upon gout, rheumatism, metallic or malarial poisoning; paralysis, not of organic origin; chronic diarrhoea; catarrhal affections of the digestive and respiratory tracts; chronic skin diseases, especially the squamous varieties, and chronic conditions due to malarial infection."

"Approved: Geo H. Torney,
J. M. Dickinson, Secretary of War. Surgeon General U. S. Army."

Since the discovery of the wonderful element Radium and the demonstration of its power of imparting its activity and potency to contiguous substances and its display of the forces—heat, electricity and light—in various peculiar forms of chemico-actinic force, and a capability of increasing as well as destroying vital activities, the suggestion naturally followed that the wonderful curative properties of these celebrated springs would upon examination and investigation be found to be due to the presence of radium or its emanations in some form of radio activity. Responding to this suggestion the Interior Department U. S. Government, having direct management and control of the U. S. Reservation at Hot Springs employed Prof. Bertram B. Boltwood of Yale College, to make exhaustive tests of these springs for this element and in summing up an abstract of his wonderful report on the completion of his work, the Department states the conclusions by Prof. Boltwood are:

"The waters of the Arkansas Hot Springs are radio active, to a marked degree. The radio activity of the waters is due to dissolved radium emanation (gas)."

The chief effect of the radiations from radium is to produce an ionization of the atoms of whatever substance the rays penetrate. Chemical effects follow as a secondary result of the ionzation. Von Noorden and Falta say that in contradistinction to all other forms of electro therapy we possess in radio active substances a means of carrying electrical energy into depths of the body, and there subjecting the juices, protoplasm and nuclei of the cells to an immediate bombardment by explosions of electrical atoms. We may therefore designate this internal treatment with radio active waters as internal electro therapy.

The concensus of expert opinion as to the value of radium springs therapeutically, is that they primarily stimulate cell activity, arousing all secretory and excretory organs, stimulating the eliminating processes, thereby causing the system to throw off waste products; that they are an agent for the destruction of bacteria and by their radiations they have positive influence on diseased tissues, exercising germicidal powers.

The cold waters of Hot Springs, Arkansas, are justly famed everywhere, both as medicinal and table waters. It is in the cold waters of Hot Springs that mineral is most evident and best results are often secured when they are drank in connection with the baths, especially in affections of kidney, bladder, stomach and rheumatic conditions. Marvelous relief in the early stages of Bright's disease and dropsy are accredited to these waters,

Among the various cold water springs are the DeSota Springs, the Mountain Valley Springs, the Radio Magnesia Springs, the Arsenic Springs and the Potash Sulphur Springs.

Publications on Hot Springs

Branner John C.—Report of the Superintendent of the Hot Springs Reservation to the Secretary of the Interior, Washington, 1891. Analyses of Hot Springs waters.

Boltwood, Bertram B.—On the radio-active properties of the waters of the hot springs on the Hot Springs Reservation, Hot Springs, Arkansas. American Journal of Science, Vol. CLXX, August, 1905.

Haywood, J. K.—Report of an analysis of the waters of the hot springs on the Hot Springs Reservation, Garland County, Arkansas. 57th Congress, 1st Session, Senate Document, No. 282, Washington, 1902.

Thompson, Frank M.—Report of the Superintendent of the Hot Springs Reservation to the Secretary of the Interior. 39 pp.. Washington, 1891. (Analyses of Hot Springs waters.)

Van Cleff, A.—The Hot Springs of Arkansas. Harper's Monthly Magazine, Vol. LVI, January, 1878, pp. 193-210. Many illustrations.

Descriptions of the City of Hot Springs, its tourist attractions and statements of the curative qualities of the Hot Springs waters is contained in illustrated literature issued by the Business Men's League of Hot Springs, the Missouri Pacific Railroad, St. Louis, and Rock Island Railroad, Chicago.

Purdue, A. H.—The collecting area of the waters of the hot springs, Hot Springs, Arkansas: Jour. Geol., Vol. 18, Pp. 278-285, 1910. Indiana Acad. Sci., Proc., 1909, Pp. 269-275, 1910.

LIST OF SPRINGS AND WELLS.

(Analyses or Qualitative tests shown in Annual Report, Arkansas Geological Survey, 1891, Vol 1)

Armstrong Springs, White county, clear odorless, sparkling with slight chalybeate taste.

Baker's Sulphur Springs, Howard County.

Big Chalybeate Spring, Garland county; flow, 268,540 gallons in 24 hours slightly effervescent.

Big Spring, Phillips county.

Black Springs, Montgomery county.

Blalock Springs, Polk county, analysis shows sulphretted hydrogen.

Blanco Spring, Garland county.

Blue Springs, Carroll county.

Bon Air (Chalybeate) Spring, Stone county; clear, heavily impregnated with iron.

Cox's Alum Spring, Scott county.

Crystal Springs, Montgomery county

Diamond Springs, Benton county, one mile east of Rogers; clear and sparkling, furnishes water for city of Rogers.

Dallas Town Spring, Polk county.

De Soto Spring, Marion county.

Dove Park (Brown) Springs, Hot Spring county; pleasant taste, no odor, analysis shows iron.

Electric Spring, Benton county near Rogers; lime water with small quantities of the alkalies.

Elixir Spring, Boone county; contains less solid matter in solution than any of the springs of the north part of the state that have been analyzed.

Esculapia Springs, Benton county, three miles from Rogers.

Eureka Springs, Carroll county; the strongest flowing are Basin and Sycamore springs. These waters are remarkable for their purity containing only from five to seven grains of solids per gallon. They contain mainly carbonates of lime and magnesia, with small amounts of sulphates, chlorides and alkalies.

Frisco Spring, Benton county, in township 19 N., 29 W., section 33.

Grandmas Chase's Springs, Garland county, six miles northwest of Hot Springs, including Red Chalybeate and Dripping Springs. The water from Dripping Spring is tasteless and odorless, with a neutral reaction and no deposit of iron; that from Chalybeate Spring forms a deposit of reddish brown hydroxide of iron; is clear and has a slight odor, but no sulphretted hydrogen.

Gray's Spring, Howard county.

Gillon's White Sulphur Spring, Garland county.

Griffin Spring, White county; four miles north of Searcy; water is strongly chalybeate.

Happy Hollow Spring, Garland county, near Arlington Hotel, in City of Hot Springs; water colorless, odorless and tasteless, with neutral reaction.

Happy Hollow Chalybeate Spring, Garland county, near Happy Hollow Spring, above described, water has faint chalybeate taste, is colorless and odorless.

Homing Hill Spring, Pulaski county, on the General Garland place southwest of Little Rock.

Howard's Mineral Wells, Independence county, near Sharp's Cross Roads, seven miles northwest of Batesville; waters are highly charged with mineral salts, are colorless and odorless, with a saline taste.

Intermittent Spring, Marion county.

Jackson Spring, Marion county.

Lithia Spring, Baxter county.

Lithia Spring, Hempstead county; five and one-half miles south of Hope.

Long Spring, Hempstead county.

Mineral Springs, Clark county, two miles northwest of Antoine.

Magazine Spring (Ellington's Gas Well), Logan county, mile from Magazine; water is clear; bubbles of gas which rise in pipe may be ignited; no reaction for sulphuretted hydrogen.

Mammoth Spring, Fulton county; largest spring in the United States; flows like a great river from side of low rocky ridge; clear with even temperature of 60° F., discharge estimate at 9,000 barrels a minute; so large an amount of carbonic acid is held in solution that the surface of the wonderful fountain is in a continual state of effervesence.

Mineral Spring, Howard county; small deposit of iron oxide.

Mountain Spring, Lonoke county; five miles northwest from Austin; considerable deposit of iron.

Mountain Valley Spring, twelve miles north of Hot Springs; tastes of iron; reaction neutral.

Mt. Nebo Springs, Yell county; near Dardanelle; located on bench of mountain.

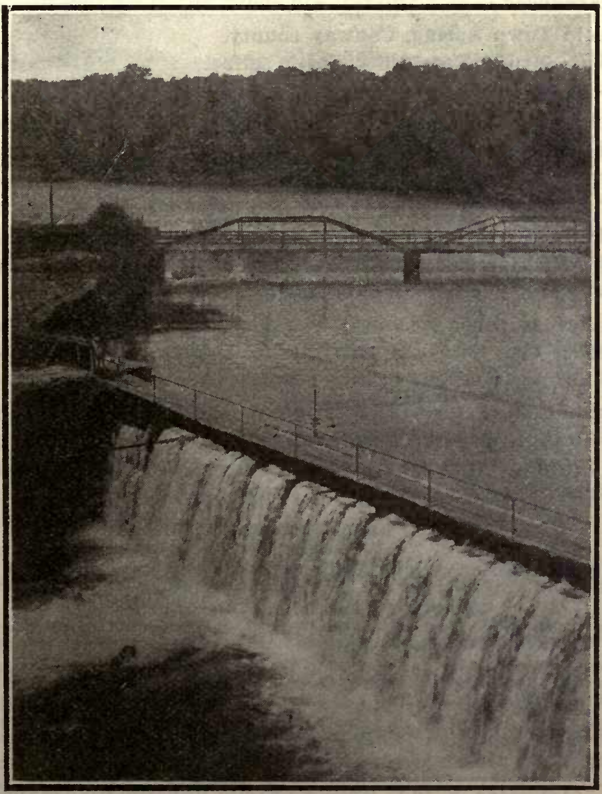
National Spring, Logan county; in town of National; water is clear and forms no sediment of iron.

Pinnacle Spring, Faulkner county; water forms a heavy deposit of iron.

Poison Spring, Carroll county.

Potash Sulphur Springs, Garland county; seven miles southeast of Hot Springs. Glauber's Salt is the chief mineral constitutent of the water.

Searcy Sulphur Spring, White county, in city of Searcy; gas bubbles from water.



Mammoth Spring, Arkansas, the Largest Spring in the World

Silurian Springs, Benton county; water flows from chert formation; clear, cool and pure.

Starne Springs, Independence county, thirteen miles southwest of Batesville; chalybeate.

Sugar Loaf Spring, Cleburne county, in Heber Springs, six springs are enclosed in a park, Arsenic, White Sulphur, Black Sulphur, Chalybeate, Red Sulphur and Eye Springs.

Silver Spring, Benton county, one of the largest and most bountiful springs in Arkansas.

Springfield Town Spring, Conway county.

State Salt Spring, Franklin county; saline.

Sulphur Spring, Newton County; nine miles from Harrison. There are several sulphur springs in this vicinity.

Stonewall Spring, Marion county.

Sulphur Spring, Benton county.

Sulphur Spring, Yell county.

Tom Thumb Spring, Newton county; six miles from Marble City and fifteen miles from Harrison, on the west side of Gaither Cave; water is clear, odorless and has a slightly alkaline taste.

