MISSOURI
BUREAU OF GEOLOGY
AND MINES

BIENNIAL REPORT *of the*

STATE GEOLOGIST

TRANSMITTED BY THE

BOARD OF MANAGERS OF THE BUREAU
OF GEOLOGY AND MINES TO THE
FIFTY-SIXTH GENERAL
ASSEMBLY, 1931

H. A. BUEHLER
DIRECTOR AND STATE GEOLOGIST
ROLLA, MISSOURI

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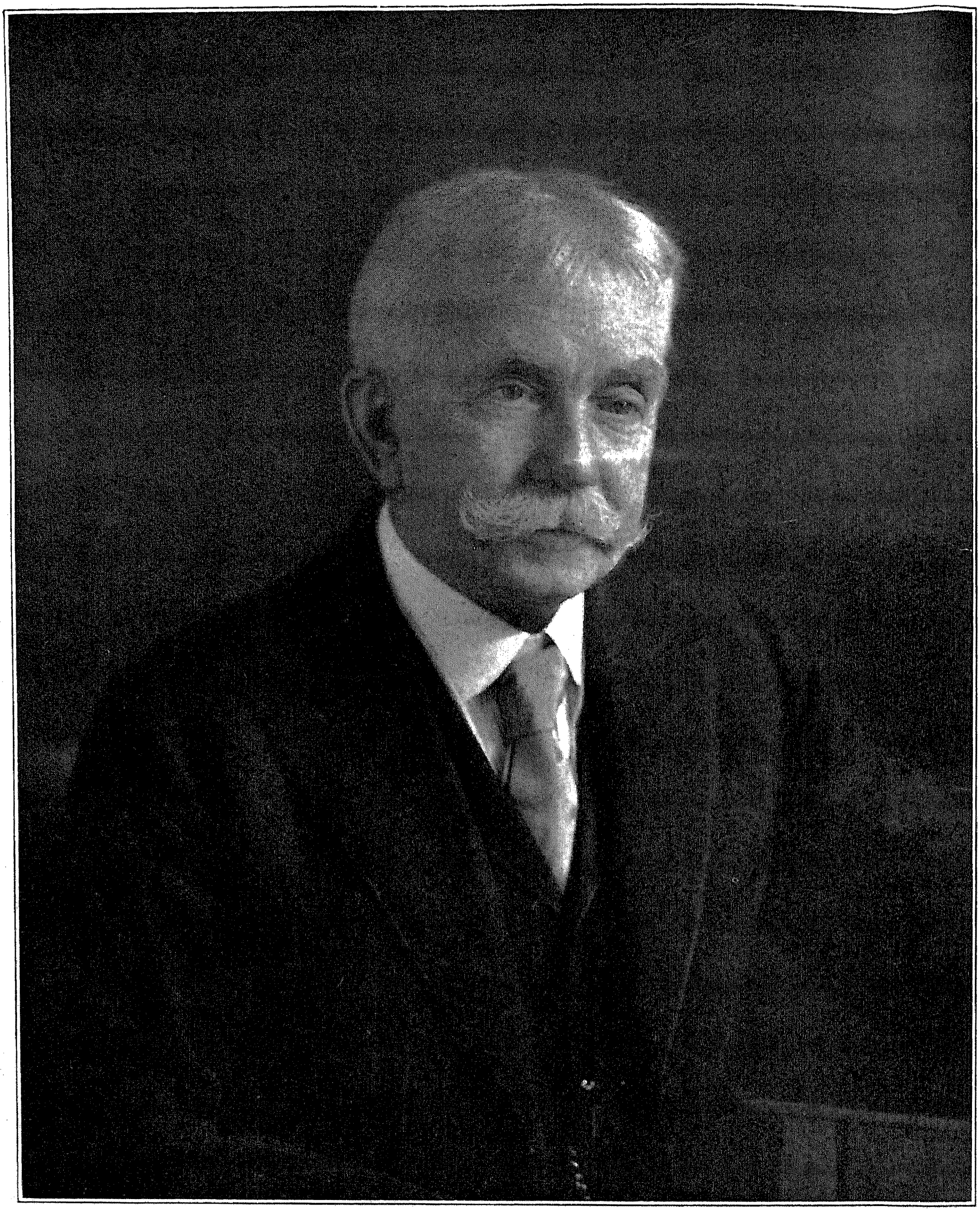


PHILIP NORTH MOORE

PHILIP NORTH MOORE.

Philip North Moore, who died suddenly at St. Luke's Hospital, St. Louis, January 19th, 1930, was appointed a member of the Board of Managers of the Missouri Bureau of Geology and Mines, by Governor Herbert S. Hadley in 1910, and served continuously under each successive administration until his death.

Dr. Moore, recognized as one of the outstanding mining engineers of the United States, was born July 8th, 1849, at Connersville, Indiana. His father, Henry C. Moore, was a civil engineer and at one time was Chief Engineer of the Missouri Pacific Railroad. His brother, Robert Moore, was for many years an outstanding civil engineer of St. Louis and the Middle West.

After receiving the degrees of A. B. and A. M., from Miami University, Oxford, Ohio, Mr. Moore spent two years at the School of Mines at Columbia University, New York, where he specialized in Geology and Mining Engineering. In 1872 he then entered upon his life work as an assistant on the Michigan Geological Survey. The following year he accepted a similar position on the Missouri Geological Survey, having as his special province the investigation of the iron ore deposits of the Ozark region. With his characteristic energy and thoroughness he studied these deposits in detail and the accuracy of his descriptions and conclusions have stood the test of sixty years of subsequent exploration. During this work he made an accurate magnetic map of Iron Mountain, a map which has proven of much value in recent explorations. After a number of years on the Kentucky Geological Survey, Mr. Moore entered the mining and metallurgical field, going to Leadville, Colorado, in 1878, where he erected and operated the first smelter in that pioneer camp. In 1882, he returned to the South and engaged in mining and smelting iron ores throughout Kentucky, Alabama and Georgia. In 1889, he moved to St. Louis and his subsequent activities as an executive in several mining companies and as a consulting engineer took him to many parts of the North American Continent.

Mr. Moore was ever active and zealous in the advancement of his chosen profession. Holding the highest of personal ethics, he instilled the same spirit in those around him. His ability and high ideals were recognized by his conferes who bestowed upon him the highest honors within their power.

The American Institute of Mining and Metallurgical Engineers elected him President in 1917, and bestowed upon him the badge of the Legion of Honor in 1929; a distinction conferred only upon members who have belonged to the Institute for fifty years. His Alma Mater, Miami University, in 1920 conferred upon him the degree of Doctor of Laws. Dr. Moore was a member of American Engineering Council from 1917-1919. In 1923 to 1924 he was Vice-President of American Engineering Council. During the World War he served on the Engineering Division of the National Research Council and later became a member of the War Materials Commission of the Department of the Interior. For years he was the guiding spirit in engineering circles in St. Louis.

No finer example of Dr. Moore's devotion to public service can be cited than his long, active membership on the Board of Managers of this Bureau. Having in mind the continual development of the rich mineral resources of the State, he was ever ready to devote time and energy to the work of the department. His early geological investigations throughout the Ozark region gave him a keen insight and wide knowledge of the possibilities of future development, not only of the mineral resources but of the potential water powers, and for many years he urged that appropriations be made in order that the necessary basic facts covering stream flow could be obtained. This was finally accomplished in 1921, and today the first great unit in the future development of our hydro-electric possibilities is nearing completion on the Osage River.

Words are inadequate to express the value of his long service to the State.

In 1879, Dr. Moore was married to Mary Eva Perry of Rockford, Illinois, who with their daughter, Elizabeth, and son, Perry North, survive him.

TABLE OF CONTENTS.

BOARD OF MANAGERS.

His Excellency, Henry S. Caulfield, Governor of Missouri, ex-officio President of the Board, Jefferson City.

Hon. Elias S. Gatch, Vice-President, St. Louis.

Dr. E. M. Shepard, Springfield, Secretary and Chairman of Publication Committee.

Hon. Charles T. Orr, Joplin.

Hon. Walter McCourt, St. Louis.

LETTER OF TRANSMITTAL.

To the President, Henry S. Caulfield, and the Honorable Members of the Board of Managers of the Bureau of Geology and Mines:

Gentlemen:—I have the honor to submit herewith a brief report covering the work of the Bureau of Geology and Mines for the years 1929 and 1930.

The pamphlet contains a brief tabulated resume of the mineral production for the same period, also three appendices covering manuscripts which are not of sufficient size to form independent volumes.

Respectfully submitted,
H. A. BUEHLER,
State Geologist.

ERRATA

Plates in Appendix I, pages 102-145, inclusive, are numbered III to XIV, inclusive, while references in text give these plate numbers from I to XII, inclusive. In referring to plates, please observe the following table:

Plate numbers as referred to in text.	Corresponding numbers actually printed on plates
I	III
II	IV
III	V
IV	VI
V	VII
VI	VIII
VII	IX
VIII	X
IX	XI
X	XII
XI	XIII
XII	XIV

CHAPTER I.

WORK OF THE BUREAU OF GEOLOGY AND MINES DURING 1929 AND 1930.

The following report briefly outlines the work of the Bureau of Geology and Mines during the biennial period just past.

The Department has under its jurisdiction three related engineering branches which have for their object the development of the natural resources of the State. Summarized these are:

(1) GEOLOGY AND MINING BRANCH, DEVOTED TO THE DEVELOPMENT OF THE MINERAL RESOURCES. THE EXPENDITURES UNDER THIS BRANCH INCLUDE SALARIES, TRAVELING EXPENSES, ENGRAVING AND PRINTING OF ALL MAPS AND REPORTS, AND THE COST OF GENERAL OFFICE OVERHEAD.

(2) WATER POWER AND FLOOD-CONTROL BRANCH, DEVOTED TO AN INVESTIGATION OF THE POSSIBILITIES OF HYDRO-ELECTRIC DEVELOPMENT IN THE OZARK REGION, AND THE STUDY OF FLOOD CONTROL ON THE MAJOR RIVER SYSTEMS THROUGHOUT THE STATE. THIS WORK IS CARRIED ON IN CO-OPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY, WHICH DEPARTMENT MATCHES STATE FUNDS DOLLAR FOR DOLLAR.

(3) TOPOGRAPHIC MAPPING BRANCH, WHICH HAS FOR ITS OBJECT THE MAKING OF AN ACCURATE MAP OF THE STATE. THE FEDERAL GEOLOGICAL SURVEY ALSO MATCHES THE STATE FUNDS DOLLAR FOR DOLLAR IN THIS WORK.

The appropriation made by the 55th General Assembly to carry on the work of the three branches was $110,000. Due to over-appropriation and uncertainty of revenues $28,150.00 was withheld until August, 1930, at which time $7,500.00 was released for topographic mapping. During October, $20,450.00 was released for needed field work, publications, equipment, and mapping. The appropriation was made in a total sum, the expenditures of each branch being apportioned by the Board of Managers. The amount for Geology and Mining, including general office expense and the publication of reports and maps, was $58,271.00, for Water Power and Flood Control $19,712.00 and for Topographic Mapping $15,351.00.

PERSONNEL.

Through the death of Philip N. Moore, in January, 1930, a vacancy on the Board of Managers was created, which was filled by the appointment of Walter McCourt, Assistant Chancellor and head of the Geological Department of Washington University.

There has been no change in the permanent scientific staff of the Geological branch. In the Water Power and Topographic branches the engineers are largely Federal employees, and the personnel changes more or less each biennium.

In addition to the following members of the staff and Federal engineers, a number of temporary employees (student labor on an hourly basis) have assisted in the laboratory, drafting room, and office.

GEOLOGY AND MINING.

Permanent Staff:

H. A. Buehler, State Geologist
H. S. McQueen, Assistant State Geologist
J. M. Thiel, Geologist, Joplin Branch
C. O. Reinoehl, Draftsman
H. W. Mundt, Chemist
Jean I. McCaw, Chief Clerk
Dorothy Shaver, Stenographer
E. E. Hawkins, Laboratory Assistant

Temporary Employees:

C. L. Dake (1929)
Josiah Bridge (1929-30)
G. A. Muilenburg (1930)
F. C. Farnham (1930)
J. G. Grohskopf (1930)
W. H. Wamsley (1930)

TOPOGRAPHIC MAPPING.

F. W. Hughes and party
C. R. Fisher and party
L. V. Johnson and party
H. P. Jones and party
J. T. Schultz and party

WATER POWER AND FLOOD CONTROL.

H. C. Beckman, District Engineer (Federal)
H. C. Bolon, Junior Engineer (Federal)
R. D. Schmickle, Junior Engineer (Federal)
C. J. Eyberg, Junior Engineer (Federal)
C. H. Jennings, Junior Engineer (State)

COOPERATION.

The three branches of the Survey involve problems that touch many of the activities of other State and national bureaus. The Broad of Managers has maintained a board policy of co-operation where assistance can be rendered and duplication avoided. Due to this policy the Bureau maintains a wide range of cooperative activities as shown by the following list:

(1) With the United States Geological Survey in studying the geology of the Ozark region, in topographic mapping, in surface water supply investigations.

(2) With the United States Bureau of Mines in collecting complete statistics covering the mineral production of the state.

(3) With the United States Census Bureau in gathering statistics covering the manufactured products derived from mineral production.

(4) With the United States Weather Bureau of St. Louis in maintaining gaging stations and reporting flood conditions of Missouri streams.

(5) With the State Board of Health in providing sanitary city water supplies.

(6) With the Industrial Bureau of St. Louis in geophysical prospecting.

(7) With the State Fair Board in maintaining a mineral and forestry exhibit at the State Fair.

(8) With the State Museum Commission in collecting and installing exhibits at the Museum in the State Capitol.

(9) With drainage districts, corporations and cities in maintaining gaging stations for the purpose of determining run-off and water supply.

(10) With the State Highway Department in topographic mapping, determining stream flow, and geologic and soil investigations.

(11) With the United States Army Engineer Corps in maintaining gaging stations on the Missouri River.

(12) With the St. Louis Chamber of Commerce and St. Louis City Plans Commission on topographic mapping of Jefferson and St. Louis counties.

The State Geologist is also ex-officio member of the State Highway Commission and the State Museum Commission.

PUBLICATIONS.

The following publications were issued during the biennial period. The reports and maps issued by the Bureau give reliable information relative to the mineral and water resources not obtainable from any other source. These reports and maps are in demand where accurate information is desired, and many of the earlier volumes are now out of print. The publications of the Bureau are on file in all libraries within the State and many of the larger libraries throughout the country, where they are available for consultation.

Insoluble Residues as a Guide to Stratigraphic Studies.—This pamphlet, issued as an appendix to the biennial report is devoted to a description of the method employed in making insoluble residues from drill and hand samples, and shows that important geological correlations can be made by the use of this method. When samples of limestone or dolomite are dissolved in hydrochloric acid there remains a siliceous residue that has been found to be characteristic for each formation, and by making such residues it is possible to determine the exact horizons being penetrated in deep drilling. This work embodies one of the most important facts discovered by the Geological Survey in many years.

The pamphlet describes chiefly the correlations made on the Cambrian and Ordovician formations as determined from deep drill cuttings. There are three cross sections showing the stratigraphy throughout the Ozark region. The plate illustrations show the general character of the insoluble residues.

The Geology of the Eminence and Cardareva Quadrangles.—'his report describes the geology and mineral resources of parts f Shannon, Reynolds and Carter counties, one of the most scenic reas in the State. The geology is complicated and involves he contact between the igneous and sedimentary rocks. Here re found strata dipping as much as 25°. This dip is not due to eformation by structural movement, but is the result of initial eposition. The region is probably a type area for such conitions in the United States. There is no other equal area in the tate noted for so many large springs, and the report describes ı some detail the nature of the extensive solution that has taken lace to form these underground rivers, as well as the formation f the many large caves and sink holes. The same process has een active over the entire Ozark country, and the results of his study are applicable to the southern half of the State.)uring the last century, intermittent attempts have been made ɔ mine copper in the area, and the deposits and prospects are escribed in some detail.

The Geology of the Potosi and Edgehill Quadrangles.—This ɘport describes the geology of the most important barytes ıining district of the State. The area is one in which there is robably greater expression of unconformity and overlap than t any other place in Missouri. The report covers the country ıst west of the Bonne Terre-Flat River lead mining district, nd is an important contribution to an understanding of the eology of the eastern Ozark region.

The Pelecypoda of the Louisiana Limestone.—This pamphlet, ublished as an appendix to the biennial report, describes a series f fossils in the Kinderhook formation. The work was underıken in connection with the study of the Paleontology of the Íississippian Series.

Mexico Quadrangle Topographic Map.—This map, embracing pproximately 225 square miles, has been issued on a scale of bout two inches per mile (1/24000), and is four times the size f the standard topographic sheet. Because of the increased ze, all topographic features, drainage, and culture are much ιore easily seen and in this regard the map is far superior to the :andard sheets.

Biennial Report.—The biennial report gives a brief summary f the activities of the three branches of the Bureau and an outne of the budget request showing the needs during the coming iennial period. The three appendices cover short papers of importance but not sufficiently large to make an independent volume. Appendix I is a brief outline of the use of insoluble residues in stratigraphic studies. This work has attracted attention throughout the country. Appendix II covers the description of certain fossils of the Louisiana Limestone, and Appendix III illustrates results obtained by geophysical surveys. This type of work has much promise of being an important aid in geological field work.

FIELD INVESTIGATIONS.

Field work has been restricted to lines of investigation that have been under way for a number of years with one new activity, namely, geophysical prospecting. During the past five years electrical and magnetic methods of prospecting have been developed to a point where many geological structures and conditions favorable to ore deposition can be determined and both magnetic and electric resistivity methods have been tried during the past two field seasons. As discussed in the following pages, this work is giving very interesting results.

Joplin Office. For a number of years the Bureau has maintained a branch office in the Joplin lead and zinc district, for the purpose of keeping a direct contact with the mining industry of that region. Due to the lack of funds this branch was closed in June of this year. The region has been mapped on a large scale, and nine township geologic maps are virtually ready for publication.

Underground Water Supplies. At the present time there is probably a greater general interest throughout the State in obtaining good, reliable, city water supplies than in any other geological problem. There is no geological factor that is of greater importance to the health and welfare of the public.

There are many good water-bearing horizons underlying various parts of the State, and a knowledge of these and of the character of the overlying formations is essential in directing drilling to a successful conclusion.

In cooperation with the State Board of Health, this Bureau is making a careful study of every well drilled for public water supply. Cuttings are submitted by the driller and after detailed examinations the depth to which casing should be set is determined. By this examination the Bureau can inform the driller at all times of the depth of the closest water-bearing horizon, and many wells that might have been abandoned because of the lack of adequate supply, have been saved by drilling comparatively short distances to water-bearing sandstones. This is one of the important investigations of the Bureau. Thousands of samples of drill cuttings are on file at the Survey headquarters. These are available at all times for examination by drillers and others interested.

Stratigraphic Studies. To determine the thickness, character, and distribution of the formations lying deep beneath the surface has always been a difficult problem, due to the general similarity of the drill cuttings obtained from the penetrated strata. In general these have a bluish gray color, without distinctive characteristics. In studying the possibilities of underground water supply through deep drilling it became necessary to have a more accurate method of determining the stratigraphy. It has been found that, if the cuttings are dissolved in hydrochloric acid, the residue remaining has a distinctive character and the formation can be determined with certainty.

During the biennial period this has been one of the important investigations of members of the staff. The results have given much information relative to the subsurface stratigraphy and structure, especially of the Ozark region. More than 15,000 insoluble residues are now on file. They cover many deep drill holes as well as some 1,500 hand samples.

Geophysical Prospecting. During the past few years worldwide attention has been attracted to possibilities of discovering oil, ores, and geological structures by electrical, magnetic, and other geophysical methods. Success has been had in many cases.

Early in 1929, Mr. George C. Smith of the Indutrial Bureau of the Industrial Club of St. Louis conferred with the Director of the Survey relative to making a study of the iron ores of South Missouri, the development of which means so much to the economic structure of St. Louis and the Ozark region. The Survey at that time was without sufficient funds to undertake all of the additional field work necessary to carry out the project, and the Industrial Bureau supplied the funds to inaugurate geophysical field work. They have devoted $8,500.00 in cooperation on this investigation, paying salaries of three assistants, field expenses, and purchasing necessary instruments. The Geological Survey purchased one magnetometer and has had one assistant in the field part time.

During the field season of 1929, magnetic methods were tried in Southeast Missouri, and during 1930 both magnetic and electrical resistivity methods were tried on various geological problems. The results have been interesting and important, and have shown that certain gelogical features can be determined where it is almost impossible to reach a conclusion by any other method.

In using the magnetometer, the attraction of the earth's magnetic field is measured; the intensity varies with different formations and with different structural conditions. The porphyry of Southeast Missouri shows a decidedly strong attraction and where this series of rocks occurs buried beneath as much as 1000 to 1500 feet of sedimentary strata, the outline of a buried knob or ridge is easily detected and mapped. In like manner the attraction on opposite sides of fault planes gives different intensities. In the Iron Mountain region a large difference is shown in the ore-bearing areas. At a number of points in the Ozark region it has been shown that the iron deposits occur in the sedimentary strata along the flanks of buried porphyry ridges, and that faulting occurs in the same area. Therefore, in future prospecting, the location of these ridges is important. In the disseminated lead district two areas have been mapped, showing the contour of the basement igneous rocks beneath from 400 to 600 feet of dolomite and sandstone. Drilling in these areas indicates that the mapping is correct. A few of the results are shown in the accompanying illustrations in Appendix III, of this report.

Depending upon its composition, porosity and other physical features, each ore and rock formation has a characteristic resistance to the flow of the electric current, and by determining the electrical resistance with depth there is a possibility of determining different stratigraphic and structural features. One party using this method has been employed during the past summer in cooperation with the Industrial Bureau. The field work has determined that sink structures, faults, and a change in physical characteristics can be well defined in many cases. Some of the results obtained are illustrated in Appendix III.

During the present season only a start was made on the many problems to which geophysical methods may be applicable. Much additional work is needed to develop the possibilities.

Oil and Gas Investigations. During the past two years much interest has been manifested in possible oil and gas production in northwest Missouri and in the vicinity of St. Louis where the spectacular development of the Dupo field of western Illinois aroused much speculation as to the extent of favorable structural conditions just west of the Mississippi River.

Because of this interest one assistant has spent the present season in studying the stratigraphy in Cass, Jackson, Clay, and Clinton counties, where most of the drilling has been done. Several gas and oil pools have been found during the past year at comparatively shallow depths. The type of structure is not pronounced, although the production is always found in structural highs. The reconnaissance work by the Survey indicates several areas that apparently are structurally favorable, and at present a plane table survey is being made of an area in Clinton County.

Cuttings from a number of holes drilled in the St. Louis area have been studied carefully. Although no production has been encountered, the drilling has shown possible structural features that should be mapped in detail, so that future drilling might be located in the most favorable territory.

Information Bureau. The Survey is constantly receiving requests for information relative to the geology of specific areas or certain mineral deposits and water powers, and one of the important functions is to see that reliable information is given in answer to such requests. This is done either by direct correspondence, by printed reports, or through a personal visit by a member of the staff.

As a result of one such inquiry the Survey was able to guide persons in St. Louis to a proper source of dolomite to be used in making open-hearth clinker. Analyses in the files of this Bureau indicated that the Bonneterre formation alone had the desired chemical composition. The Valley Dolomite Company is now operating a large quarry and plant near Bonne Terre, Missouri, based on this information.

Chemical Laboratory. Because of the cooperative agreement with the State Board of Health, the chemist of the Survey has made complete analyses of 200 samples of city water supplies during the present biennial period. The work, for the first time, has given accurate data upon the character of waters obtained from surface and deep well supplies, as well as indicating the quality of water obtainable from the various water bearing horizons throughout the State. These analyses, in addition to those made some years ago of surface supplies, as obtained from springs and rivers, give rather complete information concerning the general water supplies of the State. In addition to this work many analyses have been made on samples of minerals and rocks submitted by citizens for identification, and those requiring analyses as brought in by members of the staff.

Museum and Library. A museum of type collections of ores, rocks, minerals, and fossils, chiefly from the State, is maintained for study purposes at the headquarters of the Survey. It is invaluable to the members of the staff, and is of importance to citizens and engineers who are particularly interested in knowing the kinds and character of the rocks and ores found in Missouri.

A reference library consisting wholly of reports of other domestic and foreign geological surveys and scientific societies is also maintained at Rolla. These volumes are obtained in exchange for the reports of the Bureau. The library is open to the use of engineers and others desiring information relative to geological information in this and other countries, and is used constantly by the staff.

TOPOGRAPHIC MAPPING.

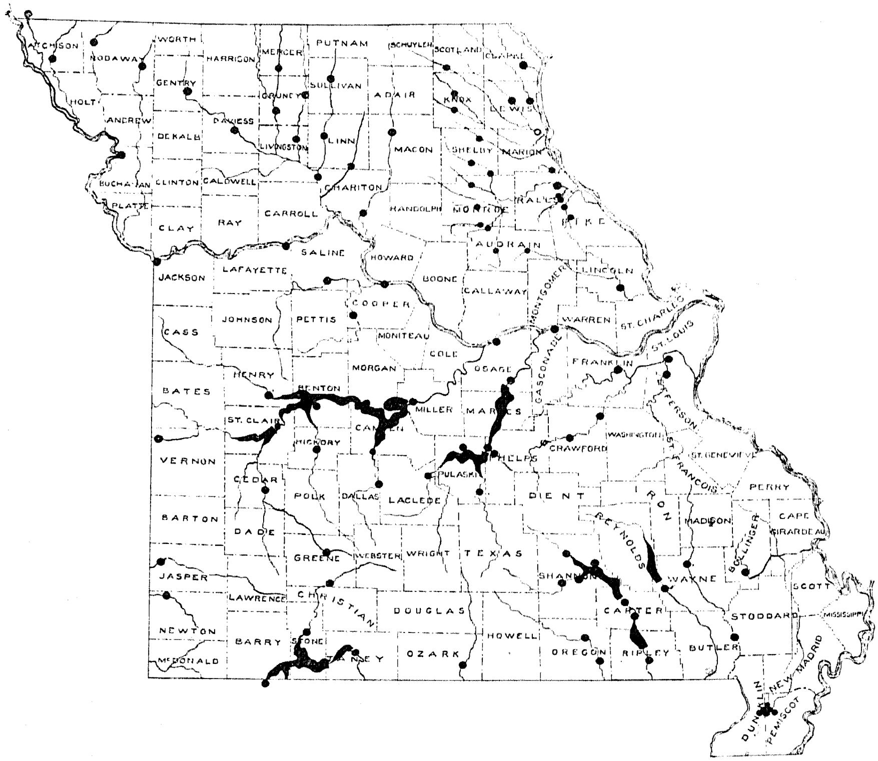
During the previous biennial period, the Mexico Quadrangle comprising approximately 225 square miles had been partially mapped. At the beginning of the present biennium, this map was completed but the work in other areas was discontinued because of withheld funds.

In August and October, 1930, these funds were released and topographic mapping was started in Jefferson, Cole, Boone, and Callaway counties.

There have been urgent requests for mapping, not only in these areas but in many regions which cannot be surveyed for a number of years unless the funds for this work are materially increased.

The mapping in Jefferson and St. Louis counties will cover an area of approximately 1,000 square miles and will include the industrial and suburban districts of St. Louis. The Illinois Geological Survey is completing a similar area including East St. Louis and Alton. The combined map will show every feature of one of the important population and industrial centers of the United States. The ultimate area to be covered in central Missouri includes the region between Jefferson City and Columbia, and south towards Eldon and the Bagnell Dam. This mapping should extend eastward to the Mississippi River, including the important fire clay district of Audrain and adjoining counties.

Missouri Bureau of Geology and Mines, Biennial Report, 1929-1930, Plate I.



Map showing location of gaging stations and lakes to be created by proposed hydro-electric developments.

WATER RESOURCES INVESTIGATIONS.

The work of the Bureau during the biennial period relating to the water resources of the State has consisted principally of a continuation of the stream flow investigations for use in water-power, flood-control, drainage, and water-supply developments. These investigations have been carried on, as in the past, in cooperation with the Water Resources Branch of the United States Geological Survey, which organization furnished trained personnel to carry on the work and during the biennial period contributed $13,100 to its cost. Twenty-nine new gaging stations were established, all at the request of cooperating parties. Two stations were discontinued. At this time ninety-six gaging stations are being maintained on the principal streams of the State, at the places shown on the accompanying map. At most stations a local resident reads a gage once or twice a day to determine the height of the water. At a few stations a continuous height record is obtained by means of recording gages. The engineers make measurements of the flow, or discharge, of the stream in terms of cubic feet per second, prepare rating curves and tables showing the flow for any gage height, and then compute from the daily gage heights the flow for each day of the year.

During the biennial period the Bureau received many requests for stream flow records for use in planning water-power, flood-control, drainage, and water-supply developments. The records have been used in planning or constructing water-power developments exceeding 700,000 horse power as follows:

The West Missouri Power Company, during the biennial period, completed the construction of a dam on Osage River at Osceola. The dam is 13 feet high and 400 feet long, and the power plant has a capacity of 2,400 horse power.

The Missouri Electric Power Company, during the biennial period, constructed a hydro-electric plant on Niangua River near Lebanon. The dam and tunnel through the hill develop a head of 40 feet and the power plant has a capacity of 4,000 horse power.

The Empire District Electric Company is now installing additional equipment in its hydro-electric plant on White River near Forsyth which will raise the capacity from 15,600 to 25,600 horse power.

The Union Electric Light and Power Company is now constructing a dam on Osage River near Bagnell which will be 100 feet high and 2,543 feet long. It will create a lake having a length of 129 miles, a shore line of 1,300 miles, and an area of 95 square miles. The power plant will have an initial installed capacity of 201,000 horse power, and will have provision for an ultimate capacity of 268,000 horse power.

The Empire District Electric Company has obtained permits from the State and Federal Government for a hydro-electric plant on White River at Table Rock near Branson. The dam is to be about 197 feet high, 1900 feet long, and will create a lake of 29,000 acres. The plant will have a generating capacity of about 220,000 horse power.

The Gasconade River Power Company has preliminary permits for the construction of two hydro-electric plants on Gasconade River between Jerome and Rich Fountain. The total capacity of the proposed plants is about 100,000 horse power.

Willis H. Meredith of the Black River Hydro-Electric Company has a preliminary permit for the construction of a dam on Black River, three miles above Leeper, Wayne County, which is intended to serve for the development of electrical power and to reduce floods along the lower stretches of the river. Surveys for the project have been made. The tentative plan is to install a plant which will develop about 30,000 horse power.

Three companies have applied for preliminary permits for hydro-electric developments on Current River. The plans of one of these companies contemplates the construction of three dams between the mouth of Jacks Fork and Doniphan and a total installation of about 80,000 horse power.

The location of these hydro-electric projects and the approximate areas of the lakes that would be created by the dams are shown on the accompanying map. The total capacity of the plants exceeds 700,000 horse power and the estimated cost exceeds $100,000,000. A good start on this construction program has been made during the biennial period. The completion of the entire program would be a great benefit to the State, by extending the use of electrical service, stimulating manufacture, and creating in the Ozark region wonderful pleasure-resort districts which would be visited each year by many thousands of pleasure seekers. The stream flow records which are being collected by the Bureau serve as the basis for the design and financing of these projects and in a large measure determine their feasibility. Without such records these projects could not be undertaken.

The disastrous floods which have visited Missouri, as well as this entire section of the country, during the past few years have made flood-control a matter of great importance. The frequent and costly losses from floods in the State, which during 1927 and 1928 alone are estimated at more than $10,000,000, have created a widespread demand for relief. The stream flow records collected by the Bureau are indispensable to the intelligent designing of flood-control works. These records show the magnitude, duration, and frequency of floods; hence the engineers can definitely determine the size of the channels, levees, or storage reservoirs necessary for proper control. Without such records the plans would have to be based largely upon estimates, probably resulting in many costly errors. During the biennial period the Bureau has received many requests from engineers in private practice for information to be used in flood control studies.

Under the authority of House Document No. 308, Sixty-ninth Congress, the United States Army Engineers are now making a study of the feasibility of improving all the important streams of the country for the combined purposes of flood-control, power development, and navigation. Such a study of all the larger streams of Missouri is now being made and in this work extensive use is made of the stream flow records being collected by the Bureau. For use in this work the engineers desired records of flow at more places than the Bureau was collecting them. For this reason the services of the United States Geological Survey (with whom the Bureau cooperates) were used to establish and maintain 16 additional gaging stations in the State. During the biennial period the sum of $14,100.00 for the support of these stations was contributed by the U. S. Army Engineers Office.

The State Highway Department has made frequent use of the stream flow records collected by the Bureau in designing new bridges for the State Highway System. In order to obtain more complete information the Highway Department assisted the Bureau in establishing 18 new gaging stations and is now co-operating in the maintenance of these stations by furnishing the services of maintenance men to read the gages.

The widespread interest through the State in the stream gaging work is evidenced by the large number of requests for the records and also by the amount of cooperation furnished by private and public agencies interested in developing the streams for water power, flood control, drainage, water supply, bridge design, and other purposes. These agencies contributed $8,-900.00 during the biennial period in order to assist the expansion of the work. This is exclusive of the amounts contributed by the United States Geological Survey and the United States Army Engineers, and the services furnished by the State Highway Department, as noted above. The following list gives the names of those who cooperated and the number of gaging stations each helped to maintain:

Missouri Highway Department	18
Missouri Game and Fish Department	4
United States Army Engineers	16
United States Weather Bureau	5
Little River Drainage District	7
Empire District Electric Co	4
Union Electric Light and Power Co	2
Missouri Hydro-Electric Power Co	3
Gasconade River Power Co	3
Missouri Electric Power Co	1
Black River Hydro-Electric Co	1
Springfield City Water Co	2
Chicago-Great Western R. R. Co	1
Total	67

At the present time these agencies are cooperating in maintaining 63 of the 96 gaging stations.

FUTURE WORK OF THE BUREAU.

Formerly the General Assembly made definite appropriations to cover the work of each branch of the department. The last Session made the appropriation in one sum, leaving to the judgment of the Board of Managers the allocation of the funds to each branch.

According to the Budget law passed at the last Session, requests for appropriation must be segregated under five major divisions, and separated into individual items under each division.

The following tabulation is a copy of the request submitted to the State Tax Commission for funds to cover the work of the department during the next biennial period. The need for each item is explained briefly, and the general plan of future work is outlined.

APPROPRIATION REQUEST—1931-1932.

The appropriation request, as shown on the accompanying budget sheet, includes the funds needed to carry on the work of three distinct engineering branches under the supervision of this Board of Managers. These divisions are:

Branch.	Request.
1) Geology and Mining	$120,120.00
2) Topographic Mapping	85,000.00
3) Water Power and Flood Control	20,000.00
Total	$225,120.00

The work of each branch is largely personal service. Salaries, traveling expenses, and publication of reports and maps are the chief items of expenditure.

The Topographic Mapping and Water Power and Flood Control branches are carried on in cooperation with the United States Geological Survey, the Federal Bureau matching State funds dollar for dollar; also, in the Water Power division, Army Engineers and others appropriate additional funds. In these two branches practically all of the staff and the transportation equipment are furnished by the Federal Survey. On the accompanying sheets the appropriation requests for these two divisions are separated into the following items:

	Topographic mapping.	Water power and flood control.
Salaries	$49,000.00	$11,100.00
Temporary help	....	2,400.00
Repairs and replacements	500.00	500.00
Traveling expenses	35,500.00	6,000.00
Totals	$85,000.00	$20,000.00

The amounts for both cooperative branches are the same as requested two years ago. The amount asked ($20,000.00) in the case of Water Power and Flood Control is the same as the appropriation made each biennium since 1921, when the work started, and by experience is known to be only sufficient to carry on this branch.

The total appropriation requested for the three branches is divided into the following items. The need for each is briefly explained.

A—PERSONAL SERVICE:

A1.	Salaries fixed by law		$24,000.00
A2.	Salaries fixed by State Agency:		
	Geological Branch	$36,420.00	
	Water Resources Branch	11,100.00	
	Topographic Branch	49,000.00	
	Total		96,520.00
A3.	Temporary employees (Geological Branch)		13,220.00
	3 computers (Water Power Branch)		2,400.00

B—ADDITIONS:

B3-10.	Transportation, automobiles (2, new)		1,000.00

C—REPAIRS AND REPLACEMENTS:

C3- 6.	Office furniture		325.00
C3-10	Replacement 2 Ford cars	$1,000.00	
	Repair all cars	3,500.00	
	Total		4,500.00
C3-11.	Geological Department	$1,000.00	
	Water Resources Department	500.00	
	Topographic Branch	500.00	
	Total		2,000.00

D—OPERATION:

D1- 1.	Communication:		
	Telegraph	$250.00	
	Telephone	250.00	
	P. O. box rent	12.00	
	Postage	600.00	
	Total		1,112.00
D1- 2.	Printing, engraving and lithographing		18,800.00
D1- 4.	Transportation of things:		
	Freight and drayage	$200.00	
	Express	300.00	
	Parcel post	800.00	
	Total		1,300.00

D1- 5.	Travel:		
	Geological Branch	$15,400.00	
	Water Resources Branch	6,000.00	
	Topographic Branch	35,500.00	
	Total		$56,900.00
D1- 6.	Contingent fund		300.00
D2- 2.	Scientific supplies		2,143.00
D2- 6.	Laundry, cleaning, etc		100.00
D2-11.	Miscellaneous supplies (camera, films, tools, etc.)		500.00
	Total		$225,120.00

PERSONAL SERVICE.

A1.—Salaries fixed by law. The maximum salaries of the State Geologist, the Assistant State Geologist and the Principal Geologist are fixed by law. The salary request for the Principal Geologist is not the maximum.

A2.—Salaries fixed by State Agency. The salaries of the Geologic Branch include the permanent assistants now employed, and a request for three additional men. For a number of years this Bureau has maintained a branch office in the Lead and Zinc district at Joplin. Due to the lack of funds this biennial period, this branch has been closed during the past six months. As shown in the outline of investigations discussed on the following sheets, there is an increasingly strong demand for reports covering the geology of lead and zinc ores, clays, barytes, marble, underground waters, and for publication of county geologic maps. Additional assistants are requested in order to partially fill this need. These investigations cannot be undertaken by the present limited staff.

The Water Power and Topographic salaries are requested as total sums. These expenditures are made in cooperation with the United States Geological Survey and other agencies. The engineering work is done largely by Federal engineers, who, when surveying in the field, submit monthly accounts covering salaries and expenses. Contracts covering a specific amount are signed with the Federal Survey each year in advance, and the State expenditures cease when this total is reached. The Federal funds are equal in amount to those supplied by the State.

Under Water Power and Flood Control the salaries needed for the State appropriation of twenty thousand dollars ($20,000.00) have been determined from past experience. The work is done in cooperation with the United States Geological Survey and other agencies which more than match State Survey funds.

The total operative cost as shown below is estimated at fifty-two thousand seven hundred dollars ($52,700.00). The State Survey supplies only twenty thousand dollars ($20,000.00), which is less than forty per cent of the total.

WATER POWER AND FLOOD CONTROL:

(Total expenditures estimated for 1931 and 1932).

