MISSOURI

GEOLOGICAL SURVEY

VOLUME VIII

ANNUAL REPORT FOR 1894

BY

CHARLES R. KEYES

STATE GEOLOGIST

WITH

ACCOMPANYING PAPERS

JEFFERSON CITY:
TRIBUNE PRINTING COMPANY, STATE PRINTERS AND BINDERS,
1895.

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LETTER OF TRANSMITTAL.

MISSOURI GEOLOGICAL SURVEY,
JEFFERSON CITY, Dec. 31, 1894.

To the President, Governor William J. Stone, and the Members of Board of Managers, Bureau of Geology and Mines:

GENTLEMEN—In accordance with the provisions of the law under which the Geological Survey of Missouri was organized, I have the honor to submit to you a report of the work done under my direction during the past year. In connection with this statement I have also given a concise summary of the status of all operations carried on since the establishment of the survey, the work now in progress and the investigations yet necessary in order to finish a complete geological survey of the State. It is essentially the biennial report of the bureau. Accompanying this are several memoirs by different members of the geological corps.

Your obedient servant,

CHARLES ROLLIN KEYES,
State Geologist.

CONTENTS.

List of Illustrations.

ORGANIZATION AND RESULTS

OF A

STATE GEOLOGICAL SURVEY

EMBRACING THE

Third Biennial Report of the State Geologist

BY

CHARLES ROLLIN KEYES

ORGANIZATION AND RESULTS

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SYNOPSIS.

INTRODUCTORY.

Among the states of the great Mississippi valley, Missouri ranks first in the value of mineral products. The reason of her high position lies not altogether in the fact that the respective ranks of the several states are according to the real worth of the mineral resources contained, but rather in the fact that Missouri first offered encouragement to the development of her natural wealth. With early foresight she began a systematic investigation of what Nature had endowed her with. Although short-lived, the result of the inquiry did more, perhaps, than any other one factor to set before the world all her latent riches. The great material development which the State has undergone dates from this time. The people of the Missourian commonwealth can never appreciate too highly the fruit of this first attempt to carry on a systematic survey of the State's domain. How fully, incomplete as the work was, it furthered the material betterment of the State, every citizen knows. The answers given then by the state geologist to the question, How will the geological survey aid us? are as true today as they were forty years ago:

"If properly conducted, it cannot fail to develop the mineral resources of our State, and place our mining interests on a more permanent basis, by inviting capital, and by securing systematic and profitable operations.

"It will increase our mechanical and manufacturing interests, by pointing out the raw materials and the facilities for converting them into articles for domestic and foreign trade.

"Agriculture will be advanced by investigating the structure and the chemical properties of the soils, as the results will enable us to determine the modes of culture necessary to sustain and even increase the productive energies.

"Commerce will also receive a new impulse, from the increased products of the farm, the mine and the work-shop

"Should the survey be made with minuteness to point out the soils of each township, the facilities for settling and the great prosperity of our agricultural communities, the reports would attract thousands of those who are yearly seeking homes in this great valley. The increase of our yeoman population and tax-payers thus secured, would soon be felt in the financial and political resources of the State.

"The development of the mineral and agricultural resources will so enhance the value of land in the State as to make an aggregate increase of a vast amount."

The same sentiment is echoed in a recent editorial, which appeared in one of the leading and most progressive of newspapers; while it is further added:

"Our artesian waters will be thoroughly understood, so that anyone in the province by simple calculations may determine within a few feet how far he will have to bore to obtain good water, and how much of a flow he will secure.

"The water-powers of every stream will be definitely known, and the conversion of this energy into electricity will eventually give us light and heat for the whole region.

"New coal fields cannot fail to develop, and the limits of the present ones will be definitely made out, so that the great sums of money now annually expended uselessly in vain searches for this mineral in portions of the State where it cannot possibly occur, may be saved and turned into more productive channels.

"Our building stones will be thoroughly tested and carefully located, for without the slightest doubt, Missouri has as good building stones as can be found in this country.

"The clay industry will receive a great impetus. Instead of importing large quantities of brick and other clay products, we would be exporting greater quantities to all the neighboring districts. The aluminum clays would also receive careful attention.

"Who can estimate the increased value of the land in the state when all the natural wealth has been pointed out. If we can judge at all from our neighboring states there is little doubt that a systematic investigation, such as is suggested, would greatly increase the value of the lands over large tracts, amounting to many times the expenditure."

OBJECT OF THE GEOLOGICAL SURVEY.

To Missourians, it is entirely unnecessary to go into details regarding the benefits to be derived from an economic geological survey. It is enough to know the favor everywhere with which the work has been received, and that the neighboring states are following the example set and are establishing similar institutions. But there are several points which cannot be too frequently emphasized.

It is one of the most universal practices for a keen business man or a prosperous merchant, when he wishes to know exactly how his affairs stand, to take an inventory of his possessions. A state, in establishing a geological survey, has also in mind an inventory of her possessions: that is, of her natural products, all of those mineral substances which may be made to serve useful purposes. But a geological survey is much more than a simple inventory—a mere taking account of stock. It not only lists the various minerals, but locates them accurately, investigates their qualities, extent and accessibility, notes their particular uses and value, and suggests improvements in the methods of obtaining and treating them for commercial purposes. In order that the information may be readily and accurately interpreted, the determinations and facts are recorded and explained on suitable maps or in the descriptive notes which accompany them.

But the direct purpose and scope of the work is often misunderstood, for in the establishment of the Geological Survey it was manifestly not the intent of legislators, as many persons suppose, to replace, by State work, individual testing and investigating, but rather to encourage and supplement personal efforts, and thereby greatly lessen the chances of failure.

Through the work of a completed geological survey there may be mentioned, among the general objects to be attained for the State:

1. The provision of a suitable foundation for detailed and intelligent search for mineral wealth. One of the chief benefits resulting from this work is the limitation of different mineral-bearing areas in which prospecting may be profitably undertaken. The necessity of this course has appeared all the more urgent as the work of the Survey has progressed. It may be a matter of considerable surprise to learn that carefully made estimates show that more money has often been wasted in many counties in a single year, through ill advised and poorly conducted efforts to discover coal and other minerals, than would annually support a systematic investigation of the entire State. Numberless abandoned diggings are met with, most of which mark fruitless efforts to obtain minerals in places where success is as utterly hopeless as could be imagined. All this useless expenditure of capital and labor might have been largely avoided, had some authoritative information concerning the geological features of the particular localities been accessible.

2. The assurance of permanency in the development of resources already known. Means are provided beforehand by which, without encountering repeated failures and inconveniences, each one may know how to turn his discoveries to best account, how to work the deposits to the best advantage, and how to prepare the product in the most suitable manner for market. The properties of the different substances and the uses to which they may be put having been determined in a practical way, the further advancement of the dependent industries is greatly simplified. On the completion of the work on any subject, all information possible is brought together, so that when a person engages in any mining enterprise or business connected with the natural resources of the region, he can hardly fail to find in the particular report something which will greatly assist him in his efforts, and prevent a useless waste of time and money.

3. The establishment of an official guaranty respecting the natural wealth of the State. Information given by disinterested persons concerning the State's possessions is always regarded as more trustworthy than when imparted by private individuals. Citizens at home, as well as abroad, have confidence in making investments, and feel that they are not entering into mere speculative fields.

4. The formation, on a scientific basis, of a standard by which the geological features of the region may be compared with those of other districts. There is a wide demand for something of this kind for purposes of instruction in schools and colleges. Text-books commonly used consider only the principles of science; the reports of the Survey supplement this outline by giving detailed information of local application.

5. An advancement of agricultural interests. This is more fully considered elsewhere under the subject of soils.

PREVIOUS WORK.

Owen's geological reconnoissance of the upper Mississippi valley in the later forties, under the auspices of the Federal government, gave to the world the first scientific account of the mineral wealth of the region. A year after the appearance of the report, Missouri instituted a special investigation of her natural resources. This geological survey of the domain was begun under favorable conditions, and the grand results of the first years of its existence in pointing out to the civilized nations of the globe the great mineral wealth of the State are known to all. But before the work had been fairly begun, unforeseen circumstances of national import arose, causing a cessation of operations for more than a decade. Reorganized in 1870, work was commenced anew, but owing to the calls one after another of the directing spirits to other fields of action, investigations were again given up after a few years. Nearly fifteen years elapsed before the geological survey of the State was again renewed in the present organization. Although up to the time of the last revival of official geological work in the State the existence of the survey had been fitful, it was not without invaluable results; how much more valuable might they have been had it been conducted under favorable conditions and without embarrassment can only be conjectured. Yet, owing to so interrupted a career, it is safe to say that not less than three-fourths of the information obtained had been practically lost to the public. Dear experience, then, not only in this State but in other states as well, has taught that a temporary survey is money largely expended in vain; that if it cannot be carried to completion, the investigation should never have been commenced; that being established and so well begun, it should be liberally encouraged to completion, that its results may endure for all time to the advancement of the State.

ORGANIZATION OF THE GEOLOGICAL SURVEY OF MISSOURI.

Six years ago the people of Missouri, through their representatives in the General Assembly, authorized the completion of the geological survey of the State. It is doubtful whether Missouri has, at any other period of her history, felt more the need of a thorough economic investigation of her native wealth. The survey contemplated was not an investigation such as was vaguely conceived by many, but one broad in its scope and far-reaching in its workings—one whose primary aim was to bring before the public the State's natural products, to encourage her material development, and to invite the investment of outside capital. Indeed, it had long been a matter of general regret that a commonwealth so happily supplied with boundless natural riches should have so little official information concerning them, to which either her citizens or the public at large could turn.

The requirements of the work are clearly set forth in

AN ACT TO PROVIDE FOR A BUREAU OF GEOLOGY AND MINES TO COMPLETE A GEOLOGICAL AND MINERALOGICAL SURVEY OF THE STATE OF MISSOURI.

Be it enacted by the General Assembly of the State of Missouri, as follows:

SECTION 1. There is hereby created and established a bureau of geology and mines for the state of Missouri, which shall be under the direction and in charge of a board of managers, which shall consist of the governor, who shall be *ex officio* president of the board, and four citizens from the state at large, who shall be appointed by the governor, by and with the consent of the senate, and shall hold their term of office four years.

SEC. 2. The board of managers are authorized, as soon as they are organized, to appoint one state geologist, who shall be a person of competent, scientific and practical knowledge of the sciences of geology and mineralogy, and who is not connected with any school or college as instructor, who shall be the director of the survey; and said geologist may appoint such assistants and subordinates, assistants and laborers as may be deemed necessary in order to make a thorough scientific, geological and mineralogical survey of the state.

SEC. 3. It shall be the duty of the state geologist and his assistants, under the instruction and direction of the board of managers, to carry on, with as much expedition and dispatch as may be consistent with minuteness and accuracy, a thorough geological and mineralogical survey of the state already begun, with a view to determine the order, succession, arrangement, relative position, dip or inclination and comparative magnitude of the several strata or geological formations within the state, and to discover and examine all beds or deposits of mineral contents and fossils, and to determine the various positions, formation and arrangement of the many different ores, clays, rocks, coals, mineral oils, natural gas, mineral and artesian waters and other mineral substances as may be useful or valuable; also to note carefully the character of the soils and their capacities for agricultural purposes, the growth of timber and other scientific matters that may be of practical importance and interest; and said geologist shall cause to be represented on the map of the state, by colors and other appropriate means, the various areas occupied by the different geological formations in the state, and to mark thereon the localities of the respective beds or deposits of the various mineral substances, and, on the completion of the survey, to complete a memoir of the geology and mineralogy of the state, comprising a complete account of the leading subjects and discoveries which have been embraced in the survey.

SEC. 4. It shall be the duty of the state geologist to make, or cause to be made, detailed maps and reports of counties or districts as fast as completed, which maps shall embrace all such geological, mineralogical and scientific details necessary to make complete reports of said districts or counties. The state geologist may also, from time to time, publish or cause to be published any reports of work completed, in the form of pamphlet or bulletins for general distribution.

SEC. 5. It shall be the duty of the state geologist to collect full suites of all minerals, rocks, ores, fossils or other mineral substances of scientific or practical interest or utility as may be discovered, and that may be necessary to form a complete cabinet collection, to illustrate the various resources of the state, as may be necessary to assist in preparing the various reports of the survey.

SEC. 6. It shall be the duty of said assistants to make full and comple examinations, assays and analyses of all such rocks, ores, soils or other substances as may be submitted to them by the state geologist for the purpose, and to furnish him with a detailed and complete account of the results so obtained.

SEC. 7. The state geologist, from time to time, may furnish items of general information or new discoveries for publication in newspapers: Provided, the preparation of the manuscript and publication thereof does not interfere with the progress or add to the expense of the survey; he may also have authority to furnish cabinets for colleges or public museums, located within the state of Missouri, of minerals, rocks or fossils: Provided, said institutions shall pay the expense of prepairing, labeling, transporting and putting up said collection; and also, further, that in the selection of said specimens the general state collection is not deprived of duplicates of the same, and that the state collection is not seriously injured.

SEC. 8. The board, with the state geologist, may determine the place for the state cabinet and headquarters of the survey.

SEC. 9. It shall be the duty of the board of managers to report to each general assembly the progress and condition of the survey, an accurate account of money spent, and such reports of the state geologist and his assistants as have been completed, together with all such information as may be deemed necessary and useful.

SEC. 10. The board shall have power to take possession of all property of former surveys, whether reports, maps, collections, instruments or other property belonging to the state, and all persons now in possession of the same shall deliver them up to the order of the president of the board of managers: Provided, that no cabinet or library already arranged shall be removed, but the state geologist and his assistants shall have the power at any time to examine or study such collections in prepairing their reports.

SEC. 11. The board may make such by-laws and regulations for the government and control of its meetings and labors of the state geologist and his assistants as may be deemed necessary.

SEC. 12. As full compensation for the members of the board of managers, they shall be allowed their necessary expenses while attending to the duties assigned them by this act. The board shall fix the salary of the state geologist, not to exceed three thousand dollars per annum, and his chief assistant, which shall not exceed one thousand eight hundred dollars per annum; for the principal assistant or palæontologist, if one is employed, not over one thousand eight hundred dollars.

SEC. 13. The state geologist may, with approval of the board, appoint other necessary assistants, whose pay shall not exceed five dollars per day, and such other necessary laborers or assistants as may be necessary, who shall receive a fair compensation for their work. He shall also have power to negotiate for such chemical work, chemical apparatus and chemicals as may be necessary, and may, from time to time, with the approval of the board, have such work done. He may also, with the approval of the board, employ special assistants in palæontology, provided it be deemed necessary.

SEC. 14. All accounts of salaries and expenses shall be made under oath, and certified by the board, and filed with the auditor of the state.

SEC. 15. The board of managers shall have the general management of the survey, and have full power to remove the state geologist and appoint his successor, when deemed necessary for the good of the work entrusted to him; and the state geologist shall have full control over his assistants, and have power to remove them when necessary.

SEC. 16. For the purpose of carrying out the provisions of this act, the sum of twenty thousand dollars is hereby appropriated, or so much as may be needed thereof.

SEC. 17. The board of managers, the state geologist and each of his principal assistants shall, before entering upon the discharge of their duties, take the usual oath of office to faithfully perform all the services required of them under this act, and to abstain from all pecuniary speculations for themselves or others in the objects of their survey during its progress.

SEC. 18 The president of the board shall, from time to time, certify to the state auditor the sum of money required to pay the salaries of the state geologist and his assistants and the incidental expenses of the bureau; and on receiving such certificates, the auditor of the state shall draw his warrant on the treasurer of the state for the requisite amount in favor of the parties and persons entitled to receive the same, and shall charge the several sums so paid to the account of the proper appropriation.

SEC. 19. All previous acts and parts of acts inconsistent with this act are hereby repealed.

SEC. 20. The importance of the completion of the geological and mineralogical survey of Missouri at an early day creates an emergency within the intent and meaning of the constitution, which requires this act to take effect at once; therefore, this act shall take effect and be put in force from and after its passage.

The law is certainly liberal in its application, comprehensive in its requirements, practical in its bearings. Not the least valuable of its measures is the provision for the diffusion of useful knowledge among the citizens of the State. The demand for authoritative information of this kind has long been so urgent, that it is a matter of much surprise that steps in the proper direction were not taken years ago. To be sure, such a movement has been twice started and twice rendered inactive, first in the fifties and again nearly a quarter of a century ago. Being only temporary, they were largely preliminary, and the results were necessarily very incomplete. Moreover, during the past two decades much information concerning the mineral wealth of Missouri has accumulated, and when brought together in a connected way with the results of other investigations it will be of the greatest value. In the same period, geology itself has made gigantic strides, not only scientifically but economically.

The great interest now shown in the examination of the natural resources of Missouri is not wholly confined to the people of the State. There are probably as many persons living without the borders of Missouri as there are within them, who are keeping themselves informed as to what is being done by the Survey. Indeed, the work has met with as universal favor and appreciation abroad as at home. As was well stated not long ago in one of the leading newspapers, Missourians are, as a rule, too busily occupied with their own affairs to go much out of their way to get information in regard to that which does not connect itself directly with the advancement of their own material interests. The benefits of the Survey appear to some people to be only indirect; hence, there is often by these persons a lack of proper appreciation of the aims and ends of the work. As the real facts become known, and the citizens become more and more acquainted with the doings of the Survey, it is extremely rare that a warm interest is not manifested. The solicitude for the carrying out and completion of the investigations begun is not shown in Missouri alone. As the published reports are made accessible, they are reviewed and talked about, more or less, in almost every country of the globe.

Along with the report on the progress of the Missouri Geological Survey, it has been thought desirable to present in some detail the general scheme of operation. As will be readily seen, the entire plan of the Survey is practical in its aim. While thoroughly economic in all its aspects, the work is so arranged that it may be carried on in a manner perfectly systematic and scientific. At all times, the investigations are conducted in a way which it is thought will best serve the interests involved.

GENERAL PLAN.

Ever since its first organization, the Missouri Geological Survey has come to direct its energies more and more to the investigation of the mineral wealth of the State from the standpoint of the utilitarian. Recently strong efforts have been made to concentrate the work still farther.

From the beginning, two classes of work have been recognized. One is rather general in its character, the other more specific. The first is denominated subject work; the second areal work. With the first it is the practice to take up each particular topic, as coal, clay, iron, lead, zinc, or soil, and to consider the deposits as a whole for the entire State. In contradistinction, areal work has for its object the treatment of all useful mineral deposits of limited districts, as a county or other convenient area, special attention being given to the local details and the accurate mapping of the different geological formations. In its main features this dual arrangement of the work has been the policy of the Survey from the start, though modifications in many details have taken place from time to time, as the changes in conditions necessitated, and as the enlargement of the scope of the work demanded. A third class of facts might be properly grouped under the head of statistics; while the fourth line of work pertains to the publication of all results.

SUBJECT WORK.

Subject work is of first importance in conducting geological investigations, for the reason that it satisfies a wide demand for information concerning the existence, mode of occurrence and properties of the various mineral substances. Deposits are not limited by modern political boundaries. Each kind of mineral, clay, or other natural product dug from the earth, belongs to some particular geological formation: that is, it is found at some horizon or level more plentifully than at others. Thus, one formation is abundantly supplied with coal, another with the ores of zinc and lead, a third with materials for the manufacture of cements, and others with still different substances of economic value. Each is found in a particular geological zone, and rarely or very sparingly elsewhere. Only within certain districts would search for a given substance be successful; outside of these areas, no amount of prospecting would ever disclose the material sought.

In obtaining information concerning each particular mineral substance, the entire subject must be carefully considered. At the outset a clear understanding of the geological structure of the rocks containing it is of prime importance. The localities where each occurs require description; the arrangement, relations and extent of the deposits must be defined; the origin and properties discussed; the accessibility and value determined;

the uses of the substances, the nature and status, both present and probable future, of the industries connected fully considered. A complete report on each special subject is therefore comprehensive in character and concise in statement. This work cannot be weighted with the details of only local interest, as this would extend the account far beyond the space that could be allotted to it. Information of an entirely local character must be recorded largely on maps or described in accounts of areas.

In the beginning, then, subject work is more important or at least is more prominent than areal work in dealing with all of the useful mineral substances found. It necessarily includes two classes: (1) the principal topics, which are the larger subjects, each requiring a very considerable period of time to finish, and (2) the subordinate subjects, which comprise numerous minor points. The former, of course, are taken up first. While they are being investigated facts are continually accumulating in regard to the collateral subjects which, with a little special attention later, will ultimately be brought together, forming valuable additions to what is already known concerning the resources of the State.

The advantages of having the work done according to topics are numerous:

1. Since particular mineral substances, as already stated, are rarely confined to single counties, but are usually distributed over several and sometimes many such districts, it is necessary to investigate each kind of deposit in its entirety. It may then be told with certainty how, and to what extent, the several locations will be benefited by the development of such minerals.

2. The general discussion of the properties, uses and magnitude of each deposit may be taken up, and the results published long before all of the work in the counties containing the particular substance can be furnished.

3. In order that lasting results may be obtained, more or less work of a general character is always necessary for the intelligible interpretation of the phenomena observed in any

one county, and to connect them with those seen in neighboring districts.

4. The investigations may be made by experts or specialists in the different lines. The results accomplished are therefore much more satisfactory, more accurate and far more valuable than if obtained in any other way. Furthermore, much less time is required and the cost is consequently very much less.

5. Since most people are engaged in one industry only, the information in which they are most interested is brought together. The miner wishes to be informed about coal, the quarryman, architect or engineer seeks good building-stones; the brick-maker desires something regarding the properties and adaptabilities of the different clays; each wants to know in regard to his special field and cares little or nothing about the others.

AREAL WORK.

In area work the economic resources of particular and limited districts receive consideration. Detailed information of a local character is considered; the present and possible future developments of the mineral wealth are set forth. Its direct purpose, then, is to satisfy constant and ever increasing demands for reliable information in regard to given localities. The desire to know about the mineral products of each particular neighborhood is so general that full details are required concerning every substance which is, or is likely to be, of value to the land-owner or occupant of the district. Probably one-half of the people of the State seek this local information.

Local information on districts is imparted in three ways: first, by descriptions and sections; second, by illustrations, and third, by maps. Probably three-fourths of the geological facts are recorded cartographically. In consequence, therefore, a modern geological map is a graphic summary of a vast amount of useful information. In addition to an accurate representation of the ordinary geographical features, as in the best atlases, a properly constructed geological map records much more. On it are indicated, within a few feet, the elevations above the sea-level of every point within the borders of the area; the drainage basins and the water powers; the distribution and limits of the different geological formations, the various kinds of ores, building-stones, clays and all minerals of economic value contained in the several beds, and the best places for obtaining all these substances. The map also forms a reliable soil index which, with some additional explanation, serves also as a guide to the distribution of the forests and plants generally.

But all the districts of the State cannot be treated alike in the mapping. Some places require far more work than others, either on account of the great importance of the mineral deposits or the natural difficulties caused by the ruggedness of the country. Other regions, as those which contain the principal iron ores, the most valuable lead and zinc deposits, or particular beds, require in the beginning accurate relief maps. Places where the immediate mineral wealth is not so great, do not need elaborate topographical maps. At the present time it is not advisable, nor, even if it were desirable, would the resources of the Survey permit their preparation without a very considerable enlargement of its powers. The work must go on as rapidly as is consistent with good and accurate results. In order of their importance must the various districts be mapped, and in proportion to their mineral wealth must the details be recorded.

The preparation of a full set of maps of this kind is not the result of a few days' effort, but of the labor of several years. As a part of the investigation into the economic resources, there is in contemplation a series of maps which shall embrace for every section of the State all of the information above mentioned. Some of them will be somewhat general in their character and will accompany the different special reports. Others will be more detailed in plan and will cover given counties or such other areas as may be thought desirable.

Among some of the last named the folio plates accompanying the sheet reports are examples. In the construction of maps showing the distribution and occurrence of mineral substances, it is of prime importance that the surface relief should be depicted in a readily intelligible manner. One which represents most closely a perfect miniature of the surface of the region is far superior to any ordinary atlas. It is invaluable not alone to the trained geologist, but is about the only practical way by which the average citizen is able to comprehend at a glance the explanations. In proportion to the exactness with which the diminutive representation approaches the actual surface, in the same proportion does the usefulness of the work increase. The modern methods of making maps are so far advanced over those of a quarter of a century ago, that there is now no excuse for any community to be without the best.

Briefly, then, a properly constructed geological map of a district not only locates accurately the various mineral deposits, but also represents the prominent landscape features by which the locations may be more readily recognized. A relief map also serves other purposes. Upon it may be based models of the more important districts which are to be taken as characteristic of much larger areas, and which are to represent in a graphic manner the structure, arrangement and relations of deposits. Eventually a relief model of the entire state may be constructed on a suitable scale. Besides for the purposes mentioned, it would afford one of the most instructive objects for presenting to the pupils of schools the geographical features of their state. With the wide introduction of the new methods of teaching geography, the value of such aids cannot be over-estimated.

STATISTICS.

Though not strictly geological in its character, the collection of statistical matter concerning the work and output of the various industries dependent upon the natural resources of the state comes properly within the scope of the geological survey. By means of this information accurate comparisons of the yearly progress made may be instituted. The figures are obtained in two ways—partly through printed circulars and accompanying blanks sent to the respective trades, and partly by personal visits of different members of the geological corps, in course of their investigations. All information is considered as strictly confidential; and the tables of comparison are arranged by counties in such a way as not to disclose the details of any individual business. The unusually favorable opportunities offered by the Survey's facilities make this class of figures of particular value, especially in the case of those industries about which little is now done in this direction.

PUBLICATION.

No feature in the investigation of the natural resources of the state is of greater importance than the placing of practical information in regard to the various deposits before the people as rapidly as possible, and at the same time in a measurably complete form. Therefore, in making public the results of the geological survey of the state, the common practice of transcribing field notes and of making incoherent preliminary reports on different subjects has been discarded. The general plan of field work is, of course, arranged so as to accord with the ultimate presentation of the results in the printed form. Hence, two general divisions are recognized in publication as in the field work, though their distinctness may not be so obvious at first glance.

The adoption of a single series of publications, uniform in size, in general style and in binding, will it is thought do away with much of the inconvenience and many of the objections arising from the various ideas of different individuals as to what is the most appropriate manner of getting out work of this kind, or from an adaptation to the particular facilities possessed by the various printers. As nearly as possible each volume will contain in the neighborhood of 400 pages, besides the necessary illustrations and accompanying maps. There will be, however, one exception—the final state atlas. Although numbered consecutively, the separate volumes are in no way dependent upon any which have gone before or any which may follow. Each may therefore be regarded as complete in itself. This plan enables one volume to be devoted to one topic and another to another. It permits the placing of results before the public as rapidly as the investigations are completed, without long and vexatious delays. A particular deposit extending into a number of districts may thus be studied thoroughly, and a report made without waiting for the entire work in the several counties to be finished. Similarly, different counties or areas may be reported upon before any special deposit is examined over all the state. In some cases the work requires a very much longer time to complete than in others; and it is often very desirable, especially with the larger subjects, that some information be made accessible before the appearance of the final report. When the work of any particular topic has reached a more or less advanced stage of completion, some special phase of the subject may be briefly discussed and emphasized in advance, but the article is always made complete in itself, depending neither upon anything which has been nor which is to be published.

The publication of results is also brought about in two other ways, (1) through the newspapers, and (2) through scientific and trade periodicals. To the newspapers are sent accounts of new discoveries and carefully prepared articles of general interest on particular deposits of certain districts. Information of a preliminary character is thus also given to the public, months before the entire work is completed and published. At the same time popular interest is enlivened and a stimulus given to local investigations. Topics of unusual geological importance are frequently discussed in papers which appear in the various scientific journals.

PROGRESS OF THE WORK.

In the general scheme of investigation which is conducted by the Geological Survey, and as the operations go on, there come to be recognized four general classes of work: (1) work completed; (2) work in progress; (3) work taken up incidentally; and (4) work yet to be commenced.

Work Completed.

Under the first of these heads are embraced all the lines of work which have been investigated thoroughly and reported upon. Of course, it is understood that this does not mean that no more observations will be made in these directions, but rather that until all the deposits are reported upon, they will have a subordinate place in the general scheme. On all topics new facts are being constantly brought to light and new phases of the questions are arising. All information of this kind is preserved, and eventually it is brought together in a supplementary report before the completion of the survey.

As to the work in progress, it may be said that reference is made directly to the principal lines of investigation which are being actively carried on. Many subordinate topics are dealt with at the same time, which will ultimately become chief subjects as the other lines are finished.

The third group of observations is complementary to the second. Facts are constantly accumulating concerning areas and deposits which cannot possibly be taken up as principal lines of investigation at once. Yet, by the time these lines are taken up for completion much valuable information will have accumulated, enabling the work to be brought to a speedy finish.

Concerning the last class it is, perhaps, hardly necessary to state that it is a physical impossibility with the present resources of the Survey to consider all subjects in the beginning Some must wait until others are disposed of. With the means at command at present, the different topics must be taken up and investigated largely in the order of their importance, or because unusually favorable facilities are presented for an early consideration. That some important subjects have been seemingly neglected is not for reason of any under-estimation of their true value and place.

IRON ORES.

One of the chief results of the first systematic work done on the geological features of Missouri was the setting before the world of the great value of the iron deposits of the State. Considerable attention was subsequently paid to the same subject at different times, but the recent decline in the iron industry of the State has again awakened special interest in this topic, and has hastened a revival of the inquiry which was abandoned more than twenty years ago.

Briefly stated, the aim of the work was to establish districts in which iron ores are most abundant, to ascertain the exact character of the deposits, in order that prospecting may be done in the most intelligible way, and to determine whether or not the conditions are favorable to the establishment of local smelting works. The results have been gratifying. In carrying out the work, the greatest amount of time was given to points practically untouched, though controlled by the promise of iron ore in a given district, and the remaining time was distributed as seemed best to serve the objects of a general report upon the iron ore of the whole state. In a former account, considerable attention was paid to the limonites on the Belmont branch of the St. Louis, Iron Mountain & Southern railroad, and on the Middle Osage river. The ore bodies there pointed out are yet hardly touched, especially the Osage deposits, and attention has therefore been called to these localities as possible ore fields. The whole tier of counties along and immediately above the Arkansas border, from and including Stoddard county to Taney, was hardly touched. There are seven counties and only a few localities reported. Recent work shows this field to be at least as productive as any in the State, and, consequently, much time has been devoted to it. Even the most conscientious effort to locate every outcrop of iron ore would in the end fail in the present state of development of the country. Enough work has been done to prove that limonite ore exists in sufficient quantities to warrant the erection of local furnaces for its smelting, and that other conditions are favorable for such an enterprise. This fact has been enlarged upon in the report.

The location of ore deposits means, however, more than the mere fixing of these outcrops alone. One outcrop points certainly to others, neither now located nor reported, and the particular aim of the work done has been to point the direction in which others may be confidently looked for.

The outcome of the investigation has been the examination of the iron ore deposits in 43 counties. It has included a determination of the general extent of iron ores in the various districts, an inquiry into their origin, an outlining of the general conditions of their distribution, a consideration of the qualities of the various ores, for which purpose a number of samples were collected, of which chemical analyses were made. In addition to fully discussing these topics, the report, which embraces nearly 400 pages, describes all the more important occurrences, and conveys recommendations regarding the best means for their development.

In further carrying on the work on the iron ores of the State, the efforts of the Survey will consist largely of systematic and detailed mapping in the iron ore regions, so that the distribution of the ore bodies, as well as the other surrounding conditions, may be shown in greater detail.

MINERAL WATERS.

As stated in the report on this subject, the investigation of the mineral waters of the State was one of the first subjects to engage the attention of the present Survey. Missouri, although not in possession of many handsomely improved resorts whose waters are of such wide reputation as to attract many visitors from abroad, has yet a great number of mineral springs, many of them of undoubted medical value, which are patronized by citizens of the State. The majority of people are unable to avail themselves of the cures of the well-known but distant resorts, and hence have recourse to what is provided at home. The investigation and the preparation of this report were hence undertaken principally for the following reasons: (1) to determine the composition and character of the waters and their values as compared with other waters which had acknowledged medicinal virtues; (2) to furnish an exact and full statement of the results reached, particularly for the use of physicians; (3) to supply certain suggestions for the guidance of the citizens of the State in the use of these waters; (4) to make the fact of the existence of these waters authoritatively and widely known, with the object of interesting others in developments and improvements at the different localities.

The results of the inquiry have been to give a full explaation of the origin, composition and therapeutics of the various mineral waters; to discuss the different kinds found within the limits of the State, and to describe fully all the springs and wells. The report is embraced in one volume of 280 pages, with 45 illustrations.

FOSSILS.

The review of the fossils of Missouri is a radical departure from the usual reports on the subject of Paleontology, in that an attempt has been made to make it as strictly economic in its bearing as possible. Instead of giving new names to an endless number of forms, accompanied by long technical descriptions, it has been the aim rather to avoid them so far as possible. The economic value of fossils is commonly overlooked. Ordinarily these remains of ancient life are regarded merely as curious; to the specialist the interest in the old organisms is wholly scientific; but by him who is fairly well acquainted with their character, and who is engaged in practical geological work, the rocks are read as a printed page. One of the best established facts of modern geological science is that there is an intimate relation between all mineral deposits and the surrounding rocks; hence the age of particular beds becomes an important factor in the early attempts to develop new mineral districts. These inferences rest upon one of the cardinal principles of geology, that the geological sequence of strata is determined most rapidly by the remains of life contained.

Thus, in reality, fossils are labels on the rocks, telling one at a glance the age of the beds being worked, and providing the most reliable guides that could possibly be secured in directing the miner and prospector to the layers most likely to contain the mineral sought.

The widespread desire which has existed for many years among certain classes of citizens who are interested directly in advancing the mineral development of the state has created a strong demand for accurate accounts of the organic remains found in the rocks of the region. This demand is becoming more and more urgent in the light of the fact that fossils have such a distinct economic importance in the determination of the age of useful mineral deposits, and hence serve as the most trustworthy guides known in the further development of the natural wealth of a region. In the attempt to satisfy properly the calls arising in connection with the work of this character, it has been the aim to present in a comprehensive report, as briefly as possible: (1) an index to the fossils of the State, through means of which forms now known to occur within the limits of the region under consideration may be recognized readily without recourse to great libraries; (2) a list of the works pertaining to Missouri fossils, in which is brought together all that has been written on the subject and which is now widely scattered and practically inaccessible; (3) a concise summary of all that has been done up to the present time in this branch of science so far as it pertains to the State; and (4) a guide to a more comprehensive study involving the solution of problems now more or less obscure concerning the arrangement and relations of the various strata. In short, it is a hand-book of the fossils of the State, adapted to the use of teacher, student and layman alike.

The general plan of treatment of the different species enumerated has been to give under each a more or less complete bibliography, by reference to which additional information or good illustrations of the forms not here figured may be found. In the diagnosis it has been the aim to give a rather full description of some leading representative of each genus, accompanied by a suitable figure, and to make the sketches of the other members of the group brief and in a great measure comparative. By this way of dealing with the subject it is thought that the characterizations of all the species will be sufficiently ample for intelligent comprehension, and for the particular uses to which the work will be put. At the same time the bulk of the report will be reduced very greatly—to one-fourth, at least, of what it would otherwise have to be. The horizon and some of the leading localities of each species are also given. The matter of localization has had to be rather general, allusion being made to the nearest postoffice usually, or, in a few instances, as when the fossil is common and the distribution wide, merely to the county. As a further help there has been appended a stratigraphical catalogue which is intended for ready reference, and a synonymic indexical list of all the names applied to Missouri species. With the many natural difficulties to be taken into consideration, it is easily understood that from a geological or biological standpoint, any stratigrapic tabulation of the fossils of the state must necessarily be quite incomplete for years to come, and must long lack uniformity in the number and kind of organisms assigned to each horizon. Nevertheless, in the present condition of knowledge there is peculiar economic importance in a special arrangement of the forms known at the present time to occur within the limits of Missouri, or on her borders, according to the strata in which they are found. With general geographical distribution known by reference to the colored geological map, the fossils which may be expected to be found in any locality in the state, may be quickly referred to without the labor of going through the whole report to pick them out. The fossils, forming as they do, labels to the deposits of commercial value, put a ready and inexpensive means in the hands of even the most inexperienced for determining what minerals of economic worth are to be sought for in the particular neighborhood, and what are not to be expected.