Valley Springs, Boone county; two large springs of clear, cold water flow from chert bed.

Watula Spring, Franklin county; north of Ozark.

Washington County Springs; descriptions and analyses of several springs.

Waters Spring, Garland county, four miles southeast of Hot Springs.

Winona Springs, Carroll county; six miles southeast of Eureka Springs.

REFERENCES.

Purdue, A. H.—Notes on the wells, springs and general water resources of Arkansas. U. S. Geol. Surv. Water Supply and Irrigation Paper, 102. Washington, 1904.

Northern Arkansas—Underground waters of eastern United States. U. S. Geol. Surv., Water Supply and Irrigation Paper, No. 114, Washington, 1905.

Water resources of the contact region between the Paleozoic and Mississippi embayment deposits in northern Arkansas. U. S. Geol. Surv., Water-Supply and Irrigation Paper, No. 145, Washington, 1905.

Water resources of the Winslow Quadrangle, Arkansas. U. S. Geol. Surv., Water-Supply and Irrigation Paper, No. 145, Washington, 1905.

Darton, N. H.—Preliminary list of the deep borings in the United States, Part I., U. S. Geol. Surv., Water-Supply and Irrigation Papers, No. 57, Washington, 1902. (Arkansas, p. 12.) Second edition, Bulletin No. 149, Washington, 1905. (Arkansas, pp. 11-14.)

Veatch, A. C.—The underground waters of northern Louisiana and southern Arkansas, with introductory remarks by G. D. Harris. Bulletin No. 1, of the Louisiana Geol. Surv., Baton Rouge, 1905.

Geology and underground water resources of northern Louisiana and southern Arkansas. Professional Paper, No. 46, U. S. Geol. Surv., Washington, 1906.

Adams, Geo. I.—Summary of the water supply of the Ozark region in northern Arkansas. Contributions to the hydrology of eastern United States, 1904. Water Supply and Irrigation Paper, No. 110, Washington, 1905.

Branner, John C.—Annual Report of the Geol. Surv. of Arkansas for 1891, Vol. I. The mineral waters of Arkansas, Little Rock, 1892.

Crider, A. F.—Drainage of wet land in Arkansas by wells. Water-Supply and Irrigation Paper No. 160, U. S. Geol. Surv., Washington, 1906.

Hopkins, T. C.—Springs: the influence of stratigraphy on their emergence, as illustrated in the Ozark uplift. American Geologist, December, 1894, with plate.

Stephenson, L. W., and Crider, A. F.—Geology and Ground Waters of Northwestern Arkansas. U. S. Geol. Surv., Water-Supply Papers, No. 399.

Alphabetical List of Minor Minerals, Not Including Magnet Cove.

Agate.—Finely variegated; Montgomery county.

Agalmatolite.—In pockets in shale, and as "selvage" in quartz seams; Saline County; Garland County; commonly; generally distributed in other counties.

Agarie Mineral.—Fine powdery incrustations on rocks or in crevices; coating of silvery shale, Montgomery County; in Peacock lode, Logan county.

Aluminite.—This, or a closely allied earthy mineral in Tertiary clays; Pulaski, Saline, Hot Spring, Pike, Sevier, and Polk counties, and northward.

Alunogen.—Reported by Purdue from Searcy County.

Aprodite.—In beds or masses; Pulaski and Garland counties.

Aragonite.—Occasionally as "flos-ferri" in iron ore deposits; distribution general, though not abundant.

Asbolite.—Sparingly in pockets or crevices among shales and intrusive rocks; Ouachita River, south of Hot Springs; possibly in Montgomery county also.

Azurite.—See Copper.

Bartholomite.—Incrustation in crevices as result of decomposition of pyrite; probably some of the red copperas, as at Rabbit Foot mine, Saline County, is this or the allied mineral, Botryogen.

Barite.—Scattering deposits in Pike, Polk, Pulaski, Saline, Garland and Montgomery counties.

Basanite.—In beds, much jointed, in axes of uplifts; Pulaski County.

Braunite.—See Manganese.

Biotite.—Sparingly in granitic rocks.

Breunerite.—Iron-magnesium carbonate; shading off into ankerite and dolomite, in similar situations; distribution irregular.

Brucite.—Hydrous magnesium oxide; occasional in masses of serpentine; Saline county.

Cadmium.—See Greenockite.

Chrysolite.—In crystals and disseminated grains in igneous and metamorphic rocks, some peridotites; Fourche Mountain and northwestwards; Pulaski and Saline counties; Murfreesboro.

Calamine.—See Zinc.

Chalcopyrite.—Sevier county, west of Gilham; not mined.

Celestite (Strontium Sulphate).—Howard, Pike, and Sevier counties, as thin layer in lower Cretaceous limestone.

Copperas.—Iron sulphate. (Malenterite), strictly, but blue vitrol (Chalcanthite) is included popularly; Melanterite appears to be more abundant than chalcanthite.

Cerusite.—See Lead.

Dolomite.—Ferriferous and cobalteferous; Hot Spring, Polk, Scott, and Logan counties.

Eleolite.—In coarse crystals in granite rock; also in massive rocks; distribution general and abundant in regions of metamorphic rocks. Pulaski Saline, Garland, Hot Spring, Montgomery, Pike, and Polk counties.

Epsom Salt.—In caves and old mine tunnels in north Arkansas.

Fluospar.—Garland County, near Lawrence; not mined.

Fiorite (Opal).—in form of Pealite, etc.; products of hot springs; sand Carbonate mine, Saline County.

Freibergite.—Kellogg and McRae mines, Pulaski County, Silver City region, Montgomery County, Sevier County; not mined.

Girasol, (Opal).—About ancient hot spring bowls, with tendency to cuboidal jointing.

Greenockite.—In zinc and lead districts of north Arkansas.

Greensands.—See Agricultural Marls and Chalk.

Halotrichite.—Incrustations in black shale; Sloan's well, Black Spring, Montgomery County; Cox's Alum Springs near Boles, Scott County.

Hydrozincite.—See Zinc.

Jasper.—Of various colors, among the ancient hot spring deposits; Montgomery County; Caddo Gap, Polk County; Eagle Hill.

Jefferisite.—Micaceous, swells enormously when highly heated; associated with aegerite-rock, and among other metamorphic rocks, as serpentine; North of Magnet Cove; Garland and Hot Spring counties; south of Hot Springs; McAllister's mill, Saline County; Montgomery county.

Labradorite.—Lime-soda feldspar; as base of intrusive rocks, in basaltic and other basic rocks.

Marls.—See Agricultural Marls and Chalk.

Melanterite.—In incrustations, etc., rarely pure; Rabbit Foot mine, Saline County.

Malachite.—Garland County, at Hot Springs, in ledge of rock several feet in thickness; not mined.

Mellite, (Honey Stone).—As incrustations on sandstones of coal measures; Scott and Franklin counties.

Mica, (Biotite).—Garland County, at Potash Sulphur Springs.

Nitre, (Saltpeter).—In dry caverns in limestone regions of north Arkansas.

Orthoclase, (Potash feldspar).—Pulaski, Saline and Hot Spring counties, in granitic and allied rocks.

Newtonite.—Pure white, soft, compact, inflexible, specific gravity, 2.37, Newton County.

Oilstone.—See Novaculite.

Pyrophyllite.—In serpentine and steatite; Saline County soapstone district, eastern end. Also reported by Purdue from Searcy County.

Psilomelane.—See Manganese.

Petroleum.—See Oil.

Pyroxene.—Only the non-aluminous green coccolite has been distinctly recognized, but other varieties may occur.

Pyrolusite.—See Manganese.

Reddle.—See Paint Minerals.

Serpentine.—Usually massive or in grains; in beds or masses of wide extent. Ten miles north of Benton; in imbedded patches in quartz, north of Blocher, Saline County.

Smithsonite.—See Zinc.

Stannite, Tin Sulphide. Tin Pyrites.—Suspected, in small quantity, because pyritous rock shows traces of tin; Silver World mine, Polk County.

Stibnite.—See Antimony.

Sulphur.—In small crystals in the upper opening of the Silver Hollow mines on the east bank of Buffalo River below the mouth of Rush Creek, at the opening on the bed of iron pyrites on the Keeling place on Tomahawk Creek, and at a few other places in north Arkansas where small quantities of pyrites are exposed.

Soapstone.—See Talc.

Sphalerite.—See Zinc.

Strontium.—See Celestite.

Syenite.—See Granite.

Thuringite.—In pockets and hot springs deposits; Hot Springs and northward in Garland County.

Travertine, or Tufa, Calcareous.—Deposited by springs and streams, locally; impure and not abundant; in northern districts where dolomites outcrop; Yell and Garland counties, also in north Polk County.

Variscite.—Montgomery County, translucent and transparent, emerald, bluish-green; not mined.

Wad.—See Manganese.

Whetstone.—See Novaculite.

Magnet Cove.

Magnet Cove has long been known to mineralogists as a locality for many rare and beautiful as well as useful minerals and there is hardly a cabinet of minerals in the world that does not contain numerous specimens from this renowned district. This small area is of great interest not only to the mineralogist, but to the petrographer both on account of the number of varieties of rock found there and of the many instances in which the association of the rocks is such that an insight into their genetic relations may be obtained.

In describing this locality Dr. Branner says:

"The Cove is the relic of an ancient basin of thermal springs. The proof of this is apparent in the mounds within the basin and in the special character of the deposits of which these mounds are composed. One of these mounds, made up of ferrous dolomite (brown spar) partly altered to ankerite near the surface, and connected with the outcrop of siliceous dolomite, occurs upon the Snow farm in section 19, 3 S, 17 W. At the southern base of this exposure is a large deposit of very coarsely crystalline calcite intermingled with crystalline, ash-gray siderite.

"About the middle of the Cove there is a deposit of magnetite, the fragments of which cover some 40 acres. This mineral occurs in fragments scattered over the surface and imbedded in the soil. It does not seem to be in place. It is claimed that the deposit is not merely superficial, though no one appears to have any knowledge of a solid bed of the material.

(The magnetite of Magnet Cove is in the form of lodestone and will attract pieces of iron as does an ordinary magnate.)