Salaries:		
H. C. Beckman, Sr. Engr. (Federal Engineer)		$9,600.00
H. C. Bolon, Jr. Engr. (Federal Engineer)		5,000.00
C. J. Eyberg, Jr. Engr. (Federal Engineer)		4,500.00
R. D. Schmickle, Jr. Engr. (Federal Engineer)		4,800.00
C. H. Jennings, Field Asst. (State Engineer)		4,200.00
40 to 50 gage readers (State pays)		6,000.00
3 computing clerks (part-time) (State pays)		3,000.00
Traveling expenses:		
(Board, lodging, auto repairs on road, gas and oil on road) (State pays part)		11,500.00
Equipment and supplies:		
(Sundries for gaging stations, hardware, etc., paper, lumber, blue prints, office supplies) (State pays part)		2,500.00
Printing Federal reports (Federal Survey pays)		1,600.00
Total cost of Water Power and Flood Control work		$52,700.00
Funds advanced in cooperation by other agencies in 1931 and 1932:		
U. S. Geological Survey	$22,000.00	
U. S. Army Engineers	5,500.00	
Other cooperating agencies	5,200.00	
Total		32,700.00
Amount of appropriation by State Survey		20,000.00
Total		$52,700.00

The salaries of the Topographic Mapping Branch are figured on the same basis. The total Topographic request is for eighty-five thousand dollars ($85,000.00) and from past experience the salaries will amount to the figure given and the other expenses, chiefly traveling, as shown under D1-5. The Federal Survey supplies the field engineers and transportation equipment. When in the field the engineers submit vouchers covering salaries and expenses each month. These are paid by the State. During the winter when the men are in Washington, D. C., the salaries and expenses are paid by the Federal Survey. Adjustments are made before the end of the year so that the Federal bureau has spent the same amount as the State appropriation.

A3.—Temporary help. The temporary employees of the Geologic branch are men employed to do geologic work during the summer field season, usually about three months of the year. They are usually college professors and graduate students. By this means expert help can be obtained without the financial burden of permanent salaries. The names listed are those employed during the present biennial period. The student labor is used for packing, cleaning, clerical work, and laboratory work. The request includes two additional geologists, each for a period of six months, and one draftsman for six months each year, the total request being for three thousand dollars ($3000.00) for additional assistants. The two new field assistants are urgently needed to take up areal geologic mapping of regions containing important mineral resources. Under the present restricted staff this line of work has been abandoned. The draftsman is required to draft maps, plates and sketches for reports. Our present engineer-draftsman is devoting most of his time to field work. This part time employee will relieve a serious congestion.

The three computers used by the Water Power and Flood Control department are students who compute stream flow and gage height data from the records sent in by the 95 gage readers. This is a routine task of large volume, and is economically done at thirty-five cents per hour. The computors have been employed during the past biennial period.

ADDITIONS.

B3-10.—Transportation and conveying equipment. (*Additions*). Two new Ford automobiles will be needed. During the field season this year there has been very acute shortage, due to the lack of available cars.

REPAIRS AND REPLACEMENTS.

C3-6.—Office furniture. The following items are needed in the office:

Swinging map frame	$100.00
Book case	75.00
Office desks	100.00
Small items	50.00
Total	$325.00

C3-10.—Transportation and conveying equipment. (Replacement).

Replacement, 2 Ford cars	$1,000.00
Repairs on all cars	3,500.00
Total	$4,500.00

The replacement of at least two of the cars owned by the Bureau will be required during the biennium. One of the old cars is now out of commission, and the other will be worn out during the coming season. The figure given for repair of the 12 Ford cars of the Survey ($3,500.00) is an estimate based on past operations without provision for major accidents that may require unusual repairs. The request does not include replacement of cars that may be completely lost or destroyed in case of theft, fire, or other cause.

C3-11.—Miscellaneous repairs and replacements.

Geological department	$1,000.00
Water Resources Department	500.00
Topographic Department	500.00
Total	$2,000.00

From past experience, items of replacement and construction at the Survey headquarters, such as building shelves, cases and boxes to hold minerals and other material, will require at least one thousand dollars ($1,000.00). This sub-item has been charged to the Geological branch. Under the Water Resources are the purchase of lumber and cost of construction of gage boxes, repairs to gaging stations, etc., and under Topography the making of concrete bench marks which must be placed every three miles on traverse and level lines, and other small items of construction and repairs, all of which will require the amounts requested.

OPERATION.

D1-1.—Communication.

Telephone service	$250.00
Telegraph service	250.00
Postoffice box rent	12.00
Postage (first class)	600.00
Total	$1,112.00

These items are self-explanatory, and are extremely low estimates.

D1-2.—Printing, binding, engraving, and lithographing. Because of material reduction in funds the past biennial periods, the bureau has not been able to publish a number of the geological maps and reports as completed. It is important to get the results of the work of the department in the hands of the public so that the facts may be used in developing the mineral industries. This item covers only those manuscripts that are on hand and those that will be ready for publication. The following is the detailed estimate:

REPORTS.

57th Biennial Report	$1,000.00
Lawrence county, geology	1,500.00
Altenburg Quadrangle, geology	800.00
Water Resources report	2,500.00
Geological-Geophysical Measurements	500.00
Green City-Queen City Quadrangles, geology	1,000.00

MAPS.

9 large scale geologic maps, Joplin district	$5,000.00
9 county topographic maps	3,600.00
Platte county geologic map	2,000.00
Green City-Queen City geologic map	1,000.00
Total	$18,800.00

D1-6.—Transportation of things. This item includes the following:

Freight and drayage	$200.00
Express	300.00
Parcel post	800.00
Total	$1,300.00

Parcel post includes the mailing of reports to our exchange list, all libraries in the State, all Geological Surveys, State officers, etc. The need may run greater than this amount, depending upon the number of publications printed. Four reports now in press will be distributed after January 1st.

D1-5. Travel and field expenses.

Geological Department	$15,400.00
Water Resources Department	6,000.00
Topographic Department	35,500.00
Total	$56,900.00

This item covers all travel and field expenses for the three branches of the Survey. The needs of the geologic branch are based on past experience and the estimated field work for each geologist and engineer during the coming biennial period. Each regular employee should spend at least six months in the field each year, and the temporary field assistants should spend six months during the biennium on field investigations. The following is an individual estimate, which is low. Some members will run over the amount, others under it.

TRAVELING EXPENSES.

	Per year.	Biennial period.
Permanent employees:		
H. A. Buehler	$500.00	$1,000.00
H. S. McQueen	750.00	1,500.00
J. M. Thiel	650.00	1,300.00
C. O. Reinoehl	750.00	1,500.00
W. H. Wamsley	450.00	900.00
J. G. Grohskopf	750.00	1,500.00
Joplin office	300.00	600.00
Geologists (2), new	750.00	1,500.00

TRAVELING EXPENSES—Continued;

	Per year.	Biennial period.
Temporary employees:		
C. L. Dake	$300.00	$600.00
J. S. Williams	300.00	600.00
J. Bridge	300.00	600.00
G. A. Muilenburg	300.00	600.00
F. C. Farnham (2 rodmen)	500.00	1,000.00
J. S. Cullison	300.00	600.00
Field assistant (1)	300.00	600.00
Field assistant (1)	300.00	600.00
Board of Managers	200.00	400.00
Total		$15,400.00

D1-6. Contingent fund—$300.00. This amount will certainly be needed for items that have been overlooked or estimated too low.

D2-2. Scientific equipment, instrument and supplies. The Bureau requires scientific equipment and supplies to operate in the field, the chemical laboratory, and the drafting room. The items listed below will be needed. A considerable part of the request is for ordinary replacement of chemicals, filter papers, vials and bags, consumed in the regular routine work of the Bureau.

Replacements of electric resistivity equipments	$200.00
Repairs to magnetometer and other physical equipment	250.00
Repairs to field instruments	200.00
1 drafting table, glass top	50.00
Chemical glassware	350.00
Reagent bottles	50.00
Replacement of heat elements (furnace oven)	75.00
Small electric hot plates (3) to replace gas heaters	18.00
Chemicals, rubber tubing, etc	250.00
Separating and other funnels	25.00
Commercial hydrochloric acid	100.00
Glass vials and corks	100.00
Cloth bags for cuttings	125.00
Small items replacing instruments, drafting materials, etc	350.00
Total	$2,143.00

D2-6. Laundry, cleaning and sanitation supplies. $100.00. This covers items needed in keeping the building clean.

D2-11.—Small tools, miscellaneous supplies and repairs. $500.00. Covers small items needed, including films, camera replacement, tools, etc.

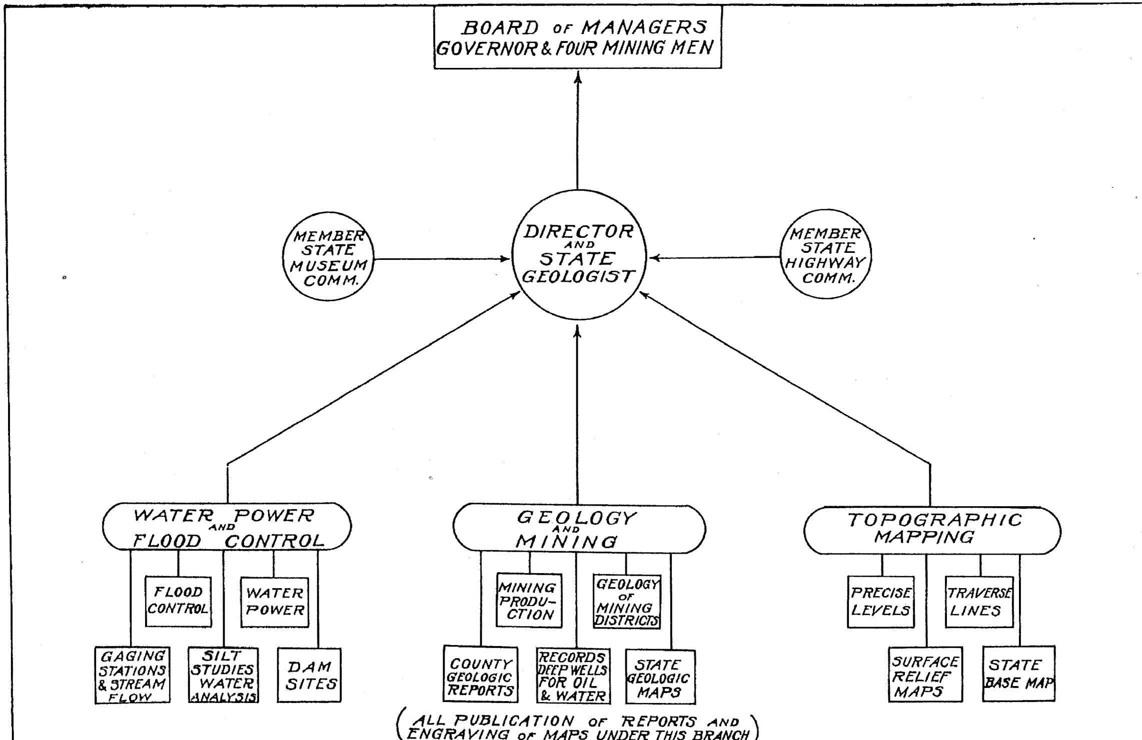
FUTURE WORK OF THE BUREAU.

There have been more requests for information and maps and greater demands for field investigations during the present biennium than during any similar period in the past. Many of our mineral industries and mining regions have not been studied or mapped in detail. In order to supply the need along a number of lines not now served, the following major investigations are planned during 1931 and 1932. In most instances the work is already in progress.

(1) *Mapping Oil and Gas Structures*: The development of gas pools in the Coal Measures of the western part of the State, and the extensive drilling campaign in the St. Louis region during the past two years, has created intense interest in the possibilities of future expansion. The Coal Measures underlie approximately twenty five thousand square miles of the northern and western portions of the State, and field work by the Survey during the past season has shown favorable structures beyond the developed district. These areas should be mapped in detail.

At least one hundred thousand dollars ($100,000.00) has been spent in drilling in and near St. Louis in an endeavor to extend the Dupo field of Western Illinois into Missouri. This bureau has studied the cuttings from many of these wells and because of the great value of the possible discovery of commercial pools in this major industrial district, a detailed report on the structural geology is urgently needed. The budget includes plans for one full-time geologist on oil and gas studies.

(2) *Underground Water Supply:* A sanitary water supply is vital to all cities and villages, and the character and depth of the underground water-bearing formations is of the utmost importance. The bureau has one full-time geologist devoted to a study of deep drill cuttings and the determination of water horizons. This work is carried on in cooperation with the State Board of Health and has proven one of the most valuable investigations now in hand. The staff has developed a method of determining the formations by the character of the residue obtained after dissolving the cuttings in acid. This discovery


BOARD OF MANAGERS
GOVERNOR & FOUR MINING MEN
MEMBER STATE MUSEUM COMM.
DIRECTOR AND STATE GEOLOGIST
MEMBER STATE HIGHWAY COMM.
WATER POWER AND FLOOD CONTROL
FLOOD CONTROL
WATER POWER
GAGING STATIONS & STREAM FLOW
SILT STUDIES WATER ANALYSIS
DAM SITES
GEOLOGY AND MINING
MINING PRODU-CTION
GEOLOGY OF MINING DISTRICTS
COUNTY GEOLOGIC REPORTS
RECORDS DEEP WELLS FOR OIL & WATER
STATE GEOLOGIC MAPS
(ALL PUBLICATION OF REPORTS AND ENGRAVING OF MAPS UNDER THIS BRANCH)
TOPOGRAPHIC MAPPING
PRECISE LEVELS
TRAVERSE LINES
SURFACE RELIEF MAPS
STATE BASE MAP

is of such importance that already four State Geological Surveys and the Federal Geological Survey have sent representatives to investigate and are starting similar work. The extensive drilling campaign in this State demands at least one full-time geologist and an assistant, in order to give the drillers prompt information.

(3) *Clay Deposits:* A study of the geology of the clay resources of the State is under way and partially completed. Missouri has the finest fire clays in the world, and is one of the foremost states in the manufacture of high grade refractories. Each variety of clay occurs under different geological conditions and a thorough knowledge of these facts is most important for future development. Plans for summer field work include continuing this work, especially in the high grade plastic clay district in Audrain and adjoining counties.

(4) *Joplin Branch Office:* The bureau has maintained a branch office at Joplin, in the Southwest Missouri lead and zinc district, for many years, During the past six months it has been closed, due to the lack of funds. This office should be re-opened and the geologic map of the district should be completed and published.

(5) *Geologic Mapping, Southeast Missouri:* The southeast Ozark region has a greater variety of important minerals than any other like area in the State. In addition to the lead ores of the Flat River district, barytes, cobalt, nickel, copper, and iron ores, occur in commercial deposits. Much of this region is not mapped geologically. Further work by the Survey is urgently needed to assist development.

(6) *Geophysical Surveys:* During the past five years entirely new methods of field work have been found to give valuable results in locating geologic structures favorable for the occurrence of oil, gas, and other mineral deposits, and in outlining geological features in areas where there are no outcrops. Through the financial assistance of the Industrial Club of St. Louis, the bureau was able to carry on investigations by magnetic and electric resistivity methods during the past two seasons. Important results have been obtained in the Southeast Missouri lead district and in the Central iron ore district. At least two summer parties should be assigned to work of this character during the coming biennium.

(7) *Answering Requests:* When possible the members of the staff make field trips to advise on the possibilities of

developing economic deposits throughout the state. This is an important service.

(8) *Water Power and Flood Control:* At present ninety-five gaging stations are maintained by this branch of the bureau, for the purpose of determining the stream flow of the various rivers of the State. The work is carried on in cooperation with the United States Geological Survey, U. S. Army Engineers, State Highway Department, City water departments, hydro-electric corporations, drainage districts, and individuals. This wide-spread interest indicates the value of the data collected.

The development of any important hydro-electric project cannot be undertaken without an accurate knowledge of stream flow. The construction of the Bagnell dam on the Osage River, involving an expenditure of thirty-five million dollars ($35,000,-000), was made possible through the data furnished by this Survey. It is one of the most important branches of the work of the department.

(9) *Topographic Mapping:* Many urgent requests for topographic maps covering areas in various parts of the state have been received by the Bureau. At the present time only about one-fourth of the State has been accurately mapped. The work is done in cooperation with the United States Geological Survey and the State appropriation is matched dollar for dollar by the Federal Government.

Among the more important requests are; for maps of the fire clay district of Eastern Missouri; areas in Lincoln and Pike counties, and Jackson County. Maps have been started covering areas in St. Louis and Jefferson Counties and in Cole and Boone counties.

VALUE OF MINERAL PRODUCTION OF MISSOURI, 1921-1929.

Commodity.	1921	1922	1923	1924	1925	1926	1927	1928	1929
Lead ore........	$11,825,280	$14,934,548	$19,692,318	$25,037,380	$32,125,281	$33,121,920	$25,043,760	$22,665,588	$25,007,094
Zinc...........	491,365	952,411	1,403,365	1,010,059	1,488,593	3,902,700	2,398,336	1,582,828	1,454,244
Coal...........	13,915,500	11,153,000	11,575,000	8,154,000	8,281,000	8,950,984	8,698,000	9,637,000	9,778,000
Clay products...	10,579,034	11,552,982	18,509,937	16,826,511	18,544,117	18,259,171	17,225,214	16,073,334	15,319,000
Cement........	8,034,540	10,457,557	13,237,141	13,515,267	14,155,795	12,917,342	11,117,047	12,367,018	11,557,905
Limestone......	2,269,457	2,409,202	3,173,622	3,624,089	4,085,883	4,416,006	4,002,987	4,476,135	5,704,241
Marble.........	627,729	816,098	1,085,122	1,229,160	1,439,604	1,446,983	1,108,159	1,425,060	932,471
Sand and gravel.	1,018,325	1,063,370	2,007,529	2,053,436	3,595,187	2,980,242	2,875,530	3,248,813	4,170,593
Lime...........	1,169,391	1,402,337	1,830,937	1,711,180	1,860,244	1,428,412	1,437,140	1,398,843	1,401,090
Lime hydrated...	487,169	551,187	674,848	642,995	750,710	790,531	752,280	853,577	918,796
Clay...........	938,135	1,238,622	1,624,789	1,441,457	1,463,880	1,571,026	1,693,792	1,442,644	1,797,448
Chats..........	259,571	306,252	431,884	520,269	399,002	382,080	526,933	475,888	646,292
Barytes........	217,913	421,568	629,097	604,390	749,927	946,595	797,465	810,203	880,319
Copper.........	17,749	107,649	29,776	23,948	1,718	150,780	59,081	9,360	394
Mineral waters..	45,670	40,149	38,145	30,000	32,000	41,955	29,452	(*a*)	(*a*)
Tripoli-Silica....	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
Iron ore........	169,516	244,928	247,975	405,622	(*a*)	532,536	(*a*)	(*a*)	661,055
Granite.........	81,389	85,093	83,804	108,084	137,348	(*a*)	90,133	69,707	54,642
Silver..........	69,902	212,656	145,361	69,475	57,538	56,160	132,638	103,451	96,813
Sandstone......	(*b*)	(*a*)	(*a*)	(*b*)	(*b*)	(*b*)	(*b*)	(*a*)	322,508
Natural gas.....	2,130	780	3,000	3,000	3,100	(*b*)	(*b*)	(*b*)	(*b*)
Pottery.........	89,657	96,513	94,985	95,936	77,090	56,684	69,849	(*c*)	(*c*)
Miscellaneous (*a*)	4,484	21,062	130,427	132,875	327,289	328,585	559,962	579,190	141,170
Totals......	$52,224,249	$58,018,949	$76,649,062	$77,239,133	$89,575,306	$92,280,692	$78,617,757	$76,639,449	$80,844,075

(*a*) Miscellaneous includes, besides items noted, Miscellaneous Stone, 1923, 1924 to 1929 and Petroleum in 1923.
(*b*) No production reported. (*c*) Included with Clay products.

CHAPTER II

MINERAL PRODUCTION OF MISSOURI.

by H. S. McQUEEN.

The total value of the minerals produced in Missouri in 1928 was $76,639,449, a sum slightly less than in the preceding year. An increase, however, is noted in 1929, the total value being $80,844,075.

In many branches of the mineral industry increases were noted in 1928, as compared with 1927, some of them being in the value of the production of coal, limestone, marble, sand and gravel, cement, lime, and barite.

The figures for 1929 also show certain increases when compared with those for 1928, especially in the value of lead, coal, lime, limestone, sand and gravel, and chats. Record figures were also established in this year for the value of limestone, sand and gravel and chats, and barite approached the record figure established in 1926.

The state is an important contributor to the mineral wealth of the nation. In 1929 it ranked first in the production of lead. In 1928 it was first in the production of barite, second in the production of fire clay, third in the output of lime, fourth in the value of marble quarried, fifth in the total value of cement, seventh in the value of clay products, and tenth in the production of sand and gravel, and stone.

In the following pages a brief resume of each industry is presented, together with statistical tables showing the output and value of each mineral resource. These figures have been collected in cooperation with the United States Bureau of Mines, and many of the tables have been taken from the mineral resources reports of that organization.

ASPHALTIC SANDSTONE.

No production of asphaltic sandstone was reported in 1928, 1929. The deposits are found to a large extent in the Cherokee sandstones of Pennsylvanian age in many counties in Western Missouri, and prospecting has shown that a large tonnage is present in Barton and Vernon Counties. The deposits in the latter county have been described in detail in volume XIX, "The Geology of Vernon County," a copy of which may be obtained from this Bureau. A general resume of the deposits in Missouri is given in Volume XVI, "The Occurrence of Oil and Gas in Missouri."

BARITE.

The production and value of this mineral, after reaching a new high in 1926, slumped in 1927, but showed a gain in 1928 and 1929. In the last mentioned year the tonnage shipped was almost the same as in 1926, the difference in value resulting from a slight decrease in the average value per ton.

In 1926 Missouri ranked first in the production of Barite, the tonnage amounting to 50% of the total mined in the United States. The state again was first in 1927, producing 44 per cent of the total but in 1928 produced 42 per cent of the total and shared first place with Georgia. The comparative figures for 1929 are not available but the increase in the tonnage and value insures the state a high position in this branch of the Mineral Industry.

The bulk of the production in Missouri comes from Washington County and adjacent parts of Jefferson and St. Francois counties. The mineral is also mined in the Northwest portion of the Ozark region in Benton, Cole, Morgan, Miller, Hickory, and Polk counties. It is also found in Franklin County and a small production has accasionally been reported from Cooper, and Texas counties.

The Industry centers around Potosi, Washington County. In this vicinity large plants have been erected for handling the ore as it is received from the mines.

The importance of the Barite industry, has lead to a study by this Bureau, of the geology, occurrence of the ore, and methods of mining and milling in the Potosi district. The various uses are also discussed. This report, Volume XXIII, "The geology of the Potosi-Edgehill Quadrangles," can be obtained by addressing the Director.

The tables below give the production by counties, the production by states, and the total state production for the past 20 years. Lists of the producers, of barite and refined barite in this state are also given.

CRUDE BARITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1927 AND 1928.

State.	1927.				1928.			
	Short tons.	Value.	Per cent.	Ave. value per ton.	Short tons.	Value.	Per cent.	Ave. value per ton.
Missouri	111,456	$797,465	44	$7.15	114,274	$810,203	42	$7.09
Georgia	94,039	580,300	37	6.17	112,316	675,509	42	6.01
Tennessee	20,537	129,999	8	6.33	20,260	150,937	7	7.45
California	13,919	71,708	5	5.15	12,557	51,502	5	4.10
Other states*	14,314	91,406	6	6.38	10,137	66,773	4	6.58
Totals	254,265	$1,670,878	100	$6.24	269,544	$1,754,924	100	$6.25

*Includes Nevada, South Carolina, Virginia and Wisconsin in 1927. Includes Colorado, South Carolina, Virginia and Wisconsin in 1928.

BARITE—TABLE OF PRODUCTION, 1909-1927.

	Number producers reporting.	Stock on hand, Dec. 31.	Shipments, tons (short).	Value.	Average per ton.
1909			34,815	$119,818	$3.44
1910			25,431	85,624	3.32
1911			21,500	81,380	3.79
1912			24,530	117,035	4.77
1913			31,131	117,638	3.75
1914			33,317	117,738	3.53
1915			39,113	158,597	4.05
1916			58,407	365,111	6.25
1917			59,046	391,363	6.62
1918			49,094	393,738	8.02
1919		8,090	73,247	640,398	8.74
1920	70	3,154	99,654	1,013,570	10.17
1921	68	10,136	25,200	217,913	8.64
1922	61	5,202	66,421	421,568	6.35
1923	85	6,111	81,701	629,097	7.70
1924	70	2,222	77,189	604,390	7.83
1925	83	4,919	101,056	794,927	7.87
1926	82	4,968	118,919	946,595	7.96
1927	57	15,276	111,456	797,465	7.15
1928	45	16,792	114,274	810,203	7.09
1929			118,679	880,319	7.41

PRODUCERS OF REFINED BARITE IN MISSOURI.

Ground Barite:
- C. P. DeLore Co., St. Louis, Mo.
- National Pigments & Chemical Co., Adelbert and St. Louis, Mo.

Barium Chemicals
- Titanium Pigment Co (Inc.), Carondelet Sta., St. Louis, Mo.

PRODUCTION OF BARITE IN MISSOURI, BY COUNTIES, FOR 1925-1928.

County.	1925		1926		1927		1928	
	Quantity sold.	Value.	Quantity sold.	Value.	Quantity sold.	Value.	Quantity sold.	Value.
Cole	2,778	$23,714	4,742	$37,071	4,271	$29,944	6,522	$43,628
Jefferson	3,745	29,647	5,924	45,402	4,844	37,460	3,687	24,516
St Francois	2,027	15,657	260	1,820	611	4,284	224	1,343
Washington	84,211	660,693	101,770	812,400	80,963	628,479	95,300	683,759
Other counties (*b*)	1,967	15,415	2,204	17,601	1,460	11,162	6,353	43,051
Undistributed	6,328	49,801	4,019	32,301	19,307	86,136	2,188	13,106
Totals	101,056	$749,927	118,919	$946,595	111,456	$797,465	114,274	$809,403

(*b*) Other counties include Franklin, Hickory and Morgan in 1925; Cooper, Franklin, Morgan, Miller and Polk, 1926; Miller and Morgan in 1927; Franklin. Miller, Moniteau and Morgan in 1928.

PRODUCERS OF CRUDE BARYTES.

Producer.	Location of Mine.
COLE COUNTY—	
Ozark Mining & Milling Co.	Henley.
National Pigments & Chemical Co.	Henley.
C. J. Emmerich	Henley.
Weber and Morrow	Russellville.
FRANKLIN COUNTY—	
H. K. Hinde	Morrelton.
JEFFERSON COUNTY—	
C. P. De Lore Co	Vineland.
R. B. Cole	Blackwell.
Valle Mining Co	Valle Mines.
Lessees of Taussig Land	Frumet.
G. L. Bernhart	Vineland.
Andrew Oliver	De Soto.
Marshall Thompson	De Soto.
Alfred K. Prince	Blackwell.
MILLER COUNTY—	
Miller County Mining and Royalty Co	Brumley.
Versailles Mining Co	Bagnell.
MORGAN COUNTY—	
H. B. Hart	Versailles.
MONITEAU COUNTY—	
Geo. H. Hubbard	California.
ST. FRANCOIS COUNTY—	
L. E. Cole	Blackwell.
C. E. Boyer	Blackwell.
Mrs. Lula Aly	Blackwell.
James Donald	Blackwell.
WASHINGTON COUNTY—	
F. A. Clary	Baryties.
Washington Land & Mining Co	Bliss.
John Long & Son	Cadet.
White & Bros.	Old Mines.
Anthony Recar	Cruise.
Arthur Dale	Mineral Point.
Eagle-Picher Lead Co	Mineral Point.
Southeast Missouri Lead Co	Mineral Point.
Point Mining & Mfg. Co	Mineral Point, Baryties.
P. C. Walton & Bros	Mineral Point.
Gratz & Stocking	Baryties.
Ode Engledow	Blackwell.
Adolph Portell	Cadet.

PRODUCERS OF CRUDE BARYTES—Continued.

Producer.	Location of Mine.
WASHINGTON COUNTY—	
Pierce and Stocking	Richwoods.
Mrs. Theodore Walther	Richwoods.
D. B. Graves	Old Mines.
G. A. Johnson	Richwoods.
C. P. De Lore Co	Mineral Point, Cadet, Potosi, Richwoods.
Andrew White	Mineral Point.
Murphy & Alden	Old Mines.
T. F. Blount & Co	Potosi, Mineral Point.
B. G. Casey	Old Mines.
Evans & Russell	Potosi.
National Pigments & Chemical Co	Potosi.
J. W. Settle	Potosi.
Thurman & Banta	Tiff, Potosi.
Geo. W. Welch	Vineland.
Steve Kelso	Richwoods.
Geo. Carr & Geo. Wallace	Belgrade.
C. A. Stocking	Fletcher.
D. W. Baker	Mineral Point.
C. C. Rose & H. O. Hollow	Richwoods.
Superior Mineral Co	Cadet.
Mineral Point Consolidated District No. 3	Mineral Point.
F. A. Schmidt	Cadet.
G. W. Starkey	Mineral Point.

CEMENT.

The state of Missouri with the exception of the central Ozark region, has a wealth of limestone and shale or clay suitable for the manufacture of Portland Cement. The deposits are strategically located near the great centers of consumption and five large plants are at present contributing materially to the mineral wealth of the state. Missouri, in 1927, ranked sixth in the production of cement, and in 1928, by virtue of an increase in output and total value, ranked fifth, being exceeded by Pennsylvania, California, Michigan and Ohio in the order named.

As shown on the accompanying list, cement plants are located in the eastern and western parts of the state; and also in different geologic provinces. In western Missouri, the limestones and shales of the Kansas City formation of Pennsylvanian age are utilized. The limestones of the St. Louis formation of Mississippian age, Pennsylvanian (Cherokee) shales, and Pleistocene loess are used at St. Louis. At Hannibal, the limestone is obtained from the Burlington formation and the shale is mined from the Grassy Creek formation, both being of Mississippian age. The Plattin limestone of Ordovician age is quarried at Cape Girardeau and mixed with alluvial clay obtained from the flood plain of the Mississippi River.

Statistics covering the production and value of cement produced in this state from 1919 to 1929, are given in the following table.

PRODUCTION OF PORTLAND CEMENT, 1919-1929.

Year.	Barrels.				Price per barrel.
	Stock on hand January 1.	Manufactured.	Sold.	Value.	
1919	676,552	5,216,347	5,496,164	$9,264,017	$1.68
1920	160,123	6,017,517	5,605,952	10,980,453	1.96
1921	571,688	4,446,091	4,375,712	8,034,540	1.84
1922	640,932	6,170,633	6,239,144	10,457,557	1.68
1923	636,625	7,305,997	7,143,883	13,237,141	1.85
1924	774,922	7,871,621	7,711,206	13,515,267	1.77
1925	921,165	8,331,751	8,168,165	14,155,795	1.73
1926	1,084,752	7,653,111	7,639,966	12,917,342	1.69
1927	1,097,897	6,778,384	6,929,229	11,117,047	1.60
1928	957,053	7,881,118	7,943,367	12,367,018	1.56
1929	896,878	8,113,304	7,984,337	11,557,905	1.45

Stock on hand December 31, 1929, 1,025,845 barrels.

PORTLAND CEMENT PLANTS IN MISSOURI.

Firm name.	Material used. *a*	County.	Town.
Atlas Portland Cement Co.	ls. & sh.	Ralls.	Hannibal.
Marquette Cement Mfg. Co.	ls. & clay.	Cape Girardeau.	Cape Girardeau.
Alpha Portland Cement Co.	ls. & clay.	St. Louis.	Continental.
Missouri Portland Cement Co.	ls. & sh.	St. Louis.	Prospect Hill.
Missouri Portland Cement Co.	ls. & sh.	Jackson.	Sugar Creek.

a =ls., limestone; —sh, shale.

CLAY AND CLAY PRODUCTS.

The value of the production of clay in 1929 established a new high record of $1,797,448, and exceeded the previous high of 1927 by over $100,000. The importance of the clay industry in this state is indicated by the increase noted and also by the fact that since 1922 the value of the output has been consistent.

The State's clay resources are varied and extensive. The diaspore clay deposits of the north central Ozark region are the only ones of commercial importance in the United States, and the material has formed the basis for an extensive high alumina refractories industry.

Missouri also has the greatest tonnage of high grade flint fire clay of any state in the union. The clay occurs in sink-hole type deposits over a wide area, and is remarkable for its consistency in physical and chemical properties.

The so-called burley clays, which have an alumina content between that of flint fire clay and diaspore clay, are also found in this state in larger quantities than in any other. In fact, so far as can be learned, its occurrence elsewhere is of slightly more than scientific interest, whereas in Missouri it is a commercial product.

At the base of the Pennsylvanian series in eastern Missouri is the Cheltenham plastic and semi-flint fire clay. It is mined extensively in St. Louis, Audrain, Callaway, and Montgomery counties, and is widely distributed in the counties adjacent.

The Pennsylvanian series is widely distributed over the northern and western parts of the state and to a smaller extent in St. Louis County. Extensive beds of shale are found which form the basis for a heavy clay products industry which contributes materially to the total mineral wealth of Missouri.

Ball and china clays of Tertiary age are found in Butler and Stoddard counties, in southeastern Missouri, and promise to be of increasing value annually. It is believed that additional deposits can be found with geologic work and systematic prospecting. Geologic work should be done to determine the areas in which arms of the Tertiary seas extended as embayments into the hill country of the Ozark region.

Stoneware clays are also found in this state, although the industry is not as extensively developed as it might be. Some of the weathered clay of the Cheltenham seam is adapted to this particular ware.

Some progress has been made on a report covering the clay resources of the state, and two brief articles have been prepared by a member of the staff for publication in technical journals. A map of the diaspore, flint and plastic fire clay districts of east central Missouri has also been issued by the Survey.

In connection with the experimental geophysical work described in this report, limited measurements were made on a few clay pits. The results indicate that additional work should be done.

It is of interest to note that Missouri ranks second among the states of the union in the production of raw clay; the statistical tables of the succeeding pages will show the value of the clays produced; a list of producers is also given.

The manufacture of clay products is one of the State's rapidly developing and important industries and is based entirely upon the raw materials briefly described above. Although a comparatively young industry when compared with the manufacture of clay products in other states, Missouri at present ranks seventh in the total value of the output. A high position is also maintained in the many branches of this industry, particularly in the manufacture of fire brick and sewer pipe.

During the past biennial period the Harbison-Walker Refractories Company of Pittsburg, Pennsylvania, has extended their holdings in this state by acquiring the plant and clay properties of the Fulton Fire Brick Company. The General Refractories Company of Philadelphia, Pennsylvania, for several years a producer of fire clays in the state, has also entered the manufacturing industry by acquiring the fire-bricks plants of the Evans and Howard Fire Brick Company in St. Louis County. The entry of these two large companies into the Missouri field is significant.

The plant of the Mexico Refractories Company at Mexico also went into production during this period. The installation is an up-to-date one and will add to the total value of the clay and clay products output. The raw material is obtained from deposits adjacent to the plant.

New tunnel kilns have also been constructed at the plant of the A. P. Green Fire Brick Company at Mexico, and improvements in plants in the St. Louis district have been reported.

The statistical tables show the distribution and value of the clay products industry, and the lists give the names of the producers.

VALUE OF CLAY PRODUCTS, 1924-1927.

Product.	1925	1926	1927	1928
Fire brick	$7,431,975	$8,520,235	$7,842,296	$7,496,991
Sewer pipe	(b)	2,819,553	2,431,782	1,888,471
Common brick	2,397,724	1,850,977	1,495,009	1,149,113
Face brick	1,428,726	1,394,055	1,238,249	1,190,494
Hollow building tile or block	557,349	537,029	346,490	(a)
Drain tile	50,960	85,936	58,481	(a)
Pottery	(a)	56,684	69,849	(a)
Miscellaneous (b)	6,754,473	3,051,386	3,743,058	4,348,265
Totals	$18,621,207	$18,315,855	$17,225,214	$16,073,334

(a) Besides the items noted above, "Miscellaneous" includes vitrified brick, enameled brick, architectural terra cotta, tile other than drain tile, silica brick, clay gas retorts, stove lining, wall coping, high alumina brick, flue lining, segment blocks, refractory cement and raw or prepared clay. High alumina brick and special fire brick shapes are included with fire brick in 1928.

CLAY MINED AND SOLD, 1918-1929.

Year.	Fire Clay.						Miscellaneous.		Total.	
	Plastic.		Flint.		Diaspore.					
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
1918	365,339	942,547	87,453	159,105	a	....	11,654	91,444	464,446	1,192,996
1919	217,905	804,376	121,928	177,750	a	....	1,552	21,907	341,385	1,004,033
1920	329,563	1,130,266	111,165	266,814	a	....	8,256	16,109	448,984	1,413,189
1921	159,831	627,289	95,963	302,485	a	....	989	8,361	256,783	938,135
1922	259,011	711,087	137,470	406,637	13,384	$109,229	12,263	11,669	412,128	1,238,622
1923	338,010	1,252,003	142,584	301,474	10,617	54,450	4,586	16,862	495,797	1,624,789
1924	376,328	1,175,847	68,392	199,688	9,252	47,407	5,598	18,515	459,570	1,441,457
1925	340,870	1,138,664	91,015	201,728	15,177	102,064	5,944	20,624	453,006	1,463,880
1926	336,809	1,225,961	97,157	212,487	18,483	100,823	8,297	31,755	460,746	1,571,026
1927	282,865	1,247,273	86,570	193,185	40,085	229,093	6,970	24,241	416,490	1,693,792
1928	325,258	1,040,016	57,889	178,393	37,439	207,155	5,440	17,080	426,026	1,442,644
1929	333,243	1,190,831	85,237	201,667	71,589	378,398	7,630	26,552	497,699	1,797,448

a Diaspore clay not separated before 1922. The diaspore totals probably included Burley clay.
b Includes kaolin, stoneware clay and clay for miscellaneous uses.
Includes ball clay, stoneware and clay for miscellaneous uses, 1926.
Includes kaolin, ball clay, stoneware and clay for miscellaneous uses, 1927.
Includes ball clay and stoneware clay, in 1928.

PRODUCERS OF CLAY IN MISSOURI, 1929.

Operator.	Type of clay mined.	Location.
AUDRAIN COUNTY—		
Farber Fire Brick Co	Plastic fire clay	Farber.
A. P. Green Fire Brick Co	Flint fire clay, plastic fire clay	Mexico.
Harbison-Walker Refractories Co	Plastic fire clay	Vandalia.
Missouri Fire Brick Co	Plastic fire clay	Farber.
BUTLER COUNTY—		
G. Earl Doane	Ball clay	Poplar Bluff.
CALLAWAY COUNTY—		
Harbison-Walker Refractories Co	Plastic fire clay	Fulton.
FRANKLIN COUNTY—		
F. A. Toelke	Flint fire clay	Gerald.
Western Fire Brick Co	Flint fire clay	Gerald.
Gasconade Flint Clay Co	Flint fire clay	Beaufort.
GASCONADE COUNTY—		
A. P. Green Fire Brick Co	Diaspore	Hermann.
General Refractories Co	Flint fire clay	Owensville.
General Chemical Co	Flint fire clay	Owensville.
Gasconade Flint Clay Co	Flint fire clay	Owensville and Rosebud.
Harbison-Walker Refractories Co	Flint fire clay	Owensville.
DeWitt C. Terril	Flint fire clay	Owensville.
Louis Hidel	Flint fire clay	Rosebud.
E. W. Roussett	Flint fire clay	Rosebud.
HENRY COUNTY—		
James W. Edwards	Stoneware clay and miscellaneous	Calhoun.
Western Fire Brick Co	Flint fire clay	
LINCOLN COUNTY—		
Harbison-Walker Refractories Co	Flint fire clay	Whiteside.
MARIES COUNTY—		
General Chemical Co	Flint fire clay	Belle.
O. B. Rogers	Flint fire clay	
MONTGOMERY COUNTY—		
Wellsville Fire Brick Co	Plastic fire clay	Wellsville.
Parker-Russell Mining and Manufacturing Co	Flint and Plastic fire clay	Wellsville.
New Florence Fire Brick Co	Flint fire clay	New Florence.
MORGAN COUNTY—		
W. S. Dickey Clay Mfg. Co	Flint fire clay	Versailles.

