MISSOURI
BUREAU OF GEOLOGY
AND MINES

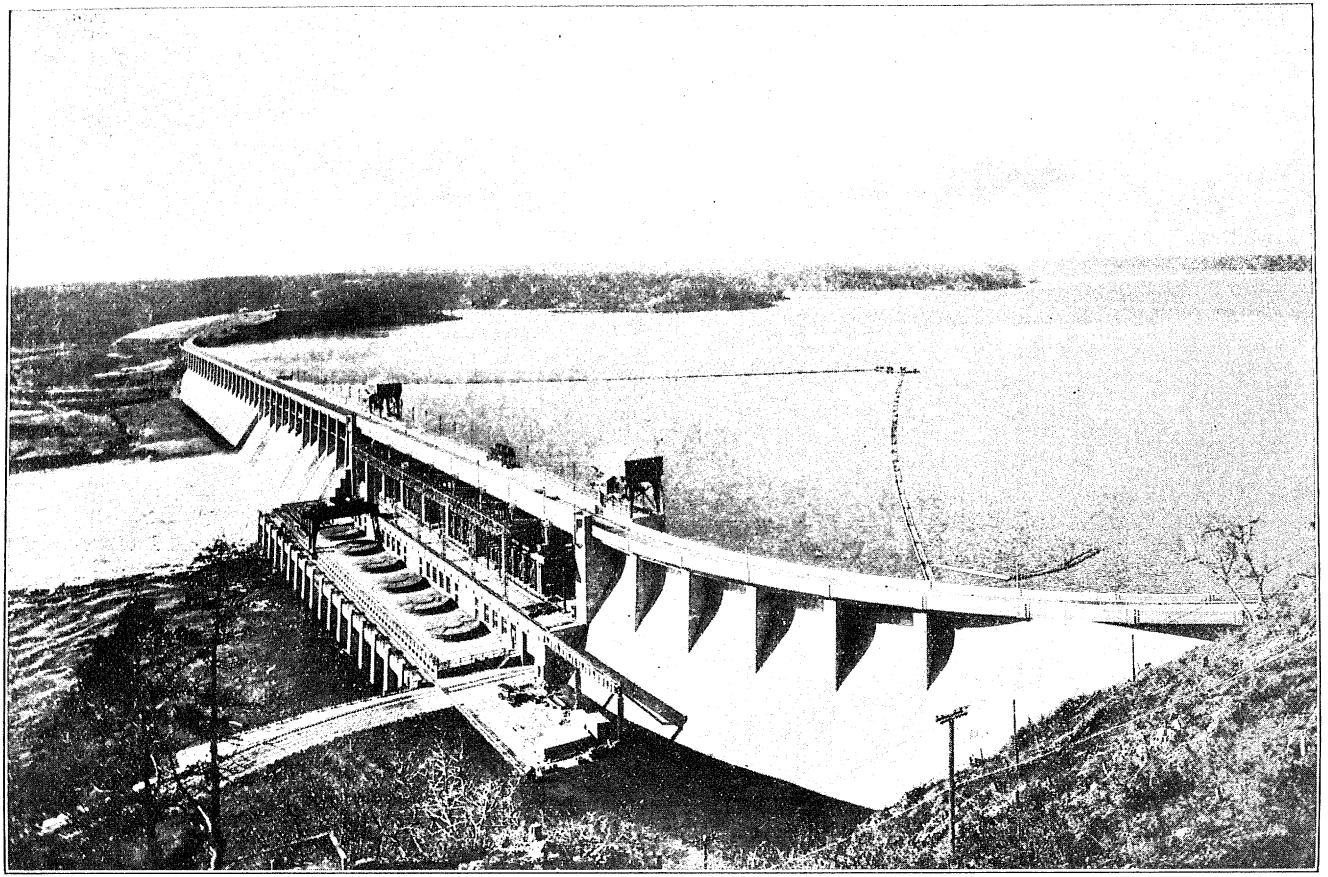
BIENNIAL REPORT *of the*

STATE GEOLOGIST

TRANSMITTED BY THE

BOARD OF MANAGERS OF THE BUREAU
OF GEOLOGY AND MINES TO THE
FIFTY-SEVENTH GENERAL
ASSEMBLY, 1933

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



Hydroelectric power plant of Union Electric Light & Power Co., on Osage River near Bagnell. Plant capacity 201,000 horse power. Dam 107 feet high, 2543 feet long; creates Lake of the Ozarks, length 129 miles, area 95 square miles.

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BOARD OF MANAGERS

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Hon. Walter McCourt, St. Louis.

LETTER OF TRANSMITTAL

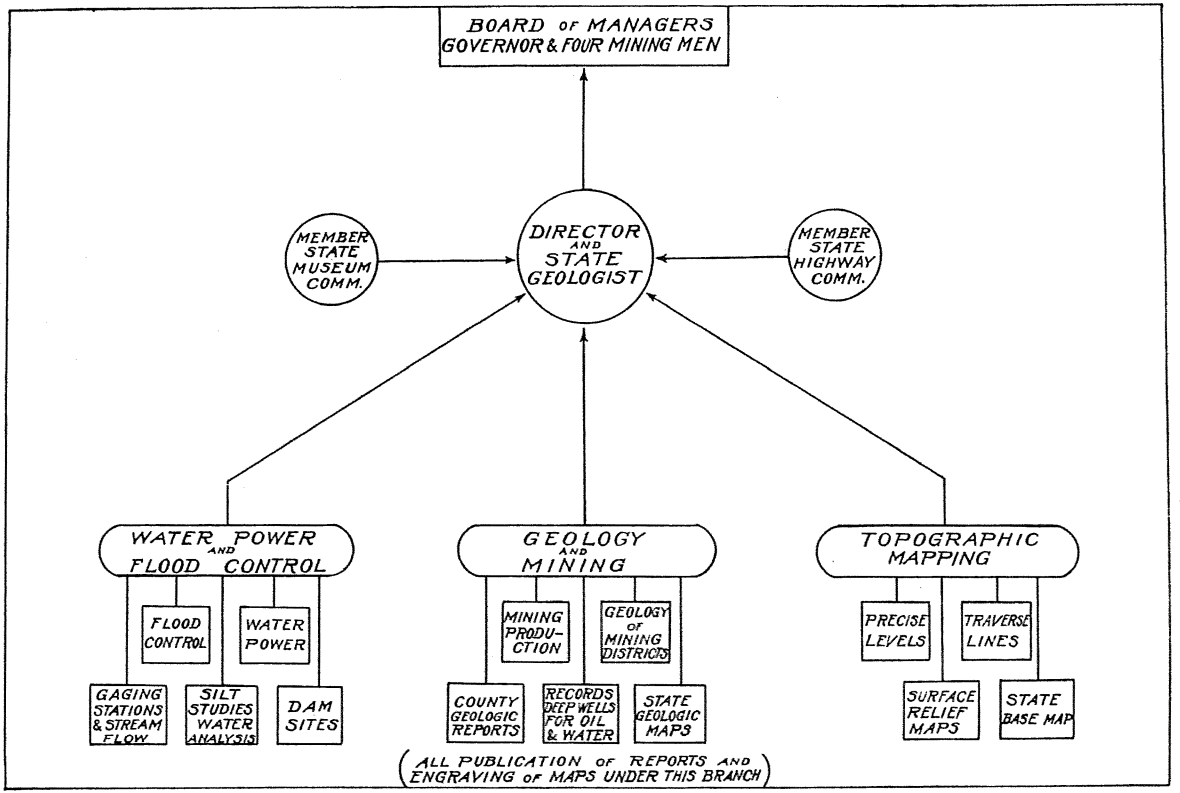
To the President, Henry S. Caulfield, and the Honorable Members of the Board of Managers of the Bureau of Geology and Mines:

Gentlemen:—I have the honor to submit herewith a brief report covering the work of the Bureau of Geology and Mines for the years 1931 and 1932.

There are attached five short appendices covering the results of investigations carried on during the biennium.

Respectfully submitted,

H. A. BUEHLER,
State Geologist.



Organization Chart, Bureau of Geology and Mines.

CHAPTER I

WORK OF THE BUREAU OF GEOLOGY AND MINES DURING 1931 AND 1932.

The following report is a brief outline of the work of the Bureau of Geology and Mines for the past biennial period. As shown by the organization chart on the opposite page, the department has under its jurisdiction three related, fundamental engineering branches which are devoted to the development of the natural resources of the State. These are as follows:

(1) GEOLOGY AND MINING BRANCH, DEVOTED TO THE DEVELOPMENT OF THE METALLIC AND NON-METALLIC MINERAL RESOURCES.

The State has extensive deposits of lead, zinc, iron, cobalt, nickel, copper, barytes, coal, pyrite, clay, limestone, marble, granite, and other minerals, all of which are capable of greater commercial production. There has been a rapid development of the mineral deposits during the past 25 years. Up to 1900 the annual value of the mineral products in the State was less than $15,000,000. During recent years the value of the output has varied from $75,000,000 to $90,000,000 per year. In comparison, this value is approximately one-fourth the value of the annual output of all agricultural products in Missouri.

The Bureau of Geology and Mines, through its publications, maps, correspondence and personal visits, has been instrumental in establishing and expanding the mineral industries. The following are instances of such help:

While mapping the geology of Ste. Genevieve County, a geologist of the Survey staff discovered and drew attention to the marble, which has since been developed near Ozora, and which is being extensively used throughout the United States for the finest of interior decoration.

More recently the Survey was able to point out through its geologic map of the Bonne Terre district, a deposit of dolomite upon which an extensive quarry has since been opened. New possibilities are continually being investigated by the Bureau.

(2) TOPOGRAPHIC MAPPING BRANCH, DEVOTED TO THE MAKING OF A COMPLETE ACCURATE SURFACE MAP OF THE STATE. THE FEDERAL GEOLOGICAL SURVEY MATCHES STATE FUNDS DOLLAR FOR DOLLAR.

The value of topographic maps is becoming better and better known and there is a far greater demand today than ever before. The U. S. Geological Survey had mapped a few quadrangles in this state prior to 1907. At that time the General Assembly established a policy of making an accurate base map of the State in cooperation with the Federal Geological Survey. Since then approximately one-fourth of the State has been covered with accurate maps. In addition to many other uses these maps are of special value in highway location, and during the present biennial period the Highway Department has cooperated with the Federal and State surveys in mapping some of the roughest areas in the Ozark Region.