"On the outcrop side of the ridge north of the Cove there are many deep pits or basins of various sizes, all of which have a comparatively narrow wall of pealite, the structure of which shows that it was accumulated by slow accretion. In every case there is a gulch leading off from the bowl in such a way as to make it clear that each spring acted as a feeder to a stream of its own. Any one who has given attention to the subject in such a region as the Yellowstone Park, will at once recognize here the infallible signs of the same kind of activity. There is a deep seated local prejudice, however, in favor of the reference of these pits to the category of ancient mines, or "Spanish diggings," but there is no evidence sustaining this theory. No miner of any age or people ever sank pits upon the very brink of a precipice without breaking away the outer wall, if it were only two or three feet or less in thickness. Some think that the nearly level rims are the dumps, but no one would take pains to raise dumps above the original level: in other words, to build up a shaft, when the waste could easily be thrown down 150 feet over the edge of the cliff. Moreover, these bowls are invariably associated with the porcelain sinters, and the only thing about any of them approaching the dump structure is the mass of debris which has fallen into the pit itself, while there are numerous evidences that hot water poured over the edges and deposited siliceous layers by evaporation, thus building up a rim exactly as hot springs are elsewhere doing today."—Report Arkansas Geological Survey, Vol. II, 1890.

Minerals Found In Magnet Cove.

Actinolite, Magnesium-calcium-iron silicate (Amphibole).—Occasional in granitic rocks.

Aegirite, Aluminium-calcium-iron-soda silicate.—near phyroxene, with alkalies; in granitic rocks, with labradorite; also enclosed in microline.

Albite.—Sodium-aluminium silicate. (Feldspar).—Sparingy in granitic rocks.

Allophane, Hydrous aluminium, silicate.—Incrustations in crevices, etc.

Almandite, Iron-aluminium silicate. (See Garnet).—Crystals aboundant in wash, also in granitic rocks.

Ankerite, Calcium-magnesium-iron carbonate.—In seams, crevices, etc., and in larger masses, in calcerous rocks; shades into dolomite and calcite.

Apatite, Calcium phosphate and chloride (or fluoride).—In crystalline rocks; also associated with dolomites.

Aplome.—Part of the common iron garnet is in this form.

Arkansite, Titanic acid (Variety of Brookite).—Thick black crystals, (orthorhombic).

Augite, Aluminium-mangesium-calcium-iron silicate (Pyroxene).—In basic igneous rocks.

Aventurine quartz.—Quartz spangled with scales or other mineral; intercalcated with black shales; Micaceous.

Bowenite.—See Serpentine; some of the serpentine is of this character.

Braunite, Manganese sesquioxide and silicate.—In veins or intrusions.

Brookite, Titantic acid.—See Arkansite. (Var.) See Psuedobrookite; occasional reddish or hair-brown crystals as "float," but Arkansite is most common.

Chrysolite.—In crystals and disseminated grains.

Coccolite.—Variety of lime-magnesia, pyroxene (Malacolite); in granitic rocks.

Cinnamon stone.—In float and in metamorphic rocks.

Dog-Tooth Spar.—This variety of calcite less common than rhombohedrons.

Dolomite, Calcium-magnesium carbonate.—In beds interstratified with grits above the tripartite shales. Perhaps some also below this horizon more siliceous. Also associated with sepentinous rocks.

Fahlunite, Hydrous silicate of Hydro-mica group. (Hydrous lime mica.) —From alteration of Iolite. Usually in granitic or hornblende rocks.

Garnet.—Include here Almandite, Andradite, Aplome, Grossularite. See Schorlomite. All occur in "float," also in garnet rock (grossular) and in granitic and feldspathic rocks.

Geyserite, Silica (Opal).—See Pealite, Fiorite, Girasol, Siliceous sinter. (Opal). In heavy deposits covering large areas, but of varying character. See under special names; Porcelain variety (Girasol) like Yellowstone Park deposits north of Magnet Cove, at "Spanish diggings."

Grossularite.—See Garnet. Grossular rock and other non-crystalline or crypto-crystalline forms.

Hornblende, Aluminous magnesia-lime Amphibole.—In syenites; Diamond Jo quarry and other places near and in Magnet Cove.

Hydrotitanite, Altered Perofskite.—In crystals, locally, form perofskite, but gray color.

Hypersthene, Magnesia-iron-silicate.—Some of the labradorite rock, bearing brookite crystals, has also this mineral.

Idocrase, Aluminium-calcium-iron-magnesia silicate.—Vesuvianite (Syn.); as idocrase rock, sometimes with imbedded crystals.

Iolite, Alumina silicate, with other bases.—In metamorphic rocks, rarely in unaltered condition. See Fahlunite for altered forms.

Limonite, Hydrous iron sesquioxide.

Magnetite, Magnetic iron ore.—In crystalline metamorphic rocks; in a local deposit at surface and in soil in fragments; magnetic; abundant.

Melanite.—Lime-iron Garnet, black variety of Andradite; or Aplome; loose crystals and in rock.

Mica.—(Biotite.)

Microcline, Alkaline alumina silicate; triclinic potash-feldspar.—Greenish, in granitic rocks, with aegirites; othoclase or albite, sometimes associated with it.

Octahedrite, Titanic oxide.—Close to Rutile. See also Brookite. Occurs sparingly with Brookite, Rutile and Arkansite, also as imbedded crystals in feldspathic or garnet base.

Oligoclase, Triclinic soda-lime feldspar.—With orthoclase in metamorphic (granitic) rocks. Not very abundant, apparently; in syenite, more or less.

Opal, Silicia.—In certain ancient hot spring deposits.

Ozarkite, Hydrous aluminium silicate, with calcium and sodium; massive variety of Thomsonite.—In masses like beds or intrusious of uncertain relations.

Pealite, Silicia; variety of Opal, or Fiorite.—In crumbling masses, usually with hard nuclei; constituent of old hot spring throats; sand carbonate mine.

Perofskite, Titanic and calcium oxides.—In cubes, octahedrons, etc., and fine twin crystals.

Pinite, Hydrous alkaline silicate; Speckstein (Syn.).—A group well represented, but needing more study; in granitic rocks, pseudomorphous after Iolite? Also other species probably pseudomorphous after nephelite and other minerals; other members of the pinite group occur here and elsewhere; Pinite schist occurs at junction of quarts with black shale.

Prase.—See Quartz. Old deposits of altered quartz.

Pseudobrookite, Titanic and iron oxide.—An iron bearing mineral, near brookite, is probably this.

Rutile, Titanic oxide.—In loose crystals and in metamorphic rocks, imbedded. Abundant in float.

Schorlomite, Calcium-iron silicate and titanite; near Staurolite; Crystals, scattered.—Dr. Koenig of Philadelphia finds the schloromite reported from this locality to be titaniferous garnet.

Silex, Silica.—Name sometimes used as synonymous with quartz; Pealite is opal, and occurs in places where ancient hot springs made surface deposits.

Siliceous sinter, Silica.—Opal or quartz; Pealite is opal, and occurs in places where ancient hot springs made surface deposits.

Smoky Quartz, Silica.—Variety of Quartz; in vein-like portions of beds; apparently more common in the regions where millstone grit is exposed.

Sunstone, pink or gray.—Cut for ornaments.

Talc, hydrous magnesium silicate.—Talcose shales and talc schists in beds and pockets with black shale.

Vesuvianite.—Yellowish green to olive green crystals; not mined.

Wavellite, Hydrous aluminium phosphate.—Common in radiated, spherical and hemispherical crystalline aggregations, and in similar forms thickly spread over rock surfaces.

Titanium.—See Brookite, Octahedrite, and Rutile.

REFERENCES.

Dana, Edw. S.—On the brookite from Magnet Cove, Arkansas. American Journal of Science, 3d series, Vol. CXXXII, New Haven, 1886.

Hillebrand, W. F.—Distribution and quantitative occurrence of vanadium and molybdenum in rocks of the U. S. American Journal of Science, 1898, Vol. VI. (Note on p. 216 has determination of vanadium in protovermiculite from Magnet Cove.)

Florence, W.—Darstellung Mikroskopischer Krystalle in Lothrohrperlen, Von W. Florence, Berg. u. Hutteningenieur in Soa Paulo. Neues Jahrbuch for Mineralogie, Geologie u. Paloantologie, Jahrg. 1898, Vol. II. (Reference to perofskite from Magnet Cove, Arkansas.)

The foyite-ijolite series of Magnet Cove. A chemical study of dicerentiation. Journal of Geology, October-November, 1901, Vol. IX, Chicago, 1901. Journal of Geology, November-December, 1901, Vol. IX, Chicago, 1901. Review, Geological Magazine, Vol. IX, London, April, 1902.

Kunz, Geo. F.—Perofskite and wavellite from Arkansas. Transactions New York Academy of Science, Vol. III, pp. 17-18, New York, 1883.

Williams, J. Francis.—Eudialyte and eucolite from Magnet Cove, Arkansas. American Journal of Science, Vol. CXL, New Haven, 1890; also separate. Abstract, Neues Jahrbuch for Mineralogie, Vol. II, Stuttgart, 1893. Abstract, Groth's Zeitschrift fur Krystallographic u. Mineralogie, Vol. XX, Leipzig, 1892.

Smith, J. Lawrence and Brush, Geo. J.—Elaeolite from Magnet Cove. American Journal of Science, Vol. LXVI, New Haven, 1850.

Melville, W. H.—Natroline from Magnet Cove, Arkansas. Bulletin No. 90, U. S. Geological Surv., Washington, 1892. Abstract, Groth's Zeitschrift fur Krystallographie u. Mineralogie, Vol. XXIV, Leipzig, 1895.

Mar, F. W.—So-called perofskite from Magnet Cove, Arkansas. American Journal of Science, Vol. CXL, New Haven, 1890. Abstract, Groth's Zeitschrift fur Krystallographie u. Mineralogie, Vol. XX, Leipzig, 1892.

Shepard, Charles Upham.—Eudialyte in Arkansas. American Journal of Science, Vol. LXXXVII, second series. Eudialyte from Magnet Cove, New Haven, 1864.

Rath, G. vom.—Mineralogische Beitrage, Verh. Nat. Ver. Preuss. Rheinl. Jahrg., Vol. XXXIV, (1877), (Rutile from Magnet Cove).

Penfield, S. L., and Pirsson, L. V.—Eudialyte, titanite and monticellite from Magnet Cove, Arkansas. American Journal of Science, Vol. CXLI, New Haven, 1891.

Brookite from Magnet Cove, Arkansas. American Journal of Science, 3d ser., Vol. CXXXI, New Haven, 1886.

Harris, G. D.—Magnetic Rocks. Science, New Ser., Vol. XXIX, New York, Mar. 5, 1909.

Genth, F. A.—Natrolite from Magnet Cove. American Journal of Science, 3d ser., Vol. CXLIII, New Haven, 1892.

Contributions to Mineralogy, Eudialyte, etc., from Magnet Cove, Arkansas. American Journal of Science, 3d Ser., Vol. CXLI, New Haxen, 1891.

Synopsis of the Regulatory State Mining Laws of Arkansas.

(Act April 4th, 1893.)

Section 5337.—Owners or operators of mines to make accurate maps or plans of same and file same with the county clerk and keep copy in their office for inspection. When new maps shall be made and filed.

Section 5338.—On failure to make such maps inspector to make same.