PRODUCERS OF CLAY IN MISSOURI, 1929—Continued.

Operator.	Type of clay mined.	Location.
PHELPS COUNTY—		
Jno. A. Gray	Flint fire clay, diaspore	St. James.
C. R. Forbes	Flint fire clay, diaspore	Rolla.
ST. LOUIS COUNTY—		
Laclede-Christy Clay Products Co.	Plastic fire clay	Christy, Cheltenham, St. Louis.
Geo. W. Gittins Clay Products Co.	Plastic fire clay	Clayton.
Evens & Howard Fire Brick Co.	Flint and plastic fire clay	Overland.
Volz Fire Clay Co.	Plastic fire clay	Clayton.
Glencoe Clay Co.	Flint and plastic fire clay	Glencoe.
Murray & Siems	Flint and plastic fire clay	Oakhill.
ST. LOUIS CITY—		
Highlands Fire Clay Co.	Flint and plastic fire clay	St. Louis.
Parker-Russell Mining and Mfg. Co	Plastic fire clay	St. Louis.
Williams Fire Clay Co.	Plastic fire clay	St. Louis.
Mitchell Clay Mfg. Co.	Plastic fire clay, flint fire clay and diaspore	St. Louis.
Mississippi Glass Co.	Plastic fire clay and flint fire clay	St. Louis.

PRODUCERS OF CLAY PRODUCTS, 1928.

Operator.	Name of product.	Location.
AUDRAIN COUNTY—		
A. P. Green Fire Brick Co.	Fire brick	Mexico.
Harbison-Walker Refractories Co.	Fire brick	Vandalia.
North American Refractories Co.	Fire brick	Farber.
BARTON COUNTY—		
Venetian Brick Co.		Oskaloosa.
BOONE COUNTY—		
Edwards Brick Co.	Face brick, common brick, hollow building tile	Columbia.
BUCHANAN COUNTY—		
Moorehead Brick and Tile Co.	Common brick, hollow building tile or block	St. Joseph.
CALLAWAY COUNTY—		
Harbison-Walker Refractories Co.	Fire brick	Fulton.

PRODUCERS OF CLAY PRODUCTS, 1928—Continued.

Operator.	Name of product.	Location.
CAPE GIRARDEAU COUNTY—		
Cape Girardeau Press Brick Co.	Common brick	Cape Girardeau.
Kasten & Sons Press Brick Co.	Common brick, face brick.	Jackson.
CASS COUNTY—		
United Brick and Tile Co.	Face brick, hollow building tile or block	Harrisonville.
GASCONADE COUNTY—		
Korff Bros. Brick Mfg. Co.	Common brick	Rosebud.
HENRY COUNTY—		
W. S. Dickey Clay Mfg. Co.	Drain tile, hollow building tile or block, sewer pipe, wall coping, segment blocks	Deepwater.
HOWARD COUNTY—		
Fayette Brick and Tile Co.	Common brick, drain tile, hollow building tile or block, fire brick	Fayette.
JACKSON COUNTY—		
Haydite Co.		Kansas City.
Hydraulic Press Brick Co.	Face brick, drain tile, hollow building tile or block, fire brick	Kansas City.
Fredericksen Floor and Wall Tile Co.	Floor tile	Independence.
Kansas City Terra Cotta and Faience Co.	Architectural terra cotta	Kansas City.
W. S. Dicky Clay Mfg. Co.	Sewer pipe, hollow building tile block, wall coping, miscellaneous	Kansas City.
JOHNSON COUNTY—		
Johnson County Brick Co.	Common brick, face brick.	Knobnoster.
LAFAYETTE COUNTY—		
Higginsville Brick and Tile Co.	Common brick, hollow building tile or block	Higginsville.
LIVINGSTON COUNTY—		
Shale Hill Brick and Tile Co.	Drain tile, hollow building tile or block	Utica.
MONTGOMERY COUNTY—		
New Florence Fire Brick Co.	Fire brick	New Florence.
Wellsville Fire Brick Co.	Fire brick	Wellsville.

PRODUCERS OF CLAY PRODUCTS, 1928—Continued.

Operator.	Name of product.	Location.
MORGAN COUNTY—		
W. S. Dickey Clay Mfg. Co.	Fire brick	Versailles.
PIKE COUNTY—		
Philip Schurfeld Brick and Tile Co.	Common brick, drain tile, hollow building tile or block	Louisiana.
ST. LOUIS COUNTY—		
Alton Brick Co.	Common brick, face brick, hollow building tile or block	Maryland Hts.
Evens & Howard Fire Brick Co.	Fire brick	Clayton.
Maes Brick Mfg., Jacob	Common brick	Luxemburg.
Missouri Pressed Brick and Imp. Co.		
Mutual Press Brick Co.	Common brick	Shrewsbury.
American Press Brick Co.	Common brick	Wellston.
Hydraulic Press Brick Co.	Common brick	
ST. LOUIS CITY—		
Missouri Fire Brick Co.	Fire brick	Cheltenham.
Blackmar & Post Pipe Co.	Sewer Pipe	St. Louis.
Evens & Howard Fire Brick Co.	Drain tile, sewer pipe, fire brick	St. Louis.
Hydraulic Press Brick Co.	Common brick, vitrified brick for paving and other uses, fire brick, face brick, enameled brick, hollow building tile or block	St. Louis.
Laclede-Christy Clay Products Co.	Sewer pipe, hollow building tile or block, clay gas retorts, fire brick, miscellaneous	St. Louis.
Mississippi Glass Co.	Glasshouse refractories	St. Louis.
Mitchell Clay Mfg. Co.	Fire brick	St. Louis.
Mound City Roofing Tile Co.	Roofing tile	St. Louis.
Northwestern Terra Cotta Co.	Terra Cotta	St. Louis.
Parker-Russell Mining and Mfg. Co.	Hollow building tile or block, fire brick, clay gas retorts, silica brick	St. Louis.
H. H. Schweer Brick Co.	Common brick	St. Louis.
Superior Press Brick Co.	Common brick, face brick.	St. Louis.
Winkle Terra Cotta Co.	Architectural terra cotta	St. Louis.
SCOTT COUNTY—		
Illmo Pressed Brick Co.	Common brick	Illmo.

PRODUCERS OF POTTERY, 1928.

Operator.	Name of product.	Location.
ST. LOUIS COUNTY—		
Missouri Pottery and Supply Co....	Red earthenware........	St. Louis.
St. Louis Pottery and Mfg. Co	Red earthenware........	St. Louis.
Western Pottery Co...............	Red earthenware........	St. Louis.
SHELBY COUNTY—		
J. B. Cluskey....................	Stoneware..............	Lakenan.
STODDARD COUNTY—		
Evans Bros......................	Stoneware and yellow and Rockingham ware......	Dexter.

COAL.

Since 1923, the tonnage and value of coal produced in Missouri has shown a steady increase. The value of this fuel in 1929 amounted to $9,778,298. The steady production would indicate that the coal produced supplies a more or less fixed market and is consumed largely within the state.

The increase in production may also be reasonably ascribed to the development of large strip coal properties, in the southwestern and to some extent in the central part of the state. Improvements in mechanical equipment used in this method of mining, and the adaptability of certain areas to stripping as a result, have been responsible for the increase mentioned.

During the years 1927 and 1928, production was reported from 26 counties, and in 1929 from 27 counties. During these three years the average number of mines in operation was 280.

Due to the considerable number of strip mines in production during this period, Barton County led the other counties of the state in output and in value of coal, the tonnage being one-third or more of the state's total.

The Richmond-Lexington district as shown by the figures on the tables is the next largest contributor. The coal is obtained principally from underground mines.

The coal beds of the state occur in the Pennsylvanian series, which has an areal distribution of approximately 20,000 square miles in the northern and western parts of the state. The bulk of the tonnage is obtained from the Cherokee formation in the lower part of the series. The area of outcrop of this formation is indicated on the State Geological Map published by this bureau. The coal deposits have been described in a report issued by the Bureau several years ago. It is to be regretted that the edition has been exhausted and is no longer available for distribution. The coal beds of Vernon County have been described in Vol. XIX of the Bureau, and copies may be obtained upon request.

In the following tables, statistics are presented which show the status of this industry for the past several years. The list of producers has been taken from the 1929 report of the Inspection Department, State Bureau of Mines.

PRODUCTION OF COAL, 1915-1929.

Year.	Tonnage.	Value.	Average price per ton.
1915	3,811,593	$6,595,918	$1.73
1916	4,742,146	9,044,505	1.97
1917	5,670,549	13,755,864	2.42
1918	5,667,730	17,126,498	3.02
1919	3,979,798	12,766,366	3.21
1920	5,369,565	22,230,000	4.16
1921	3,551,621	13,915,500	3.92
1922	2,924,750	11,153,000	3.77
1923	3,403,151	11,575,000	3.40
1924	2,408,880	8,154,000	3.29
1925	2,694,215	8,281,000	3.07
1926	3,008,495	8,950,984	2.98
1927	3,064,343	8,698,124	2.84
1928	3,732,421	9,636,923	2.54
1929	4,030,311	9,778,298	2.43

COAL PRODUCED IN MISSOURI IN 1927.

County.	Net tons.				Value.		Number of employes.				Average number of days worked.
							Underground.				
	Loaded at mines for shipment.	Sold to local trade and used by employes.	Used at mines for steam and heat.	Total quantity.	Total.	Average per ton.	Miners, loaders, and shot-firers.	All others.	Surface.	Total.	
Adair	152,585	24,384	4,904	181,873	$469,608	$2.58	287	86	34	407	198
Audrain	....	9,740	....	9,808	47,284	4.79	40	9	5	54	178
Barton	1,101,921	10,302	27,876	1,140,099	3,070,256	2.69	268	38	657	963	147
Bates	208,177	11,385	4,725	224,287	514,594	2.30	189	31	137	357	166
Boone-Howard	53,998	20,770	....	74,780	211,161	3.60	77	11	72	170	175
Caldwell-Grundy-Harrison	4,684	7,845	555	13,084	58,442	4.46	33	14	5	52	200
Callaway	....	31,908	....	31,936	117,891	3.69	81	18	24	123	192
Chariton	....	7,238	....	7,238	20,282	2.78	11	5	1	17	186
Clay-Platte	51,773	24,429	1,391	77,593	306,906	3.96	214	60	33	297	156
Henry-Johnson	244,053	15,071	....	266,364	678,588	2.55	51	25	151	227	246
Lafayette	148,717	48,732	3,592	201,041	679,580	3.38	702	171	62	935	113
Linn	....	20,411	....	29,336	99,057	3.37	105	22	14	141	150
Macon	60,479	36,312	1,331	98,122	287,382	2.92	266	58	25	349	121
Monroe	....	1,211	....	1,211	5,361	4.13	7	3	2	12	155
Putnam	....	22,981	....	32,117	82,026	2.55	112	22	13	147	108
Ralls	12,682	....	....	13,752	48,707	3.56	44	10	5	59	149

Randolph..........	142,384	59,570	....	206,791	544,188	2.63	300	89	35	424	225
Ray................	272,000	44,234	916	317,150	1,130,182	3.56	1,053	207	99	1,359	120
Schuyler............	7,995	4,364	....	12,359	35,151	2.83	28	3	1	32	163
Vernon-Cedar.......	122,214	1,006	....	125,402	291,478	2.32	19	6	82	107	178
Concealed..........	17,445	2,712	13,597	....	....	....	....	....	....	....	....
Totals..........	2,601,107	404,605	58,631	3,064,343	$8,698,124	$2.84	3,887	888	1,457	6,232	155

The figures are concealed where less than three producers report in a county.

COAL PRODUCED IN MISSOURI IN 1928.

County.	Net tons.				Value.		Number of employes.				Average number of days worked.
							Underground.				
	Loaded at mines for shipment.	Sold to local trade and used by employes.	Used at mines for steam and heat.	Total quantity.	Total.	Average per ton.	Miners, loaders, and shot-firers.	All others.	Surface.	Total.	
Adair	135,070	20,479	6,763	162,312	$361,355	$2.22	249	108	27	384	175
Audrain and Ralls	11,925	12,802	58	24,785	99,410	3.10	67	17	9	93	187
Barton	1,344,814	6,695	22,821	1,374,330	3,295,317	2.40	235	37	602	874	150
Bates	162,640	29,923	1,350	193,913	408,566	2.11	173	37	134	344	150
Boone and Howard	66,594	39,819	159	106,572	263,839	2.68	84	20	78	182	185
Caldwell, Grundy, Harrison, and Schuyler	7,622	9,408	590	17,620	71,912	4.08	62	21	9	92	227
Callaway	....	34,691	12	34,703	128,917	3.72	67	13	29	109	214
Chariton	....	7,915	....	7,915	26,120	3.28	20	5	2	27	188
Clay and Platte	53,534	31,578	3,144	88,256	346,745	3.92	267	68	26	361	137
Henry	200,436	36,960	11,500	248,896	556,047	2.23	24	4	116	144	222
Johnson	39,580	5,446	1,380	46,406	123,826	2.67	63	10	9	82	267
Lafayette	429,538	54,839	9,153	493,530	1,384,986	2.81	671	215	67	953	231
Linn	8,991	19,409	....	28,400	105,893	3.73	89	11	11	111	160
Macon	180,912	30,523	5,356	216,791	531,531	2.45	323	66	41	430	205
Monroe	....	4,093	....	4,093	18,626	4.64	11	4	2	17	135

Putnam............	9,442	14,225	6	23,673	63,276	2.66	114	11	9	134	111
Randolph...........	113,672	60,670	4,897	179,239	472,589	2.64	306	77	38	421	200
Ray................	326,678	41,228	1,512	369,418	1,131,193	3.06	843	141	62	1,046	170
Vernon and Cedar...	104,957	4,000	2,612	111,569	246,475	2.20	29	4	127	160	119
Totals.........	3,196,405	464,703	71,313	3,732,421	$9,636,923	$2.58	3,697	869	1,398	5,964	180

The figures are concealed or combined with other counties where less than three producers report.

COAL PRODUCED IN MISSOURI IN 1929.

County.	Net tons.				Value.		Number of employes.				Average number of days worked.
	Loaded at mines for shipment.	Sold to local trade and used by employes.	Used at mines for steam and heat.	Total quantity.	Total.	Average per ton.	Underground. Miners, loaders, and shot-firers.	Underground. All others.	Surface.	Total.	
Adair	121,542	25,013	5,012	151,567	$368,194	$2.43	201	53	35	289	202
Audrain and Ralls	14,833°	9,664	60°	24,557	91,611	3.73	60	14	6	80	190
Barton and Jasper	1,602,631	8,362	16,361	1,627,354	3,471,687	2.13	204	32	600	836	178
Bates	232,527	30,894	6,690	270,111	542,147	2.07	129	28	187	344	145
Boone	....	36,002	40	36,042	113,026	3.14	65	22	10	97	161
Caldwell, Grundy, Harrison and Schuyler	4,791	10,737	....	15,528	67,715	4.36	51	14	7	72	169
Callaway	....	34,667	12°	34,679	126,419	3.63	61	13	29	103	199
Clay and Platte	67,200	39,025	3,350	109,575	392,853	3.58	238	87	25	350	367
Henry	216,404	53,753	9,800	279,957	563,137	2.01	38	12	110	160	193
Johnson	33,090	8,423	993	42,506	111,676	2.63	67	6	5	78	234
Lafayette	371,640	63,011	8,504	443,155	1,197,088	2.70	640	187	68	895	213
Linn	10,191	23,849	350	34,390	127,442	3.69	90	12	10	112	146
Macon	176,517	35,634	5,356	217,507	557,438	2.56	322	53	36	411	176
Monroe	....	502	502	2,132	....	3.98	2	2	1	5	100
Putnam	9,489	15,932	....	25,421	70,468	2.75	77	16	11	102	139

Randolph and Chariton..........	129,491	47,292	3,063°	179,846	457,663	2.54	296	76	38	410	331
Ray................	389,211	52,302	2,587	444,100	1,307,673	2.95	868	214	64	1,146	185
Vernon and Cedar...	88,109	3,155	2,250°	93,514	209,929	....	26	6	94	126	165
Totals..........	3,467,666	498,217	64,428	4,030,311	$9,778,298	$2.43	3,433	849	1,336	5,618	194

The figures are concealed or combined with other counties where less than three producers report.

LIST OF COAL PRODUCERS, 1929.

Compiled by and taken from annual reports of the State Bureau of Mines Inspection Department.

Operating company.	P. O. address.
ADAIR COUNTY—	
Adair Coal Company	Kirksville.
Arctic Coal and Mining Company	Box 66, Novinger.
Black Bottom Coal Company	Kirksville.
Blacksmith Coal Company	Connelsville.
City of Kirksville (Pump Station)	Kirksville.
Gates & Bachman Coal Co	Stahl.
Hanlin Coal Co	Connelsville.
Kansas City Midland Coal and Mining Co	Novinger.
Novinger Brothers & Co	Novinger.
Phillips Bros	Green Castle.
Ray & Williams	Stahl.
Riverside Coal Company	Novinger.
Scott & Von Langham	Novinger.
Slope Coal Company	Youngstown.
Steen and Morrow	Route 6, Kirksville.
Thorington, S. S	Route 2, Stahl.
B. G. Four Coal Co	Greentop.
Neff Seth, C., and Sons	Route 1, Novinger.
AUDRAIN COUNTY—	
Midway Coal Company	Vandalia.
Moser Coal Company	Martinsburg.
Quisenberry & Son Coal Company	Vandalia.
BARTON COUNTY—	
Alston Coal Company	Pittsburg, Kan.
Clemens Coal Company	Pittsburg, Kan.
Central Coal and Coke Company	Kansas City.
Cornell Coal Company	Pittsburg, Kan.
Crowe Coal Company	Kansas City.
Elm Branch Coal Company	Mulberry, Kan.
H. and H. Coal and Mining Company	Arcadia, Kan.
Liberal Coal and Mining Company	Liberal.
Minden Coal Company	522 Main, Joplin.
Mulberry Coal Company	205 Globe, Pittsburg.
Patterson, W. W., Coal Company	Pittsburg, Kan.
Pittsburg and Midway Coal Mining Company	415 Globe, Pittsburg.
Stephenson-Fenimore Coal Company	316 Globe, Pittsburg.
Western Coal and Mining Company	830 Planters, St. Louis.
BATES COUNTY—	
Consolidated Mines	Rich Hill.
Desirant, F., and Jule	Hume.
Donalson-Ryan Coal Company	Rich Hill.
Foster Coal Company	Pleasanton, Kan.
Hall Coal Company	Rich Hill.

LIST OF COAL PRODUCERS, 1929—Continued.

Operating company.	P. O. address.
BATES COUNTY—	
Hume-Sinclair Coal Mining Company	Hume.
J. F. Klaner Coal Company	205 Globe, Pittsburg.
Lloyd, F. W., Coal Company	Foster.
Mullies Coal Company	Pleasanton, Kan.
Ritchie Coal Mining Company No. 1	Rich Hill.
Schooley Coal Company	Foster.
BOONE COUNTY—	
Boyd Coal Company	Columbia.
Crosswhite, J. J	Columbia.
Davidson, Jesse	Columbia.
Harris Coal Company	Columbia.
Hoersch Coal Company	Columbia.
Keene, E. B	Columbia.
Lewis Coal Mine	Brown Station.
Lawson, I. P	Columbia.
Neinaber Coal Mine	Route 7, Columbia.
Oakland Cash Coal Co	Route 10, Columbia.
Oliver, J. F	Columbia.
Reese, R. H., Coal Company	Route 7, Columbia.
Smarr Coal Company	207 N. 8th, Columbia.
Tharp and Sons	Columbia.
CALDWELL COUNTY—	
West Mine Coal Company	Hamilton.
Carson and Company	Hamilton.
CALLAWAY COUNTY—	
Davis, Thomas	Stephens.
Harris, C. A., Coal Company	Fulton.
Harriss, R. L	Route 3, Fulton.
Hill-Gohring Coal Company	Fulton.
Reed, J. F., and Sons	Fulton.
Nickles, O. N	Stephens.
Scott and Shy	Fulton.
Sherman Coal Company	Fulton.
Trigg-Crowson Coal Company	Fulton.
CHARITON COUNTY—	
Chariton County Coal Company	Marceline.
Perkins, Roy	Keytsville
Slater, Roy E	Perry Hill.
CLAY COUNTY—	
Fairplay Coal and Development Company	Excelsior Springs.
Missouri City Coal Company	Missouri City.
Mosby Block Coal Company	Mosby.

LIST OF COAL PRODUCERS, 1929—Continued.

Operating company.	P. O. address.
GRUNDY COUNTY—	
Trenton Mining Company	Trenton.
HARRISON COUNTY—	
Melbourne Mining Company	Melbourne.
HENRY COUNTY—	
Cahal & Irwin	Calhoun.
Missouri Public Service Company	Clinton.
Milo Park Coal Company	Deepwater.
Reliance Coal Corporation	Clinton.
Standard Coal Company	R. 3, Clinton.
Tebo Coal Company	Clinton.
West Missouri Power Company	Pleasant Hill.
HOWARD COUNTY—	
Howard County Mining Company	1330 Grant, Kansas City.
JASPER COUNTY—	
Bainter Coal Company	Alba.
JOHNSON COUNTY—	
Bowen Coal and Mining Company	Windsor.
Daley, Victor	Windsor.
Hazel, Wm	Montserrat.
Kramer Coal Company	Montserrat.
Nance & Humphreys	Windsor.
Pendley, D. H	Montserrat.
LAFAYETTE COUNTY—	
Atwood Coal Company	Lexington.
Atlas Coal Company	Waverly.
Banks, Ira O	Higginsville.
Burns, Joe	Higginsville.
Bush, Sam	Mayview.
Canning & Marchette	Lexington.
Corder Coal Company	Corder.
Farmers' Fuel Company	400 Rialto, Kansas City.
Goring & Gann Coal Company	Higginsville.
Hamilton & Son	Higginsville.
Holman Coal Company	Lexington.
Imperial Coal Company	Corder.
Jelicic & Hotmer Coal Company	Wellington.
Lynch & Son Coal Company	Higginsville.
Napoleon Coal Mine	Napoleon.
Peek, H. S	Lexington.
Riley, J. W., Coal Company	Corder.
Collet & Hartwig	Higginsville.
Edwards, Lee A	Higginsville.

LIST OF COAL PRODUCERS, 1929—Continued.

Operating company.	P. O. address.
LAFAYETTE COUNTY—	
Horton, E. R	Mayview.
Heersman, James, Jr	Doner.
Summers, Emmet, Coal Company	Corder.
Tyler Coal Mine	Aullville.
Wegener & Son Coal Company	Higginsville.
Wilcoxon Coal Company	Lexington.
Wilson Mining Company	Corder.
Winfrey & Devlin Coal Company	Corder.
Wrzceiona, Chas. A., Coal Company	Higginsville.
Johnson, August	Higginsville.
Peper, Arthur	Lexington.
Rogers' & Boyle	Higginsville.
LINN COUNTY—	
Bucklin Coal Company	Bucklin.
Bunker Hill Coal Company	Marceline.
Landreth Coal Company	Box 404, Marceline.
Schaefer Coal Company	Brookfield.
Home Coal Company	Marceline.
Wine Coal Company	Brookfield.
Wine, G. C	Brookfield.
MACON COUNTY—	
Bevier Coal Company	Bevier.
Bischof Coal Company	Bevier.
Central Coal and Coke Company	Kansas City.
Green. Levi	Jacksonville.
Kitchen, J. L	Bevier.
Home Coal Company of Macon	Box 222, Macon.
Lingo Coal Company	New Cambria.
Midway Fuel Company	Bevier.
Morelli, Angelo	R. 4, Callao.
Riley Brown Coal Company	Jacksonville.
Roberts Coal Company	Macon.
Truitt Coal Mine	R. 2, Bevier.
Morty, Loyal	Macon.
O'Connor, Thomas	Macon.
MONROE COUNTY—	
Bloodworth, V. G	Madison.
Eubanks, C. G	Madison.
Duval Coal Mine	Madison.
Montgomery, W. J	Paris.
Maxey, L. H	Madison.
Maxey, James W	Madison.
Garnett, Ed	Madison.

LIST OF COAL PRODUCERS, 1929—Continued.

Operating company.	P. O. address.
MONTGOMERY COUNTY—	
Hays Coal Mine	Wellsville.
PUTNAM COUNTY—	
Ball Coal Company	R. 2, Coatsville.
Billingston & Clay	Stahl.
Dole, Bert, & Son	Mendota.
Dixon, H. G	R. 8, Unionville.
Maulsby & Carter	Unionville.
Mendota Block Coal Company	Mendota.
Murray, J. E	Powersville.
Shrake, Ollie	Livonia.
Walnut Coal Company	Unionville.
Vietch, Elmer	Unionville.
Bramball Bros	Mendota.
Buster Bros	Unionville.
Cassady, V. A	Livonia.
Daves, Irwin	Unionville.
Datson, L. L	Coatesville.
Garr, G. E., & Son	Coatesville.
Jarman, Milo	Unionville.
Kingston, O. L	Unionville.
Morningstar, A. J	Unionville.
Mannon, H. D	Mendota.
RALLS COUNTY—	
Clark Coal Company	Perry.
Boudener Coal Company	Perry.
Davis Coal Mine	Perry.
Howard, Frank	Perry.
Hurley Coal Mine	Perry.
Mills, Jess	Perry.
Perry Coal Company	Perry.
Home Coal Company	Perry.
RANDOLPH COUNTY—	
Anderson, James	Moberly.
Busy Bee Co-operative Coal Company	Huntsville.
Cannon, E. E	Clark.
Doleshy, Wm	Moberly.
Frazier Coal Mine	Huntsville.
Hill Coal Company	Huntsville.
Johnson, J. C	Huntsville.
Kerr & Kraft Coal Company	Huntsville.
Kribbs Brothers	Moberly.
Kribbs, S. W., & Son	Moberly.
Marriott Coal Company	Moberly.
Mea Coal Company	Moberly.
Moberly Fuel and Transfer Company	Moberly.

LIST OF COAL PRODUCERS, 1929—Continued.

Operating company.	P. O. address.
RANDOLPH COUNTY—	
Moniteau Coal Company	Higbee.
Rodger Brothers Coal Company	Huntsville.
Tharp, Bob	Huntsville.
Swetman, A	Jacksonville.
Tornow, Fred C	Clark.
Willsie, J. G	Jacksonville.
Citizens Coal Company	Higbee.
Halbrook & Essy	Moberly.
Jones, W. H., & Son	Huntsville.
Simpson & Rudkin	Huntsville.
RAY COUNTY—	
Bryce, J. W., & Son	R. 4, Richmond.
Bucklinger, J. F	R. 3, Hardin.
Clay Coal and Mining Company	Excelsior Springs.
Conrow & Williams	Richmond.
Crispin Coal Company	Richmond.
Edgar, Pearl H	Norborne.
Edgar, W. T	Hardin.
Elmira Coal Company	511 Interstate, Kansas City.
Fowler Coal and Mining Company	Richmond.
Hubbell-Hamilton Coal Company	Richmond.
Mercantile Coal and Mining Company	Richmond.
Ottman & Dickson Coal Company	Richmond.
Pickering Coal Company	Richmond.
Ray County Coal Company	Richmond.
Rayville Coal Company	Rayville.
Seek, Jack	R. 4, Norborne.
Thomas Brothers Coal Company	Orrick.
Three "W" Coal Company	Henrietta.
Vibbard Coal Mining Company	Vibbard.
Ballard Coal Company	Hardin.
Bates, F. C	Richmond.
Blair, Hugh	Rayville.
Chenoult Coal Company	Richmond.
Hill, Perry J	Richmond.
Gaut, J. M	Norborne.
Johnsone, L. E., & Sons	Hardin.
Raminces, I. T	Hardin.
Camden Coal Company	Camden.
Central Coal and Coke Company	Camden.
Mutual Coal and Mining Corporation	Camden.
Pickering, Geo., Coal Company	Richmond.
ST. CLAIR COUNTY—	
Collins & Bourland	Osceola.
Smith, C. P.	Osceola.

LIST OF COAL PRODUCERS, 1929—Continued.

Operating company.	P. O. address.
SCHUYLER COUNTY—	
Hoover, W. M.	Coatesville.
VERNON COUNTY—	
Highway Coal Company	Rich Hill.
N. & S. Coal Company	Pittsburg.
Yarcho, A. F., Coal Company	Nevada.
Hamilton Coal Company	Arthur.

COPPER, COBALT AND NICKEL.

A small amount of copper was reported during the last two years. At present there are no deposits being worked and that produced was derived from matte recovered in the smelting of lead ores from southeast Missouri. There are two areas within the state from which copper ores have been produced, and in which some exploratory work has been done. One area is located in Ste. Genevieve County, the deposits being discussed fully in a recent report, Volume XXII, which has been issued by the Survey. The other district is located in Shannon County, and a report just completed, Volume XXIV, describes fully the occurrence of the ores, the future possibilities, and the interesting geologic features of the area. Copper has also been found in other parts of the State, but deposits found to date do not appear to offer any great possibilities of becoming large producers.

There has been no production of cobalt or nickel in the Fredericktown district, in Madison County, in recent years. However, some prospecting with churn drills has been done.

IRON ORE.

In 1929, the total value of iron ore was $646,292, the production being the largest recorded for several years. During the past biennial period the four types of iron ores found in this state were being produced. Red hematite, found in typical filled-sink type of deposits was being obtained from the Acid mine near Sullivan, Franklin County; from near Reese and Anutt in Dent County; and from near Licking in Texas County.

Production of specular hematite from Iron Mountain by the Missouri Ore Company was reported until the fall of 1930, when the mine and plant were shut down as the result of a shortage of water.

A small tonnage of limonite was also produced. The Missouri Brown Iron Ore Company operated deposits of primary limonite at Puxico, Stoddard County, and near Hillard, Butler County. The company also produced secondary limonite from the Sanderson mine near Chaonia in Wayne County.

There has been considerable interest shown in the Missouri deposits during the last two years, and prospecting has been in progress. In this connection the Survey has experimented with geophysical methods of prospecting as a guide to locating additional deposits. The methods used and the results are given elsewhere in this report. (Appendix III.)

LEAD.

The lead belt of southeast Missouri is the largest producer in the world, and is the most important factor in the total mineral wealth of the state. In 1929 the value of lead produced in Missouri was $2,341,506 greater than the value produced in 1928, and was only slightly less than the value of the production in 1927.

In the southeast district, a greater tonnage of crude ore was hoisted in 1928 than in 1927 and 1929. However, there was a noticeable decrease in the total value of the concentrates, which was due to the decrease in the average value per ton.

Exploration work has continued during the past two years. In this connection, magnetometer surveys have been made by the Survey. The results are described elsewhere in this report. Many churn and diamond core drill samples have also been obtained. These will be studied in the survey laboratory in an endeavor to zone the sedimentary formations and correlate them throughout the district by means of the insoluble residue method. Some information regarding the character of the ore-bearing portion of the Bonneterre dolomite may also be obtained.

The properties of the Desloge Consolidated Lead Company in the Southeast Missouri Lead belt were acquired by the St. Joseph Lead Company during the past biennial period.

PRODUCTION OF LEAD IN MISSOURI, 1927-1929.

District.	1927.				1928.				1929.			
	Galena.		Carbonate.		Galena.		Carbonate.		Galena.		Carbonate.	
	Quant. (short tons).	Value.	Quant. (short tons).	Value.	Quant. (short tons).	Value.	Quant. (short tons).	Value.	Quant. (short tons).	Value.	Quant. (short tons).	Value.
Southwestern Missouri:												
Aurora, Bryceville and Wentworth (a)	18	$1,440					63	$3,800	71	$6,370	20	$1,200
Carl Junction	2	170										
Duenweg, Porto Rico	1,225	110,100			24	$1,963	1	61	2	170	4	250
Granby	235	17,085			151	10,260			114	8,397		
Joplin	559	45,072	200	$12,000	684	53,248	100	5,979	659	55,004	100	6,000
Oronogo	147	10,057			161	10,702			68	5,438		
Spring City, Spurgeon and Seneca	73	6,192	100	6,000	120	9,065			140	10,012	30	2,000
Smithfield, Zincite and Belleville (b)	164	14,826			46	3,609			1	96		
Thoms Station (b)	325	24,802										
Waco	168	12,803			62	4,486						
Webb City, Carterville and Prosperity (a)	180	15,202			150	11,572			203	17,781		
Dade and Hickory Counties	10	850										
Green County					15	1,200						
Taney County									5	425		
Totals	3,106	$258,599	300	$18,000	1,413	$106,105	164	$9,840	1,263	$103,693	154	$9,450
Southeastern and Central Missouri	279,441	23,360,294			274,925	19,107,891			277,986	21,017,310		
Totals	282,547	$23,618,893	300	$18,000	276,338	$19,213,996	164	$9,840	279,249	$21,121,003	154	$9,450

(a) Aurora only in 1928 and 1929.
(b) Includes Smithfield and Zincite only in 1926; Smithfield and Belleville only in 1927; Smithfield and Thoms Station only in 1928; Zincite and Klondike only in 1929.
(c) Does not include Prosperity in 1927 and 1929.

TENOR OF CRUDE LEAD ORE AND CONCENTRATES IN SOUTHWEST MISSOURI, 1926-1929.

	1926.	1927.	1928.	1929.
Total crude ore, short tons	1,025,500	513,800	281,300	428,400
Total lead concentrates in crude ore, per cent	0.54	0.66	0.56	0.33
Lead content of crude ore, per cent	.39	0.50	0.41	0.25
Average lead content of galena concentrates, per cent	76.8	76.5	74.2	76.3
Average lead content of carbonate concentrates, per cent	60.0	60.0	59.1	60.0
Average value per ton:				
Galena concentrates	$105.74	$83.26	$75.16	$82.31
Carbonate concentrates	78.87	60.00	60.00	61.36

VALUE AND TENOR OF LEAD ORES, 1923-1929.

Year.	All Missouri.			Southeast Missouri only.			
	Total concentrates.	Total value concentrates.	Total crude ore.	Galena concentrates in crude ore.	Lead in crude ore.	Average lead in concentrates.	Average value per ton concentrates.
1923	262,442	$19,692,318	5,314,900	4.88	3.21	65.9	$74.94
1924	296,004	25,037,380	6,059,700	4.83	3.26	67.6	84.55
1925	317,972	32,112,009	6,209,800	5.06	3.43	67.6	100.91
1926	305,767	28,793,639	6,261,600	4.80	3.32	69.0	93.98
1927	282,547	23,636,893	6,310,200	4.42	3.17	71.7	83.62
1928	276,502	19,223,836	6,292,500	4.37	3.17	72.1	69.50
1929	374,837	29,195,858	6,439,600	4.31	3.13	72.7	75.61

LIME.

The value of the output of the lime industry has increased steadily during the past four years and in 1929 reached a total of $2,319,886. In 1928, when the last comparative figures were available the state ranked third in the production of this important material.

The limestones of Mississippian age are the chief source of the raw stone used. In the important Ste. Genevieve district, the Spergen limestone is well developed, and the high grade oolitic rock furnishes the basis for an extensive lime burning industry, which produces a product suitable for chemical uses. The Ste. Genevieve district has been described in Volume XXII, published by the Survey.

The Burlington limestone, also of Mississippian age, is used at Hannibal, Marion County, at Osceola, St. Clair County, at Ash Grove, Galloway, and Springfield in Greene County and at Pierce City, Lawrence County. This formation has a widespread distribution and is present over large areas in Eastern, Northeastern, Central and Southwestern Missouri.

The Kimmswick limestone of Ordovician age is used at Brickeys, Ste. Genevieve County, and at Mincke and Glencoe in St. Louis County. The stone burns to a strong gray lime. It is used extensively in plastering.

Several years ago the Survey published a detailed report covering the lime and cement resources, copies of which are available for distribution.

The tables below give the production and value of the lime produced in Missouri for a period of several years; also the detailed figures covering the output, value and uses of lime burned in 1927, 1928 and 1929. A list of producers is also given. In 1929, production was reported from 13 plants. The total number of kilns was reported as 82.

PRODUCTION AND VALUE OF LIME, 1917-1929.

Year.	Lime.			Hydrated lime.		
	Quantity (tons).	Value.	Average value per ton.	Quantity (tons).	Value.	Average value per ton.
1917......	234,936	$1,435,914	$6.48	32,120	$219,600	$6.88
1918......	166,795	1,376,046	8.25	34,942	345,754	9.90
1919......	141,504	1,333,095	9.42	39,245	402,620	10.26
1920......	157,126	1,735,002	11.04	51,987	584,283	11.24
1921......	113,291	1,169,391	10.32	45,903	487,169	10.61
1922......	147,960	1,402,337	9.48	56,024	551,187	9.84
1923......	182,503	1,830,937	10.03	63,823	674,848	10.57
1924......	182,814	1,711,180	9.36	60,651	642,995	10.60
1925......	202,058	1,860,244	9.21	71,290	750,710	10.50
1926......	180,016	1,428,412	7.93	83,451	790,531	9.47
1927......	183,374	1,437,140	7.81	84,402	752,280	8.91
1928......	202,797	1,398,843	6.89	100,217	853,577	8.52
1929......	208,820	1,401,090	6.70	107,759	918,796	8.52

OUTPUT, VALUE, AND USES OF LIME BURNED IN 1927-1929.

Use.	1927.		1928.		1929.	
	Quantity (tons).	Value.	Quantity (tons).	Value.	Quantity (tons).	Value.
Building chemical........	101,763	$929,260	210,949	$1,645,865	197,041	$1,539,647
Paper mills....	18,381	144,935	13,399	82,150	14,052	94,348
Tanneries.....	2,384	20,615	2,653	19,732	2,542	19,667
Metallurgy....	27,456	189,949	35,084	202,834	47,207	270,561
Water treating.	31,909	267,664	38,319	282,804	49,906	359,093
Other.........	85,883	636,997	2,610	18,897	5,831	36,570
Totals....	267,776	$2,189,420	303,614	$2,252,282	316,579	$2,319,886

PRODUCERS OF LIME IN MISSOURI.