The report is in two parts, containing altogether over six hundred pages and fifty-six plates, besides a revised geologicalical map of the State.

LEAD AND ZINC.

Lead and zinc form Missouri's most prominent mineral products. The real importance of these metals is further comprehended when it is known that as a producer of the first named ore the state ranks second among the states of the Union, and of the second metal first, supplying more than two-fifths of the entire amount of mineral in the United States.

The rapid growth of the lead and zinc industry of recent years made the subject one of the first demanding the attention of the Survey. The magnitude of the work with its constantly increasing development can only be appreciated by one who has gone carefully over the ground. The investigation was begun, first in connection with the United States Geological Survey, and later independently. Although in getting the results into permanent form for presentation there have occurred some delays, as necessarily there must always in work of so extensive a character, the added value to the report will amply compensate for all seeming procrastination.

The report has been divided into three parts. The first contains an historical sketch of the metals, and a summary of what is known of them in all countries of the globe. Particular attention is given to the lead and zinc-producing districts of North America with which the Missouri product is brought into competition. A chapter is also devoted to the metallurgy of the metals, and the various processes are described with sufficient minuteness for all practical purposes. Concise tables of the production in the United States are also given in this connection, together with the prices.

The second section outlines the history of mining in Missouri, and the general geology of the southern half of the State. The development of the mining in the State is traced from the time of the earliest explorations. The physical characters of the lead and zinc regions are described at length. The geological formations containing the metals under consideration are referred to in a general way, and considerable detail entered into in the case of the most important localities. The lithological differences are compared and some of the salient structural features pointed out. Under ore deposits is a full consideration of the distribution, the form, structure and composition of the ore bodies, their manner of formation and the origin of metalliferous veins. Concerning the latter topic, the various theories are set forth and their application to Missouri deposits clearly given. Smelting and manufacturing received the attention they demand, and full statistics are given regarding the production of the two metals in Missouri, the prices received from year to year, and the total output of the various counties.

The third part is an account of the Missouri mines, with a systematic and detailed description of the important developments and occurrences of lead and zinc. Three districts are recognized: the southeastern, the central and the southwestern. Here is incorporated all the detailed information concerning the various camps. Many of these are mapped and the workings of typical individual mines plotted. This is the portion of the work which will appeal most directly to the people actually engaged in working in the diggings.

LOCAL GEOLOGY.

In the preparation of reports upon particular localities it has been found advantageous in the case of some of the most important mining districts to take as the unit a rectangular area measuring 15 minutes of latitude and longitude. This, on a scale of 1-62500, or one mile to an inch, gives a map about $13\frac{5}{8}$ by $17\frac{3}{8}$ inches. The unit is called a sheet, and the reports on the areas which are named after a leading town within its borders, sheet reports. Three of these sheet reports have been completed, viz.: Higginsville, Bevier and Iron Mountain. A dozen similar ones are nearly completed.

The Higginsville sheet includes part of Lafayette county and a small portion of Ray, and embraces an area of nearly 232 square miles. The report accompanying the map describes in great detail the geological features and mineral resources. It forms a folio of 18 pages, equivalent to about 100 pages of the ordinary octavo.

The Bevier sheet report in a similar way is based upon a detailed examination which has been carried on in portions of Macon, Randolph and Chariton counties. This account is embraced in about 85 pages, with suitable illustrations.

The Iron Mountain sheet covers parts of Iron, St. Francois and Madison counties, and represents the results of work completed in a portion of southeastern Missouri. There are 95 pages in the report accompanying the map.

Work in Progress.

The investigations concerning the natural resources of the state run along parallel lines, termed subject and areal work. While covering the same ground in part, they do not necessarily occasion duplication in either field work or publication. Of these two divisions, the former, from its nature, must in the beginning receive greater attention. The very nature of the case makes it impossible to take up all subjects in the beginning, renders it necessary to give greater prominence to some lines of work and to finish them up before branching out in new directions. As the work is completed in the various fields and the reports are made, the efforts are directed to other branches, only incidental notes being continued on those subjects which have been reported upon. Attention has already been called to some of the work which may be regarded as completed.

Concerning the work now being actively carried on, special mention should be made. Much of it is well along toward completion, and must soon be regarded as work finished.

INVESTIGATION OF CLAYS.

The work on the clays of the state is now practically completed, and the report will be ready shortly to go to the printer. The investigation has a peculiar value, and the thoroughness with which it has been conducted lends special interest. The practical experimental work on clays has never before been attempted by any state in the Union, and nowhere in the Mississippi valley has this class of material received so careful a consideration. In the testing of the clays, not only the chemical, but also the physical properties are determined. Through the latter especially the various comparisons may be more thoroughly appreciated, and the exact character of the diferent deposits more readily understood. The following outlines the method, taking for example a sample of typical fire-clay:

A preliminary examination shows :

Color varying from light ash to drab.

Texture nearly uniform, fine grained, compact.

Taste "lean," gritty.

Slacks slowly into irregular granules, with little uniformity of size.

Accessories : pyrite not perceptible ; sand as grains from one-tenth to one-thirtieth of an inch in size, freely disseminated.

A physical examination shows :

Specific gravity, 1,950.

Plasticity, as determined by working a clay paste, is eminent ; as determined by the tensile strength of air-dried briquettes it has a maximum of 172, the average of ten samples being 155 pounds per square inch.

Water required to make a plastic, easily worked paste is 15.4 per cent.

Air shrinkage, in drying bricklets ranging from four inches by one-fourth inch to eight inches by four inches averaged 5.6 per cent in ten samples. It can be dried rapidly in a warm air bath at 125 to 200 F. without breaking.

Fire shrinkage, in burning air-dried samples at a vitrifying heat averaged 2.3 per cent in the three samples ; requires care and slow heat to avoid cracking.

Total shrinkage, or the sum of the fire and the air contraction, averages 7.9 per cent, which is remarkably low.

Fusion takes place at about 2400 F., or a white heat ; incipient vitrification takes place at 2100 F., or at a bright cherry-red heat.

Color of burned clay is light-gray.

Conclusions: This fire-clay is a fairly good refractory material used for temperatures as high as 2300 F, or a very bright cherry heat. It admits of rapid air-drying without cracking, and does not fissure readily in firing. The total shrinkage being very low adds greatly to its value in any practicable application of the clay. Being highly plastic, it moulds admirably. The burnt ware is quite strong. The clay, when washed, may be used successfully by potters. It is even possible that a white ware may be produced if the clay is properly washed and treated.

Among the subjects exhaustively discussed in this report are:

1. The origin and composition of the clays of Missouri.

2. The methods of sampling and analysis.

3. The physical and chemical properties of the various clays.

4. The cicroscopical examination of clays and its value in the determination of the value of a deposit.

5. The uses to which the various kinds of clay are and may be put, and a consideration of the best varieties adapted to each specific purpose.

6. The general geology of the state with special reference to clay deposits, their distribution and availability.

7. The brick and drain tile clays, the localities yielding the best qualities and the methods followed in rendering the poorer grades workable. There will also be embraced a special consideration of the clays used in making paving brick and sewer-pipe. The recent extensive use of brick as a paving material, and its superiority over many other substances, has rendered the subject of brick for this purpose one of very great importance, and one to which sufficient attention has not yet been paid. Paving streets with hard bricks is fast becoming popular in the larger towns and cities. Tests are continually being made which go to prove that the durability of a street paved gith good vitrified brick compares more than favorably with that of streets paved with other material.

8. Fire-clays and other deposits for the manufacture of refractory products. There will be given in this connection extensive comparisons of the raw materials from the different localities in the state, and reference to noted places beyond its limits. Deposits of this material have been found in large quantities and of very superior quality.

9. Pottery clays, their properties, distribution and location; also the materials used for glazing and in mixtures.

10. China clays and kaolin, of which large quantities have recently been brought to light in the southeastern part of the state especially.

11. The principal industries based upon clay, and descriptions of the works and clay pits.

12. Preparation of clay for manufacture into the different products, and the methods used.

13. Recommendations for better methods of manipulation. The importance of raising the standard of excellence of clay goods can not be overestimated. It not only aids directly the manufacturer of the prohucts, but indirectly greatly benefits every citizen by providing him with a superior quality of material at no higher a price than he would otherwise give for the inferior article.

14. Complete statistics in regard to the production of the various kinds of clay goods.

Besides, the report is accompanied by a full bibliography of the writings on clays and a complete glossary of terms used. When printed the volume will contain in the neighborhood of 700 pages, divided into 21 chapters and 6 appendices. It will be accompanied by several large maps and over 40 full-paged engravings, besides numerous cuts.

Altogether, the report on clays will form one of the most valuable contributions to economic geology ever published, not only for Missouri, but for the entire United States. It completes one of the most inportant lines of work yet undertaken by the survey.

STUDY OF THE CRYSTALLINE ROCKS.

The granites and porphyries of Southeastern Missouri are of unusual interest and great commercial value, for the reason that they are the only crystalline rocks occurring in the Mississipi valley between Central Arkansas and Lake Superior, and between the Appalachians and the Rocky Mountains. The development of these areas is therefore of special importance on account of the wide extent of territory they are capable of supplying with a high grade of building and ornamental stone.

The investigation has consisted in mapping all the areas and making a careful examination of the different occurrences. The microscopical characters have received particular consideration, and mineralogical composition determined with great detail. By this means comparisons have been made with similar rocks from other localities which are now used largely for building materials, and with which the Missouri stone must come into competition when placed on the market. This work is practically completed. The determination of a few odd points will enable the account to be printed shortly. The report, in addition to discussing the topics already mentioned, will also take up the general geology of the crystalline rocks and the relations of the various masses to one another. Since the rocks considered in this connection are the only ones found within the limits of the state which are truly eruptive or igneous in origin, the subject deserves more than passing notice, both from a scientific and a popular stand-point. The fact that one part of the state was once the seat of energetic volcanic action creates a widespread interest in these rocks.

WORK ON THE COAL DEPOSITS.

The investigation of the coal deposits of the state was one of the first subjects taken up after the organization of the survey. Notwithstanding the fact that this material ranked among the most important of the mineral resources of Missouri, and the state stands ninth among the states of the Union in coal production, less was known concerning its structure and distribution than perhaps any other deposit of economic value.

The investigation was begun by selecting the localities where mining was in progress, it being the object to obtain all data possible from districts already well known. "As an outcome of this preliminary work there has been printed, and in large part distributed, a preliminary report upon the coal deposits of the state. This report contains over 200 octavo pages. As is implied by its title, however, and is distinctly expressed in the preface, it is essentially a preliminary report. It is in large part a presentation of only the bare facts of the occurrences of the coal, the facts of most direct economic importance, and these are presented in a popular way. The justification for the presentation of such preliminary report lies in the urgent demand for information concerning the subject; but, though this report is calculated to satisfy this demand to a great extent, it should by no means be taken as a measure of all that can be presented, and all that will be attained through the work in the coal regions."

The most important part of the investigation yet remains to be completed. Practically nothing concerning the correlation and stratigraphy of the seams has been published as yet that applies directly to the state. Since the appearance of the preliminary report, much valuable information has accumulated, and during the past few months the subject has been taken up with renewed vigor. At the outset it was found that in order to make satisfactory progress, it was necessary to carry on the work in a perfectly systematic manner. Localities must be studied first which are likely to furnish most readily a key to the structure, character and disposition of the coal beds over large areas. The leading geological features of these districts must be carefully made out, and the examination extended into neighboring regions. In this way the extent of territory covered and the amount of practical information secured is far greater than can possibly be obtained in any other way.

The area of the Coal Measures of Missouri includes nearly 25,000 square miles; besides, there are numerous Carboniferous otliers, or isolated areas, along and beyond the borders of the productive measures which make up many additional square miles. The investigation of the coal deposits of the state is thus seen to be a work of no small magnitude. Detailed attention to the coal industry in all its phases involves labor which cannot be completed in a few months; it requires much more time to make satisfactory observations, to accumulate all facts and carry on proper tests.

In the final report on coal there are to be included:

1. A general sketch of the coal deposits and geology of the region.

2. A detailed account of the geological features of the coal district. This embraces a full description of the different kinds of beds and their associations, the minute structure of the coal-bearing strata, the exact relations of the different seams, the distance from the surface that it is necessary to go in order to reach them, the pointing out of notable and easily recognized strata which may serve as guides in searching for

particular veins, and all kindred information of practical import.

3. A description of the uses and properties of Missouri coals, with tables of chemical analyses of all the principal varieties from the different counties, the adaptabilities of the various kinds for steam, domestic and metallurgical purposes and for gas-making. In this connection will be considered all information tending toward a greater development of the coal industry, including the utilization of coal-dust, slack and such lignites as may occur.

4. A discussion of practical mining in the state, the methods employed and improvements which may be made, the kinds of machinery used and its advantages, the best plans and the most suitable machinery for prospecting.

EXAMINATION OF BUILDING STONES.

In variety and quantity of good stone suitable for building and all constructive purposes, no state in the Mississippi valley is surpassed by Missouri. Yet no systematic investigation of the building materials of the state has ever been accomplished. That Missouri has excellent grades of quarry stones is manifest from the demands made for certain qualities. That the state should have many other equally good building stones is not unreasonable to expect. Nevertheless, the state continues to go beyond its boundaries for many of the better grades of rock for building. Of the vast sum of money which is expended every year for stone used in construction of all kinds, a large proportion goes to other states. Hence, it is greatly to be deplored that a more exact knowledge of the state's building stone was not acquired years ago. Recognizing this deficiency, an investigation of the building materials of the state was begun with the first organization of the geological survey. The subject soon proved to be much larger than was anticipated and had to be divided up, different portions being taken up by different persons. Some of the topics have already been reported upon, while others have received but little systematic attention as yet.

The work of investigating the building stones, though early commenced, was interrupted and greatly delayed from time to time on account of circumstances entirely beyond the control of those engaged in the undertaking.

The importance of the inquiry can hardly be overestimated. It is a fitting subject to be taken up by the state, and benefits all citizens alike. Architects and engineers commonly have neither the apparatus nor the inclination to make extensive tests in regard to local building materials. Consequently, they employ stone which already has its reputation established. Thus, the lack of authoritative information in regard to local resources causes the rocks of the state to be discarded, and building stones to be transported half way across the continent, and often placed upon ledges of rock in every way their equal, or even their superior. The quarrying industry at home does not receive the support it should, while foreign markets are entered and purchases made.

Among some of the chief factors which determine the value of building stone are accessibility, durability, strength, structure and reputation. No matter how excellent a stone may be, it is of course valueless for constructional purposes if it does not have good transportation facilities. Durability is a phase of the subject which cannot be determined readily from hand specimens, and is usually brought out through experience. Stones, which ordinarily withstand the influences of atmospheric agencies, readily waste away when exposed to conditions quite different from those of their native places, and the acid-laden air of great cities is especially deleterious to rock. The resistance to weathering is ascertained best in the field by careful examination of the native ledges. These observations may be supplemented by tests in the laboratory. Strength, however, is usually the only factor tested in determining whether or not a given stone shall be used.

The work is sufficiently far along to outline fully the scope of the investigation. In making the observations, special attention is given to the distribution of the ledges and layers best adapted to building purposes, the properties recommending the various kinds of stone, and the effects of weathering upon the natural outcrops. Special attention is given to the minute structure of building stone and changes which they undergo in the process of weathering, as revealed by the microscope. This is practically a new field as regards constructional materials, and has never been systematically applied to rocks as building stones. It promises most fruitful and interesting results.

In the report which has already been begun it is intended to give full descriptions of the localities and of the quarries now opened, statistics as to production, and the methods of getting out the stone. Illustrations of some of the finer grades of the ornamental varieties and the more important buildings and constructions erected from Missouri stone will also be given.

INQUIRY CONCERNING MINERALS.

Aside from the mineral deposits which are at the present time mined on a commercial scale, there exist a large number of other minerals which are not yet taken out in quantities sufficient to be of much value in trade. Facts in regard to these are continually accumulating from all parts of the state. Some of these minerals are known to have a very considerable economic value, and will necessarily soon be the subject of special inquiry. Others will be found to have only a scientific interest. Many having little or no value from an economic standpoint are now attracting popular attention and are causing considerable expenditures of money, time and labor every year, with absolutely no possibility of any adequate returns. On the other hand, a number of those having a great economic value are not being worked to the extent that they deserve, or they have received no notice whatever. Even though many of the minerals in the state should prove to be of no commercial importance, negative results are by no means without value. Proof that certain deposits are not extensive enough, or are not of a sufficiently high grade for profitable working, will be the means of preventing annually a great waste of money and energy.

For the study of these minerals much fine material has been brought together. In their consideration there will be given a complete list of the various kinds, full descriptions of their different occurrences, a catalogue of the known localities of each, and the possibilities of their extent and utilization. A careful crystallographic examination will also be undertaken. Since Missouri affords some of the finest samples in the world for this line of inquiry, the subject will prove to be of exceptional interest and value.

SPECIAL LOCAL GEOLOGY.

As already explained, there are particular areas smaller than counties which require detailed mapping in a somewhat different manner than in the case of the county as a whole. These areas are designated as sheets. Since the beginning of the present survey a number of typical areas have been selected as districts demanding this kind of minute mapping. Those in which the work is now practically finished are known as:

1. Lexington Sheet, in Lafayette county.
2. Warrensburg Sheet, in Johnson county.
3. Huntsville Sheet, in Randolph county.
4. Mine LaMotte, in Madison county.
5. Richmond Sheet, in Ray county.
6. Clinton Sheet, in Henry county.
7. Calhoun Sheet, in Henry county.
8. Carthage Sheet, in Jasper county.
9. Joplin Sheet, in Jasper county.
10. Bonne Terre Sheet, in St. Francois county.
11. Bolivar Sheet, in Polk county.
12. Aurora Sheet, in Lawrence county.

The reports accompanying one-half of these sheets were written and revised during the past year, and will soon be ready for publication. They are on the same plan and in the same style as the three sheets completed — the Higginsville, Bevier and Iron Mountain.

MINERAL RESOURCES OF COUNTIES.

In conducting the areal work of the state it is quite probable that with a large part of it the county, instead of the sheet, must be taken as the most convenient unit upon which to report. As the state is the political unit of the nation, so the county is the political unit of the state. When, therefore, in either the larger or the smaller of the two provinces it is desirable to consider any subject with special reference to its areal distribution, the units mentioned become the natural divisions into which a complex topic may be separated. In former years this was universally the practice; in the earlier work the recorded results of all investigations were contained in the county reports. At this time the country was new, and little more was required than to indicate the existence of the various deposits; moreover, much of the energy of the Survey was necessarily directed toward tracing the limits of the different geological formations.

Although it has become of recent years the practice to adopt a smaller and more scientific unit as the basis of areal reports, there nevertheless remain good grounds for retaining the county as the unit in all cases except the most important mining districts. Indeed, the reasons for making the county the areal unit in the treatment of the natural resources of a region are many:

1. It is the most widely known and familiar political division of local importance.

2. It is the district concerning which nearly every person in the state who is interested in the natural products of his neighborhood inquires.

3. It forms a convenient district for working out geological details.

4. It is an area whose size is perhaps best suited to the purposes of instruction in the schools.

5. It is especially adapted to the encouragement of detailed work by local observers.

6. It is the district most commonly inquired about by investors living in other parts of the state or in different places beyond its limits.

7. In Missouri it is an area well suited to the preparation of maps.

8. It in no way interferes with the adoption of other units of uniform size for a state atlas, as occasion demands.

In the beginning of the investigation into the natural resources of the state, a general reconnaissance must be made, and the subject-work pushed somewhat more vigorously than the areal work. This having now been accomplished in great measure, the energies of the survey will be directed toward pressing to rapid completion the more strictly local inquiries and the work which is of more direct benefit to the people at large. It was not possible to accomplish this until after certain preliminary work was taken up. Detailed investigation of a number of counties has already been undertaken where the conditions are especially favorable. Although every county in the state must be thoroughly studied before the completion of the survey, it is readily understood that all of these districts cannot be taken up at once. Some must of necessity be studied before others. In making a beginning in this direction, the work has been governed to a great extent by the investigation as a whole, those regions being taken up first which best furnish an index to the surrounding counties, thus enabling the work to be done over large areas, and in a much shorter time than would otherwise be possible. Another important factor in determining the priority of certain counties in which operations have been begun has been the presence of volunteer and local assistants. In this way some counties containing educational institutions have afforded special facilities. The instructors of geological classes in the several colleges have given, to a greater or less extent, attention to the natural features of the surrounding country, and have often accumulated considerable information. By utilizing the facts previously obtained, and by extending the observations so as to accord with the general plan of the survey, the state comes into possession of material of great practical value at a small cost. The reports of these counties will thus serve not only for purposes of class instruction, but will reach the public much sooner than they would under less favorable circumstances. In this way work has been undertaken in a number of counties, and considerable progress has been made.

The general scheme followed in the discussion of each county includes a brief general account of the surface relief and drainage, a description of the lithological characters of the different rocks and the geological structure of the strata. The principal geological subdivisions are considered separately, and the means of recognizing each pointed out. All the mineral deposits of a useful nature are described, the various localities taken up in detail, the extent and distribution defined and the present and future value noted. The soils and minerals are also discussed, and the discriminations to be made are pointed out. Chemical analyses and practical tests of the various substances are also given. Illustrations are incorporated wherever required. A map on a suitable scale accompanies the report of each county.

SUMMARY OF GENERAL GEOLOGY.

The geological and structural features of Missouri formations have never been discussed on broad lines and in accordance with modern methods. The want of something of this kind has long been felt, and the demands for such information daily becomes more urgent. Of course, an account of this kind cannot be gotten up in a few months, even if all the energies of the survey were directed toward it. It is only acquired as the result of years of labor. Happily, however, the greater part of the information may be obtained as the work on the more directly useful lines is being prosecuted.

All geological investigation, in its accomplishment, demands the settling of certain broad fundamental questions relating to the origin and succession of the formations; and these must be considered in order that the best results may be secured in regard to the more strictly economic work. Some of these problems are wide-reaching in their bearing. They are not confined to a single district, nor a single county, but may extend over a greater part of the state, or through several states. Fortunately, many of these problems had already been partially or wholly solved before the work of the Survey had begun. A general study of the rocks, their arrangement and relations in this and adjoining states, had been made. These results greatly facilitated the preliminary investigations which invariably must precede all detailed examinations. With the broad general questions of interstate importance already tolerably well understood, those which apply more particularly to the state alone are much more easily taken up and more readily solved than they could be otherwise. There is considerable work of this kind yet to be done. A discussion of it, which embraces a somewhat generalized and co-ordinated consideration of the lithological characters of the different formations, the structure and arrangement of the various beds, and a classification of the formations in accordance with the latest criteria of geological science, is necessary. The direct bearing of the general geological problems upon the more strictly economic phases of the several topics is shown more in detail in connection with the remarks on the different subjects of which special mention has been made.

Enough facts have been already accumulated and sufficient data brought together to enable the general scheme of the final report to be fully outlined. It includes a general description of the geological features and structure of the upper Mississippi valley, particularly as applying to Missouri. It takes up the separate geological formations and describes in detail the characters and distinguishing features of each. It considers the arrangement, succession and thicknesses of the formations, the variability of the different strata, the unconformities and deformations. It notes particularly the useful minerals and substances occurring in the different parts of each formation, and points out how most readily to detect the deposits; it considers also other useful materials which are not as yet utilized.

It discusses further the origin, conditions of deposition, and the associations of the various beds.

It is necessary in this connection to mention only some of the problems of unusual interest. The occurrence and relations of the post-Paleozoic formations in the southeastern corner of the state; the exact limits and relations of the Upper and Lower Coal Measures; the character of the divisional plane at the base of the Coal Measures; the exact position of the lead and zinc-bearing formations on the border of the Ozark uplift; the character of the Devonian in Missouri and its exact equivalents to similar formations of other parts of the Mississippi valley; the subdivisions of the Silurian; the extent and upper limits of the Cambrian rocks—all of these questions are of the utmost import, not only scientifically, but economically.

DICTIONARY OF ELEVATIONS.

As set forth in a former statement, the subject of hypsometry of the state has never received exact investigation. "The elevations of different points in the state are only approximately determined, and the distribution of the zones of equal altitudes not defined. In connection with mapping, it becomes quite necessary that the relative elevations, at least, of various points in the state which are included within the different areas, should be known with reasonable exactness. The datum to which all such elevations are referred is the 'mean sea-level'; and in all cases it is necessary to reduce all assumed altitudes to this standard. The primary base-lines are the lines of precise leveling of the Mississippi and Missouri River Commissions along the respective streams, and the trans-continental line of the U. S. Coast and Geodetic Survey which traverses the state. The secondary base-lines are the lines of leveling for the various railways, where constructed or surveyed throughout the state, as embodied in their profiles or level-books. As the methods by which railroad leveling is done are far less exact than the precise leveling of the government surveys, errors in the determinant of altitudes frequently occur, and, in order that their results may be used, the errors must be detected and eliminated.

For this purpose, profiles or lists of elevations along all the various railroads have been obtained. These have been compared at their intersections, and any discrepancies which are detected have been inquired into and corrected. As all the various lines are adjusted, a net-work of lines of level throughout the state is found, upon which may be based all mapping." The report, which is now practically completed, contains a corrected list of elevations along all the lines of railroad, and is accompanied by a map on which are indicated the lines of precise leveling over all the district. Aside from its invaluable aid in connection with the work of the Survey, it will satisfy a great and ever-increasing demand for information of this character.

Work Prospective.

From the beginning, it has been the policy of the Survey to take up first those subjects which were thought to demand greatest attention, and as far as possible in order of their importance. Aside from these topics, there yet remain a number of themes which as yet have practically remained untouched. With the present resources for conducting the work, it is of course a physical impossibility to carry on all lines of investigation at once. Some must of necessity wait until others have been fully disposed of satisfactorily.

It is unnecessary to call special attention to all of the lines of work which must be taken up before the survey of the natural resources will have been regarded as measurably complete, and a full invoice of the state's possessions and possibilities will have been made known. But there are a few subjects which are urgently requiring early notice.

SOILS.

Of all the states in the Mississippi basin, Missouri is to be particularly benefited by a systematic inquiry into the exact character of the soils. Lying only partly within the drift area, fully one-half of the state's area possesses soils which are directly dependent for their degree of fertility upon the underlying rocks. With this intimate relation between the various strata and the soils into which they graduate, the question assumes an importance that is practically impossible to arrive at in the more northern districts.

Of recent years, there has probably been no phase of geology which has attracted more attention than the study of soils. Owing to the great fertility of the virgin prairies of Missouri, artificial fertilizers have not as yet come into use as in the older states of the Union and in the densely populated countries of Europe. Nevertheless, it has begun to dawn upon many communities, as it must necessarily sooner or later everywhere, that the soils may not yield so abundantly as years go by. In different parts of the country, the real conditions are rapidly being comprehended and efforts being made to rejuvenate the failing soils. The awakening is now occurring in many places, particularly in the eastern and southern states. But the subject is not only receiving attention in those districts where the soils are partly or wholly "worn out." It is beginning to be found out that in many places, even where the soil is surpassingly fertile, proper treatment may greatly increase the yield of the products raised.

Aside from the inherent qualities of the soils, there are certain climatic conditions which need careful noting. More than once during the past two decades have occurred in this and in neighboring states, in successive years, violent fluctuations in the total yield of the various crops, and at least two or three times within the period the crops have narrowly escaped almost total failure, owing to prolonged drouths. Human efforts are of little avail in attempting to change these varying climatic conditions, but it is quite possible to effect the same results by manipulating the soil so that it will retain sufficient moisture to carry all vegetation safely through the most protracted dry spells. The accomplishment of this is made possible through the proper chemical and physical investigation of the different soils.

Heretofore geology has been almost universally regarded as the sole aid to mining; but of recent years it has come to be considered that it is destined soon to be the chief factor in the advancement of agriculture. The interdependence of the science of geology and the science of agriculture is daily becoming more and more intimate. The relations between the primative rock ledges and the soils resulting from their disintegration are ever becoming better understood. The principle lying at the base of the more recent soil investigations is that each geological formation gives rise to a more or less well-marked type which is especially adapted to particular crops. The latest work in regard to this subject has been on the physical rather than on the chemical side, and the results have been so eminently satisfactory that it seems desirable to summarize briefly the conclusions deduced from the application of a mechanical analysis of the soils.

"In the first place, starting from the fact that the farmer, simply from the character and appearance of the soil, is better able than the chemist, with the most refined analysis, to tell what kind of grain it will produce, there is reason to believe that the differences in the value of the soils are due rather to their texture and the arrangement of grains than to their chemical composition; that all soils contain sufficient food material to support crops for years; and that their value is measured not by chemical composition, but by their relation to the moisture contained.

"Moisture in a soil, or the circulation of water in it, is very important, and is believed to be one of the leading determining factors in the local distribution of plants. The circulation of water in the soil is brought about by two forces, gravity and surface tension. The first is constant, and acts always in the one direction, so that it may be practically neglected. The second acts in any direction, either by pulling the water up to the plant or away from it, according to circumstances. Careful investigation and calculation has shown that, upon an average, fifty per cent of the volume of the soil contains no solids, but is made up of only water and air, and may be regarded as empty space. If a soil is slightly moist, the water will form films around the component grains. If there is an increase of water these films will thicken, and, the amount of surface exposed being smaller in proportion to the weight of water, the surface tension will become low. If, however, the amount of water be decreased the surface tension increases, as the surface exposed is much greater in proportion to the less weight of water." (Bain.)

In a cubic foot of soil the total surface exposure of the particles is usually in the neighborhood of 50,000 square feet, or a little more than an acre. In some kinds of soil it is over two acres. This amount of space may be divided in different ways, and the manner in which it is broken up controls largely the surface tension of the soil moisture. In turn, this determines the relation of the soil to the amount of water it will hold. Experiments have shown that different chemicals have two distinct effects upon the soils. One is to directly modify the surface tension of the soil moisture, and the other is to indirectly accomplish the same result by inducing changes in the texture. Since upon the surface tension existing in the soil depends its ability to absorb and to retain moisture, important changes in the capacities of land may be brought about through the application of proper chemicals, and the power of a given soil to resist drought may be very greatly increased.

The importance of this soil work has awakened a special interest in it all over the country, and especially in the eastern states. The Department of Agriculture at Washington has also taken the subject in hand, and has established a special bureau whose energies are to be devoted in this direction. The work in a general way is to be extended over the whole of the national domain. In order, however, that such an investigation of the soils may be made more directly responsive to the needs of Missouri, and the results made available at the earliest possible moment, special work in this direction must be begun by the state at an early day.

ARTESIAN WATERS.

The demand for artesian waters, while not so widespread as in the states north and west, is yet urgent in many parts of Missouri. The desire for this source of water is not because the state is not well supplied with streams at the surface, nor because of unfavorable climatic influences, but by reason of the great convenience in the use of flowing wells, and on account of the common belief that such water is exceptionally pure. With the desire of securing flowing wells, borings have been put down in all parts of the state. In a large number of cases failure has resulted. Why the efforts are not successful is marveled at, since the principles involved in a successful artesian flow are so simple that it comes to be generally believed that the governing conditions are equally simple, and all that is necessary is to put down a hole far enough and a flowing well will result. In reality the conditions of a successful flow are quite complex, and the practical determination of artesian areas involves a broad comprehension of the general geological features of the region, not of the state alone, but of the surrounding territory as well.

Although work on this subject has not yet been formally begun, there has, nevertheless, been considerable information obtained indirectly. Records of a large number of borings and deep wells have been secured, and samples of the drillings or cores preserved whenever possible. When the theme is taken up and the work of collecting facts concerning the artesian probabilities for the various portions of the state is pushed vigorously, the data now constantly accumulating will form an invaluable foundation. Moreover, the collection of drill records adds vastly to a knowledge of the characters of the older and more deeply buried formations in Missouri, and discloses much of value in regard to their texture and structural relations.

It is perhaps somewhat premature to give at this time an outline of a report, but the investigation would embrace, among others, the following considerations:

1. A mapping out of the different areas supplying artesian flows.

2. The essential conditions of flowing wells, with special application to the state. The structure of the region, the geographical distribution of the formations, the texture of the rocks, the amount of rainfall, and kindred topics, come under this head.

3. The nature of artesian wells, and questions pertaining to the flow, the force and the factors upon which it is dependent, the height to which the water rises, causes of decrease in flow and methods of increasing it.

4. The special uses of the waters, such as the adaptabilities of artesian flows, their values as sources of power, as supplies for city water-works, and as medicinal remedies.

5. Methods of boring and special forms of machinery which have been found to be most economical, and a description of these, are within the scope of the work.

6. Particular and unusual conditions of individual areas.

It will be readily seen that fundamental to this work is the careful collection and study of the records of all wells previously sunk in the state. These records become very largely the basis of subsequent work. In the determination of flow-levels, certain geological horizons have been found to be water-bearing. For example, the Dakota sandstone is in South Dakota the source of many wells; in northeastern Iowa the St. Peter sandstone is the best known stratum performing a similar function. It becomes important to determine which among the many layers is most likely to prove valuable for this purpose. Next to the question of what horizon may be expected to furnish supplies of water, comes that of the depth at which it will be encountered. This may be made out by a careful comparison of the levels of outcrops, surface waters, horizons in neighboring wells, and similar data. The areas available for artesian wells can, therefore, only be determined by a detailed study of the structure and texture of the rocks, as well as the other conditions mentioned.

ROAD MATERIALS.

Throughout the country the question of bettering the public highways has of recent years been receiving wide-spread attention. While the subject is largely an engineering one, and while a discussion of the advantages and general durability of good roads in the state also comes within the province of other fields, there are, nevertheless, certain phases of the question which properly come within the range of the investigations for which the Survey was organized. Among the things which may be regarded as demanding attention are the localities and character of any superior stone suitable for improving the roads, the facilities for transportation and the approximate cost of quarrying and preparation. In addition, the qualities and properties of these rocks are to be considered. The location of good gravels, their areal extent and their quality should also receive attention. The subject of the utilization of burnt clay as a road material should be fully discussed. Some of the railroads are already using burnt clay for ballast in preference to rock, sand or gravel, with good results, so that the extension of the use of this material to highways is in reality beyond the experimental stage. In this connection, special attention should be paid to the great dump-heaps which are always found at the mouths of coal mines over a considerable area of the state, and which, through spontaneous combustion, afford large quantities of thoroughly burnt clay. The extent to which these dumps might be used for road construction, at practically the cost of hauling the material away, is a matter of no small consequence.

WATER-POWERS.

The water-powers of Missouri appear destined to soon assume an importance previously not thought of. Since the recent great development of and the constant widening of the uses of electricity call for an inquiry for utilizing the energies now going to waste in the rapid streams of the state, especially those in the southern half, the day cannot be far distant when the powers of the water-ways must be converted into a form of energy of the highest practical utility, capable of being transferred great distances with small loss, and of furnishing not only the light, but heat, and the means of running machinery of all kinds. The amount of power that may be brought under control and turned into useful ways from the streams of the state is unquestionably great, and is a problem of the utmost import to every community.

NATURAL GAS AND OIL.