(3) WATER RESOURCES BRANCH, DEVOTED TO INVESTIGATIONS COVERING WATER POWER AND FLOOD CONTROL POSSIBILITIES ON THE MAJOR STREAMS THROUGHOUT THE STATE. THE FEDERAL GEOLOGICAL SURVEY MATCHES STATE FUNDS DOLLAR FOR DOLLAR.

The 51st General Assembly placed under the jurisdiction of this Bureau the task of obtaining information concerning the flow of the rivers of the State, and gaging stations were established on all important Missouri streams. Prior to inaugurating this work very little information was available regarding the actual flow of any of the major streams of the State. Flood control cannot be studied without the knowledge of the amount of water being carried during times of flood. Well planned drainage work requires accurate records of stream flow to determine the size of drainage ditch needed. Water power possibilities cannot be determined without accurate records of the daily flow of a stream. The value of these records for water power development is indicated by the fact that when this work was started there were no projects in this state contemplating hydroelectric developments. Since that time the Bagnell dam, costing in the neighborhood of $35,000,000 has been completed, and the so-called Table Rock dam on White River, which will cost in the neighborhood of $30,000,000 has gone to construction license. Neither of these dams could have been planned or built without accurate stream flow records obtained by this department.

APPROPRIATION.

The 56th General Assembly made an appropriation of $151,752 to carry on the work of the three branches of this bureau during the present biennial period. Because of economic conditions, $42,000 was withheld from the appropriation of the Bureau during the biennium, making the total available sum $109,752. The widespread interest in, and the value of the work of the Bureau is indicated by the fact that outside co-operative funds totaling $150,195 were contributed during the current biennial period. Of this amount $4,520 was contributed toward salaries and expense accounts of members of the geologic staff in investigating iron ores and geophysical mapping by the Industrial Club of St. Louis, the Tri-State Lead and Zinc Association of Southwest Missouri, and by municipalities for water analyses through the State Board of Health. The sum of $125,000 was contributed by the U. S. Geological Survey and the State Highway Department chiefly for making strip topographic maps in the very roughest portion of the Ozark region, where these maps are of importance in highway location. The U. S. Geological Survey, U. S. Army Engineers, and private individuals, cities, and corporations desiring information regarding possible water supplies, hydro-electric developments, and drainage systems contributed $20,675 to the work of the Water Resources Branch.

In addition to direct cooperative funds, the U. S. Army Engineers completed, in cooperation with the U. S. Geological Survey, approximately 2000 square miles of topographic mapping in Southeast Missouri for the purpose of making a study of flood control, and spent $13,900 independently on surface water investigations, the work being done by the Federal engineers connected with this Bureau.

COOPERATIVE AGENCIES.

The following agencies cooperated with the Bureau during the biennial period:

(1) United States Geological Survey in (a) Topographic Mapping, (b) Water Resources. The Federal Survey meets State appropriations dollar for dollar in each branch, and largely furnishes the engineers for carrying out the

work which is agreed upon by the State Geologist and the Director of the Federal Survey.

(2) Industrial Bureau of St. Louis in studying Central Missouri iron ores by magnetic methods. During 1930 the Industrial Bureau paid salaries and traveling expenses of summer field parties for this work which was successful in helping develop new iron ore deposits.

(3) Tri-State Lead & Zinc Ore Producers Association, in making a magnetic map of the Joplin district. The Association paid the salary and traveling expenses of one member of the Bureau staff for the work in Jasper and Newton counties, and extended the work through the Kansas and Oklahoma lead and zinc areas. The work was done during the summer of 1931.

(4) The State Highway Commission, in topographic mapping and stream gaging. The Geological Survey furnished the Highway Department copies of all geologic maps covering field work not yet published. The Highway Department cooperated in making highway strip maps throughout the Ozark region, and read the gages on 18 gaging stations in Northeast Missouri. These gages are located on small streams and the data relative to floods are important in determining the size of bridges.

(5) State Board of Health, in providing sanitary water supplies. Drillers are required to send samples to determine the depth of casing in order to prevent the possibilities of surface contamination. Also, the Survey chemist made 417 water analyses of samples taken from city water supplies, which work was paid for by the city authorities.

(6) U. S. Weather Bureau of St. Louis, in maintaining gaging stations and reporting flood conditions on Missouri streams.

(7) State Fair Board, in maintaining an exhibit of minerals at the State Fair. One member of the staff is in attendance at this exhibit during State Fair week.

(8) State Resources Museum Commission. As a member ex-officio of the State Museum Commission the State Geologist cooperates in the matter of mineral exhibits for the State Capitol.

(9) City of St. Louis, in an economic study of the quarries of the city in correlating the various beds indicating those portions of rock series suitable for use as concrete

aggregate and those portions that are inferior. Also in the making of a topographic map of the city, the Engineering Department supplying the base map.

(10) U. S. Army Engineers, in establishing and maintaining gaging stations on the Missouri River, the Army paying all expenses connected with the work.

(11) State Securities Commission. The staff of the Survey passes on the applications of all mineral and oil requests to sell stock. Where trips are necessary to examine the property the applicant pays all expenses.

(12) Drainage districts, in determining the river and ditch stream flow.

(13) Corporations and cities, both in the determination of underground and surface waters considerable work is done in cooperation.

(14) U. S. Bureau of Mines, in the collection of statistics covering the mineral production of the State.

PERSONNEL.

Of the permanent staff two of the older members resigned during the biennial period—Mr. Jos. M. Thiel, geologist, and Mr. H. W. Mundt, chemist. Mr. R. W. Rolufs was employed as chemist, and Mr. J. G. Grohskopf, a graduate of the School of Mines, and Mr. C. D. Gleason, a graduate of the State University, were employed as assistant geologists. Mr. Willard Farrar, a graduate of the School of Mines, was employed as draftsman and assistant geologist. In addition to the present permanent staff, temporary employes are utilized mainly during the summer months, and student labor on an hourly basis has assisted in the laboratory and office. In the Topographic Mapping and Water Resources branches the men are Federal employees subject to change by the Federal Geological Survey. The permanent geological and office staff is as follows:

GEOLOGY AND MINING.

Permanent Staff:

H. A. Buehler, State Geologist.
H. S. McQueen, Assistant State Geologist.
J. G. Grohskopf, Geologist.
C. D. Gleason, Geologist.
C. O. Reinoehl, Field Engineer.

W. Farrar, Draftsman and Assistant Geologist.
R. T. Rolufs, Chemist.
Jean I. McCaw, Chief Clerk.
Dorothy Shaver, Stenographer.
E. E. Hawkins, Janitor and Laboratory Assistant.

Temporary Employees:

C. L. Dake, (1931-1932).
G. A. Muilenburg (1931).
F. C. Farnham (1931).
J. S. Cullison (1931-1932).
Carl Tolman (1931-1932).
V. T. Allen (1932).
F. C. Greene (1932).
B. R. Thompson (1932).

TOPOGRAPHIC BRANCH.

Field parties are supplied by the Federal Geological Survey.

WATER RESOURCES BRANCH.

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).

FIELD INVESTIGATIONS.

In planning the work of the Bureau an endeavor is made to reach every part of the State during the biennial period, and during the present biennium some work in at least one of the branches has been carried on in every county in the State, and in many counties work has been done by all three branches. The following is a brief outline of the major investigations.

Oil and Gas Possibilities. Definite results have been obtained in the oil and gas investigations carried on during the present biennium in the western portion of the State. With the discovery during recent years of numerous profitable oil and gas pools along the western border of the State, there has been increasing interest in the possible production thruout Northwest Missouri, and there has been a constant demand

upon this Bureau for reliable detailed knowledge of the formations in which the oil and gas occur and the character of the structures from which production is obtained. In order to obtain the needed information field work has been carried on from Vernon to Platte and Clinton counties, and a study made of the individual producing pools. Over 1700 drill records have been collected, and elevations of the wells in most of the pools have been determined and the structures outlined.

Two appendices to this Biennial Report outline briefly the summary of the information obtained. Appendix II, by Mr. F. C. Greene, shows the character of the more important pools. The work indicates that these pools follow structural conditions, as the production in all cases is obtained along the crests of anticlines.

A driller's cross-section has been prepared extending from Vernon to Clinton County, showing the character of the formations and the depth and character of the various oil and gas sands throughout the entire distance. In conjunction with the surface map showing the location of the various pools this section will be of the greatest help in future prospecting.

There is every reason to believe that there are many additional structures that will be productive and that with careful mapping the general area of production can be extended into the northwest part of the State. The results already published illustrate what can be expected with additional work.

The Bureau plans to extend the investigation beyond the present area in which development is being done and will endeavor to give additional reliable data regarding the general stratigraphic and structural conditions throughout that part of the State.

Appendix III is a report by Glenn G. Bartle, covering the Blue Springs gas pool in Jackson County. It gives in detail the geologic conditions existing in the largest gas pool developed to date. It indicates that the gas is found on anticlinal structures and that the chief production comes from well-defined sand horizons. A productive, erratic thick sand is described, which is apparently similar in origin to the Warrensburg channel sandstone outcropping in Johnson County. The structural maps and cross-section clearly illustrate the structural and stratigraphic features of this pool, which is typical for west Missouri. The report also shows by a series of curves and graphs, the character of the production during the life of the pool.

The Coal Measures, or Pennsylvanian series, from which formation the oil and gas are obtained, underlie approximately 25,000 square miles, chiefly in the northern and western portions of the State. Only a small part of this area has been developed and there are possibilities of many additional structures in the counties in which production is now being obtained.

It is believed that there are important structures north of the present developments, and it is planned to continue the study of the structure and stratigraphy throughout the coming biennial period in that area.

Iron Ores. During the preceding biennial period an active investigation of the iron ore deposits was started in cooperation with the Industrial Club of St. Louis. The salary and expenses incurred in this work were paid by the Industrial Club because of its interest in developing a greater ore supply for the industrial district of St. Louis. This cooperation extended through the first year of the present biennial period.

In view of this work much interest was aroused and many prospects opened. Shipments increased from practically nothing to from 500 to 600 tons per day until, because of the depression, the East St. Louis furnace discontinued the purchase of ore. The output came from both the red and brown ore fields.