Producers.	Location.
GREENE COUNTY—	
Ash Grove Lime and Portland Cement Company..	Ash Grove and Galloway.
The Marble Head Lime Company..............	Springfield.
JEFFERSON COUNTY—	
Glencoe Lime and Cement Company............	Byers.
LAWRENCE COUNTY—	
Peirce City Lime Company....................	Peirce City.
MARION COUNTY—	
The Marble Head Lime Company..............	Hannibal.
ST. CLAIR COUNTY—	
Osceola Lime Company.......................	Osceola.
STE. GENEVIEVE COUNTY—	
Arrowhead Manufacturing Company............	Brickeys.
Peerless White Lime Company.................	Mosher.
Ste. Genevieve Lime and Quarry Company......	Ste. Genevieve.
Western Lime Works.........................	Ste. Genevieve.
Bluff City Lime and Stone Company...........	Ste. Genevieve.
ST. LOUIS COUNTY—	
Glencoe Lime and Cement Company............	Mincke, Glencoe.
Centaur Lime Company.......................	Glencoe.

MINERAL WATERS.

The nationally known watering resort of Excelsior Springs, Clay County, continues to be the leading producer of mineral waters in Missouri. The output comes from mineral springs located in and near this town, and from highly mineralized deep well waters. Mineral waters are also obtained in many other parts of the state as indicated in the list of producers given below.

There has been a noticeable decrease in the production and value of mineral waters during the past few years. A part of this at least is attributed to the failure of many producers to report their output to the Survey.

The value of the output from 1914 to 1929, follows:

PRODUCTION OF MINERAL WATERS, 1914-1929.

Year.	Value.
1914	$74,793
1915	83,363
1916	109,814
1917	57,175
1918	38,478
1919	39,641
1920	50,892
1921	45,670
1922	40,149
1923	38,145
1924	30,000
1925	32,000
1926	41,955
1927	29,452
1928	12,000
1929	11,898

PRODUCERS OF MINERAL WATERS.

Proprietor.	Name of spring.	Location.
BARRY COUNTY—		
S. S. Sandy	Radium Springs	Seligman.
CEDAR COUNTY—		
Wm. Reed	Eldorado Springs	Eldorado Springs.
CLAY COUNTY—		
Crystal Mineral Water Company	Crystal Mineral Springs	Excelsior Springs.
Excelsior Saline Water Company	Excelsior Saline	Excelsior Springs.
Mrs. H. Varney	Lithia No. 1	Excelsior Springs.
Salt Sulphur Water Company	Salt Sulphur Wells	Excelsior Springs.
Natrona Springs	Natrona Wells	Excelsior Springs.
Mrs. Callerman	Soda Saline Well	Excelsior Springs.
Sulpho-Saline Water Company		Excelsior Springs.
COOPER COUNTY—		
E. A. Windsor	Chouteau Springs	Chouteau Springs.
JACKSON COUNTY—		
Ulrich & Boisin	Crystal Springs	Kansas City.
Crystal Springs Water Co	Crystal Springs	Kansas City.
JEFFERSON COUNTY—		
Bokert Springs Mineral Water Co.	Bokert Springs	DeSoto.

PRODUCERS OF MINERAL WATERS—Continued.

Proprietor.	Name of spring.	Location.
MERCER COUNTY—		
J. S. Haymaker	Haymaker Mineral Well	Mercer.
PIKE COUNTY—		
The Bowling Green Mineral Spring Company	B. B., Epzo, Fronzo and Bowling Green Lithia Water	Bowling Green.
Amos and Margaret Turner	Hornet	Bowling Green.
ST. LOUIS COUNTY—		
Belcher Water, Bath and Hotel Company	Belcher Artesian Well	St. Louis.
Old Orchard Mineral Springs	Old Orchard Mineral	St. Louis.
SALINE COUNTY—		
Missouri Mineral Water Company	Sweet Springs	Sweet Springs.

OIL AND GAS.

During the past three years considerable interest has been manifested by oil and gas operators in the shallow fields of Western Missouri. Oil and gas have been known to occur in this part of the state for many years and production at shallow depths had been obtained in Vernon, Bates, Cass, Jackson and Clay counties. The real impetus to the gas industry probably resulted in the drilling in, up to the present time, of over 60 wells on the Belton structure in Cass and Jackson counties. Production from this field had been obtained as early as 1904, and in 1918, the Survey published a report, on the area. A detailed structure map was included. A pipe line terminating in Kansas City has been constructed to handle the output of gas.

The shallow depths, the ease of drilling and the production obtained have resulted in the search for other areas. During the latter part of 1929, 16 gas wells were drilled west of Drexel, Cass County, in the adjoining area in Kansas. In 1930 production was extended northeast into Missouri and 20 or more wells were completed north and east of Freeman, Cass County. A pipe line is being constructed.

The most extensive drilling campaign has been in Jackson County. In the vicinity of Blue Springs, some 60 gas wells have been drilled, the average depth being about 350 feet. The wells have an average open flow of about 1,000,000 cubic feet per day.

Gas has also been found in the Bannister ridge field south and east of Raytown, where approximately 50 productive wells, with a total open flow of 30,000,000 cubic feet, have been completed. The wells range in depth from 450 to 500 feet.

Gas has also been found at Vale, on the property of the United Brick and Tile Company. It is used to fire the kilns. Fourteen holes have been drilled, however, not all of them were producers.

About 18 productive wells have been drilled at Lees Summit, the gas being used for local consumption. In the southeast part of Jackson County near Lone Jack, some 40 gas wells have been completed.

Oil has also been found in a number of wells in the Belton-Martin City fields, at Lees Summit and at Lone Jack. Near Lees Summit, 16 wells have been drilled on Unity Farm. The settled production varies from one-half to two barrels of heavy oil per day. Two wells have recently been completed on the Hoke farm near Lees Summit with a reported production of 20 barrels each.

The drilling campaign has been extended into the area north of the Missouri River, and 18 wells have been brought in on the Paradise structure, 6 miles northeast of Smithville, in Clay County with a total of 8,000,000 cubic feet of gas. In the same county about 2,000,000 feet of gas, from 5 wells, has been obtained from the Avondale structure.

Gas has also been obtained from three wells near Plattsburg, and an area five miles southwest of that town is now being drilled.

A pipe line is now being constructed to gather the gas in the Avondale, Paradise and Plattsburg fields. This line will supply Trimble, Mecca, Plattsburg and Lathrop.

Production has been obtained mainly from sandstones in the Cherokee formation. Some production has also been obtained from the overlying Henrietta beds, and to a small extent from the Pleasanton sandstones.

From the field work to date, it appears that production is obtained from small folds, superimposed upon broad, flat anticlinal structures trending in a northwest-southeast direction. These broader structural features were first outlined in Volume XIII, "Stratigraphy of the Pennsylvanian Series," which was published by the Survey in 1914. They were again described in Volume XVI, "The Occurrence of Oil and Gas in Missouri," published 1918. There is the suggestion that local structures favorable for the accumulation of gas occur as the result of the intersection of minor folds, striking in a northeast-southwest direction with the major folds mentioned above.

The survey has published besides the reports mentioned, bulletins describing the geology of Jackson and Vernon Counties; the Leavenworth-Smithville folio (in co-operation with the U. S. Geological Survey); a state geological map; and many topographic maps covering the counties in which activity is being shown at the present time. Unpublished geologic and structure maps and a detailed report covering Platte County are available for consultation.

During the past year a member of the staff has been investigating areas in this part of the state and it is hoped that this work may be extended. The Survey has many records of drilling in Western Missouri, and will appreciate receiving from operators additional ones, as well as sets of drill samples. Log books and sacks will be furnished free of charge.

Such information will be of value in outlining in greater detail the major structural features, and hence areas that merit testing.

The area contiguous to St. Louis has also been of interest as the result of the discovery of oil in the Kimmswick limestone of Ordovician age, in the Dupo field, across the river in Illinois. A number of tests have been drilled, but to date no production has been found. Sets of samples from most of these wells are on file in the Survey office. A detailed study of them will lead to a better understanding of the possibilities in Eastern Missouri.

PYRITES.

In the central Ozark region, the sink-hole type deposits of red hematite have originated from the oxidation of the original mineral, pyrite. In many of them the alteration has not been completed and commercial deposits of pyrite are found in the lower part of the deposits. The mineral was mined for many years and used for the manufacture of sulphuric acid. There is no production at the present time.

SAND AND GRAVEL.

This branch of the mineral industry shows in 1929 a notable increase in value of the total production, over the preceding years and establishes a record value of $4,170,593. The production exceeds that of the year 1928 by $921,780, and that of the previous record year of 1925 by $575,406.

The increase in production and value is no doubt the direct result of the passage of the $75,000,000 Road Bond Issue in 1928, and the pushing toward completion of the state's primary and secondary system of highways. A considerable amount of the output was also used for structural purposes, such as buildings, bridges, culverts, etc.

In so far as the sand and gravel resources are concerned, the state may be roughly divided by the Missouri River into two parts. That portion lying south of that river, including the Ozark region abounds in deposits of both materials. The chert-bearing dolomites and limestones and the beds of sandstone exposed within the area of the Ozark uplift contribute large quantities of sand and gravel to the swift streams of that region. The widespread distribution of the deposits in this part of the state and their accessibility have contributed materially to the rapidity of construction of the splendid highway system of that rugged province. The deposits have also been used for other purposes, one notable one, being the use of local materials in the construction of the hydro-electric plant near Bagnell on the Osage River.

The north half of the state, with the exception of the eastern and southeastern portions is mantled by glacial clay and consequently is not so favorably situated with respect to deposits of these materials. Locally, suitable deposits have been found in the glacial drift, and additional deposits are being continually sought.

Besides the uses mentioned, the sand produced in this state is utilized in the glass-making industry, for cutting and grinding purposes and for engine sand. A considerable portion of this material is obtained from the St. Peter sandstone which outcrops in the eastern part of the state.

Several years ago the Bureau published a detailed report covering the sand and gravel resources of Missouri. The known, as well as possible deposits, are discussed, and the results of many tests are given. Copies of this report are available upon request.

The statistical tables given below cover the production of sand and gravel in this state, and the location of the deposits is indicated by the list of producers.

OUTPUT AND VALUE OF SAND AND GRAVEL FOR 1928-1929.

	1928.		1929.	
	Quantity (short tons).	Value.	Quantity (short tons). (c)	Value. (c)
Building sand	1,223,547	$722,807	1,244,725	$855,727
Building gravel	1,180,406	764,236	810,607	616,497
Paving sand	743,642	490,130	1,266,690	872,546
Paving gravel	885,691	671,440	1,488,740	1,202,020
Glass sand	145,554	188,960	123,141	178,531
Molding sand	95,503	64,814	82,970	59,095
Engine sand	65,010	47,271	32,837	20,832
Other sands (a)	150,675	104,936	185,100	175,318
Railroad ballast (b)	761,198	194,219	381,665	190,027
Totals	5,251,226	$3,248,813	5,616,475	$4,170,593

(a) Includes cutting and grinding sand, railroad ballast sand and miscellaneous sand.
(b) Includes miscellaneous gravel.
(c) Subject to revision.

PRODUCTION OF SAND AND GRAVEL, 1915-1929.

Year.	Quantity (short tons).	Value.	Average value per ton.
1915	2,889,211	$675,684	$ .23
1916	3,643,205	877,634	.24
1917	2,274,072	1,101,745	.48
1918	1,743,616	772,753	.44
1919	1,665,295	873,333	.52
1920	1,909,314	1,356,352	.71
1921	1,539,073	1,018,325	.51
1922	1,970,345	1,063,370	.54
1923	3,719,243	2,007,529	.54
1924	4,081,200	2,053,436	.50
1925	5,523,605	3,595,187	.65
1926	4,611,952	2,980,242	.64
1927	4,829,473	2,875,530	.59
1928	5,251,226	3,248,813	.62
1929	5,616,475	4,170,593	.74

LIST OF SAND AND GRAVEL PRODUCERS, 1928-1929.

Operator.	Name of product.	Location.
BOLLINGER COUNTY—		
Lutesville Sand and Gravel Co.	Paving sand, gravel	Lutesville.
BUCHANAN COUNTY—		
Pioneer Sand Co.	Building sand, paving	St. Joseph.
BUTLER COUNTY—		
Randles Sand and Gravel Co.	Building sand and gravel.	Poplar Bluff.
Energy Coal and Supply Co.	Building sand, paving sand, gravel	Poplar Bluff.
CAPE GIRARDEAU COUNTY—		
Cape Girardeau Sand Co.	Building sand	Cape Girardeau.
CARROLL COUNTY—		
Wellington, Parkins	Structural sand (for concrete and metal)	Carrollton.
COLE COUNTY—		
Jefferson City Sand and Gravel Co.	Building sand	Jefferson City.
COOPER COUNTY—		
Missouri River Sand and Gravel Co.	Building sand, paving sand	Boonville.
CRAWFORD COUNTY—		
State Highway Department	Paving and road-making gravel	Steelville.
FRANKLIN COUNTY—		
W. W. Goran	Moulding sand	Gray Summit.
Denton Sand and Gravel Co.	Paving and road-making.	Pacific.
Pioneer Silica Products Co	Glass	Pacific.
Missouri Hardstone and Brick and Tile Co.	Structural sand	Pacific.
W. G. Kruel	Paving and road-making gravel	
GREENE COUNTY—		
State Highway Department	Paving and road-making gravel	Springfield.
HOWARD COUNTY—		
Glasgow Sand Co.	Building sand	Glasgow.
JACKSON COUNTY—		
Stewart Sand Co.	Building sand	Kansas City.

LIST OF SAND AND GRAVEL PRODUCERS, 1928-1929—Continued.

Operator.	Name of product.	Location.
KNOX COUNTY—		
Ed Belcher	Paving and road sand, structural gravel, paving and road gravel	Marysville.
LEWIS COUNTY—		
Keokuk Sand Co	Structural sand	Keokuk, Iowa.
Missouri Gravel Co	Structural paving and road-making sand	LaGrange.
State of Missouri Highway Dept		LaGrange.
LIVINGSTON COUNTY—		
Johnson-Hudson Gravel Co		Chillicothe.
MARIES COUNTY—		
State Highway Department	Paving and road-making gravel	
MARION COUNTY—		
Lawson Coal and Sand Co	Structural sand, railroad sand, engine sand	Hannibal.
MONROE COUNTY—		
State Highway Department	Paving and road gravel	
MORGAN COUNTY—		
State Highway Department	Paving and road gravel	
OSAGE COUNTY—		
State Highway Department	Paving and road gravel	
PEMISCOT COUNTY—		
Caruthersville Sand and Gravel Co.	Structural sand, paving and road-making sand, structural and paving and road-making gravel.	Caruthersville.
PERRY COUNTY—		
Arkansas Rock and Gravel Co		Wittenberg.
PIKE COUNTY—		
Northeast Missouri Sand and Gravel Co		Bowling Green.
PETTIS COUNTY—		
H. H. Hanenkratt		5202 Brookwood Ave., Kansas City, Mo.
PULASKI COUNTY—		
C., R. I. & P. Railroad	Structural gravel, railroad ballast	

LIST OF SAND AND GRAVEL PRODUCERS, 1928-1929—Continued.

Operator.	Name of product.	Location.
ST. CHARLES COUNTY—		
Tavern Rock Sand Co.	Glass sand	Klondyke.
St. Charles Sand and Material Co.	Paving and road-making	St. Charles.
ST. LOUIS COUNTY—		
Missouri Portland Cement Co.	Gravel, building sand	Jedborg.
St. Louis Material and Supply Co.	Building sand and gravel	314 N. Fourth St., St. Louis.
Alpha Portland Cement Co.		St. Louis, Valley Park.
Meramec Portland Cement Co.	Structural sand, structural gravel	St. Louis.
ST. LOUIS CITY—		
Missouri Portland Cement	Building sand	St. Louis.
Ruprecht Sand and Material Co.	Structural sand	St. Louis.
STONE COUNTY—		
State Highway Department	Paving and road gravel	
WRIGHT COUNTY—		
State Highway Department	Paving and road gravel	

SILVER.

The small output of silver is recovered in the refining of lead obtained from the disseminated deposits of southeast Missouri. According to the Bureau of Mines, the concentrates from this district, considered over a period of years, average about one ounce of silver to the ton.

The Einstein mine in Madison County has not been in production. Galena was produced from the property at one time which carried 30 to 40 ounces of silver per ton.

PRODUCTION OF SILVER IN MISSOURI, 1923-1929.

Year.	Ounces.	Value.
1923	177,270	$145,361
1924	103,694	69,475
1925	86,340	57,538
1926	90,000	56,160
1927	233,931	132,638
1928	176,840	103,451
1929	181,638	96,813

STONE.

The total value of the production of stone in 1929, was another field in which a new high was established, the total being $7,731,615. The increase is due to the record production of limestone and sandstone and to a smaller extent, in the increase in production and value of chats, or tailings from the milling of lead-zinc ores in Southeast and Southwest Missouri.

The stone resources of the State are varied. The chief contributors to this industry are given in the table below, and discussed in detail under each respective heading.

VALUE OF STONE PRODUCED IN MISSOURI, 1914-1929.

Year.	Limestone.	Marble.	Granite.	Sandstone.	Chats.	Total.
1914....	$2,160,958	(*a*)	$77,971	$3,588	$340,616	$2,583,133
1915....	2,049,772	(*a*)	85,624	10,104	346,358	2,491,858
1916....	1,990,419	$156,942	80,390	14,991	433,645	2,676,387
1917....	1,679,677	227,520	58,241	6,862	214,007	2,186,307
1918....	1,359,755	238,111	54,523	(*b*)	135,319	(*c*) 1,787,708
1919....	1,759,029	360,287	(*b*)	(*d*)	206,353	(*e*) 2,325,669
1920....	2,776,936	616,550	114,663	(*b*)	167,028	(*c*) 3,675,177
1921....	2,269,457	627,729	81,389	(*d*)	259,571	3,238,146
1922....	2,409,202	816,098	85,093	(*b*)	(*f*) 306,252	(*c*) 3,593,183
1923....	3,173,622	1,085,122	83,804	(*b*)	(*f*) 431,884	(*c*) 4,795,370
1924....	3,624,089	1,229,160	108,084	(*d*)	520,269	5,473,613
1925....	4,085,883	1,439,604	137,348	(*d*)	399,002	6,058,874
1926...	4,416,006	1,446,983	(*g*) 154,850	(*d*)	382,080	6,399,919
1927....	4,002,987	1,108,159	(*g*) 145,447	(*d*)	526,933	5,783,526
1928....	4,476,135	1,425,060	(*g*) 236,436	(*g*)	475,888	6,613,519
1929....	5,704,241	932,471	(*g*) 126,103	322,508	646,292	7,731,615

(*a*) Included in limestone.
(*b*) Not given, less than three producers.
(*c*) Not including sandstone.
(*d*) No production.
(*e*) Not including granite.
(*f*) Revised.
(*g*) Also includes trap rock; and miscellaneous stone and sandstone in 1928.

LIMESTONE.

A study of the geologic column of Missouri will show that limestone is the predominating sedimentary rock. It is likewise the predominating contributor to the total value of the stone produced, and in its own right is an important feature of the state's mineral industry, as the total value of $5,704,241 in 1929 will attest. The production in this year established a new high record, and an increase since 1919 of nearly $4,000,000. The increase is no doubt due in a large measure to the construction of the State system of paved roads, and to the general construction program, which reflects the state's development as a whole.

Limestone beds adapted to many uses are extensively developed in many parts of the State, and in particular to most of the larger towns and cities. In fact, limestone is available to all except a few counties.

The tables given below show the value of the limestone produced. The production is classified according to uses. The list of producers also indicates the general location of the deposits.

VALUE OF LIMESTONE PRODUCED ACCORDING TO USES, 1926-1929.

Purpose.	1926	1927	1928	1929
Rough construction	$3,440	....	$1,405	$42,522
Dressed building	....	(a)	25,152	....
Rubble	327,105	240,311	504,672	377,541
Riprap	597,309	565,165	843,106	1,806,529
Railroad ballast	78,400	344,006	165,227	193,952
Concrete and road making	3,107,147	2,522,539	2,531,038	2,803,551
Flux	11,952	10,277	18,697	24,287
Glass factories	(b)	40,092	34,329	(b)
Agriculture	71,523	77,875	102,028	161,838
Miscellaneous (b)	219,130	202,722	250,331	294,021
Totals	$4,416,006	$4,002,987	$4,476,135	$5,704,241

(a) Includes paper mills, lime burners, paving and curbing, sugar factories, whiting, filler for asphalt, rubber, and paint, and other uses, and rough architectural stone in 1929.

PRODUCERS OF LIMESTONE IN MISSOURI.

Firm.	Type and uses of stone.	Location of quarry.
ANDREW COUNTY—		
St. Joseph Quarry Company......	Concrete...............	
Stewart Stone Company.........	Rubble, riprap, road-metal and concrete..........	Amazonia.
BOONE COUNTY—		
J. N. Fellows...................	Riprap, concrete, agricultural.................	Columbia.
U. S. Engineer's Office..........	Riprap.................	Wilton.
Missouri State Penitentiary......	Riprap, road metal and concrete..............	
BUCHANAN COUNTY—		
Heumader Quarry Company......	Road metal and concrete.	
BUTLER COUNTY—		
John W. Rook & Son...........	Road metal, concrete and riprap...............	Butler.
CALLAWAY COUNTY—		
U. S. Engineer's Office..........	Riprap.................	Cedar City.
CAPE GIRARDEAU COUNTY—		
Edward Hely Stone Company....	Concrete, railroad ballast, road metal, agricultural.	Cape Girardeau.
The Arnold Stone Company......	Riprap.................	Neely's Landing.
Barret Lime Quarries, Inc........	Riprap.................	Neely's Landing.
Marquette Cement Mfg. Co......	Road metal and concrete, railroad ballast........	Cape Girardeau.
CLARK COUNTY—		
L. W. Lewis Sons..............	Railroad ballast.........	Dumas.
CLAY COUNTY—		
S. H. Atwood & Son............	Riprap, road metal and concrete.............	Liberty.
Excelsior Springs Rock Co.......	Road metal and concrete.	Excelsior Springs.
Lester Clevenger................	Riprap.................	
Consumers' Material Corp......	....	
COLE COUNTY—		
Pope Construction Company.....	Concrete...............	Cottonrock.
COOPER COUNTY—		
Blackwater Stone Company......	Road metal and concrete.	Blackwater.
Missouri State Reformatory......	Riprap, road metal and concrete, railroad ballast..................	
Missouri, Kansas & Texas Ry....	Railroad ballast, riprap...	Sweeney.

PRODUCERS OF LIMESTONE IN MISSOURI—Continued.

Firm.	Type and uses of stone.	Location of quarry.
FRANKLIN COUNTY—		
U. S. Engineer's Office	Riprap	Berger.
L. G. Krull	Concrete	
GREENE COUNTY—		
Ash Grove Lime and Portland Cement Company	Road metal and concrete	Ash Grove, Galloway.
Springfield Special Road District	Road metal and concrete	
Missouri Crushed Stone Products	Road metal and concrete	
Phenix Marble Company	Rough architectural dressed rubble	Phenix.
Sunshine Quarries, Inc	Road metal and concrete	
Williams & Schneider Stone Co	Road metal and concrete	Springfield.
Stigall Construction Company	Road metal and concrete	
Horton Stone Company	Road-making	Springfield.
Marblehead Lime Company	Lime, road-making, railroad ballast, concrete	Springfield.
HARRISON COUNTY—		
Concrete Material Corp	Road metal and concrete	Bethany.
HOWARD COUNTY—		
U. S. Engineer's Office	Riprap	Glasgow-Lisbon.
JACKSON COUNTY—		
Kansas City Public Service	Riprap, road metal	
Jackson County	Rubble, road metal and concrete	
Findlay Malborough Realty Co	Rubble	
Frank Flin Construction Co	Rubble	
U. S. Engineer's Office	Riprap	Eton.
Dietz Hill Investment Co	Road metal and concrete	Kansas City.
Beyer Crushed Rock Co	Concrete	
Halpin-Dwyer Construction Co	Concrete	Kansas City.
Frank J. O'Hearn	Rubble	Kansas City, 26th and Grand Ave.
McTernan-Halpin Construction	Concrete	
H. J. Nichols Crusher Co., Inc	Road metal and concrete	Kansas City.
Board of Public Welfare	Road metal and concrete	Leeds.
Missouri Portland Cement Co	Road metal and concrete	
JASPER COUNTY—		
Carthage Marble Corp	Rubble, railroad ballast, flux	
Carthage Crushed Limestone Co	Whiting, concrete, flux, glass factories, agricultural, miscellaneous	Carthage.
Independent Gravel Co	Whiting, concrete, flux, glass factories, agricultural, miscellaneous	Joplin.

PRODUCERS OF LIMESTONE IN MISSOURI—Continued.

Firm.	Type and uses of stone.	Location of quarry.
LAFAYETTE COUNTY—		
U. S. Engineer's Office	Riprap	
Wegener & Son	Road metal and concrete	
Wilson Mining Co., Lessees	Road metal and concrete	Corder.
LEWIS COUNTY—		
C. F. Nagle	Riprap	
LINCOLN COUNTY—		
Crystal Carbonate Lime Co	Rubble, riprap, whiting, concrete, flux, glass factories, agricultural, miscellaneous	Elsberry.
LIVINGSTON COUNTY—		
Johnson-Hudson Gravel Co	Road metal and concrete	
MARION COUNTY—		
Marblehead Lime Co	Concrete, flux, railroad ballast, agricultural	
Branham Quarry Co	Riprap, road metal and concrete	Hannibal.
Central Crushed Stone Co	Riprap, road metal and concrete	Hannibal.
Independent Gravel Co	Riprap, road metal and concrete	
MONITEAU COUNTY—		
U. S. Engineer's Office	Riprap	Sandy Hook.
ST. CLAIR COUNTY—		
Osceola Lime Co	Road metal and concrete	
St. Charles Lime and Quarry Co	Riprap	
STE. GENEVIEVE COUNTY—		
Ste. Genevieve Lime and Quarry Co	Miscellaneous stone	
Peerless White Lime Co	Fluxing, sugar factories, glass factories	Mosher.
Arnold Stone Co	Riprap	Ste. Genevieve.
Ozora Marble Quarries Co	Riprap	Ozora.
SALINE COUNTY—		
U. S. Engineer's Office	Riprap	

PRODUCERS OF LIMESTONE IN MISSOURI—Continued.

Firm.	Type and uses of stone.	Location of quarry.
St. Louis County—		
Mutual Quarry Co	Rubble	
Grant Road Quarry Co	Rubble, riprap, road metal and concrete	Mincke, Carondelet.
St. Louis Public Service Co	Railroad ballast	Brentwood.
Denny Road Quarry Co	Paving, rubble, riprap, road metal and concrete.	Webster Groves.
Kansas City Bridge Co	Riprap	
Edw. Kasselbaum	Riprap, road metal and concrete	
Glencoe Lime and Cement Co		
West End Quarry and Constr.	Curbing, rubble, road metal and concrete	Fern Ridge.
Steffen Bros	Rubble, riprap, road metal and concrete	
Frank Ruprecht Quarry Co	Rubble, road metal and concrete	
Sinclair Quarry and Constr. Co	Rubble, riprap, road-making, paint grinders	Vigus.
St. Louis City—		
Bambrick Bros. Constr. Co	Rubble, road-making	St. Louis.
Big Bend Quarry	Rubble, riprap, concrete, miscellaneous	Maplewood.
T. E. Cavanaugh	Rubble, concrete	
Felig Construction Co	Concrete, rubble	St. Louis.
Hoffman Bros. Constr. Co	Rough bridging, riprap, road-making, concrete	St. Louis.
Tower Grove Quarry and Construction Co	Riprap, road-making, concrete	St. Louis.
Union Quarry and Constr. Co	Rubble, concrete	
Rock Hill Quarry and Constr. Co.	Curbing, rubble, riprap, road metal and concrete.	
S. J. White Stone Co	Riprap	
Warren County—		
U. S. Engineer's Office	Riprap	Bernheimer.

MARBLE.

The Mississippian limestones of Greene, Jasper and Newton counties in Southwest Missouri, and the Devonian limestones of Ste. Genevieve County, Missouri, constitute the basis for an extensive marble industry, and one which contributes materially to the beautification of many fine buildings erected throughout the country. Among them, may be mentioned, according to the United States Bureau of Mines, the Fisher Building of Detroit, Mich., and the Hunt County Courthouse of Greenville, Texas, in which Carthage stone was used for exterior purposes.

Carthage stone for interior work was also used in the United States Post Office, Coeur d'Alene, Idaho; Industrial Trust Building, Providence, R. I., and Southwestern Bell Telephone Building, Dallas, Texas, and in several others.

The marble from the quarries south of Joplin, in Newton County, was used for exterior work in the Missouri State Highway Building, Jefferson City; the Connor Hotel, Joplin, and Bethany College, Lindsborg, Kansas. The stone was also used for interior work in the Connor Hotel, Joplin, Mo., the Bank of New York, New York Athletic Club, and Fuller Building, New York City.

The marble from Ozora, Ste. Genevieve county, has recently been used in interior work in the Fisher Building, Detroit, Mich., and the Capitol at Harrisburg, Pa.

In 1928, the value of the output was slightly less than in 1926, the record year. A decrease in production is noted for 1929. In 1928, the state ranked fourth among those of the union in the value of marble produced, being led by Tennessee, Vermont, and Georgia in the order named.

A list of marble producers is given below; also tables showing the production and value of marble according to uses for the period 1926 to 1929, inclusive.

PRODUCTION OF MARBLE ACCORDING TO USES, 1926-1929.

	1926.		1927.		1928.		1929.	
	Quantity, cubic feet.	Value.	Quantity, cubic feet.	Value.	Quantity, cubic feet.	Value.	Quantity, cubic feet.	Value.
Rough building, exterior......	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
Rough building, interior.......	155,630	$274,123	116,870	$209,230	117,970	$214,982	73,030	$107,637
Dressed building, exterior.....	327,410	445,974	243,920	367,481	(*a*)	(*a*)	232,510	317,189
Dressed building, interior.....	172,140	645,452	164,560	493,753	176,974	614,593	127,630	393,147
Monumental, dressed.........	32,630	80,698	9,080	15,334	24,810	36,410	21,610	43,202
Other uses.................	6,792	736	266,210	12,361	315,198	559,075	213,030	71,296
Totals.................	694,602	$1,446,983	800,640	$1,108,159	634,952	$1,425,060	667,810	$932,471

(*a*) Included in "other uses"; also includes pulverized and broken stone used for miscellaneous purposes.

MARBLE PRODUCERS IN MISSOURI IN 1926-1927.

Producer.	Use.	Quarry location.
GREENE COUNTY—		
Phenix Marble Co.	Rough building (interior), interior and exterior dressed building	Phenix.
JASPER COUNTY—		
Carthage Marble Corp.	Rough building interior, interior and exterior, dressed building, dressed monumental, crushed stone	Carthage.
F. W. Steadley & Co.	Exterior dressed building, dressed monumental	Carthage.
NEWTON COUNTY—		
Joplin Marble Quarries	Rough and dressed building, dressed monumental, and miscellaneous uses	Joplin.
STE. GENEVIEVE COUNTY—		
Ozora Marble Quarries	Interior	Ozora.

GRANITE.

The total output of granite was valued at $69,707 in 1928, and $54,642 in 1929.

The granite quarries are located in Iron, St. Francois, and Wayne Counties in the St. Francois mountain area of southeastern Missouri. The areas in which this rock outcrops is shown on the state geological map issued by this Bureau. The granite has been discussed in Volume II, "Quarrying Industry."

The stone produced is used for rough construction, rough architectural granite, rough and dressed monumental stone, paving blocks, riprap and concrete.

A list of granite producers follow.

GRANITE PRODUCERS IN MISSOURI IN 1926-1927.

Name.	Purpose used for.	Quarry location.
IRON COUNTY—		
A. J. Sheahan Granite Co.	Rough monumental, paving blocks, riprap, roadmaking	Graniteville.
ST. FRANCOIS COUNTY—		
A. G. Asplof	Paving blocks	Doe Run.
Missouri Red Granite Co.	Monumental stone	Graniteville.
Schneider Red Granite Co.	Rough monumental stone, paving blocks, riprap, concrete	Graniteville.
WAYNE COUNTY—		
P. O. Keefe	Riprap	Granite Bend.

CHATS.

Missouri ranks first in the production of chats, or crushed rock waste obtained in the milling of the lead-zinc ores of Southeast and Southwest Missouri. It is of interest to note that the production of this material reached a record value of $642,292 in 1929.

Chats are used as railroad ballast, in concrete aggregate and in the case of the Southeast Missouri material for agricultural purposes. In computing the value shown in the tables an arbitrary price of 25 cents per ton is used.

VALUE AND UTILIZATION OF CHATS IN MISSOURI, 1913-1929.

Year.	Railroad use (tons).	Commercial use (tons).	Total.	Value.
1913	1,231,005	797,884	2,028,889	$304,333
1914	1,687,331	583,440	2,270,771	340,616
1915	1,713,884	595,307	2,309,191	346,379
1916	2,268,370	622,600	2,890,970	433,646
1917	1,010,620	416,096	1,426,716	214,007
1918	672,335	274,794	902,129	135,319
1919	827,700	548,057	1,375,757	206,353
1920	448,211	665,311	1,113,522	167,028
1921	585,680	606,643	1,730,473	259,571
1922	455,755	769,254	1,225,009	306,252
1923	1,064,050	663,487	1,727,537	431,884
1924	1,411,318	669,757	2,081,075	520,269
1925	964,897	631,112	1,596,009	399,002
1926	875,243	653,056	1,528,299	382,080
1927	1,302,110	805,510	2,107,620	526,933
1928	1,254,700	648,852	1,903,552	475,888
1929	1,514,646	1,070,524	2,585,170	646,292

SANDSTONE.

During the past few years the production of this rock has been negligible. However, in 1929, a total value of $322,508 was produced as the result of the opening up of a number of quarries. The value established a new high.

The stone was used for riprap, and the entire production was obtained in Carroll County. The producers in 1929 were as follows:

U. S. Engineer Office.
S. J. White Stone Company.
Chicago and Great Western Railway Co.

TRIPOLI.

The deposits of this material, in production during the Biennial Period, are located near Seneca, in Newton County and in the adjacent area in Oklahoma. The tripoli varies from very porous, absorbent, to dense, hard, rock-like material. The deposits occur near the surface and open-pit methods of mining are utilized.

In this area, the deposits are found associated with siliceous limestones of Mississippian age, and have originated from the solution of the limestones, and the concentration of the siliceous residues. Studies of drill cuttings from the Joplin area in the sub-surface laboratory of the Survey during the past year have shown that upon digestion in hydrochloric acid, two distinct zones of siliceous limestones yield insoluble residues, one of which is very similar to the material quarried; and the other is slightly similar. The first zone is found in what is tentatively correlated as the Warsaw formation, the other or lower zone being in the Burlington formation. It is planned to continue the studies, to determine if possible, the stratigraphic position of the tripoli deposits, and to obtain more information with regard to the origin.

The tripoli is ground in plants at Seneca and Carthage; and the resultant product is used for foundry facings, as a filler in rubber goods, in paints, in the glass industry, in the manufacture of pottery and in enamels. It is also employed as an abraisive, chiefly in polishes and in soap and cleansers. The tripoli can also be sawed into shapes, and is used efficiently for filter stones. These can be cleansed by reversing the flow of water.

At the present time, the chief producers are The American Tripoli Company and the Independent Gravel Company. As there are less than three producers, the total value is concealed in the table showing Missouri's mineral wealth under the heading "Miscellaneous."

ZINC.

The Thoms Station-Smithfield district was the principal producer of sphalerite in 1928. The Waco and Joplin districts followed in order. The Duenweg-Porto Rico and Spring City-Seneca districts were the chief producers of carbonate ore during this year.

In 1929 the Waco district was the largest producer of sphalerite, the total value being considerably more than in 1928. In the other districts there was a decrease in total value, and as a result in the total value of the state's production. In this year there was a slight increase in the total value of the carbonate produced, the largest tonnage being mined in the Aurora and Spring City-Seneca districts.

During the year 1930, the low price of spelter and concentrates has not been conducive to large production of ore and also the conditions in the industry have not warranted active drilling campaigns. An increasing amount of sphalerite is being recovered each year in milling of the lead ores of Southeast Missouri.

The tables given below were prepared from statistics compiled by Mr. J. P. Dunlop, of the U. S. Bureau of Mines.

At the present time the Survey is studying suites of drill samples from the Tri-State district with a view of extending the present knowledge of the sub-surface stratigraphy and also the problems of silicification that are presented in this ore-producing area.

PRODUCTION OF ZINC IN MISSOURI, 1927-1929.

District.	1927.				1928.				1929.			
	Sphalerite.		Silicate and carbonate.		Sphalerite.		Silicate and carbonate.		Sphalerite.		Silicate and carbonate	
	Short tons.	Value.	Short tons.	Value.	Short tons.	Value.	Short tons.	Value.	Short tons.	Value.	Short tons.	Value.
Southwestern Missouri:												
Aurora, Bryceville and Wentworth, (c)	1,386	$47,148	32	$770					40	$1,684	610	$14,100
Carl Junction	68	2,970										
Duenweg, Porto Rico	57	2,210	162	4,860			300	$6,356			221	4,600
Granby	228	9,594	583	15,303			130	2,742			113	1,948
Joplin	2,117	79,870	343	8,724	2,958	$109,550	93	2,255	1,661	66,496	4	80
Oronogo					5	127	1	18	2	31		
Spring City, Spurgeon, Seneca (a)			207	4,925			463	9,322			404	7,982
Thoms Station, Smithfield (b)	6,393	209,109			10,237	405,866						
Waco	7,953	330,185			3,084	113,699			8,562	340,228		
Webb City, Carterville, Prosperity	146	3,325			140	3,868			74	2,520		
Wentworth					973	34,663						
Zincite, Smithfield, Belleville, Klondike (d)	8,937	409,052							2,969	128,355		
Hickory and Dade counties			30	1,050								
Totals	27,285	$1,093,463	1,357	$35,632	17,397	$667,773	987	$20,693	13,308	$539,314	1,352	$28,710
Southeast and Central Missouri	8,390	289,816			6,597	236,111			7,031	277,332		
Totals	35,675	$1,383,279	1,357	$35,632	23,994	$903,884	987	$20,693	20,339	$816,646	1,352	$28,710

(a) Spring City-Seneca in 1927; Spring City-Spurgeon in 1928.
(b) Thoms Station only in 1927.
(c) Wentworth only in 1928; Aurora only in 1929.
(d) Smithfield-Belleville only in 1927; Smithfield included with Thoms Station in 1928; Zincite and Klondike in 1929.

TENOR OF CRUDE ZINC ORE AND CONCENTRATES PRODUCED IN SOUTHWEST MISSOURI, 1927-1929.

	1927.	1928.	1929.
Total crude ore, short tons	513,800	281,300	428,400
Total zinc concentrates in crude ore, per cent	5.57	5.47	3.80
Zinc content of crude ore, per cent	3.21	3.23	2.26
Average zinc content of sphalerite concentrates	58.3	59.9	60.3
Average zinc content of silicate and carbonate	38.2	39.5	40.2
Average value per ton—			
Sphalerite concentrates	$40.08	$38.38	$40.53
Silicate and carbonate	26.26	20.97	21.24

PRODUCTION OF ZINC ORE IN MISSOURI, 1913-1929.