The possibilities of finding natural gas and oil have long occupied the attention of Missourians. With the recent discovery and extensive use of these substances in the neighboring provinces, the interest in the subject has been renewed and greatly intensified. Indeed, it may be truthfully said that during the past decade no geological question has occasioned more popular concern than that of the likelihood of obtaining natural gas and petroleum within the limits of the state. In a number of places shallow borings have yielded, from time to time, sufficient quantities of natural gas for local use. The success of these small wells has led to the putting down of much deeper ones, and the expenditure of considerable amounts of money. The excitement awakened by the discovery of oil and gas in Pennsylvania, Ohio and Indiana has stimulated still further the efforts to secure them in Missouri. The general opinion has been, not only in this state but in others as well, that the only prerequisite necessary to the securing of a successful flow of natural gas and oil is the sinking of a deep well. In reality the subject is much more complex than is commonly supposed. There are certain natural conditions, all of which must be fully considered before a successful flow of either substance can be obtained. The absence of any one of these can only result in failure. These conditions may be reduced to four categories: There must be (1) a suitable receptacle or reservoir in which the oil and gas may accumulate; (2) a non-porous cover to retain them; (3) a particular geological structure or arrangement of strata, and (4) a pressure sufficient to force the oil and gas to the surface.

So far as is known, the extent to which the satisfying of these conditions, insofar as they pertain to Missouri, is accomplished, may be briefly stated here. The presence in the rocks of Missouri of considerable quantities of petroleum is well known. The occurrences of extensive coarse sandstones, conglomerates and porous limestones, which act as reservoirs, are also known. The existence of compact, impervious shales, which serve as covers for the more porous beds, is well understood. Artesian or hydraulic pressure sufficient to bring to the surface oil or gas, should either exist, is present throughout most of the state. The remaining condition—that of geological structure—is the chief one which requires investigation in Missouri. The particular phase of geological structure in question is that the rocks must be tilted. This causes in the porous rocks a movement of the water, oil and gas particles, in a simple mechanical arrangement. They accumulate in order of their specific gravities—the water at the bottom, then the oil, and finally the gas at the top. The special structure of the strata which will accomplish the desired effect is ordinarily known as the arch, fold or anticline. When the top of a fold is pierced gas escapes; when the arch is penetrated a little farther down oil flows out, and when the base of the bow is drilled into only water appears. The most essential line of investigation that is connected with the inquiry into the probabilities of the occurrence of oil and gas in the state is the determination of the location, extent and trend of the folds.

LIME.

Perhaps no state in the Union is better supplied than Missouri with limestone suitable for the manufacture of a high grade of quicklime. Some localities are furnishing a quality of lime which may be regarded as having no superior in the world. Recent inquiry has shown that the lime industry is not developed nearly to the extent that it might be, and that rocks well adapted to the manufacture of lime are more generally distributed than was supposed. In many places where lime was formerly burned, the industry could now be readily and profitably revived, as the circumstances which formerly militated against its continuance are now largely removed. The subject of lime was one of the first which was taken up for investigation, but owing to circumstances which could not be foreseen, the examination was delayed after the work had fairly begun. Among the topics to be considered in this connection are the properties and qualities of the various limes made in the different localities, the superiority of certain grades, and the chemical and physical characters of the rocks especially adapted to lime manufacture. The components which give value to lime and those which have a deleterious effect are much better understood at the present time than they were formerly; and the grade of lime that can be produced from given limerocks may now be predicted with considerable accuracy. The methods adopted and the improvements which may be made in the lime industry should receive full consideration. This industry should be one of the most noteworthy in the whole state.

CEMENTS.

With the rapid development of the material prosperity of the state, cements come to have a greater and greater importance each year. The term itself has recently come to be used in a much broader sense than formerly, and now applies to all those calcined lime products which will set or harden under water. Those grades which are capable of a more or less complete hardening are commonly called hydraulic limes, and are generally considered better than the ordinary varieties. Aside from the so-called hydraulic limestones which occur in various parts of the state, there are doubtless other materials which are capable of being made into a high grade of Portland or hydraulic cement. The investigations should determine the extent of the deposits, their composition and the methods of preparation.

DRIFT DEPOSITS.

Although a systematic examination of the unconsolidated deposits lying above bed-rock in the northern half of the state was begun, the removal of the person in charge to a distant locality, beyond the limits of the state, led to the temporary abandonment of the investigation. The work outlined consists of a reconnoissance to determine the general character, relations and geographical distribution of the various Pleistocene deposits. It will lay the foundation for a part of the study of the soils and road materials, and will further have an important incidental bearing upon other economic questions.

MINOR TOPICS.

Among the minor deposits which should be eventually investigated thoroughly are a number of more or less wide interest.

Substances suitable for the manufacture of mineral paints are of more than local import.

The sands for glass-making and other purposes require careful discrimination. Glass-making has already become an important industry in the state, and the deposits should be accurately delineated.

Marls for fertilizing purposes may in the future form valuable acquisitions to the mineral wealth of the state, though they may not be used at present. The extent and location of the deposits should be made known.

CABINET.

The collections made during the pursuit of the various lines of investigation are always divided into two classes. One group is composed entirely of specimens obtained for the purpose of study or analysis; the other group is made up of specimens for exhibition in the cabinet. Heretofore the latter has received comparatively little attention, partly for reason, perhaps, of the insufficient room to properly display them. It is expected that in the future much more time may be devoted to this branch of the work. The progress of the survey is now far enough along to enable this to be done in a highly creditable manner, provided the requisite amount of display space is obtained. In connection with the different lines of inquiry, there accumulates a large quantity of valuable material which illustrates in an admirable way the natural products of the state. The best and most typical of these are brought together, carefully labeled, and deposited in the rooms set aside for them. It is expected, ultimately, that all of the mineral materials found in each county will be fully represented, and the collection will form a complete index of what may be obtained in the state. Being attractively displayed and conveniently placed, architects, engineers and others may readily and easily examine and compare the various samples, and learn what is best adapted for their respective purposes. The cabinet serves to show, in the best manner possible, what Missouri possesses. There are represented the various ores, clays, building-stones, soils, limes, coals, minerals, fuels and innumerable other things of interest, as well as the products made from various raw materials. A series of photographs is also being prepared to illustrate the various geological phenomena, and, incidentally, Missouri scenery. A set of charts is in preparation showing the distribution and structure of the various useful deposits. The models already referred to in connection with mapping are also designed to be made useful in this connection.

The material for the cabinet which has been obtained by different members of the Survey is added to by the co-operation of many individuals. Owners of various quarries have thus offered to furnish, suitably dressed, different samples of building and ornamental stones. Proprietors of clay industries have been liberal in supplying suites of their wares and the raw materials. Operators have endeavored to send in representative sets of their mine products; others have likewise aided. Although this work has only been fairly started, the ensuing year will show great gains.

In extending the usefulness of the work of the Survey, special attention is now being paid to the selection of an educational series of specimens illustrative of the mineral resources of the state. As might naturally be expected, in connection with the minerals for the cabinet there necessarily accumulate many duplicates which are not needed by the Survey after they have been studied and reported upon. Most of this material is of the greatest value for class instruction in colleges and high schools, and may be made available for this purpose at little or no additional expense to the Survey. A number of educational institutions have already expressed a desire to obtain suites illustrative of the geology and economic resources of the state. In the case of the State University, installments of this kind have already been selected and made ready. Additional collections will follow shortly, and other institutions provided for in order of their applications.

As a further aid in college instruction, and as a special means of familiarizing the students with geological phenomena in Missouri, a set of selected photographs pertaining to Missouri geology has been arranged for, and may be disposed of at the nominal cost of making the prints. This series will be added to continually, and will be made more and more complete as the work of the Survey goes on. A printed list of these photographs, which may now be had, will be printed shortly, together with an explanation of the phenomena they represent. From this catalogue each instructor will be able to choose those photographs he most desires.

LIBRARY.

No special effort has been made to form a complete library. However, through exchanges and gifts from scientific institutions, a nucleus of a geological library has been established. It is essentially a working collection of books, and is designed to serve as a reference library for those directly interested in the geology of the State. Several hundred books bearing directly upon geology, besides many others incidentally referring to geological themes, have been secured. In addition, a considerable number of pamphlets and unbound volumes have been acquired. At the present time these are in the geological rooms. Efforts are being made to make the collection as complete as possible in the literature pertaining directly to the local geology of the State, and in the publications which, though relating to the geology of other states, throw light on the geological structure and resources of Missouri.

In this connection there is in preparation a complete bibliography of the literature relating to the geology of the state. It is in the form of a dictionary catalogue, with abundant cross-references.

PUBLICATIONS OF THE SURVEY.

A full explanation has already been made of the general plan adopted in the reports of the Survey. In placing the results of the various investigations before the public, progress was necessarily apparently slow. The reasons are obvious. Now that the survey is under good headway, the reports on the various lines of work taken up will appear in more rapid succession than heretofore. Altogether there have been printed in the various reports about 3000 pages, of which over one-half have been issued during the past eight months; and during the same period nearly as much additional manuscript has been revised and made ready for printing.

Briefly, the contents of the reports are appended.

BULLETINS.

470 Pages, 13 Plates, 11 Figures.

CONTENTS:

No. 1. Administrative report; Coal Beds of Lafayette county; Building Stone and Clays of Iron, St. Francois and Madison counties; Preliminary Catalogue of Fossils Occurring in Missouri.

No. 2. Bibliography of Geology of Missouri.

No. 3. Clay, Stone, Lime and Sand Industries of St. Louis City and County; Mineral Waters of Henry, St. Clair, Johnson and Benton Counties.

No. 4. Description of Lower Carboniferous Crinoids of Missouri.

No. 5. Age and Origin of the Crystalline Rocks of Missouri; Clays and Building Stones of Certain Western-Central Counties Tributary to Kansas City.

SHEET REPORTS.

204 Pages, 11 Plates, 28 Figures.

CONTENTS:

No. 1. Higginsville Sheet, Lafayette county: Topography, hydrography, soils, forestry, stratigraphic and structural geology, coal, building stones, and clays.

No. 2. Bevier Sheet, including portions of Macon, Randolph and Chariton counties.

No. 3. Iron Mountain Sheet, including portions of Iron, St. Francois and Madison counties.

BIENNIAL REPORTS.

150 Pages, 5 Plates, 1 Diagram.

CONTENTS:

1. Biennial Report of the State Geologist, transmitted by the Bureau of Geology and Mines to the Thirty-sixth General Assembly.

2. Biennial Report of the State Geologist, transmitted by the Bureau of Geology and Mines to the Thirty-seventh General Assembly.

3. Biennial Report of the State Geologist, transmitted by the Bureau of Geology and Mines to the Thirty-eighth General Assembly.

VOLUME I. PRELIMINARY REPORT ON COAL.

BY ARTHUR WINSLOW.

227 Pages, 1 Plate, 131 Figures.

CONTENTS:

VOLUME II. IRON ORES.

BY FRANK L. NASON.

366 Pages, 9 Plates, 62 Figures.

CONTENTS:

VOLUME III. MINERAL WATERS.

BY PAUL SCHWEITZER.

256 Pages, 34 Plates, 11 Figures.

CONTENTS:

VOLUME IV. PALEONTOLOGY (PART I).

BY CHARLES ROLLIN KEYES.

314 Pages, 34 Plates, 9 Figures.

CONTENTS:

VOLUME V. PALEONTOLOGY (PART II).

BY CHARLES ROLLIN KEYES.

320 Pages, 22 Plates, 2 Figures.

CONTENTS:

VOLUME VI. LEAD AND ZINC DEPOSITS (SECTION I).

BY ARTHUR WINSLOW.

387 Pages, 12 Plates, 71 Figures.

CONTENTS:

VOLUME VII. LEAD AND ZINC DEPOSITS (SECTION II).

BY ARTHUR WINSLOW.

401 Pages, 28 Plates, 196 Figures.

CONTENTS:

VOLUME VIII. ANNUAL REPORT.

BY CHARLES ROLLIN KEYES.

400 Pages, 30 Plates, 16 Figures.

CONTENTS (accompanying papers):

VOLUME IX. AREAL GEOLOGY (READY).

BY C. F. MARBUT AND OTHERS.

350 Pages, 5 Maps, 20 Plates, 30 Figures

VOLUME X. ANNUAL REPORT.

BY CHARLES ROLLIN KEYES.

350 Pages, 15 Plates, 25 Figures.

INDIVIDUAL WORK OF THE GEOLOGICAL CORPS.

During the past year the efforts of the Survey have been restricted in regard to all the field work somewhat more than in previous years. The energies of the different members of the geological corps have therefore been directed largely toward bringing together some of the results obtained during several years of investigation, finishing up this work so that it could be published, and in preparing for the press other information secured. The necessary field work has been undertaken for completing the reports on the several subjects begun in previous years.

In addition to the administrative duties connected with the Survey, and the editing and supervision of the printing of the reports, the State Geologist has personally undertaken to complete the investigation of the building stones of the state, the work of which has progressed as rapidly as circumstances would permit. A general account of the geology of the state has also been begun, but this must necessarily go on slowly at first. Besides, numerous field examinations have been taken in order to settle disputed or doubtful points which have come up in the course of the work in different parts of the state. The report on Paleontology was finished and published. Several minor papers were also prepared for different scientific journals.

Mr. E. H. Lonsdale, who was formerly connected with the Survey, but who has for the past year and a half been engaged in geological work in a neighboring state, has recently resumed work in Missouri. He is thoroughly familiar with the investigations being carried on and the details of the various lines of work in progress. As a special theme of investigation, he has undertaken an inquiry concerning certain building materials of the state, and it is presumed that a report embodying the results of this work will form one of the most instructive reports to appear, and at the same time one of great practical value.

Dr. Erasmus Haworth has recently given considerable time to a full and a final revision of his report on the crystalline rocks of Missouri. This is a very interesting piece of work, and one which has long been needed, for practically nothing has been written regarding the economic value of the granites of Missouri. The rock has proved to be a good grade of stone for all kinds of building and ornamental purposes. Moreover, it has no equal in the Mississippi valley, and is destined to have far wider utilization than at the present time, though some of the finest buildings in the large cities have been constructed of it, in part at least. The study of these rocks was begun some ten years ago at private expense. Afterward it was continued in connection with the Federal survey. Subsequently the investigations were taken up under the auspices of the Missouri survey. The original plan was therefore changed somewhat, and the work adapted to the special needs of the people of the state. The report is now practically ready, and will form a part of volume VIII.

Prof. H. A. Wheeler has continued his investigations and experiments upon the clays of the state. The field work is completed, the physical tests finished and the chemical analyses made. The report is already more than half written, and the entire manuscript promises to be ready for printing by the first of June next. The wealth of Missouri in clay for nearly all purposes is something astonishing, as brought out by the recent study. The discovery of extensive deposits of good china clays will certainly attract capital sufficient to start up on an extensive scale a new industry for the state.

Mr. C. F. Marbut, who has had charge of the detailed mapping for some time, has pushed the work with vigor. During the past summer he has finished several of the sheets previously begun. Before the close of the season all the work assigned to him was completed in a thoroughly satisfactory manner. During and since his completion of the field work on the several areas, Mr. Marbut has written full accounts of the geology, and these reports, by the time the drawings for the illustrations are prepared, will be ready for the press. The demand for these sheets has become urgent, and it is hoped that no unnecessary delays will occur to prevent an early publication of these reports. Further, a report of the hypsometry, or the altitudes of the state, upon which Mr. Marbut has been engaged as part of his work for the past four years, is finished, and forms a part of volume VIII. It will be essentially a dictionary of elevations of all the towns and principal points in the entire state. All errors and discrepancies have been carefully eliminated so far as possible, and all altitudes reduced to mean sea-level as a datum plane.

Mr. Arthur Winslow has been engaged chiefly in bringing together materials for his report on the lead and zinc deposits, first as an officer of the Survey and later by contract. This work was begun several years ago, and notes gathered and observations made without serious interruptions during that period. In July of the present year the manuscript of the report was finally completed and the printing begun. For the succeeding five months the final revision of the work was carried on, and the proofs read as the matter went through the press; two bulky volumes aggregating 800 pages, illustrated by suitable cuts and maps, are the outcome of these efforts.

Mr. J. D. Robertson was in the employ of the Survey during the first half of the present biennial period. His efforts were directed largely to assisting on the lead and zinc report.

Prof. E. M. Shepard, who for several years past has been engaged upon the areal geology of the region around Springfield, has recently submitted a detailed account of his observations, which will be incorporated in a very full report on the district. It forms a valuable contribution to the geology of the southwestern part of the state, and it is hoped that the printing of the report may be begun early in the spring.

Prof. J. E. Todd, who has spent several summers in making a study of the drift or superficial deposits of the state, has commenced the preparation of a report on the subject, with the assurance that it will be ready for submission early in the summer.

CO-OPERATION OF FEDERAL AND STATE SURVEYS.

An effort has been made recently to obtain aid from the United States Geological Survey on work which is too expensive for the state organization to undertake satisfactorily without greatly increasing its facilities, yet it is work which is very necessary as a fundamental help to the determination of the economic resources of a district. As a result, the director of the Federal Survey has expressed a willingness to cooperate in certain lines of work, and it is expected that a party will be put in the field during the coming season. The plan has worked well in other states, and it is believed that Missouri will be greatly benefited by the aid thus received.

EXPENDITURES DURING THE BIENNIAL PERIOD.

During the past biennial period the appropriation for the continuance of the Survey was only one-half as much as it was during previous terms. A tabulated statement showing the distribution of the funds is given below:

Salaries	$9,329 07	Field supplies	4 93
Subsistence	464 20	Library, books	$96 37
Railway fares	535 22	Photographs and supplies	103 74
Horse and wagon hire	263 45	Reports, printing	3,415 82
Postage and telegrams	179 53	Reports, binding	168 00
Freight and express	475 14	Maps	757 55
Office instruments	76 85	Plates	420 46
Office furniture	80 95	Figures, drawing, etc	131 43
Office supplies	157 58	Office printing	86 19
Cabinet supplies	6 80	Temporary assistance	361 35
Laboratory instruments	7 48	Special assistance	2,741 86
Laboratory supplies	133 23	Balance	1 10
Field instruments	1 70		$20,000 00

FUTURE OPERATIONS OF THE GEOLOGICAL SURVEY.

PRESENT STATUS OF THE WORK.

In continuing the geological survey of Missouri, profit should be derived from the work of the past, and careful attention paid to the experience gained. In the previous pages there have been briefly outlined the scope of the survey and methods followed in investigating the natural resources of the state. A summary is also given of what has already been accomplished, of the work which is now in progress, and of the work which yet remains to be taken up. It may be readily inferred that a geological survey of a region, a thorough investigation of the useful deposits of a given district, is not something which a state may well do without, but in reality is one of the fundamental factors in all industrial activities.

The demands for information and aid which are continually being made upon the survey from nearly every part of the state, show clearly the wide-spread interest taken in the different lines of investigation with which it has to deal. As the work continues, the fact is becoming more and more generally recognized by the people that the class of investigations now being carried on is what should have been undertaken and completed long ago. The work of the geological survey is now fairly begun. The plans of operation are progressing systematically. The results are rapidly accumulating. In order that the work may be carried to completion, time is required. Any delay, back-set or suspension of the work can only give rise to a depreciation, in a great measure, of the results already secured. That the attainments may last for all time to the benefit of the state, liberal provision is necessary to carry the work to completion.

In following the history of the geological survey of the State, it will be seen that its life has been a fitful one. To quote from one of the recent biennial reports: "It has existed for a few years only to be discontinued before any plan of work was completed, and at the sacrifice of much of the result reached. It has been weakened by successive changes of management, with accompanying changes of policy. Its trained corps of employes and its equipments for work have been lost during the interim between two periods of activity; its collections designed to illustrate the resources of the State have been scattered, and with it all a considerable sum of money has been expended. Yet the interests which this work is especially devoted to have continued to exist, and have continued to demand recognition and will always continue to do so, whether it be through a Bureau of Geology and Mines, through a Board of Internal Improvements, through a Bureau of Statistics, or through a Special Commission. And these facts, true as regards Missouri, are based upon the experience of other states and nations. Just so surely as it is true that it is conducive to the welfare of the State that the existence, the extent and the nature of its mineral resources should be determined and made known, just so surely will such work be prosecuted. History would teach us that the question is, not whether these facts shall be determined or not, but whether they shall be determined now or later. If determined now, the results will be available at once and the benefits will be felt immediately; if determined later, the beneficial effects will be deferred in proportion. The work is not to be regarded as a luxury which a rich state may afford, but which a poor state may dispense with; it is an investment which will yield good returns to the poor as well as the rich; it is a work of improvement which will enhance the value of property; a work in harmony with the peace-loving spirit of the age, in accordance with which the energies of the state are being directed more and more toward industrial development."

RECAPITULATION.

To summarize briefly, the work finished during the past biennial period, as shown by the published results, has been the report on paleontology, in two parts; the lead and zinc report, also in two parts—four volumes in all; and two sheet reports—the Iron Mountain and the Bevier. The work on ten other sheets has been in great part finished, and the reports on crystalline rocks and several minor subjects have been made ready for printing. The investigation of the clays and building stones and the mapping of certain areas have made good progress.

Of the work demanding immediate attention, there are the reports which are practically complete and now regarded as ready for publication. These are five sheet reports on areas in the central and western parts of the state, which were prepared during the past summer, the reports on the granite rocks of the southeast, the dictionary of elevations, and the memoir on the formations of the Coal Measures. Besides, there are several important reports which are very nearly ready, some requiring a little field work, others needing some further preparation and revision before being sent to the press. Among these may be mentioned two sheets in the southeastern part of the state, four sheets and Greene county, in the southwest, and the report on clays of all the state.

There are several lines of work which are far enough along to be completed during the next two years; these are the examination of the building stones and the geology of several districts. As new work, the examinations of all useful minerals of the state and of building materials should be commenced at an early date.

CONTINUATION OF THE INVESTIGATION.

Previous estimates made for conducting the operations of the geological survey have been based on $10,000 for the biennial term, and during the first three years the amount made available was at this rate. During the next biennial period there will be, in addition to the continuation of the regular work and the accomplishment of the necessary field operations, a large amount of material which must be prepared for printing; and this last feature will form a much heavier item of expense than heretofore, for the reason that results have been allowed to accúmulate. Nevertheless, it is believed that the work is now so far advanced that it may be carried on successfully and satisfactorily on $14,500 annually, or $29,000 for the biennial term. This amount is considerably less than what has been counted on in former years. Of course a larger amount would enable the work to go on just so much faster, and permit the results to be brought out more rapidly. But it is believed that with a moderate outlay, even though the work be extended somewhat, it can be conducted more economically, and in reality more speedily, than if a larger sum were expended one term, and in the next, perhaps, a much smaller one.

In order that the work may be continued with the same vigor during the next two years, the annual appropriation should not be less than that in the past. There is, however, a desire to have the investigations go on more rapidly, the reasons for which have already been stated. If the work is to be extended in the manner expected, an enlargement of the means for the next one, two or more biennial periods, as the case may be, is necessary, after which a diminished amount would suffice until the completion of the survey. The advantages recommending this plan, rather than that of smaller expenditures extending over a long period of years, are, greater economy, more definite limitation to the completion of the work, quicker attainment of results, and earlier presentation of the information to the public.

In this connection it may be stated, quoting again from a former report, that "few people who have not been engaged in such work, or who have not tried to carry it over a great state like this, so as to produce results which shall be as authoritative as such official work ought to be, realize how small an appropriation of $10,000 per year is, when the magnitude of the interests involved is considered.

"Ten thousand dollars represent:

Between ½ and ⅓ of a cent per individual;
One cent per every forty-acre tract;
One-fortieth of a cent per acre;
One eight-hundredth of one per cent of the total assessed valuation of property;
One two-hundreth part of the state revenue;
One one hundred and fiftieth part of the total expenses of the state.
One-twentieth of one per cent of the annual value of the mineral products of the state.

"The sum represented by an increase in the land value through the work of the survey, of only five dollars per acre, and of only twenty square miles, would pay for the operations of the survey, as at present run, for about six years, and this small amount is now in places paid for mining rights in the state upon lands known to be underlain by coal. An increase of the same amount over two thousand square miles would raise the amount received by the state from taxes by about $20,000 per year."

Put in another way, one of the areas of detailed mapping and covered by a "sheet" contains in the neighborhood of 230 square miles. In a coal area, where the presence of the coal beds is established by the survey, the value of the land is greatly enhanced. Placing it at only $10 an acre for such an area, which is low in those districts which have been investigated thus far, the total increase in the valuation would bring into the state treasury every year over $1500. This in itself is more than what the state originally expended on the area, and in itself is a good investment.

The portion of this ten thousand dollars per year derived from different sources is as follows:

From taxes on real property	$5,500 00
From taxes on personal property	1,600 00
From taxes on railroad, bridge and telegraph companies	550 00
From license from dramshops, etc	900 00
From taxes on merchandise and manufacturing plants	450 00
From fees and special taxes, about	1,000 00
Total	10,000 00

DISTRIBUTION OF REPORTS.

The printing of the reports is naturally the heaviest item of expense connected with the survey, and ordinarily should use up fully one-half of the available resources. This expenditure may be in great measure overcome by modifying the present way of distributing the reports. After supplying the reports to the members of the legislature, state officers, state institutions, college and school libraries and leading newspapers of the state, and persons giving aid to the Survey, first-class libraries and geologists of national reputation beyond the limits of the state, and a small number to satisfy future demands and exchanges, all remaining volumes may be sold at the cost price of each volume, the moneys thus accruing to be covered back into the treasury of the state. By this method of distribution, from one-half to two-thirds of the total amount of printing would, in the course of a decade, revert to the treasury. The selling price per volume would never be more than one dollar, and often only one-half of this — an amount sufficient to prevent undue wasting. Reports would get into hands where they would do the most good to the state. The distribution could be more properly and more equitably made. The geological reports have an intrinsic value, and under the present method of disposition command good prices at the book dealers, as the editions are exhausted.

Even the old Swallow report of 1855 now sells for $2.50 or $3. The Pumpelly report and atlas of 1872 readily brings $8; and the Broadhead report of 1874, $5. These facts are mentioned merely in order to show how the reports of the geological survey are regarded by those living not only inside the state, but far beyond the borders as well. Furthermore, similar scientific reports of other states and of nearly every civilized country issuing publications of this kind are held for sale, usually at cost. The geological reports of the neighboring states of Arkansas, Iowa and Minnesota are thus sold; and the scientific memoirs issued by the Federal government are distributed in a similar manner.

THE CRYSTALLINE ROCKS OF MISSOURI

BY

ERASMUS HAWORTH.

CRYSTALLINE ROCKS OF MISSOURI.

BY ERASMUS HAWORTH.

CONTENTS.

GENERAL GEOLOGY OF THE MISSOURI CRYSTALLINE AREA.

(By Charles R. Keyes)

GEOGRAPHICAL DISTRIBUTION.

The massive crystalline rocks of Missouri are confined to the southeastern part of the state. They occur in irregular masses and isolated hills extending over an area 70 miles square, which is widely known as the Iron Mountain country. The series consists of granites and porphyries as the principal types, with several varieties of dark, trappean rocks which are chiefly diabase and which occur in the form of dikes. All are very old—in fact, the most ancient rocks exposed within the limits of the state. They are regarded as igneous in nature, and as pre-Cambrian in age. The nearest exposures of rocks of like antiquity occur in northern Wisconsin and Minnesota. Outcrops of other crystalline masses are found in central Arkansas, but all of these are much younger, probably Cretaceous, and consequently are in no way related to those of Missouri.

Pilot Knob is approximately the center of the crystalline district. For a distance of perhaps a dozen miles in all directions from this point, the massive crystallines form the greater portion of the surface rock; while in an easterly direction they are practically continuous for more than twice as far. Beyond the large central field the exposures gradually become less and less frequent. To the north they do not reach much beyond Bismarck. Northeastward they are found in Ste. Genevieve county, 30 miles from Pilot Knob. On the east, hills of similar rock are abundant as far as Castor creek. To the south they stretch away in large masses for many miles, with occasional outcrops as far as the boundary line of Butler county. To the southwest they extend into Shannon county and perhaps even beyond. They stretch out to the west almost unbrokenly to the east fork of Black river; while numerous scattered hills

ST. FRANCOIS MOUNTAINS; PILOT KNOB FROM ARCADIA.

THE FALLS; EAST FORK OF BLACK RIVER; PORPHYRY LEDGE.

continue even beyond the middle fork of the same stream. Toward the northwest similar rocks occur at short intervals as far as Little Pilot Knob in Washington county.

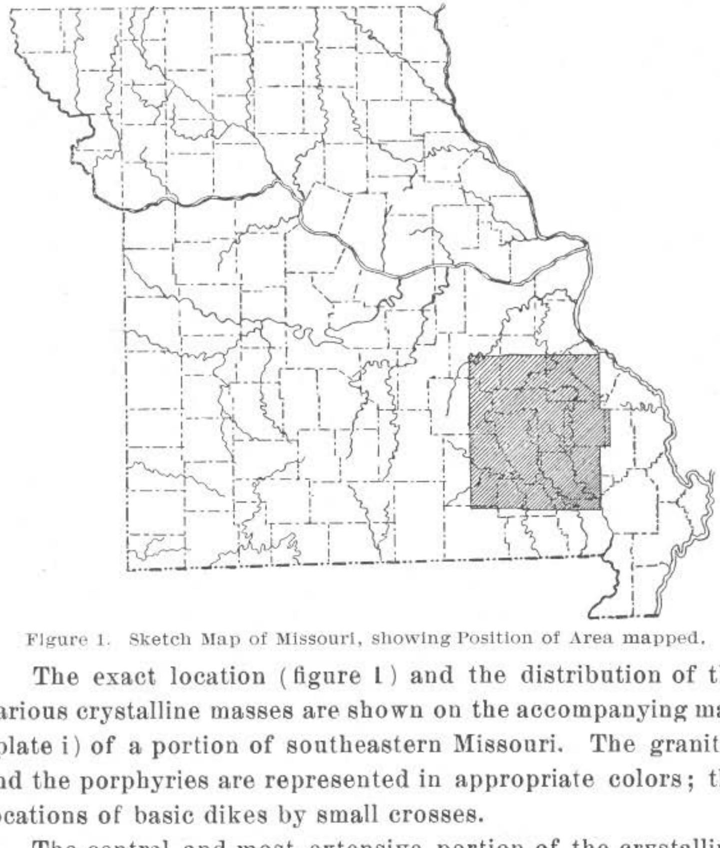


Figure 1. Sketch Map of Missouri, showing Position of Area mapped.

The exact location (figure 1) and the distribution of the various crystalline masses are shown on the accompanying map (plate i) of a portion of southeastern Missouri. The granites and the porphyries are represented in appropriate colors; the locations of basic dikes by small crosses.

The central and most extensive portion of the crystalline area is, as just stated, in the vicinity of Pilot Knob and Iron mountain, and occupies the median parts of townships 33 and 34, north, in ranges III, IV and V, east of the fifth principal meridian, with occasional extensions much farther in several directions. The crystalline area is almost unbroken for a distance of thirty miles southeast and southwest of Bismarck, which is situated near the northern margin of the great central district. The other masses of similar rock are much smaller and are widely scattered.

PHYSIOGRAPHY.

Topography.

The crystalline area of southeastern Missouri is a highland district, for which reason it has received the name of St. Francois mountains* (plate ii). It forms the eastern part of the Ozark uplift in Missouri. The elevations rise from 500 to 800 feet above the surrounding valleys, and from 1200 to 1800 feet above the sea-level. They consist of numberless hills and peaks, short undefined and irregular ridges, low conical tumuli, which are here and there clustered together, but more frequently are separated from one another by broad tortuose valleys, whose surfaces are billowy, rolling or dotted by low subsidiary mounds, and whose streams, as a rule, neither meander in wide flood-plains nor gouge out deep gorges for their cannels, but allow the surrounding hills to come down to the water's edge in long graceful slopes, rarely seen elsewhere. While there are no peaks which stand out prominently above all others, the group itself rises out of and above the broad plateau surface, having the general gentle slopes of the uplift whose crest passes through a portion of the highland district.

Within the area mentioned there is a great diversity of topographical features, and at the same time a remarkable similarity everywhere. No pronounced types of relief are discernible in the different portions of the region. That there is a decided mountainous aspect to the landscape is certain, but the elevations defy all attempts at satisfactory and systematic classification. No well-defined ridges or broad gentle vales are present. There are nowhere marked relief features which can be ascribed directly to geological structure, such as folding, faulting, and other results of orogenic movements which are usually found in most mountainous districts. All is the result of comparatively gentle corrasion on a slowly rising plain that has oscillated slightly upward and downward for long ages, worn down nearly to base-level time and again, per-

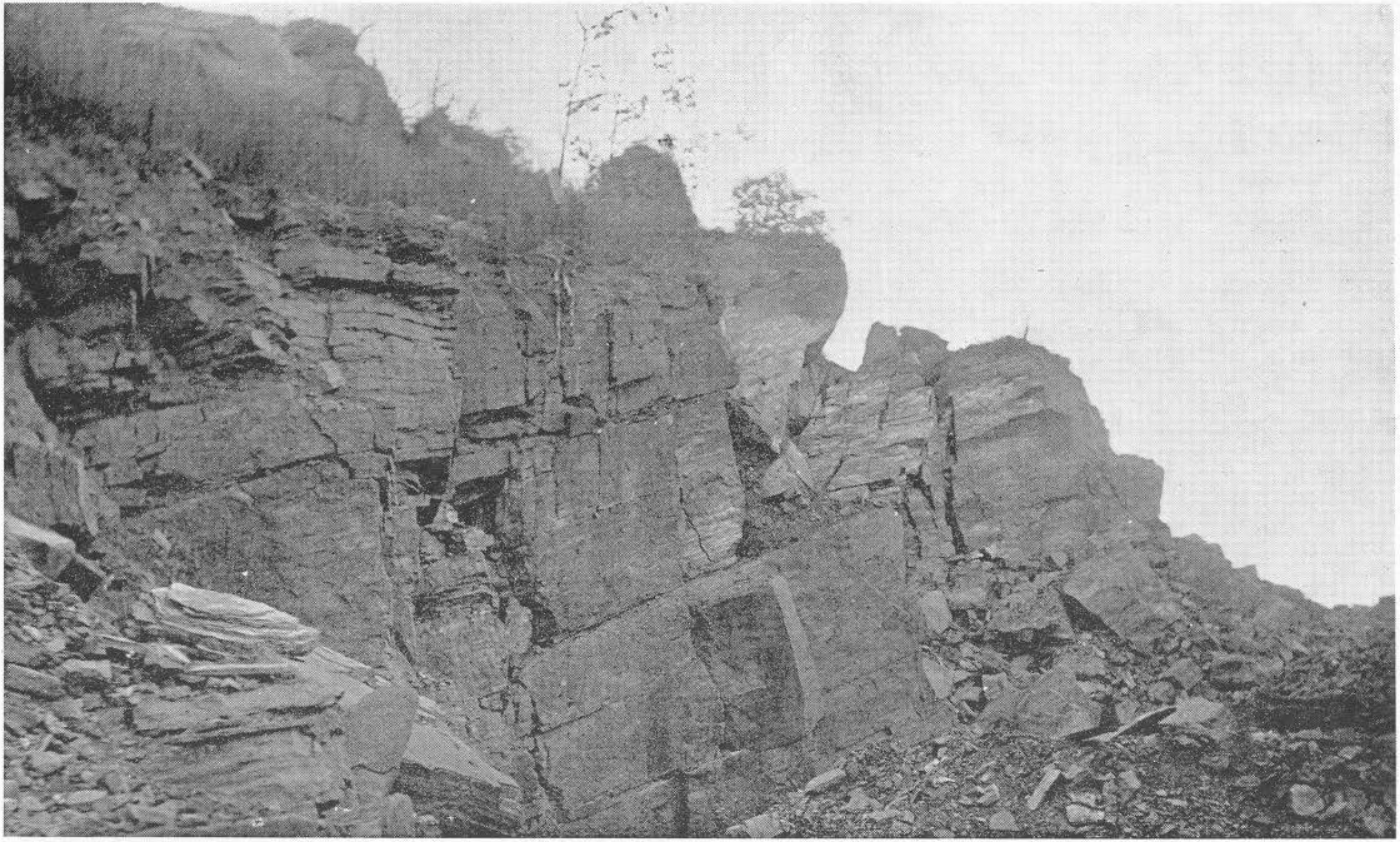
*Missouri Geol. Sur., Iron Mt. Sheet, p. 4, Jefferson City, 1894.

haps, and which is now once more being vigorously ground down under the ceaseless action of meteoric agents and running waters. Long exposure to atmospheric influences has produced rounded, even outlines, and has removed all traces of sharp contours and serrated crests, if they ever existed. From the top of one of the more commanding heights there stretches away on every hand an interminable succession of rounded prominences, each more or less completely isolated, varying little in altitude, yet rising behind one another until lost in the dim haze of distance. The nearer ones are quite irregular, and present all stages of degradation, from the masses sharply trenched by freshet runnels, to the smooth conical hills with their smaller outlying mounds which have long since become separated from the larger peaks through secular decay of the intervening rock. Everywhere are shown the effects of moderate decay and erosion of masses of varying resistance and of different capabilities of resisting disintegration.