In addition to the regular methods of geologic field work the deposits were surveyed with a magnetometer. In a number of cases an area of high magnetic intensity was found in the sink-type of red ore deposit. Shafts sunk at these points demonstrated the fact that in every case high-grade specular ore occurred near the surface. At the Silver Hollow and Christy banks excellent ore was encountered at the points indicated by the magnetic survey.

During the past summer a magnetic map was prepared of the Crawford County iron ore area, and the relation of the iron ores to the magnetic field determined. Many of the major deposits have been found to occur in the regions of low magnetic intensity. This fact will prove of great benefit in future prospecting in that the most favorable territory for prospecting can be determined magnetically. Work will be continued in this field with the resumption of mining activity.

Clay Deposits. Missouri has a greater variety of valuable clay deposits than any other state in the Mississippi Valley. During the past three biennial periods considerable field work has been done on the plastic fire clay district in Audrain, Calla-

way, and adjoining counties, and a detailed survey was made of the diaspore-flint fire clay district of the North Central Ozark region.

Diaspore clay is not produced in commercial quantities at any other point in the United States, nor in fact in the world. It is especially valuable in the manufacture of super refractories and is extensively used for this purpose. First-grade diaspore clay containing 70% alumina is found associated with white, non-plastic flint fire clay, which contains 40% alumina. In many of the pits rough or burley clay is produced, which carries intermediate percentages of alumina.

The constitution of the diaspore clay is a matter of much economic importance in its future use. During the present biennium, microscopic work has been started to ascertain if possible the method of the formation of this clay. The work has not yet progressed sufficiently to make a final decision.

Ground Water Supply. A pure water supply is the most important factor in the health and welfare of any community. Many of our worst epidemics of typhoid fever have been caused by contamination as the result of polluted surface waters seeping into poorly protected wells. In many cases this is due to openings in the formation leading to the surface where casing is not set sufficiently deep to keep seepage out.

In cooperation with the State Board of Health the Bureau is examining the cuttings from wells drilled for water supply throughout the State. After examination the Survey determines the depth to which casing shall be set to exclude surface waters.

As an indication of the extent of this work the cuttings from 340 drill holes have been received and examined. This is at the rate of one drill hole every two or three days. A total of from 15,000 to 20,000 samples of cuttings were received. This branch of the work is one of the most important investigations of the Bureau, as it is directly related to the future health of the people of the State.

Good ground water in abundance occurs in various sandstone and cherty limestone horizons and frequently the examination of the cuttings shows that with slightly additional drilling an excellent water horizon will be encountered.

To make such a prediction a detailed knowledge of the formations passed through is necessary. As described in the last biennial report the Bureau has developed a method of dissolving the cuttings in acid and examining the insoluble residue.

It has been found that each formation leaves a type of residue which differs from every other formation. This gives a most reliable method of determining the geologic horizon. The ground water and stratigraphic problem deals with every part of the State, and since now more accurate information can be given, the Bureau is being called upon more and more for additional information.

The Bureau has cooperated with a number of cities during the past biennium in connection with drilling wells for water supplies. In this work, geologic examinations have been made in most instances prior to drilling, to determine the proper location of the well. Advice has been given with regard to the diameter of the hole, the character of the rock section to be drilled, and the depth to the most productive water bearing horizon.

As drilling proceeds, samples are collected and forwarded to the Survey. A study of them, by the method previously described, shows the formation being drilled and indicates the depth at which casing is to be set in order to prevent contaminated surface waters from entering the hole. Representatives of the Bureau have visited many of the drilling wells in order to advise in regard to problems connected therewith. This cooperation has been extended to the following towns during the past two years: Cuba, Arcadia, Mountain Grove, Fulton, St. Clair, Cassville, Windsor, Noel, Ironton, and Potosi.

Detailed field investigations were also made at Clinton. Surface waters, supplemented by mineralized well waters are used in this town at present, and an attempt was made to obtain a location that would yield a more satisfactory deep well water. It was found, that such a locality existed, but it was too far from the limits of the town to be economically feasible at this time.

That the work of the Survey in establishing casing points, and thus protecting wells from contamination, has been successful is indicated by the fact that many well drillers and individuals now seek the advice of the Survey prior to and during the drilling of private wells.

As a result of this study of well samples by means of the insoluble residue method, considerable new information is being obtained relative to the occurrence of ground water. Prior to the development of this method, it was impossible to determine water-bearing zones in the thick limestone and dolo-

mite sections. This can now be done, and as a result many wells that would have been completed with only a limited quantity of water, have been deepened to a "break," where the yield was considerably increased. In certain localities deep drilling results in a supply of undesirable mineralized water, and attention and study have been given to this problem. The St. Louis district is an area in which this situation is particularly acute, and during the last biennium many well samples have been examined, and field work has been undertaken in order to determine the total depths to which wells might be satisfactorily completed.

At the present time, the members of the staff are assembling on a series of maps the data which bear directly on the problem of well-water supplies. These, when completed, will show the thickness of formations, their attitude with respect to structural features such as faults and folds, the regional static water table, and the quality of the water from the different horizons. Some of the maps have been practically completed and are now being consulted by engineers and well drillers at the office of the Bureau.

The development of water supplies will continue with the growth of the State, and additional demands are and will continue to be made upon the Bureau for accurate information. In this work many citizens of the State are reached indirectly, and the safeguarding of their health and property with sanitary and adequate supplies of water constitutes an important function of the Bureau.

Magnetic Surveys. The magnetic investigations carried on by this Bureau during the preceding biennial period were discussed briefly in Appendix III of the report of the State Geologist to the 56th General Assembly. The results obtained apparently indicated a direct relation between magnetic intensity and the buried topography of the old pre-Cambrian surface and a definite relation of the ore deposits to this structure. In view of this fact the magnetic work was continued during the present biennial period.

Because of the lack of funds, the Industrial Club of St. Louis continued financial cooperation in a study of the iron ore region, and the Tri-State Lead & Zinc Ore Producers Association paid for surveying Jasper and Newton counties as well as the remainder of the Tri-State district in Kansas and Oklahoma. The field work covering the above projects was completed during the year 1931. During 1932 the Survey continued work with its own funds.

Appendix IV of this report gives some of the results of the work during the present biennial period and contains a map showing the work that has been completed.

The map of the Joplin district indicates that there has been no major ore deposit developed on areas of high magnetic attraction. The ores all occur along the flanks or in areas of low attraction. With this result in view it is evident that prospecting would not be as favorable on the areas of high attraction, and therefore they should probably be the last areas in which to look for ore. Very much the same condition is shown by the work done in Crawford County where the major ore deposits and the principal faults are found in the areas of low magnetic attraction.

In addition, a series of traverse lines were run as shown on the map accompanying Appendix IV of this report. These lines show very decided differences in magnetic attraction thruout the State, and detailed surveys can be started from hub stations which are established at intervals of about ten miles. Detailed surveys were also made of Cape Girardeau, Perry, Scott, and part of Stoddard counties as part of a plan to cover Southeast Missouri.

The results of the magnetic work in outlining the relation of geological structures and ore deposits to magnetic intensity is apparently of importance and it is planned to continue the work throughout the other areas showing mineral deposits.

Stratigraphic Studies. A study of the rock formations of Missouri, in the area of outcrop and where they are buried beneath the surface and only penetrated in drilling, constitutes an important phase of the geologic work of the Bureau.

Each of the mineral resources occurs under geological conditions that are definitely connected with these formations, hence such studies are necessary in order that the mineral deposits may be correctly interpreted and advice given for their orderly and proper development.

During the past biennial period stratigraphic studies have been undertaken in practically every part of the State. They consist of detailed surveys of limited areas, and reconnaissance studies of a broader nature.

During the field seasons of 1931 and 1932, geologists of the staff accompanied Dr. E. O. Ulrich and Dr. Josiah Bridge of the U. S. Geological Survey on field trips through the Ozark

region. Approximately ten days were spent in each of the above mentioned years in this work.

In cooperation with the engineering department of the City of St. Louis, a stratigraphic study was made covering the limestone formations in and near the city. This work was undertaken primarily to determine which formations or parts of formations contained stone suitable for use in concrete construction, and what beds were unfit for this purpose. The general succession of formations has been plotted in a diagram and each quarry in and near the City of St. Louis has been shown in its proper stratigraphic position. The diagram not only indicates the character of the stone now being obtained, but indicates what may be expected on continuing to quarry in depth.

Incidental to the above investigation a general study of the formations and structure of St. Louis County has been made. The region is underlain by different formations and shows two well-defined anticlines striking in a northwest direction. These indicate structures similar to that at Dupo, Illinois, and in fact one of them is the northwestern extension of the same structural feature.

Additional field work was carried on in Cape Girardeau, Bollinger, and adjoining counties, and the mapping started last biennial period in the vicinity of Cape Girardeau was extended to the south and west. This entire region shows major structural conditions. Quarrying south of Cape Girardeau has been materially affected by a series of faults striking northwest and southeast. The work is intended to show the distribution of the formations and the areas where faulting has affected the continuity of formations. The region abounds in deposits of tripoli, ball clay, kaolin, limestone, glass sand, and other non-metallic minerals, and a knowledge of the detailed geology is essential to further development of these minerals.

Igneous Rocks. During the present biennium a study of the igneous rocks outcropping in Southeast Missouri has been undertaken. Both porphyry and granite constitute large areas in the region of outcrop and their relation not only to the overlying sedimentary beds but to the ore deposits at Iron Mountain, Pilot Knob, Einstein Silver Mine area, and other localities are of interest and importance.

The relation of the various porphyry flows to each other and to the granite is important in interpreting the geologic history of this important region.

In connection with this investigation a detailed study was made of the Silver Mine area. A report of this area is published as Appendix I.

The Einstein and other mines of this district are unique among the mineral deposits of the Central Mississippi Valley. They occur in the granite and porphyry and differ radically from the mineral deposits found in the dolomites and limestones throughout the Ozark region. It is the only area in which tungsten and argentiferous galena have been found in the State of Missouri.