Year.	Sphalerite.			Carbonate and Silicate.			Total value.
	Quantity short tons.	Value.	Average price per ton.	Quantity short tons.	Value.	Average price per ton.	
1913	225,850	$9,180,960	$43.10	21,531	$483,463	$22.45	$9,664,423
1914	189,765	7,351,726	38.65	19,648	415,185	21.13	7,766,911
1915	241,111	18,382,520	76.23	25,412	1,243,458	45.00	19,625,978
1916	277,176	22,878,215	82.60	26,894	1,350,381	50.21	24,228,596
1917	231,588	16,453,629	70.80	30,986	1,254,975	40.50	17,708,604
1918	95,555	4,899,347	51.30	17,816	574,136	32.23	5,473,483
1919	51,813	2,108,382	40.69	11,741	320,853	27.33	2,429,235
1920	39,431	1,805,561	45.80	9,494	337,003	35.50	2,142,564
1921	19,490	490,731	25.18	60	634	10.57	491,365
1922	27,844	888,494	31.91	3,008	63,917	21.25	952,411
1923	32,156	1,303,093	40.52	3,774	100,272	26.57	1,403,365
1924	23,261	974,765	41.91	1,453	35,294	24.29	1,010,059
1925	26,187	1,418,719	54.18	2,269	69,874	30.80	1,488,593
1926	47,473	2,315,362	48.77	3,669	115,982	31.61	2,431,344
1927	35,675	1,383,279	38.77	1,357	35,632	26.26	1,418,911
1928	23,994	903,884	41.88	987	20,693	22.08	924,577
1929	20,339	816,646	40.10	1,352	28,710	21.23	845,356

FINANCIAL STATEMENT FOR 1929-1930—SUPPORT FUND.[a]

1929.

H. A. Buehler	$4,905.27
Jos. M. Thiel	2,731.33
H. S. McQueen	3,228.09
Office	1,673.54
C. O. Reinoehl	1,784.34
H. W. Mundt	1,590.31
C. L. Dake	826.07
Josiah Bridge	359.00
E. E. Hawkins	1,200.00
E. M. Shepard	54.98
P. N. Moore	11.75
E. S. Gatch	12.30
C. T. Orr	59.38
T. D. Murphy	1,136.61
R. E. Peck	350.00
E. B. Branson	189.45
J. S. Williams	669.92
E. N. Humphrey	269.75
Jean I. McCaw	1,022.20
A. A. Smith, Postmaster	375.82
Ruth Glass Co	118.70
L. T. Hudson Motor Co.	496.00
Jones Motor Co	489.00
Hugh Stephens Printing Co	49.75
E. Leitz, Inc	96.30
Total	$23,699.86

1930.

H. A. Buehler	$5,621.42
Jos. M. Thiel	3,606.19
H. S. McQueen	3,366.64
Office	3,093.05
C. O. Reinoehl	2,318.35
H. W. Mundt	1,233.99
Josiah Bridge	606.33
E. E. Hawkins	1,241.69
E. M. Shepard	33.93
E. S. Gatch	12.93
W. E. McCourt	12.78
C. T. Orr	56.50
T. D. Murphy	562.06
J. S. Williams	100.00

a. Support fund chargeable with cost of publication of Eminence region geological report and Biennial Report, now in the hands of the State printer. Estimated cost—$2600.00.

1930—Continued.

Jean I. McCaw	$1,255.00
A. A. Smith, Postmaster	235.96
Ruth Glass Co	240.80
Long Motor Co	1,523.10
Jones Motor Co	486.61
Botz Printing Co	1,608.95
Dorothy Shaver	675.00
W. H. Wamsley	683.35
J. S. Cullison	445.49
R. T. Rolufs	300.00
J. G. Grohskopf	120.50
E. B. Branson	180.60
Missouri School of Mines	612.97
Mound City Engraving Co	765.25
Shell Petroleum Co	500.00
Bemis Bag Co	323.28
St. Louis Paper Bag Co	92.35
Goodrich Rubber Co	282.96
U. S. Geological Survey	155.00
Keuffel & Esser Co	105.60
Underwood Typewriter Co	61.03
F. H. Farnham	420.72
Henry Heil Chemical Co	127.94
A. Hoen & Co., Lithographers	1,503.00
Total	$34,571.32

FINANCIAL STATEMENT FOR 1929-1930—WATER POWER FUND.

1929.

H. C. Beckman	$2,517.67
Verle L. Austin	324.62
Albert L. Hill	128.70
C. H. Jennings	1,541.40
H. C. Bolon	969.06
Milburn Hassler	106.67
Gage Readers	2,395.65
Total	$7,983.77

1930.

H. C. Beckman	$3,941.40
Verle L. Austin	357.78
R. D. Schmickle	633.57
H. C. Bolon	733.95
C. J. Eyberg	914.27

1930—Continued.

C. H. Jennings	$1,726.90
Milburn Hassler	233.33
H. W. Mundt	319.72
Gage Readers	2,867.95
Total	$11,728.87

FINANCIAL STATEMENT FOR 1929-1930—TOPOGRAPHIC MAPPING FUND.

1929.

F. W. Hughes	$3,500.06

1930.

F. W. Hughes	$1,451.38
J. M. Lawson	3,342.18
L. V. Johnson	351.93
H. P. Jones	247.51
J. T. Schultz	1,159.83
G. W. Moore	406.02
T. V. Cummins	467.09
W. C. Elledge	162.69
W. E. Baird	106.61
T. F. Murphy	518.81
F. W. Weber	252.10
D. K. Cabaniss	863.58
S. B. O'Hara	213.06
E. W. Gouchenour	446.39
T. W. Ranta	456.87
S. S. Evans	30.83
Jos. H. Taubr	299.82
Stuart T. Penick	468.87
J. A. Duck	320.00
M. J. Harden	179.66
Total	$11,851.04

APPENDIX I

INSOLUBLE RESIDUES AS A GUIDE IN STRATIGRAPHIC STUDIES

By H. S. McQueen

INTRODUCTION

The correlation of non-fossiliferous drill samples is one of the difficult problems encountered in sub-surface stratigraphic studies. During the past six years the writer has used a method whereby the original dolomite or limestone cuttings have been digested in dilute hydrochloric acid, and the resulting insoluble fractions or residues have been taken for study. Insoluble residues from hundreds of drill samples and hand specimens collected in the field have been prepared and examined. Most striking results have been obtained and indicate that correlations can be made over wide areas with certainty. The study has also suggested that the use of insoluble residues is not limited to correlative purposes only, but may be used with success in other fields of sedimentary research.

Up to the present time the detailed investigations by this Bureau have been restricted to the Cambrian and Lower Ordovician formations which include the Ozarkian and Canadian systems of Ulrich. The following pages are devoted largely to the results obtained in this study. Sufficient work has been done, however, to indicate that similar results also can be obtained in a study of the Silurian, Devonian, Mississippian and Pennsylvanian series in this state. The work is now being extended to cover these major stratigraphic divisions.

HISTORICAL SUMMARY

An important function of the Missouri Bureau of Geology and Mines is a study of samples from wells drilled in various parts of the state. Considerable difficulty has always been encountered in definitely correlating the cuttings obtained from formations of the Cambrian and Lower Ordovician systems of the Ozark region. The complex stratigraphy has presented many problems~~, not only in this study, but also in the field~~, and it has only been with detailed work that the major features have been fully recognized.

For some thirty years, Mr. E. O. Ulrich, of the United States Geological Survey has been engaged in stratigraphic studies in the Ozark region of Missouri, in cooperation with geologists of the Missouri Survey. As a result of these investigations, many features of the stratigraphic succession have been established. Years ago, Ulrich suggested that the formation and heavy concentration of chert on hillsides was due, in the main, to conditions of surface weathering of the original siliceous limestone or dolomite. That certain formations yielded distinct and characteristic types of chert had been known for years and as the detailed studies were carried on, additional stratigraphic units were added to the general section. With the exception of the Upper Cambrian series, they were defined in the field by characteristic chert, which is abundant in the areas of outcrop.

The study of insoluble residues had its inception in 1924, although the idea was in mind in 1923. At this time ~~the writer~~ was engaged in mapping certain structural features in an area in southern Missouri underlain by dolomite and dolomitic limestones of the Jefferson City and Cotter formations of Lower Ordovician age, (Canadian of Ulrich). ~~During the course of a field conference,~~ Mr. H. A. Buehler, Director of the Missouri Survey, suggested that certain sections be measured in detail and samples taken from the different beds of dolomite for the purpose of studying the original rock, and also the insoluble residues obtained by digesting the dolomite in hydrochloric acid. The sections were measured and the samples were brought to the laboratory. Detailed chemical analyses were made of the original, as well as the insoluble material, and samples of the latter were studied microscopically ~~by the writer~~. Certain differences were noted in the residues, and these checked the field observations. A short time later residues were made on drill samples from a deep well in southeast Missouri. An examination of them proved to be very helpful in the correlation of the formations penetrated, and also enabled the Survey to advise definitely in regard to several problems connected with this drilling.

This experience and the idea proposed by Ulrich, that the cherts of the Ozark region were, in the main, the result of concentration under conditions of surface weathering, suggested that the rocks might carry siliceous material and chert as distinctive as the material of weathered outcrops. The study of additional residues indicated that this was true and later detailed work has served to increase the reliance placed in this method of making correlations.

ACKNOWLEDGMENTS

The development of this method of study has indicated, to some extent, the acknowledgments that the writer is pleased to make.

To Mr. Ulrich, credit is given for his suggestions regarding chert, and for information regarding the stratigraphic succession; to Mr. Buehler, the writer not only acknowledges credit for suggesting an investigation which led to this study, but also for his enthusiasm, for the many suggestions furnished concerning the various phases of the work, and for his encouragement and interest; due credit is also given to Mr. C. L. Dake and Mr. Josiah Bridge, who have furnished much information regarding details of the stratigraphy obtained during the course of field studies. Mr. Dake has also generously collected many hand samples from carefully measured sections, which have added immeasurably to the success of this study. The assistance of Mr. T. D. Murphy, of the Missouri Survey, who has examined many samples, and furnished details that are incorporated in this publication, is gratefully acknowledged. Mr. E. E. Hawkins, of the Missouri Survey, prepared the residues for study and made suggestions with regard to the method of procedure.

Due acknowledgment is also made to Mr. H. S. Thomas, Tidal Oil Company, Tulsa, Oklahoma; Mr. John Reeves, Empire Oil and Refining Company, Eldorado, Kansas; Mr. C. M. Boos, Empire Oil and Gas Company, Fort Smith, Arkansas; Mr. A. I. Levorsen, Independent Oil and Gas Company, Tulsa, Oklahoma; and Messrs. R. J. Riggs and W. W. Clawson of the Indian Territory Illuminating Oil Company, Bartlesville, Oklahoma, who courteously furnished suites of samples from wells encountering the "siliceous lime" in those states. The detailed features of these samples will be discussed in a later paper.

METHOD OF PROCEDURE

There is nothing new in the principle involved in the preparation of the samples, for the reaction of dolomite and limestone with hydrochloric acid is a familiar one. Trager[1] has

[1]Trager, Earl, A., A Laboratory Method for the Examination of Well Cuttings, Econ., Geol., Vol. 15, pp. 170-176, 1920.

small, could be determined successfully. The sample is covered with 50 cubic centimeters of commercial hydrochloric acid diluted to half strength with water. In the case of dolomite, the samples are placed on a sand bath. In order to decrease the strong immediate reaction, the more freely effervescing limestones are treated in the cold and the dilute acid solution is added very slowly. After the samples have ceased to effervesce, the beakers are removed from the sand bath. When the samples are left on the sand bath for too long a period, the liquor, particularly after effervescence has ceased, has a tendency to become thick and gelatinous, and to contain small slender crystals of gypsum. The latter are formed by the reaction between the sulphuric acid present in the commercial hydrochloric acid, and the limestone or dolomite.

Siliceous shells form on the outside of the grains of very siliceous carbonate rocks, and it has been found that this shell prevents, or at least retards, further reaction. When complete digestion has not been obtained, water is added to the sample, and carefully decanted with the removal of fine silt. The silt fraction ~~has been~~ saved in some instances, but in any case it should be removed or separated from the fraction consisting of slight to much greater density, as well as larger sized particles, for the fine silt particles mask the real nature of the residues. Acid of the same strength is again poured over the sample, and the whole warmed on a sand bath. When no reaction is apparent the sample is again washed with water to remove any trace of soluble salts that would, upon drying, coat the insoluble material. The time required for heating during this step is usually considerably shorter than during the first step of similar nature. In some cases it ~~has been~~ necessary to use the dilute acid solution a third time to completely digest the sample. This is particularly true in the case of fine-grained, or dense, very siliceous dolomites. When this step is necessary, it is again followed by washing with water. The sample is placed on a sand bath and thoroughly dried; after which, it is ready for study.

quip The equipment required for making insoluble residues depends upon the number of samples that are to be made at any one time. In the laboratory of the Missouri Survey, as many as 200 samples have been prepared for study by one man in the course of eight hours. In order to facilitate the handling of a considerable number, wood trays with one-half inch wire-screen bottoms have been made. These trays have an inside measurement of 28 by 18 by 2 inches. Sixty beakers can be handled in the tray described, the use of which obviates the individual handling of that number. The wire screen bottom permits warming a series very rapidly.

In order to limit the time required for the preparation of the samples, a one-gallon bottle equipped similarly to the ordinary washing bottle of every chemical laboratory is used to contain the acid. This permits the rapid introduction of the dilute acid into the samples.

The material prepared is filed in cork-stoppered glass vials, and labelled to correspond to the labels on the original samples.

METHOD OF EXAMINATION

A wide field binocular microscope has been found to be suitable for the examination of the samples. Low power lenses may be used, as a broad field that permits observing as much of the sample as possible is desired. A magnification of twenty diameters is generally used.

Small pans for containing the samples are used in the examination. These are roughly triangular in shape, measuring 5 by 3 inches; the depth being about one-fourth of an inch. The long end is cut off so that the material, after an examination, can be poured into the bottle. They have been found to be very convenient. Black paint may be used effectively on the pans.

This method of study is not limited to the laboratory, for since its inception, the writer has had occasion to visit a number of drilling wells. Where doubt existed as to the formations being drilled, residues were prepared in a simple field kit, and the examination made with a hand lens.

CHARACTERISTICS OF INSOLUBLE RESIDUES

The characteristics of the insoluble residues from the Cambro-Ordovician formations are quite variable, but nevertheless of such occurrence that they not only indicate major rock divisions but formational units as well. Chert is the predominant insoluble material or constituent of the residues as will be noted in the descriptions of the formations. Many distinct types and variations have been observed. The variations, however, are of such a nature and so restricted as to occurrence that they indicate formational units and may be used as a basis in correlative studies. The sand content of the residues is next to that of chert. It varies from extremely fine, angular, well cemented grains to coarser, rounded and frosted grains. Upper Cambrian sands have certain characteristics, Lower Ordovician sands others. The present work has brought out certain features in the sands that are of much value in establishing the identity of certain formations.

In the Bonneterre and Davis formations, shale predominates in the residues. It varies from soft waxy, to porous or dense micaceous fragments, but shows sufficient distinctions that each formation may be recognized. Likewise, the characteristics noted are quite different from the shales of the younger formations, and in the absence of chert or other material the shale may be reliably used for the purpose of correlation.

Clay and silt frations are common to the residues from many formations, and often constitue a considerable percentage of the original dolomite or limestone. Certain of them appear to have definite characteristics and, in some instances, they have been sufficiently diagnostic to be of value. Although a study of the silt or clay fractions is associated with this investigation, they have not been studied in detail and will not be considered further in this paper.

Other materials present are the undissolved heavy minerals among which may be mentioned pyrite, hematite, limonite and sphalerite. Certain formations have been found to carry abundant pyrite, others limonite. There has been no endeavor to separate these heavy minerals from the siliceous fraction of the residue as the mass characteristics are what are desired in the identification of formations.

The most striking of several interesting features noted in this study, are the casts or impressions of dolomite crystals preserved in the insoluble chert, shale, glauconite, pyrite and limonite. For these the name *dolocast* is proposed and is used in this paper. The dolocasts vary in size, as well as in arrangement, but strangely enough possess characteristics that serve to identify the insoluble residues from the various formations in which they occur. They are highly developed in the cherts from the dolomitic formations referred to the Ozarkian system by Ulrich, and to a lesser extent in the cherts from the formations of Lower Ordovician (Canadian) age, where they may be seen as occasional fine to coarse casts scattered through a matrix of chert, or as innumerable coarse casts which predominate and are separated from each other by thick intervening walls of silica. Others show innumerable fine casts with thinner intervening walls, giving them a lace or sponge-like structure.

These dolocasts have been found only in residues obtained from dolomites, and so far as the present work is concerned have not been found in the insoluble constituents obtained from limestones. The occurrence of the dolocasts is an expression of the process of silification, dependent, to some extent perhaps, upon the size of the original dolomite crystals. The formation of these significant casts is the result of the deposition of silica in the interstices between the dolomite crystals. A study of hand samples of dolomite often shows a granular structure, the crystals being loosely cemented with relatively more soluble and less dolomitic material than the crystals themselves. In some cases, the interstitial material is that replaced, although complete replacement of the entire mass is evident in some fragments. This replacement is often strikingly shown by the abundant occurrence of dolocastic chert, at or near unconformable contacts, or formational boundaries, or above and below sandstone beds.

The occurrence of these dolocasts is not accidental, nor is it confined to the Cambro-Ordovician rocks of Missouri alone, for an examination of residues from churn drill samples from the Knox dolomite of eastern Tennessee and core drill samples from the "siliceous lime" of Oklahoma has shown the presence of siliceous skeletons in which the dolocasts are beautifully developed. It is of interest to note that the Oklahoma samples were collected from a depth of over 6200 feet below the surface. (pl. 9–B)

The presence of these casts in shale, glauconite, and pyrite of one formation suggests that new and different interpretations should be given in any review of their history. A somewhat similar feature has been noted in the minerals from ore bearing dolomite and should be considered in any genetic study of the ore bodies.

In the section in the Ozark region of Missouri the dolocasts first appear in the Upper Cambrian series, where they are restricted to shale, glauconite and pyrite of the Bonneterre formation. This restricted occurrence of the dolocasts in the material mentioned readily indentifies this formation in drill as well as hand samples.

Siliceous oolites are also an important feature of the residues from certain formations. Prior to this study they were not used as a guide in sub-surface investigations. Certain significant differences can now be noted in them, however, and these can be used in the correlation of formations. The occurrence of siliceous oolites is particularly marked at or near contacts of dolomite, sandy dolomite, and standstone, or along formational or intra-formational boundaries.

Two types of siliceous oolites can be differentiated. The first appears to be a replacement by silica of the dolomitic oolite occurring in a dolomitic matrix. In the Bonneterre formation, which is characteristically low in siliceous material, a zone of oolitic dolomite has been found. This occurrence suggests that oolitic dolomites may also occur in the other formations. However, these oolites appear to have been subsequently replaced by secondary silica, which is more abundant in these formations. This type of oolite is best observed in fractured surfaces where the darker spherical or ovoid shaped bodies are enclosed in a matrix of lighter colored chert. Oolites of this type appear to be best developed in the beds of the Eminence, Van Buren, Gasconade and Cotter formations.

The second type is commonly found in sandy dolomite or sandstone, particularly where the grains of the latter are cemented with dolomite. In these, secondary silica appears to have replaced the dolomitic filling, then coated the grains of sand, and in some instances, completely replaced them. This replacement is indicated by the various stages observed in many clusters obtained from the same beds. In the oolites thus formed nuclei of sand grains are common.

This type of oolite is particularly abundant in the sandy Roubidoux and Cotter formations. It has also been observed to a lesser extent in the other formations, the Gunter member of the Van Buren formation being an example.

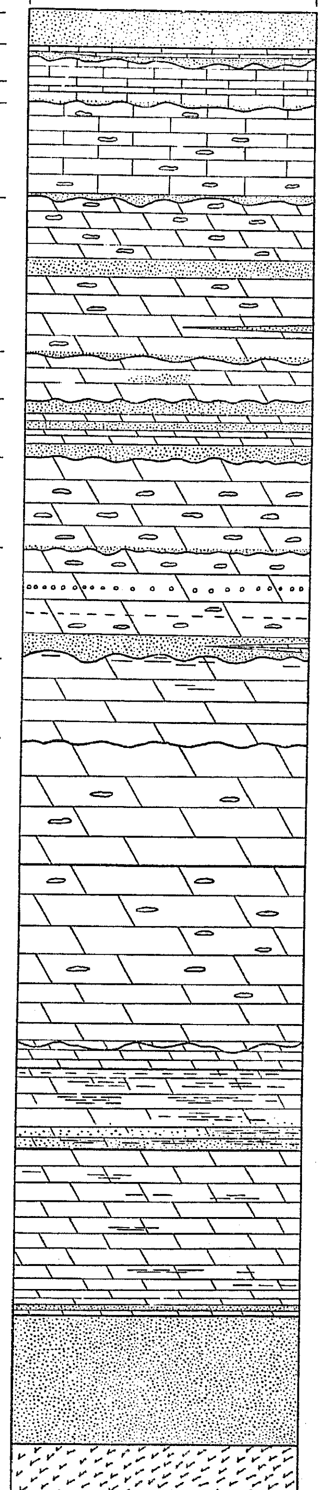
FORMATIONS STUDIED

The formations studied and discussed in this paper range from Upper Cambrian to Lower Ordovician in age and include the beds of the Ozarkian and Canadian systems of Ulrich. It is not the purpose of this report to present the detailed lithologic features of each, but to describe the characteristics of the insoluble residues obtained from them. The columnar section

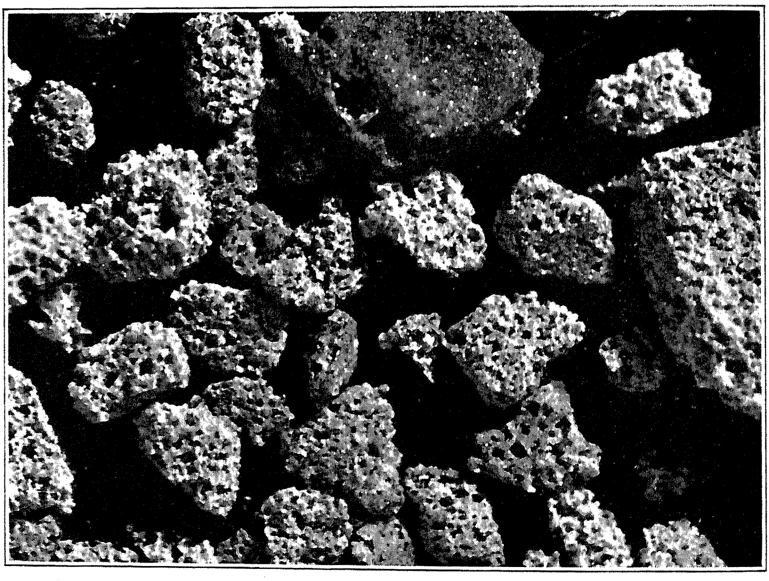
GENERAL COLUMNAR SECTION OF THE OZARK REGION IN MISSOURI

System	Systems of E. O. Ulrich	Series of E. O. Ulrich	Formation	Thickness in Feet	Character of Rocks
ORDOVICIAN	ORD.	Big Buffalo	ST. PETER	0-100	Sandstone, white, rounded and frosted grains.
			unconformity		
			EVERTON	0-40	Sandstone, white, rounded and frosted grains at base overlain by limestone or dolomite, usually containing considerable sand and some shale.
			unconformity		
	CANADIAN	Upper	SMITHVILLE	0-120	Limestone, magnesian, slightly argillaceous, non-cherty.
			unconformity		
			POWELL	0-250	Limestone, magnesian and dolomite; very cherty with occasional thin beds of sandstone.
			unconformity		
			COTTER	100-420	Dolomite, dense to finely crystalline; argillaceous and very cherty. Siliceous oolite is characteristic. Beds of sandstone are common to the formation.
			unconformity		
			JEFFERSON CITY	40-120 +	Dolomite, dense to finely crystalline, sometimes argillaceous. Some white chert; occasionally sandy in the middle portion.
			unconformity		
		Middle	ROUBIDOUX	100-160	Sandstone and dolomite inter-bedded. Former white, fine-grained and angular. Latter dense to finely crystalline and very cherty. Chert, sandy chert and siliceous oolite are abundant.
			unconformity		
	OZARKIAN	Upper	GASCONADE	140-200	Dolomite, light colored, finely crystalline with characteristic hard blue chert.
			unconformity		
		Middle	VAN BUREN	35-235	Dolomite, finely crystalline, dark bluish gray; often granular; with white, dense, porcelain-like and oolitic chert.
			GUNTER SANDSTONE	0-60	Sandstone, fine to medium grained, characteristically rounded and frosted.
			unconformity		
CAMBRIAN			PROCTOR	0-225	Dolomite, light gray, moderately crystalline, non-siliceous with some inter-bedded pale green colored shales and some included pyrite.
			unconformity		
		Lower	EMINENCE	80-320	Dolomite, light colored, crystalline, characterized by an abundance of gray and light blue-gray vitreous chert. Siliceous oolite is common.
			POTOSI	0-480	Dolomite, light brownish-gray to chocolate color, with an abundance of drusy quartz and chert; dolomite usually contains considerable organic matter.
			unconformity		
	CAMBRIAN	Upper Cambrain	DERBY-DOERUN	0-60	Dolomite, hard, fine grained, argillaceous, but relatively non-siliceous.
			DAVIS	0-215	Dolomite, with some magnesian limestone; usually fine-grained, very shaly and sandy throughout. Base characteristically marked by very sandy dolomite.
			BONNETERRE	160-440	Dolomite and magnesian limestone, fine to coarsely crystalline, light gray to brown in color with thin inter-bedded green and brown shales, contains practically no chert; very sandy near contact with Lamotte Glauconite is very characteristic of the formation.
			LAMOTTE	0-350	Sandstone, fine to coarse grained, yellow to white in color, subangular to rounded. Locally dolomitic; generally arkosic at base.
			unconformity		
Pre Camb.	Pre Camb.				Undifferentiated granite, rhyolite porphyry, quartzite, schist, gneiss and slate.

Section



A. Dolocasts in light-green colored shale characteristic of Bonneterre formation. Specimen photographed from hand sample collected in Section 6, T. 29 N., R. 3 W., Shannon County, Missouri. X 18.



B, Brown, spongy, finely dolocastic shale characteristic of the upper part of the Bonneterre formation. This shale has been found in a number of wells from eastern to western Missouri. It is extremely well developed in the Bonneterre of western Missouri. Specimen from deep well near Carthage taken at a depth of 1434 feet. X 18.

(pl. 1) shows the stratigraphic sequence and the thickness and general features of the formations under consideration. Detailed descriptions of the formations have been published in other reports of this Bureau,[7] and additional information concerning the formations will be published in forthcoming reports.[8]

It is interesting to note that the Upper Cambrian formations, as restricted by Ulrich, contain shale and fine angular sand in abundance. Chert is almost lacking. In the dolomites of his proposed Ozarkian System chert predominates, and sand and shale are confined to certain definite horizons which will be discussed later. Chert is also the dominant constituent of the Lower Ordovician (Canadian of Ulrich) formations, although in certain parts of the section large quantities of sand are present.

The characteristics of the insoluble residues from the formations studied are given in the succeeding pages.

BONNETERRE FORMATION

In the type locality of southeast Missouri, this formation is a slightly shaly to almost pure magnesian limestone or dolomite and is distinguishable from the younger dolomites by its lack of chert. As a result, the insoluble residues obtained are small and comparatively low in their content of siliceous material.

The dominant insoluble material in drill and hand samples is shale which varies in color through shades of green and brown to black, the former being soft and waxy. The green and brown colored varieties are characteristic of the formation in that they show dolocasts, a feature that has not been found to date in the shales of the overlying formations. The dolocastic green shale is marked by irregularly distributed but very definite casts, somewhat larger than those in the brown shale. (pl. 2–A) However, in the latter they are more regularly spaced and so arranged as to give it a sponge-like appearance. (pl. 2–B) Both types of shale have been obtained from samples collected in the southeast Missouri lead belt. In western Missouri the brown shale in particular is present, the green dolocastic shale having been noted in only one deep hole near Kansas City. It is significant that

[7]Buckley, E. R., Geology of the Disseminated Lead Deposits of St. Francois and Washington counties, Missouri Bureau of Geology and Mines, 2d. Ser., Vol. IX, 1908.

Weller, Stuart, and St. Clair, Stuart, The Geology of Ste. Genevieve County, Missouri Bureau of Geology and Mines, 2d. Ser., Vol. XXII, 1928.

[8]Dake, C. L., The Geology of the Potosi-Edge Hill Quadrangles, Missouri Bureau of Geology and Mines, 2d. Ser., Vol. – (In preparation).

Bridge, Josiah, The Geology of the Eminence-Cardareva Quadrangles, Missouri Bureau of Geology and Mines, 2d. Ser., Vol. – (In preparation).

the dolocastic shale occurs most abundantly in the upper part of the formation.

Outside of the lead belt, the Bonneterre residues are slightly different in that they show in addition to the shale described, an influx of an angular, extremely fine grained, well indurated, glauconitic sandstone, or siltstone. The grains are light to pinkish in color and are cemented into easily recognized fragments.

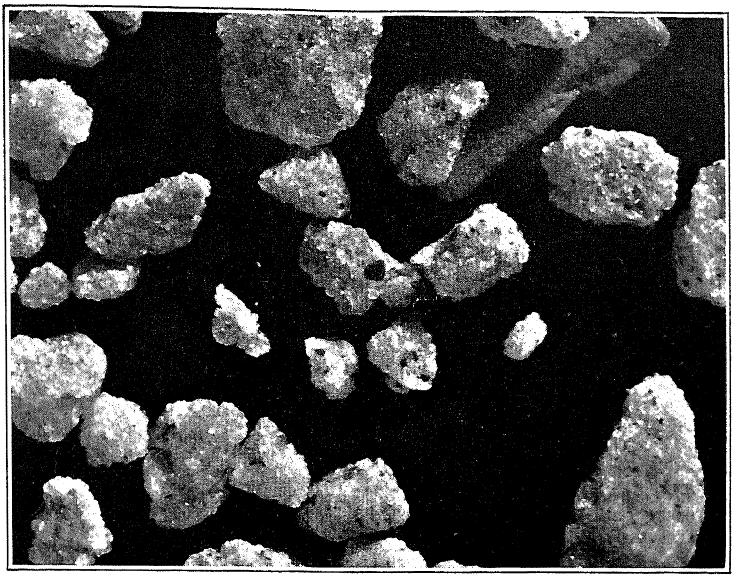
The abundance of glauconite has been a distinguishing field characteristic of the Bonneterre formation. This mineral, being relatively insoluble, is also an essential mineral in the insoluble residues. It occurs as small particles with smooth rounded surfaces or shows the significant dolocastic structure. Glauconite also occurs in the Davis, and occasionally in the other formations of the Cambro-Ordovician. However, the quantity of this mineral is relatively small when compared with that of the Bonneterre; also, it does not appear to have the marked dolocastic feature and seldom possesses the deep green color and size of the Bonneterre type.

Pyrite is a common mineral of these residues, and often shows the significant dolocastic feature noted in the other constituents. The structure, however, is that of the fine network exhibited in the brown shale, and in general does not possess the coarser, thicker walled dolocasts of the pyrite in the Potosi and Eminence residues.

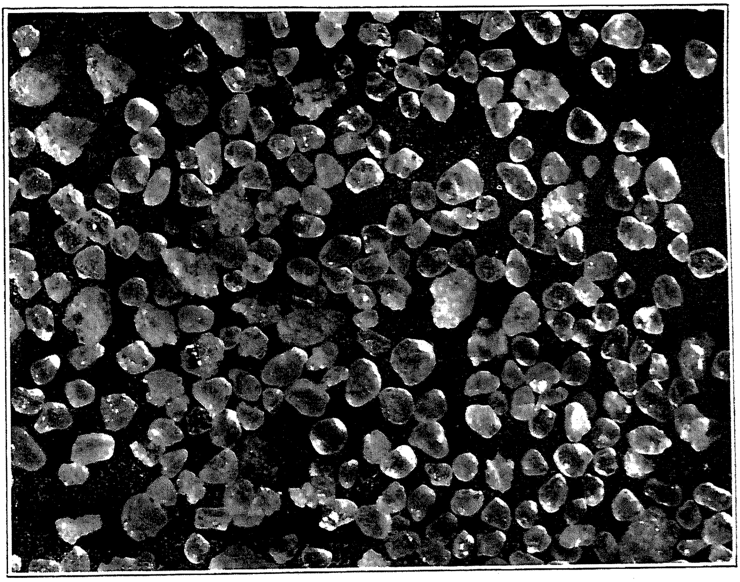
DAVIS FORMATION

The change in sedimentation from the Bonneterre to the Davis formation is well marked in the field and is likewise expressed in the characteristics of the insoluble residues obtained from the latter. The Davis residues contain sand, shale, and argillaceous material. The former is somewhat similar to that found in the Bonneterre. However, distinguishing characteristics that differentiate the two may be noted. In general, the sandstone of the Bonneterre is finer grained, more calcareous and less argillaceous than the coarse, angular sandstones of the Davis formation. Muscovite also appears as a more common constituent in the Davis shale, whereas glauconite is more abundant in the Bonneterre, the two formations being considered as a whole. (pl. 3–A)

In many wells penetrating the Davis-Bonneterre contact, a definite zone of sandy dolomite has been observed at the base of the former. The grains are fairly well rounded, always frosted

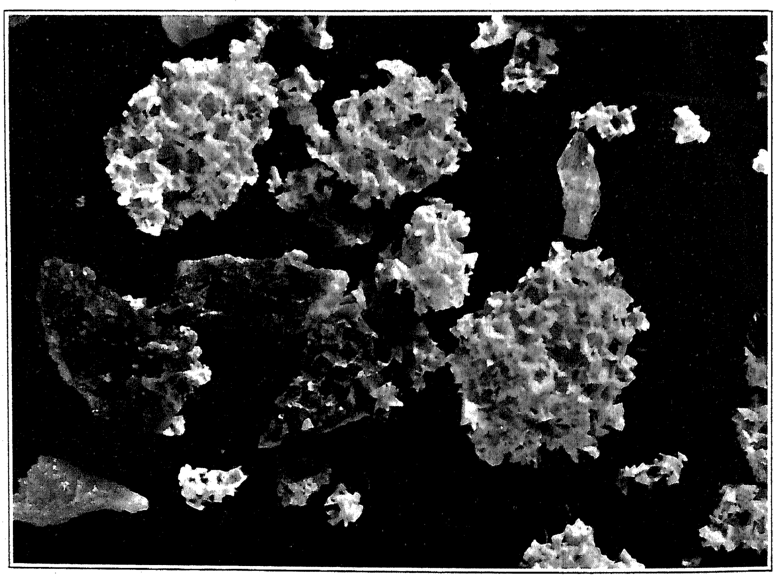


A. Fine-grained angular glauconitic sandstone which is characteristic of the Davis Formation, in the area of outcrop and in all wells in which the formation is penetrated, depth of 1400 feet, California well. X 18.



B. Fine subangular to rounded and frosted grains of sand which characteristically mark the base of the Davis formation. This sand is found in every well penetrating the Davis-Bonneterre contact. Residue from sample collected at a depth of 1170 feet in deep test well at Salem, Missouri. X 18.

A. The coarse abundantly dolocastic chert shown is characteristic of the Potosi Formation. Photograph is of Potosi residue from a deep well at California, Missouri. The depth is 1210 feet. X 10.



B. The drusy quartz which is shown as bright glassy fragments is as characteristic of the Potosi formation as is the accompanying dolocasts. The photograph shows a Potosi residue from a depth of 1265 feet in a well at West Plains. X 10.

and although fine, are coarser than the grains of the angular sandstone. (pl. 3–B) This sandy dolomite, because of its persistence, may now be safely relied upon as being the basal bed of the Davis.

Prior to this study, there appears to have been no knowledge regarding the sandy character of this formation. As additional cuttings from wells penetrating the Davis were studied, it was apparent that the sandy material was of unusual persistence, and of much help in the determination of the formation. This led to an investigation of the formation in the field. A number of outcrops in the type locality of southeast Missouri were sampled, and as a result the sandy beds were found at a position in the section corresponding to that determined in the study of drill samples. This sand may be used for the purpose of correlation as it has been found wherever the Davis has been encountered.

The shale from this formation is unlike any other shale of the Cambro-Ordovician section. As a general thing it is very micaceous, and has a characteristic manner of breaking into thin plates. Insofar as this study has been extended it appears to be entirely lacking in the dolocastic feature and also occurs in considerably more abundance than the shale of the Bonneterre, or for that matter in any other formation of the section under consideration. The Davis formation always contains a considerable quantity of argillaceous material, and the percentage of clay or silt might be considered a distinguishing factor.

DERBY-DOERUN FORMATIONS

In his study of the lead deposits of southeast Missouri, Buckley[9] identified two formations in the upper part of the Upper Cambrian series and gave to them the names Derby and Doerun. In this paper the two names are used together as the limited amount of material available for study has not been sufficient to make a clean-cut separation of the two.

The residues representing these formations are generally high in argillaceous material, but not to the extent of the Davis. They are cream to buff colored, whereas the Davis argillaceous fractions are usually dirty gray or grayish green in color. They also lack the sandy facies observed in the Davis. These formations appear to be almost entirely free from shale. Like the

[9]Buckley, E. R., The Geology of the Disseminated Lead Deposits of St. Francois and Washington Counties, Mo. Bur. of Geol. and Mines, 2d. Ser., Vol. IX, pp. 44-49, 1908.

other formations of the Upper Cambrian the Derby-Doerun beds are not high in siliceous material. That present occurs as small aggregates or masses of quartz, or as occasional fragments of dense gray or brown chert.

The differences in the residues are sufficient to separate these formations from the Davis. They are also easily separated from the extremely siliceous and very easily identified residues from the overlying Potosi formation.

POTOSI FORMATION

Of the formations of the Cambro-Ordovician section of the Ozark region, the Potosi formation, by virtue of its highly siliceous and characteristic nature, is the most readily distinguishable in the field. The insoluble residues are no exception. In the formations underlying the Potosi, siliceous material is conspicuously lacking, but it becomes extremely abundant and diagnostic in this formation, which in this State marks the base of the Ozarkian system of Ulrich.[10]

To the writer, the Potosi presents the most striking, and insofar as correlation is concerned, the most characteristic assemblage of insoluble constituents observed in the section under consideration. The typical drusy quartz which is characteristic of the formation in areas of outcrop is likewise the most important and abundant constituent of the insoluble residues. It can be used with much certainty for the purpose of correlation. This ever present, characteristically banded chalcedony, while showing variations in size or thickness of the individual bands and also in color, is the same throughout. The convex surfaces of the druse are invariably coated with quartz crystals. When examined under the microscope the larger bands may be seen to be made up of many smaller, intricate bands, crinkled into irregular lines. In finely ground samples the expression of the druse appears to be limited to broken fragments or broken crystals of quartz. It is quite clear that there is a concentration of the druse at the surface or near zones of solution below the surface, for in holes penetrating the formation at considerable depths, the percentage of the material is always much smaller than in samples obtained where weathering and concentration have been dominant processes.

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[10]Ulrich, E. O., Revision of the Paleozoic Systems; Bull. Geol. Soc. of America, Vol. 22, 1911, p. 27.

In the Upper Cambrian series, as restricted, the dolocasts are confined to the shale, but in the Potosi, they make their first appearance in the chert. The dolocastic chert of the Potosi is as characteristic as the druse or crystalline quartz. Like the original dolomite, the chert is brown in color, and marked by many perfect casts of the dolomite crystals. (pl. 4, 5–B) Dolocastic chert is also contained in the younger formations, but may be distinguished from the Potosi by the general absence of the brown color; also by the fact that the Potosi casts are larger, and with thicker intervening walls. Similar dolocasts are also well developed in the convex or inner surfaces of the druse fragments. This formation also contains a brown colored, waxy, dense to slightly quartzose chert, occasionally slightly oolitic, near the base of the formation.