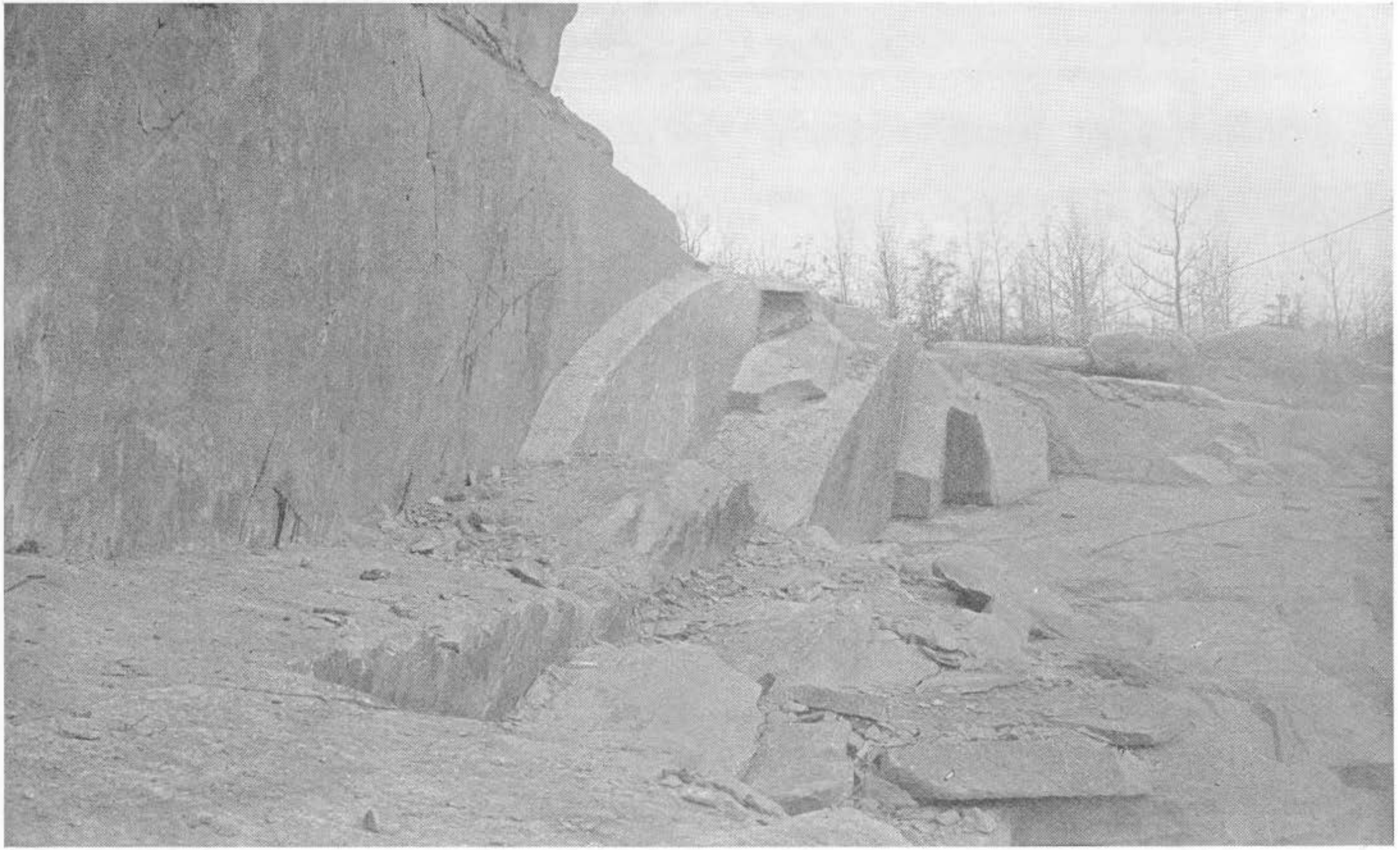
The components of the St. Francois group are usually rather steep-sided, and rise with some abruptness from the narrow broken valleys. In the central part of the area nearly every elevation is made up of igneous rock, while most of the valleys between are composed of less resistant limestones. The various types of rocks give such characteristic phases of topography to the different parts of the district, that the true lithological nature of the rock composing a hill may be readily inferred at a distance of several miles.

East of the great central mass of crystallines the country is comparatively level, or rather not so rugged as in the immediate vicinity of the porphyry hills. In passing still farther toward the border of the area, the topography continually changes; the porphyry is less frequently found in the valleys, and more and more of the hills is composed of limestone. The granites in various places form high, steep prominences. To the west the difference in the surface relief of the granite areas is even more marked. No less than four of the most conspicuous elevations here are made up of granite. One of these on the east fork of Black river, in the vicinity of the "falls" (plate iii), connects with the long row of prominent porphyry hills, but is higher than any of them. Another is three miles north of the one last mentioned, between the East fork and the Imboden. It is called "Hightop," for it towers above all the hills surrounding it, rising 635 feet above the valleys at its base, and compares in this respect favorably with Shepherd mountain, the largest and highest porphyry peak of the central area. The third principal granite hill lies to the south, and its height is about the same as the two mentioned; while the fourth is about a mile east of Hightop. Farther west are still other crystalline hills, but they are composed of porphyry. Beyond the Imboden fork is another tributary known as Shut-in fork. The word "shut-in" is a name usually applied throughout the region to every place in which two hills are close together with a stream flowing between. In this case the two hills forming the "shut-in" are very high, particularly the westernmost, which rises 610 feet above the stream.

Throughout the Black river country, there is unusual regularity in the courses of the streams; from which fact it may be inferred that there is a corresponding symmetry in the arrangement of the elevated portions of the region, instead of promiscuous scattered positions of the hills so common elsewhere. There is a series of long rows of elevations between the streams. Generally the southernmost point of each is the highest, as in the case of Hightop and the other granite hills mentioned above. From the summit of any prominent elevation in this region there is visible every crystalline mass within a radius of many miles. Here and there may be noticed a prominence standing out more boldly than the others, and they often after closer inspection resolve themselves into rude ranges. The most prominent of these groups is in the vicinity of Annapolis. The row forms a broad curve extending to the southwest a distance of three miles. To the east and southeast there are first a few small porphyry hills in the immediate vicinity of the town, and beyond this a large elevation with three prominent spurs. These hills in turn stretch away to the southeast, almost connecting with the row of mountains on the east bank of Crain Pond

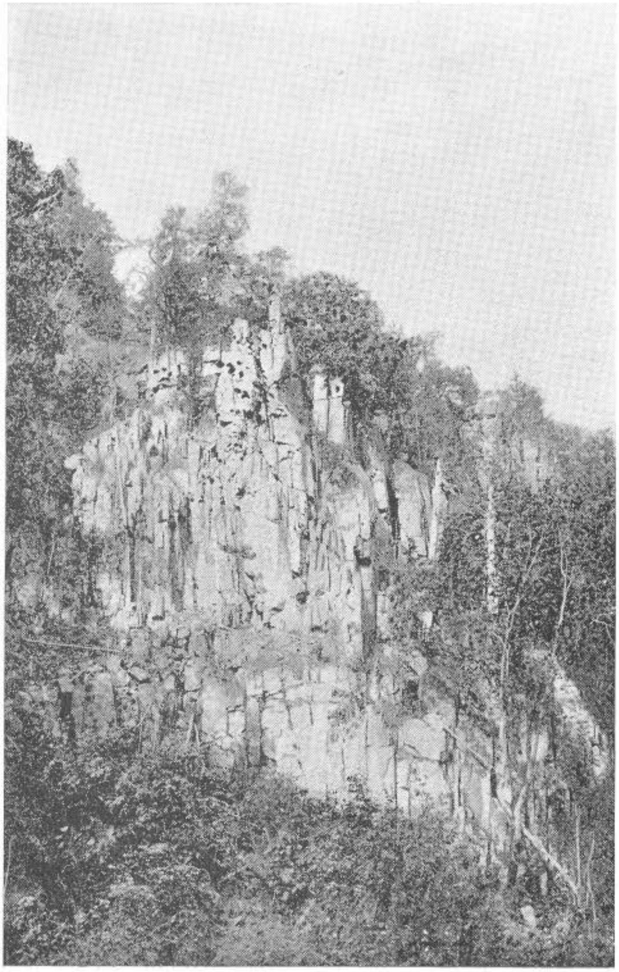


APPEARANCE OF PSEUDO-STRATIFICATION PLANES IN PORPHYRY.



JOINTING OF GRANITE QUARRY OF SYENITE GRANITE CO., GRANITEVILLE.

JOINTING OF GRANITE PORPHYRY, EAST BANK OF EAST FORK OF BLACK RIVER.



PORPHYRY COLUMNS ON MARBLE CREEK AT FRENCH MILLS.

creek, and from thence to Gray mountain immediately east of Brunot.

Southward from the point of view just mentioned, across a stretch of six or seven miles of lowland, is a second row of hills extending east and west and reaching from Black river to the St. Francois. On the west is Mann, and on the southeast Rubel mountain. Both are large porphyry hills. Beyond the latter are McFadden, Aley and Mud Lick mountains, the latter two rising 710 and 793 feet above the surrounding valleys. The last one is the larger of the two and consists of two separate peaks. The eastern base is washed by the St. Francois river.

Still farther to the southward from the point of vantage named are other hills which appear as an irregular row trending east and west. The westernmost is Finley mountain, a large peak covering nearly six square miles and reaching from the Iron Mountain railroad on the east almost to Black river on the west. It rises 725 feet above the valley, and may be regarded as one of the largest prominences of the region. To the east is Clark mountain, the highest and grandest hill in the whole area. It is conical in form and rises majestically to a height of 843 feet above its base. It may be seen from every prominent peak south of Iron mountain, and appears to rise so high above the surrounding hills that it almost seems higher than any of those to the north. Looking in that direction from Clark mountain, the whole country for a distance of 30 miles is visible, from Black river to Knob Lick. The interval between the two points rises as a wall upon the landscape. Hightop and Shut-in mountains appear to the northwest, Shepherd mountain to the north, Black and Blue mountains to the northeast, with numberless intervening hills of almost equal height and nearly equal prominence.

One more district deserves special mention in this connection. It is along the St. Francois river below the Silver mines. The hills close in on each side, but usually allowing a valley wide enough to contain extensive farms, first on one side of the stream and then on the other, while at other places it narrows to a width scarcely sufficient to admit the passage of the river. The hills are very large. On the west bank are Black, King, Gray and Mud Lick mountains, with less prominent ones between. On the east bank are peaks which rise fully as high.

Drainage.

The crystalline area is the highest part of southeastern Missouri. Descending gradually on all sides from this place, the drainage becomes nearly quaquaversal. The declination of the surface, except perhaps toward the west, is quite rapid, and in consequence the streams erode their valleys vigorously—not so fast, however, as to form canyons along their courses, but at a rate sufficiently marked to prevent the channels from meandering much and forming flood-plains. For the most part the valleys are broad trenches, with the flowing contours of the hills continuing down to the channels of the streams themselves.

GEOLOGICAL FORMATIONS.

Crystallines.

The broad distinction to be drawn between the rocks of southeastern Missouri are between the basal crystallines, which are largely igneous in origin, and the non-crystallines, which are sedimentary. Most of the former are massive, just as they solidified from a molten state; the latter are fragmental, in the same condition as when deposited layer upon layer in the quiet shallow seas of long ago. The first comprise principally granitic masses; the second are stratified limestones and sandstones.

Igneous character.—Previous to the recent work in the crystalline area it had been a commonly expressed opinion that the rocks, in large part at least, were metamorphic in character; that they were all highly altered sedimentary deposits. The result of later investigation has been to establish beyond all doubt the truly igneous nature of these rocks. Both field observations and microscopical examinations agree in this respect. Recapitulating the evidence as recently set forth,* the

*Missouri Geological Survey, Bul. 5, p. 15, Jefferson City, 1891.

eruptive character is deduced from the following considerations:

Field Evidence:

1. There is an absence of true bedding, which is so characteristic of sedimentary rocks.

2. There is shown nearly everywhere a very pronounced flowage and banded structure, which is so commonly observed in lavas; and in a few places such structures as lithophysæ, which are found in modern outflows of molten masses.

3. There occurs abundantly a well-defined volcanic breccia, the fragments of which are embedded in a felsitic ground-mass. The irregular angular fragments themselves show flowage structure.

4. Scoriaceous and amygdaloidal material, common in lavas, has been detected at a number of points.

5. Tufaceous rocks have been observed on Shepherd mountain and elsewhere.

6. There is no graduation of the crystalline masses into the non-crystalline or stratified rocks.

Petrographical Evidence:

1. The texture of the ground-mass of the porphyries and breccias is identical with that of masses whose eruptive nature is well known.

2. The flowage structure is even more manifest when the rocks are examined microscopically than when in the field.

3. Broken crystals, due to the motion of a viscous lava after certain minerals had become crystallized, appear frequently.

4. Many crystals show clearly magmatic corrosion similar to that shown in the lavas of modern volcanoes.

5. The structure of certain portions of the rock indicates it to be truly amygdaloidal.

6. There is nowhere found metamorphic minerals in the rocks.

Geological Structure.—In the early references to the crystalline rocks, attention is called to a peculiar though imperfect bedding observable in many of the exposures, and it was probably this fact more than any other, as well as the fact that no discrimination was made between the massive porphyries and the apparently clastic beds occupying small areas—as for example at the summit of Pilot Knob—that led to the general belief that most of the rocks were highly metamorphosed sedimentaries.

Imperfectly developed stratification, which is often apparent in the eruptive granites and porphyries, and in other regions in other massive crystallines also, arises in two ways. In the first place, as will be seen further on, the Missouri massive rocks are thought to be, in part at least, ancient effusives or volcanics. They are supposably great masses of molten material which have been forced out to the surface. Many of the exposures of the region reveal the presence of seams which impart to the rock a rudely stratified appearance. The effect is not unlike that shown at the top of Pilot Knob (plate iv), which, however, is not a porphyry flow, as was once supposed.

Planes of pseudo-stratification are widely known in volcanic rocks, and in almost all massive formations which have cooled from a liquid state. In the case of the effusive masses, a decided lamination is frequently produced by successive flows which follow one after another at sufficiently long intervals to admit of a cooling and partial solidification to take place at the surface of the different outpourings. Planes of separation are also commonly formed through contraction in cooling. Volcanic rocks show further a slight difference in chemical and mineralogical composition in different parts, which gives rise to banding. When cooling takes place the difference in composition occasions division planes more or less parallel to one another, and also parallel to the surface. It has been observed in the porphyry hills of Missouri that the dip of these planes often coincides with the present slopes of the elevations. At Pilot Knob, for instance, and at Buzzard mountain, which are separated by a narrow valley, which was originally some 300 feet deeper than at present, as is indicated by the borings of the diamond drill, the different porphyry ledges show on the north side of the former that all the division planes dip to the north. In a similar way, on the south side of the latter mountain the dips are to the south. On Cedar hill the same phenomena of the planes dipping with the hillside at all points of observation are presented.

The second way in which pseudo-stratification planes develop in the massive rocks is through crustal movements. Elevation of large areas as the result of orogenic pressure produces great stresses which must be relieved. Folding, faulting and slaty cleavage are the results when the pressure is very great; jointing and false stratification arise when the strains are small. The effects are very different with different rock masses. If the body of rock be hard and brittle, as in the case of quartzites, the blocks may be very small, often scarcely a foot each way. If the rock be some tough stone, as granite or diabase, the blocks may be exceedingly large, sometimes several hundred yards intervening between the different joint-planes. Orogenic stresses may sometimes assist strains induced by contraction in cooling, and operate largely in the same direction—most frequently horizontally, thus giving a well-defined bedded aspect to the rock masses. The stratification ascribed to the crystallines may, therefore, be regarded as secondarily acquired, and not as a primary condition obscured through metamorphic action.

Weathering of Granitic Rocks.— In this connection it may be well to call attention to some exceptionally fine examples illustrating the way in which granitic masses decompose, of which jointing and the development of pseudo-stratification planes may be regarded as the first stage in the process of rock dissolution. It is a well-known fact that in the regions farther north, within the limits of the glacial boundary, the granites and other hard, massive rocks which occur at the surface, present a remarkable fresh appearance—all the effects of decay being strikingly absent. In comparatively recent times, geologically speaking, the glaciers removed all the loose material from the areas over which they passed, and the boulders from the old ledges in the far north now lie strewn over the surface of the country to the southward, so far, approximately, as the Missouri and Ohio rivers. South of the line thus marked out, ice invasions have not affected the rocks, which have long been decaying without interruption. In the crystalline area of Missouri, all of the various stages of disintegration are well shown, from the solid unaffected mass, to the incoherent granitic sands.

The horizontal division planes to which reference was made as producing an effect similar to stratification are crossed by other series of joints which are vertical. These seams are the natural breaks in the continuity of the rock of which advantage is taken in quarrying. (Plates v and vi: the first is from the quarry of the Syenite Granite Company at Graniteville, and the second is from the east bank of Black river.) The origin of these joints is due in part to contraction of the igneous masses during the original cooling, and in part to the severe torsion to which they have been subjected. The latter force is in all probability in action at the present time; for as will be shown in another place, crustal movements have been in active operation during very recent periods, and continue so to the present time. That systematic jointing may actually arise from strains of this kind has been satisfactorily proven experimentally by Daubree*, and appears to find full confirmation in other extensive trials, as well as in the field. The most prominent vertical jointing-planes present a remarkable uniformity of direction. The results of a large number of observations taken in different places and by different persons show that they have very slight variations in direction, the planes trending about north 60 degrees east. Only in a few cases have the deviations been very marked. The various quarries exhibit the jointing phenomena best, though it is also well shown along the various bluffs bordering the streams and on the surfaces wherever the rock masses are not concealed by a mantle of detrital material.

A second series of prominent vertical seams has been made out, which makes angles of about 80 and 100 degrees with

*Etudes syn de geol. Exper., p. 300., Paris, 1879.

those just mentioned. These two classes of vertical seams in connection with the horizontal ones have been observed cutting the rock masses into rhomboidal blocks; but these are only locally developed to a high degree of perfection. In the granites, as a rule, there are comparatively few other minor division planes, but quite generally in the porphyries irregular seams in all directions have abundant developments. This is occasionally true of some of the fine-grained varieties of granite where, in a few places, they are so numerous as to render the rock unfit for quarry purposes. Vertical jointing-planes are especially well shown at a number of places. One mile above the mouth of the Little St. Francois river, a cliff of porphyry on the right bank is more than 100 feet in height; and in it the vertical seams are sharply developed, forming prismatic structures similar to those which are so characteristic of basaltic columns, though they lack regularity of shape. On the north bank of Marble creek at a point known as French mills, another good example is presented (plate vii).

With the granitic mass subdivided into more or less rectangular blocks of varying size, access of meteoric waters is readily permitted, and the seams become wider as the blocks begin to break down. The edges, being attacked from two directions, succumb much more easily than the sides. The corners, being affected from three sides, break down still more rapidly. As a result, there is eventually formed a more or less spheroidal mass from each block. These rounded masses or boulders are commonly separated from one another by a greater or less thickness of granitic sand. If undisturbed, the process may go on to a depth of many feet. A vertical section through a place thus decaying, as is sometimes shown in quarries, imparts to the ledge an aspect not unlike a great wall of Cyclopean masonry, layer upon layer of huge rounded blocks rising one above another with all the regularity and precision of human efforts. The interior of the boulders in each case may be perfectly fresh and well adapted for building purposes. As decomposition progresses, the amount of interstitial sand gradually increases and the rounded blocks become proportionately smaller. If at this stage running water passes over the mass, the blocks with rounded edges are soon made to stand out prominently as the sands beneath and around them are washed away, giving rise to a striking tesselated surface (plate viii), which may assume a characteristic *roches moutonees* appearance. Should the sand be removed at a later stage, boulders of all sizes are uncovered and rest on the less decomposed ledges beneath (plate ix). An excellent example of these exhumed boulders occurs at Graniteville, in Iron county, where they are known as "elephant rocks" (plate x). The final stage of disintegration is a bed of sand with occasional decomposed pebbles of the original rock scattered through it. In the decomposition of granite the texture may remain in appearance as in the original rock, but upon excavation is found to be merely soft, incoherent sand.

The action of atmospheric agents on different crystalline rocks is varied. The principal elements of destruction are oxygen and carbon dioxid, both of which act vigorously in the presence of moisture. These two gases are taken from the air by rain and surface waters, and are carried downward to great depths, provided they are not all absorbed earlier by the materials with which they come in contact. In this way the rocks are most affected by them along the seams and fissures, and along the more minute cleavage cracks of the different minerals.

The chemical and mineralogical composition of a rock determines largely its capacity to resist atmospheric agencies or to yield to their influence. A mass rich in ferrous iron and magnesia is affected more than one poor in these elements; hence the basic rocks as a rule are readily decomposed. The texture of a rock also has much to do with its durability. In general, the finer the grain the more durable the rock. The minerals in the coarse-grained mass always have cleavage lines more or less well developed, along which water will pass the same way as along the larger jointing-planes, only more slowly, and disintegration follows.

The Missouri rocks present great variation in chemical and mineralogical composition, as well as great range in texture. But few objectionable mineral constituents are present to any considerable extent, and these are confined almost entirely to the basic dikes, rocks which are used but little for constructional purposes. Olivine and augite in such rocks make them comparatively easily altered.

Basic Intrusives.—After the granites and porphyries were formed they were cracked or jointed. Through the openings thus formed, or along the lines of weakness, there was forced a basic lava that now constitutes the dikes (figure 2), which are very different from the granites and porphyries. The dike

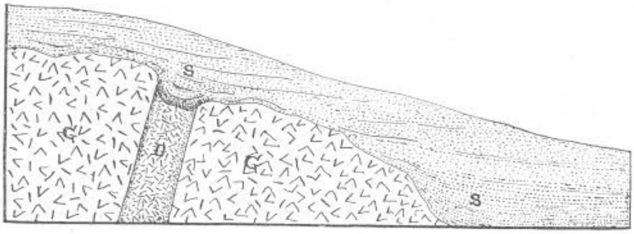


Figure 2. Basic Dike in Granite, at Silver Mines.

rocks contain only 45 to 55 per cent of silicic acid, while the granites average over 70 per cent. In color they are dark green to black, while the others are generally light-colored, gray, red or brown. They have a specific gravity so much higher than the acid rocks that they are easily distinguished by the weight. Although the dikes are small, their large number and wide distribution, taken together with their peculiar character, cause them to attract wide attention. They were formed before the sedimentary rocks were laid down, as is plainly shown in different places by the limestones overlying them.

Geological Age.—Recognizing the fact that the crystalline rocks are eruptive in nature, their exact relation to the surrounding stratified series is of great interest. That they were formed before the limestones and sandstones were deposited is shown in a number of different ways. In the first place, the stratified rocks everywhere overlie the igneous masses. While it is recognized that this fact in itself is not sufficient to prove beyond doubt that the former are older than the latter, yet in the present instance, when taken in connection with the fact that the region is not crumpled as in other mountainous districts, it is very conclusive. In the second place, there is the entire absence of any phenomena suggesting contact metamorphism, which would have certainly resulted had the eruptives been forced up through the strata of the region. Thirdly, there is abundant evidence of an extensive erosion period previous to the deposition of the limestones and sandstones. The fourth line of evidence is the presence of numerous rounded fragments of the porphyries and granites included in the stratified rocks where these are observed to rest upon or against the crystalline masses. Numerous drill-holes in the Iron Mountain and Pilot Knob regions pass entirely through the stratified rocks into the crystallines below, so that the total thickness of the limestones and sandstones may be readily made out in many places. The indications are that the ancient erosion was even more vigorous in its action than at present, and that the inequalities of the surface were greater. In the valleys, as the land area subsided, there were flat-lying fragmental beds which finally covered the old mountain peaks and ridges. At the present time erosion has gone so far as to nearly obliterate all evidence of the former topographic forms. In the new valleys of today are the last remnants of the limestones which were laid down in the old depressions. In those cases, which at the present time show ridges bisected or even cut up into several hills, modern erosion has manifestly modified very materially the original surface relief.

Inasmuch as some of the magnesian limestones and sandstones appear to be Cambrian in age, and since previous to the deposition of the marine beds there was a long interval during which the crystallines were subjected to profound erosion, there should be little hesitancy in assigning the eruptives to a pre-Cambrian age. For the reasons set forth, they have been regarded as Archæan.

In this connection it may not be out of place to mention certain deposits which have been referred to the Algonkian; but concerning the correctness of the reference time only will indicate. These beds consist of slates and conglomerates made up of porphyry fragments which aggregate 200 feet in total thickness. The area is a very small one, and occupies the summit of Pilot Knob. If they really represent the remnant of the Algonkian, a far wider time interval than has been commonly adopted separates the sedimentaries from the igneous masses.

Sedimentary Rocks.

Besides the massive rocks, there is present in the crystalline area a large variety of limestones and sandstones. The igneous rocks are Archæan in age, as already stated. They were subjected to prolonged degradational action, and it was upon their deeply eroded surface that the sandstones and limestones were laid down during early Paleozoic times, probably burying to a very considerable depth many and perhaps all of the old peaks and elevations. The exact geological age of the different parts of sedimentaries of the region has not yet been determined with accuracy. Certain small portions may belong to the Algonkian. That the Silurian is well represented appears evident; that a part belongs to the Cambrian there is little reason to doubt; but just where the line should be drawn between the two systems of strata is not material in this connection. The entire sequence belongs to what has been called the Ozark series, or the Magnesian limestone formation of earlier writers.

On the whole, the stratified rocks of the region are as yet little understood in their real relations to the other geological formations of the state. In southeastern Missouri the Paleozoic rocks from the top of the column down to the base of the Trenton are well known. Beneath the latter there is, according to Shumard,* a bluish limerock, having a thickness of

*Geol. Sur. Missouri, 1855-1871, p. 2?6, Jefferson City, 1873.

upward of 70 feet. It may be regarded, however, as the non-fossiliferous portion of the formation just mentioned. But below all this comes a great sequence of dolomites and sandstones, to which the name Magnesian limestone series has been applied. By the earlier geologists there were considered to be four great limestones alternating with sandstones; but of late it has come to be believed that the relations of these beds are not exactly in accordance with the views formerly expressed. East of the crystalline area, and trending in a broad curve northwest and southeast, are the oldest paleozoic rocks whose geological age is definitely known. Immediately west of this belt of strata, which is the fossiliferous Trenton limestone, and a considerable band of similar rock almost without fossils, is a narrow zone of what has been termed First Magnesian limestone, and then in a somewhat broader belt the First of Saccharoidal sandstone. A short time ago it was suggested that the latter probably rested unconformably upon the strata beneath, and more recently Winslow* found in the vicinity of Pacific, 40 miles west of St. Louis, and elsewhere, unmistakable evidences of a marked unconformity at this horizon. Now the Magnesian limestones and sandstones of the crystalline area are, according to the best evidence, at a geological level considerably below the Saccharoidal sandstone. In this all who have worked in the region agree.

Regarding the age of the rocks, Broadhead, who has been in the region more than anyone else, perhaps, is inclined to assign a large part of them to the Cambrian. Very recently Walcott, in his correlation essay on the Cambrian of North America, sums up all that is known on the subject, and colors in his map of the continent, as Cambrian, all of the sedimentaries of the crystalline district of Missouri. In a recent critical review of the fossils of the state, collections from the Magnesian limestone made by different individuals were carefully examined; but the material proved, on the whole, to be so fragmentary, and the exact or even approximate horizons where

*Missouri Geol. Sur., Vol. VI, p. 356, Jefferson City, 1895.

the particular forms were obtained, were so poorly determined that practically nothing could be inferred regarding the relations to one another of the fossil-bearing horizons in the different localities. Many of the fossils, imperfectly preserved as most of them were, appeared to be undoubted Silurian forms, while others possessed a very decided Cambrian aspect; but in no case were the faunas extensive enough to warrant an exact arrangement of the succession. Although considerable information concerning the geology of the crystalline area has been obtained, there yet remains to be done much detailed work in stratigraphy before an exact correlation of the various strata and of the faunal zones can be made in southeastern Missouri.

The nearest region of similar rocks—one which has moreover been thoroughly investigated and with which the Missouri strata are to be compared—is in northeastern Iowa and the adjacent portions of adjoining states. It is therefore the Cambro-Silurian section of the Upper Mississippi that must serve as a standard of comparison for the Missouri rocks under consideration, and with which detailed correlations must be made. This fact necessarily has great weight in all attempts to correlate the rocks of the district. In the absence of faunal evidence that was at all satisfactory; with so small a proportion in the Mississippi valley of the Silurian existing below the Trenton, which is an horizon clearly defined in all parts of the basin; with a thickness in Missouri of Magnesian limestone and Saccharoidal sandstone below the Trenton nearly twice as great as between the same horizon and top of the Cambrian in Iowa; with the evident existence of a marked line of unconformity at the base of the First sandstone; and with a considerable sequence of limestone and sandstone beneath the physical break mentioned, the evidence appeared, at the time of the recent review of the geological formations of the State, to be amply sufficient for regardinig, provisionally at least, the Magnesian limestone series below the Saccharoidal sandstone as Cambrian. Whether or not this line is the correct division remains to be determined. The final conclusion must be derived from a consideration of abundant fossils, after a careful stratigraphic connection of the various sections has been made.

GEOLOGICAL STRUCTURE.

Forming the eastern portion of a broad, dome-like uplift, the sedimentary strata dip away from the crystalline area in all directions except, perhaps, toward the west. The granitic nucleus having been an old land area when the sediments began to be deposited around its margin, the strata originally had naturally a slight seaward inclination, which in direction coincided approximately with the present dips. But the inclination of the beds is much greater at the present time than when first laid down, for the crystallines form the center of the upward movement. This augmentation of the dips has taken place at different times. A geological cross-section from the center of the crystallines to the Mississippi river presents, so far as known, essentially the same features that were depicted by Shumard. The strata immediately above the crystalline rock are usually sandstones of greater or less thickness. This is succeeded by limestones, which, however, often thin out and are replaced by sandstones as they approach the elevations of granite. This is, in all likelihood, the case in most of the cross-sections which may be made from the central part of the crystalline area outward. Such a section is presented along the line from Iron Mountain to Ste. Genevieve on the Mississippi river (figure 3).

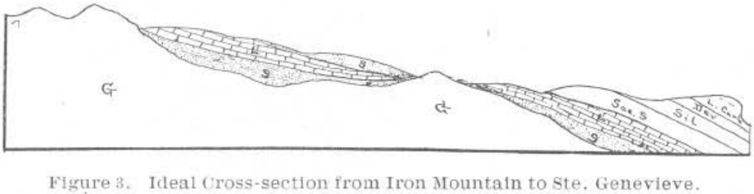


Figure 3. Ideal Cross-section from Iron Mountain to Ste. Genevieve.

The marked unconformity with which the sedimentaries rest upon the underlying crystallines is much more than an ordinary break in regular deposition, for the stratified beds were deposited upon a surface, the relief of which was more broken and the extremes of altitude much greater than they are now. It is very remarkable that at the present time this old topography is being exhumed gradually through erosion, and that merely a few remnants of the great mass of limestone which once covered the granitic rocks now remain in the bottoms of the old depressions once occupied by the ancient water-courses, and which also coincide nearly with the present valleys. Drill-holes put down in some of the existing limestone valleys have passed completely through the stratified rocks and have penetrated the crystallines beneath. This is shown at a number of points in the vicinity of Iron Mountain, Pilot Knob and elsewhere. The relations of the two kinds of formations are represented in the cross-section of the Iron Mountain region (figure 4). The details of the juncture of sedimentaries and crystallines are well shown on the Little St. Francois river (plate xi), near Fredericktown, in Madison county (figure 5). Over the surface of the porphyry is spread a layer of crystalline fragments and rounded boulders of various sizes. The sandstones, with planes of false-bedding distinctly marked and inclined at a high angle, pitch away from the central porphyritic elevation. A short distance from the crystalline mass the sand-

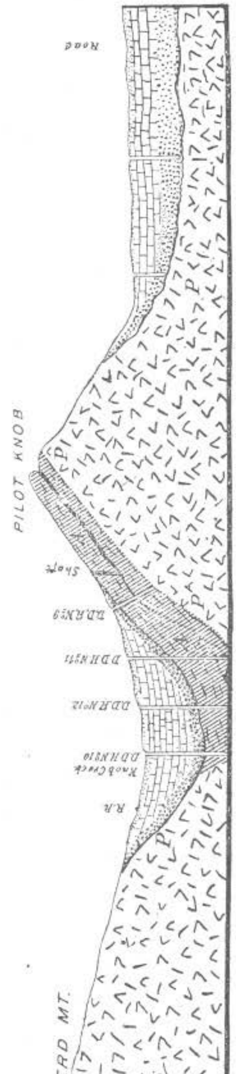


Figure 4. Geological Cross-section in the Iron Mountain Region.

stones, by the addition of calcareous material, pass rapidly into heavily bedded limestones. This transition takes place both upward and laterally. In the former direction the change is often abrupt. The sand grains become fewer and fewer and more widely separated, until within a narrow limit, the passage from a pure silicious sandrock to a homogeneous limestone is complete. When the hills were gradually depressed below the level of the water, wave motion quickly removed all loose material on the surface, depositing it on the sides of the old

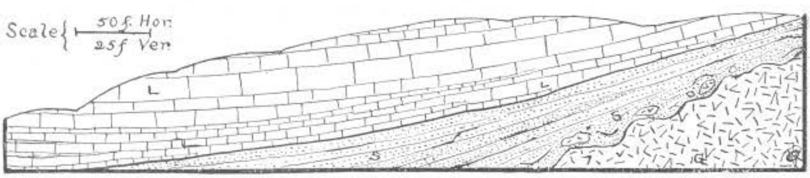


Figure 5. Stratified Rocks resting against Porphyry.

peaks. Sandstones and limestones, with occasional shales, thus filled the old valleys. When from any cause the currents became stronger, tongues of sand were sent far out into the waters and finally covered by limestones. Thus on the sloping, sinking shores sands were laid down. Their seaward extent varied greatly at different horizons—sometimes covering the calcareous deposits; sometimes allowing themselves to be covered. Thus closely following the ancient land surface, a continuous sandstone exists, representing several or many horizons. Farther outward, or seaward, sandstone beds are found intercalated in limestone. This disposition of beds is graphically shown in the accompanying diagram (figure 6).