Section 5339.—Escapements to be made. Time for making same.

Section 5340.—Ventilation to be provided for. Mines to be examined for fire damp. Ventilation, how produced.

Section 5341.—Bore holes to be provided twenty feet in advance of working place.

Section 5342.—Means of signaling to be provided and safe means of hoisting and lowering. Manner of making cages.

Section 5343.—No person under fourteen or female of any age allowed to work in mines, nor any boy under sixteen unless he can read and write. Engineers must be experienced and sober; not under eighteen years old. Number of persons to ascend and descend in a cage.

Section 5344.—Gates and bonnets to be furnished. Safety appliances for engine and gang-ways.

Section 5345.—Accidents must be reported to mine inspector, and in case of death to coroner. The inspector to investigate.

Section 5346.—Governor to appoint mine inspector.

Section 5347.—Duties.

Section 5348.—Owners to furnish necessary facilities for examination of mines. Penalty for refusal.

Section 5349.—Inspector to file complaint with circuit court for violations of act. Duties of judge in such cases.

Section 5350.—Right of action for injury.

Section 5351.—Misdemeanor to injure any appliance of a mine.

Section 5352.—Necessary timber for props to be kept on hand.

Section 5353.—Weighman and check weighman, and duties.

Section 5354.—Penalty for inspector to fail to do his duty. Proviso; only applies to coal mines and miners employing over twenty men.

Section 5355.—Operator to furnish list of hands to sheriffs, assessors and collectors, when: penalty for refusal.

Section 5356.—Coal mine operators to keep correct scales and measures. Two miners can require inspector test.

Section 5357—Coal to be weighed before screened, unless otherwise agreed. Amended by Act 219, Acts of 1905, and Act 49, Acts 1915.

Section 5358.—Violation of act misdemeanor.

Lien of Miners.

Section 5359.—Miner given lien on output of mine and all machinery, tools, etc.

Mining Claims.

Section 5360.—Notices of all kinds to be filed with recorder of the county.

Section 5361.—Fees

Section 5362.—Recorder to make plat in record book of each claim located.

Section 5363.—Limitation of actions on.

Section 5364.—Owner or agent may file affidavit of assessment work done.

Section 5365.—Recorder to keep record plat book showing all legal subdivisions affected by notice with a complete index.

Section 5366.—Failure to keep such index misdemeanor; penalty.

Later Acts.

Act 159 of the Acts of 1911—Provides punishment for lessees for defrauding lessors of royalties.

Act 13, Acts of 1909—Requires corporations doing business in Arkansas to have two regular pay days each month.

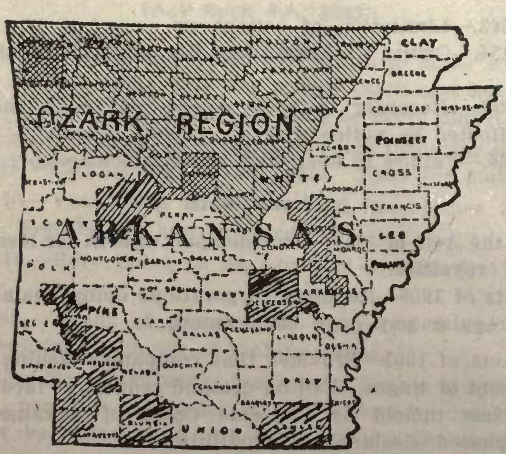
Act 101, Acts of 1901—Provides that companies issuing script or store orders in payment of wages, shall on demand redeem at face value in lawful money. This law upheld by Supreme Court of Arkansas. Other laws subsequently passed declared unconstitutional.

Act 134, Acts of 1919—Provides wash houses at coal mines with hot and cold water, shower baths, lockers and clothes hangers; state mine inspector given general supervision.

Act 486, Acts of 1919—Provides a board of five examiners composed of two miners, two operators and a fifth member to be selected by the other four, to examine and issue certificates to fire bosses, hoisting engineers, mine foremen and mine inspectors, provided that those holding positions at time Act goes into effect and who have five years experience, shall be granted certificates without examination upon payment of $3.00 fee; specifies qualifications of applicants and provides fees; provides that certificates shall be issued in two grades; board has power to revoke certificates for sufficient cause.

Act 163, Acts of 1905 Amended by Act 268, Acts of 1905, Authorizes all persons owning, or controlling by lease or purchase, any copper, lead, zinc, iron, marble, stone, rock, granite, slate, coal or other mineral lands in the State of Arkansas, to construct, own and operate short connecting lines of railway or tramway, and granting them the right of eminent domain in condemnation suits.

Act 69, Acts of 1907—Known as the Fellow Servant's Act—Gives right of action against any employer for injuries or death resulting to his agents, employees or servants, either from the employer's negligence or from the negligence of some of his employees, servants or agents; applies to operators of coal mines as well as to railroads.



Soil Areas Surveyed in Arkansas.

BRIEF DESCRIPTION OF THE SURVEYED SOILS OF ARKANSAS.

Under past state geological surveys no attempt has been made to make a general soil survey of the state, though such information would be of great value to the agricultural industry. Doctor Branner frequently comments upon the characteristics of our soils with reference to their more profitable utilization in the producing of crops and gives valuable suggestions for using the limestone deposits of certain areas for correcting the acidity of soils in other sections, and the College of Agriculture at Fayetteville, with the aid of its soil experts, has given some attention to the study of the various soil types. However, the more important work done in soil investigation has been conducted by the Federal Government through the Bureau of Soils, Department of Agriculture, Complete soil surveys have been made in 15 counties, work is in progress in several other counties, and a general review of the soils of some 10 other counties is contained in a publication entitled "Soil Reconnaissance of the Ozark Region of Missouri and Arkansas." Approximately one-half of the state's area is included in these government soil surveys and it is understood that the work will be continued until the entire state is surveyed. With active state cooperation, such as might be rendered should a new geological survey be established, this work would be more quickly completed and the farming industry would be lastingly benefitted for a knowledge of the soil is necessary to its profitable management. Below is a synopsis of publications issued by the Bureau of Soils, U. S. Department of Agriculture, on the subject of Arkansas soils. Each of these reports is accompanied by a large map and full discussion of the various soil types. Copies may be had upon application to the U. S. Bureau of Soils, Washington, D. C.:

SOIL RECONNAISSANCE OF THE OZARK REGION.

By CHAS. F. MARBUT,

Bureau of Soils, United States Department of Agriculture

The region as a whole consists of three main subdivisions or belts of country, each with a characteristic expression, differing from either of the others. They are: (1) The Ozark Dome, (2) the Boston Mountain Plateau, and (3) the Ouachita Mountains.

The Ozark Dome is an elevated region known as the Ozark Mountains, the Ozark Plateau, or the Ozark Hills. As a whole it is topographically an elongated dome. Its axis lies in a northeast-southwest direction, its eastern end lying approximately on the Mississippi River about 50 miles south of St. Louis and its southwestern end in northeastern Oklahoma. Its eastern boundary, so far as this report is concerned, is the western side of the Mississippi Valley and the western side of the lowland region of southeastern Missouri and northeastern Arkansas. Its southern boundary runs across northern Arkansas from Batesville on the east through Fayetteville to the state line in the northwestern part of Washington county. Its western boundary extends from the western part of Cooper county, Mo., southwestward across the Missouri-Kansas line near the northwestern corner of Jasper county, Mo., and joins the southern boundary in northeastern Oklahoma. Its northern boundary lies a few miles north of the Missouri River. This report covers only that part of it lying south of the river.

The Boston Mountain Plateau is an elongated block of high land lying in a southeast-northwest position, its eastern end lying along the western boundary of the Mississippi lowlands in Independence and White counties, Ark., and its western end extending into eastern Oklahoma. It lies between the White and Arkansas rivers, the greater part of it being drained to the latter stream. It includes the northern part of the sandstone-shale region.

The Ouachita Mountains lie south of the southern slope of the Boston Mountain Plateau, and includes all that part of the state bounded by the plateau on the north, the White River lowland on the east, and the Coastal Plain on the south. They consist of alternating narrow eastwest ridges separated by broad lowland belts with occasional isolated areas of flat-topped plateaus, none of the latter, however, reaching the elevation of the Boston Mountain Plateau.

Ozark Dome.

The Ozark Dome is a large area and includes a wide range of conditions that are of determining influence in soil building and in agricultural progress Its several parts vary widely in the character of the rock underlying the country, in the topography, and to a considerable extent in climate. These factors have caused still wider variations in the character of the soils which have been produced by them and since economic conditions are dependent on the combined effect of all these factors such conditions must vary more widely than any one of the natural factors, no two of the latter neutralizing each other.

The soils are alike in being practically all residual, leaving out of consideration for the moment the alluvial soils, most of which are merely reworked local material. They are alike also in being almost universally of a grayish, yellowish, reddish, or brownish color—some color other than black. They differ also from the surrounding prairie soils in being almost universally stony.

In the Ozark Dome the soils, including the silty phase of the Fayetteville, have been differentiated into 16 groups, each being derived from rocks differing from those of each of the other groups in lithologic character.

The area including the soils of each group, with one or two minor exceptions, occurs as a belt of varying width and curving more or less parallel with the boundaries of the region. The whole region becomes, therefore, one of concentrically arranged belts of soils, few of them making a complete circuit, but all of them curving with the curve of the regional boundary. In some cases distribution is obscure because of the raggedness of the boundary lines due to dissection and because of the varying width of some of of the belts. The area of Rough stony land soils is the center around which the other soils are grouped.

Boston Mountain Plateau.

The soils of the Boston Mountain Plateau vary in texture from clays to sands. The dominant soils are sandy loams, loams, clay loams and clays. The clays lie on the shale beds and occur most abundantly, therefore, along the north-front slope, on the various valley-side benches, and on the plateau surface. The latter manner of occurence is most common in the eastern part of the plateau. The shale beds have outcrops in larger areas in the eastern part of the plateau so that the larger areas of clay soil are north-front and eastern features. Shale beds occur in the western and central parts of the plateau also, but with the exception of one thick bed forming the main mountain-side bench, they seem to be thinner here than in the eastern part. It is possible that the smaller proportions of smooth plateau surface in this section and the greater proportion of slope have made the clay beds less effective areally soil formers by limiting their outcrops to slopes. In such positions the shale outcrops occur as narrow belts along the slopes. The soils from them are not conspicious.