Pyrite, limonite and marcasite are common to this formation, and hematite has been found in a few instances. The first three mentioned often show dolocasts similar in size and arrangement to those of the Potosi cherts. Aggregates of small flat plate-like fragments of crystalline quartz have been noted in the formation in a number of wells. This material, like the chert, is very dark brown in color and is associated with other Potosi constituents. For these reasons it may be identified as belonging to the Potosi formation.

EMINENCE FORMATION

The character of the Eminence residues is so distinct that the formation may be readily differentiated from the underlying Potosi formation, as well as the overlying nonsiliceous Proctor dolomite. The Eminence dolomite is very siliceous, and the insoluble residues contain a considerable percentage of chert which is the distinguishing feature. A common type is a white to light bluish-gray, very vitreous, quartzose chert, which has a live, somewhat glassy appearance and fine but even texture. It is so distinct from the cherts of the adjacent formations that in the laboratory of the Missouri Survey it is characteristically known as "Eminence Chert". The Eminence also marks the first appearance of siliceous oolite or oolitic chert in considerable quantities. (pl. 6–B) The oolites are found embedded in the chert, or as quartz cemented clusters. They appear to be fairly uniform in size, and almost without exception are perfectly spherical in shape, but coated with very fine crystals of quartz. The oolites usually show a distinct concentric structure arranged around slightly darker-colored nuclei.

The dolocastic feature is also splendidly presented in the chert observed in many Eminence residues. Here again the material is of a siliceous nature. The casts, however, are smaller than those observed in the underlying Potosi formation, and the intervening siliceous walls are much thinner, the mass having a fine lace-or skeleton-like structure. (pl. 6–A) Gray or white chert, marked by veinlets or incrustations of crystalline quartz is also common to the Eminence residues. This type of chert usually possesses the characteristic even-grained texture.

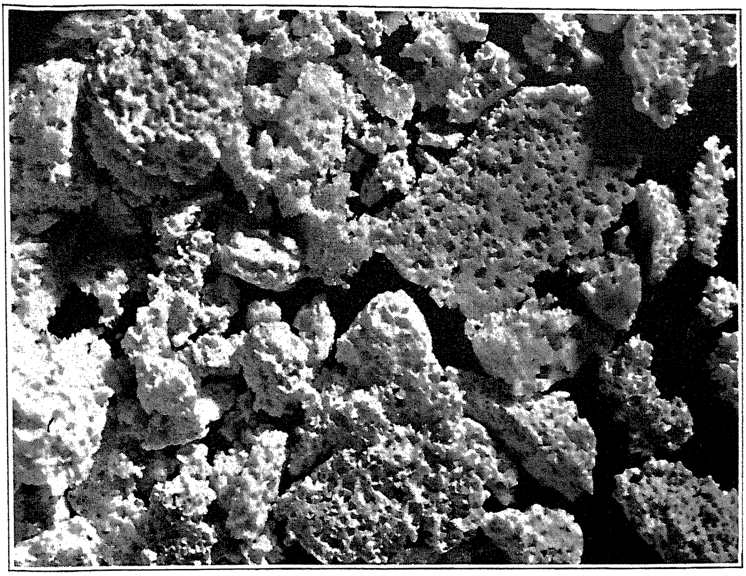
Granular aggregates of crystalline quartz have been noted in practically every well examined, in which the Eminence has been encountered. This material appears to be amorphous, but when examined under the microscope is found to be crystalline and can be readily identified as quartz. It is commonly blue gray in color, with a vitreous, glassy luster. It is quite distinctive of the formation. Sponge-like and slightly dolocastic pyrite and limonite, the latter being pseudomorphic after the former, are also common to the Eminence, and occur in abundance in many residues.

PROCTOR FORMATION

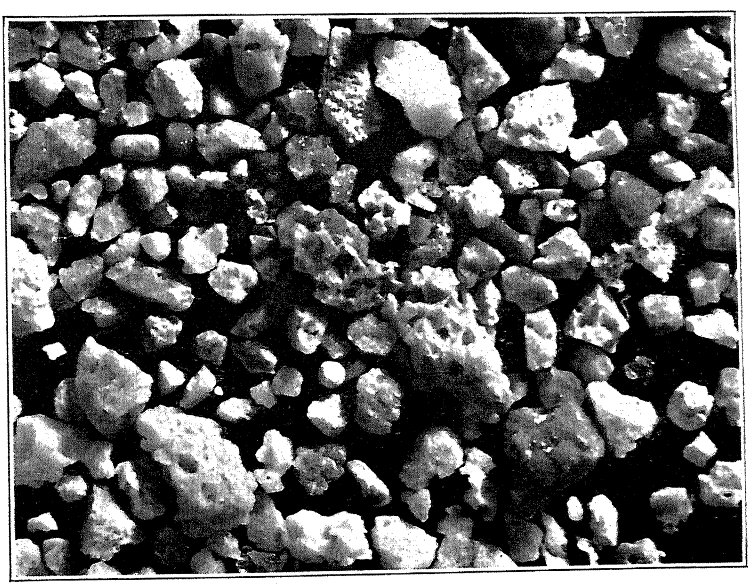
The lack of insoluble material may be as diagnostic as its presence. The Proctor formation is a striking example. In the western part of the state, this relatively pure dolomite yields practically no siliceous material and the insoluble residue, if any, consists of dark, porous, sponge-like pyrite, with fragments of bright-green, smooth, waxy shale, which apparently occurs as thin seams interbedded with the dolomite. The shale lacks the dolocasts which mark the Bonneterre shale, and also the general characteristics of the Davis shale.

The low percentage of insoluble material in the Proctor dolomite, and the much greater quantities in the overlying formations has given considerable information regarding caving or ravelling of material from above. In the examination of many Proctor sections, Van Buren or Gasconade cherts have been found. There is no question but what the ravelled material can be identified in the residues, and in this matter alone, a study of the insoluble material is of great value.

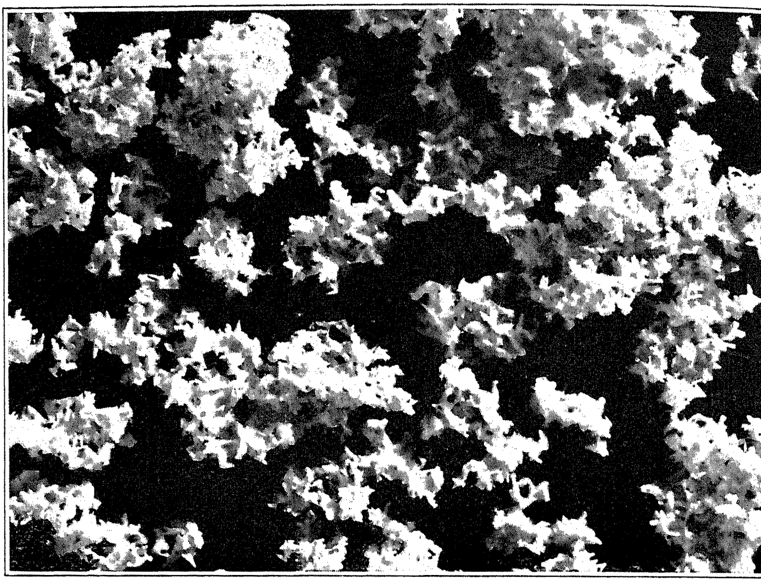
In several drill holes in western Missouri a thin sandstone or sandy dolomite marks the base of the Proctor. As observed



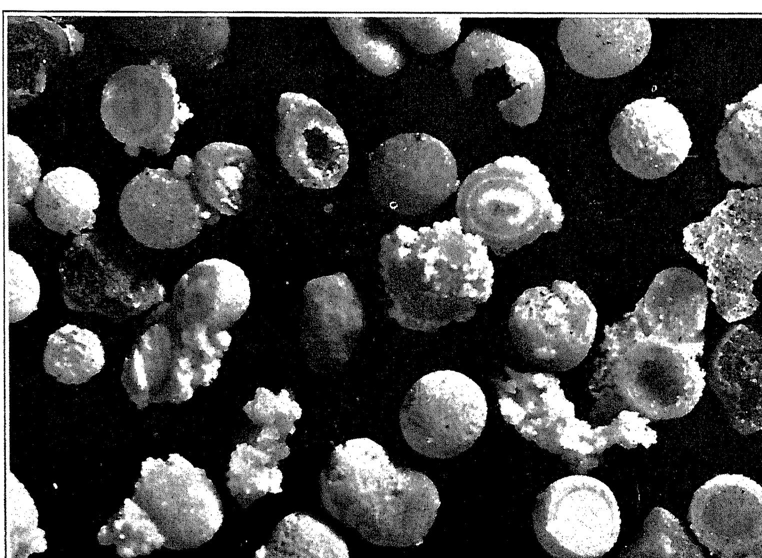
A. The dolocasts in the Eminence chert shown in the photograph are much smaller than those which occur from the residues of the underlying Potosi and give the chert a sponge-like appearance. This residue is from a depth of 240 feet in a drill hole in Perry County. X 10.



B. The glassy banded druse, as well as the dolocastic chert of the Potosi Formation, is shown in this residue which is from a depth of 1220 feet in a well at Pomona. X 10.



A. The Eminence dolocasts are characteristically finer than those found in the other formations and the arrangement is also such that the resulting siliceous residue is a porous, spongy mass. This type of siliceous residue is very characteristic of this formation. Sample from a depth of 250 feet in a core drill hole in Perry County. X 18.



B. The oolites shown above are very typical of the Eminence formation. Those shown are from a hand sample collected in the vicinity of Decaturville, Camden County. X 18.

in the insoluble residues, it has a dirty-gray color, and occurs as indurated masses of fine, fairly well rounded and frosted grains.

In the southern part of the state some 30 to 100 feet of dolomite lying between the base of the Van Buren and the top of the Eminence formation carries a small amount of shale, and a relatively small amount of chert. Although the Proctor formation has not been definitely recognized in the field in this part of the state, these beds are so designated because of the low content of insoluble material, the presence of the green shale and their stratigraphic position. The formation appears to be absent in eastern Missouri.

The heavy siliceous residue of the overlying Van Buren and underlying Eminence formations, and the low content or almost entire absence of insoluble material in this formation are sufficiently diagnostic for its identification.

VAN BUREN FORMATION

The name Gasconade has been applied to the cherty dolomite beds lying between the Gunter sandstone member at the base, and the overlying Roubidoux formation. Ulrich believes, however, that two formations occupy this interval and for the upper part he has retained the name Gasconade formation, but for the lower part he has proposed the name Van Buren. In recent field work, Bridge[11] has used the term Van Buren to designate a faunal member lying above the Gunter sandstone member and a well defined oolite bed in the Gasconade. Subsurface studies by the writer have indicated that the two formations may be distinguished on the basis of their insoluble residues, and in this paper they are described separately.

The base of the Van Buren formation is marked by a sandstone member. Ulrich believes that this sandstone is older than the true Gunter and for that reason has proposed for it the name Van Buren sandstone. The present study would indicate, however, that the sandstone is traceable in drilling over wide areas. As it occupies the stratigraphic position of the Gunter member that name is retained in this paper. The sandstone in many localities is absent, but in the southern part of the state has a known thickness of at least 60 feet. It contains locally a large amount of dolomite, and for this reason the horizon of the sandstone, where thin, was often overlooked in the examination of

[11]Bridge, Josiah. The Geology of the Eminence-Cardareva Quadrangles, Mo. Bur. of Geol. and Mines, 2d. Ser., Vol. – (In preparation).

drill samples. As seen in the insoluble residues, the sandstone is graded into two distinct sizes which may be described as fine and medium-grained. It is generally well-rounded and highly frosted with a pearly luster. The grains are occasionally pitted and some secondary enlargement has been noted which gives the appearance of angular grains. The Gunter sandstone may be distinguished from the Lamotte and the Roubidoux sandstones by the differences in degree of rounding and sizing. It usually contains a sufficient quantity of characteristic chert to render its determination quite certain. The character of the insoluble residues of the over and underlying dolomites is also such, when compared with the formations associated with the Roubidoux and Lamotte sandstones, that it can be readily recognized. In localities where the sand is absent, the horizon can be determined by the change in the character of the residues from the associated formations.

The cherty Van Buren formation may be easily separated from the underlying non-cherty Proctor formation, and the character of the chert is also such that it may be distinguished from the overlying cherty Gasconade formation. Insoluble residues from this formation are generally large, the bulk of the material being white to light-gray, dense to translucent chert. Perhaps one of the most characteristic types is white, dense, slightly to very quartzose chert, the outer surfaces of which are incrusted with small colorless crystals of quartz. Small stringers or veinlets of the same material cut through the material in every direction. Quartz banding has been noted on the outer surfaces of some of the white, dense fragments. White, dull, to live, dense porcelain-like chert is also common. In the dull chert, small but well developed dolocasts have been observed. The casts differ from those of the Eminence in that they are smaller with thicker intervening walls. They also occur less abundantly and are more irregularly distributed throughout the fragments. They simulate somewhat the same type of chert found in the Potosi formation. However, it may be distinguished by the smaller size, as well as the absence of the characteristic druse and brown color of that formation.

It is interesting to note that the dolocastic Van Buren chert is found only in the lower 50 to 75 feet of the formation, and its first occurrence in drill sample residues is a practical guide to the amount of drilling necessary to reach the Gunter sandstone member.

The formation contains siliceous oolite and oolitic chert in abundance. In general, they differ from the oolite of the Eminence formation in that they are less perfectly rounded, and when free do not show the incrustation or outer shell of finely crustalline quartz. The Van Buren oolites are also smaller than those of the Eminence formation; they likewise lack the uniformity in size observed in those of that formation.

As this formation is studied in detail, it is apparent that it may be separated into two units, the division between the two being marked by the top of the zone of dolocastic chert mentioned. Above the dolocastic horizon the chert is more translucent, while below the chert is denser, and marked by quartz veinlets and incrustations. The upper zone appears to be present chiefly in the South Central Missouri Basin, as only the lower division has been noted elsewhere.

GASCONADE FORMATION

As used in this report, this formation consists of cherty beds of dolomite lying between the Roubidoux formation above and the Van Buren formation below. The insoluble residues from each are distinct enough to afford a basis for separation and correlation.

Chert is the dominant constituent. It is nearly always gray to dark bluish-gray or blue, in some cases being so dark that its color has been described as bluish-black. The chert is dense, live, almost glassy and in some specimens has a granular crystalline appearance.

Much of the Gasconade chert is vitreous and quartzose but lacks the even glassy texture of the Eminence and to some extent the chert of the Van Buren. It is also much darker than any similar material that might be mistaken for Van Buren or Eminence chert. Dark-gray, waxy, translucent chert is also found in the Gasconade residues. Dark-blue banded cherts occur in the samples from some wells.

As compared with the Van Buren formation, the residues do not contain as much oolitic chert or siliceous oolite. The Gasconade oolites are light-colored, in a matrix of darker colored, usually bluish-gray, chert. The oolites are oval to spherical in shape but lack the uniformity, degree of rounding and also the definite size of the individual oolites noticed particularly in the Eminence and, to a lesser extent, in the Van Buren formation.

Many of the oolites are hollow, the remaining outer portion suggesting the chert or siliceous shell that originally surrounded sand grains. In some instances this hollow shell is filled with fine quartz crystals. Two definite zones of siliceous oolite have been recognized in this formation, one near the top and the other at what is taken to be the base of the formation. The latter is often accompanied by a small amount of sand, and as suggested previously, evidence has been obtained that suggests a replacement of the individual sand grains by chert. Below this thin oolitic zone there is a distinct change in residues to the lighter colored and distinctive chert of the Van Buren formation. This siliceous oolite has been observed in the field and had been identified in drill samples from a number of wells. Apparently it is a zone which may be used successfully for the purposes of correlation.

The upper beds of the Gasconade appear to contain less siliceous material than the beds of the lower part. This is suggested by cuttings from wells so cased that ravelling or caving is eliminated.

ROUBIDOUX FORMATION

This formation is composed of alternating beds of sandstone and dolomite. It can be determined in field mapping on the basis of the lithologic characteristics, as well as by the characteristic fossils. The determination of the formation in deep drilling was more difficult. In general, the formation was correlated on the basis of the sandstone beds, and the dolomite in the upper and lower parts were referred to the over and underlying formations.

This difficulty has been overcome for the beds of this formation yield comparatively large residues which contain certain features lacking in the associated formations.

Sand is the chief constituent and most characteristic material in the Roubidoux residues. It is fine-grained, except possibly in the basal part where it is often slightly coarser. The grains are usually angular, unfrosted and show characteristically the results of secondary enlargement.

In many instances the cementing material is dolomite, but in others it is gray or bluish-gray secondary chert. This type of material is very characteristic of the Roubidoux and occurs in considerable abundance. Some specimens may be described as cherty sandstone, others as sandy chert. This material often has a very oolitic structure and when examined shows a replacement by chert of the dolomite cement between the grains, or a later stage in which the sand grains have concentric and successive coatings of secondary silica. Another and perhaps final stage indicates the complete replacement of the sand grains. These stages in replacement can often be seen in the same fragment.

Another diagnostic type of oolite is common to the cherts of the Roubidoux. These are usually dark colored, spherical to elliptical in shape, and very irregular in size. Radial internal structures are common, the lines seemingly converging in a central nucleus. The enclosing chert is generally light-colored. In this respect it differs from the underlying Gasconade chert. Much of the chert is a dead-white variety and shows the result of the circulation of water. It would be well to mention that the Roubidoux, in many parts of the state, is a splendid aquifer.

The origin of the oolites is similar to that of the cherty oolitic sandstones. In this type the material was probably oolitic dolomite, with the dolomitic matrix more readily replaced than the dolomite of the oolites. In this generally sandy formation where the circulation of water is a dominant factor, silica in solution would be transported, and would replace the dolomite beds, particularly those lying between two layers of sandstone. As a result the entire bed of oolitic dolomite would be replaced.

Chert occurs abundantly in the Roubidoux, and in some localities the large amounts of this constituent and the small amount of dolomite would again indicate a replacement of the latter. The chert is dense, vitreous and waxy and varies in color from light-gray to brown. Quartz crystals, much coarser in size when compared with the same material in other formations are common.

JEFFERSON CITY FORMATION

The low content of insoluble material from this formation, when compared with the larger amounts from the overlying Cotter and the underlying Roubidoux formations, is a characteristic by which this formation may be distinguished.

Chert is the chief constituent of the Jefferson City samples. It is nearly always light-colored, translucent, and has a waxy luster, or, on the other hand, a dead, soft, tripoli-like structure. The former is present to a great extent in the upper part of the formation, and the latter is often found near the contact with the Roubidoux. Oolitic chert is not as common to this formation as it is to the associated formations. However, a white chert, with fine white spherical oolites has been noted. Grains of sand have been found in the residues and probably come from thin sandstone or sandy dolomite beds which occur in the middle of the formation.

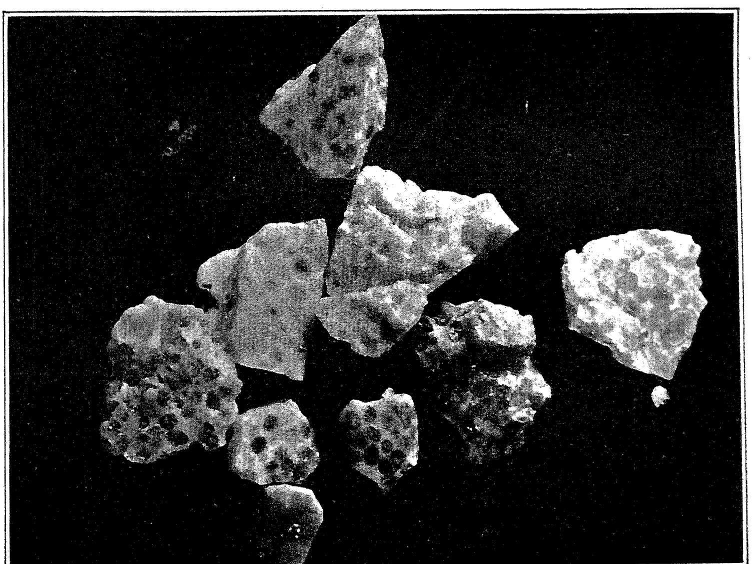
The Jefferson City cherts lack the banding seen in the overlying cherts of the Cotter, and do not have the vitreous or glassy appearance of some of the Roubidoux cherts. Fine granular silica is found to some extent. This is not surprising as a well defined bed in the Central Ozark Region shows small cavities filled with "sugary" silica.

COTTER FORMATION

Although chert is present in all the formations between the Cotter and the top of the Upper Cambrian series, it attains in this formation its greatest development, as well as its widest range in general character.

The Cotter cherts are very distinctive, and may be easily distinguished from the chert of the associated formations. Gray, blue-gray or brown-colored, concentrically banded cherts are common to this formation. The cherts of the Cotter are also very oolitic, in fact, much more so than those obtained from the other Cambro-Ordovician formations. The oolites and oolitic chert vary in color, in shape, in size and in arrangement in the chert matrix. A distinctive brown-colored oolite is characteristic. (pl. 7–A) It is generally well rounded, although the outer surfaces, particularly when occurring as free oolites, are coated with fine brown-colored quartz crystals. It has been noted that where the brown oolites occur in chert, the cementing material is always light-colored, thus effecting a sharp differentiation between the two. The brown oolite is found in considerable abundance in many wells drilled in this state, and insofar as present knowledge is concerned is restricted to this formation. White to gray oolitic chert, in some cases the result of the replacement of sand grains by secondary silica, is also common to the upper part of the formation. Dead-white chert showing a few fine dolocasts, as well as a soft porous, slightly dolocastic chert has been observed. The latter is common to the base of the upper Cotter. Brown quartzose and vitreous brown cherts are found

A. Brown-colored, quartz-coated, siliceous oolites are characteristic of the lower part of the Cotter formation. The sample shown represents a residue taken from a well at Lamar, depth 615 feet. X 18.



B. The grey translucent chert with included grains of sand is characteristic of the Cotter Formation. This sample, was taken from a well at Ozark, depth 165 feet. X 15.

in the lower part of the Cotter, and although similar in color to the Potosi, they differ from the cherts of that formation in that the dolocasts are not as numerous or as well defined and the assemblage lacks the associates common to that formation. A type of chert which has been assigned to the Cotter is a brown, dense, even-grained material marked by small spots of white, which simulate an oolitic structure. This chert has been found in deep wells in Kansas, Missouri and also in Oklahoma. It occurs in the lower part of the formation. Sandy chert (pl. 7–B) similar to that of the Roubidoux has been noted, particularly in the middle and basal portions. It is always associated with other residual constituents of the Cotter, and occurs less abundantly than in the Roubidoux. Many fragments of Cotter show well-developed quartz crystals, also alternating bands of quartz and chalcedony. Compared with similar chert from the older formations, certain differences may be noted with study. In particular, the quartz crystals are not as definitely sized, also the arrangement of the bands is not as distinct or regular. Some of the chert also shows quartz veinlets.

Considerable sand is found in the Cotter. Near the base of the upper member a well-defined bed of sandstone, or sandy dolomite is usually encountered. The base of the formation is also marked by sand, and thin beds in other parts of the formation are common.

The studies of the different sands have not progressed to the extent that Cotter sands can be readily identified. In comparison with the Roubidoux they appear to be finer-grained, and with respect to the Gunter sand lack the sizing noted, as well as the degree of rounding and frosting.

Soft porous sponge-like pyrite is found throughout the Cotter section. The occurrence of sphalerite is such that it should also be mentioned. This mineral has been noted in the lower division of the formation, and is also associated with similar chert from what is designated as the Cotter formation in deep wells in Osage County, Oklahoma. Fragments of dark green shale are noticeable in the residues from the upper part of the formation.

Sponge-like aggregates of extremely fine-grained, angular sandstone occur in the Cotter residues. It is buff to greenish-gray in color and occasionally contains glauconite. It differs, however, from the fine sandstone of the Upper Cambrian series, in that it lacks the abundant glauconite, and muscovite. It can also be distinguished by the presence of associated Cotter material.

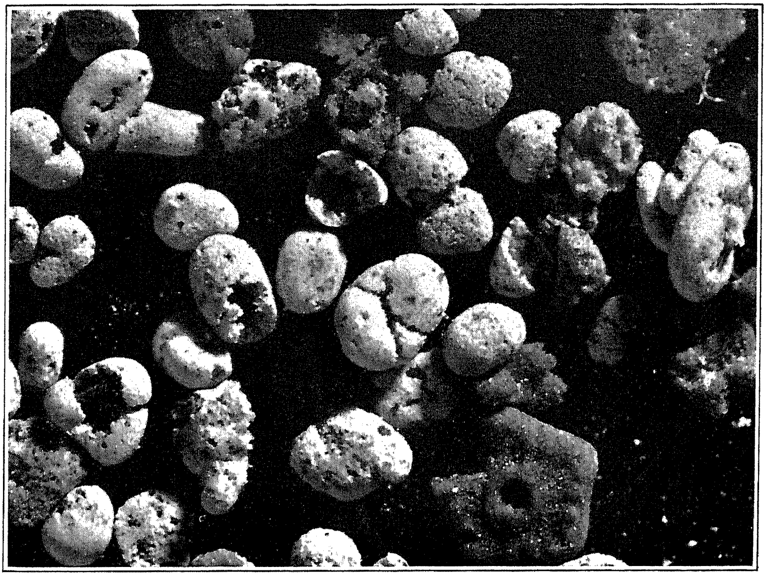
POWELL FORMATION

This distribution of this formation in Missouri is such that it has been drilled in only a few instances. In its general lithologic details it is similar to the underlying Cotter formation. The residues, however, show sufficient differences that the two formations can be separated.

The Powell formation is less dolomitic and its residues constitute a lower percentage of the original material than that of the Cotter. A common constituent of the Powell is a chalcedonic-quartz druse in which banding and quartz incrusted fragments have been noted. This simulates, in a way, the druse of the Potosi formation, except that it lacks the regularity in arrangement of the bands and also lacks the associated chert. Soft, porous, "rotten" chert is common to the Powell residues, as well as to areas of outcrop. Dense, brown, gray or white cherts are also common to this formation, and some of them show fine dolocasts. Sand is present, but is usually fine grained and not as abundant as in the Cotter. Pyrite and fragments of green shale also have been noted.

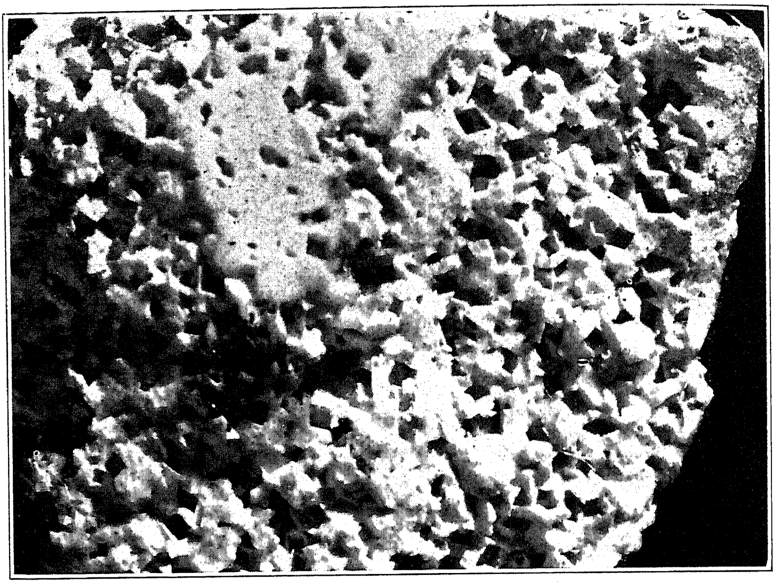
SMITHVILLE—BLACK ROCK FORMATIONS

These formations have been shown on the recent edition of the *Geologic Map of Arkansas*. To date, the detailed features of each have not been published, nor has an opportunity for a detailed study of their insoluble residues been presented. They occur between the Powell dolomite and the St. Peter sandstone. The Smithville is thought to occur in southeast Missouri, for in a few wells, limestone and slightly dolomitic limestone yielding a small residue have been found above the Powell formation. To date the overlying Black Rock limestone has not been recognized in Missouri. However, this formation appears to be amenable to study by the method under discussion, for insoluble residues from samples collected in the type locality at Black Rock, Arkansas, yield residues that should aid in its determination. The formation appears to be more fossiliferous than the underlying beds and silicified forms occur abundantly in the residues prepared from hand samples.

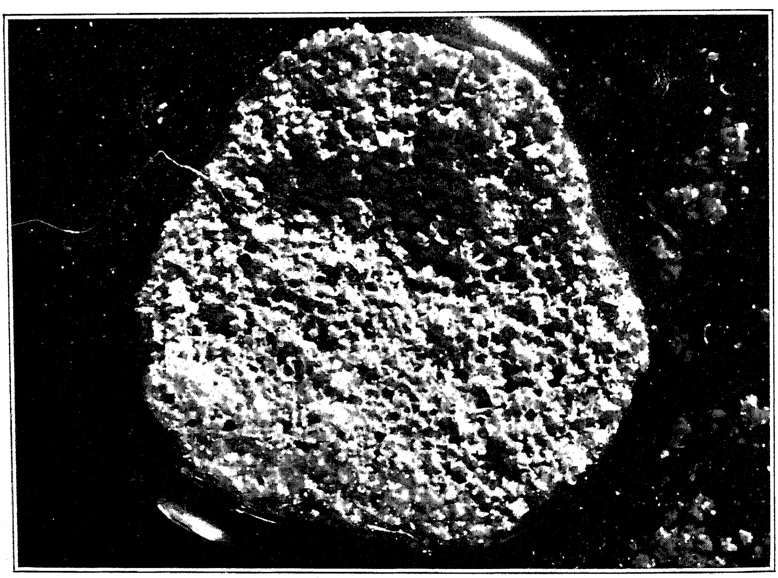


A. Silicified fossils occur abundantly in many residues. The very interesting one shown was prepared from a hand sample of the oolitic bed of the Drum member of the Kansas City Formation. Sample was collected at Kansas City. X 10.

B. Insoluble residues on a number of samples have shown that a pyritized microfauna is characteristic of the basal beds of the Maquoketa Formation. The white barrel-shaped segments of crinoids from the underlying Fernvale Limestone are shown in the upper part of the photograph. The sample was collected at a depth of 950 feet in a test well in St. Charles County. X 18.



A. Insoluble residues from the Knox dolomite have shown the presence of well developed dolocasts and chert. The fragment shown is from a hand sample collected in the vicinity of Mascot, Tennessee. X 10.



B. Dolocastis chert or spongy siliceous skeletons have also been found in residues from the Arbuckle Limestone. The photograph is made of a fragment collected in the Oklahoma City, Oklahoma, oil field, at a depth of 6220 feet. X 10.

YOUNGER FORMATIONS

In connection with the study of many drill samples, this method of study has been extended to cover, to some extent, the entire geologic column in Missouri. Although the detailed features of the different formations have not been determined, it may be of interest to briefly mention the results obtained on formations beyond the scope of the present paper.

As the result of the discovery of production from Ordovician limestones in the Dupo, Illinois, field, some drilling has been done in adjacent parts of eastern Missouri. It is interesting to note that the Kimmswick, the producing formation, although considered to be relatively pure limestone, yields a small but characteristic residue. The overlying Fernvale and basal Maquoketa beds yield most striking ones. These formations are known to be present in eastern Missouri, but the former appears to be not over five feet in thickness. Insoluble residues from two wells have given a most interesting silicified microfauna characteristic of the Fernvale and so diagnostic that even though thin, the formation can be readily separated from the overlying Maquoketa beds, with an equally interesting pyritized microfauna and the underlying Kimmswick limestone. (pl. 8–B.) A similar pyritized Maquoketa fauna was obtained from a sample taken from a deep well in Butler County, Kansas. In this instance, the value of insoluble residue studies is apparent.

No attempt has been made to examine in detail insoluble residues from Silurian and Devonian formations. Certain ones carry chert, however, and should be amenable to this study. Residues obtained from a few hand samples were small, but nevertheless interesting.

The limestone formations of the Mississippian are very favorable for study. The chert not only has definite characteristics for each formation, but carries, in many instances, silicified fossils, some of which can be identified. Wells penetrating a complete section of the Mississippian have been definitely correlated into formational units, and the correlations have been extended to other wells. It is planned to consider these formations in another paper.

Geologists engaged in sub-surface studies of the Pennsylvanian formations will be interested in knowing that hand samples of limestones from the Kansas City, Lansing and Douglas formations have given very striking residues rich in silicified micro-fossils. (pl. 8–A). Distinctive features can be noted in the residue from these formations, as well as from different members. This series offers an exceedingly interesting field for this method and it is planned to study the Missouri representatives in detail.

CROSS SECTIONS

In the accompanying cross sections, the formations have been determined and correlated between the drill holes shown, on the basis of similarities in insoluble residues obtained from the original samples. As the studies are continued much additional information will be available. For instance, certain intraformational zones of similar characteristics can now be recognized and in time these should be amenable to correlation. As the detailed features of the Cambro-Ordovician are better known some revision of the contacts drawn on the sections may be necessary. However, those shown have been consistently made and certain diagnostic features may be seen in the residues from each formation.

The North-South section from Buckner, Jackson County, to Carthage, Jasper County, (pl.10) will probably be of interest to geologists engaged in sub-surface studies in Kansas. It represents the first attempt to definitely correlate a series of deep wells in western Missouri. This section shows two very interesting features. The first is the presence of an elevated area of pre-Cambrian metamorphic rocks between southern Jackson and northwest Vernon counties. In the latter it appears to reach its maximum elevation, for in the deep well at Rinehart, metamorphic rocks were encountered at a depth of 1000 feet. It slopes to the north and at Rich Hill was encountered at a depth of about 1380 feet and near Greenwood, southern Jackson County, it was reached at a depth of 2200 feet. Its extension to the south is conjectural, although metamorphic rocks have been found in a deep well in Barry County in the southwest part of the state. In these wells quartzite, slate, schist and gneiss have been found. Granite was encountered north of the area of metamorphic rocks as shown by the deep wells near Buckner, Lamar, Nashville and Carthage.

This section shows another interesting feature in that it indicates the relation of the sedimentary rocks to this buried pre-Cambrian ridge, as well as the stratigraphic succession in western Missouri. As determined by this study the Davis, Derby-Doerun and Potosi formations are absent and the upper part of the Eminence dolomite rests upon the Bonneterre formation. In these wells the Bonneterre formation and the Lamotte sandstone of Upper Cambrian age are thin when compared to the thickness determined in other parts of the state. These formations are absent in the well at Rinehart where the Gasconade formation rests upon metamorphic rocks, and at Rich Hill, the older Eminence dolomite probably overlies metamorphic rocks of pre-Cambrian age, although samples from the contact are not available for study. These overlaps point out the relationship of the sedimentary beds to the pre-Cambrian and indicate a regional type of overlap.

The section from New Franklin, Howard County, to Branson, Taney County, (pl. 11) is different in certain respects to the one just described. The most striking feature shown is the presence of formations that are missing in western Missouri, and also the thickening of the formations below the base of the Gasconade dolomite. This is particularly noticeable in the wells located on the south flank of the Ozark dome.

In the wells shown, the Davis and Potosi formations are present. Both are absent in western Missouri. The Eminence formation approaches its maximum thickness in the state, and the maximum thickness of the Proctor also is attained. On the south flank of the dome deep wells have penetrated a greater thickness of the Gunter sandstone member of the Van Buren formation than on the north flank, and the overlying dolomite of this formation also is much thicker.

The section suggests that the crest of the regional structure occurs in the vicinity of Decaturville. Here a pegmatite dike or boss intrudes the sedimentary rocks, the resultant structure being very complex. There is a suggestion that this intrusion may be responsible, in part at least, for the maximum elevation of the formations at this place.

The east-west section from Perryville, Perry County, to Carthage, Jasper County (pl. 12) crosses several dominant structural features in southern Missouri, which have an important bearing on the stratigraphic sequence.

In the deep hole at Perryville, drilling was started in the Joachim dolomite and at a depth of 3033 feet was completed in what is taken to be the transition beds between the Lamotte sandstone and the Bonneterre formation. This well penetrated the greatest known thickness of pre-St. Peter sediments found to date in this state. The formations drilled show the results of thickening, as well as the wedging in of a formation between the St. Peter sandstone and the Powell formation. This is thought to be the Smithville formation. In this hole the Cotter formation is much thicker than the general average, but this increase has been confirmed by other wells recently drilled in eastern Missouri.

To the west, in the St. Francois Mountains an example of overlap similar to those described by Dake[12] and Bridge[13] can be seen, for in the Fredericktown drill hole the Potosi rests directly on the Bonneterre, the Davis and Derby-Doerun formations being absent. They reappear in the hole drilled near Black, and are also present in the drill holes at Salem and Pomona. In the latter the formations, in the main, are very thick and this locality is at, or near, the deep part of a well-defined basin which is known to exist in southern Missouri. An expression of this basin also may be seen in the well sections from Cabool to Seymour, and the thickening of the beds in the wells shown in the southern half of the New Franklin-Branson section is attributed to deposition within this basin.

The comparison of the Carthage hole with the Pomona hole shows a thinning of all the formations below the base of the Roubidoux formation, and the complete absence of the Potosi, Davis and Derby-Doerun formations. The effect of this overlap is probably present in Kansas, for in a deep well in Butler County residues suggestive of the Van Buren were found to overlie pre-Cambrian igneous rocks and to the south in Madison County, Arkansas, a deep well encountered the Eminence dolomite above pre-Cambrian rhyolite porphyry.

VALUE OF THE STUDY

It is quite evident that any study whereby nonfossiliferous drill samples can be identified as to formation, and then correlated over considerable distances, is of inestimable value in subsurface studies. The accompanying cross-sections and the formational descriptions are results of the present study. Prior to this investigation, the drill samples from the holes shown were not correlated with any certainty.

[12] Dake, op. cit.
[13] Bridge, op. cit.

That residues of much similarity and representing as they do a given formation are found over wide areas is very significant. It is true that not all residues from a given formation are identical. Minor differences in individual constituents, the addition of certain materials, or the loss of others, can be noted. However, regardless of the changes, the residues in their general features are the same for a formation throughout the area covered by this paper. In the study of the residues, success is obtained by noting the general features of the samples rather than the minute differences. This should be borne in mind.

In any method where the question of detail is involved, times becomes a factor. In this study a brief examination of the residues often indicates the formation. The procedure or method of preparation is simple and it is not necessary to have a completely equipped laboratory in which to make the examination. Consequently field determinations can be made. Insoluble residues from formations deeply buried and a considerable distance from the outcrop might show minor dissimilarities to those found elsewhere in the same formation. However, the essential thing is not the actual determination of a formational name, but the determination of zones of similar insoluble residues.