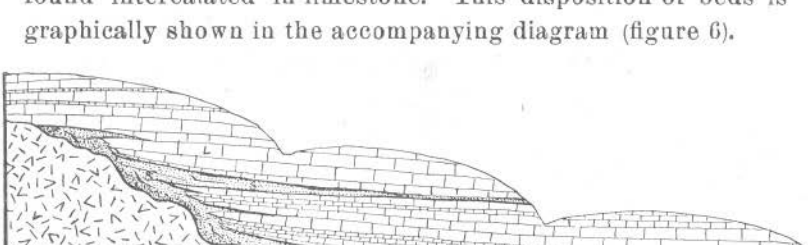
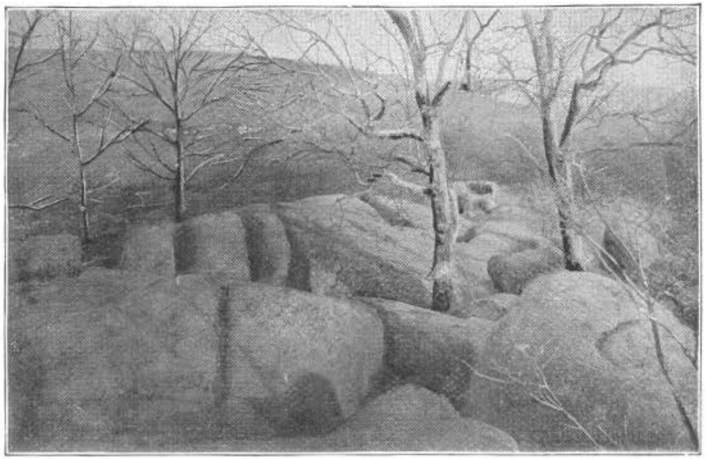
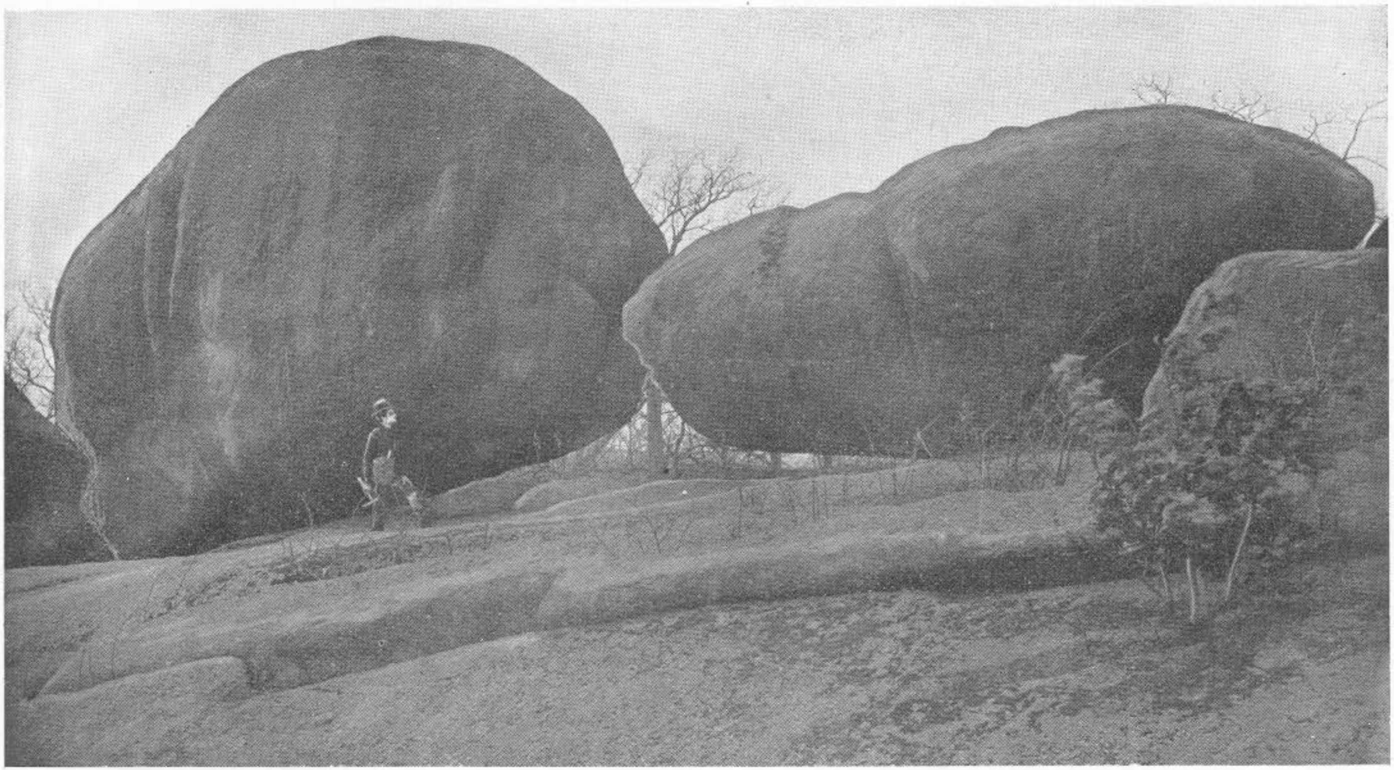


Figure 6. Relations of Stratified and Crystalline Rocks.



TESSELATED SURFACE OF GRANITE.

DISINTEGRATION OF GRANITE.



"ELEPHANT ROCKS" OR BOULDERS OF DECAY, GRANITEVILLE.

JUNCTURE OF LIMESTONE AND PORPHYRY, FREDERICKTOWN.

CLASSIFICATION OF THE CRYSTALLINE ROCKS.

In general, there are three prominent yet relatively distinct criteria by which eruptive or crystalline rocks are classified. They are chemical composition, mineralogical association, and texture, or the minute structure of rock. Each of the three factors must be regarded; for if any one is neglected, rocks are widely separated which are in reality genetically closely related; others which should be widely separated are brought together. If only a chemical basis is considered, a granite and a glass may be called the same, for many of them agree in composition. Should the mineral constituents be depended upon entirely, no better arrangment is obtained; for then a granite and a fine-grained quartz-porphyry would be identical, as would also a gabbro and a melaphyre. Neither would it be more fortunate to choose texture alone as a means of classification; for then a granite, a gabbro and a peridotite would be classed together. The former would have from 70 to 80 per cent silicic acid, and the latter so low as 42 or 43 per cent; the one would abound in quartz, the other would be free even from such silicate minerals as feldspars.

CHEMICAL COMPOSITION.

There is comparative unanimity in making the chemical composition the basis of classification to the extent of dividing all crystalline rocks into two great groups, the acidic and the basic—the division line between the two being arbitrarily fixed at a silicic acid content of 60 per cent. This is a very convenient standard. Yet it should be clearly understood that it is entirely arbitrary, and consequently must be disregarded at times. Thus, some of the classes counted acid rocks usually have facies which grade into those that according to this classification would be in the basic division. A good illustration of this is furnished by the table of analyses given under the porphyries, in which a certain porphyry is shown to have a little less than 60 per cent silicic acid. Yet this rock is a member of the acid series and should be classed as such.*

MINERALOGICAL CONSTITUTION.

The mineralogical composition is closely related to the chemical make-up of the rock, and the two are quite dependent upon each other. It is only in the extreme cases that the acid and basic minerals are found intimately associated in rocks. If free quartz is abundant the acid silicate minerals, such as orthoclase and microcline, may be expected. If quartz is entirely absent, but little of these minerals is found, and in their places the more basic silicates, such as the pyroxenes, hornblendes and olivines, abound.

There are a few general exceptions to this rule, exceptions which probably depend upon the extraordinary physical conditions under which the minerals are formed. Thus, Iddings† has described the basic iron silicate, fayalite, from an obsidian with over 75 per cent of silicic acid. The same author, Diller, and the writer, have described quartz phenocrysts from basic rocks, some of which had but little over 53 per cent of silicic acid. Outside of these and similar exceptions, there is comparative regularity in the association of minerals in rocks.

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*Loewinson-Lessing has proposed (Bul. Soc. Belg. de Geol., t. iv, p. 1, 1890) to use instead of this arbitrary line the presence or absence of free quartz as the division line between acid and basic rocks. As is well shown, the per cent of silicic acid alone is not a very scientific basis, yet it is an exceedingly convenient one. The atomic weights and the valency of the basic elements have an important bearing. Thus, the pure magnesium silicate Mg_2SiO_4 forsterite, has 42.9 per cent SiO_2., while the pure iron silicate Fe_2SiO_4, fayalite, has but 29.4 per cent of SiO_2, the difference being due to a difference in the atomic weights of the bases. And yet, from the chemical standpoint forsterite is no more acid than fayalite. Similarly, many rocks may be largely composed of neutral salts which have a higher per cent of silicic acid than others partly composed of acid salts, as chemists use the term. Should we accept the system of classification offered by Loewinson-Lessing, it would add greatly to the work of determining where a rock belongs, and at the same time it would increase our knowledge of the chemistry of rocks. But a great difficulty would be met with in the basic eruptives which bear free quartz, as many basalts and diabases are known to do. Rocks which from every other consideration are decidedly basic would be classed as acid. Also, syenite with no free quartz would be called basic, although in reality it would be much more acid than the quartz-bearing diabase and basalt.

†U. S. Geol. Sur., Seventh Ann. Rep., p. 270. Washington, 1888.

The number of species occurring in any one rock is not great, generally not more than three to five, if the relatively unimportant accessories be neglected.

TEXTURE.

The minute texture of a rock seems to have no relation to chemical or mineralogical composition. It depends rather on the physical conditions under which a magma solidifies.

If a large volume of a molten magma is lifted only a portion of the way to the surface, it will solidify very slowly and under great pressure. The resulting rock is coarsely crystalline, and, further, as each constituent mineral is formed at about the same time, and they are thus brought into contact with one another they mutually interfere with one another, preventing the formation of regular external outlines. Such mineral masses are mere grains, yet each has its molecules arranged as in well-formed crystals, so that the optical and other physical properties are normal. A texture produced by such a mass of crystals may well be termed granular. As it is the texture common to granites, it has also been named granitic.

The opposite extreme of conditions is found when the lava is poured out upon the surface of the earth and allowed to cool very rapidly and under slight pressure. The rocks formed in this way differ radically in texture from those just described. Different kinds of gases, held in solution by great pressure, now escape, leaving cavities where the gases once existed. Scoriaceous is the term generally used to express such conditions. Should the gas cavities subsequently become filled with mineral matter by any secondary processes, the rock becomes amygdaloidal—so called on account of the almond-shaped kernels in the gas cavities. Should the gas cavities be sufficiently numerous and small, and be drawn into tube-like forms by the last movements of the lava, a pumice is produced, and the texture is named accordingly. The movements of the lava just before solidification takes place often produce a peculiar banded and wavy appearance, somewhat similar to that observed in slag which runs from the blast furnace. Such a texture is called the flowage texture, or flow structure, and is common in most effusive rocks. The bands wind and curve around the different inclusions, such as gas cavities, phenocrysts and fragments of colder portions of the lava. Minute crystals of different kinds arrange themselves in rows, straight or curved, very much like the pieces of drift-wood in the current of a swollen stream, and are left in whatever positions they chanced to have when the motion ceased. Such surface-flows often solidify into a glass, as ordinary obsidian; or, portions or all of it may become crystallized. If a glass is met with, the texture is spoken of as vitreous; otherwise, it is called crystalline. It often happens that certain mineral constituents form well-shaped crystals, while the remainder of the rock mass is still a liquid. When the final solidification takes place, these first crystals are left scattered through the mass, and if they are sufficiently large, they become quite prominent features of the rock. Such crystals, regardless of their mineralogical character, are called phenocrysts. On account of their not being brought in contact with other crystals on every side they generally assume their characteristic geometric forms, and hence, may be called idiomorphic crystals: that is, crystals having forms peculiar to themselves, in contradistinction to the allotriomorphic crystals of a granular texture.

Rocks which have solidified during two distinct periods, and which as a result have idiomorphic phenocrysts are said to have the porphyritic texture. This term is important and has quite a history. A certain rock has long been known in Egypt which has many light-colored feldspar phenocrysts in a fine-grained, purple ground-mass. It was used extensively by the Romans, and is now often known under the name Roso Antico. In allusion to its red or purple color it was named porphyry, from the Greek word signifying purple. But so many other rocks have since been found which have the same texture—prominent phenocrysts in a fine-grained ground-mass—that the adjective term, porphyritic, has been extended to all such, simply because the texture of the original porphyry was of this nature. In this way it is now applied to any and every rock of this texture, entirely regardless of its color. Further, the noun porphyry has been extended to all rocks with a porphyritic texture, but the word carries with it no thought of color. The porphyritic texture, therefore, is that particular kind produced by there having been two different periods of crystallization. During the first more or less prominent phenocrysts of one or more minerals develop, and during the second the ground-mass solidifies. The phenocrysts may be of any mineral, or of any size, and the ground-mass may be vitreous, or finely or coarsely crystalline.

But distinct as the porphyritic texture seems to be from the granitic, the two pass into each other by all possible grades of transition. There is a coarse-grained rock with a granular ground-mass as coarse as ordinary granite, in which feldspar phenocrysts occur from two to three inches long. From this type a series may be traced in one direction into the granites by the phenocrysts becoming less prominent until they entirely disappear, and in the other direction by the ground-mass becoming finer until a typical porphyry is reached.

A third texture quite distinct from both the granular and the porphyritic is also quite common. It consists essentially of long, slender crystals, usually one or more of the basic feldspars, imbedded in a crystalline ground-mass of other minerals, as augite and olivine. It is common in basic rocks, especially the diabases. The long, slender feldspar crystals, often called lathe-shaped, were the first to form as the magma solidified. Around these the other constituents crystallized, filling all spaces. The texture resembles the porphyritic in that one set of crystals forms first, and the granitic in that it is coarsely crystalline throughout. Such a texture is called ophitic.

A number of other names have been given to different textures, each of which is only a subdivision of one of the three mentioned.

Having now considered the different criteria of classification, the different kinds of rocks found in Missouri may be arranged. In a general way the classification of Rosenbusch has been followed, but occasionally deviations have been made.

The peculiar gradations from one type into another so often found render it well-nigh impossible to follow any system, without a few arbitrary rulings.

With reference to chemical composition, two great groups may first be made: the basic and the acidic. The basic rocks are the younger, and generally occur in dikes cutting the others. Their acidity varies from about 45 to 55 per cent of silicic acid, so far as it is now known, but a more extended chemical examination, possibly, will reveal a slightly greater range. Mineralogically, they are composed principally of the triclinic feldspars, augite, and often a large amount of olivine. In texture they are ophitic, or some modification of this. Many of them have considerable glass, while others are exceedingly fine-grained. In naming these rocks, the old term "trap" or "trappean" is entirely too general to be employed, for it does not signify anything, excepting in a very general way. Derived from the German "treppe," meaning stairway, it was first applied to basic rocks which were spread out in broad thin layers, the broken edges of which somewhat resemble a stairway. From this it was extended to basic rocks in general, and especially to the basic dike rocks, and as such, is applicable here. But its indefiniteness makes it undesirable. The term "dolorite" is also used by petrographers, especially the English, to cover a large class of basic eruptives, and is a very comprehensive term. Allport* has suggested that it be used as a group name to include the great mass of rocks between the gabbros and basalts in texture, which are composed essentially of plagioclase and augite, with or without olivine. In this way it would include all of the basic rocks of Missouri now under discussion. Teall, in his British Petrography, follows Allport. But the German petrographers have not used the name dolorite to any considerable extent; neither have the majority of Americans. In its stead the name "diabase" is used to cover all augitic plagioclase rocks, either with or without olivine, which have the ophitic texture. This term will be adopted here, and will cover all the well-crystallized varieties of the basic erup-

*Quart. Jour. Geol. Soc., London, vol. xxx, p. 529.

tives, or the dike rocks. Those which have a more or less porphyritic texture will be called diabase porphyrites, or augite porphyrites. Should a rock similar in composition assume the granular texture, especially if the pyroxene present is diallage, common consent would give it the name gabbro. Two different dikes have been found, the rocks in both of which somewhat resemble a gabbro. Neither is a typical example of it, and therefore, for the sake of simplicity, they will be called diabases, the same as the others.

The acid eruptives likewise have different grades of texture, passing from the granitic through the porphyritic into the vitreous or glassy. The crystalline end of the series, of course, will be called granite. It varies chemically from about 77 to about 60 per cent of silicic acid. Mineralogically it is composed principally of quartz and orthoclase, with microcline, the acid plagioclases, biotite, and hornblende.

The well-crystallized varieties are called granites, or syenites. The latter term has already been applied to some of them, and a small village and postoffice in Missouri still bear the name. At present syenite is usually regarded as a rock with a granular texture, composed essentially of orthoclase and one or more of the ferro-magnesian silicates, as hornblende, augite, or biotite, with essentially no quartz. According to this there is not a real syenite in the state, although the blue granite at Syenite somewhat resembles a quartzitic variety. It is therefore an easy matter to decide that all the well-crystallized acid rocks should be called granites.

In the case of the rocks of intermediate texture greater difficulties are met with. Such terms as porphyry, quartz-porphyry, orthoclase-porphyry, felsite, quartz-felsite and porphyrite have been employed to designate similar masses. The name felsite, with various modifying prefixes, is almost universally used by the English and also by some Americans, while the Germans, and perhaps a majority of the Americans, rarely if ever employ it.

The term porphyry, in the abstract, as already stated, is applicable to any form of a rock, provided it has the porphyritic texture. Yet, as is well known, it is rarely applied to any excepting the acid rocks, and in this way, by general consent, it may be used as a group name. This seems all the more desirable with the case in hand, because it has been so widely used in connection with the Missouri rocks. Almost every one who has written about them has called them by this name. The citizens throughout the region where they occur know them by the same title, and a majority are able to recognize them at sight. It would therefore seem unfortunate to discontinue its use, even though there are objections to it. For these reasons it will be used as a group name, and will be applied to all the acid eruptives which are not sufficiently well crystallized to come under the name granite. The green-colored porphyries in the vicinity of Des Arc and Piedmont, which carry plagioclase phenocrysts and much epidote in the ground-mass, will be called porphyrites to distinguish them from the more acid members. The minor subdivisions will be given further on, where the porphyries are described in detail.

The classification presented may be summarized as follows:

Crystalline Rocks.	Basic, 45 to 55 per cent SiO_2.	Well crystallized—Diabase, and Olivine Diabase.	
		Porphyritic—Diabase-porphyrite.	
	Acid, 60 to 80 per cent SiO_2.	Well crystalized—granite.	
		Porphyritic	Quartz and orthoclase phenocrysts—Porphyry.
			Plagioclase phenocrysts—Porphyrite.

DIKE ROCKS, OR BASIC ERUPTIVES.

CHEMICAL COMPOSITION.

The analyses thus far made of the basic eruptives show that their acidity varies from 45.4 per cent to as high as 53.4 per cent of silicic oxide, SiO_2. Opportunity has not yet been afforded to determine the composition of the more acid varieties, some of which would likely yield as high as 60 per cent of silicic acid. The following table gives the results of the different analyses made, to which a few others are added for comparison:

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Loss	0.26	....	....	....	....	4.34	....	3.36
SiO_2	46.94	53.06	53 40	33.88	45.40	45 38	51.78	48.62
Al_2O_3	16.91	....	....	5.33	....	16.62	14.20	16.25
Fe_2O_3	12.53	....	....	} 29 35	....	4.06	3.59	3.42
FeO	4.16	....	....		....	8.63	8.25	9.12
MgO	8.20	....	....	0.63	....	9.41	7.63	4.93
CaO	9.00	....	....	30.71	....	8.19	10.70	5.91
Na_2O	2.15	....	....	....	....	2.20	2.14	5 23
K_2O	0.54	....	....	....	....	0.71	0.39	1.60
P_2O_5	0 28	....	....	....	....	....	0.14	0.36
TiO_2	....	....	....	....	....	....	....	1.86
	100.75	....	....	100.30	....	99.54	98.82	100.66

I. Olivine-diabase from Skrainka, Madison county. (St. Louis Sampling and Testing Works.)
II. Quartz-bearing diabase porphyrite, No. 15001. (McClurg.)
III. From same as II, No. 366. (Coates.)
IV. Garnet, in No. 15607. (St. Louis Sampling and Testing Works.)
V. From the falls on East fork Black river, No. 15607. (St. Louis Sampling and Testing Works.)
VI. Olivine diabase, Clegyr Faig, Wales. (Geikie, Quart. Jour. Geol. Soc., vol. XXXIX, p. 293.)
VII. Diabase, West Rock, New Haven, Conn. (Hawes.)
VIII. Diabase, Weilburg, in Warsaw. (Quoted from Kalkawsky's Elements of Lithology.)

It will be seen that the Missouri rocks are fully as basic as the average rocks of similar mineralogical composition from other parts of the world. It is interesting to note that the relative amounts of the ferrous and ferric iron are in the reverse order from the usual diabase, and that there is a larger amount of iron than is commonly the case. The ratio between the lime and soda is normal, and indicates that the feldspars are principally labradorite and bytownite.

Mineralogical Constituents.

The minerals present in the various basic eruptives are the following, which are given approximately in the order of their abundance: Plagioclase, augite, olivine, hornblende (both the green fibrous and the brown), biotite, quartz, chlorite, iron oxide, ilmenite (with its common decomposition product leucoxene), apatite, pyrite, epidote, garnet, orthoclase and glass.

Feldspars.

With but one exception, the feldspars in all cases belong to the soda-lime or plagioclase series. In the one case they are a mixture of plagioclase and orthoclase. The plagioclases vary from the acid andesine to the most basic anorthite, with labradorite and bytownite greatly predominating. The long, slender lath-shaped crystals are most common, especially in the well-crystallized rocks, and in the groundmass of the porphyritic ones. The phenocrysts in the diabase porphyrites are usually short and stout, with well-formed crystallographic faces. Comparatively few rocks carry feldspar phenocrysts to any considerable extent, but those which do have them remarkably well developed. (No. 15493.) A good example is from the seven-foot dike exposed in a ravine on the south side of the Little St. Francois river (Tp. 33 N., R. VI E. section 14). The ravine enters the river a short distance above the old ford on the Thompson place. A twelve-inch margin on each side of the dike appears to be free from phenocrysts, but the middle five feet carries so many that the whole rock is strikingly spotted, the light flesh-colored feldspars contrasting strongly with the back-ground (plate xii). Many of the crystals are nearly two inches in diameter.

Another dike which shows feldspar crystals prominently is one which also carries many phenocrysts of quartz (No. 15001). It is fully described elsewhere (plate xiii). The feldspar crystals sometimes have considerable quantities of the groundmass included within them. Quite as often the included matter is so diffused throughout the crystals, that macroscopically it can scarcely be recognized excepting by the different shades of color that it gives. In such cases the conditions correspond closely with those in the quartz-porphyries when a quartz crystal extends out into the ground-mass. The peculiar texture then produced by it has been named the poecilitic by Williams. The feldspar phenocrysts are often twinned, the two parts of the twins being about the same size and symmetrical with reference to each other, while within each half the finer striations occur in great variety. The borders of the feldspar (as in 15001) are often effected in an interesting way (figure 7) For a short distance inward from the margins the crystal is filled with microscopic cavities very fine and close together. It is possible that they represent former inclusions of the groundmass which in some way has been leached out. However, the crystal from which the drawing was made appeared to be entirely fresh, so that it would appear hardly probable that any removal of material could have been effected without producing a greater alteration in the feldspar. The fine twinning lamellæ pass entirely through the border. In a number of instances there is a very narrow rim of feldspathic material outside of the porous border, similar to a zone noticed in some of the crystals which had the inclusions of the groundmass, as above explained. Often sections made through the borders of other phenocrysts (No. 15498) do not show this phenomenon. A few other dikes bear feldspar phenocrysts,

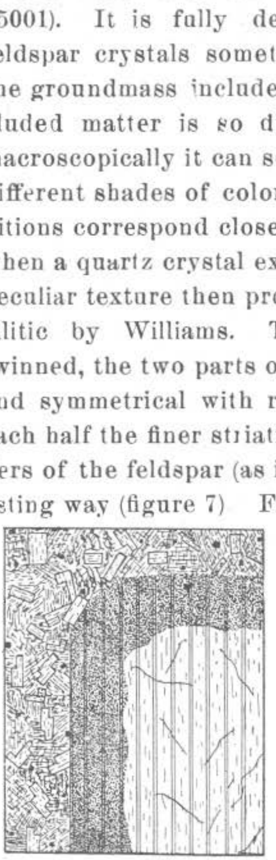

Fig. 7. Quartz-Diabase Porphyrite: triclinic feldspar phenocryst, with border filled with minute cavities.

but none of them are prominent, and consequently they need no especial mention here.

The great majority of the dike-rocks have the long, slender feldspar crystals so common to diabase. The crystals vary in size according to the coarseness of the rock. Some of them are nearly an inch in length (No. 15553). From this they decrease to microscopic dimensions. A fair idea of the feldspars in the ordinary olivine diabase may be gained from figure 1, plate xiv (No. 15566.) It will be seen that the crystals are arranged entirely without order, and that some of them show beautifully the twinning striations. Such parallel-banded structure produced by the polysynthetic arrangement, according to the albite law, is the most common form of twinning among certain feldspars. (See also figures 8 and 9.) In the first figure, a number of individuals are twinned according to the albite law; in the second figure a group of similar crystals, with a peculiarly interesting arrangement, is shown. The twinning laminæ are exceedingly narrow in some crystals. In one instance over seventy of them were counted in a crystal not more than one-sixteenth of an inch wide. It is a common occurrence for narrow bands to alternate with wider ones (figure 2, plate xiv). Frequently one-half of a crystal will be crowded with laminæ and

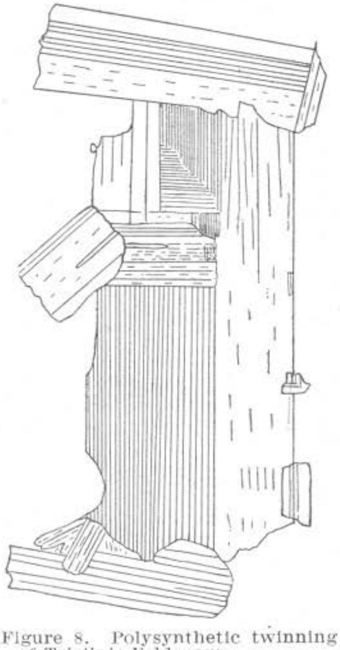

Figure 8. Polysynthetic twinning of Triclinic Feldspars

Figure 9. Cluster of Plagioclase Crystals in Olivine Diabase.

the other half have but few (figure 8). Other modes of twinning are also known, among which those combining the albite and the pericline laws are the most frequent (figure 2, plate xiv). Other illustrations of the feldspars are shown in figure 1 and 2, plate xv. In each of these the crystals are surrounded by glass. A general idea of the relative amount of feldspar in the diabases may be gained by an examination of plate xvi, figure 1, which shows the amount, size and shape of the augite and olivine in the whole of a thin section, the remainder of the space being occupied by feldspar (No. 15268).

Orthoclase has been found in but one dike-rock (No. 235), and here it constitutes only a portion of the feldspar present. It forms idiomorphic or hypidiomorphic crystals (figure 1, plate xviii). The peculiar granophyric border around the crystal is similar to many of those found in the granites. The difference in color in the crystal is due to the central part being badly kaolinized; the outer portion is quite fresh.

The feldspars are often badly decomposed. This is likely due principally to weathering. The greater part of the specimens necessarily were taken from or near the surface where the weathering agents had free access. One interesting feature about this however, is the common observation that the central part of the crystal is decomposed more than the outer part. Weathering alone would not produce such results. This is not only true of the diabase feldspars, but also to a considerable extent of those in granite as well. Similar observations have been made by others and upon feldspars from widely separated localities. It would seem that in some way the molecular stability in the border of the crystal is greater than in the central portions.

Augite.

The augite is very uniform in color in the different dike-rocks. It is always a light pinkish buff when viewed by transmitted light; but dark or black by reflected light, and as seen in the specimens. In the well-crystallized diabases the augite never has any regular form, but fills the spaces between the feldspar crystals. In the porphyritic varieties the crystalline form is much more pronounced. The cleavage lines often are perfectly formed, some of them passing only in one direction when the section is cut in the zone of the two pinacoidal faces, $\infty P \grave{\infty}$ (010) and $\infty P \bar{\infty}$ (100); while in other cases they meet each other at nearly right angles, indicating that the section is cut approximately parallel to the basal plane, OP (001). The external form of the crystal is sometimes prominent, as is shown in figure 1, plate xvii, an augite crystal in a glassy rock from the big boss at the tin mines (No. 15012). The interior of this crystal contains a negative crystal filled with glass. The section represented is cut parallel to the basal plane, so that the two pinacoidal and the prismatic faces are well exhibited in the negative crystal, and partially in the external form also. The prismatic cleavage lines are very well shown. In the fine-grained diabase porphyrites the augite crystals are not so large. Twinned augites are common—the ordinary type of contact twins with the clinopinacoidal face, $\infty P \grave{\infty}$ (010), serving as the twinning plane, being the most frequent. Other forms are known but are not very abundant. One is shown in figure 2, plate xvii—a large crystal of augite with a band of secondary hornblende around it. The small member attached to the right side of the larger one seems to be in twinning position, forming the so-called cruciform twin, although it does not appear on the left side of the large crystal. The orthodome $P \bar{\infty}$ (101) serves as the twinning plane.

In many of the thin sections examined, the augite appears to be perfectly fresh. In others it is badly altered—green, fibrous hornblende and chlorite being the most common products of alteration. This change is most pronounced on the borders and along the cleavage and fracture lines. In such cases, the mingling of the bright green and fresh-looking hornblende with the pink augite presents a strange contrast (figure 2, plate xvi, from No. 15052). It represents, fairly well, the method of alteration so commonly observed in the augites. In a few instances, the augite is changed along its border to a solid rim of a dark, greenish-brown hornblende, quite similar in appearance to the ordinary brown, basaltic variety, but assuming a green hue (figure 2, plate xvii). The irregularity of the inner portion of the hornblende border, and the way it follows fracture-lines, preclude the idea that it may be an instance of parallel growth. The rock from which it came (No. 235) has many large crystals, everyone of which that has been examined possesses a similar hornblende border, although few of them are as regular as the one figured. Some of them are more inclined to the green, fibrous variety. It is interesting to note that no pyroxene other than augite has been found in the basic eruptives of Missouri — not even a single case of diallage.

Olivine.

Olivine is abundant in many of the diabases, but not in all of them. When viewed by transmitted light it has the usual characteristic watery, transparent, light-green color. Its external crystallographic form is rarely developed; only in a few instances could any of the faces be recognized. The common forms in which it occurs are spherical, elliptical, or irregular grains. Cleavage lines are seldom present, but fracture lines, which are usually curved rather than straight, are very abundant. In its method of decomposition the olivine seems to have followed the augite quite closely. The borders of the crystals and the fracture lines present surfaces on which the weathering agents have worked, producing a pleochroic green product which appears to be uralite. Delicate fibers are produced sometimes in great number, and seem to be identical with those from augite. In a majority of instances the borders have been changed to a solid green mass without the production to any considerable extent of the green fibers. It is a remarkable fact that with so much olivine in so many of the rocks, not a single example of well-formed serpentine has anywhere been found.

Grains of black oxide of iron are common in the olivine. Sometimes they are arranged in a row around the border, sometimes they are grouped near the center; or they may have certain other irregular positions. It was first thought that these were decomposition products, inasmuch as they seemed to be most numerous in the olivines which were badly altered. But numerous fresh grains carry them also, and they are found in the freshest part of the grain, so that it would appear they have no connection with the alteration of the olivine.

In amount the olivine varies greatly. Some of the dikes have none, others a great deal. It is quite noteworthy that, with perhaps two or three exceptions, all the best crystallized dikes have large amounts of it, and those less perfectly crystallized have none. Not a single glassy rock examined has a trace of olivine. The big dike, or boss, at the tin mines seems to be glassy in places and free from glass in others. At least some of the thin sections from there carry much glass, and others carry none. Those which have no glass sometimes have olivine; but not a single section examined has both olivine and glass. The hand specimens, if good ones were procured, had to be taken from the dump piles left from the mining operations, so that there was great uncertainty as to what part of the dike they came from. It cannot be said certainly at this time that there is more or less glass in one part than in another.

Hornblende.

It is doubtful if hornblende occurs as an original constituent in a single dike-rock in the state. In places, however, it is comparatively abundant. The mining operations at Iron Mountain have exposed considerable masses of it. Here numerous dikes cut the porphyry and the ore, some of which have been followed to a depth of more than a hundred feet. The exact character of the original dike cannot be ascertained. At present great masses of hornblende closely resembling amphibole anthophylite are lying on the surface where they were left by workmen.

On the Payne land (Tp. 33 N., R. V E., sec. 17) prospecting has developed a layer of asbesti-form hornblende in the residual clays. Some of it looks very much like a poor variety of asbestos, so much so that it has attracted the attention of different persons interested in the mining of this mineral. The original deposits have not yet been disclosed, but as numerous diabase boulders have been found covered by the clays there is but little doubt that some of the dikes which cut through the porphyry hill are the former location of the hornblende. About a mile to the southeast of this place along the southeastern part of Blue mountain, in the extreme southeastern corner of section 16, another similar deposit has been found. It is reported that years ago a few barrels of the asbestos reached the market from here. During the summer of 1888 a few days' work was done with a hope that the original home of the asbestos could be determined; but the effort was futile. All that could be found was a two or three-inch layer of inferior material which had been formed with the residual clays, indicating that it had either been brought down from farther up the hill, or that it was the remainder of a rock, the other portions of which had been completely decayed. No traces of it could be found in the rock on the hillside above. As several different dikes are found near by, it may well be supposed that the material in question originally belonged to one or more of them. Another place where hornblende seems to be fairly abundant is in a dike cutting the porphyry on the Smith land (Tp. 34 N., R. IV E., Sec. 24). Here considerable masses of the actinolite variety have been dug up in prospecting, some of which would form good museum specimens. In different places the fracture openings in the diabase have been filled with green hornblende, some of which now appears as little veins or seams of hornblende from one-fourth to three-fourths of an inch wide.

The green, fibrous hornblende produced from the alteration of augite has already been mentioned, so that it need not be repeated here. In some of the dike-rocks this alteration has been carried so far that the augite is entirely gone, and much of the fine-grained mass also is changed to hornblende. A notable example of this is the dike-rock on Black river, at the falls, which contains the garnets. Along with the alteration of the augite to green hornblende are a few examples of a partial change to a brown hornblende. Only one thin section has been examined which showed this. It appears as little spots here and there through the large augite crystals, each of which is strongly pleochroic, and in every way resembles basaltic hornblende.

Biotite.

This mineral is quite scarce in the Missouri dike-rocks. It has been found in a few instances in beautiful, well-preserved plates. But even in this case, the biotite is so rare that it cannot be detected in hand specimens. In a few other rocks it has also been found, in some of which it forms broad sheets, as seen under the microscope. The black mica in this rock (No. 375) is particularly fresh and strongly pleochroic.

Quartz.

Quartz occurs in a few dikes in a very unusual and interesting way, and also as a regular constituent (No. 235), forming, with the feldspar, masses of micro-pegmatite and granophyric borders around some of the orthoclase crystals, as already mentioned and illustrated (plate xviii, figure 1). The other mode of occurrence is quite different. In three, and possibly more, of the dikes, quartz is found as phenocrysts in a fine-grained groundmass composed of plagioclase and augite, or its alteration product, hornblende. Quartz phenocrysts rarely occur in rocks so basic as these; therefore the subject deserves more than passing notice. The dike which produces this anomaly the most abundantly is located about eight miles southeast of Ironton (Tp. 33 N., R. V E., Sec. 10, NW. qr.). A dike about five feet wide cuts through the granite which at this place chances to be exposed over a small area, all the surrounding surface for several rods being covered deeply with soil. No specimens could be obtained from the dike in place without drilling and blasting, as it was worn to a level with the granite. Numerous boulders of apparently the same kind of rock were strewn over the surface. These afforded opportunity for gathering all the material desired. The peculiar phenocrysts of both quartz and feldspar which could be readily seen in the dike were also present in the boulders, leaving practically no doubt as to the identity of the latter (plate xiii). The large phenocrysts are feldspar; the smaller spots are quartz.