The sandy loams and loams occur in belts and areas in the eastern part of the plateau and in larger areas in the western part. They are often stony and are usually fine, rather than course, sandy loams. It is probable that mechanical analyses of most of these soils would show that they should be classed as loams rather than sandy loams. Sand occur pratically over the whole area of the plateau and the clay soils usually have an inch or two of sand overlying them. The sandy soils also usually have a considerable proportion of clay in their sub-surface and subsoil. Sandy soils predominate along the whole southern border of the plateau. Shale beds are exposed, but the smooth surfaces of considerable size are underlain by sandstone. Mountain-side benches are of rare occurence; hence the clay beds have very little opportunity to express themselves. They occur in saddles along the ridge tops and in a few small ridge-top areas. Practically all these soils are gray on the surface, yellow in the subsurface, and red below 24 inches. Only occasionally does yellow subsurface color persist downward.

Silt soils occur on the flat plateau surfaces, on the limestone areas of the north-front slope and interior basins, and in the red cedar areas of the southern slope. The Plateau-top areas are usually the leached areas of shale-derived soils where the clay constituent has been washed down into the subsoil. The limestone soils are silty clay soils, and, like the others, have heavier subsoils.

True sands occur very rarely only in places where the clay and silt, normally found associated with the soils, have been washed out.

The predominant soil color is gray at the surface, becoming yellow a few inches below the surface. Below the yellow layer the subsoils are red. Second in importance of the soil colors is probably yellow, followed by red, brown and black. The surface inch or two of soil is almost universally gray. Beneath this the yellow appears. Along the roadways the yellow is made more prominent by the grinding of the soil into powder, the powdered soil being more yellow than the soil in place. On the flat areas the grays are much more prominent, especially where the drainage is incomplete. The coarser sandy soils are usually gray, often, however, with a tinge of yellow.

There are no red surface soils in the Boston Mountain Plateau and brownish reds occur in very few places. Yellowish red is, however, a common color in the clay soils. The clay benches and much of the clay upland surface soil of the plateau has a very pronounced yellowish-red, or possibly reddish-yellow, subsoil and subsurface. On the clay bench lands this is practically universal.

There is a narrow belt of brownish-red soils along the north-front slope in the northwestern part of the area. They are loams derived from a calcareous sandstone.

The brown soils occur most abundantly on the high ridges and hills of the central hill belt of the plateau. They occur also in other parts of the area, usually derived from the medium-grained sandstones. This is especially true of the thin-bedded sandstones of brown color which disintegrate into the so-called black and red gravelly land.

The brown soils of the high ridges and hills have a reddish cast, with less prominent yellow, while the lower lying brown soils are more apt to be yellowish brown, except the reddish brown and brownish reds referred to above, and isolated occurences on the northward slopes elsewhere. The walnut and locust land is dark reddish brown wherever it occurs. The silt soils derived from the limestone beds of the north front-slope and the interior basins are reddish brown, but lighter in tone than the sandstone soils of the same color.

There is only one belt of black soils in the region. This is the soils of the north front-slope belt that have been derived from the thick black shale beds occuring there in association with thin limestone beds.

The soil layer is of moderate depth only. Bedrocks outcrops frequently, and even on smooth areas the depth to the rock is usually from 2 to 6 feet. The rock can usually be seen in the roadside ditches. True hardpan is of very rare occurence on the plateau. It probably does not exist. On the flat clay and silt surface the tougher subsoil is sometimes called hardpan, but it is not hard as a rule and is not impervious—neither hard nor acts as a pan. The shallowness of the soil, however, makes a great deal of it susceptible to drought.

The soils of the Boston Mountain Plateau, not including the lowlands, lower plateaus, and ridges of the Ouachita region along the Arkansas River, are predominantly Fayetteville soils. Associated with these are Hanceville soils and two groups which have been designated as Jamestown and Winslow.

The Ouachita Mountains.

This report is concerned with that part of the Ouachita Mountains that lies between the Arkansas River and the foot of the southern slope of the Boston Plateau block. It includes ridge and lowland belts typical for the region, and along the northern border a series of plateaus, more or less isolated by lowland belts and areas, essentially like the upland surface of the Boston Mountain Plateau, within Region No. 1, but considerably lower. Their surfaces lie at a maximum elevation of about 1,200 feet. From Scotland eastward to the White River lowland at Searcy there is a continuous lowland belt between these plateaus and the south foot of the Boston Mountain Plateau. South of these plateaus lies the typical belted country with its alternating ridges and lowland belts. The ridges and plateaus are well defined but low, so that the whole area north of the Arkansas River is an area of low relief when compared with the Boston Mountain Plateau, and will be described as such. The area is wedge-shaped, running to a point at the western State line and reaching maximum width at the extreme end, where it abuts against the White River lowland area. The boundary lines are, on the north, the south boundary of the plateau already described, on the south the Arkansas River, and on the east the Missouri Pacific Railway approximately. It includes about 2,700 miles.

The rocks of the Ouachita belt are the same as those in the Boston Mountain Plateau. The same beds of sandstone and shale which lie in a nearly horizontal position under the latter lie under the former in part in a horizontal position, but mainly in a series of folds or up bows and down bows, so that the individual layers of rock plunge downward into the earth at angles varying considerably in steepness, often practically vertical. The corresponding beds lie, when horizontal, at a lower altitude in part of the Ouachita belt included in this report than in the plateau. The lower altitude of all the beds has depressed the lower beds so deep beneath the surface that they are not exposed on the surface at any place in the Ouachita region. This applies especially to the rocks which form the Jamestown soils. These soils do not occur, therefore, in the Ouachita region.

The rocks forming the Winslow soils are exposed in many places in the Ouachita belt, but not in positions favorable to the development of Winslow soils. The reason is probably climatic.

Alluvial Soil of the Ozark Region.

The alluvial soils throughout the Ozark region are predominately brown to reddish brown. In a few places terraces with gray to nearly white soils occur, but they are of very limited distribution. In the Ouachita region there are considerable areas of gray first-bottom alluvial soils which approach the Holly soils in character, though they are derived entirely from sandstones and shales. They are of about the same agricultural value as the Holly.

The alluvium along all the streams of the Ozark Dome, the Boston Mountain Plateau, and the larger streams of the mapped Ouchita belt which rise in the plateau is of quite uniform color and producing capacity. The soils derived from this material are typical Huntington soils. In the Ozark Dome they are gravelly as a rule, and often redder in color than the typical Huntington. The gravel consists wholly of chert. The subsoils have more red in their color than the soils. The types are not usually so light in the subsoil as some of the alluvial soils of the Boston Mountain Plateau. In the latter region the soils are brown rather than reddish brown, but otherwise are much like those of the Dome region, except that their subsoils are much more porous, being made up in many cases largely of sandstone cobbles reaching the size of boulders in some cases.

Areas of Different Soils.

Soil	Acres
Howell soils,	5,842,944
Springfield soils,	4,893,696
Clarkesville soils,	4,550,400
Alluvial soils,	3,785,472
Fayetteville soils:	
Stony loam,	1,951,488
Mainly silt loams,	589,824
Lowland phase,	714,240
Lebanon soils,	1,428,480
Union soils,	1,331,712
Hagertown soils,	979,200
Izard soils,	776,448
Berryville soils,	755,712
Iberia soils,	665,856
Appleton silty soils,	628,992
Owensville silt loam,	550,656
Jamestown soils,	541,440
Fredericktown soils,	435,456
Dent soils,	343,296
Appleton soils,	299,520
Cedar Valley soils,	294,912
Hanceville soils,	274,176
Rough stony land,	241,920
Tilsit soils,	177,408
Winslow soils,	129,024
Glenn soils,	69,120
Pocahontas soils,	27,648
Total,	32,279,040

Description of Prairie Soils.

The typical soil of the prairies of Arkansas is known as the Crowley silt loam, the name being derived from Crowley, La., where a similar soil is widely developed. It's physical characteristics and availability have been described by Bonsteel as follows:

"The Crowley silt loam is a brown or ashy gray silt loam ranging in depth from 10 to 16 inches, underlain by a gray or mottled heavy silt loam or silty clay which frequently contains concretions of iron and calcium carbonate. The subsoil ranges in color from gray to reddish yellow, mottled with red and brown, and is stiff and impervious in all localities where it has been encountered. * * * * *

Before the introduction of rice culture upon this soil very little agricultural use was made of it. In Arkansas the prairie grasses were used for grazing purposes, and the better drained and higher lying portions of the type were beginning to be cultivated to cereal grains and forage crops. These uses of the type, however, are entirely subordinate to its principal utilization as the chief rice-growing soil of the Western Gulf States. While small areas are annually planted to cotton, corn, cowpeas and even oats or wheat, the great use of the soil is for the production of the rice crop.

The Crowley silt loam, owing to its flat topography, to its slight elevation above the main drainage channels, and to the impervious nature of both the surface soil and subsoil, is in its natural condition for the most part poorly drained. * * * * *

The Crowley silt loam is the typical rice land of southwestern Louisiana and east-central Arkansas. It is probable that more rice is grown upon this soil than upon all other rice soils in the United States. In fact, the development of this type for agricultural purposes has been almost coextensive with the development of the rice industry in the Western Gulf States."—By L. W. Stephenson and A. F. Crider, Water Supply Paper No. 399, U. S. Geol. Surv.

ASHLEY COUNTY.

Twelve soil types have been mapped in Ashley county.

The Richmond silt loam is by far the most extensive type. It is derived from the loess. It is best suited to the production of general crops. A poorly drained phase and a prairie phase, the latter affording excellent pasturage and general farming land, are distinguished on the map. In recent years the prairie phase has been in demand for rice growing.

The Crowley silt loam is a productive soil in considerable demand for rice growing. A timbered phase will need draining to fit it for cultivation.

The Ruston fine sandy loam and very fine sandy loam are for the most part well-drained soils, suitable for all farm, truck and fruit crops. If not properly handled they are soon depleted of organic matter.

A small area of the Orangeburg fine sandy loam exists in the county. It is especially well suited to trucking and orcharding, as well as to the general farm crops.

The Portland very fine sandy loam is the most productive soil in the county. It occupies slight ridges in the eastern bottoms and is well adapted to general farm and truck crops.

The Portland clay is more or less swampy and is in very evident need of drainage, after which it will likely become a strong and lasting soil.

The Vicksburg silt loam is a productive first-bottom soil occuring along upland streams, and subject to frequent inundations. On areas that are not too often overflowed excellent crops are produced.

The Waverly silt loam is a grayish first-bottom soil lying along the Ouachita and Saline rivers and the upland streams. Owing to its poor drainage and frequent inundations it is in a water-logged condition.

The Waverly silt loam, heavy subsoil phase, and Waverly very fine sandy loam constitute the greater part of the flat, imperfectly formed terraces along the Ouachita and Saline bottoms. In their present overflowed condition they are unfit for cultivation. Some portions are used as range for hogs.

The Boeuf very fine sandy loam occupies small, irregular ridges lying from 3 to 5 feet above the surrounding terrace areas. They are usually cleared and in cultivation and are not seriously affected by floods.