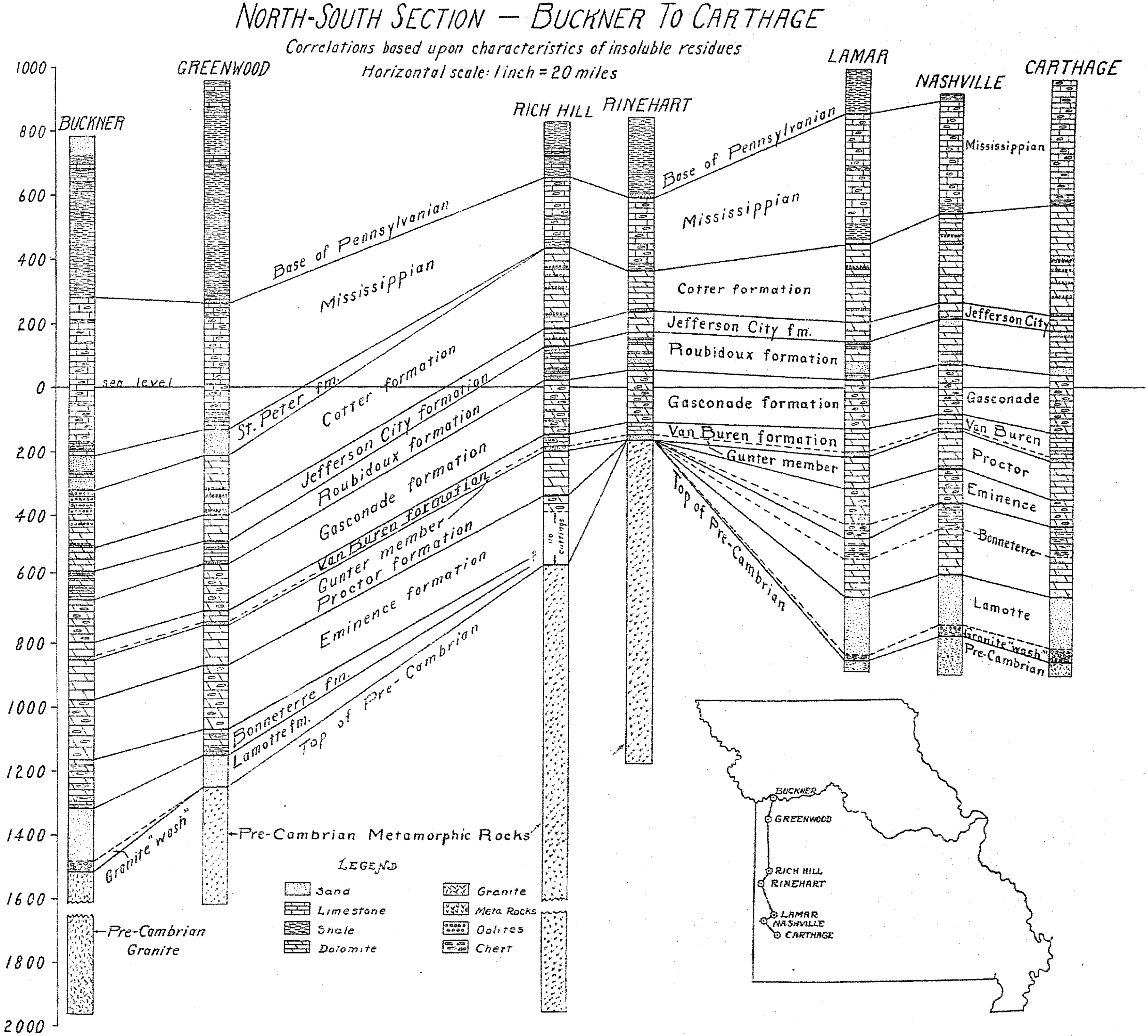
A study of drill samples from the "siliceous lime" of Kansas and Oklahoma has been an interesting phase of this investigation. Some of these samples were taken from a depth of over a mile below the surface, and several hundred miles from the outcrop. Nevertheless, certain zones were defined and the same, or, at least, similar zones were found in other wells many miles away. There is no question that the "siliceous lime" in the Osage County field of Oklahoma can be zoned and correlated with other wells. The most remarkable thing is the fact that in the residues from these wells in south central Kansas and north central Oklahoma certain characteristic features of the Cambro-Ordovician formations of Missouri can be noted. An attempt to correlate the "siliceous lime" sections of the Mid-Continent field with the section in Missouri would be premature at this time in view of the fact that no opportunity has been presented for examining well samples in the intervening distance. However, a study of the samples of this broad stratigraphic unit will be undertaken at a later date with this in view. The value of a similar study to geologists of the Mid-Continent oil field is apparent. It will permit the determination of the character of the producing formations, the stratigraphic sequence of the "siliceous lime", the presence or absence of formations in drilling, and also data of value in the preparation of sub-surface structural contour maps.

This method of attack has also been found to be successful in studying the Cambro-Ordovician Knox dolomite in the Appalachian Mountain province of eastern Tennessee. Residues prepared from drill samples indicated that two formations were encountered in drilling in a particular locality, with an unconformity between the two. Zones or horizons of considerable similarity were also identified, and information was obtained that not only permitted the correlation of the two holes, but also gave data of value in determining the structure. Detailed field work in the area followed, and the two formations previously indicated by the residues were identified on the basis of lithologic features and faunal content. This determination was particularly important because ore bodies in this district are found at this unconformity.

The identification of formations from hand samples is also possible. Many sections have been measured and carefully sampled in this state. When studied, the formation or formations could be identified and contacts definitely located. In other instances, hand samples doubtfully referred to a formation in field mapping have been studied. Such striking residues have been obtained that the samples could be referred to their proper formation.

This study is of considerable importance in the field of economic geology. Its possibilities in oil field work have been described. In drilling metalliferous ore bodies in sedimentary rocks, the minerals contained, where insoluble in weak acid, can be observed more easily than in the original samples. The recognition of unconformities, the determination of structure, and the knowledge gained of the character and nature of the rock are features that can be recognized. In Missouri, the study has been made chiefly with reference to ground water supplies. The importance in such work is the recognition of formations and the determination of the depths to water-bearing horizons.

Residues, particularly in areas where siliceous carbonate rocks are drilled, are guides to the ravelling or caving of material from the overlying formations. Caving is noted in many drill holes in this state by association of insoluble materials rep-


NORTH-SOUTH SECTION — BUCKNER TO CARTHAGE
Correlations based upon characteristics of insoluble residues
Horizontal scale: 1 inch = 20 miles
BUCKNER
GREENWOOD
RICH HILL
RINEHART
LAMAR
NASHVILLE
CARTHAGE
1000
800
600
400
200
0
200
400
600
800
1000
1200
1400
1600
1800
2000
sea level
Base of Pennsylvanian
Mississippian
St. Peter fm.
Cotter formation
Jefferson City formation
Roubidoux formation
Gasconade formation
Van Buren formation
Gunter member
Proctor formation
Eminence formation
Bonneterre fm.
Lamotte fm.
Top of Pre-Cambrian
Granite "wash"
Pre-Cambrian Granite
Pre-Cambrian Metamorphic Rocks
cuttings
Jefferson City fm.
Gasconade formation
Top of Pre-Cambrian
Mississippian
Jefferson City
Gasconade
Van Buren
Proctor
Eminence
Bonneterre
Lamotte
Granite "wash"
Pre-Cambrian
LEGEND
Sand
Limestone
Shale
Dolomite
Granite
Meta Rocks
Oolites
Chert
BUCKNER
GREENWOOD
RICH HILL
RINEHART
LAMAR
NASHVILLE
CARTHAGE

resenting two formations in the residual fractions of the lower formation. The caving of soft sand beds has been noted, as well as the caving of cherty zones. Insoluble residues from the Missouri formations have also been used to check the accuracy and care in sampling. The residues, in general, are sufficiently characteristic that the identification of a sample out of place with respect to formation can be made without difficulty.

Insoluble residues have a wide application in strictly scientific studies. They show the character of the rocks and the different constituents, and thus indicate the character of the sediments that were deposited, the possible source of the materials and the conditions under which they were laid down. In the method of preparation, the presence of organic matter can be easily detected. This determination is especially important in the field of Petroleum Geology.

Erosion surfaces and unconformities have been recognized. Areas in which sedimentation in basins has been a dominant process have been determined. Important overlaps have also been recognized. The residues also yield data regarding other processes affecting calcareous rocks. When and how did dolomitization or silification take place? The answer, as well as the solution of many other problems in the field of sedimentation, will be found, to a great extent, in a study of the insoluble residues.

December 1, 1929.

APPENDIX II

THE PELECYPODA OF THE LOUISIANA LIMESTONE[1]

JAMES S. WILLIAMS

The pelecypods described in this paper were collected in connection with an investigation of the Louisiana (Kinderhookian) limestone and its fauna. As the investigation is not completed and as all but two of the Louisiana pelecypods are new to the formation and furnish new data which may be of use in correlation, this paper is published in advance of the complete report.

The Louisiana pelecypods tend to confirm the suggestion made by Weller[2] in 1905 that the Glen Park and Louisiana formations are at least in part equivalent. Two species, *Leda diversoides* (Weller) Moore and *Parallelodon sulcatus* (Weller) Moore occur in both formations. The presence in the Louisiana of *Palaeoneilo ignota* Herrick, *Grammysia hannibalensis* (Shumard) Hall, and *Leda spatulata* Herrick from the Waverly group of Ohio indicates that the Waverly and Louisiana seas were connected.

The Louisiana formation is typically composed of dense blue to gray limestone beds separated by brown dolomitic clay partings, but it includes a few beds of sandy shale below the limestone beds. The following columnar section was measured at the type locality at Louisiana, Missouri.

Section along Town Branch, Louisiana, Missouri

	Ft.	In.
Burlington limestone:		
Coarsely crystalline, gray to cream limestone, highly crinoidal; contains beds and lenses of chert; exposed near top of hill; poorly exposed........	80–90	
Hannibal formation:		
Gray to brownish-green sandy shale, very poorly exposed; thickness estimated..........	70–80	
Louisiana limestone:		
Dense bluish-gray limestone broken into small rectangular blocks by jointing; beds are about 3 inches thick near the top and average 6 to 7 inches in the lower part. Soft brown shale partings separate the limestone beds; partings average about 1½ inches in thickness; where unweathered the partings are of hard brown argillaceous dolomite. Limestone beds are drab to white where weathered. At base of exposure a 12-inch bed of limestone occurs. Fossils are abundant in the clay partings near base and are common well up in the formation. *Spirifer marionensis* Shumard, *Productella pyxidata* Hall, *Syringothyris hannibalensis* (Swallow) and other fossils were collected from the limestone beds. Thickness measured (upper contact not exposed)...	35	

[1]The writer wishes to express his obligation to Dr. E. B. Branson for criticism of this paper, and to Professor R. R. Rowley for assistance in collecting and for the loan of specimens.

[2]Weller, Stuart, *The Fauna of the Glen Park limestone:* St. Louis Acad. Sci. Trans., vol. 16, No. 7, p. 467, 1906.

	Ft.	In.
Yellow-brown and green sandy shale, literally crowded with fossils. *Spirifer marionensis* Shumard and *Productella pyxidata* Hall are the most abundant forms		4
Grassy Creek shale:		
A few feet of blue to black shale exposed along creek downstream from above locality. Thickness not measured.		
No Chouteau limestone was exposed in the above section.		

Pelecypods are rare in the formation, only one of the species described being represented in the collections of the University of Missouri by more than three specimens. Most of them came from the yellow-brown shale at the base of the Louisiana, but specimens of *Grammysia hannibalensis* (Shumard) Hall and *Aviculopecten marbuti* (Rowley) Moore were collected from the limestone beds. Pelecypods were found at only a few localities. An exposure near Saverton, Ralls County, has yielded more specimens than any other locality. The next greatest number of specimens was collected from outcrops along the railroad at Louisiana, Missouri. The collecting localities referred to in the specific descriptions are listed below.

Locality 593—SW. ¼ sec. 18, T. 54 N., R. 1 W.—Town Branch, Louisiana, Pike County, Missouri.

Locality 615—NE. ¼ sec. 18, T 54 N., R. 1 W.—North of Louisiana Milling Co., Louisiana, Missouri.

Locality 623—Sec. 3, T. 52 N., R. 1 E.—Near Salem Church, 1½ miles west of Kissenger, Pike County, Missouri.

Locality 634—NE. ¼ sec. 30, T. 56 N., R. 3 W.—2½ miles southwest of Saverton, Ralls County, Missouri.

The preservation of many of the specimens is poor, and much of the material is fragmentary. All the specimens identified are essentially complete, however, and the characters of the shells are sufficiently distinct to be definitely determined. Fragmentary materials are discussed in the last paragraph of the paper. Most of the specimens are internal molds.

DESCRIPTION OF SPECIES

Order Prionodesmacea

Family Grammysiidae

Genus Grammysia de Verneuil

Grammysia hannibalensis (Shumard) Hall .

Plate I, Figures 1-4

1855. *Allorisma hannibalensis* Shumard, Missouri Geol. Survey, First and Second Ann. Repts., pt. 2, p. 206, pl. C, fig. 19.
1865. *Sanquinolites hannibalensis* Winchell, Acad. Nat. Sci., Philadelphia Proc., p. 128.
1870. *Allorisma Sedwickia hannibalensis* Winchell, Am. Philos., Soc. Proc., vol. II, p. 256.
1870. *Grammysia hannibalensis* Hall, Preliminary Notice of Lamellibranch shells, p. 62.
1875. *Grammysia hannibalensis* Meek, Ohio Geol. Survey, Paleontology, vol. 2, p. 300, pl. 16, figs. 5 a-c.
1884. *Grammysia hannibalensis* Walcott, U. S. Geol. Survey, Mon. 8, p. 244, p. 20, fig. 4.
1885. *Grammysia hannibalensis* Hall, Paleontology of New York, vol. 5, pt. 1, p. 381, pl. 61, figs. 29-30, 33.
1886. *Grammysia hannibalensis* Claypole, Wyoming Hist. and Geol. Soc. Proc., vol. 2, pt. 2, p. 248.
1888. *Grammysia hannibalensis* Herrick, Denison Univ. Sci. Lab. Bull., vol. 3, p. 75, pl. 4, fig. 13.
1888 *Grammysia hannibalensis* Herrick, Denison Univ. Sci. Lab. Bull., vol. 4, pl. 6, fig. 11.
1889. *Grammysia hannibalensis* Miller, North American Geology and Paleontology, p. 483, fig. 831.
1894. *Allorisma hannibalensis* Keyes, Missouri Geol. Survey, vol. 5, p. 127.
1895. *Grammysia hannibalensis* Herrick, Ohio Geol. Survey, vol. 7, pl. 17, fig. 11.
1898. *Grammysia hannibalensis* Weller, U. S. Geol. Survey, Bull., 153, p. 297.
1908. *Grammysia hannibalensis* Rowley, Missouri Bur. Geology and Mines, vol. 8, 2d ser., p. 94, pl. 19, figs. 3 and 6.
1909. *Grammysia hannibalensis* Grabau and Shimer, North American index fossils, vol. 1, p. 383.
1913. *Grammysia hannibalensis* Dall, Zittel-Eastman Textbook of Paleontology, fig. 650.

The original description of this species is as follows:

Shell transverse, subovate, rather depressed; anterior extremity rounded, posterior extremity obliquely truncated and obtusely angulated; basal margin gently rounded; hinge margin slightly concave; beaks obtuse, situated at about one-third the distance from the anterior to the posterior extremity; surface marked with about eighteen concentric ribs, the lower ones broad and angulated, those near the beak rounded and very close together.

Dimensions.—Length, 18 lines; height, 9 lines.

In 1875, Meek described the species as follows:

Shell small, transversely subovate or subtrapezoidal, with anterior and umbonal regions gibbous, and the height at the beaks equaling about three-fifths the length; anterior end sloping abruptly from the beaks above, with a straight or slightly concave outline, to the lower end of the lunule, where it narrowly rounds into the base, or is sometimes subangular, base forming a broad semi-elliptic or semi-ovate curve; posterior extremity more compressed, apparently sometimes a little gaping, usually narrowly rounded in outline at the middle; and thence truncated obliquely forward and upward above, to the posterior extremity of the hinge; cardinal margin more or less nearly horizontal, straight, or a little concave in outline, and inflected along its entire length so as to form a well-defined escutcheon; lunule generally distinctly defined, rather deep, and presenting an obovate outline; beaks prominent strongly incurved at right angles to the hinge, so as to bring their points nearly or quite in contact; posterior umbonal slopes prominently rounded; posterior dorsal region abruptly compressed, and sometimes separated from the swell of the umbonal slopes by a faint undefined sulcus extending from immediately behind each beak, obliquely backward and downward to the truncated edges of the posterior ends of the valves. Surface ornamented by usually well-defined concentric ridges and furrows, that are small and very regular on the umbones and strongest anteriorly, but generally become obsolete on the posterior dorsal region; crossing these a small, very obscure sulcus may often be seen extending from each beak nearly directly downward to the base.

Remarks.—The specimens in the collections of the University of Missouri correspond satisfactorily with Meek's description. Figure 3 is of a specimen from the collection of Professor R. R. Rowley of Louisiana, Missouri. The other specimens figured belong to the collections of the University of Missouri. Figures 2 and 4 are of a small specimen.

Occurrence.—Both of the identifiable specimens came from the limestone beds of the Louisiana. One is from locality 634, near Saverton, Ralls County, Missouri. and the other is from Louisiana, Missouri. Professor Rowley's specimen also came from Louisiana.

This species is rather widely distributed in lower Mississippian formations in the United States.

Collections.—Louisiana specimens: R. R. Rowley collection; University of Missouri, 3644, 3645.

Superfamily Nuculacea

Family Nuculidae

Genus Nucula Lamarck

Nucula krugeri Williams, n. sp.

Plate I, Figures 14, 15.

Shell small, subquadrate to subcircular in outline, depressed convex. The dimensions of two of the cotypes are: length 17½ mm. and 17 mm., height 15.5 mm. and 14 mm., distance of beaks from front 9 mm. and 815 mm., respectively, thickness approximately 3 mm. Another specimen is more convex but is apparently distorted. Beaks inconspicuous, projecting slightly above the hinge line, anteriorly directed, situated about midway between anterior and posterior margins.

Anterior margin gently rounded to antero-dorsal margin which intersects it about one-fifth the distance from beak to ventral margin; ventral margin gently rounded to almost straight, merging into the rounded anterior margin; posterior margin truncate, forming a straight line from ventral margin, which it joins at an angle of approximately 95°, to postero-dorsal margin; postero-dorsal margin slightly convex; antero-dorsal margin concave.

Valves gently convex, greatest convexity about one-third the distance from dorsal to ventral margin. Umbones flattened, anterior umbonal slope terminating dorsally in a concave ridge; posterior umbonal ridge straight, following the postero-dorsal outline of the shell, intersecting posterior margin one-fifth the distance from beak to lower margin. Lunule and escutcheon poorly defined, the former indicated by the concavity of the dorsal margin. Posterior and anterior umbonal ridges diverging at an angle of 130°. A flattened area extends from beak to posterior margin and is delimited ventro-anteriorly by a slight ridge extending from beak to postero-ventral margin.

Surface marked by fine indistinct concentric lines of growth. Pallial line and muscle scars not preserved. Hinge taxodont. Teeth preserved on only one specimen. In this specimen there are three teeth in front of the beak and nine teeth posterior to the beak. Teeth beneath beak and for a short distance on either side are not preserved. The specimens are all internal molds.

Remarks.—This species may be easily distinguished from other Mississippian forms of the genus by its subquadrate outline, truncate posterior margin, and the flat area extending from the beak to the posterior margin. The dentition beneath the beaks is not preserved and a chondrophore could not be made out. The species is placed in the genus on the basis of taxodont dentition and general form.

The species is rare in the Louisiana limestone, only three specimens having been collected. All are molds of right valves. It is named for Fred Kruger, who collected one of the cotypes.

Occurrence.—Three specimens from the yellow-brown shale at locality 634, Ralls County, Missouri.

Collection.—University of Missouri, 3642 (cotypes).

Family Ledidae

Genus Palaeoneilo Hall

Palaeoneilo ignota Herrick

Plate I, Figure 21.

1888. *Palaeoneilo ignota* Herrick, Denison Univ. Sci. Lab. Bul., vol. 4, p. 44, pl. 4, fig. 15.
1889. *Palaeoneilo ignota* Herrick, Am. Geologist, vol. 3, pl. 2, fig. 15.
1895. *Palaeoneilo ignota* Herrick, Ohio Geol. Survey, vol. 7, pl. 16, fig. 15.
1898. *Palaeoneilo ignota* Weller, U. S. Geol. Survey Bull. 153, p. 407.

Herrick's original description is as follows:

> Shell of medium size, moderately convex, rather thick, height two-thirds the length, the greatest height a little posterior to the beaks which are one-third the distance from the front, basal margin semi-elliptical, terminating before and behind at nearly one-half the height; anterior margin sub-parabolic; posterior outline rather acutely terminating at about one-third the height from the somewhat oblique hinge; posterior projection compressed; surface most ventricose near the middle, marked only by very fine, numerous crowded concentric striea. Hinge with five moderate teeth in front and fifteen or more very fine denticules behind which diminish toward the beak. Length, 14 mm., height, 9 mm.

Remarks.—Three specimens in the collection of the University of Missouri belong to this species. One of them is 17½ mm. long and 12 mm. high; another, a small individual, is 11 mm. long and 9 mm. high. The dentition beneath the beak is not preserved in any of the specimens, there is no sinus below the posterior umbonal slope, and the generic reference is therefore uncertain. However, the arrangement of teeth on either side of the beak and the general form of the shell suggests that this species belongs to *Palaeoneilo*.

On one specimen there are four anterior teeth and 11 posterior teeth, but there is an area on either side of the beak in which no teeth are preserved. Another specimen has three anterior and nine posterior teeth, but this specimen also has an area in which no teeth are preserved.

The basal margin in the specimens collected terminates nearer to two-thirds the distance from the base to the dorsal surface than to one-half this distance, as in the type. A distinguishing character of this species is the gentle slope of the posterior umbonal ridge.

The posterior part of the shell is not preserved in any of the specimens. They are all internal molds.

Occurrence.—One specimen from the yellow-brown shale at locality 615, along the Mississippi River at Louisiana; one specimen from the blue shale at locality 593, Town Branch, Louisiana; and one specimen from the yellow-brown shale at locality 634, Ralls County, Missouri. This species also occurs in the Waverly beds in Ohio.

Collection.—Specimens examined are University of Missouri, 3647, 3648, 3656.

Genus Leda Schumacher

Leda diversoides (Weller) Moore

Plate I, Figures 8-11.

1906. *Nuculana diversoides* Weller, St. Louis Acad. Sci. Trans., vol. 16, No. 7, p. 448, pl. 2, figs. 4 and 5.

1928. *Leda diversoides* Moore, Missouri Bur. Geology and Mines, vol. 21, 2d ser., p. 137.

The following is Weller's original description:

> Shell small, elongate-subovate in outline, subcuneate behind, the width a little more than one-half the length. Beaks prominent, incurved above the hinge-line, situated about one-third the length of the shell from the anterior extremity. Cardinal margin slightly convex from the beak anteriorly, and concave posteriorly to the posterior margin which is very short and sharply rounded; ventral margin slightly convex posteriorly, becoming gradually more curved anteriorly where it passes into the regularly rounded anterior margin. Valves rather strongly convex anteriorly, the umbo prominent, becoming gradually more depressed posteriorly, the umbonal ridge sub-angular, following the postero-cardinal margin of the shell, the cardinal slope from the ridge nearly vertical, in larger specimens even undercut so that in a direct view of the valve the slope cannot be seen. Surface marked with very fine, regular, concentric lines, about five or six occupying the space of one millimeter. . . . . The dimensions of two specimens, one right and one left valve, are: Length, 16 and 10.5 mm., width 9 and 6.2 mm., convexity, 3.75 and 3 mm.

Remarks.—The specimens studied are about the same size as the cotypes. Some of them are slightly more concave dorsally than the cotypes and, possibly, are a little more acuminate posteriorly and less convex. The lesser convexity is partly because they are internal molds. The ornamentation is preserved on only two of the specimens.

This species may be compared with *L. saccata* Winchell, *L. spatulata* Herrick, and *L. similis* Herrick, but the acute angle made by the divergence of the anterior umbonal ridge from a vertical line drawn from the beak to the ventral margin is smaller in this species than in any of the above, and it differs from them in size and shape. It is not so large as *L. similis* and has a higher height-length ratio. *L. spatulata* is more acuminate posteriorly than *L. diversoides*, somewhat more strongly curved along the postero-cardinal margin, and its most anterior part is near mid-height. *L. saccata* is a smaller species which was not figured by its maker. Herrick's figure suggests that it is less curved along the postero-cardinal margin and more acuminate posteriorly. *L. diversoides* is also related to *L. diversa* Hall but is larger and has more abrupt cardinal slopes from the umbonal ridges. The true differences of these and other closely related species of the genus are somewhat obscure, and a careful study of all the types or of large collections might result in the consolidation of some of the species. Identification of these specimens was made mainly on the basis of size and general form. Two of the specimens have the following length-height measurements: Length 15 mm., height 8½ mm.; length 13.5 mm., height 8 mm.

Occurrence.—Three specimens from the yellow-brown shale at locality 634, southwest of Saverton, Ralls county; and two from locality 615, along the Mississippi River, Louisiana, Missouri.

This species also occurs in the Glen Park limestone.

Collections.—Walker Museum, 11330 (cotypes) from Glen Park formation; University of Missouri, 3650-3653.

Leda rowleyi Williams, n. sp.

Plate I, Figure 7.

Shell large for the genus, inequilateral, subovate to subcircular in outline, somewhat contracted and produced posteriorly. The dimensions of the holotype are: length 17 mm., height 14 mm., convexity about 2.5 mm.

Beaks distinct, posteriorly directed, situated near the mid-length of the shell. Umbones depressed, inconspicuous. Antero-dorsal margin convex, sharply rounding into the rounded anterior margin. Ventral margin gently curved, merging into the posterior margin, which is short, more abruptly rounded than the ventral margin and subtruncate above and forms an acute angle with the dorsal margin. Greatest posterior extension at junction of postero-dorsal and posterior margins which is about one-third the distance from beak to ventral margin. Postero-dorsal margin concave.

Valves depressed convex, greatest convexity near the beaks. Umbones flattened; anterior and posterior umbonal slopes gently convex. A broad flattened to gently convex area extends from the beaks to the ventral margin and is delimited anteriorly and posteriorly by the points where the ventral margin merges into the anterior and posterior margins respectively. The anterior-posterior convexity of the shell is much greater in front of this area and somewhat greater behind it.

Surface of the shell marked by fine concentric lines of growth, which differ in strength and are more conspicuous and stronger near the ventral margin.

Muscle scars oval, imperfectly preserved, probably subequal. Pallial line not entirely preserved. No hinge teeth preserved. The type is an internal mold.

Remarks.—Only one specimen of this species has been collected, and it is an internal mold. The preservation is not perfect but sufficient to distinguish it from any described species. The reference to the genus is made mainly on general form and muscle impressions; no hinge teeth are preserved.

This species is closely related to such forms as *L. nasuta* Hall, *L. curta* Meek and Worthen, and *L. chesterensis* Weller. It is much larger than *L. nasuta*, the anterior margin is shorter and more abruptly rounded, the shell is less transverse, and most posterior point is higher. From *L. curta* it differs in its larger size, in the greater convexity of its postero-dorsal margin, and in its more subcircular shape. Its closest relation seems to be with *L. chesterensis*, from which it differs mainly in its smaller size, more abruptly curved and less extended anterior margin, its greater height-length ratio, and the greater relative height at which the posterior margin intersects the postero-dorsal margin.

The species is named for Professor R. R. Rowley of Louisiana, Missouri, who accompanied the writer on many of his collecting trips.

Occurrence.—Yellow-brown shales at locality 634, near Saverton, Ralls County, Missouri.

Collection.—University of Missouri, 3649 (holotype).

Leda spatulata Herrick

Plate I, Figures 12, 13.

1888. *Nuculana* (*Leda*) *spatulata* Herrick, Denison Univ. Sci. Lab. Bull., vol. 3, p. 79, pl. 9, fig. 11; pl. 7, fig. 35.

1898. *Nuculana spatulata* Weller, U. S. Geol. Survey Bull. 153, p. 382.

The following is Herrick's original description:

Shell elongate oval, broadly expanded anteriorly, acute behind; beaks small, slightly prominent, acute, about seven-twentieths the entire length from the anterior margin; hinge line rather strongly concave; teeth (if present) small; anterior margin forming a bold, uniform curve, reaching nearly as high as the beaks, with its greatest anterior projection above or near the middle; lower outline gently convex, nearly attaining the hinge posteriorly, but separated from it by a short truncate posterior margin. Greatest convexity about one-third the height of shell from the beaks; umbonal ridge with a sudden, but gentle slope. The surface is marked by very numerous, fine lines of growth—about six occupying the space of 1 mm., in the shells measured. Length (1) 20, (2) 17, (3) 16.5; height (1) 9, (2) 7, (3) 8; distance from beak to front (1) 4, (2) 3, (3) 3; height of beak above longest transverse axis, (1) 7, (2) 6, (3) 5.

Remarks.—One well preserved specimen and two imperfectly preserved specimens from the Louisiana probably belong to this species. All are internal molds. The anterior margin of this species is less abrupt than that of *L. diversoides* (Weller) and its most anterior part is higher. It is more acuminate posteriorly and the cardinal margin is somewhat more curved posteriorly. It is not as large as *L. similis* Herrick, which it resembles closely, and the greatest convexity of its anterior margin is higher. Herrick states that its hinge line is more concave and its ventral margin more convex, but his figures do not show this to be true.

Herrick's measurements of the distances of the beaks from the fronts of the shells seem to be wrong, and his statement made in the first few sentences of the description that the beaks are about seven-twentieths the length of the shell from the anterior is right, if one may judge from measurements of his figures. The dimensions of the one well-preserved specimen from the Louisiana are as follows: Length 15 mm., height 8.2 mm., distance of beaks from anterior margin 6 mm. The other two specimens are too incomplete for satisfactory measurement.

Specimens described by Girty[1] from the Pocono of Pennsylvania have been compared with this species. These specimens are imperfect and distorted and the identification, as indicated by Girty, is uncertain. They appear to be more closely related to *L. saccata*, if that species is valid, than to *L. spatulata*.

Occurrence.—Yellow-brown shales at locality 615, along the Mississippi River, and at locality 593, Town Branch, Louisiana, Missouri; and at locality 634, near Saverton, Ralls County, Missouri.

This species also occurs in the Waverly beds in Ohio.

Collection.—Louisiana specimens: University of Missouri, 3654, 3655.

Superfamily Arcacea

Family Parallelodontidea

Genus Parallelodon Meek

Parallelodon louisianensis Williams, n. sp.

Plate I, Figures 5, 6.

Shell of medium size, subovate in outline, highest posteriorly, height slightly over one-half the length. The dimensions of a left valve, the holotype, and a right valve, a paratype, are respectively: Length 16.5 and 13.5 mm.; height, from beak to ventral margin normal to hinge line, 9 and 7.5 mm.; greatest height, measured normal to hinge line and about four-fifths the distance from anterior to posterior margin 10.5 and 8 mm.; convexity 2.5 and 2 mm. Beaks anterior, situated one-fifth to one-seventh the distance from anterior to posterior margins, distinct but not prominent, incurved, extending over the hinge line, anteriorly directed; umbonal region well defined, oblique.

Dorsal margin broken, probably straight. Hinge line straight, about three-fifths to three-fourths the total length of shell. Anterior shell margin shorter than posterior margin. Dorsal part of anterior margin not preserved; ventro-anterior margin sharply rounded, merging into the ventral margin. Ventral margin nearly straight, curving into anterior and posterior margins, diverging from hinge line at an angle of about 20

[1] Girty, George H., *The Pocono fauna of the Broad Top Coal Field, Pennsylvania;* U. S. Geol. Survey, Prof. Paper 150 E, p. 121, pl. 23, figs. 19, 20, 1928.

degrees, slightly situate medially. Posterior margin broadly rounded, more gently rounded above but not truncate, greatest posterior extension of shell below middle of posterior margin.

Valves moderately convex, greatest convexity in the umbonal region, flattening toward margins, with least convexity along the posterior margin. Cardinal slopes from umbonal ridges concave on either side of beak, becoming gently convex posteriorly. Anterior and posterior umbonal ridges forming an obtuse angle; posterior ridge much the longer, merging into the general convexity of the shell posteriorly. Anterior umbonal ridge describing a curved line in passing from beak to ventral margin, the mid-point being nearer the posterior of shell than are its dorsal or ventral extremities. Posterior umbonal ridge paralleling hinge line for one-third the distance from beak to posterior margin and thence turning abruptly toward ventro-posterior extremity and forming an angle of approximately 30 degrees with the hinge line and flattening into the general convexity of the shell, intersecting posterior margin at about one-third the distance from ventral to dorsal margins. A broad flattened or gently convex area bounded by the umbonal ridges and bisected by a very shallow, somewhat indistinct sinus extends obliquely from beak to the ventral margin.

Surface of valves marked by concentric lines of growth. Two elongate posterior teeth nearly parallel to the hinge line occur on one of the specimens. No anterior teeth are preserved. Pallial line simple. Muscle scars not preserved. Both specimens are internal molds.

Remarks.—This species is closely related to *P. sulcatus* (Weller) Moore from the Glen Park limestone, but adult specimens were easily distinguished from the cotypes of that species by differences in shape. These differences result mainly from differences in convexity and in the directions of the umbonal ridges.

Occurrence.—The holotype is from the yellow-brown shale at locality 615, along the Mississippi River, at Louisiana, Missouri. The one paratype is from the yellow-brown shale at locality 623, near Kissenger, Pike County, Missouri. Another specimen, which is incomplete, is from the limestone beds of the Louisiana formation, also at locality 623.

Collection.—University of Missouri, 3656 (holotype), 3657 (paratype).

Parallelodon sulcatus (Weller) Moore

Plate I, Figures 16-20

1906. *Macrodon sulcatus* Weller, St. Louis Acad. Sci. Trans., vol. 16, No. 7, p. 450, pl. 2, figs. 6-9.

1928. *Parallelodon sulcatus* Moore, Missouri Bur. Geology and Mines, vol. 21, 2d ser., p. 137.

Weller's original description of this species is as follows:

Shell equivalved, of medium size, subovate to subelliptical in outline, widest posteriorly, width one-half or a little more than one-half the length, beaks situated anteriorly but not terminal, prominent, elevated above the hinge-line; hinge-line three-fifths to three-fourths the total length of the shell. Dorsal margin straight along the hinge-line, obtusely subangular at each end where it joins the anterior and posterior margins; posterior margin broadly rounded, sometimes obliquely subtruncate above, the greatest posterior extension of the shell below the middle; ventral margin usually straight through the greater portion of its length, curving upward in front and behind, sometimes slightly convex throughout; anterior margin short, regularly rounded. Valves gibbous in the umbonal region, the umbonal ridge merging into the general convexity of the valve posteriorly; the cardinal slope from the umbonal ridge concave, very abrupt near the beak, becoming more gentle posteriorly; the ventral slope longer and more gentle than the dorsal, with a flattened area or a broad, shallow sinus extending obliquely from the umbo to the middle of the ventral margin. Surface marked by regular, concentric lines separated along the posterior half of the umbonal ridge by intervals of one-half to one millimeter, or occasionally by wider intervals, and towards the beak by smaller intervals; also marked in unworn specimens, upon the posterior half of the shell and especially on the cardinal slope, with very fine, radiating costae which are interrupted at concentric lines. Hinge straight, with two or three small oblique teeth anterior to the beak, and one or two posterior teeth subparallel to the hinge-line; ligament external, attached to a narrow, elongate, flattened area which is longitudinally striate.

The dimensions of three specimens are: Length, 16, 13, and 11.3 mm.; width, 8, 7.5 and 6 mm.; length of hinge line, 11, 7.5 and 8 mm.; convexity, 4.5, 3.5 and 3 mm.

Remarks.—Three specimens of this species have been collected from the Louisiana limestone. Only one of them has a sinus, but the flat area extending from the umbo to the middle of the ventral margin is distinct on all of them. The specimens are all internal molds and are not quite as convex as the cotypes, with which they were compared. Two of them are right valves, and the other is a left valve. The radiating striae mentioned by Weller are not preserved, and concentric lines of growth are but faintly preserved. The specimens from the Louisiana are about the same size as those from the Glen Park. A small individual has a length of 11 mm. and a height of 6 mm. Another individual has a length of 13 mm. and is 7 mm. high. Two elongate posterior teeth approximately parallel to the hinge line are preserved on the smaller specimen. The hinge line on this specimen is relatively longer than that of the cotype of about the same size, but the relative length is within the limits set by Weller for the species.

This species is closely related to *P. hamiltoniae* Hall and to *P. ovatus* Hall. It differs from the former in size and in the flattened area and sinus that extend obliquely from the beaks to the ventral margin. *P. ovatus* differs from it in having a greater height compared to length, a curved hinge line and a truncate dorso-posterior margin. The dorsal part of the posterior margin in *P. sulcatus* is subtruncate to rounded.

P. sulcatus has also been compared with *Elymella missouriensis* Miller and Gurley but it differs in several respects from that species. *E. missouriensis* is more globose, its umbonal area more tumid, its beaks elevated higher above the hinge line, and its length-height ratio greater. The hinge line of *P. sulcatus* is shorter compared to the length of the shell, its posterior umbonal slope more angular, the lack of parallelism, between the hinge line and the basal margin more pronounced, its shell much wider posteriorly, and its dorso-posterior margin more oblique. The types of *E. missouriensis* have no hinge teeth preserved.

Occurrence.—One specimen from the yellow-brown shale at locality 615, along the Mississippi River, at Louisiana, Missouri; one specimen from the yellow-brown shale at locality 593, Town Branch, Louisiana, Missouri; and one poorly preserved specimen from the limestone beds of the Louisiana formation at locality 623, near Kissenger, Pike County, Missouri.

This species also occurs in the Glen Park limestone.

Collections.—Walker Museum, 11335 (cotypes) from Glen Park formation: University of Missouri, 3659, 3660, 3661.

Superfamily Pectinacae

Family Pectinidae

Genus Aviculopecten McCoy

Aviculopecten marbuti (Rowley) Moore

Plate I, Figures 22-24.

1908. *Pernopecten marbuti* Rowley, Missouri Bur. Geology and Mines, vol. 8, 2d ser., p. 93, pl. 19, fig. 23.

1928. *Aviculopecten marbuti* Moore, Missouri Bur. Geology and Mines, vol. 21, 2d ser., p. 47.

Rowley's remarks concerning the holotype and his description are as follows:

This fine shell, "double sided" as it is, is exfoliated and injured about the edge, having been broken from the hard limestone. The patch of test remaining shows it to have had very fine longitudinal striations and rather strong concentric cross lines of growth. The length is greater than the width and the shape is broadly ovate.

Hinge line rather short. Beak distinct. The shape of the wing-like extremities of the hinge area are probably as indicated by the dotted lines but the specimen is so injured that we cannot be certain of this. The shell is low convex in both valves and the test rather thick. This may be, after all, an *Aviculopecten*. The cross lines of growth are lamellate and with a wavy appearance as they cross the longitudinal striations.

It is very rare, a single specimen being all the writer has ever found.

The specific name is for Prof. C. F. Marbut, professor of geology in the Missouri State University.

The type is from the bottom layer of the limestone at the mouth of Buffalo creek.