Thin sections cut through the quartz grains show that each grain is surrounded by a border within the groundmass (figure 2, plate xviii). The border breaks up under the microscope into an aggregate of crystals, generally pointing toward the quartz phenocrysts. At present the crystals are green hornblende, and are decidedly pleochroic, although quite likely originally they were augite. The nature of the groundmass also can be seen in this figure. In the specimens examined, almost all of the augite of the groundmass has been changed to hornblende. The same rock, or at least one from near the same place and having almost identical properties, was examined some years ago.* At that time Mr. Coates, of the chemical department of Johns Hopkins University, made a silica determination of the rock, including the quartz phenocrysts, and obtained for his result 53.40 per cent of SiO_2. Recently Mr. C. E. McClurg, of the University of Kansas, has determined the acidity of the groundmass (No. 15001) from which all the visible quartz phenocrysts were excluded. He obtained 53.19 per cent of SiO_2, which is practically the same as that obtained by Mr. Coates.

A few other rocks possess the same kind of quartz phenocrysts. Two miles northwest of the last mentioned locality, a narrow dike is full of them, but there appear to be no feldspar crystals (No. 15045). Thin sections from this specimen are practically the same as those already described. Also at the Silver mines small boulders of quartz-bearing dike-rocks occur on the surface, but the dike itself could not be found. There is a large outflow of dike-rock in section 26, township 33 north, range vii, east (No. 15501), which has many small feldspar phenocrysts, with which are associated also a few quartz grains. Still again, in the Black river district (Tp. 33 N., R. 2 E., Sec. 16), a dike-rock possesses feldspar phenocrysts and

*American Geologist, Vol. I, p. 378. Minneapolis, 1888.

a few quartz grains. It would thus seem that the quartz-bearing basic rocks are scattered over a large area, which fact makes them all the more interesting.

Until quite recently free quartz crystals in so basic a groundmass were quite unknown, and from a chemical standpoint it would have been thought impossible; but during the last six years a number of similar discoveries have been made. In 1887 Diller* described a quartz-bearing basalt from Cinder cone, near Lassen peak, California. Subsequently† he extended the description of the rock. The quartz crystals are evenly scattered through the mass, but are not accompanied by feldspar crystals as in Missouri. The basalt contained 57.25 per cent of silicic acid, SiO_2. In 1890 Iddings‡ described quite fully quartz-bearing basalts from New Mexico, Colorado, Arizona and Nevada, some of which had no more than 51.57 per cent of SiO_2. In different subsequent papers the same writer has added to the discussion of the subject given in his first publication. In all of the cases mentioned by Diller and Iddings, the quartz grains are surrounded by a border of augite crystals like those herein described.

The explanation for this apparent anomaly, as advanced by Iddings and as now generally accepted, is that the lava at one time existed under such physical conditions as regards temperature and fusion that it was supersaturated with quartz, and that as a consequence a portion of it crystallized out. When those conditions were finally changed and the lava was brought to or near the surface, the quartz grains began to redissolve, but the final solidification of the lava, or some other cause, prevented the complete solution. During this latter action the borders of augite were formed. This explanation, it will be seen, is based upon the modern conception of a lava being a solution product, rather than one of fusion. The borders around the feldspar crystals in the same rocks have already been described and illustrated.

*Am. Jour. Sci., (3), Vol. XXXIII, p. 45. New Haven, 1887.

†U. S. Geol. Sur., Bull. 73. Washington, 1891.

‡U. S. Geol. Sur., Bull. 66, Letter of transmittal. Washington, 1888.

Chlorite.

This mineral is present only as a secondary product, and is consequently most abundant in badly weathered rock. There is no regularity in its form. Sometimes it constitutes small patches scattered through a large crystal of olivine, augite or mica. Sometimes it is in the feldspar, iron or other materials, having been carried over from adjacent minerals; and frequently it occupies the entire space left by the decay of crystals of the minerals mentioned. The chlorite adds greatly in imparting the familiar green color to so many of the weathered dike-rocks.

Iron Oxide.

Iron oxide is scattered everywhere through the dike-rocks. In no instance observed is it very abundant; but it is present in microscopic grains in every specimen examined. The large grains often have the outlines of a square—so frequently, in fact, that it is significant of crystallization in the regular system, which implies the presence of magnetite. In many places where the dike-rocks have been extensively decayed, the beds of the little streams are rich in a black sand which is almost pure iron oxide, collected in different places in this way, from the clays of decomposition.

Ilmenite.

Ilmenite, or titanic iron oxide, is found also in the dike-rocks, but only to a limited extent. Usually it is partially decomposed, producing the well-known leucoxene, which is readily distinguished under the microscope.

Apatite.

Apatite is everywhere present in the dike-rocks, in the form of long, slender crystals penetrating the other larger constituents. Thin sections cut at random through the rock show the crystals in many different ways, from the full length to the hexagonal cross-section. No instance of large crystals has been noted. There are no indications that valuable economic deposits of the mineral are to be expected.

Pyrite.

Pyrite is found in a few of the dike-rocks in a very interesting manner, in the form of little grains scattered through the rock as regularly as though it were an original constituent. The quartz-bearing diabase has it in tolerable abundance, in grains from one-sixteenth to one-eighth of an inch in diameter. Pyrite is usually looked upon as secondary in origin. Just why this notion should universally prevail may be a little hard to understand. Were it not for the widespread opinion to the contrary, a few of these rocks might be looked upon as carrying primary pyrite. Every feature of its relation to the rock mass indicates this, and it appears unavoidable to adopt such a view.

Epidote.

Epidote is sparingly present in the dike-rocks, and then only as a secondary product. With but few exceptions it is in the form of minute scales scattered through the decomposing minerals, and consequently needs no special consideration. The big dike or boss on Captain creek (Tp. 32 N., R. VI E., Sec. 19) has larger quantities of epidote. Here it lines some of the seams in the rock. Thin slabs broken from the walls, make fair museum specimens. At the big boss on Black river (Tp. 34 N., R. II E., Sec. 26), many crystals of epidote may be collected in the soil of the fields, especially after spring rains. The peculiar appearance of such material has led the land-owners and others to think possibly something of great value lies hidden beneath the surface. Similar occurrences have been noted in the localities already given where the asbesti-form hornblende has been found. The epidote from the south end of Blue mountain cannot be distinguished in character from that on Black river.

Garnet.

Garnets have been found in connection with the dike-rocks in one locality only. This is at the falls on the east fork of Black river, in the dike which has overflowed the fissure. A short description of these garnets with accompanying cuts has already been published.* The overflow of the dike material has formed a contact line between the basic lava and the quartz porphyry, which can be traced for several rods along the bank of the creek. The former seems to have been corroded along the contact line, probably by fumarole action, to such an extent that when viewed from a short distance it appears quite porous. The cavities thus produced are literally filled with small garnet crystals, the largest of which are not more than one-third of an inch long.

The crystals are brown in color, varying from greenish-brown to almost black. They usually have a coating of brown dust, or mud, evidently decay products of the rock. When this is removed they present perfectly fresh surfaces, some of which are highly polished. Crystallographically they are at first a little perplexing, on account of the differently distorted forms they present. The normal form is the regular rhombic dodecahedron, ∞ O (110), occasionally with very minute icositetrahedral faces truncating the edges. The latter were always nearly microscopic in size, whether on the regular crystals or the distorted ones, and are therefore not represented in the figures. Four different types of distortion have been made out, each of which is represented by many different crystals, although, of course, they grade into one another.

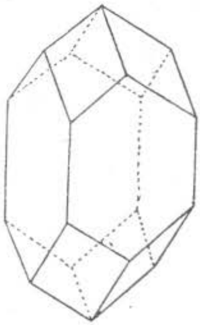

Figure 10. Garnet, first form.

First (figure 10), the four planes normal to the plane of the lateral axes are elonated, giving the crystal an apparent tetaggonal symmetry, thus resembling a combination of the prismatic faces ∞ P (110), with the pyramid of the second order P∞ (011). The angles, however, are all 120 degrees, showing that they are all faces of the rhombic dodecahedron.

Second (figure 11), six planes in one zone are elongated, so that the crystal apparently has the symmetry of the hexagonal

*Haworth: Proc. Iowa Acad. Sci., Vol. I, pt. ii, pp. 33-35. Des Moines, 1890.

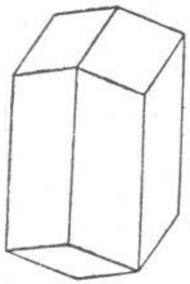

Figure 11. Garnet, second form.

system, resembling a common form of calcite with prismatic and rhombohedral faces. Here again all the angles are 120 degrees. If it were a hexagonal form the prismatic angles would, of course, have this value; but the angles between the prismatic and rhombohedral faces would not, so that the difference is readily detected.

Third (figure 12), is a case differing from the one first given in the unequal development of the four faces, and so developed as to resemble the pyramidal faces of the second order. In this way a form is produced apparently having the monoclinic symmetry, and composed of the two pinacoidal faces, $\infty P \breve{\infty}$ (010) and $\infty P \bar{\infty}$ (100), in combination with rather steep pyramidal faces $\pm P$ (111). But the uniform value of the angles dispels the illusion.

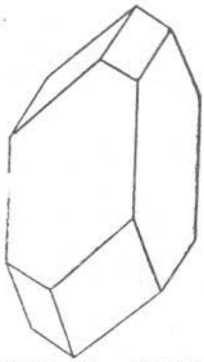

Figure 12. Garnet, third form.

Fourth (figure 13), is a form which again simulates the monoclinic symmetry. The crystal seems to be formed by the combination of the prismatic faces ∞P (110), the clino-pinacoidal faces $\infty P \breve{\infty}$ (010), the clino-dome, $P \breve{\infty}$ (011), and the plus orthodome, $+P \bar{\infty}$ (101) a combination strictly in accord with the laws of symmetry. Here again the uniform value in all the angles of 120 degrees shows the real form.

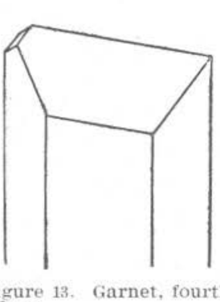

Figure 13. Garnet, fourth form.

A chemical analysis of well-preserved crystals, made by the St. Louis Sampling and Testing Works, gave the following results. Unfortunately the two iron oxides were not separated, but regarded as $Fe_2 O_3$.

SiO_2	33.88	CaO	30.71
MnO	00.20	MgO	.63
Fe_2O_3	29.35	Total	100.30
Al_2O_3	5.53		

There is, therefore, no doubt but that the mineral is a lime-iron garnet, and should be referred to the variety melanite. The specific gravity, as determined by means of the specific gravity flask, is 3.6002. The dike rock itself has a specific gravity of 2.7434, and gave 45.50 per cent of silica, SiO_2.

Aside from this one instance, no garnets have been found in the dike rocks. Broadhead reports having found garnet at the old Ketchiside tract, a few miles south of Ironton, but none of them have been personally examined for identification; neither was anything learned of the nature of the rock in which they occur. Similarly, Nason mentions garnets occurring at Iron Mountain, but gives no details.

Calcite.

This secondary mineral has been found in small quantities in many instances in badly weathered rocks, but never as an important constituent. Simply minute quantities are found here and there through the decomposed matter and in the ordinary forms.

Glass.

Some of the dike-rocks carry a great deal of unindividualized matter, or glass, of a dark color, which has such a relation to the crystals of the different minerals that it may well be considered here as a constituent. In the dikes which carry coarse crystals of feldspar and augite in connection with the glass, the latter is found lodged between the feldspar crystals, just as the augite usually is in diabase with the ophitic texture. This presents a very striking appearance when viewed with the microscope, for it contrasts so strongly with the feldspar and the augite. Two different dikes show this pre-eminently—one the boss at the old tin mines, and the other on the east bank of the river at Silver mines. In the former the feldspars and the augites are the coarser, but the same general features prevail throughout the two. The glass, instead of being perfectly solid, is filled with long, slender crystal skeletons of two different kinds, the one dark which seems to be iron oxide, and the other light, which probably is feldspar. The glass core in the augite crystal from Tin mountain has already been shown (figure 1, plate xvii).

In a number of the other dikes glass is found, but not so noticeably as in these two. A small side vein three inches wide from the big dike, carrying the large feldspar phenocrysts (No. 15498), is almost all glass. Macroscopically it appears almost like an obsidian. It is to be noted that the glass will weather and turn green, the same as the ferro-magnesian minerals. Numerous instances have been seen in different thin sections, especially from the Tin boss, of the glass being changed into green fibrous hornblende, or uralite, the same as the augite. This, no doubt, accounts for small dikes so often being holocrystalline, and having the body so nearly entirely composed of green hornblende, as mentioned under the consideration of that mineral.

Other Constituents.

A few other secondary constituents have been found, but they are not of sufficient abundance nor importance to merit more than a passing notice. To this category belong kaolin, so often produced by the decomposition of the feldspars; scales of muscovite, produced in a similar way; iron rust, formed by the weathering of the iron-bearing minerals and the hydration of the grains of iron oxide; and possibly a few other minerals. When rocks decay there is generally a complexity of products, some of which are of no special significance.

TEXTURE.

Of the three textures outlined, the ophitic and the porphyritic are well represented, while a few dykes have textures somewhat like the granitic. A majority of the dikes have the porphyritic texture, but by areas of the rock masses exposed, the ophitic perhaps predominates.

Ophitic Texture.—This is produced by the association of the long, slender feldspar crystals with other material, usually augite, which is intimately crowded in between the feldspar crystals so that all the space is occupied (figure 1, plate xiv). Such a texture is common to all the dike-rocks in the vicinity of Skrainka, where the extensive quarry in the olivine diabase is located; at the big boss of dike material on Black river (Tp. 34 N., R. II E., Sec. 26), and at a score or more other locations throughout the region. With but few exceptions, every dike known over five feet wide has this texture.

Porphyritic Texture.—This is well illustrated in the hand specimens represented by plate xii, the essential characteristics being the presence of phenocrysts of some mineral in a background of a finer-grained material. The rock in this dike (No. 15498) contains the large feldspar crystals already described. The quartz diabase (No. 15001) also has the porphyritic texture (plate xiii). Still again, the glassy rock from the tin mines (figure 2, plate xv) and the glassy dike on the east bank of the river at Silver mines (figure 1, plate xv) have the porphyritic texture. Nearly all of the smaller dikes have a fine-grained groundmass, with here and there a larger crystal, so that they should be referred to the same class. This makes the number of dikes with the porphyritic texture very large, for it includes perhaps two-thirds of all that are known.

Granular Texture.—A few dike-rocks are known in which this texture is approached, but it is not well represented in any of them. In a general way, it is quite similar to a rock with a granitic texture, the hand specimens especially appearing so. But a careful examination shows that it is more nearly a mixture of the ophitic and porphyritic. Such phenocrysts of orthoclase as are shown in figure 1, plate xviii, and of augite, as the one in figure 2, plate xvii, strongly recall the porphyritic texture. The numerous long, slender feldspar crystals, which in places are abundant, make it allied to the ophitic; and yet in other parts it is quite like the granitic. Such mixtures of texture are common in some rocks, and are always difficult to name. Another example is the coarse rock (No. 15553) from Captain creek. This is less strongly allied to the granular texture than the one mentioned; and yet the coarse masses of augite do not appear like that mineral ordinarily does in the ophitic texture. It has so many long, slender feldspar crystals that it is quite strongly related to the ophitic.

CLASSIFICATION.

It seems desirable to make as few classes of any one great group of rocks as will serve to designate the essentially different members of the series. Accordingly, but four general divisions are made of the Missouri basic rocks to which the following names are applied: diabase, olivine-diabase, diabase-porphrite, and melaphyre. The former is applied to all the olivine free, well-crystallized rocks which have the ophitic texture, and which are free from prominent phenocrysts of any kind. The second is used to designate rocks similar in character, but which, in addition to the above, have olivine as an essential constituent. The third name is made to cover all the olivine-free dike-rocks which have the porphyritic texture, all the exceedingly fine-grained ones which are nearly free from phenocrysts, and all the glass-bearing varieties which contain no olivine. The fourth is given to all that carry both olivine and glass. As already stated, no particular thin section has been examined which carries both constituents. But each of them has been found in comparative abundance in the same rock-mass, and therefore it is thought the name is applicable. All other glass-bearing rocks seem to be olivine-free. The whole scheme may be arranged as follows:

Basic Intrusives.	Holocrystalline.	Ophitic.	Olivine free—Diabase.
			Olivine-bearing—Olivine Diabase.
		Porphyritic	Quartz free—Diabase-Porphyrite.
			Quartz-bearing—Quartz Diabase Porphyrite.
	Glassy.	Olivine free—Diabase Porphyrite	
		Olivine-bearing—Melaphyre.	

GEOGRAPHIC DISTRIBUTION OF VARIETIES.

The dike-rocks are scattered irregularly over the whole of the crystalline area. They are most numerous in the two townships east of Ironton. On the accompanying map (plate i), their location is indicated by the small black crosses. The dikes are commonly small seams cutting the granite and porphyry, and usually do not average more than two or three feet in width, while some of them are less than an inch. Their length cannot be estimated so well, for it is seldom that they can be traced more than 50 or 100 yards until a mantle of soil conceals them. In passing through the region, the first indication of a dike, usually, is the presence of numerous dark-colored boulders lying on the surface. They are peculiar in a number of respects, and, therefore, may be readily recognized. Their color is generally a dark green or black, with occasionally numerous white streaks, due to the long, slender, white feldspar crystals. Ordinarily, the feldspars are dark, and consequently attract no attention.

When struck with a hammer the boulders give a metallic ring, which is in strong contrast with the sound issuing from a boulder of granite or porphyry under similar conditions. The same kind of material is sometimes found in oblong or circular areas instead of dikes, which are then called bosses. These differ from dikes only in shape. The decay of the dikes is characteristic of the rock, differing in some respects from the disintegration of the other masses. The boulders always have rounded forms. The seams through the small dikes are, without exception, normal to the walls: that is, to the surface of radiation of heat, and consequently the direction of greatest contraction. In this way, some of the narrow dikes appear to be built of blocks lying transversely. When the blocks are thrown upon the surface by the decay of the wall-rocks or otherwise, the corners and edges are rounded by weathering. Such surface boulders generally are comparatively sound throughout, for the products of decay fall away as fast as formed. But when the boulders become embedded in soil, the secondary matter cannot be removed. The result is that they decay in such a manner that concentric shells are formed from the surface of each boulder. In operating the quarry at Skrainka, six or eight feet of boulders and soil was cut through. The face of the wall produced seemed to be composed principally of such circular and elliptical shells, the spaces between being snugly filled with soil. Occasionally an olivine diabase boulder weathers irregularly so that its surface is rough and warty looking — the protuberances being from a third to two-thirds of an inch in diameter. Also, when a great mass of the solid olivine diabase decays, it often has myriads of little kernels left through the freshly-formed soil. The soil produced from the dike-rock material differs greatly in color from that produced from any other rock in the region. It is of a peculiar, often dark, speckled color. The dark color is due to the dark augite principally, and the light specks to little feldspar grains, which seem at times to resist final decay remarkably well.

Certain of the most prominent dikes and bosses require detailed description.

Tin Mines Boss.—No other dike-rocks in the state have attracted nearly so much attention as those at this place. The locality is on the northwestern flank of the Tin mountain, a large hill which touches the south bank of the Little St. Francois river (Tp. 33 N., R. VI E., Sec. 35). The mass reaches from the base of the hill near the creek to a point about 300 feet up, beyond which no trace of it has been detected. It is fully fifty yards wide. To the north, across the creek, no indication of a dike of any kind was found within a distance of one mile. At present it must be looked upon as being a boss of dike material rather than an ordinary dike. The character of the rock is peculiar and interesting. Macroscopically, it appears to be relatively coarse-grained, black in color and waxy in luster. Large pieces of it lying around the old dumps show that seams were not especially developed in it. Microscopically it is seen to be composed of plagioclase, augite, olivine and glass, with an abundance of apatite and little shreds of iron oxide produced by the arrangement of minute grains in rows. The rock is therefore a melaphyre, and has the distinction of being the only one in the state to which the name is applicable.

Over twenty years ago great excitement was caused by the report that this melaphyre contained tin ore, or rather, that the whole mass of rock was tin ore. Mining operations were conducted quite extensively for a few years, and large quantities of the material were brought to the surface. The place was named the Tin mines, a local application which still clings to it, and which is retained in this report. It is needless to add that no tin ore was found, and that there is no indication of any being present.

Skrainka.—This name is applied to a stone quarry, and a little village which once existed near by (Tp. 33 N., R. VI E., Sec. 3, N. ½). The quarry was opened in a boss of olivine diabase which is located on the south side of a large porphyry hill. A branch dike extends eastward for a distance of nearly 200 yards, and possibly farther. One also reaches to the southwest nearly as far. The seams in the rock trend northeast and southwest. Occasionally there are streaks in the rock where the white feldspars are unusually abundant, giving the rock a lighter color; also, some of the seams are filled with secondary hornblende. The great mass of rock is a typical olivine diabase. Its chemical composition has already been given. Mineralogically, it has plagioclase, augite and olivine, with apatite and iron oxide present in small quantities. It is coarse-grained, dark blue in color, and forms an excellent stone for paving blocks, for which purpose the quarry was operated. The characteristic toughness of the rock rendered it difficult to work profitably, so that after ten years or more of active operation the quarry shut down. So basic a rock, and especially one containing so much olivine, of course should not be used for structural purposes. But for street-paving in the larger cities, where the mechanical wear is so much more rapid than the weathering decay, these properties are not so objectionable.

The country for three or four miles to the west, south and southeast of Skrainka contains an unusually large number of dikes, all of which are composed of the same kind of rock. They are particularly noticeable to the south along the main road between Fredericktown and Ironton. Beginning immediately south of Skrainka, and about a mile away, a dike or system of dikes follows the road toward Fredericktown for a distance of nearly two miles. It cannot be traced continuously, and therefore it may be a series of outflows. In a few places the large boulders have been worked into paving blocks, and even some little quarrying has been done at one point. At other places along the little branch followed by the road, the decayed surface of the dike may be traced for rods. Boulders are numerous over the entire distance. To the west of Skrainka, similar and perhaps equally extensive disturbances have occurred. Large masses of olivine diabase boulders are common here and there for a distance of two or more miles. On the whole, this is one of the best localities for this kind of rock to be found in the state.

Black River Boss.—Twenty-four miles west of Skrainka is the largest boss of dike material known in Missouri (Tp. 34 N., R. II E., Sec. 26). It covers about 160 acres, a large part of which is now occupied by cultivated farms. It rises into a considerable hill to the south, and is partly bordered on the north by a ravine. The rock is so nearly identical with that at Skrainka that neither macroscopically nor microscopically can any essential differences be made out. This is the place, already mentioned, where so much epidote occurs in a cultivated field. It is particularly abundant on the western hillside at this place. As might be expected, so large a mass of an eruptive rock is associated with smaller dikes in the vicinity; east, west and north they are to be found, all composed of the same kind of material.

Falls Dike.—At the falls on Black river (Tp. 33 N., R. II E., Sec. 16) a dike has been found which overflowed the walls of the fissure and formed considerable masses on the surface.

This has already been described in connection with the discussion of garnets, and need not be mentioned further.

Russell Mountain.—The northwestern part of Russell mountain is composed of a rock so similar to the dike material that undoubtedly it should be classed with it. Forty acres or more are covered with boulders partially filled with gas cavities, thus forming a scoriaceous rock, the groundmass of which has numerous small microliths of feldspar, so arranged that a trachytic texture is produced. At one point on the east side a broad, flat sheet of the solid rock is found, which in every respect resembles the fine-grained dikes. This is therefore an unusually interesting place, as it is the largest surface known in the state to be covered by the outwelling of dike rock material. No chemical examination has been made of this rock, but it appears to be considerably more acid than the Skrainka diabase.

Marble Creek.—About a mile above the point at which Marble creek makes its last turn toward the east, a considerable mass of dike material is found on the east bank of the stream, close by a school-house. How large the dike is or the area of dike-rock was not definitely determined. To the east is a small hill, occupying approximately forty acres, which appears to be composed principally of tufa, but how basic it is cannot be said. The weathering agents have changed the iron principally into iron rust, so that it has a brownish red color. Most likely it is a diabase tufa. The rock itself is fine-grained, and is characterized by having many distinct spots on the fresh surfaces, which correspond to the "surface mottlings" of Pumpelly or the poecilitic structure of Williams.

Silver Mines.—In this locality a number of different dikes occur. The largest is on the left bank of the St. Francois river at the dam. Here the solid granite is cut by a dike which has a width of 50 inches, trending northeast and southwest. It has worn away faster than the enclosing granite, so that the horizontal seams permit the blocks to drop out, leaving steps. The rock in this dike carries a great deal of glass. On the west side of the river a dike one and one half feet wide occurs below the dam. It is badly weathered, and probably has had its glass changed to green hornblende and chlorite. Otherwise it is quite like the one on the east side. Farther back from the river other dikes undoubtedly exist, for the surface is strewn with boulders in different places. One of these series has already been mentioned as quartz-bearing. The disturbance here has been considerable, as is shown by the numerous dikes and fissures now carrying quartz and metalliferous veins. Some of these fissures having been filled with dike-rock lava and others not, indicates that the two series of fissures were not contemporaneous.

Captain Creek Boss.—Nearly a mile to the east of Captain creek (Tp. 32 N., R. VI E., Sec. 29) a comparatively large area of dike material has been found. The whole surface is covered with a heavy mantle of soil, excepting here and there where the rock is exposed. At one place, years ago, prospectors sank a shaft about ten feet into the rock, and thus gave an excellent opportunity to study its character. Along the seams an unusually large amount of epidote has been deposited. Fragments broken from the walls contain fairly good museum specimens of the mineral. The body of the rock is unusually coarse-grained, the long, slender, white feldspar crystals often attaining a length of three-fourths of an inch. It is composed almost entirely of plagioclase and augite — the large grains of the latter giving the rock a somewhat granular texture.

Origin of the Dikes.—Concerning the indications of a common origin for the basic dikes and bosses, it may be said that invariably the dikes trend northeast and southwest, with the few exceptions lying approximately at right angles to this direction. This implies that they are, in general, contemporaneous. This northeast and southwest direction, it will be remembered, is the same as that of the most prominent vertical seams in the granites and porphyries, which possibly accounts for this particular direction having been followed by the fissures; for, being the direction of least strength in these rocks, it is therefore the direction of least resistance. So far as established by actual observations, the dikes have not been found to connect with one another. Whether they do below the surface is only conjecture. The only direct evidence, therefore, of a common origin for the dike-rocks is the similarity of form and wonderful similarity of kind. The former coincidence, as just explained, indicates that they are contemporaneous, but it is not conclusive evidence. Should orographic movements occur in the future sufficiently strong to produce similar fissures, the tendency would be for them to follow the same direction, for the same cause: that is, the fissures in the country rock. But the similarity in kind of matter is a strong indication that they have a common origin. When it is remembered that the olivine diabase on Black river is nearly like that at Skrainka, twenty-five miles away, and that all the diabase between the two extremes is practically the same, it is a good indication that the different dikes had a common origin. Neither is there greater variation in kind with variation in latitude, or north and south directions. It may therefore be concluded provisionally that the dikes in this part of the state are contemporaneous, and that they had a common origin, the present differences in the rock depending principally upon the different physical conditions under which the molten material solidified.

GRANITES AND GRANITE-PORPHYRIES.

CHEMICAL COMPOSITION.

In chemical composition the granites of Missouri are very similar to those from other localities. Their most distinguishing feature is their relatively high percentage of sodium, which, as may be seen from an examination of the accompanying table, is above the average for granites. This is undoubtedly due to the comparatively large amounts of plagioclase present. A few analyses of other granites have been added to the list for comparison.

TABLE OF CHEMICAL ANALYSES OF MISSOURI GRANITES.

Locality.	Loss at 100°C.	Loss on ignition.	SiO_2	Al_2O_3	Fe_2O_3	FeO	NiO	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	TiO_2	Totals.	Authority.
Graniteville.	....	0.52	77.05	11.77	2.33	.....	.....	.....	2.21	......	3.88	2.90	0.023	......	100.68	Melville.... ....
Ironton, 6 m. E......	0.14	0.85	69.94	15.19	1.88	0.60	.....	0.03	1.15	0.92	4.29	3 95	0.13	0.25	99.32	Melville............
Silver Mine, 2.m. W.	....	....	73.98	14.32	....	.....	.....	.....	1.04	......	3.32	4.56	......	......	....	St. L. Samp. wks.
Middlebrook, 5 m. E.	....	....	77.04	12.29	....	.....	.....	.....	.....	....	.....	.....	......	......	....	St. L. Samp. wks.
Hogan, 7 m. E......	....	....	74.06	... .	....	.....	.....	.....	.....	....	.....	.....	......	......	....	Melville............
Hogan, 7 m. E......	....	....	77.38	....	....	.....	.....	.....	.....	.....	.....	.....	......	......	....	Melville............
Ironton, 6 m. E......	0.22	0.54	72.35	13.78	1.87	0.36	0.20	0.06	0.87	0.42	4.49	4.14	0.13	0.44	99.87	Melville............
Skrainka	....	....	69.51	....	....	.....	.....	.....	.....	.....	.....	.....	......	......	....	Bradford ....
Schönberg.	....	1 06	76.12	13.42	1.28	.....	.....	.....	0.34	0.19	4.89	3.10	......	......	....	Kalkamsky........
Vogesen........	....	0.85	62.09	16.43	2.34	2.03	.....	.....	2.32	3.08	4.66	4.07	......	0.56	....	Kalkamsky........
St. Cloud, Minn.	.. ..	....	74.43	12.68	....	.....	.....	.....	1.28	0.25	2.33	1.53	......	......	....	Minn. G. S.........
Monson, Minn	....	....	73.47	15.07	....	.....	.....	....	4 48	0.12	0.38	5.59	......	......	....	Ordway...... .....

MINERALOGICAL CONSTITUENTS.

The Missouri granites are composed principally of orthoclase and quartz, with some microcline, plagioclase and biotite. Besides these are occasionally hornblende and several other minerals in minute quantities, and some of secondary origin. All of these, and certain others which are found in mineral veins in the granites, are enumerated approximately in the order of their relative abundance: Orthoclase, quartz, microcline, plagioclase, biotite, hornblende, iron-oxide, muscovite, apatite, zircon, topaz, galena, wolframite, fluorite, lithia mica, sericite, pyrite, chlorite, epidote, calcite.

Orthoclase.

Orthoclase is the most abundant mineral in the granites. It presents a great variety of forms, varying from perfect idiomorphic crystals to truly allotriomorphic individuals. Frequently the large crystals have numerous small quartz grains scattered through them, forming an irregular mosaic. In size there is a variation from minute grains to crystals fully two inches long. The finest examples of the large idiomorphic forms are found at the Graniteville quarries; also at the Pilot Knob quarry, one mile south of Graniteville; at an exposure one and one-half miles southeast of Hogan; and at the new Gabriel and Buford quarry, recently opened two miles west of Cornwall. Embodied within the granites are many more idiomorphic and hypidiomorphic crystals, which are not visible macroscopically, but which are made out under the microscope. The crystalline form of the orthoclase presents nothing different from that which may be seen in almost any granite, the prismatic and pinacoidal faces with the basal plane being represented by many of the phenocrysts. Twins are common among the well-formed crystals, the Carlsbad law being the one usually followed.

The degree of freshness of the feldspars is quite varied, depending largely upon the specimens examined. In gathering samples from all over the area, regardless of whether quarries have been opened or not, considerable badly weathered material is often met with. The feldspar in such cases is, of course, more or less decomposed. Samples taken from quarries where good material may be obtained exhibit the feldspars as well preserved as in any granites on the market. The blue granite at Syenite, extensively worked for paving blocks, contains the freshest-looking feldspars of any examined. A large proportion of the crystals in this rock seem to be perfectly fresh. The feldspars from some places have a dark, cloudy appearance, as though partly composed of iron oxide, or other opaque material. A close examination shows that this is partly due to minute cavities scattered throughout the crystals; but this explanation will hardly account for all of the cloudiness. The ordinary processes of decomposition probably are responsible for a part of it, but even then, some of the felspars are apparently much more affected than others. The irregularity of occurrence of such cavities precludes the idea that they may correspond to the solution planes of Judd. As decomposition advances there are formed the ordinary products, muscovite in minute scales, kaolin, epidote or chlorite if there chances to be a suitable mineral present to furnish the iron, and perhaps some other materials. In the granites from Graniteville also the feldspars sometimes contain grains of a crystalline, isotropic, highly refracting mineral which seems to be an almost colorless garnet, although the grains are so small that they have not yet been identified as such with certainty.

Many of the idiomorphic and hypidiomorphic feldspar crystals in both the granite and granite-porphyries present phenomena in the way of crystal enlargements which are of great interest. The material for the illustrations has been drawn from both granites and granite-porphyries. The crystal enlargement has been noticed in different kinds of rock in widely separated localities. The blue granite at Syenite furnishes the largest number and the best examples; different granites along Stout creek show the same, but less perfectly. The granophyric granites from almost all over the district have examples of practically the same thing; and many of the coarser orthoclase-bearing porphyries furnish excellent examples. The enlargements are produced by the feldspar material being added to the original phenocrysts in such a way that the new is oriented with the old, so that in the true sense of the term the original crystal has had a secondary growth. This structure differs essentially from the ordinary zonal structure, in that a complete cessation in the development of the original crystal took place, as is shown by the sharp line separating the two parts; and yet it is akin to the zonal structure, in that the original crystal has been enlarged after first formed. While the secondary growth was taking place the new material was completely under the control of the molecular force exerted by the parent crystal, sometimes forming a broad band completely enclosing the latter (figure 1, plate xix). The parent crystal is darker and more decomposed than the new border, which is fresh and clear, but the two parts have exactly the same orientation.

A second kind of enlargement is similar to the one just mentioned, but differs by the border not being entirely around the parent. (See figure 2, plate xix, and 1 and 2 of plate xx.) The first of these has the crystallographic form of the parent unusually well preserved. The new material has collected around it somewhat unevenly, yet the cleavage lines extend out through the new parts.

A third mode of enlargement is effected by the production of a granophyric border adjacent to the parent crystal. In this case the feldspar material is oriented with the parent, and becomes a part of it, the granophyric portions being many times the size of the central nucleus, and so largely composed of feldspar matter that the quartz is scarcely seen. In another instance a twin crystal has the granophyric growth surrounding the central mass (figure 2, plate xx), the form of the twin being maintained throughout. It will be noticed that the twinning is as well shown in the secondary part as in the original crystal. There is another mode of twinning which is interesting. A rod-like feldspar crystal penetrates a rounded feldspar phenocryst, one which has suffered resorption to a considerable degree, but around the margin on one side secondary enlargement has taken place to a limited extent. The long slender crystal has had its length increased by about one-sixth, the new material having the same orientation as the old (figure 2, plate xxi). This form of enlargement passes directly over into the ordinary granophyric structure which is so well represented in many Missouri rocks (figure 2, plate xxi). It is a common observation to see little feldspar nuclei scattered through the granophyres. Always in such cases the feldspathic matter is oriented with the nuclei. Sometimes a mass of micropegmatite will have a granophyric border. Such granophyric masses in reality are crystals, as is shown where the different parts are in twinning position. For a similar reason certain other sections should be mentioned, which are from a granite rock near Skrainka (Nos. 15495 and 15496) possessing characters in some respects quite remarkable. The feldspar here is partly plagioclase. The granophyric and micropegmatitic structures abound throughout. A small amount of hornblende is present; also numerous badly corroded quartz phenocrysts and a few orthoclase crystals similarly corroded. The hornblende generally is in the form of long, slender, rod-like aggregates of little grains, or in ray-like streams, which are always parallel in position with the feldspar rays in the granophyres.