Swamp includes the narrow strip of the first bottom occuring along the Saline and Ouachita rivers and a strip of terrace formation most likely composed of the Waverly and Bouef soils with interspersed sand and clay depressions. Owing to its inaccessibility, due to the high water, no attempt was made to separate this area into soil types.—Soil Survey of Ashley County, Ark., by E. S. Vanatta, B. D. Gilbert, E. B. Watson and A. H. Meyer, U. S. Bureau of Soils, 1914.

COLUMBIA COUNTY.

As the county lies within the Gulf Coastal Plain, the upland soils are of sedimentary origin. Including Meadow, 27 soil types are mapped. The upland, sedimentary soils are classed in the Susquehanna, Ruston, Orangeburg, Norfolk, Caddo and Lufkin series and the streambottom alluvial soils in the Ocklocknee and Bibb series and Meadow on the first bottoms, and in the Myatt, Cahaba and Kalima series on the second bottoms, or terraces.

The Susquehanna fine sandy loam and very fine sandy loam are extensively and successfully used in producing cotton, corn and miscellaneous crops. The Susquehanna sandy loam is used for the same purposes, but it is not quite so productive. The Susquehanna clay is of small extent and is the result chiefly of erosion. The rougher areas are best suited to pasturage, while smoother portions are fairly suitable for cultivation.

The Ruston fine sandy loam and very fine sandy loam are productive soils, used for cotton, corn and miscellaneous crops. These soils appear well suited to peaches and various fruits. The Ruston sandy loam is better suited to cotton than to corn, owing to its somewhat droughty nature. The Ruston sand is a deep sandy soil, inclined to be droughty. It is used for general crops, but is better adapted to vegetables and early truck crops.

The Orangeburg fine sandy loam is a well-drained soil, well suited to general farm and fruit crops.

The Norfolk fine sandy loam and very fine sandy loam are productive soils, well suited to general farm crops. The Norfolk sand is a loose sandy soil, rather droughty and not very productive. It is used for general farming, but is better adapted to early truck.

The Caddo fine sandy loam and very fine sandy loam are low, flat, poorly drained soils. The better drained phase are cleared and used for general farming. These soils afford good pasturage, but are in need of artificial drainage.

The Lufkin silt loam is a low, flat, poorly drained soil of compact structure, mainly forested. The better phases are cultivated with some success. General farm crops are grown and rice probably would prove successful. The Lufkin clay is mostly timbered and not suited for general crops. It could probably be used for rice.

The Ochlocknee fine sandy loam has a small development, but most of it is well suited to corn and forage crops. The Ocklocknee very fine sandy loam and silt loam are brown soils, practically all forested, the former type including most of the overflowed stream bottoms. The poor drainage and frequent occurence of overflow preclude their extensive development. They are used as a range for stock.

The Bibb very fine sandy loam and silt loam are light-colored soils which are forested and subject to periodical overflows. They afford some pasturage.

The Myatt very fine sandy loam is flat and poorly drained. Some of it is used for cotton and corn, but most of it is forested and used for stock range.

The Cahaba fine sandy loam and very fine sandy loam and the Kalmia fine sandy loam are generally well drained terrace soils, well suited to the general farm crops. Alfalfa might be successfully grown on these soils. The Cahaba fine sand is a porous sandy soil. It gives fair results with corn and cotton, but is better adapted to early vegetables.

Meadow is a poorly drained, first-bottom type of variable soil material which is best suited for pasturage.—Soil Survey of Columbia County, Arkansas by Clarence Lounsbury and E. B. Deeter, U. S. Bureau of Soils, 1916.

CONWAY COUNTY.

The soils of the area have been classified into nine types. Five of these are residual upland and four are alluvial bottom soils. The upland soils have been correlated with the Fayetteville series, and the bottom soils with the Wabash series.

Some of the upland soil types, notably the Fayetteville stony loam, are well suited to the production of apples where sufficient clay is found in the subsoil. There are phases of this type that could be used profitably in the production of peaches, provided a shipping point is sufficiently near.

The soils along the river are wholly different from those on the hills and require different treatment. Most of them are well suited to the production of cotton and corn and two types, namely, the Wabash clay and the Wabash silt loam, will grow good crops of rice in those areas where the surface is flat and the drainage somewhat poor. The Wabash silt loam, where the water table is from 5 to 10 feet below the surface, will grow good alfalfa. This is also true of the Wabash clay where good surface drainage can be secured.—Soil Survey of Conway County, Arkansas, by James L. Burgess and Chas. W. Ely. U. S. Bureau of Soils, 1908.

CRAIGHEAD COUNTY.

The greater part of the soils belong in the lowlands, comprising both first and second bottoms. The soils range in texture from heavy plastic clay to loamy sand. In all, 13 types of soil, one with a shallow phase, are mapped in Craighead county. These are grouped in 9 series.

The Memphis soils are encountered throughout the extent of Crowleys Ridge. They are well drained and are used mainly for the growing of cotton and corn. Fruits, vegetables and peanuts, lespedeza, white clover, Bermuda grass and forage crops do well.

The Grenada silt loam is also an upland type, but is less well drained than the Memphis soils. This type is easily cultivated and is highly esteemed for growing cotton, corn and peanuts. Lespedeza, white clover and Bermuda grass afford good grazing.

The Collins silt loam is a first-bottom soil occuring within the limits of Crowleys Ridge. It is developed principally along Big Creek and its tributaries. It is subject to overflow and is poorly drained. The principal crops are cotton, corn and hay. Lespedeza does well and can be grown to good advantage both for hay and pasturage. White clover and Bermuda grass also afford good pasturage.

The Sharkey clay, locally known as "gumbo," is encountered in the sloughs and the "sunk lands" lying east of Crowleys Ridge. The typical forest growth is cypress and tupelo gum. Although much of this land is now covered with water, drainage canals are being constructed which should reclaim large areas. Only a small part of the type is cultivated. Where drainage is good cotton and corn do well.

The Waverly clay occurs in the western part of the county along Cache River. It is poorly drained first-bottom soil and practically none of it is in cultivation. With artificial drainage this type will be productive. It will be found especially adapted to grasses and forage crops. Lespedeza, clover and Bermuda grass will give good yields of hay and pasturage.

The Calhoun silt loam and its shallow phase constitute the "white" soils on the broad terraces on both sides of Crowleys Ridge. Drainage is poor. The greater part of these soils is forested. Corn, cotton, wheat, oats, sorghum, rice, lespedeza, Bermuda grass, redtop, alsike, clover and cowpeas are grown to some extent.

The Oliver fine sandy loam and silt loam are terrace soils, used principally for growing cotton and corn. In places the underdrainage is poor, but in general the soils of this series are sufficiently drained and productive.

It is well suited to the production of lespedeza, white clover and Bermuda grass.

The Lintonia fine sandy loam, loamy sand and silt loam are among the best soils in the county and produce excellent yields of cotton and corn. They occur as second-bottoms, or terraces, and are generally well drained. The greatest development of the series is near the St. Francis River. It also occurs in the vicinity of the Cache River. Cotton and corn are the principal crops. Lespedeza, white clover and Bermuda grass do well, especially on the silt loam.

The Crowley silt loam is used mainly for the production of rice. If thorough drainage were established, preferably with tile drains, the type could be used successfully for the production of the other crops of the region.—Soil Survey of Craighead County, Arkansas, by E. B. Deeter, In Charge, and L. Vincent Davis, U. S. Bureau of Soils, 1917.

FAYETTEVILLE AREA.

Nine types of soil were mapped in the Fayetteville area besides Meadow and Rough stony land. The limestone soils are all silt loams with heavy silt loam or silty clay loam subsoils. Wherever the topography is much broken, varying amounts of chert are present. Where well drained—as most of the upland portions are—these soils are well adapted to the production of apples, peaches and berries and when well farmed satisfactory yields of the staple farm crops are obtained. The Clarksville silt loam ranges in price from $25 to $150 an acre, depending on location, buildings and amount of orchard; the Clarksville stony loam $5 to $15 unimproved, and $10 to $80 improved; and the Gascondae silt loam from $10 to $40 an acre. The limestone bottomland, the Wabash silt loam, is perhaps the best type in the area for general farming and is worth $50 an acre for that purpose, but because of its non-adaption to fruit it can be bought for less than some of the upland fruit soils.

The sandstone uplands are loams and fine sandy loams overlying clay loams or fine sandy clays. The Upshur loam is a good soil for general farming, and where favorably located it is well adapted to the tree fruits and berries. It may be bought at prices ranging from $15 to $100 an acre.

The Upshur fine sandy loam is one of the best types in the area for the production of strawberries. Peaches and apples also do remarkably well when the topography and drainage are favorable, and selected positions within this type furnish conditions almost ideal for these crops. The yields of farm crops are only moderate, and the soil must be fertilized to obtain profitable returns, but it responds quickly to fertilizers. Part of the type is somewhat inaccessible, and this lowers its value. Such areas range in price from $5 to $50 an acre. Accessibility areas bring from $20 to $100 an acre, depending upon improvements and the amount of orchard.

The Upshur stony loam is adapted in part to tree fruits, general farming and permanent pasture, depending upon position and stone content Its price ranges from $5 to $50, averaging possibly $20, an acre.

The Wabash clay loam and Wabash loam are bottom-land soils derived principally from sandstone wash. They are both excellent types for corn, grass and forage crops, and in well-drained fields the other cereals are sometimes grown to advantage. In general these types are not adapted to the tree fruits, but strawberries and the cane fruits do well where drainage is good. These types may be purchased for from $10 to $50 an acre.

It would be easily possible to improve the management of the farming lands of the area in certain respects. The methods of cultivation are generally inadequate. Few of the soils receive sufficient preparation before planting, and in many instances increased tillage would profitably enlarge the crop returns. Crops are not harvested at the proper stage of ripeness, and in some cases there is much wasted. The former happens in the hay harvest, and the latter with corn, particularly, and in lesser degree with the cereals. At least one-half of the feeding value of the corn fodder is wasted because of failure to gather properly or in due season, and enlarge amounts of straw are lost. Stable manure is very valuable, particularly on the upland soils, but few farmers exercise any care in saving it.—Soil Survey of the Fayetteville Area, Arkansas, by Henry J. Wilder and Charles F. Shaw, U. S. Bureau of Soils, 1907.

FAULKNER COUNTY.

The upland soils are residual from Pennsylvanian sandstones and shales. The alluvial soils, except those along the Arkansas River, have been formed from material derived from the near-by hills and valleys. The Arkansas River bottom soils consist of local upland sediments mixed with a large quantity of residual prairie sediments.