A more extensive description prepared by the writer after an examination of the holotype is as follows:

Shell of moderate size, thin, subovate-alate, slightly inequilateral, height greater than length. Dimensions of the holotype are: Height 40.5 mm.; greatest length, measured about half the distance from beak to ventral margin, 31.5 + mm. (shell broken); width of hinge line 18 + mm. (incomplete); thickness 4.5 mm.

Beak of left valve distinct, extending slightly beyond the hinge line. Umbones distinct, lateral slopes diverging at the beak at an angle of approximately 80 degrees; anterior umbonal slope more abrupt than posterior slope, reaching the anterior margin at about two-fifths the distance from the beak to the ventral margin; posterior umbonal slope more gradual, intersecting the posterior margin about one-half the distance from the beak to vent al margin. Anterior margin of shell broken, probably gently rounded; posterior margin broken, probably straighter than the anterior margin; dorsal part of posterior margin probably straight. Anterior ear incomplete, smaller and more convex than posterior ear, with a suggestion of a byssal notch; posterior ear nearly flat.

Shell structure lamellose; ornamentation poorly preserved over most of the shell, consisting of fine radiating somewhat discontinuous plications alternating in strength, crossed by concentric striae, giving a reticulate appearance; where the striae cross the plications slight knobs occur. About 2 plications occupy the space of 1 mm. Concentric striae are spaced approximately the same distance apart as the plications.

Right valve nearly plane, covered by rock and not accessible for description.

Interior shell structures not observed.

Remarks.—This species was referred to *Pernopecten* by Rowley mainly on the basis of general form as the dentition is not preserved. *Pernopecten* was erected in 1865 by Winchell for several forms intermediate between *Aviculopecten* and *Perna*. It embraces those forms externally like *Aviculopecten* but having "a central ligamental pit with accessory ligamental pits on either side." It differs from *Perna* in general shape and in having subcentral beaks and pits on both sides of the beak. Winchell's type was *P. limaeformis*. He did not figure the species. However, Hall[1] in 1884 examined Winchell's type specimen and confirmed his description of the hinge structure. *Crenipecten* was proposed by Hall in 1883 to include those forms which externally resemble *Pernopecten* but which have no central ligament pit. Several species now included under *Pernopecten* were formerly placed under *Entolium*. *Entolium* differs from *Pernopecten* in the angle at which the ears diverge from the beaks, in lacking a straight hinge, and in that in most of the species of *Entolium* radiating striae are either rare or absent.

Most *Pernopectens* differ in shape from most *Aviculopectens*. In practically all of the figured specimens of *Pernopecten* the hinge line is shorter and ears smaller than in typical *Aviculopectens*. The posterior ear meets the posterior margin of the shell at a higher angle in *Pernopecten* than in *Aviculopecten*, the ear and posterior margins being nearly parallel in *Pernopecten*. Most *Pernopectens* are higher compared to length than typical *Aviculopectens*. These things however, do not constitute generic differences though

[1]**Hall, James,** ***Paleontology of New York*****, vol. 5, pt. 1, p. 81, 1884.**

they may indicate genera. Winchell[1], the founder of the genus, used the differences in shape of the ears in placing *P. limatsu* among the *Pernopectens* rather than among the *Aviculopectens*.

Rowley suggests that *A. marbuti* might belong to *Aviculopecten* or to *Crenipecten*. The writer believes it is an *Aviculopecten*. The ears, hinge line, and anterior and posterior margins are incomplete, and hence, the form one gives to the shell is a matter of its logical restoration. An incomplete left valve that is in the collection of the University of Missouri and probably belongs to this species is more convex in the umbonal region, somewhat smaller, and has none of the surface markings preserved, but its anterior margin and its anterior ear are well preserved, and its ventro-posterior margin can also be made out. If it were broken in the same places in which the holotype is broken, it would, aside from its greater convexity, resemble the holotype very closely. If the anterior and posterior margins of the holotype were restored to correspond with the anterior and posterior margins of this specimen, the shape of the holotype would be similar to that of most *Aviculopectens*. The length of the anterior part of the hinge line of the specimen in the collections of the University of Missouri indicates that the hinge line is nearly, if not quite, as long as the shell.

This species differs from other *Aviculopectens* in ornamentation and general shape. It is closely related to *A. crenistriatus* Meek, but that species is larger and its posterior ear is not so distinctly set off from the shell. It is also closely related to *A. granvillensis* Herrick, *A. hardinensis* Worthen, and *A. indianensis* Meek and Worthen, but differs from the first in size and from the other two in its finer plications. Two species from the *Carboniferous* of Nova Scotia, *A. lyelli* Dawson and *A. reticulatus* Dawson have similar ornamentation. The incompleteness of the holotype of *A. marbuti* makes it difficult to compare it with other forms.

The holotype consists of two valves. The one figured is probably a left valve as it is more convex and as there is a slight deflection on one of the ears that may be a byssal notch.

Occurrence.—Limestone beds of the Louisiana formation along Town Branch, Louisiana, Missouri.

Collections.—Holotype, R. R. Rowley collection: University of Missouri, 3643.

Fragmentary Materials

Fragmentary materials in the University of Missouri collections that are unidentifiable represent probably eight or nine other species of *Pelecypoda*. At least three species that probably belong to *Parallelodon* are in the collections. There are also probably three species of *Aviculopecten*, one specimen that is probably a *Sanquinolites*, another that is probably a *Palaeoneilo*, and another that probably represents another species of *Nucula*. None of these specimens is complete enough for specific determination.

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[1]Winchell, Alexander; Acad. Nat. Sci. Phila. Proc. for 1865, p. 126, 1865.

PLATE I

Figures 1-4. *Grammysia hannibalensis* (Shumard) Hall.

1. A left valve of a specimen from Louisiana, Missouri, with posterior of shell well preserved.
(University of Missouri, 3645.)
2. Anterior view of a small specimen from locality 634, near Saverton, Ralls County.
(University of Missouri, 3644.)
3. Anterior view of a specimen belonging to R. R. Rowley, collected at Louisiana, Missouri.
4. Lateral view of specimen shown in Figure 2.

Figures 5, 6. *Parallelodon louisianensis* Williams, n. sp.

5. The holotype, a left valve, from the yellow-brown shales of the Louisiana formation, locality 615, Louisiana, Missouri.
(University of Missouri, 3656.)
6. A right valve (paratype) from the yellow-brown shales, locality 623, Pike County, Missouri.
(University of Missouri, 3657.)

Figure 7. *Leda rowleyi* Williams, n. sp.

7. A right valve, the holotype, from the yellow-brown shales of the Louisiana locality 634, Ralls County.
(University of Missouri, 3649.)

Figures 8-11. *Leda diversoides* (Weller) Moore.

8, 9. A right and a left valve (cotypes) from the Glen Park limestone.
(Walker Museum, 11330.)

10. A left valve from the yellow-brown shales of the Louisiana formation, locality 615, Louisiana, Missouri.
(University of Missouri, 3650.)
11. A right valve from the yellow-brown shales of the Louisiana formation, locality 634, Ralls County.
(University of Missouri, 3652.)

Figures 12, 13. *Leda spatulata* Herrick.

12. A left valve from the yellow-brown shales of the Louisiana formation, locality 615, Louisiana.
(University of Missouri, 3654.)
13. An incomplete left valve from the yellow-brown shales, locality 634, Ralls County.
(University of Missouri, 3655.)

Figures 14, 15. *Nucula krugeri* Williams, n. sp.

14, 15. Two right valves (the cotypes) from the yellow-brown shales of the Louisiana limestone, locality, 634, near Saverton, Ralls County.
(University of Missouri, 3642.)

Figures 16-20. *Parallelodon sulcatus* (Weller) Moore.

16, 17, 19. Three of Weller's cotypes from Glen Park limestone.
(Walker Museum, 11335.)

18. A right valve from the yellow-brown shales, locality 593, Louisiana, Missouri.
(University of Missouri, 3660.)
20. A small right valve from the yellow-brown shales of the Louisiana formation, locality 615, Louisiana.
(University of Missouri, 3659.)

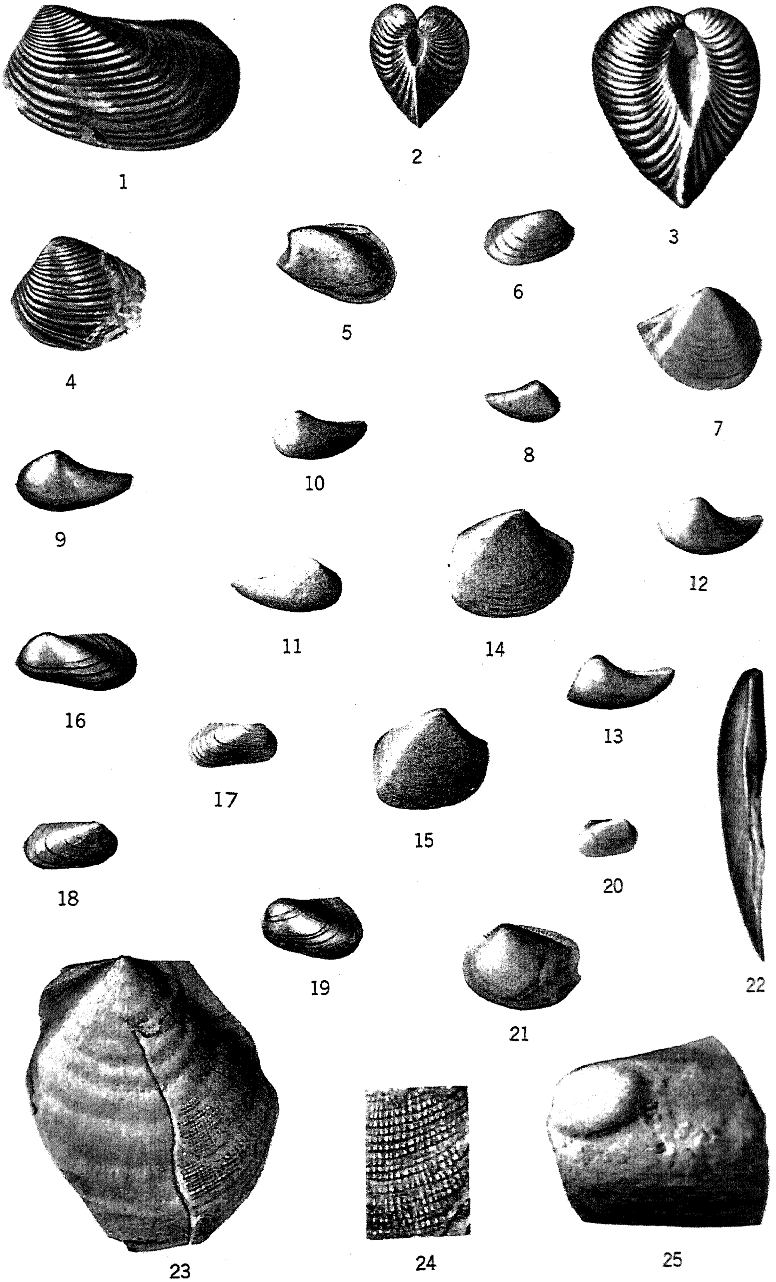


Plate I

PLATE I—*Continued.*

Figure 21. *Palaeoneilo ignota* Herrick.

21. An internal mold showing dentition, from the yellow-brown shales at Louisiana, Missouri.
(University of Missouri, 3646.)

Figures 22-24. *Aviculopecten marbuti* (Rowley) Moore.

22, 23. Posterior and lateral views of the holotype, from the limestone beds of the Louisiana formation at Louisiana, Missouri.
(Collection of R. R. Rowley.)

24. A portion of the surface of the holotype (X 2) showing ornamentation.

Figure 25. *Sanquinolites* sp.

25. An incomplete specimen that probably belongs to this genus. Yellow-brown shales of the Louisiana formation, locality 634, Ralls County.
(University of Missouri, 3667.)

APPENDIX III

GEOPHYSICAL PROSPECTING.

Field work by F. C. Farnham (electric resistivity), G. A. Muilenburg, C. O. Reinoehl, and J. G. Grohskopf (magnetic survey.)

During the past ten years, geophysical methods of prospecting have received much attention throughout the world. In many instances these methods have proven successful, either in determining the location of ore bodies and oil pools or in determining geological structures favorable to the occurrence of commercial deposits. In general these methods are based on the physical properties of the materials forming the outermost strata of the earth's surface. Magnetism, electrical conductivity, gravity, and the ability to transmit vibrations, are factors that enter into a majority of these methods.

During the past two seasons this Bureau has undertaken investigations along this line in co-operation with the Industrial Bureau of the Industrial Club of St. Louis. The Industrial Bureau purchased instruments and financed the major portion of the field work. Two lines of work have been carried on, viz., magnetic measurements over known and unknown formations, and electrical resistivity measurements made of known and unknown formations.

It has become increasingly evident as the work has progressed that there are a large number of factors entering each problem, and that it will be necessary to get considerable data before it is possible to come to definite conclusions concerning the applicability of these methods to certain problems. However, the results obtained up to the present time seem to indicate that certain problems may be solved by the use of these methods.

Electrical Resistivity Measurements.

Electrical resistivity measurements offer possibilities in the solution of several types of geological problems. This is true because the electrical resistivity of different portions of the earth's crust varies over such a wide range of values. Whereas, in studying magnetic and gravitational effects, variations, which are a very small proportion of the total field, are found, in electrical measurements differences of as high as several hundred times are encountered. Another factor which contributes to the usefulness of electrical measurements is the fact that a relatively large number of the factors entering the problem are under the control of the observer. However, the condition of the surface of the ground does have an influence upon the measurements so that the use of this method may be limited to certain localities and to certain seasons.

The method used in making the measurements for the present study is known as the Gish-Rooney method of measurement of earth resistivity. This is an adaptation of the four electrode method of measuring the resistivity of a semi-infinite body. The method of procedure is as follows:

Four electrodes are placed in the surface of the ground along a straight line and spaced at equal intervals. A known current is passed through the earth by way of the two extreme electrodes. This gives rise to a difference in potential between the two intermediate electrodes which can be measured. If the distance between consecutive electrodes is denoted by a, the current flowing through the pair of extreme electrodes by I, and the difference in potential between the intermediate pair of electrodes by V, the resistivity of the ground is given by the equation

$$\left(\rho = 2\pi a \frac{V}{I} . \right)$$

where p is in ohm centimeters if V is in volts, I in amperes, and a in centimeters.

If the earth is not homogenous the value obtained for the resistivity is approximately the average resistivity of a semi-cylinder of the material of length a and radius a situated between the two intermediate electrodes.

If, at a given point, a series of measurements are taken with increasing electrode spacing, in general the calculated resistivity at the different electrodes spacings will be different.

Figure A, Plate 1, shows the variation of resistivity with electrode spacing in two instances. Since in order for any portion of the earth's crust to have any effect upon a given measurement it must be within a distance of the line containing the electrodes equal to the distance between consecutive electrodes, the curve also shows the variation of resistivity with depth.

The curves show that the resistivity is relatively high near the surface of the ground, decreases with increase in depth to a certain point, and then increases with increase in depth. The interpretation of the curves is that at the surface there is comparatively dry, unconsolidated material. As the depth increases the mositure content increases until the contact between overburden and rock is reached. At this depth the resistivity begins to increase because of the relatively lower moisture content of the rock. Thus it is apparent that in certain cases it is possible to measure the depth of overburden by this method. In the two cases shown the depth of overburden was checked by auger holes and found to be very near to that given by the curves.

Figure B, Plate 1, shows two determinations of the variation of resistivity with depth in a fire clay pit. These observations were taken at two different drill holes in the same pit. The drill records show that drill hole No. 1 went through overburden to a depth of eleven feet, from eleven to forty-seven feet through fire clay, and at forty-seven feet went into sandstone. An examination of the curve showing the variation of resistivity with depth at this drill hole will bring out the very close check obtained with the drill records, the curve showing the contact of overburden with clay at eleven feet and the contact between clay and sandstone between forty-five and fifty feet. At drill hole No. 2 the curve of variation of resistivity with depth shows the contact of overburden with clay to be about twelve feet and the contact of clay and sandstone about fifty feet. The drill records give the contact of overburden and clay at fifteen feet and the contact of clay with sandstone at fifty feet. The apparent failure of the resistivity measurements to give the contact of overburden with clay may be explained by the fact that a four-foot layer of limestone immediately overlay the clay.

Figure C, Plate 1, is a resistivity profile across a sink hole which is filled with fire clay. The measurements were taken at intervals of about 100 feet along a line which crossed about the center of the pit. At each point the resistivity was measured with an electrode spacing of 25 feet. From this profile it appears that the extent of the pit can be determined by resistivity measurements.

Figure D, Plate 1, is a resistivity profile across a fault. The measurements were taken at intervals of about 130 feet, the resistivity at each point being measured with an electrode separation of 75 feet. It is apparent from the figure that the ground on the east side of the fault has a resistivity varying from about 30 to about 90 units, while the ground on the west of the fault has a resistivity between 100 and 300 units. This would indicate that it should be possible to trace this fault by means of electrical measurements. It remains for future work to actually trace out this structure.

Plate 2, is a resistivity map of the region in the vicinity of an inclined shaft which has gone down 35 feet in iron ore. This map would indicate that the shaft is located at the southeast edge of a sink structure which is about 1200 feet east and west by about 700 feet north and south. Depth determinations inside and outside of the sink are very characteristic. Those inside of the sink show a resistivity of about 100 units down to depths of about 150 feet, while those outside show a resistivity many times that large. Thus it appears that under the conditions obtaining in this case some information as to the location and extent of a favorable structure for the occurrence of iron ore may be obtained by this method.

Plate 3, is a resistivity map of an area in which there are topographic indictions of sink structures. This map was made by measuring the resistivity of the ground, using an electrode spacing of 50 feet, at points 200 feet apart. The lines on the map are lines drawn through points having the same resistivity. From the map it is evident that there is a structure which has a definite northeast-southwest direction. This area lies just to the west of a known fault of rather great displacement, and just to the northeast of an old worked-out iron mine. It remains for further work to determine possible relation of the structure shown on this map and the above mentioned structures.

Magnetic Surveys.

Magnetic Surveys have been made during the field season of 1929 and 1930. During 1929, Mr. G. A. Muilenburg and Mr. C. O. Reinoehl ran experimental lines over different formations and different geological structures using a Hotchkiss Superdip magnetometer. During 1930 C. O. Reinoehl, John Grohskopf, and G. A. Muilenburg carried on the work with the Hotchkiss and two Askania magnetometers.

In making a magnetic survey the magnetometer is set up on known points and the magnetic intensity measured. Corrections are made for variations due to temperature and daily variation.

The following plates illustrate the general type of results obtained. They indicate that striking differences in the magnetic field occur in comparatively short distances and that geologic features are no doubt the controlling factor.

The three profiles Pl. (4) Fig. (a) show the results obtained in running three lines across a buried igneous ridge. The lines were run with a Hotchkiss Superdip magnetometer, readings were taken every half mile. The lines were run across a topographic ridge, all geological evidence seems to indicate that it is a reflection of a buried igneous ridge. Profile AA shows, as its maximum change, a difference of about 85 scale divisions, the length of this profile is about 7 miles and is probably along the long axis of the buried structure. Profile BB is at right angles to profile AA and shows as its maximum change a difference of about 95 scale divisions. This profile is about 4 miles long and probably is at right angles to the trend of the buried structure. Profile CC is also at right angles to profile AA and parallel to profile BB. It will be noted that the change here is only 55 scale divisions, hence this profile is probably near the end of the ridge. These three profiles probably outline the length and width of a buried igneous ridge some 5 miles in length by about 2½ miles in width.

The numbers in Pl. (4) Fig. (b) indicate the readings obtained over a sink structure containing iron ore, the outline of the sink being shown by the dotted line. The readings were taken with an Askania Magnetometer. Near the center of the map it will be noted that a reading of 259 gammas was obtained which is about 240 gammas (approximately 8 scale divisions) higher than the readings 100 feet away in each direction. This anomaly was detailed by taking readings every 25 feet radially about it, the results show a very rapid variation, of large magnitude, in a relatively small area. Boulders of iron ore picked up at this point were found to be magnetically polarized. This sort of anomaly has been found in a number of other iron prospects.

The profiles Pl. (4) Fig. (c) show the results obtained in running 2 lines with a Hotchkiss Superdip Magnetometer at right angles to a basic igneous dike. The readings were taken every 300 feet. This dike is exposed where the arrow is drawn and is about 20 feet wide. Both profiles show a general similarity in that the reading on each profile (with the exception of reading 205) is directly at the dike. The excessively high reading of 205 was detailed on 20 foot centers and found to be very localized. It is probably due to a segregation of magnetite.

A very striking anomaly Pl. (5) Fig. (a) was obtained in running four parallel lines at right angles to a fault zone. The readings were taken with a Hotchkiss Superdip magnetometer at intervals of one-fourth mile. The faulting in the area is very complex and it is very probable that a number of faults are included in each profile. The major fault over which the lines were run has a throw of at least 1,000 feet. The four curves taken as a whole all show an increase in the readings over the fault zone. It is possible that profiles AA and DD were taken at or near the section of the fault where the throw diminishes or that there are not as many minor faults at the section where these profiles were taken.

Plate (5) Fig. (b) is a contour map of a sink hole containing iron ore. The readings were taken with an Askania magnetometer at intervals of 100 feet, the contour interval is very nearly one scale division. The two most outstanding features of the contour map are (1) the general slope from west to east and (2) the high point marked 443 near the east-central portion of the map. The high point was detailed on 5-foot centers and it was found to be restricted to a circular area having a diameter of about 25 feet. It is very similar to the variation of Pl. (4) Fig. (b). The general slope from west to east seemed very suggestive of a buried igneous ridge. To verify this suggestion lines AA, BB, and CC, were extended west about a thousand feet as shown Pl. (5) Fig. (c). The profiles show that after the maximum is reached the readings again drop to the west. The contour of the profile is very similar to the contour of those obtained in crossing an igneous ridge.

√

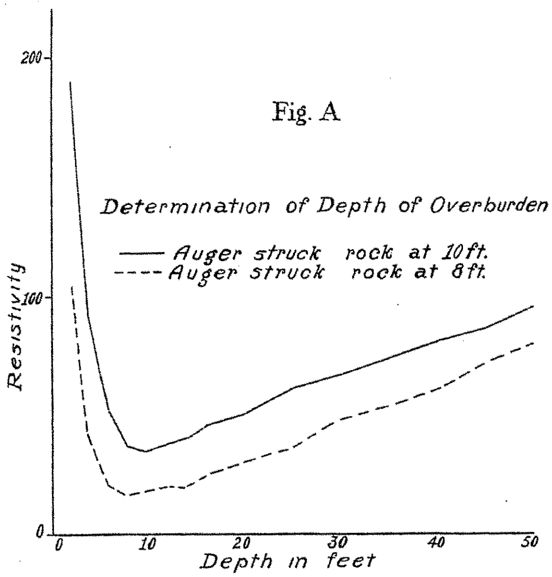


Fig. A

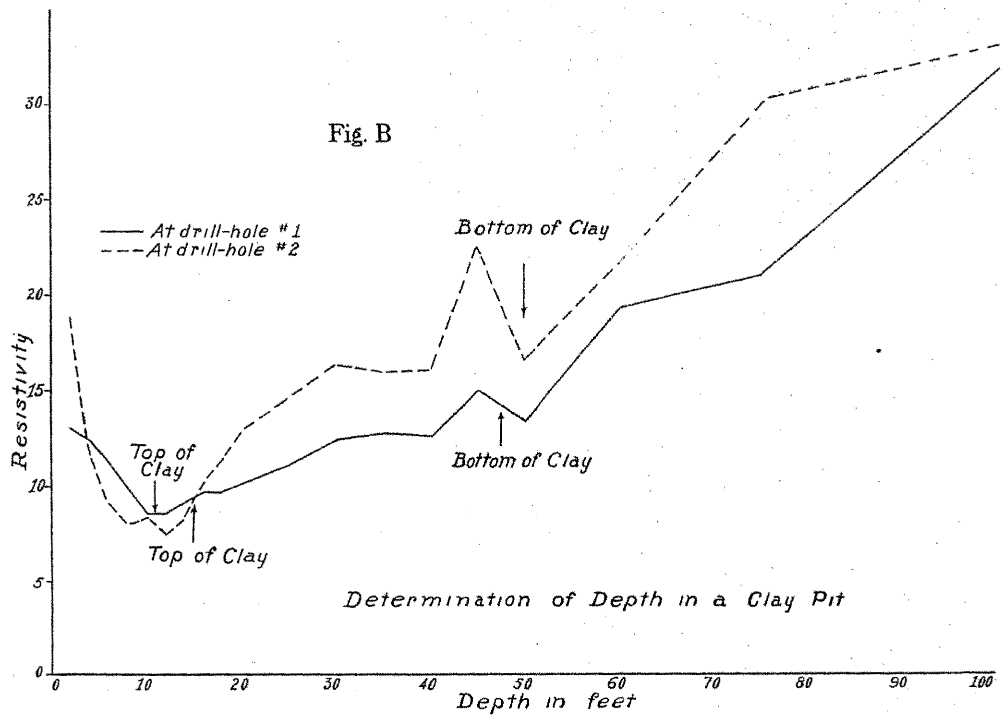


Fig. B

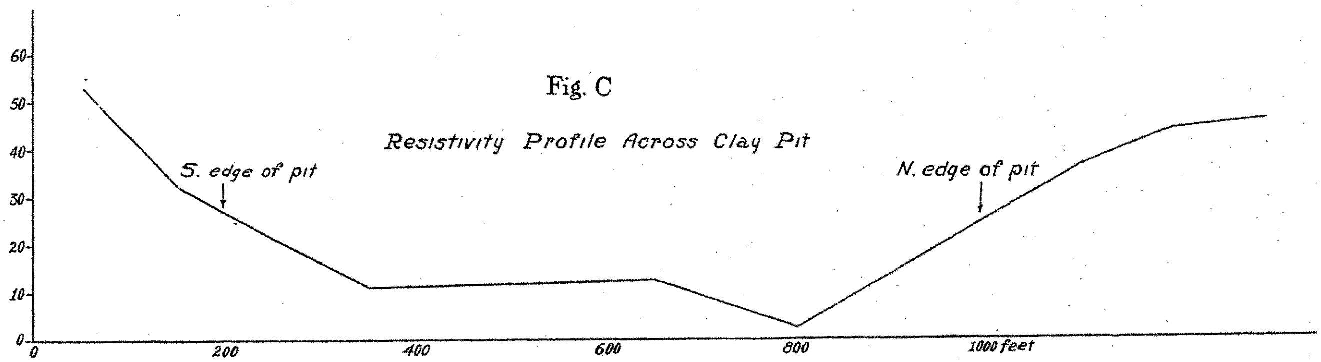


Fig. C

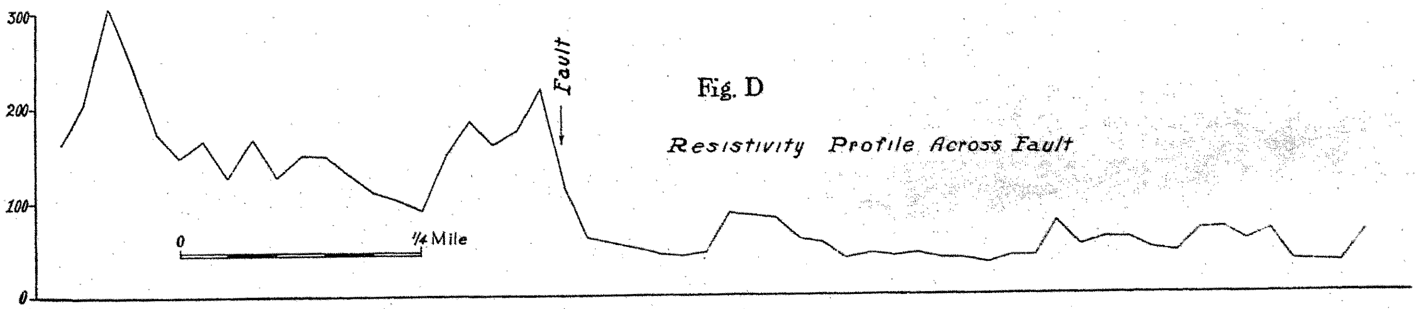
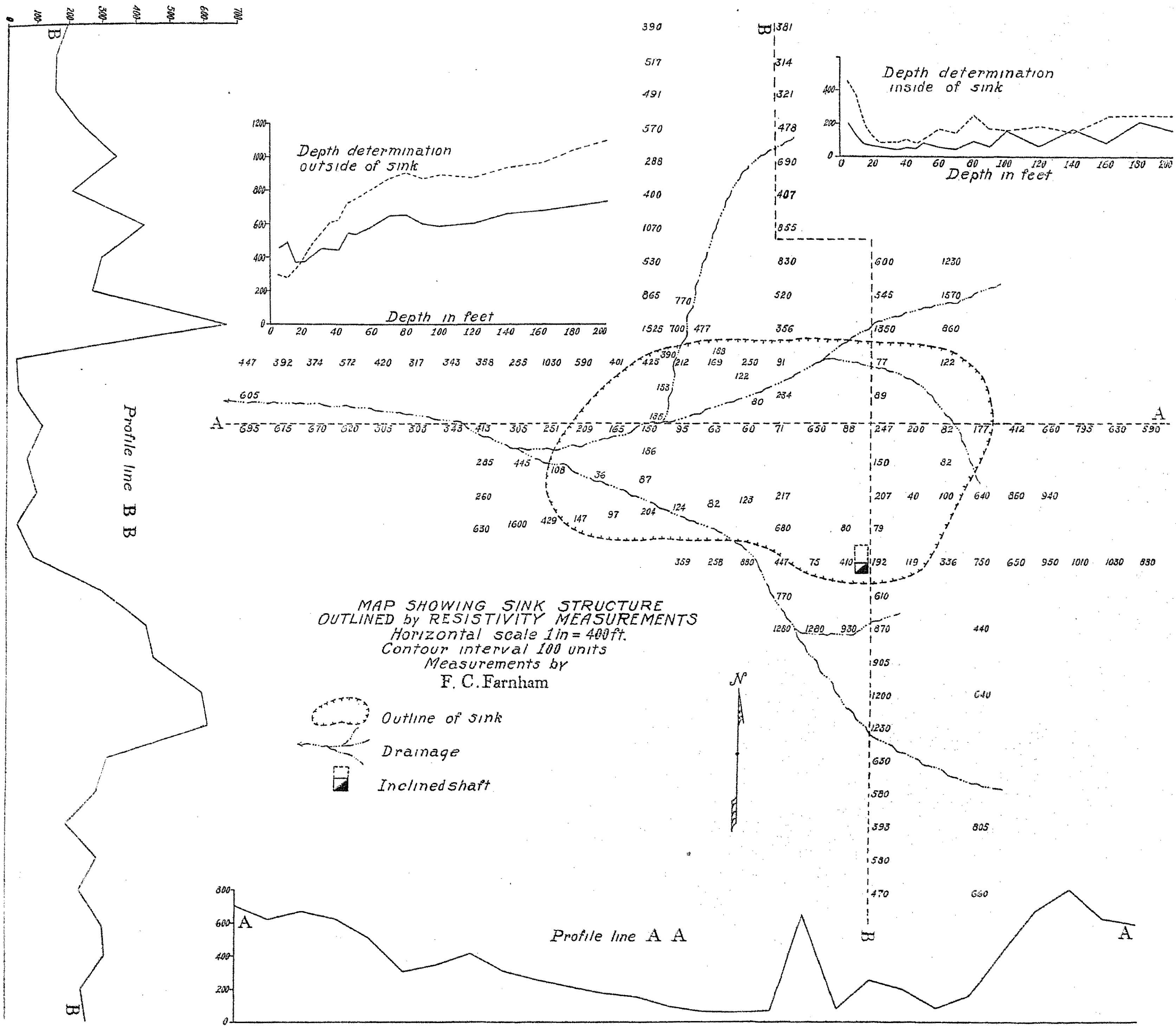
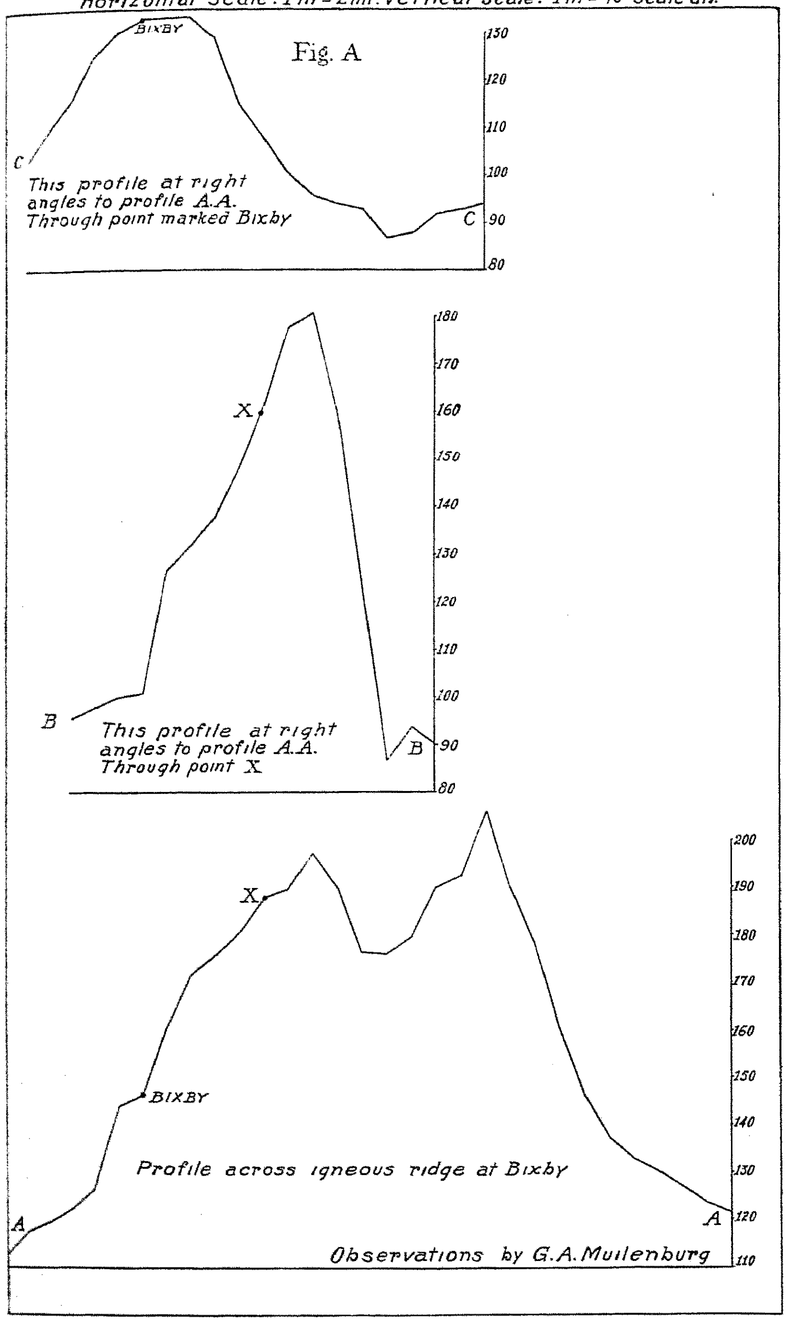
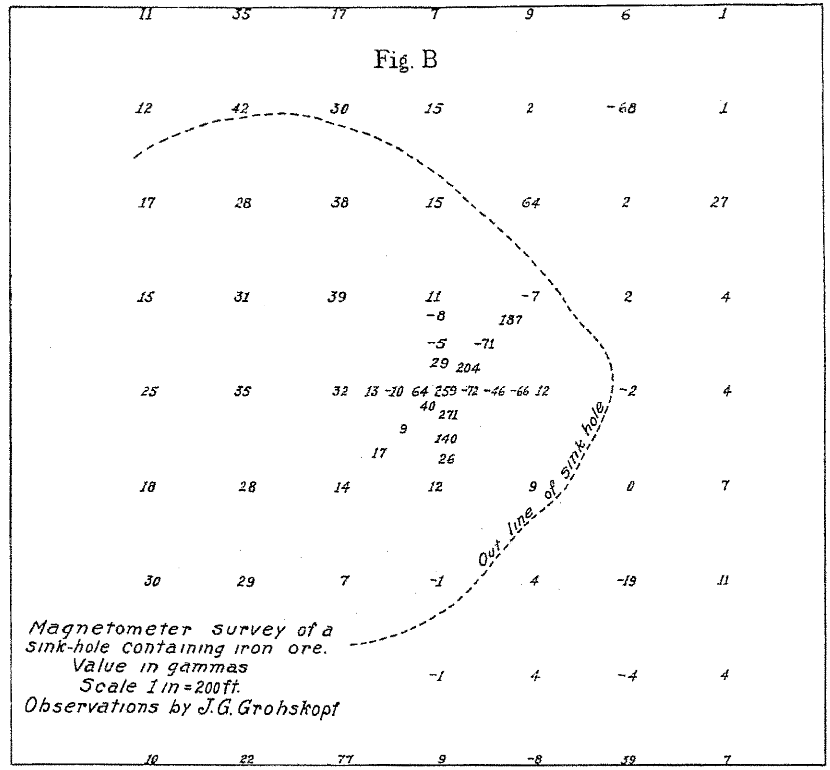


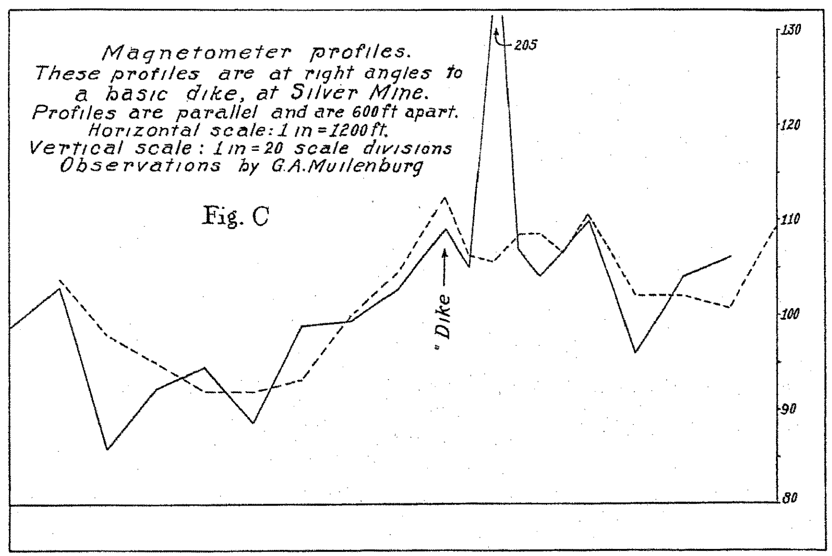
Fig. D


MAP SHOWING SINK STRUCTURE
OUTLINED by RESISTIVITY MEASUREMENTS
Horizontal scale 1in = 400ft.
Contour interval 100 units
Measurements by
F. C. Farnham
Outline of sink
Drainage
Inclined shaft
Depth determination outside of sink
Depth in feet
Depth determination inside of sink
Depth in feet
Profile line B B
Profile line A A
N

Magnetometer profiles across a buried igneous ridge
Horizontal scale: 1 in = 2 mi. Vertical scale: 1 in = 40 scale div.







Magnetometer profiles across Weingarten fault
Scale: vertical 1 in = 20 scale divisions; horizontal 1 in = 1 mi. By G. A. Muilenburg