Shell Knob Quadrangle. Throughout Southwest Missouri, in Barry, Stone, Taney, Christian and adjoining counties there are known deposits of lead and zinc ore, which have been mined to some extent south of Springfield in Christian County. A major fault plane extending from the Arkansas state line northwest through Stone County to east of the Aurora lead and zinc field has been prospected, especially near the Arkansas boundary. The deposits along this fault plane were described in a former biennial report, but no additional field work has been done in that region in recent years. Other fault planes and structural zones known to occur in the area have not been studied or mapped.

The formations are chiefly the Jefferson City-Cotter-Powell series, capped by the basal member of the Mississippian System. The lower members of the series have a much greater thickness than in the central or eastern Ozark region, and correspond more nearly to the formations found in the Arkansas lead and zinc district to the south.

In order to have geological data covering this region, mapping of the Shell Knob Quadrangle in Barry and Stone counties has been started during the biennial period. A magnetic map was first prepared which showed a general northeast-southwest direction of high magnetic attraction, indicating pronounced pre-Cambrian buried ridges having a similar strike or direction. Later surface mapping has outlined pronounced faults which follow the structural features of the basement rocks. The formations have been studied in detail and all mineral showings have been described. One additional field season will complete the surface mapping of this quadrangle, which is a type area for the entire region.

Chemical Laboratory. In cooperation with the State Board of Health, studies of city water supplies have been continued

through this biennial period, and in connection with this work the chemist has made complete analyses of 417 samples of deep well and surface-water supplies. The cost of these analyses is paid for by the cities and individuals for whom the work is done.

As the samples have been submitted from all parts of the State and from wells of different depths, the Survey has been able to tabulate the general character of the water obtained from the various water-bearing horizons. Maps are being prepared which will show the character of the water supply and water-bearing horizons throughout the State.

In addition some 250 samples of iron ores, clays, granite, porphyry, limestone, and other minerals were analyzed. These samples were collected by members of the staff or were submitted by citizens for determination.

Museum and Library. The reference library maintained by the Bureau received the usual number of volumes from geological and other scientific bodies in exchange for the reports of the Bureau. The volumes are available to engineers and geologists as well as members of the staff.

Several thousand hand specimens and drill-core samples comprising largely detailed sections of various formations have been added to the museum during the biennium.

TOPOGRAPHIC MAPPING.

In cooperation with the United States Geological Survey and the State Highway Department, topographic mapping has been carried on throughout the biennial period. Some 2,000 square miles of the roughest area in the Ozark region were mapped as irregular areas and strips where highway location is difficult. They are located chiefly throughout the southern part of the State. In order to adjust these areas properly so that they can be incorporated finally in quadrangle and county maps, it was necessary to run several thousand miles of traverse and level lines.

Mapping was also continued in the Jefferson and St. Louis County areas in preparing a complete topographic map of the metropolitan area. The State of Illinois has completed mapping East St. Louis and surrounding territory, and when completed the combined map will cover the entire industrial region of St. Louis.

In addition to the work done in cooperation, the Federal Geological Survey in cooperation with the U. S. Army Engineers

mapped 2,000 square miles including eight quadrangles in Cape Girardeau, Bollinger, Butler, Wayne, and adjoining counties. This area lies at the junction of the Ozark hill country and the lowland region of Southeast Missouri, and the maps were desired especially by the Army for a study of flood-control problems.

The outline map on the opposite page (Pl. III.) indicates the areas in which topographic maps have been completed. Approximately one-fourth of the State has been covered with good maps.

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

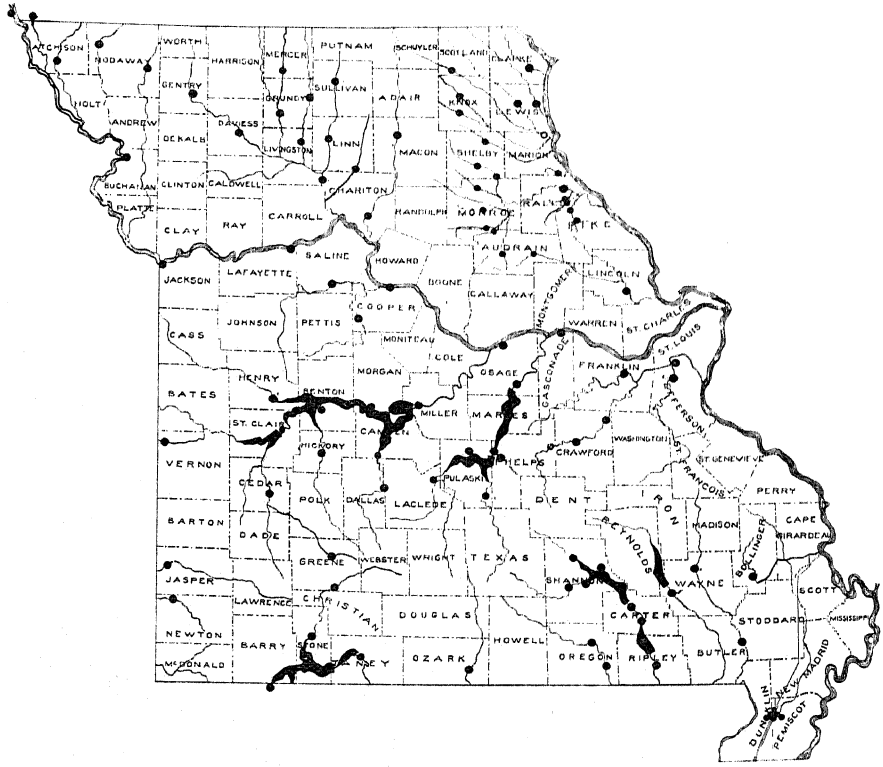
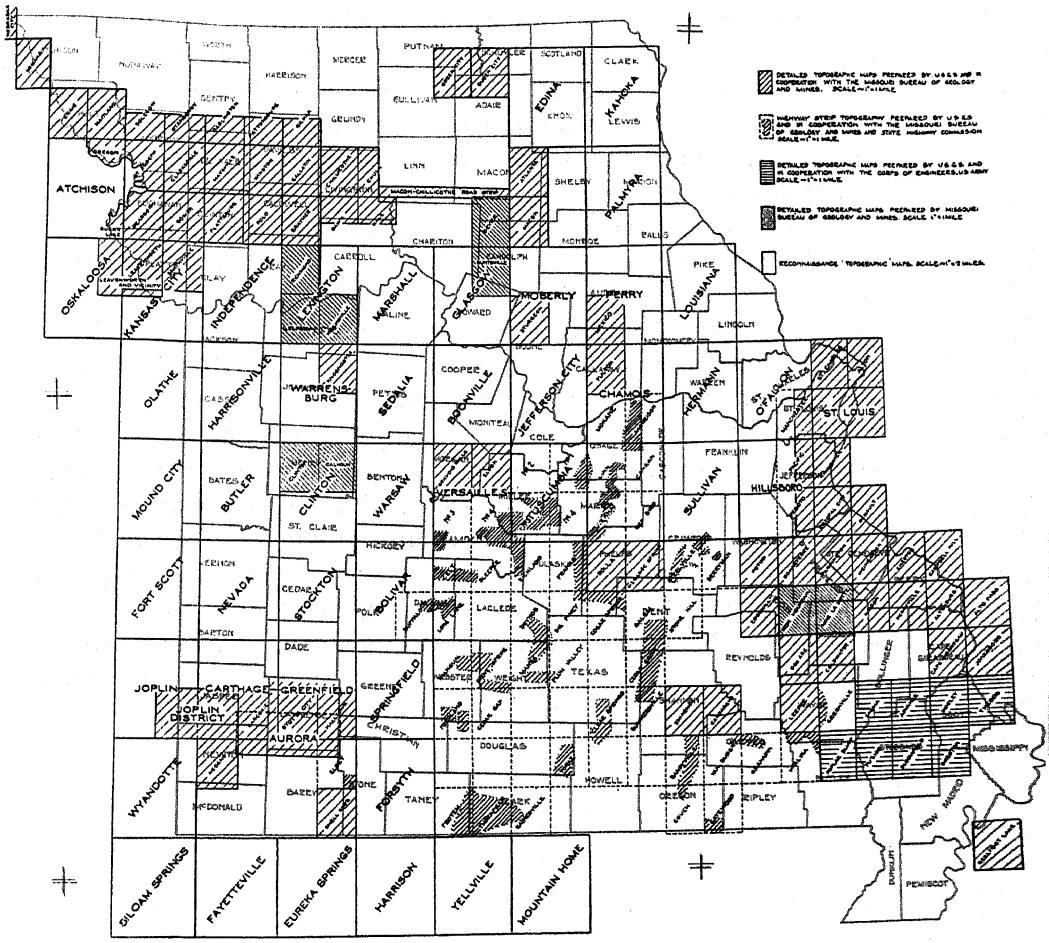


FIG. 1. Map showing location of gaging stations and lakes developed or to be created by proposed hydroelectric developments.



Map showing areas surveyed topographically to January, 1933.

United States Geological Survey, which organization furnished trained personnel to carry on the work, and during the biennial period contributed $20,700 to its cost. Twelve new gaging stations were established, all at the request of cooperating parties. Ten stations were discontinued. At this time 96 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 16 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, water-supply, and sewage-disposal developments, and new bridges for the State highway system. The stream flow records constitute important basic information necessary for the design of these improvements.

The accompanying table shows the present constructed and proposed water power plants in Missouri which have a capacity of 100 horse power or more. A number of smaller plants, used mainly to operate grist mills, are not included in the table.

WATER POWER PLANTS IN MISSOURI

(With capacity of 100 horse power or more)

Stream.	Name of Plant.	Owner.	Horse Power.
Constructed Plants:			
Osage River	Bagnell	Union Electric Light and Power Co	201,000
White River	Ozark Beach	Empire District Electric Co	25,600
Niangua River	Decaturville	Missouri Electric Power Co	4,040
Osage River	Osceola	West Missouri Power Co	2,400
Shoal Creek	Grand Falls	Empire District Electric Co	958
Sac River	Caplinger Mills	Ozark Utilities Co	700
Elk River	Noel	Empire District Electric Co	150
Spring River	Carthage	H. S. Cowgill	150
Spring River	Bower Mills	Ozark Utilities Co	100
Hunter Creek	Vera Cruz	Jason E. Roy	100
		Total constructed plants	235,198
Proposed Plants:			
White River	Table Rock	Empire District Electric Co	220,000
Gasconade River	Jerome and Rich Fountain	Gasconade River Power Co	100,000
Current River	Blair Creek, Mill Creek and Hargus Eddy	Current River Power Co	80,000
Black River	Leeper	Willis H. Meredith	30,000
		Total proposed plants	430,000
Total constructed and proposed plants			665,198

The water power plants on Osage River near Bagnell and Osceola and the one on Niangua River near Decaturville were completed during the past three years at a cost of about $36,000,000. Their design and construction were based upon the stream flow records collected by the Bureau. Without such records these plants could not have been built and the beautiful Lake of the Ozarks, with a length of 129 miles and an area

of 95 square miles (resulting from the construction of the Bagnell dam), could not have been created. During 1930 and 1931 the generating equipment in the plant on White River at Ozark Beach was replaced with new and more efficient equipment, and the capacity of the plant was increased from 15,600 to 25,600 horse power. This improvement also was based upon the stream flow records collected by the Bureau.