The upland soils are classed with the Hanceville and Conway series. The Hanceville soils have brown to reddish-brown surface soils and red, moderately friable subsoils. The Hanceville stony loam is largely forested, but much of it could be used for raising live stock and growing fruit. The shale loam is of small extent. The Hanceville gravelly fine sandy loam and fine sandy loam types are used extensively for the growing of cotton and corn. They are lacking in organic matter and are generally in need of lime. The loam type is cultivated extensively; it has good drainage and is free from large quantities of rock fragments.

The Conway silt loam is the typical valley soil of the county. Much of the type is in need of drainage. The better drained areas give moderately good yields of cotton, corn, vegetables and sweet and Irish potatoes The wet areas furnish excellent pasturage and hay.

The brown first-bottom soils along the streams other than the Arkansas River are mapped as the Pope fine sandy loam and silt loam. They are particularly well adapted to the growing of corn. The gray equivalent of the Pope series is the Atkins, of which series the silty clay loam and clay are encountered in Faulkner county. These soils are prevailingly in need of better drainage.

The Muskogee silt loam is a poorly drained terrace soil occuring along the outer margin of the Arkansas River bottoms. It lies above overflow. Fair yields of cotton and corn are obtained on this soil.

The first-bottom soils along the Arkansas River are mapped as the Portland, Yahola and Miller series.

The Portland very fine sandy loam and silt loam have brown surface soils and chocolate-brown to chocolate red subsoils. Almost all their acreage is used for growing cotton and corn or as pasture land. The Portland clay is a very productive soil, but it is deficient in drainage. Parts of it have been reclaimed by ditching and as much as 1 bale of cotton per acre is produced.

The Yahola very fine sandy loam is used extensively for growing cotton and corn. A part of the type lies above normal overflow. Drainage is good.

The Miller series is characterized by chocolate-red or chocolate-reddish brown surface soils and chocolate-red subsoils. The Miller silty clay loam and clay are among the most highly esteemed soils in the country, giving good yields of cotton, corn and alfalfa.

Riverwash includes areas of loose sand which are frequently overflowed and have little agricultural value.

Rough stony land comprises very stony ridge areas and steep slope land. It is too stony or steep for cultivation, but is suited in some measure to forestry and grazing.—Soil Survey of Faulkner County, Arkansas, by E. B. Deeter, In Charge, and Henry I. Cohen, U. S. Bureau of Soils, 1919.

HEMPSTEAD COUNTY.

There are 33 types and one phase of soils mapped in Hempstead county. These are grouped in 20 series. About 75 per cent of the soil material is residual in origin and the remainder alluvial. The fine sandy loam and clay types predominate. The residual or upland soils are classed with the Houston, Oktibbeha, Sumter, Susquehanna, Lufkin, Ruston, Orangeburg, Norfolk and Caddo series; the soils of the first bottoms of flood plains with the Trinity, Miller, Yahola, Portland, Bibb and Ochlockonee series, and those of the second bottoms or stream terraces with the Kalmia, Amite, Leaf, Myatt and Muskogee series.

The Houston clay is the most productive upland type of Hempstead county, practically all of it is under cultivation. It is especially well suited to the production of long and short staple cotton, corn, cowpeas, peanuts and alfalfa.

The soils of the Oktibbetha series—an upland series—are of moderate extent. They are underlain by calcareous deposits at shallow depths and are productive. Between 50 and 75 per cent of their area is under cultivation .

The Sumter clay has a rolling to hilly topography and is very much washed and dissected by gullies. General farming is carried on to a small extent on this soil, but yields are below the average for the county.

The Susquehanna very fine sandy loam is one of the most extensive and important soils of the county. Cotton, corn, cowpeas, sorghum and oats do very well on this type and on the better drained portions of the Susquehanna silt loam and clay. The Susquehanna gravelly loam has a rolling to hilly topography. The rougher areas are best suited to pasturage, but the smoother areas are fairly suitable for cultivation.

The Lufkin clay is a poorly drained soil of low agricultural value. Cotton, corn, oats, sorghum and Bermuda grass are grown, but the yields are low.

The Ruston very fine sandy loam and fine sandy loam are the predominating types of the county. They are well suited to general farming and to the production of cantaloupes and early radishes. The Ruston gravelly sandy loam is a very inextensive type, cultivated in conjunction with the fine sandy loam. Yields are somewhat lower than on the latter type.

The Orangeburg fine sandy loam, although comparatively inextensive, is a productive soil. Cotton, corn, cowpeas, sorghum, peanuts, oats, cantaloupes, early radishes and a variety of other crops are grown. The soil is well suited to peaches and other fruits. The Orangeburg gravelly fine sandy loam is somewhat less productive than the fine sandy loam.

The Norfolk fine sand is especially well suited to peaches. cantaloupes, early radishes and truck crops. Fair yields of cotton and corn are obtained.

The Caddo very fine sandy loam and silt loam are poorly drained and unimportant, only a relatively small proportion of their area being suitable for cultivation. Cotton, corn and grasses are the principal crops.

The Trinity clay, where drained, is one of the strongest soils of the county. Corn, cotton, alfalfa and Bermuda grass do especially well.

The Miller very fine sand and clay are well suited to cotton, corn, alfalfa and Bermuda grass. The poorly drained areas are not in cultivation.

The Yahola silty clay loam, while comparatively inextensive, is an important soil. It is well suited to cotton, corn, alfalfa and Bermuda grass.

The Portland clay is very poorly drained and probably less than 5 per cent of it is under cultivation. It is naturally a strong, productive soil.

The Bibb very fine sandy loam and clay are very poorly drained and are subject to inundations. They are used almost exclusively for grazing.

The Ochlockonee very fine sandy loam, silt loam and clay, where properly drained, are very well adapted to the production of cotton and corn. The poorly drained areas are used for pastures.

Most of the Kalmia very fine sandy loam, on account of poor drainage, is used only for grazing, but where fair drainage has been established moderate yields of cotton, corn, cantaloupes and early radishes are obtained.

The Amite loam, although inextensive, is one of the best general-farming and trucking soils in the county. Nearly all of it is under cultivation.

The Leaf silt loam, where properly drained, gives good yields of cotton, corn, cowpeas and oats. The Leaf clay is used largely for grazing.

The Myatt very fine sandy loam and clay are poorly drained and unimportant. Only about 5 per cent of the former and none of the latter is cultivated.

The Muskogee clay loam is a poorly drained soil, used mainly for grazing. A few small fields are devoted to the production of cotton and corn, and fair yields are obtained.—Soil Survey of Hempstead County, Arkansas, by Hugh E. Taylor, In Charge, and W. B. Cobb, U. S. Bureau of Soils, 1917.

HOWARD COUNTY

This county includes four distinct groups of soils: Upland soils, derived from the weathering of sandstone and shale; upland soils of sedimentary origin; terrace or old-alluvial soils; and first-bottom or recent-alluvial soils. The soils are separated into 34 types, representing 21 series, in addition to Rough stony land.

The upland soils of residual origin, embraced in the Appalachian Province, are classed in the Hanceville series. Those derived from Coastal Plain sediments are classed in the Greenville, Orangeburg, Ruston, Caddo, Susquehanna, and Oktibbeha series where noncalcareous, and in the Houston and Sumter series where calcareous. The terrace soils are classed in the Amite, Cahaba, Kalmia, Myatt, and Leaf series. The first-bottom soils of calcareous nature are correlated with the Trinity, Catalpa, and Portland series, and the non-calcareous types with the Hannahatchee, Ochlockonee, Bibb, and Pope series.

The Hanceville fine sandy loam is the most important of the residual soils, which occupy the northern part of the county. The Hanceville soils are well to excessively drained, and in general are good agricultural types.

The Coastal Plain soils are desirable agricultural types, well suited to a wide range of crops. The Greenville gravelly loam is one of the most important peach soils in the United States.

The terrace and first-bottom soils are very productive types where well drained. Owing to their generally level surface they need artificial drainage in many places.

The soils of Howard County offer good opportunities for diversified farming. The sandy soils are well adapted to trucking and general farming. The gravelly soils are well suited to fruit. The calcareous soils are especially adapted to alfalfa and long-staple cotton. In general the soils are deficient in organic matter, and on many of the types commercial fertilizer is apparently necessary for the best results.—Soil Survey of Howard County, Arkansas, by M. W. Beck, in charge, M. Y. Longacre, F. A. Hayes and W. T. Carter, Jr.

JEFFERSON COUNTY.

Twenty-two soil types, representing ten series, are mapped in the county. The soils are classed in two general groups, the upland or sedimentary soils and the lowland or alluvial soils. The upland soils are the direct product of the weathering of unconsolidated sedimentary deposits of the Tertiary age. They comprise five soil series, the Ruston, Susquehanna, Caddo, Norfolk and Lufkin. The upland soils, excluding the Ruston, are poorly drained and require ditching or tiling to make them fully productive. They are also acid.

The lowland or alluvial soils are derived from two main sources, (1) material transported from the Permian Red Beds, giving rise to the Miller series, and (2) reassorted material of the upland soils, forming the Portland and Yahola soils of the Arkansas River flood plain and the Ochlockonee and Bibb soils along the small streams traversing the upland. The heavier types of the bottom soils, the silty clay loams and clays are usually imperfectly drained, a condition which can be improved largely through the construction of lateral drainage ditches to the main canals which are completed. The sandy and silt loam types of the alluvial soils constitute the best agricultural land in the county. They are very productive where carefully farmed.

There is a general lack of organic matter in the soils, a condition which warrants the general recommendation that every economical means be employed to increase this constituent through rotation, manuring, legume growing and green manuring. This will necessitate greater diversification of farm enterprises than under the present one-crop system, but the change will increase the yields of cotton, the money crop. In addition a large part of the present expenditures for food supplies will be saved and the necessity of buying nitrogen in commercial forms will be to some extent removed.—Soil Survey of Jefferson County, Arkansas, by B. W. Tillman, In Charge, R. R. Burn, W. B. Cobb and Clarence Lounsbury, of the U. S. Department of Agriculture, and G. G. Strickland, of the Arkansas Agricultural Experiment Station, 1916.

MISSISSIPPI COUNTY.

The soils range from loose, incoherent sands to heavy, plastic clays. They are divided into two general classes, the first-bottom soils and the second-bottom or terrace soils.

The Sharkey soils, of the first bottoms, are the most important in the county. They are poorly drained for the most part, but occur in large bodies and are strong and productive. A large part of this series is still in forest. Good yields of cotton, corn, and alfalfa are obtained on the Sharkey clay, better drained phase.

The Sarpy soils are uniformly brown in color and have sandy subsoils. They occur along the banks of the Mississippi River and other streams. The very fine sandy loam, silt loam and silty clay loam are the most important types. Good crops of alfalfa, cotton, corn and red clover are grown on these soils.

The Yazoo soils occur in the vicinity of Clear Lake, Archillion and Archillion Station.

The Wabash series is represented by one type, the Wabash clay. The soil occurs in low depressions throughout the terraces of the northwestern part of the county.