In this connection it may be well to refer briefly to similar phenomena observed associated with the quartz crystals in the porphyries. In some of these (figure 1, plate xxii) there is a quartz phenocryst surrounded by a fine-grained groundmass, in which the quartz material is oriented with the central crystal. The feldspathic matter is irregularly oriented, but the quartz crystal in reality extends out into the groundmass for a long distance. Similar crystals are shown in figures 2, plate xxii, and 1, plate xxiii, in the first of which there is represented the central crystal cut in rhombic section, and around which the secondary matter occurs in great abundance. In the second instance the crystal in the middle has been wonderfully corroded, the resulting shape resembling a double anchor. Around this the secondary matter is arranged, and even solid grains have been formed on both sides of the anchor-like part. Regarding the way in which the secondary growth was brought about, the idea was advanced* a few years ago that the time of enlargement was the final period of consolidation in the rock magma. The material at hand at that time was so limited that little could be done in the line of establishing such views. With the greatly extended field of observation, much additional evidence has been obtained. Material has been examined which furnishes every possible step of graduation, from the solid, broad rim completely encircling the parent crystal, through the solid but incomplete border, the complete and incomplete borders of granophyric material, to the most common form of granophyric structure. The various phenocrysts, great and small, which have suffered corrosion or resorption, show that with many of the granites and granophyres there were two periods of solidification. Now, the groundmass of these rocks most likely assumed a crystalline form at the time of solidification. Devitrification doubtless took place to some extent after solidification in some instances; but all the crystallization of these rocks can hardly be attributed to this agent. So, also, dynamic agents and the processes of weathering produce wonderful internal molecular rearrangement, breaking down some crystals and building up others, during which changes crystal enlargements of feldspars, hornblende and augite have been brought about. But with the Missouri rocks in which the secondary enlargements have occurred, it is shown very conclusively by the general characters of the rocks and minerals that dynamic agencies have influenced them little, if any.

It may therefore be concluded that (1) the period of crystal enlargement or subsequent growth was the same as the period of crystallization of the groundmass in the granites, the granophyres, and probably some of the coarser porphyries, and (2) that this period was synchronous with the final solidification of the rock magma. The original phenocrysts were of course formed prior to this time, and were corroded. During the pro-

*American Geologist, Vol. I, p. 292. Minneapolis, 1888.

gress of final solidification, the molecular control of the nuclei over the new material was sufficient to cause it to become oriented the same as in the original crystals. By virtue of their strong molecular attraction they modified and controlled in the same manner as nuclei of soluble salts are known to do when dropped into solutions supersaturated with their own materials. This is a strong confirmation of the modern conception of liquid lavas which considers them to be solutions. A point is reached in the cooling process when the solvent, the "mother liquor" so to speak, is supersaturated with feldspar or quartz material, as the case may have been, and the nuclei present helped to determine its crystallization. It would be improper, however, to conclude that all the phenomena of secondary enlargement must of necessity have originated while the rock magma was still plastic. There is good reason for believing that many of the porphyries originally were glasses. The devitrification processes within such may have been instrumental in producing a secondary growth in some cases. But it should be remembered that the best and most numerous examples in Missouri come from the granites, coarse granophyres and coarse porphyries, not a single case having been thus far observed in the fine-grained porphyries. It evidently will be as difficult to discriminate between secondary enlargements produced by these two processes as it is to determine positively between the common forms of crystallization produced respectively by them, a discrimination which cannot always be made.

During the past few years a number of investigators have described different kinds of secondary enlargements from both clastic and massive rocks, and a brief review of the subject may not be without interest.

Sorby* seems to have been the pioneer in this line of work, although Bonney† possibly noticed such conditions first. He called attention to enlarged quartz grains in sandstone, quartzite and mica schist. He was followed by Young‡, who described large quartz grains in the Cambrian sandstone of

*Proc. Geol. Soc., London, 1880, p. 62.
†Quart. Jour. Geol. Soc., London, Vol. XXXV, p. 666.
‡Am. Jour. Sci., (3), Vol. XXXIII, p. 257; and ibid, Vol. XXXIV, p. 24, 1881.

Wisconsin. In the same year Hague and Iddings* made detailed mention of enlargements in quartzites of Silurian, Devonian and Carboniferous ages, but their report was not published until 1892. Also in 1881 Hopfner† gave a description of certain zonal structures in the triclinic feldspars from Mount Tajumbina, Peru, and according to his observations certain irregular developments of these produce forms somewhat similar to the enlargements herein described. The following year Williams‡ noted at some length certain zones around both quartz and feldspar in quartz porphyry from the Black forest, which he attributed to the continued growth of the crystals during the effusive period. In 1883 Irving and Van Hise† described and figured quartz crystals from sandstone and quartzite from various places in America, which had been greatly modified by secondary enlargement. In many instances they found the old rounded quartz grain was supplied with well-formed crystallographic faces, the new material in which was invariably oriented with the central nucleus. The latter writer¶ subsequently called attention to certain feldspar crystals from fragmental rocks, which had been enlarged by the growth of new material on the borders. In one instance a twin crystal was found which was enlarged in such a way that the twinning law governed the new material the same as the old.

In the same year Becke,|| in an article entitled "Eruptivgesteine aus der Gneissformation des niederosterreichischen Waldviertels," described certain zones of feldspar material around plagioclase crystals which should be referred to a secondary growth during the second period of consolidation. The rock in which they occur is a kersantite. He divides the constituent minerals into two classes. The first group includes feldspar, biotite, augite, olivine and quartz. He says that they were formed before the solidification of the rock mass, and

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*U. S. Geol. Sur., Monog. XX, 1892.

†Neues Jahrbuch, 1881, Band. II, 164.

‡Neues Jahrbuch, Beilage Band. pp. 605-607, 1882.

§Am. Jour. Sci., (3), Vol. XXV, p. 401, New Haven, 1883; also U. S. Geol. Sur., Bul. 8, Washington, 1893.

¶Am. Jour. Sci., (3), Vol. XXVII, p. 399, New Haven, 1884.

||Min. und Petrog. Mitth., Bd. IV, pp. 147-171. 1884.

correspond to the "elements de premiere consolidation" of Fouque and Levy. The second includes plagioclase rich in soda, orthoclase, quartz and pale green hornblende, and corresponds to the "elements de seconde consolidation" of the same authors. He then says: "These last constituents, which cannot be called secondary in the ordinary sense of the term, and which I have called constituents of the second order, are at times most intimately associated with the above mentioned constituents of the first order; oligoclase and micropegmatite appear as a rim of parallel growth around the andesine kernel of the second order."* Again he says: "The feldspar crystals (of the first order) are united with the 'Zwischenmasse' (the material of the second order) by means of the oligoclase zones;"† and further: "also the oligoclase zones pass directly over into the micropegmatite, as is shown by the fact that the feldspar in the same extinguishes with the oligoclase zones of the adjacent feldspar crystal."‡ In the same article he mentions the secondary growth of hornblende crystals, which he thinks occurred after the consolidation of the rock. He considers that "The nature of the occurrence of these enlargements leaves no doubt but that during their formation there was no longer motion within the rock."§ The original crystals were a compact, brown hornblende, but the secondary margins were of the familiar light green fibers, which always are secondary in origin, and which are due to either dynamic or weathering agents. They penetrate the surrounding portions of the rock, because they were formed by a molecular rearrangement of the rock mass. Bleibtreu,‖ in a paper entitled

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*"Die letzteren Gemengtheile, die man nicht als secundär im gewöhnlichen Sinne des Wortes bezeichnen kann, die ich deshalb als Gementheilen II Ordnung bezeichnen werde, sind mit den früher angeführten Gementheilen I Ordnung zum Theil auf das Innigste verbunden; Oligoklas und Mikropegmatit erscheint als parallel fortgewachsene Hülle um die Andesinkerne I Ordnung." Page 170.

†"Die Feldspathkrystalle sind mit der Zwischenmasse durch die Oligoklashülle verbunden."

‡"Auch setzen sich die Oligoklashüllen häufig direct in Mikoropegmatit fort, was daran erkannt wird, dass der Feldspathgrund desselben gleischzeitig mit der Oligoklashülle benachbarten Feldspathkrystalle auslöscht."

§"Die Art des Auftretens dieser Fortwachsungen lässt keiner Zweifelt das während der Ausbildung dieser Fortwachsungen mechanische Bewegungen innerhalb dieses Gesteins nicht mehr stattgefunden haben."

‖Zeitschrift der deutsch. geol. Gesel., Bd. XXXV, pp. 489-556, 1883.

"Beitrage zur Kenntniss der Einschlusse in der Basallten, mit besonderer Berucksichtigung der Olivinsfels Einschlusse," describes numerous instances in which feldspar and other minerals have been partially fused by basalt lava, and on cooling have had secondary rims attached which were oriented with the original crystals. In April of the same year Hussak,* in a paper entitled "Uber den Cordierit in vulkanischen Auswurflingen," describes the same kind of occurrences, in substance, as those mentioned by Bleibtreu.

Doelter and Hussak,† in 1884, published an account of some very interesting experiments made by fusing different kinds of natural volcanic rocks, and observing the effect which the fused masses had upon natural crystals of feldspar and other minerals. Portions of the crystals were dissolved, and upon cooling recrystalized in the form of grains and lath-shaped crystals, which were oriented by the original crystal, often grading into it in such a way that no well-defined line was left between the two parts. In 1885 Van Hise‡ gave a description of the secondary enlargement of hornblende crystals in fragmental rocks; while two years later Koch§ described feldspar enlargements in a kersantite which he thought could be best explained by attributing them to subsequent growth of the original crystals from the molten magma. Van Hise‖ also again directed attention to the secondary growth of crystals, this time of both augite and hornblende, in an altered diabase of the Gogebic iron-bearing series of Michigan and Wisconsin. A secondary growth of hornblende is attached to hornblende produced from augite by the ordinary and well-known process of paramorphism. The author says: "The added hornblende has found room for itself * * * * by penetrating the surrounding feldspars. Similar new hornblende is also found included in the partly decomposed feldspar in numerous small, fibrous, independent individuals," thus showing how badly the

*Issued with above title; also Sitzb. der k. Akad. der Wissenschaft, I Abth., April Heft., Band. LXXXVII., 1883.

†Neues Jahrbuch, 1884, Bd. I, pp. 18-44.

‡Am. Jour. Sci., (3), Vol. XXX, p. 231, New Haven, 1885.

§Jahrbuch der k. Preuss. geol. Landesanstalt, 1887, pp. 77-78 and 98.

‖Am. Jour. Sci., (3), Vol. XXXIII, pp. 385-388, New Haven, 1887.

rock had been affected by dynamic or weathering processes. In other cases the augite had not been changed to hornblende, but many crystals were surrounded by a sheath of secondary hornblende, which penetrated the adjacent feldspar crystals as in the other instances. Merrill,* when he published his paper on "Secondary Enlargements of Augite in a Periodite from Little Deer Island, Maine," recorded observations made upon a rock which was composed originally of olivine and augite, the former of which "in nearly every case examined has gone over completely into serpentine." Around the margin of some of the augite crystals borders of an unusually colorless augite had formed, the material in which is oriented with the original crystal. In the same year Bonney† described secondary enlargement of biotite fragments in argillaceous rocks; and at the same time Haworth‡ made mention, with considerable detail, of secondary enlargements of feldspar crystals in granites and granophyres. In the following year Judd§ published a paper, "On the growth of Crystals in Igneous Rocks after their Consolidation," illustrated by three figures of secondary enlargements of feldspar crystals, and four figures copied from Haworth's article just referred to. The conclusion is reached that the secondary enlargement was produced by metamorphic agencies long after the rocks solidified, even after they had been subjected to great erosion and weathering. He also advanced the opinion that "the formation of the different varieties of micropegmatitic, centric, pseudo-spherulitic and miarolitic structures, respectively," are secondary, or subsequent to the solidification of the rock magma. However, the conditions he describes are such that almost a refusion is necessary in order to bring about these changes. He says: "Subsequently (after the erosion and before the secondary growth) this old lava was buried to the depth of several thousands of feet by the later out-welling of basaltic and other

*Am. Jour. Sci., (3), Vol. XXXV, pp. 488-490, New Haven, 1888.
†Quart. Jour. Geol. Soc., London, Vol. XLIV, p. 15, 1883.
‡American Geologist, Vol. I, p. 292, Minneapolis, 1888.
§Quart. Jour. Geol. Soc., London, Vol. XLV, pp. 175 186, 1889.

lavas." In 1891 Wolff* called attention to secondary enlargements of feldspars in a paper entitled, "Metamorphism of Clastic Feldspar in Conglomerate Schists," and a year later Hobbs† described and figured similar growths in crystals of feldspar, garnet and tourmaline in clastic rocks. He shows that frequently the secondary border is a different variety of triclinic feldspar from the central nucleus. In some cases twins have the twin formation in the new growth, and in other instances they do not. At the same time Whittle‡ also mentioned the enlargements of both tourmaline and feldspar crystals in a like manner. A little later Romberg§ published a very interesting account of alterations which have occurred in certain granite masses in the Argentine Republic, some of the results of which were the production of secondary enlargements of feldspar crystals and the formation of granophyre and micropegmatite. He is inclined to believe that these changes are the result of weathering.

Lastly, Graeff‖ described feldspar enlargements in the eruptive rocks in the environs of Cingolina, Padua. Other investigators have also made observations of similar character in many different portions of the globe, and in different kinds of rocks. Such may be gleaned from the early work of Tornebohm, of Zirkel, of Knop and of Lang.

Microcline.

Crystals of this mineral are often seen in the examination of thin sections of granite. They seem to be most abundant in the granites at Graniteville, although by no means confined to one locality. There is no special difference in the arrangement of the feldspar constituents in the microcline-bearing rocks, the peculiar checkered appearance, or cross-hatching under the microscope with crossed nicols, being the only apparent difference between it and orthoclase.

*Bul. Mus. Comp. Zool., Vol. VI., pp. 173-183, 1891.

†Bul. Geol. Soc. America, Vol. IV, pp. 167-178, 1892.

‡Bul. Geol. Soc. America, Vol. IV, pp. 147-166, 1892.

§Neues Jahrbuch, Beilage Band VIII, pp. 275-406, 1892.

‖Neues Jahrbuch, Band I, p. 123, 1893.

Plagioclase.

Its general habit is like that of the orthoclase, excepting that the crystals are more slender. The mineral occurs much more sparingly than either of the other feldspars, and in many of the granites seems to be entirely wanting. It is most abundant in the granites which carry the largest amounts of biotite. There appears also to be an unusually large amount in the rocks from the vicinity of Mine La Motte station, especially those lying to the northwest. The large per cent of soda in the granites, as shown by the chemical analyses, makes it probable that the plagioclase is principally albite.

Quartz.

The quartz in the granites is of the ordinary kind. Its abundance, too, is the same relatively as that commonly observed in other granites of the same degree of acidity, varying from place to place as the acidity of the rock varies. Many of the granites are composed almost entirely of orthoclase and quartz, in which case, knowing the percentage of silicic acid, the relative amount of each constituent may be calculated. The same end may be accomplished for the other granites, provided the composition of the other constituents is known. Such a calculation shows that the proportion of quartz varies from 34 to as low as 25 per cent for the granites which have been analyzed. In many of these rocks the quartz crystals have a tendency toward idiomorphic forms; also, the general arrangement of the quartz and other constituents often shows that the porphyritic structure is approached in the rock mass. It is not uncommon to find quartz crystals which will have well-formed crystallographic faces on two or more sides, as seen in thin sections. There is the least tendency in this direction in the most basic granites, those which carry the largest amount of biotite and hornblende. In the blue granite from Syenite, the quartz generally appears to have been crowded aside by the feldspars and forced to occupy the irregular spaces between them. The same is true to a great extent in the biotite granite, such as that on the hill west of Wesley chapel (Tp. 33 N., R. VI E., Sec. 17).

In many places where the structure is somewhat intermediate between the granitic and porphyritic, the rocks of which, however, have the habit of granite in color, fracture and rounded forms produced by weathering, the quartz appears in phenocrysts as well as in allotriomorphic forms. It is by no means rare to find a broad feldspar crystal enclosing two or more such grains of quartz, as though the latter formed first and the feldspar crystals formed around it. From the latter form there is an easy graduation into the granophyres and micropegmatites so common in different places, in which the quartz assumes the form of rod-like crystals, many of which in the same neighborhood have the same orientation, as though they were different parts of the same crystal. The quartz grains generally are filled with gas cavities, often in the form of negative crystals. In some of the fissures in granite, especially a small one met with in the quarrying operations at Graniteville, well-formed crystals of quartz are associated with other minerals common to such fissures. It appears that at different times the walls of the fissures have been coated with a layer of iron oxide deposited either from solution or from a vapor, probably the latter. Many of the crystals show that they have acquired considerable growth since each coating of iron oxide was formed, for within the crystals some distance beneath the surface the coatings are plainly visible. A perfectly transparent layer of quartz has been formed outside of this, continuing the growth of the crystal as though nothing had interfered with it. The surface of all crystals, and the granite walls as well, were similarly coated when the fissure was opened, showing that the last process here was the formation of an iron coating. The quartz found in the cavities is of two varieties: a perfectly clear and transparent one, and the ordinary smoky quartz—the two kinds often being side by side or in close proximity. The crystals are composed of prismatic and rhombohedral faces $\infty R(10\bar{1}0)$ and $R(10\bar{1}1)$. The large vein at the Silver mines also furnishes a large amount of quartz, some of which shows well-formed crystals, but the greater part of it is massive. Other veins also in different places produce similar material. In fact, small quartz grains are quite common through the granite.

Biotite.

This mineral is scarce in the majority of Missouri granites, but is particularly abundant in a few places. At Graniteville dark areas are occasionally met with in the granite, which are composed principally of biotite that has been segregated in a peculiar way. The areas are from a few inches to three, five or more feet in diameter, and in many cases gradually widen, the biotite becoming less and less until it entirely disappears. Specimens of biotite granite may therefore be obtained at this place, which in reality do not represent the granite of the quarries; for the biotite-bearing portions are usually of little value for dimension stone. The granites sent into the market, therefore, excepting perhaps the paving blocks, are almost entirely free from biotite. The granitic rocks along Stout creek, in the vicinity of Silver mines, as well as the Syenite and Doe Run rock, all carry a varying amount of black mica. In a few other places this mineral is also quite abundant over small areas. Perhaps the most remarkable instance is the granite just west of Wesley chapel, about four miles southwest of Fredericktown. Near the church the rock is a true biotite granite, carrying the dark mica in great abundance. But to the west and northwest the biotite gradually becomes scarce, until it finally almost entirely disappears.

The form of the biotite crystals is exceedingly varied. Sometimes small flakes of it only can be seen irregularly scattered through the rock; sometimes much larger pieces showing the cleavage lines quite well are met with.

Decay has generally progressed quite noticeably in the biotite, due largely to weathering. The first indication of alteration is a greenish appearance of the mineral. Following this is the breaking up process resulting in the formation of chlorite, epidote, and other similar products. The micas are good indexes by which to judge the degree of mechanical force that has been exerted on rocks after their formation. If there has been much motion, or pressure sufficient to produce a crushing effect, the elastic mica generally shows it as well or better than other rock constituents. It is interesting to note that the mica scales in the rocks under consideration show no sign whatever of mechanical deformation, which is good evidence that the granites have not been crushed or crumpled to any great extent or otherwise affected mechanically since their formation.

Hornblende.

This mineral is almost unknown in the Missouri granites. The blue granite at Syenite has a few small crystals, and they occur sparingly in the granite exposed on the right bank of the St. Francois river near Syenite, and also along Stout creek near the boundary line between Iron and Madison counties. But in no instance is it in great enough quantity to materially affect the character of the rock. Quite different, however, is a rock which has been quarried for paving blocks on the first hill west of the olivine diabase quarry at Skrainka. Here the hornblende occurs in the form of long slender needles, or more often in the form of little granules which have arranged themselves in rows, or it is gathered around phenocrysts of quartz (figure 2, plate xxiii). In the latter case there is no reactionary rim around the quartz similar to those described in the quartz-diabase-porphyrite. The hornblende granules have simply collected in this way, without apparently affecting the phenocrysts mentioned.

Iron-Oxide.

Iron-oxide is found in all the granites, but always in the form of minute grains. It is scattered through the rock comparatively evenly, and in such small amounts that it attracts little attention. Its actual amount is, however, several times that of the zircon or apatite.

Zircon.

Minute zircon crystals are abundant, usually embedded in feldspar crystals. The largest one measures only 0.118 mm., while many of them are not one-fourth this size. They have a habit of forming in clusters around fragments of biotite or hornblende, as though in some way they had been attracted. Thirty or more crystals have been counted in one group. The pleoçhroic zones so common around zircon crystals of other places are here also well represented. They are many times as wide as the crystal is long, and when examined without an analyzer they show beautiful changes of color as the stage of the microscope is revolved—some shade of red predominating.

Apatite.

This phosphate-bearing constituent of the granites is sparingly present in the form of long, slender needles which penetrate the feldspar and biotite, showing that the apatite was formed first. They are rarely broken, and when so the different parts are not removed from each other, indicating that the rock masses have suffered almost no movements or disturbances since the crystals were formed. In general appearance they are quite like the crystals of the same mineral already described as occurring in so much greater quantities in the diabases.

Chlorite.

This mineral is everywhere present in greater or less quantities in all granites which are much weathered. It is formed principally from the biotite and other iron-bearing minerals, although its presence is not always confined to such minerals, for the iron is sometimes leached out and carried over into the feldspars where the chlorite may be formed. The greater part of it, however, is located where the former biotite or hornblende crystals existed. The first change that occurs is the production of the green color along the border of the crystal and along cleavage and fracture lines. Next, there is usually a breaking up of material into a great many little fibers or flakes which are strongly pleochroic. Finally, when the weathering process has gone far enough the pleochroism diminishes and the whole material assumes a clouded appearance, which shows that the original crystalline structure is practically destroyed.

Muscovite.

Muscovite has not been found as an original mineral in any of the granites. It occurs as a vein mineral in places, and also as a secondary product in many of the feldspars, especially in the weathered granites. In the latter form it may be seen in small thin scales scattered irregularly through the mass. It is exceedingly brilliant when examined between crossed nicols. The feldspar crystals carrying it are always badly decomposed, and are largely filled with kaolin and other products of decay.

At least two different veins in the granite have been found which produce considerable quantities of a mica closely resembling muscovite. The principal part of the mica in the vein at Silver mines carries so much lithia that it should be called a lithia-mica, although undoubtedly some of it is muscovite. But the mica in the fissures at the Graniteville quarries seems to have no lithia, as was shown after a careful examination by Mr. J. D. Robertson in the chemical laboratory of the survey, and by repeated flame tests made subsequently. Further, its optical properties correspond closely to those of muscovite, so there is little doubt about its identity. However, it is less brilliant under the microscope when examined with crossed nicols than muscovite usually is, and also is more rigid and less elastic. It has a perfect cleavage and is transparent, indicating that decomposition has affected it but little. Many well-formed crystals occur. They vary in size from one-sixteenth of an inch to an extreme of nearly four inches. They are often so crowded together that it is difficult to distinguish between the twins and similar forms which are merely simple crystals in contact. Yet many instances of twins are found which obey the common mica law. In the larger crystals the cleavage faces show plainly that there was a period of cessation in growth during which time the surfaces were coated with other material, probably the iron oxide which coated the quartz in the same vein, so that when the second growth began a well-formed line of demarkation was left between the parts. In places this distinction is so great that the cleavage pieces break along it, while in other parts of the same crystal the material of the two growths is held together.

At a point on the St. Francois river a number of distinct veins trending northeast and southwest cut through the granite rock (Tp. 33 N., R. V E., Sec. 12). Their walls are not vertical, but generally dip toward the southeast at an angle of from 60 to 70 degrees. Some of these are filled with veinstuffs of peculiar kinds, indicating that fumerole action has been quite active here at one time. The largest vein has afforded a considerable amount of silver-bearing galena, from which the name Silver Mines was derived. The wall rocks have been altered for several feet back on each side of the veins, producing a great mass of micaceous-looking material which seems to be sericite. Along with this, and especially within the vein proper, a number of other minerals have been deposited, all of which plainly indicate the former fumerole action. Such minerals will be described separately.

Sericite.

As just stated, the feldspars in the granites composing the walls of the principal vein at Silver mines are badly altered for several feet on each side of the vein. Since the mines have been abandoned, they have filled with water to such an extent that they cannot be entered. It was therefore impossible to gain information other than that furnished by the materials still lying on the surface, and the comparatively contradictory statements of different citizens living near. It is quite probable that this corrosion reaches into the solid granite on each side for a distance of at least ten or twelve feet, and possibly farther. The surface rocks in places where mining had not been done showed the same effect, so much so that on the northeast side of the river the location of the vein was traced for a mile or more. The sericite has replaced almost all of the feldspar, so that the rock is practically composed of sericite and quartz, the former of which is in the form of fibrous masses that under the microscope break up, sometimes into long, slender, silky masses, and at other times into narrow bands, or scrap-like crystals. In cases where the metamorphic effect has been the greatest, a product results which much more closely resembles serpentine, although it is doubtful if any genuine examples of this mineral are found in this locality.

Zinnwaldite.

In the vein material already mentioned, there is a great deal of micaceous matter which appears to be zinnwaldite or lithia mica. In color it is a dark to steel gray, with a bronze brown on cleavage surfaces by reflected light. It always occurs in small crystals — the plates and cleavage ranging from one-eighth to three-eighths of an inch. The cleavage surfaces are never smooth, but always wrinkled or crushed as though the whole mass had been badly crumpled. The small size of the crystals is not due to a scarcity of the material, for frequently masses several inches across occur. An examination before the blow-pipe showed that the mica was easily fused, yielding an opaque black mass which was magnetic. During fusion the flame gave the characteristic red color due to lithia. It is therefore evident that it is a lithia mica possessing the properties of zinnwaldite.

Topaz.

Intimately associated with the sericite at Silver mines is a mineral which was finally diagnosed as topaz. In the thin sections made from the altered granites, it seems to constitute a very considerable proportion of the mass. It is of irregular shape—no crystal having been seen with perfectly formed outlines. Yet quite often it was possible to locate the direction of its crystallographic axis by means of the microscope. Its high index of refraction — as plainly shown by its apparent great thickness in the slide—its parallel extinction, and its polarization colors, strongly indicate that it is topaz. Portions of it were separated by means of a heavy solution (sp. gr. 3.12), and were examined in different ways, each result indicating the correctness of the determination above given. The amount of the mineral is very considerable, for it is found wherever the granite of the wall-rock has been altered by the fumerole action.

Fluorite.

Fluorite is very common in the vein-stuff at Silver mines, and occurs sparingly in the altered granitic wall-rock of the vein. It is intimately mixed through the vein with the quartz, zinnwaldite and wolframite. Its most common color is a rich amethyst, from which it grades into the paler shades. No instance has been observed of a perfectly-formed crystal, although it always has the crystalline structure, as is shown by its perfect cleavage. In blasting operations, such crystals as may be formed seem to have been broken, and generally the mineral constituents appear to have been formed simultaneously, so that geometric outlines could not be produced. In the little veins at Graniteville, fluorite occurs frequently, usually in well-formed cubes, which are found here and there projecting from the small spaces between the crystals of quartz and muscovite. The difference in the mode of formation is quite noticeable in this respect. At the Silver mines all of the cavities were filled, the different minerals forming simultaneously; while at Graniteville the cavities were only partially filled, so that well formed crystals could be produced.

Wolframite.

This interesting mineral occurs in the main vein at Silver mines in sufficient quantity to indicate that it might be of commercial importance. It was found very sparingly where the vein was first opened on the bank of the river, but back in the hill southwest about one-fourth of a mile, a shaft was sunk, known as the "Apex" shaft, which produced considerable quantities.

The mineral in question is dark steel gray in color, with a dark reddish-brown streak and a specific gravity of 7.3. It has not been analyzed quantitatively, but qualitatively it has furnished iron, manganese and tungstic oxide in great abundance. When boiled with aqua-regia, a heavy yellow powder of tungstic oxide soon settles in the bottom of the vessel. It sometimes occurs in masses sufficiently large to give cleavage surfaces from two to three inches long, yet it is so intermixed with the quartz that no good crystals could be found. The cleavage in one direction is perfect—the faces produced being almost as brilliant when fresh as broken cubes of galena. No indication of cleavage in other directions was observed. This corresponds very well with wolframite crystals from other places, which have a perfect cleavage parallel to the clinopinacoidal face $\infty P \grave{\infty}$ (010). The surfaces of the wolframite crystals often are coated with a yellowish powder, which also sometimes extends into the adjacent quartz, and which seems to be the tungstic oxide produced from the wolframite by weathering. Little crevices through the parent mineral usually are lined with the same yellow coating.

The occurrence of the four minerals, topaz, fluorite, zinnwaldite and wolframite, in this locality is exceedingly interesting on account of their commonly recognized association with cassiterite or tin ore, which usually is found in fissures in granitic or other acid rocks. In this instance, however, the cassiterite seems to have failed to form, as did, also, the scheelite and tourmaline which are comparatively common associates. The nature of the decomposion of the granite walls of the fissures, in connection with these interesting minerals, leaves no doubt but there was here a genuine fumerole action, during which time the heated vapors from below not only corroded the wall-rocks, but also brought up in a volatile form the different elements necessary for the production of these several minerals.

TEXTURE OF THE GRANITES.

The texture of the granites varies greatly in different localities. Six different types may be made out, but each grades into the others.

1. There is a well-crystallized variety which has no apparent approach to a porphyritic texture, but which is entirely composed of allotriomorphic crystals. Such a rock is indeed quite rare, and has never been found extending over any considerable area. Its best representative, perhaps, is in the new quarry of Melne and Gordon, near Cornwall; it is usually known as the Cornwall granite. In places the rock has the pure granitic texture, and is very coarse-grained, many crystals of both quartz and feldspar being fully one-half inch in diameter. Only a short distance away, however, large phenocrysts of feldspar make their appearance, or the stone grades into a coarse-grained porphyry. So, also, is the rock at Graniteville. In places through the quarries the ledge presents a typical granitic texture. Many of the stones used for architectural and constructional purposes in St. Louis, Kansas City and elsewhere bear witness to this, and when examined on the dressed surfaces appear to be typical granites. But this is the exception at Graniteville. Syenite is the third place where the true granitic texture is represented; and the old Doe Run quarries, north of the river, form a fourth locality. But here, as elsewhere, such a texture is not possessed by even one-half of the granite, the gradations into other forms occurring on every hand. The granites in the vicinity of the Silver mines and along Stout creek sometimes possess the granitic texture to perfection, while often within a distance of fifty feet a graduation will begin which leads away into one or another of the different modifications. The granite so abundant on the comparatively low ground to the southwest of the Knob Lick hill, along the eastern side of the St. Francois river, is another example of the same kind.

2. The second type of texture is one which belongs to a granite-porphyry in which there are large phenocrysts of feldspar embedded in a groundmass, which itself is a well-crystallized granite. This type is prevalent in all the coarser granites. At Graniteville, the seat of the most extensively operated granite quarries in the state, prominent phenocrysts are very abundant. They are characteristic constituents in a

large proportion of the stone quarried. Yet the groundmass itself is a coarse granite. Here, also, many feldspar phenocrysts may be found in the black masses of segregated biotite already described. Across the limestone valley to the south is the Pilot Knob quarry. The granite is about the same as that at Graniteville, only the feldspar phenocrysts are more abundant. Also, at the little granite knoll, one and one-half miles to the southeast of Hogan, and known locally as the Allen quarry, a similar rock occurs. The largest feldspar phenocrysts are fully two inches long, and the groundmass itself is a coarse granite. Toward the north of the area the rock gradually becomes finer, and soon passes over into porphyry.

3. The third grade of texture is similar to the second, being an extreme case of it, in which the groundmass is much finer. Numerous examples are known. In general, the so-called granites in the Black river region belong to this class, although in some instances the groundmass is comparatively coarse and the phenocrysts are not very abundant. Another illustration of this type of texture is shown in an exposure on the northwest side of a large porphyry hill four miles southeast of Ironton (Tp. 33 N., R. IV E., Sec. 11). The rock has the general appearance of a granite in the degree of coarseness, in fracture, and in the rounded forms produced by weathering. Feldspar phenocrysts from one-fourth to one-half an inch in length are so abundant that it requires a close examination of the hand specimens to recognize that the rock has a different groundmass. But under the microscope the groundmass is seen to be a medium-grained microgranite. It recalls the "nevadites" of the west, which were once mistaken for rocks with a granitic structure. Perhaps the best illustration in the whole state of this third type is the rock at the new quarry of Gabriel and Buford of Fredericktown (Tp. 32 N., R. VII E., Sec. 2). The feldspar crystals are more than an inch long, and are embedded in a groundmass about like a coarse-grained microgranite (plate xxiv). The rock weathers in the same way as a granite, producing large, rounded boulders,

some of which are ten or more feet in diameter. Its fracture is also like that of the granite, so that it can be worked as well, perhaps, as any rock in the state.

4. The fourth structure is that in which the phenocrysts of quartz are imbedded in a groundmass composed almost entirely of feldspar, or of a granophyric mixture of the two minerals. It might appear that this is essentially the same as the one last given, but the rocks differ so radically from them that they may be readily discriminated at a glance. They have a solid red terra cotta color, slightly different from the colors of any of the porphyries in the state, a moderately coarse texture, and are distinguishable from the coarse granophyres and true granites in the same neighborhood only by the quartz phenocrysts which appear in them about in the same way that they do in a good example of quartz porphyry. In other words, if the groundmass of an unusually red quartz porphyry without feldspar phenocrysts could become exceedingly coarse, so that it would be either a coarse granophyre or an ordinary granite in texture, the product would be similar to the rock in question. A large area lying to the south of Stono, and fifty square miles or more in extent, is covered by this red granite, which in many places, especially on the higher ground, has the phenocrysts of quartz so well developed, as above explained, that it is quite often difficult to determine whether it is a granite or a quartz porphyry. The summit of Buck mountain is regarded as a porphyry, but the characteristics of the rock here gradually change, until in the valley to the west an unmistakable granite is reached. Throughout this whole area similar variations may be found in different places. All of the rocks have the fracture of granite, as distinguished from that of porphyry, and also give rise to rounded boulders in weathering, which indicates that they are more closely allied to the former than to the latter type. Outside the Stono district similar features are not so well marked, yet they are known in many places.

5. Another type of structure is the granophyric and micropegmatitic. These two terms are used by petrographers with a persistency indicating that they are distinct, when in reality

they are so nearly identical and so intimately associated in nature that they should not be separated in name. The former term is applied to rocks which have a groundmass composed of an intimate growth of quartz and feldspar, so related that each mineral seems to be in the form of long, narrow bands, or relatively thin parallel plates standing on edge. Beautiful and fantastic figures are sometimes produced in this way. At times such plates radiate from a common center, forming a circular structure which corresponds to a sphere in the solid; sometimes they form great fan-shaped or dove-tailed shaped areas; at other times the rays meet each other at almost right angles, or at other angles corresponding to the position of the different parts of crystallographic twins. In these different cases the plates of each mineral over a considerable area are oriented alike, so that in reality they belong to the same crystal individual. In such a case, if the feldspar alone is considered it would appear with a great many quartz inclusions; similarly, if the quartz alone is regarded it would contain a large number of feldspar crystals within it (figure 2, plate xxi). Common usage would apply the name micropegmatitic to a texture composed of an intimate growth of quartz and feldspar in which the quartz appears to be in rods rather than in plates. Even then the particular thin section examined must be cut transversely to the rod of quartz. In this way the ends of the quartz rods will be presented instead of the sides. The quartz areas thus seen are usually triangular, as though a three-sided prism had been cut out. Often also it would seem that too large a prism began to form for the material at hand. One side would develop and hook-like additions at each end so placed that the external angle of sixty degrees would be preserved. Here, as with the granophyric forms, the different parts of each mineral have the same orientation over considerable areas (figure 2, plate xxi). The name micropegamatite is derived from the coarser rock known as pegmatite, a variety of which is called graphic granite, on account of the peculiarly shaped quartz areas when seen in transverse sections, recalling the old Assyrian characters and writings. The distribution of rocks exhibiting such structures is very wide. There is scarcely a granitic area in the state in which portions of it are not represented. The small outlying granitic areas generally have this structure throughout. The two small areas west of Hogan are good examples. So also is the little area of granite on the west hill side at the "shut-in" on Stout creek, two and one-half miles east of Ironton. The granite in the west quarry at Skrainka has such a texture throughout, and what is equally interesting, the long, slender, ray-like bands of feldspar sometimes become quite large. Other localities might be mentioned which furnish examples.