The disastrous floods which have visited Missouri, as well as this entire section of the country, during recent 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 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 17 additional gaging stations in the state. During the biennial period the sum of $13,900 for the support of these stations was contributed by the U. S. Army Engineers.

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 17 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 and of engineers to help make flow measurements during periods of high water.

The stream flow records collected by the Bureau have also been used during the biennial period by engineers, city officials, and the State Board of Health, in studies relating to municipal water supplies, sewage disposal, and stream pollution. The Bureau cooperated with the cities of Maryville, Springfield, and Joplin, in collecting records of flow of nearby streams for these purposes.

A wide public interest is being shown in the large springs of the State, and many requests are received for information regarding their flow. After three years of deficient rainfall, the flow of the springs, during the autumn of 1932, became the lowest that it has been in many years. The low flow is of primary interest to any one desiring to build a fish hatchery or a pleasure resort. For this reason the Bureau measured the flow of all the large springs of the State during this low period. The Bureau also cooperated with the State Game and Fish Department in determining the daily flow, throughout the biennial period, of four large springs in State parks—namely, Big, Alley, Round, and Bennett Springs.

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 $12,100 during the biennial period in order to assist the expansion of the work. This is exclusive of the funds contributed by the United States Geological Survey and the United States Army Engineers, and of the services furnished by the State Highway Department and State Game and Fish Department, as noted above. The following list gives the names of those who cooperated and the number of gaging stations each helped to maintain during a part, or the whole, of the biennial period:

Missouri Highway Department	18
Missouri Game and Fish Department	4
United States Army Engineers	17
United States Weather Bureau	5
Little River Drainage District	7
Empire District Electric Co	4
Union Electric Light and Power Co	5

Current River Power Co	3
Gasconade River Power Co	3
Missouri Electric Power Co	1
Willis H. Meredith	1
Springfield City Water Co	2
City of Maryville	1
City of Joplin	1
City of Springfield	1
Total	73

At the present time these agencies are cooperating in maintaining 54 of the 96 gaging stations.

APPROPRIATION REQUEST—1933-1934.

Under the present budget system the funds of this department are appropriated under four heads entitled (1) SALARIES, (2) EXPENSE, (3) NEW EQUIPMENT, (4) REPAIRS AND REPLACEMENTS. Each item represents the total request for all three branches of the Bureau.

The total request for operating the three branches of the department for the coming biennial period is $175,102 separated into the following amounts devoted to each branch:

Geology and Mining	$105,102
Topographic Mapping	50,000
Water Resources	20,000
	$175,102

Summarized under the budget system this amount is divided as follows under the four heads provided for by the budget:

Salaries	$108,770
Expense	59,712
New Equipment	1,395
Repairs and Replacements	5,225
	$175,102

The following tabulation indicates the divisions under which the appropriation is requested:

SALARIES:		
Personal Service:		
Geology and Mines	$58,770	
Topographic Mapping	35,000	
Water Resources	15,000	
		$108,770

EXPENSE:		
Operation:		
Communication	$1,312	
Printing and binding	22,900	
Transportation of things	1,100	
Travel:		
Geology and Mines	13,800	
Topographic Mapping	15,000	
Water Resources	5,000	
Cleaning and sanitation	100	
Miscellaneous supplies	500	
		$59,712
NEW EQUIPMENT:		
Operative equipment and laboratory supplies		1,395
REPAIRS AND REPLACEMENT:		
Scientific supplies	$1,900	
Office furniture and equipment	325	
Replacing 4 Ford cars, repairs on all cars, including tires, batteries, etc	3,000	
		5,225
TOTAL		$175,102

The work of the department is largely a matter of personal service and operating expenses. The request for the Geology and Mining Branch covers the salaries, expenses and office cost of the present permanent staff and temporary summer assistants employed during the present biennial period. No expansion in the working force is contemplated.

In the Geology and Mining branch it is planned to continue the investigations now under way. The study of the oil and gas possibilities in Northwest Missouri will be continued. The formations in which the present pools occur have not been prospected nor mapped north of the present productive areas. The formations in that region are buried deeper, and under proper structural conditions may develop important pools in entirely new territory. There are, no doubt, many additional structures in the region now producing.

Magnetic surveys have shown apparent important relations between ore deposits and geologic structures and the magnetic intensity, and it is planned to continue this work in other ore bearing fields. Work will also be continued in the Central Missouri iron ore district, and additional work will be done on the constitution of the diaspore clays, and a further study made of the plastic fire clay district of East Central Missouri. The investigations covering water supplies will be continued in co-

operation with the State Board of Health, and the general stratigraphic work in areas already under investigation will be continued.

The above lines of activity are a continuation of work already in progress. If funds are available many additional lines of economic investigation should be undertaken. This State is now producing some of the finest marble in the United States. The marble industry is an important one. Approximately one-half of the barytes produced in the United States in mined in Missouri. The tripoli industry in Newton County is unique in the Mississippi Valley. There are no reports covering the above mineral industries. There are still large areas of potential lead and zinc producing areas that have not been mapped in detailed.

Under expense the above total includes an item of $22,900 for printing reports and maps. During the last few biennial periods, funds have not been sufficient to provide for the publication of reports and maps that have been prepared, and there is now a number of volumes that should be made available to the public. One of the important factors in the matter of real service of the department is making the results of the field work available to the public, and in this regard the publication of its reports and maps is the most important avenue. The following is a list of the reports and maps that should be published during the coming biennial period:

Reports:	
58th Biennial Report, including appendices, or shorter geological reports	$2,000
Lawrence County, Geology of	1,500
Altenburg Quadrangle, Geology of	800
Water Resources Report	2,000
Platte County, Geology of	1,000
Green City—Queen City Quadrangles, Geology of	1,000
Mississippian System, Geology of	3,000
Maps:	
9 large scale geologic maps, Joplin district	5,000
9 county topographic maps	3,600
Platte County, geologic map of	2,000
Green City—Queen City Quadrangles, geologic map of	1,000
Total	$22,900

Continual requests for topographic maps in areas that have not yet been surveyed are being made. Only about one-fourth of the State has been covered by accurate maps. During

the present biennial period the U. S. Geological Survey matched dollar for dollar the State funds appropriated by the State Geological Survey and State Highway Department. If similar cooperation continues during the coming biennial period it is planned to continue making highway strips, map areas in Jackson and adjoining counties, and complete the mapping in St. Louis County.

The same amount has been requested for the Water Resources Branch as has been expended each biennial period during the last twelve years. This amount has been found to just about cover the State's proportion of the expenses in this branch of the work, and cannot be reduced without seriously injuring the continuity of the stream-gaging records. The U. S. Geological Survey will appropriate dollar for dollar the amount appropriated by the State. Corporations, individuals, and cities will add materially to this cooperative fund. It is estimated that practically $30,000 will be donated as cooperative funds against the $20,000 appropriated by the State. This means that the State provides but $2.00 of every $5.00 spent for this kind of work. The activities for the coming biennium will follow the work of previous bienniums in measuring the stream flow on the principal rivers of the State.

VALUE OF MINERAL PRODUCTION OF MISSOURI, 1923-1931.

Commodity.	1923	1924	1925	1926	1927	1928	1929	1930	1931
Lead concentrates	$19,692,318	$25,037,380	$32,112,009	$28,793,639	$23,636,893	$19,223,836	$21,130,453	$16,640,768	$9,898,703
Zinc concentrates	1,403,365	1,010,059	1,488,593	2,431,344	1,418,911	924,577	845,356	573,607	127,131
Coal	11,575,000	8,154,000	8,281,000	8,950,984	8,698,000	9,637,000	9,778,000	8,967,033	7,248,000
Clay products	18,509,937	16,826,511	18,544,117	18,259,171	17,225,214	16,073,334	15,319,000	13,212,081	7,010,925
Cement	13,237,141	13,515,267	14,155,795	12,917,342	11,117,047	12,367,018	11,557,905	11,470,751	5,052,840
Limestone	3,173,622	3,624,089	4,085,883	4,416,006	4,002,987	4,476,135	5,704,241	4,819,475	3,962,469
Marble	1,085,122	1,229,160	1,439,604	1,446,983	1,108,159	1,425,060	932,471	851,337	553,761
Sand and gravel	2,007,529	2,053,436	3,595,187	2,980,242	2,875,530	3,248,813	4,170,593	4,776,078	2,646,756
Lime	1,830,937	1,711,180	1,860,244	1,428,412	1,437,140	1,398,843	1,401,090	1,861,605	835,914
Lime hydrated	674,848	642,995	750,710	790,531	752,280	853,577	918,796	805,090	645,326
Clay	1,624,789	1,441,457	1,463,880	1,571,026	1,693,792	1,442,644	1,797,448	1,275,787	738,607
Chats	431,884	520,269	399,002	382,080	526,933	475,888	646,292	355,821	335,865
Barytes	629,097	604,390	749,927	946,595	797,465	810,203	880,319	938,812	539,152
Copper	29,776	23,948	1,718	150,780	59,081	9,360	394	22,958	.....
Mineral waters	38,145	30,000	32,000	41,955	29,452	(a)	(a)	20,025	(b)
Tripoli-Silica	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Iron ore	247,975	405,622	(a)	532,536	(a)	(a)	661,055	508,354	337,144
Granite	83,804	108,084	137,348	(a)	90,133	69,707	54,642	48,599	38,591
Silver	145,361	69,475	57,538	56,160	132,638	103,451	96,813	65,531	11,600
Sandstone	(a)	(b)	(b)	(b)	(b)	(a)	322,508	288,120	158,485
Natural gas	3,000	3,000	3,100	(b)	(b)	(b)	25,920	85,120	122,720
Pottery	94,985	95,936	77,090	56,684	69,849	(c)	(c)	(c)	(b)
Miscellaneous (a)	130,427	132,875	327,289	328,585	559,962	579,190	141,170	239,663	192,243
Totals	$76,649,062	$77,239,133	$89,562,034	$86,481,055	$76,231,465	$72,539,446	$76,384,466	$67,826,615	$40,456,232

(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 and J. G. GROHSKOPF.