The terraces or second bottoms are situated west of Big Lake in the northwestern corner of the county. They are not subject to ordinary overflow. The soils of the terraces are classed with the Lintonia and Calhoun series.

Lintonia are the more important of the terrace soils. They are uniformly brown in color, and for the most part sandy in texture. Good crops of corn and cotton are grown on these soils.

The Calhoun soils occur in small areas, and represent low, poorly drained spots in the terraces.

Meadow and Overwash are miscellaneous soil types mapped.—Soil Survey of Mississippi County, Arkansas, by E. C. Hall, T. M. Bushnell, L. V. Davis, William T. Carter, Jr. and A. L. Patrick. U. S. Bureau of Soils, 1916.

POPE COUNTY.

The soils are residual and alluvial. The former are derived from sandstones and shales and the latter from western residual prairie materials and from local alluvium.

Six upland residual soils are mapped in addition to the Rough stony land classification. Five of these belong to the Hanceville series and one to the Conway series. Of the alluvial soils of the upland, five types belong to the Pope series, one to the Atkins series and two to the Waynesboro series. Of the Arkansas River soils 14 types besides Riverwash are mapped. These soils represent the Reinach, Yahola, Bastrop, Brewer, Osage, and Muskogee series. The stony loam, fine sandy loam and loam of the Hanceville series each have a low phase.

The Hanceville fine sandy loam is used for the production of cotton and corn and miscellaneous crops. Fruit, particularly peaches, is an important product. The low phase is devoted to about the same crops, but has a lower elevation and is more accessible.

The Hanceville stony loam is a rough soil, but portions of it are fairly well suited for cultivation. This type is adapted to fruit growing.

The Hanceville very fine sandy loam, shale loam and the low phase of the loam are comparatively heavy textured soils suitable for general farming. They need thorough cultivation and an increase in humus supply. The Hanceville loam, being a mountain soil, is not adapted to cotton, but produces fair crops of corn and small grains. Vegetables and fruit do well.

The Conway silt loam in general is a low, poorly drained soil not well suited in its present condition to general crops. Grass does well and stock raising could easily be conducted on it. The soil is in need of artificial drainage.

The Pope silt loam is an alluvial soil. It is well adapted to corn and cotton. Portions of the type have rather poor drainage. The Pope loam has about the same value as the silt loam.

The Pope fine sandy loam is suited to corn and cotton, vegetables and truck crops. The soil is in need of organic matter.

The Pope sandy loam and the stony loam are well suited to corn and to some extent to cotton and miscellaneous crops. The type is so rough that cultivation is difficult, but it is considered a strong soil.

The Atkin silt loam is poorly drained alluvial soil, which is mainly forested. Cleared areas afford some pasturage.

The Waynesboro loam and stony loam are suited to general farming.

The Reinach very fine sandy loam is an Arkansas River soil, chiefly devoted to cotton and corn. The Reinach fine sand is droughty and has a low agricultural value. The silt loam of this series is suited to cotton, corn and forage crops.

The Yahola very fine sandy loam has practically the same value as the Reinach very fine sandy loam. The Yahola very fine sand and the fine sand are loose, porous soils inclined to be droughty. They comprise good Bermuda grass pastures, and are well adapted to vegetables and early truck crops. The Yahola silt loam gives good yields of cotton and corn.

The Bastrop clay produces fair crops of cotton, but is rather too heavy for corn. On a few better-drained fields alfalfa does well. Portions of the type are poorly drained.

The Brewer silt loam and very fine sandy loam are dark-colored soils, well suited to corn and cotton, the Brewer clay is a heavy soil, portions of which are rather poorly drained. Good crops of cotton are produced, and on the better-drained phases alfalfa makes a good growth.

The Osage silt loam has about the same value as the Brewer silt loam.

The Muskogee silt loam and very fine sandy loam are high-terrace soils fairly well suited to general crops.

Rough stony land is a nonagricultural type, suitable for forestry.

Riverwash is of small extent and has no present agricultural value.—Soil Survey of Pope County, Arkansas, by Clarence Lounsbury and E. B. Deeter, U. S. Soil Survey, 1915.

PRAIRIE COUNTY.

The soils of the area are derived from unconsolidated materials which were laid down in quiet water. There were eight types mapped. The Acadia silt loam is the most extensive, covering about one-third of the area of the county. It occupies the timbered uplands area, and much of it is under cultivation. It gives good yields of cotton, corn and oats.

The Crowley silt loam is next in point of extent, covering about 24 per cent of the area of the county. It is a friable and easily tilled soil and especially adapted to the production of grain.

The Waverly clay nearly equals in extent the type last mentioned. It is a river bottom soil and subject to overflow. In favorable seasons good yields of cotton and corn are secured.

The Waverly silt loam is a poorly drained type found in depressions occupying intermittent stream valleys. The type is little cultivated, but could be made productive by proper drainage.

About 1,300 acres only of the Biscoe silt loam occur in Prairie county. It is found in the eastern part of the county between Cache and White rivers. It is adapted to cotton, which gives moderate yields. Corn is a secondary crop. A sandy phase could be used for trucking.

The Calhoun clay, a low-lying upland soil, has about the same extent as the Biscoe loam. The surface is level and the drainage is poor, and at present the type is but little cultivated, though it would be a very good cotton soil if reclaimed.

The Collins silt loam, a type of minor importance, occupies about 2 per cent of the entire county. It occurs along small streams. The principal money crop is cotton, of which small yields are secured. Corn and potatoes are also important products.

The Morse clay is an unimportant type occuring along the slopes of streams. It is difficult to cultivate and gives only moderate yields of cotton and corn.

The soils in the prairie section are well adapted to the production of rice, where irrigation is practicable. The rice industry has made considerable progress in other counties of Arkansas and there appears to be an excellent opportunity for rice growing in this section. The water for irrigation will have to be pumped from wells.

The greater part of the Crowley silt loam would be greatly improved by underdrainage. The bottom-land types are overflowed, but possibly could be protected by levees and would be valuable land for corn and cotton if reclaimed.—Soil Survey of Prairie County, Arkansas, by William T. Carter, Jr., F. N. Meeker, Howard C. Smith and E. L. Worthen, U. S. Bureau of Soils, 1907.

YELL COUNTY.

The upland soils are residual from sandstone and shale. The alluvial soils consists largely of material derived from the local uplands, although the soils of the Arkansas River bottoms are composed largely of residual prairie material. Including Riverwash and Rough stony land, 23 soil types are mapped in Yell county.

The upland soils are included in the Hanceville and Conway series. Some of the Hanceville stony loam is adapted to the production of fruit, but the steeper areas and those more remote from shipping points offer better opportunities for stock raising than for any other use. The Hanceville fine sandy loam and very fine sandy loam are fairly strong soils for cotton and corn, and produce fruit of good quality. They are deficient in organic matter. The Hanceville loam is extensively cultivated. Deeper plowing and the more general growing of legumes are necessary for best results on this type.

The Conway silt loam is an extensive upland soil type occuring throughout the valley areas. The surface is level to gently rolling and the type is, in general, poorly drained. Liming and artificial drainage should make the soil more productive.

The terrace or second-bottom soils include the Waynesboro, Bastrop, Reinach, Brewer, Teller and Muskogee series. The Waynesboro series is developed along the smaller streams of the county, draining the local uplands, while the remaining terrace series named are developed in the Arkansas River Valley.

The Waynesboro loam is a relatively inextensive soil of moderate productiveness. Cotton and corn are the chief crops. Corn yields from 15 to 30 bushels and cotton from one-third to one-half bale per acre. Drainage is deficient in places.

The Bastrop very fine sandy loam resembles the Miller very fine sandy loam. It is a well-drained, productive type, of small extent. The Reinach very fine sand is mainly used for cotton and corn, but melons and cantaloupes of excellent quality can be grown on this soil. The Brewer silt loam and Brewer clay are low second-bottom soils, dark brown to black in color. The silt loam is a durable soil and is well drained. The clay in many places is poorly drained. Both types are good cotton soils. The Teller very fine sandy loam is a high-lying second-bottom soil. It has a brick-red subsoil. The Muskogee silt loam is a poorly drained terrace soil developed on the outer margin of the Arkansas River bottoms. Artificial drainage is necessary to fit land of this type for cultivation.

The alluvial first-bottom soils along the smaller streams are classed in the Pope and Atkins series. The Arkansas River first-bottom soils, where the source of the alluvium is largely residual prairie soils and permian Red Beds materials, are classed in the Miller and Osage series.

The Pope series includes the fine sandy loam, loam and silt loam types. These are productive soils. The Atkins silty clay loam and clay are poorly drained soils subject to overflow. They are best suited in their present condition for use as hay and pasture land.

The predominating color of the Miller very fine sandy loam, silt loam and clay is brownish red. These soils produce good yields of cotton, corn and alfalfa. They are naturally calcareous. The Osage clay is an intractable soil, generally poorly drained. It is known locally as "black gumbo."

Riverwash includes areas in which the soil is a mixture of river-deposited sands and clays. The land is frequently overflowed and is of little agricultural value.

Rough stony land includes slopes of rough topography and stony nature, valuable only for the timber and pasturage afforded.—Soil Survey of Yell

County, Arkansas, By E. B. Deeter, In Charge, and Clarence Lounsbury, U. S. Bureau of Soils, 1917.

REFERENCES.

Ashley County, by E. S. Vanatta, B. D. Gilbert, E. B. Watson, and A. H. Meyer, 1914.

Columbia County, by Clarence Lonnsberry and E. B. Deeter, 1910.
Craighead County, by E. B. Deeter and L. Vincent Davis, 1917.
Conway County, by Jas. L. Burgess and Chas. W. Ely, 1908.
Howard County, by M. W. Beck, M. Y. Longacre, F. A. Hayes and W. T. Carter, Jr., 1919.

Fayetteville area, by Henry Wilder and Chas. F. Shaw, 1907.
Hempstead County, by Arthur E. Taylor and W. B. Cook, 1917.
Jefferson County, by B. W. Tillman, G. G. Strickland and others, 1916.
Mississippi County, by E. C. Hall, T. M. Bushnell, L. V. Davis, Wm. T. Carter, Jr., and A. L. Patrick.

Ozark region of Missouri and Arkansas, by Curtis F. Marbut, 1914.
Pope County, by Clarence Lonnsbury and E. B. Deeter, 1915.
Prairie County, by Wm. T. Carter, Jr., F. N. Meeker, Howard C. Smith and E. L. Worthen, 1907.

Stuttgart area,
Yell County, by E. B. Deeter and Clarence Lonnsbury, 1917.
Faulkner County, by E. B. Deeter and H. I. Cohen.
Drew County, by B. W. Tillman.
Perry County, in progress.
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