The State of Missouri is one of the important mineral producers of the nation. It leads in the production of lead and barite and ranks high in the production of high grade fire clays; in fact, in this field, it is the only producer of high alumina or diaspore clay in the world. The State is also an important contributor to the nation's total output of cement, limestone, marble, sand and gravel, lime, coal, and tripoli, and has the only commercial deposits of granite in the central Mississippi Valley region. The gas pools of Western Missouri, although small in comparison with the larger pools of the Mid-continent region, are nevertheless becoming sources of fuel for many localities. Their development during the past two years has been one of the important features in the exploitation of the State's natural resources. An extensive development of the iron ores has also been under way during the past two years.

The table on the preceding page shows the value of the output of the mineral resources of the State. These figures have been collected in cooperation with the United States Bureau of Mines.

A summary of the important features in each branch of the State's mineral industry is given on succeeding pages, together with statistics covering the production and value of the output.

ASPHALTIC SANDSTONE.

During the past two years, the State Highway Commission has investigated the suitability of asphaltic sandstone for highway construction, and in this connection decided to build experimental sections on U. S. Highway No. 54 in Vernon County. As a result, a number of asphaltic sandstone deposits were opened by operators and the material was furnished for this project.

The deposits are of Pennsylvanian age and occur in the Clear Creek ("Bartlesville") sandstone, and in an overlying sandstone, which is possibly the "Red Fork" of Oklahoma. These sands are discussed in Appendix II of this report and their position in the geologic column is also indicated. The Clear

Creek sandstone, and the asphaltic sandstone industry in general have been described in the reports of this Bureau on the Geology of Vernon County, Volume XXI; The Occurrence of Oil and Gas in Missouri, Volume XVI, and The Sand and Gravel Deposits of Missouri, Volume XV.

C. E. Heinz and W. F. Netzeband have lately published a very interesting article: "The Missouri-Kansas Rock Asphalt Deposits", Roads and Streets, October, 1932. It covers the recent developments in detail.

The asphaltic material in Southwest Missouri occurs in sandstones composed of fine, angular grains, cemented with limestone, silica, or asphalt. Mica is invariably present and occurs disseminated throughout the rock, or segregated along the bedding planes.

The content of bitumen in the sandstones as described in the reports mentioned above varies greatly, and from place to place, within the same deposits. Locally, it may amount to as much as 14 per cent, or on the other hand, may be only a trace. In the deposits being worked the content averages about 6 per cent. The character of the bitumen is also variable, and locally may be a fairly light oil which oozes slowly from the rock, or it may be a hard black substance, formed, no doubt, from the evaporation of the more volatile constituents.

It is interesting to note that in the area to the north and west the asphalt-bearing sandstones produce gas and oil under favorable structural conditions. The role of anticlines and domes in the occurrence of asphaltic sandstone is not fully known, but it seems likely that the richest material will be found at or near the tops of such structural features.

Although deposits of sandstone predominate in this state, one deposit of asphaltic limestone is being worked near West Line, Cass County. The containing rock is an oolitic phase of the Bethany Falls limestone.

Complete figures covering the production for 1931 and 1932 are not available. The following companies, however, were producing this material during that time:

K. A. Spencer Company, Eldorado Springs, Cedar County.
Reliance Rock Asphalt Company, Ellis, Vernon County.
Universal Paving Company, Deerfield, Vernon County.
Mr. Belrose, Deerfield, Vernon County.
Barton County Rock Asphalt Company, Iantha, Barton County.

Missouri Asphalt Sales and Engineering Company, Iantha, Barton County.
Huffty Rock Asphalt Company, Liberal, Barton County.
Mr. Roudebush, West Line, Cass County.

BARITE.

The State of Missouri ranks first in the production of this important mineral. In 1930, a record total of 132,640 short tons valued at $938,812 was mined, and the output constituted 56 per cent of the total production of the nation. A decline was reported in 1931, but the total of 93,417 tons valued at $539,152 enabled the state to maintain its position in this branch of the mineral industry.

Statistics indicate that 90 per cent of the barite produced in the state comes from the Potosi district, located in northeastern Washington, northeastern St. Francois, and southwestern Jefferson counties. The mineral occurs in red surface clays overlying the cherty dolomites of the Potosi or Eminence formations. It is mined by hand from comparatively shallow holes, from which it is hoisted by hand-powered windlasses. It is generally coated with the red sticky clay in which it occurs. When mining has progressed to an extent in each separate hole that working conditions become unsafe, a second hole is started nearby. As a result of this method of mining, an area worked for barite soon becomes characterized by a series of holes, with accompanying mounds of red clay.

As much of the red clay is removed by hand as possible and the ore is then hauled to the nearest shipping point where it is sold for cash or exchanged for food, clothing or supplies.

Locally, large-scale operations are used in the district, the barite being mined with steam shovels, and separated from the red clay and chert by washing and milling. A plant for preparing the mineral for its various uses is in operation at Fountain Farm, near Cadet, and other plants for washing the clay from the mineral are also operated in the Potosi district.

The Potosi district has recently been covered in a report of the Bureau, Volume XXIII, from which detailed information regarding the geology, occurrence of the mineral, its method of preparation, and uses may be obtained.

Barite is also produced in Cole, Camden, Franklin, Hickory, Moniteau, Morgan, and Miller counties, the combined output of these counties in 1930 being about 10 per cent of the state pro-

duction. The mineral occurs in the same manner as in the Potosi district.

It is interesting to note that the production of barite in Missouri has increased from a total of 25,431 short tons valued at $85,624 in 1910 to 132,640 short tons valued at $938,812 in 1930.

The mineral has many uses: as an ingredient in pigments, as a filler in rubber, oil cloth, linoleum, and paper, in the chemical industry, and as a mud used in the drilling of oil and gas wells, where the rotary method is employed.

CEMENT.

This important material of construction is prepared from the burning of an intimate mixture of limestone and shale. The state has extensive deposits of these constituents, which are favorably located with respect to points of consumption and transportation facilities. At present five plants of considerable size are located near St. Louis, Kansas City, Hannibal, and Cape Girardeau, where satisfactory deposits of raw material are located.

In 1930, the total output of 8,030,528 barrels valued at $11,470,751 closely approached the record established in the year 1925. A decrease from those figures was reported for the year 1931, a total of 5,103,287 barrels being sold, the total value being $5,052,840. Missouri is one of the important producers of Cement in the Mississippi Valley and ranked eighth in total production, among the States of the union in 1930.

The Bureau has prepared a report covering this important resource, and a copy may be obtained upon application to the Director.

CLAY AND CLAY PRODUCTS.

In 1930, Missouri ranked third among the states in the production of clay, the output valued at $1,275,787 being exceded only by the production in Georgia and Pennsylvania. Production in Missouri in 1931 was valued at $738,607, the decline in value being also noted in the other states.

The extensive deposits of fire clay contribute by far the greatest percentage of the total. Plastic fire clay with a value of $873,000 in 1930 and $525,429 in 1931, lead the list of raw clays, from the standpoint of output. It is mined from the

Cheltenham seam, of Pennsylvanian age, which is widely distributed in east Central Missouri, and to a less extent in the St. Louis district.

The clay is plastic to semi-plastic in nature, and is well adapted to the manufacture of fire brick. It is mined and burned in a number of plants in the city of St. Louis, and in Audrain, Callaway and Montgomery counties in east central Missouri.

The hard, non-plastic flint fire clay is found chiefly in the north central Ozark region of southern Missouri, although other deposits are found scattered throughout east central Missouri, along the margins of the area underlain by the Cheltenham seam. In the area first mentioned, the flint fire clay occurs in sandstone-lined sink hole type deposits, the size of which varies considerably.

This clay is capable of withstanding temperatures, on the average, of about 3100° F, and is extensively used in the manufacture of high grade fire brick. The production of this type of clay was valued at $135,565 in 1930, and $80,709 in 1931.

An unusual clay, known as diaspore clay, is found associated with the flint fire clays in the deposits in the north central Ozark region. It is high in alumina content, the No. 1 grade averaging 70 per cent or more. This grade is low in silica and fluxing impurities. Diaspore clay when made into shapes and burned is used for many purposes where high heat resisting properties are desired. It also resists the action of certain slags. The most important use of diaspore refractories is probably in rotary cement and lime kilns.

In 1930, 6,947 tons of diaspore clay, valued at $42,500 were produced. There was a slight decrease in 1931, the total tonnage mined amounting to 5,899 tons, valued at $28,962. The decrease in value was due in a measure to the decrease in the price per ton.

The Bureau has published a map showing the distribution of the Cheltenham seam in east central Missouri, and the productive area of flint and diaspore clays in the north central Ozark region.

A microscopic study of the fire clays is now being conducted. The results are expected to furnish information regarding their mineralogical composition and the behavior of bricks made from these clays under the conditions of service.

The state also has a wealth of other clays. Outstanding among them are the dark colored, but light burning ball clays

of Butler County, from which chinaware, floor and wall tile, electric insulators and other high grade clay products are made. Deposits of white kaolin also occur in Bollinger County.

Deposits of shale, suitable for the manufacture of sewer pipe, face brick, common brick, hollow building tile, drain tile and terra cotta, are found throughout the Pennsylvanian System, which covers approximately 25,000 square miles.

The manufacture of various clay products in Missouri is related to the supply and character of the raw material. Fire clays, as previously indicated, are the most important of the clay resources, and fire brick the most important among the manufactured products. In 1930, the value of the output of fire brick amounted to $8,023,411 and in 1931 $3,771,927. The total value of clay products in these same years was $13,212,081 and $7,010,925, respectively.

COAL.

Missouri ranks fifteenth among the states of the union in the production of coal, and among the minerals produced within the state ranked second in 1931 and fourth in 1930. The output of this fuel in 1930 was 3,853,150 tons valued at $8,967,033, and in 1931 the output amounted to 3,620,497 tons valued at $7,248,000.

Coal production from the numerous beds of the state has been relatively consistent for the past few years. This indicates a stable and fixed consumption, and in general, shows that coal produced in Missouri has not suffered as greatly in competition with other fuels, as it has in other states.

Although the coal beds do not in general attain the thicknesses of those in some states, they are remarkably persistent, and extend from north central to southwest Missouri. Information regarding the position of the coals in the geologic column and their distribution below the surface will be found in Appendix II of this report.

In some counties of the state, workable beds of coal are found relatively close to the surface and as a result, a considerable tonnage is now being obtained from strip pits. The overburden of clay and rock is removed with steam shovels of large capacity, and the coal is likewise loaded with smaller shovels. This method of mining is extensively employed in Barton, Bates, Vernon, and Henry counties.

In value of production for 1931, the largest coal producing counties in order of rank are Barton, Bates, Lafayette, Henry, Ray, Macon, Randolph, Adair and Clay counties, which produced, in 1931, coal with a total value of $6,220,000 or slightly more than 90 per cent of the state total.

Other coal producing counties in 1930 and 1931 were Audrain, Boone, Callaway, Caldwell, Cedar, Chariton, Dade, Franklin, Grundy, Harrison, Howard, Jasper, Johnson, Linn, Monroe, Platte, Putnam, Ralls, Schuyler, and Vernon.

COPPER, COBALT AND NICKEL.

In 1930, copper, with a value of $22,958 was produced in this state. The metal was derived from the matte recovered in the smelting of lead concentrates produced in Southeast Missouri.

Copper is known to occur at the Cornwall group of mines in Ste. Genevieve County and at several localities in Shannon County. No production from these mines has been reported in 1930 and 1931. The deposits are interesting from a geological standpoint and descriptions of them have been published in the reports of this Bureau.

During the past two years, there has been no production of cobalt and nickel from the mineralized areas near Fredericktown, Madison County.

IRON ORES.

There has been more development and interest in the deposits of iron ores in 1931 and the early part of 1932, than in any other branch of the state's metallic mineral resources. This activity resulted from the demand by the blast furnace in East St. Louis for softer and less refractory ores.

Although no new records have been established from a production standpoint, the value of the output, $508,354 in 1930 and $337,144 in 1931 is interesting, due to the fact that the largest producer, the Iron Mountain specular hematite mine, was shut down during this period.

Mining activities were concentrated on the filled sink deposits of the central Ozark region from which red hematite, and a small tonnage of blue hematite were produced, and on the limonites, or brown iron ores, which occur in residual clays in many counties in the southeastern Ozark region.

During this period the Survey has actively assisted in the development work, by giving advice in the field and office, and in making geological and geophysical studies. A report covering the last mentioned is given as an appendix in this publication.

Production is reported from 20 counties in the state, and in most of them several mines were operated. Limonite was produced in Bollinger, Butler, Carter, Gasconade, Howell, Madison, Oregon, Osage, Pulaski, Reynolds, Ripley, Shannon, and Wayne counties. Red hematite was mined in Crawford, Dent, Franklin, Iron, Madison, Phelps, St. Francois, and Texas counties.

In September, 1932, the blast furnace in East St. Louis, which consumes all of the Iron ore produced in Missouri, was shut down, thus closing the producing mines.

No recent reports covering the iron deposits have been published by the Bureau. Considerable information has been obtained, however, as the result of field studies and it is available for study at the Bureau office.

LEAD.

The disseminated lead deposits of the Flat-River-Bonne-Terre District are the largest contributors to the total mineral wealth of the state. These deposits are likewise a dominant factor in the production of lead in the United States, as a whole, and in 1930 produced 36 per cent of the nation's total.

The lead bearing mineral is chiefly galena or lead sulphide, which occurs as disseminated particles in the dark colored Bonneterre dolomite of Upper Cambrian age. The lead carries silver, in the proportion of one fine ounce per ton, and some copper, both of which are recovered in refining operations. Zinc sulphide is an associated mineral in some parts of the district.

The lead-zinc deposits of the Joplin District also contributed to the state's total production of lead. In this district the ore is found in cherty limestone of Mississippian age. Galena and lead carbonate are both mined.

The total value of lead concentrates produced in the years 1930 and 1931 is indicated by the table on the following page:

VALUE OF PRODUCTION OF CONCENTRATES, 1930-1931.

	1930.	1931.
Southeast Missouri (galena)	$16,558,920	$9,833,045
Joplin district (galena and lead carbonate)	81,848	65,856
	$16,640,768	$9,898,703

In southeast Missouri the ore carried 4.15 per cent and 4.36 per cent galena concentrates per ton of crude ore, in 1930 and 1931 respectively. The per cent lead in the crude ore for the two years average 3.14 per cent, and the average metallic content of lead was 73 and 72.4 per cent. Average value per ton of concentrates ranged from $59.60 in 1930 to $43.93 in 1931.

The total short tons of metallic lead produced in 1930 was 199,632, valued at $19,963,200. In 1931, 160,121 short tons were produced, the value being $11,848,954.

LIME.

Deposits of high grade limestone suitable for burning into lime are located in many parts of the state. The largest producing district at this time is located at Ste. Genevieve, where the oolitic Spergen limestone occurs extensively. Plants are also located at Springfield, Ash Grove, Galloway, Osceola, Pierce City and Hannibal, where the Burlington limestone is extensively developed, and at Mincke and Glencoe where the Ordovician Kimmswick limestone is available.

In 1930, the total value of the output of lime amounted to $1,861,605 and in 1931, the output was valued at $1,481,240.

The bulk of the lime produced in this state has a high calcium content, and is used for many purposes. The chief uses are in the building and chemical industries, which consumed lime with a value of $1,133,024 in 1930 and $885,527 in 1931.

The product is also used extensively in the treatment of surface water supplies, and as a flux in the metallurgical industry. A small portion of the output is consumed annually by paper mills, tanneries, and other industries.

MINERAL WATERS.

The State of Missouri is noted for its mineral waters, the two chief centers being Excelsior Springs in Clay County and Eldorado Springs in Cedar County as shown by the Bureaus' list of producers. Mineral waters are also available from springs or deep wells near Seligman, Barry County; Chouteau Springs, Cooper County; De Soto, Jefferson County; Kansas City, Jackson County; Princeton, Mercer County; Bowling Green, Pike County; St. Louis, City and County, and Sweet Springs, Saline County. There are also other mineral springs scattered over the entire state.

Accurate figures covering the production of mineral waters are not available. The lack of this information is due in part to the fact that considerable quantities are consumed locally, and therefore it is difficult to determine the actual amount and value. Complete figures covering the production and value are not kept by some producers but a total state wide production of over $20,000 was reported in 1930.

GAS AND OIL.

During the past few years, the gas and oil resources of the state have been more actively explored than any other branch of the mineral industry.

In the western part of the state gas and oil are being obtained at shallow depths, and appendices to this report describe the occurence of these fuels in detail. The interest shown in oil and gas has led to considerable field work by this Bureau, and attention is being given to other areas that, in the future, may possibly add to the total annual output.

Although the available figures do not indicate a large production, they do show an increase from 324,000,000 cubic feet, with a value of $25,920 in 1929 to 1,534,000,000 cubic feet with a value of $122,720 in 1931.

Figures covering the production of oil are not complete, but oil used for fuel is being obtained from shallow wells in Jackson and Cass counties.

PYRITE AND MARCASITE.

Since the close of the World War, there has been no production of iron sulphide in this state until 1932.

With the curtailed production of zinc, and the smelting thereof, there has been a demand for sulphur gas, which was recovered in the roasting of zinc sulphide. As a result of this demand, there has been increased activity in the development of new or previously known deposits of these iron sulphides in the Ozark region.

The mineral is found in the lower portion of filled-sink structures and in association with iron ores. Field studies by this Bureau have furnished information relative to these deposits and as a result, the pyrite in the Ruepple Mine, near Stanton, Franklin County, is now being mined. Drilling has also been done at other deposits, the Cherry-Valley Mine, being an example.

SAND AND GRAVEL.

In 1930, the production of sand and gravel reached a record total of 5,956,766 short tons, valued at $4,776,078. The figures for 1931 show a decline, the total output being reported at 4,807,626 short tons, valued at $2,646,756.

The deposits of sand and gravel in Missouri are extensive and the output of each is used for a number of purposes. The largest quantity of both materials is used in paving, with the building industry consuming the next largest amount. A considerable tonnage is also used annually for railroad ballast. Various types of sand suitable for molding, engine, cutting and grinding, and glass are available from the St. Peter sandstone which outcrops in the eastern part of the state. The most extensive deposits of sand and gravel are found in the stream valleys of the Ozark region, and in this area, particularly near the larger towns and cities, large quantities of each material are dredged annually.

The development of the State Highway system has added materially to the consumption, and in the future considerable quantities of gravel will be used locally, in the completion of the farm-to-market road system.

An exhaustive report describing the sand and gravel deposits of Missouri has been issued by this Bureau.

SILVER.

The lead concentrates from the disseminated deposits of Southeast Missouri carry on the average, about one ounce of silver per ton. This is recovered in the lead refining process and

each year, the total amounts to several thousand dollars. In 1930, 170,120 fine ounces with a value of $65,531 were recovered, and in 1931 the output was 40,000 fine ounces, the value being $11,600.

Silver has also been produced from the Einstein Mine in Madison County. This deposit is one of the most interesting in the entire Mississippi Valley Region and is described in detail in Appendix I of this Biennial Report.

STONE.

Deposits of limestone, marble, granite and sandstone occur within the borders of Missouri, and constitute an important part of the state's natural resources, and the output, in 1931, valued at $6,426,157 ranked fifth in the list of the minerals produced. In 1931, the output of stone was valued at $5,103,261 which entitled this industry to rank fourth in the state's mineral production.

Each branch of the stone producing industry is discussed on succeeding pages.

LIMESTONE.

Deposits of limestone are widely distributed throughout the state, and the production of this important material dominates the total production of the stone industry.

Limestone is used for many purposes, but chiefly in general construction. Its use in road making and in riprap also consumes a large proportion of the rock quarried. It is used to a less extent for rubble, railroad ballast, rough construction, as a flux, in glass factories, for agricultural purposes, in sugar refining, for whiting, and as a filler in rubber and paint.

In 1930, the value of the output was reported to be $4,819,475. Of this sum, a total production of $2,694,023 was used in highway, building and general construction; it was also used for riprap; and river improvement, chiefly on the Mississippi and Missouri rivers, increasing the value of the output by the sum of $1,806,529.

MARBLE.

The limestones of Devonian and Mississippian age annually contribute to the mineral wealth of the state. The quarry near Ozora, Ste. Genevieve county, obtains stone from the Devonian

limestone formation and the product is used extensively in the interiors of many large buildings of the country. The marble from the Mississippian limestones is quarried extensively near Carthage, Joplin, and Phenix and is used in exterior and interior work in several outstanding buildings.

The output of marble in 1930 was reported to be 607,384 cubic feet, valued at $851,337. In 1931, 217,570 cubic feet were produced, the total value being $553,761.

GRANITE.

The familiar granite of the St. Francois Mountain region of Southeast Missouri forms the only commercial deposits of this rock in the Mississippi Valley. It is extensively quarried near Graniteville, Iron County, and is used for rough and dressed monumental stone, for rough architectural granite, for rough construction, as paving blocks, for riprap and as an aggregate in concrete.

The deposits of granite in the state have been described in a publication of the Bureau, and additional information will be found in Appendix I of this report.

In 1930, the total value of the granite production was $48,-599, and in 1931, the value of the output was $38,591.

CHATS.

The waste material produced in the milling of zinc and lead ores is known as chats. In the disseminated lead district of southeast Missouri, the chat is dolomite, and is used primarily for railroad ballast, agricultural purposes, and in road making. The waste material of the Joplin district is flint or chert, and is is used for railroad ballast, road making and in construction. Although a by-product, the value of production attains a respectable figure, as a total value of $355,821 in 1930, and $335,865 in 1931 will attest.

SANDSTONE.

In recent years there has been an increased production in this branch of the stone industry. The chief use has been for riprap, used on the Mississippi River, in the general construction program of the Corps of Engineers, United States Army.

The output was valued at $288,120 in 1930 and $158,485 in 1931.

TRIPOLI.

The principal deposits of this siliceous material are located near Seneca, Newton County. The tripoli of this district varies from a very porous to dense, hard, rock-like material. It occurs at or near the surface, and appears to have been formed by the solution of very siliceous limestone.

The material is ground in plants located at Seneca and Carthage and is used for foundry facings, in the glass, paint and rubber industries, and in the manufacture of pottery and enamels. The material is a natural abrasive and is used in polishing and cleansing compounds.

As there are less than three producers of tripoli in this state, the statistics of production cannot be revealed and the total value is concealed under the heading "Miscellaneous" in the table accompanying this chapter.

ZINC.

Zinc ores occur in the Joplin district of Southwest Missouri, and in the disseminated deposits of Southeast Missouri. The total value of the state's production in 1930 was $573,607, and $127,131 in 1931.

In the area first mentioned 11,172 short tons of sphalerite, zinc sulphide, and 1,696 tons of zinc silicate and carbonate were mined in 1930; the total value being $415,491. In Southeast Missouri 8,411 short tons were produced, the value being $158,-116.

The largest production of zinc in the Joplin district in 1930 came from the Waco Camp, with the area contiguous to Joplin ranking second. Production was also reported from Aurora, Granby, Oronogo and the Spring City-Spurgeon camp.

In 1931, production of sphalerite was reported from the Waco, Granby, Carl Junction, Wentworth-Stotts City, Joplin and Oronogo Camps. The total value was $79,371.

Sphalerite, with a value of $43,000 was produced in Southeast Missouri. Small amounts of silicate and carbonate areas were also mined in the southwest Missouri camps, which, with the production mentioned above, gave the total state output a value of $127,131 for zinc concentrates for 1931.

The available figures indicate a total of 328,8
of crude ore were hoisted in Southwest Missouri

104,800 short tons in 1931. The per cent of zinc concentrates in the crude ore was 3.89 per cent and 3.76 per cent in 1930 and 1931, respectively.

The metal content was 2.25 per cent and 2.15 per cent respectively in the same years. The average zinc content of the sphalerite concentrates was 60 per cent and 58.6 per cent.

In 1930, 10,811 short tons of metallic zinc were produced in the state with a total value of $1,037,856, and in 1931, 3,205 short tons with a value of $243,580 were reported.

It is interesting to note that many miners have been digging ore on a small scale in some of the mines of the district. The outlay for this type of mining is small and the returns provide the necessities of life.

FINANCIAL STATEMENT FOR 1931-1932—GEOLOGY.

1931.

H. A. Buehler	$5,939.43
H. S. McQueen	4,340.92
Jos. M. Thiel	3,386.36
C. O. Reinoehl	1,886.30
R. T. Rolufs	1,510.00
W. H. Wamsley	302.42
Office	1,970.69
Dorothy Shaver	900.00
E. E. Hawkins	1,321.00
J. G. Grohskopf	1,302.69
F. H. Farnham	400.81
W. Farrar	1,089.00
J. S. Cullison	500.92
C. L. Dake	609.41
Carl Tolman	941.91
C. D. Gleason	933.03
Student Labor	354.90
Jean I. McCaw	1,500.00
B. H. Rucker	175.30
A. A. Smith, Postmaster	300.00
E. M. Shepard	76.77
W. E. McCourt	12.75
Charles T. Orr	58.96
American Askania Corporation	133.70
Clara Redmond	50.00
Woodworth Motor Co	352.20
Rolla Motor Co	494.70
Ruth Glass Co	124.00
A. Daigger & Co	117.00
A. S. Aloe & Co	150.55
Bemis Bro. Bag Co	85.04
Botz Printing & Stationery Co	206.96
K. Jones Motor Co	483.61
Fred Wilhelm	229.50
E. B. Branson	79.20
Gypsy Oil Co	50.00
Total	$32,370.13

FINANCIAL STATEMENT FOR 1931-1932—Continued.

1932.*

H. A. Buehler	$5,740.48
H. S. McQueen	4,499.83
Jos. M. Thiel	750.00
C. O. Reinoehl	2,742.45
R. T. Rolufs	1,068.66
Office	1,172.85
Dorothy Shaver	900.00
E. E. Hawkins	1,320.00
J. G. Grohskopf	2,513.14
W. Farrar	1,661.51
J. S. Cullison	751.73
C. L. Dake	796.01
Carl Tolman	865.05
C. D. Gleason	2,151.71
Student Labor	958.20
Jean I. McCaw	1,570.10
A. A. Smith, Postmaster	348.60
E. M. Shepard	83.27
Walter McCourt	17.20
Charles T. Orr	130.24
Ruth Glass Co	181.20
A. S. Aloe & Co	150.00
Bemis Bro. Bag Co	110.25
Botz Printing & Stationery Co	285.32
Fred Wilhelm	36.00
Keuffel & Esser Co	75.31
Firestone Tire & Rubber Co	242.40
F. C. Greene	2,199.28
Victor T. Allen	300.00
M. G. Handly	340.00
Wm. A. Brown	339.99
F. J. McCaw	357.40
Mo. School of Mines & Metallurgy	37.00
Blackwell-Wielandy Company	89.50
Underwood Elliott Fisher Co	57.55
Heil Corporation	34.78
B. R. Thompson	747.45
Jones Motor Co	395.00
Glenn G. Bartle	83.61
Spencer Lens Co	165.82
Mound City Engraving Co	370.53
Robert B. Wing	100.00
Total	$36,739.42

*Geology in 1932 chargeable with cost of publication of 57th Biennial Report, now in the hands of the State printer. Estimated cost, $1,504.00.

FINANCIAL STATEMENT FOR 1931-32—WATER RESOURCES.

1931.

H. C. Beckman	$739.10
Student Labor	401.85
R. D. Schmickle	239.89
C. H. Jennings	1,198.85
J. T. Sturm	303.33
W. A. Brown	58.45
Gage Readers	532.00
Total	$3,473.47

1932.

H. C. Beckman	$1,834.48
Student Labor	1,021.61
C. H. Jennings	1,947.93
J. T. Sturm	73.33
H. C. Bolon	147.07
G. H. Musson	356.67
C. J. Eyberg	29.27
Gage Readers	834.00
Total	$6,244.36

FINANCIAL STATEMENT FOR 1931-1932—TOPOGRAPHY.

1931.

T. V. Cummins	$575.79
E. J. Fennell	317.52
F. W. Hughes	1,045.97
D. W. Weber	914.73
M. J. Harden	447.97
S. T. Penick	181.72
H. F. Leo	12.35
C. A. Killian	228.53
F. L. Whaley	197.14
L. V. Johnson	423.65
W. R. Broaddus	1,093.38
A. W. Plushnick	200.07
C. L. Sadler	432.69
G. T. Hawkins	226.67
F. J. McMaugh	110.00
E. L. McNair	151.11
E. W. Gouchenour	491.79
Geo. W. Moore	671.46
H. S. Milsted	448.44
Daniel Kennedy	210.85
C. W. Birdseye	92.33
Total	$8,474.16

FINANCIAL STATEMENT FOR 1931-1932—Continued.

1932.

J. L. Sanders	$157.50
E. W. Tibbott	202.22
W. H. S. Morey	133.33
F. W. Hughes	1,594.38
C. L. Sadler	1,429.72
F. L. Whaley	1,264.07
J. C. Hilliard	100.83
G. E. Sisson	325.83
H. A. Bean	27.50
E. J. Essick	7.78
W. R. Broaddus	4,485.17
Chas. E. Reick	950.27
Fred Graff, Jr	175.00
R. L. McCammon	133.33
A. J. Ogle	145.83
H. S. Senseney	141.67
H. S. Milsted	1,001.67
J. M. Rawls	751.68
J. A. Shumate	443.65
J. B. Leavitt	278.28
S. T. Penick	395.92
J. A. Holman	155.83
Daniel Kennedy	594.25
L. V. Johnson	667.68
M. J. Harden	22.20
R. O. Davis	562.49
J. B. Leachman	59.04
H. F. Leo	229.80
Total	$16,436.92