6. The last structure to be mentioned may be defined as fine-grained granular or very coarse microgranitic. A considerable portion of the rocks under discussion seem to be entirely void of phenocrysts of any kind, or at least of prominent ones, but are composed of granular aggregates of quartz and feldspar, with occasional accessories of the ferro-magnesian minerals. It is difficult to locate such rocks, for they generally change with great frequency into one or more of the different types already given. They are therefore simply facies of other types.

It will be recognized that only one of the foregoing types of structure belongs to a true granite. The others are given here, because the rocks in which they are found on the whole are more closely related to granite than to any other type. They have all the physical properties of a granite except the one feature mentioned, and this is always sufficiently coarse to admit the rock being worked in every way as the true granite. In another place this great class of intermediate rocks will be fully described—rocks which are neither granites nor porphyries, but which occupy intermediate positions between the two.

CLASSIFICATION OF THE GRANITES.

On account of the great diversity of structure and the frequent gradation of forms, it would be a difficult matter to classify the granites according to the hard-and-fast lines of classification often employed. At the very beginning the fact is met with that no discrimination is possible between the granites proper and the coarse-grained porphyries, by regarding the former as the deep-seated or plutonic rocks, and the latter as dike or intrusive rocks, as Rosenbusch and others have done. There is generally a total absence of evidence favoring such a discrimination. At Graniteville, for example, the true granites and the granite porphyries have unmistakably the same origin, for they both belong to the same rock mass. Further, they are so nearly identical that neither the workman, the salesman nor the purchaser makes any distinction between them. In such cases it certainly would be unfortunate to attempt a separation, further than the mere statement that to the critical eye the two types are presented. With but few exceptions, in those cases where the porphyritic type is well represented, similar reasons are presented for doubting the advisability of separating the rocks into the two classes. At the Pilot Knob quarry near Graniteville, the Allen quarry near Hogan, and the Gabriel and Buford quarry southeast of Fredericktown, the granite porphyry is not directly connected with other granitic masses, and may have originated in the form of bosses erupted through the porphyry. It is exceedingly doubtful about such being the origin in the first two instances named; while probably the granite porphyry at the Gabriel and Buford quarry was formed by an independent eruption. Still greater difficulty is met with when the types of fine-grained granites and granophyres are considered which graduate directly into the porphyries of undoubted effusive origin. If granite is usually a deep-seated rock, with the porphyritic modifications occupying the position of dikes, it is still more surprising to find granites among the effusive rocks. Yet such a difficulty is met with in classifying the Missouri crystalline rocks. In the following classification, origin therefore will have to be ignored.

Mineralogically the granites are very simple, so much so that no difficulty is met with in this particular. Many of them are composed almost entirely of quartz and feldspar, and the others have but little biotite and hornblende. The blue granite at Syenite is the richest in hornblende of any known, and is correspondingly the poorest in quartz; yet the latter mineral is present in such large quantities that the rock must be called a granite. From a mineralogical standpoint, there are three classes of granitic rocks: granite, biotite-granite or granitite, and hornblende granite. With reference both to texture and mineralogical composition, the following scheme has been made out, which represents the different granitic rocks perhaps as well as can be done by any classification. It should be borne in mind that they graduate into each other with reference both to texture and composition, and the fine-grained ones in turn pass gradually into the porphyries.

Granite.	Granular.	1. Granite—Quartz and orthoclase, with microline and plagioclase.
		2. Granitite or biotite granite—Same constituents as above, with addition of black mica.
		3. Hornblende granite—Same as above, with the addition of hornblende.
	Porphyritic.	4. Granite porphyry—Mineralogically same as granite; phenocrysts feldspathic.
		5. Granite porphyry—Mineralogically same as granite; phenocrysts quartzose.
	Granophyric.	6. Granophyre—Mineralogically same as granite.

GEOGRAPHIC DISTRIBUTION AND GENERAL GEOLOGIC CHARACTER OF THE GRANITES.

The principal mineralogical and petrographical characters of the granites having been given, their distribution and general field and microscopical characters may be considered. The granites at the principal quarries will be first described, and later, those in the less familiar portions of the district will be treated.

Graniteville.—This is the most widely-known quarry in the state—partly on account of the different companies now in operation there, and partly on account of its nearness to the two prominent iron-ore mines — Pilot Knob and Iron Mountain. The granite exposure forms a long, narrow belt trending almost north and south, and is approximately three-fourths of a mile long by one-fourth of a mile in width, lying in sections 10, 11, 14, township 34 N., R. III E. It is entirely surrounded by limestone, excepting at the northeast corner, where it joins a porphyry hill. How far the granite extends under the limestone cannot be stated at present. A little less than a mile to the south the porphyry hills set in. On the north side of these hills is the Pilot Knob granite quarry, at which place the granite is so nearly the same in character as that at Graniteville, that little doubt can be entertained about the two belonging to the same granitic area. Could the limestone covering between the two places be removed, the continuation of the one into the other might then become apparent.

At Graniteville the character of the products of surface-weathering is most beautifully and extensively shown. Immense rounded boulders of rock are found lying in place, to which reference has already been made. The granite at this place is usually coarsely crystalline. It is a light brownish red in color, and when the immense blocks which may be readily obtained here are dressed and erected as monuments or laid in a wall, they present as fine an appearance as perhaps any other variety. There are two additional peculiarities of the rocks which might be mentioned. One is the irregular appearance of the large feldspar phenocrysts which add beauty and variety to the rock but complexity to its description. Why the phenocrysts should be so irregular in their location seems rather enigmatical. The other peculiarity is that here and there through the granite are areas in which biotite has been segregated in the peculiar manner already mentioned. This phenomenon is very interesting, for it shows the possibility of the production of distinctly different rocks from the same molten magma. It is similar to the formation of balls of biotite, or "kugel" in the "kugel gabbros," "kugel diorit," "kugel" or "orbicular" granite, the difference being that the segregation has not been carried to quite so great an extent, and the biotite is not quite so concentrated. The granite exposed to the south, or the Pilot Knob granite, has the large feldspar phenocrysts even more abundantly than in the Graniteville granite, while the black mica areas seem to be entirely wanting.

The granite forms a steep bluff facing to the north, so that it would be an easy matter to open a quarry having a long, broad face of rock to work upon. To the south and southwest the granite joins the porphyry into which it seems to pass gradually.

Syenite.—This locality with its environs is of great interest. The granite is apparently of two distinct types, yet possibly they pass into each other. The Knob Lick hill rises to the south into a prominence of coarse porphyry. To the east and northeast, sandstone covers the entire country for miles. To the north and northwest, across the river, sandstone is also very abundant, but granite is exposed in a few places. On the north side of the Knob Lick hill the granite reaches down almost to the river. The old Allen and Smith quarry is here located, as is also that of Melne and Gordon. The granite in these quarries is called gray granite, in contradistinction to the blue granite near by. The former is composed principally of quartz, a light-red and at times almost milky feldspar and biotite. To the south and southwest of the Melne and Gordon quarry an uneven band of coarse-grained porphyry sets in, which, as far as can be seen, does not extend far in any direction. The surface is so covered with soil that it renders the locating of boundaries difficult, and at times impossible. To the south and southeast of the two quarries mentioned a zone of blue granite is found. This has been worked for paving blocks in a great many different places. The color is deepest on the northeastern border, where it passes in under the sandstone. To the west in all directions it gradually loses its characteristic color, and appears to pass by gradual transitions into a reddish or gray granite, quite similar to the granite at the quarries near the river. With such a heavy mantle of soil covering so much of the surface, it would be difficult to say whether the blue granite represents a distinct eruption, or whether it is simply an instance of local variation in the same mass. The general similarity in texture of the two rocks indicates the latter. The blue color of the rock is due partly to the biotite and hornblende. The feldspar itself is generally of a peculiarly light blue color. This, mixed with the fine scales of biotite and the few crystals of dark hornblende, produces the color which characterizes it. With the graduations in color to the west a reddish feldspar appears, and the blue feldspar becomes less prominent. This rock contains the least quartz of any granite known in the state, and at the same time the most hornblende, and consequently closely approaches a syenite. The granites have been cut by dikes of basic rocks, as already described, which add still greater interest to the geology of this locality. Across the river to the north a few quarries have been opened, some of which are producing an excellent grade of stone. At the old Allen and Smith quarry, on Doe Run, there is a considerable variation in color in the granite. Sometimes within a few inches the color changes from a dark red to a light red, or vice versa. This rock also has considerable biotite and an occasional crystal of hornblende.

Granite Bend.—Perhaps the most famous granite region in the southern part of the area is Granite Bend, in township 27 north, range 4 east. Two little hills of granite a short distance apart have furnished an immense amount of material for paving blocks, which is almost the only product of the quarries. The rock varies in color somewhat, but is always some shade of red, due to the red feldspar. Under the microscope it is seen that the only constituents present in any considerable amount are quartz and feldspar. They grow together in such a way that granophyric structures are produced. No rock is known in the whole Archæan area which has this texture better developed.

Bismarck.—Granite occurs in a number of different places in the vicinity of Bismarck, the largest area being about four miles to the northeast. Here is a granite knoll nearly a mile long, but less than half a mile wide. Near the northern point (Tp. 36 N., R. IV E., Sec. 20) a heavy blast was put in at the quarry operated by Allen and Vetch. The ground was nearly level, but by sinking a shaft sixty feet deep and driving side tunnels, the explosion of a heavy charge of powder threw immense blocks to the surface, some of which were thirty feet or more long. The granite is moderately fine-grained, of an even texture throughout, and red in color with occasional black spots, due to the presence of biotite, which is irregularly scattered through the rock. In general appearance it is similar to the great mass of granite so abundant to the south of Stono. Under the microscope it is seen to have a combination of the granitic and granophyric textures. At the southwestern extremity of the granite area another small quarry has been opened for getting out paving blocks. Here the rock is a little coarser and has more black mica, which is quite unevenly distributed, giving the rock a decidedly spotted appearance. The texture is also a mixture of the granitic and granophyric. A short distance south of this point, section 31, a similar but smaller granite exposure is found. It contains a small amount of biotite evenly distributed, but in no particular differs essentially from the granite just described. To the southeast is the large area which reaches from Stono to Fredericktown. It is not apparently continuous over all this distance, but probably would be were the mantle of sandstone and limestone removed.

Stono.—Beginning a short distance north and east of Stono is a very large area of granite. The rock is red in color and of even texture, excepting that many phenocrysts of quartz are present. These features continue to the south to Brewer creek, to the southeast beyond Buck mountain, and to the southwest as far as the granite extends. The uniformity in color and texture over so large an area is remarkable. In places the phenocrysts of quartz disappear, in which case the grain of the rock usually becomes a little coarser. On the higher points and hills the quartz phenocrysts are more numerous, and in this way the rock passes over into a quartz porphyry with a coarse groundmass. Under the microscope, the structure of the rock usually presents a mingling of the granular and the granophyric or micropegmatitic. Mineralogically, there are present only quartz and feldspar, with occasionally a very little biotite. No quarrying has been done in this district.

The surface indications are that almost every quarter-section of the area contains rock that could be worked into paving blocks, and quite likely dimension stone.

Brewer Creek.—Continuing south from the Stono area the granite reaches and crosses Brewer creek. In many places large, rounded boulders of granite may be seen along the hill-side, as at Graniteville. They differ only in size. The rock in general is more crystalline than in the district previously mentioned, and the granophyric texture is less frequent. The mineralogical composition, however, is not much changed. The western boundary of the granite is bordered by porphyry, excepting, perhaps, in a few places where a sandstone covering conceals the rocks from view.

Stout Creek and Silver Mines.—Still further to the south the same granite area passes across Stout creek and to the southeast across the St. Francois river, near the Silver Mines. The broad expanse of level country in this district is principally covered by sandstone, but here and there it is worn away, leaving the granite exposed. In this way the areal outlines of granite are made more irregular than they otherwise would be. With the change of location there has been a corresponding change in the character of the granite. South from Brewer creek the texture of the rock becomes still coarser and the biotite becomes more common. The granite along Stout creek, near the line between Iron and Madison counties, is as well crystallized as any in the state. Biotite in small amounts is everywhere present, both along the creek and down the St. Francois river, to the southern extremity of the area below the Silver Mines. Hornblende is occasionally found in scattering crystals, as in the Doe Run granite near Syenite. The feldspar throughout the area is not so red as further north, and the color of the rock is correspondingly changed to more of a gray, produced by the commingling of the light feldspar with the dark grains of mica. A small amount of quarrying has been done at different points along the north bank of Stout creek, but on account of the distance from transportation the stone interests have not developed much. Here, also, are a number of instances of the granite extending up the hill and meeting the porphyry in a similar manner as that described to the north. Also, there are many large granite boulders lying along the hillside and some places on the level ground.

South Syenite.—The comparatively level ground to the south of Knob Lick is covered for miles with a rock which may be called granite, although portions of it are quite as much like porphyry. No location is known furnishing better instances of the gradual transition back and forth from the granitic to the porphyritic characters. Further, transitions are often on level ground, whereas those already mentioned are generally on hillsides. The summit of Knob Lick hill is composed of a coarse porphyry, but sufficiently granitic in character to admit of its being worked into paving blocks. Immediately south on the level and low ground the rock is but little better crystallized in places, but in other situations it becomes an average granite. No definite limits can be assigned to such areas, for the transitional forms often are half a mile or even more in extent. To the southwest, toward the St. Francois river, a few well-defined hills are met with which are composed of typical porphyry. The mineralogical composition of the granite in this area is in no respect different from that already described. It seems always that the largest amount of black mica is to be found in the crystallized varieties. Thus, in the environs of the Abbot quarry, one and one-half miles southwest of Knob Lick hill, the granite is well crystallized, and also carries a considerable amount of biotite; while to the east the biotite becomes less abundant, and the well-crystallized granite grades into the semi-granite above mentioned.

Mine la Motte.—To the southeast of the Syenite area above described lies the Fredericktown and Mine la Motte district. Instead of a solid mass of granite covering a township or more in extent, there are small areas, sometimes among the limestone and sandstone, and at other times forming portions of the porphyry hills. It would be difficult to mention each of these in detail. Within the limits of Fredericktown different granite areas are exposed at the surface, or have been reached in well-digging. On the south bank of the little brook between the town and the depot, a granite knoll of only a few rods in width exists. South of town a short distance, at the Cahoon place, granite was struck in digging a cellar. North of the depot another little outcrop is exposed, while in various other places small areas of granite rise above the surrounding limestone, showing plainly that could the limestone beds be explored to shallow depths, a large extent of crystallines would be found. The granite in the areas around Fredericktown and Mine la Motte seems to be very similar. It differs considerably from that to the northwest, and also from that in the small areas which join the porphyry hills. In texture it is well crystallized, but not so coarsely as the granite in the quarries at Syenite and other places, nor does it have the granophyric texture to any considerable extent. Mineralogically, its most notable feature is a large amount of plagioclase, probably albite. No chemical examination has been made of it, but from its mineral contents it may be inferred that it is very rich in soda. Biotite is also moderately abundant, but no more so than is often noticed elsewhere.

The granite in the areas intimately connected with the porphyry differs from that just described in having less biotite and plagioclase, and in almost universally having the granophyric and micropegmatitic structures well developed. This is particularly true of the first area west of Fredericktown. The eastern hillside is apparently a fairly well-formed granite. The rock has the granitic fracture, and weathers into rounded boulders as the granite always does. But under the microscope the granophyric structure is disclosed. The same is true of the two small areas to the south, across the Little St. Francois river. To the southeast, at the extreme border of the low lands called Cedar bottom, there are two or three interesting granite areas. One is especially so on account of its topographic features. A comparatively small but very steep hill (Tp. 33 N., R. VI E., Sec. 31) rises to a height of about 300 feet above the valley. It is composed of a granite almost exactly like that in the Stono area. In places the quartz phenocrysts are well and beautifully developed. The color is the characteristic red, and the groundmass is almost solid feldspar. The small area on the northwest part of Matthews mountain, in section 34 of the same township, and that on the extreme eastern part of Tin mountain, in section 29, are worthy of special study, for they show well the graduation of granite into porphyry. There are the well-crystallized granite, the intermediate varieties, and the porphyry, all within easy access, and all exposed to view on the hillside. In the extreme north of the area there are also a few interesting points. A hill similar to the one just given near Cedar bottom occurs in the north part of the township in section 5. It stands out alone, and is composed of granite of the Stono variety. Also, north of Mine la Motte a mile or more is another occurrence. The little stream called Rock creek passes over sandstone throughout most of its course. At one point it has cut a deep valley between the two opposing sandstone hills, and has reached the granite. For half a mile more along the creek the beds of granite are exposed. At one place the brook has worn in under the sandstone hill, leaving a hanging wall which projects forty feet or more out over a granitic floor.

Castor Creek.— East of Fredericktown a few miles, considerable granite is exposed. The area is not one of solid surface, but rather one in which several rock outcrops exist. The granite of these exposures is practically the same and resembles the Stono granite to a remarkable degree. Its texture varies slightly, both quartz and feldspar phenocrysts occasionally occurring. Under the microscope it is seen to be composed of a mixture of the granular, with unusually fine examples of the granophyric texture. Some of the feldspar phenocrysts have enlargement borders of a granophyric nature. The most picturesque occurrence of granite boulders outside of Graniteville occurs along the brow of the largest hill in the area. They may be seen all around the elevation, but are most numerous and largest on the north side. They are also very prominent along the eastern side of the first little granite hill west of this. No better place could be desired for opening a quarry, as regards the character of the rock and the broad, high face along the bluff, than is afforded by both of these hills. The immense size of the boulders shows that the granite does not have too many seams to make it unsuitable for dimension stone. Quarrymen should bear this in mind, for when the rock is full of seams the boulders produced by weathering are small, but when the boulders are large, positive evidence is at hand that the seams are comparatively scarce throughout the rock, as is well shown by the large boulders at Graniteville and the small ones in so many places where good paving blocks are taken out, but where the dimension-stone industry has proved a failure on account of the numerous seams throughout the rock.

To the southwest of this place a few miles, in the neighborhood of Cornwall, two other interesting exposures of granite occur (Tp. 33 N., R. VII, Sec. 26). It has already been alluded to as the Cornwall granite. A little hill scarcely 200 feet high, one-fourth by one-half mile in area, not only furnishes all this granite but a considerable amount of porphyry as well. Here also are fine examples of transition from granite into porphyry. The east end of the hill is granite, and the rock at the eastern part is the coarsest of any known in the state. In passing to the west the texture becomes finer, and by the time the middle of the hill is reached it has changed into a tolerably coarse-grained porphyry. About two miles south of this (Tp. 32 N., R. VII, Sec. 2) is the Gabriel and Buford quarry, from which the specimen represented in plate xxiv was taken. A porphyry hill composed of a dark porphyry, with occasional phenocrysts of both quartz and feldspar, is found here. Cutting through the hill in an east and west direction is the mass of granite, which is about two hundred yards wide. The eastern extremity of the hill is so covered with soil that its condition could not be determined. There is no doubt, however, but that the granite was erupted through the porphyry. In support of this view is the well-defined contact line of the light-red granite with the dark porphyry, which can be seen in a few places. A mass of the dark porphyry was also found included in the granite. This was in the middle of a large boulder which had been split open by a blast when the rock was being prospected. Such an occurrence is all the more interesting on account of the many places known in which it is thought the granite and the porphyry belong to the same eruption. A description of this granite porphyry has already been given. Following down Castor creek other granite areas are occasionally met with, none of which need be especially mentioned. So also on the lower St. Francois river occasional granite hills occur, which some day may become the seat of quarrying industries.

Black River.—On the East fork of Black river a few exposures of granite occur that should be especially noted. The largest one forms the left bank of the stream at the falls. From this point the granite extends south, east and north, and covers in the aggregate nearly two square miles. Over this large area there is considerable variety in the character of the rock presented, yet it retains a remarkable similarity throughout. It has the ordinary red color, is moderately fine-grained, and carries feldspar phenocrysts, which are larger and more numerous toward the south. The bluff at the falls furnishes the best exposures. Here the almost vertical walls are nearly 100 feet high. There are many more seams, both vertical and horizontal, than are generally found in granite (see plate vi). Mineralogically the rock is composed of quartz, orthoclase, plagioclase and biotite. The groundmass is coarsely crystalline and generally granitic, although often the granophyric structure is approached. The phenocrysts are partly orthoclase and partly a triclinic feldspar, with a few porphyritic quartz crystals. Regarding the origin of this granite there is some uncertainty. It is quite possible that it is genetically the same as the porphyry to the east. There is little, if any, evidence indicating the same origin for the porphyry hill to the west; but, on the contrary, there are good reasons for believing that the western hill is entirely independent of the granite.

The porphyry extends from it across the stream and a short distance up the bank. This, it will be remembered, is the location of the overflow dike material already mentioned. In places it appears that a vein of the dike-rock lies between the granite and the porphyry, as though it had been forced up between the two masses. To the south the highest point of the hill is granite. To the northeast the surface is covered with soil, so that nothing could be determined regarding it.

The next largest area of granite is on the hill called High Top, some two miles to the north. As the name implies, it is a prominent topographic feature. It joins a row of lower porphyry hills to the north, itself forming the southern extremity of the series, so that it stands out boldly upon the landscape. The whole of the hill is granite. To the north it may be continuous with the porphyry hill, or it may not; the soil covering prevents observations. The rock is similar to the granite at the "falls," but is a little grayer in color. The phenocrysts of feldspar are uniformly present, but they are neither so large nor so conspicuous on account of their color as those in the other granites. The microscope shows that the groundmass is almost entirely granular, and is composed of quartz and orthoclase, with traces of plagioclase and a sprinkling of biotite in small scales. To the west of High Top, a distance of perhaps a mile, another small granite area forms the northern extremity of a long porphyry hill, though on the east it is bounded by a covering of chert. Here the granite area undoubtedly graduates into the porphyry to the south. In color, composition and texture it is about the same as the granite on High Top, differing only in having the granophyric structure more prominently developed. In the extreme southeast part of the same township (section 36), there is a large circular hill called Round mountain, which is peculiar in the character of the rocks composing it. The southern part is covered by chert more than half way to the summit. As the chert covering disappears, a coarse porphyry or granite porphyry is met with. This extends to the summit and down the north side more than half way to the base, where porphyry is found. The granite porphyry differs slightly from those just described in being more of a blue-gray color, and in carrying a larger porportion of phenocrysts of feldspar of both the orthoclase and plagioclase varieties; considerable black mica is also present. Weathering has produced considerable epidote—some of the feldspar crystals, for example, being entirely filled with numerous little crystals of this mineral. The groundmass is exceedingly fine-grained for so coarse a rock. The numerous and large feldspar phenocrysts so predominate that they control the general appearance, the fracture and the form of the boulders produced by weathering, making the rock in all of these particulars resemble granite. The granite areas in the western territory differ so radically from the granite in other places as regards their topographic features that they at once become of great interest in this respect. In one instance, already mentioned, the granite is probably independent of the adjacent porphyry hills to the west. It is quite probable that three of the areas, High Top, the Falls and the Round mountain granites, represent independent eruptions which took place after the surrounding masses were formed.

PORPHYRIES.

CHEMICAL COMPOSITION.

In chemical composition there is a variation from a very acid quartz-porphyry to the more basic porphyrites. Few complete analyses have yet been made, but a large number of partial ones have been obtained. The following table gives the results of ten such determinations. Three additional analyses are given, showing the composition of similar rocks from Europe.

TABLE OF CHEMICAL ANALYSES OF MISSOURI PORPHYRIES.

Locality.	Loss at 100°C.	Loss on ignition.	SiO_2	Al_2O_3	Fe_2O_3	FeO	NiO	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	TiO_2	Totals.	Analyst.
Ironton, 6 m. E.	0.22	0.54	72.35	13.78	1.87	0.36	0.20	0.06	0.87	0.42	4.49	4.14	0.13	0.44	99.87	Melville
Ironton, 6 m. E.	0.12	0.30	71.33	12.55	3.75	0.85	0.15	0.04	0.94	0.58	4.20	4.52	0.16	0.55	100.04	Melville
Ironton, 6 m. E.	0.17	0.26	71.88	12.88	3.05	1.05	0.02	tr.	1.13	0.33	4.46	4.21	0.15	0.22	99.81	Melville
French Mills		0.18	69.54	14.77	6.58	0.46			1.34	0.29	4.24	3.03	0.12		100.55	St. L. T. & S. W.
Piedmont		0.26	68.61	14.84	1.48	5.40			1.65	0.63	2.28	3.70	0.23		99.08	St. L. T. & S. W.
Silver Mine, 2 m. W.			74.12	13.82					1.41		3.80	5.25				St. L. T. & S. W.
Middlebrook, 5 m. E.			77.88	12.28												St. L. T. & S. W.
Arcadia			70.15													McClurg
Hogan, 2 m. E.			61.50													Melville
Hogan, 2 m. E.			59.72													Melville
Brithdir		1.10	72.57	13.64	2.28				1.00	0.64	6.17	2.07			99.47	Teall
Dabritz		1.97	76.92	12.89	1.15				0.68	0.98	4.27	0.68			99.54	Kalkamsky
Ilfeld.		3.45	61.97	16.27	7.42			0.07	1.38	2.71	4.04	2.55			99.93	Kalkamsky

The analyses indicate a series varying from very decidedly acid to comparatively basic varieties. The most interesting feature, perhaps, is the presence of a large amount of the alkalies—especially soda. The six analyses show that the combined alkalies vary between six and a little over nine per cent, with all but one of them higher than 7.25 per cent, and a little over eight per cent for the average of the six analyses.

By comparing this with the table of analyses of the granites already given, it will be seen that there is a close similarity. The porphyries appear to be a little more basic than the granites, and also to carry a little higher percentage of the combined alkalies. Were judgment passed upon the analyses alone, a few of these samples might be called keratophyres, especially the one from the Silver mines which has such a large relative amount of soda. It is exceedingly doubtful, however, if there is a single typical keratophyre to be found in the whole list of rocks studied, for in their general properties the soda varieties are by no means sufficiently distinct to warrant the establishment of such a class. Both macroscopically and microscopically the Piedmont rock much more resembles the keratophyres than does the Silver Mine mass. Further, it is so characteristically distinct from the great mass of the porphyries that some distinction seems advisable, but it carries too small a percentage of combined alkalies to render the use of the name keratophyre proper.

Another interesting feature of the chemical properties of some of the porphyries is the relatively large amount of iron contained. It will be seen that two of them have an aggregate of about seven per cent of the two oxides, which is very unusual for porphyries which do not carry the ferro-magnesian silicates. In the one from Piedmont there is a total absence of these, while the one from Silver mines carries a considerable amount of epidote; yet, strangely, nearly all the iron is in the ferrous state — a fact which is difficult to account for by its mineralogical components as shown by the microscope. Further chemical examination possibly would show that the epidote so abundant, relatively is a ferrous rather than the ordinary ferric variety similar to the one reported by Lacroix,* although this epidote is as stongly colored as the ordinary variety.

It is also of more than passing interest to note that nickel is reported in each analysis made by Melville. As the location of the samples is hardly more than a dozen miles from the Mine la Motte lead mines, at which nickel ores have been found in considerably quantity, it lends color to the idea that possibly the latter deposits were furnished their nickel by the decomposition of the contiguous crystalline rocks. As the other analysts did not examine for nickel, their results by no means show its absence from the other rocks. Similar remarks might be made regarding the presence of manganese, a metal comparatively widely disseminated through all the rocks in the southeastern part of the state.

MINERALOGICAL CONSTITUENTS.

The great similarity between the mineralogic composition of the porphyries and the granites cannot be too strongly emphasized. Scarcely a mineral is found in one that is not also present in the other. Further, those which are most abundant in the one also predominate in the other. It is therefore unnecessary to give a description of the different minerals in such great detail as was done with the granites.

Feldspar.

The feldspars vary much more widely in their properties in the porphyries than in the granites. Orthoclase, microcline and the plagioclase varieties are represented—of the latter those so basic as labradorite. They occur as phenocrysts and in the groundmass. They are present in well-formed crystals, and in those which have been badly corroded by the resorption action of the magma.

Orthoclase is the principal feldspar in the great mass of the red varieties, especially in the quartz porphyries. As this variety is more abundant, perhaps, than all others combined, it will be seen that orthoclase has a wide distribution (figure 1,

*Bull. Soc. Min. de France, p. 150, 1887.

plate xxv). The crystals are badly corroded. The same kind of corrosion is also shown in many other examples.

Microcline is by no means of rare occurrence in the porphyries. The characteristic twinning lines are very prominent. The crystals often contain certain decomposition products. In some places, particularly in the vicinity of Annapolis, the porphyries contain many large microcline phenocrysts, some of which are at least one-third of an inch in diameter. These are associated with porphyritic crystals of quartz and plagioclase. Frequently they are well formed and have sharp crystallographic outlines.

Plagioclase is comparatively common in many of the porphyries. It is particularly abundant in the more basic varieties, and especially in the green porphyries in the vicinity of Des Arc and Piedmont. In a rock which is exposed in a hill west of Middlebrook (No. 15291), plagioclase occurs very abundantly in the form of prominent phenocrysts from one-sixteenth to one-eighth of an inch in diameter. A specific gravity determination, made by means of the Thoulet solution, gave a result of 2.665, which shows that it probably is andesine. No quartz phenocrysts are associated with it. The rock toward the west gradually changes in character, and the feldspars lose their peculiar, fresh, waxy lustre and become red in color. Quartz phenocrysts also appear and the mass assumes the general aspects of the ordinary quartz orthoclase porphyry. In one example long, slender plagioclase crystals occur in a fine-grained rock, in the groundmass of which are many feldspar microliths, a facies of groundmass and of phenocrysts as well, which is not very common, although occurring here and there over the whole Taum Sauk district. It shows the flowage structure well. No quartz is present, excepting in the groundmass. Certain of the plagioclase crystals are often broken and show a partial redissolving by the magma (figure 14). The rock in which they occur is the light gray variety, occurring one mile west of Shepherd mountain. It carries so many large feldspar phenocrysts that macroscopically it appears to be quite coarse-grained, but under the microscope it is seen to be almost vitrophyric, spherules being numerous between the phenocrysts. This case is remarkable as being the only instance observed in which there are broken crystals

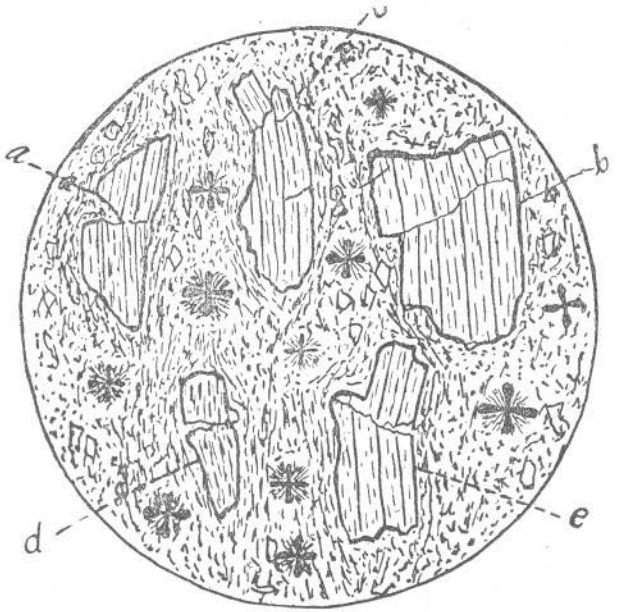


Figure 14. Bent and Broken Feldspar Crystals; groundmass is spherulitic and shows the flow structure. X 44.

due to movement in the magma. Such breaks are produced by motion in the magma after it has become very viscous, so that one part of the crystal may be held with relative firmness while the other part may be moved. Such results are most generally frequent near the surface, where surface cooling is rapid, and consequently an approach to solidification is obtained before equilibrium is established in the magma in its new position. The plagioclase phenocrysts which are so abundant in the green porphyries to the south, are more basic than the plagioclase crystals usually found in rocks having quartz in the groundmass. A specific gravity determination by means of the Thoulet solution, of one of these feldspars from a specimen taken at the Piedmont quarry, gave 2.716, which corresponds to labradorite or bytownite. The optical properties of many others show that they are comparatively basic, but it is probable the most of them are about as heavy as andesine. Considerable chemical work yet remains to be done upon them. The crystals are often badly corroded, as though the lava in which they were formed had partially redissolved them after they were formed. Many of them are also considerably decomposed and partially filled with epidote.

Quartz.

Quartz occurs in all the porphyries, either as phenocrysts or in the groundmass, and usually in both ways. In the former case it presents a great variety of forms—sometimes appearing in crystals bounded by well-preserved outlines, sometimes with borders rounded and corroded, as is so common in quartz porphyries (figure 15, also figure 2, plate XXV), or with the

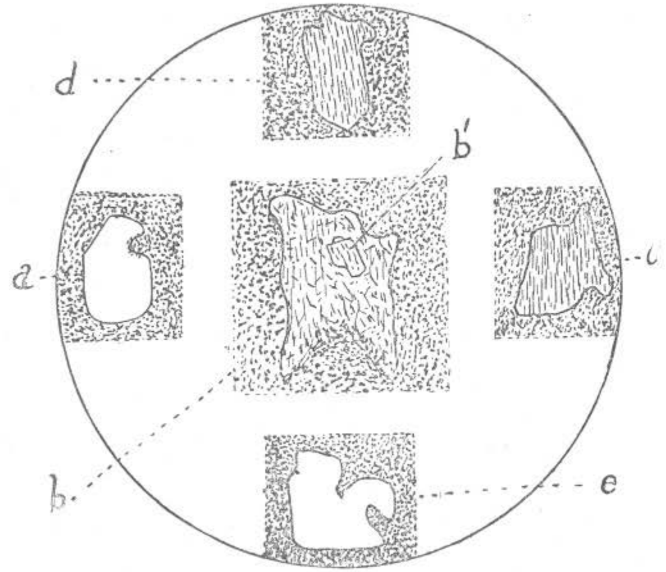


FIGURE 15. Microscopic Appearance of the quartz and feldspar crystals, and of an included fragment of a breccia, which have been subjected to magmatic corrosion. X 44. *a.* Quartz. *b.* Fragment containing a corroded feldspar crystal, b1. *c.* Orthoclase crystal from quartz porphyry. *d.* Orthoclase from a breccia. *e.* Quartz from quartz-porphyry.

edges irregular—so rendered by the encroachment of the feldspar crystals in the groundmass. In cases of the latter the quartz material, for some distance outward, usually is oriented with the central grain. The quartz enlargements are interesting and remarkable—fully as much so as those of feldspar enlargements already described. A number are shown on plate xxii, in which figure 2 represents a rhomboidal section of quartz with unusually well-preserved outlines. Around it on every side the quartz in the groundmass has the same orientation, so that when viewed between crossed nicols, if the central crystal is light the quartz in the groundmass is also light, and when the central crystal is dark the other is likewise dark. If the quartz or gypsum-plate be inserted between the thin section and the analyzer, the whole area will become colored the same tint. Figure 1 of plate xxiii represents another crystal with a very badly corroded border. Figure 1, plate xxii, represents the same phenomenon. The central crystal has well-defined boundaries on two sides; although granules of the groundmass have encroached somewhat upon it. Fully one-fourth of the thin sections examined which carry quartz phenocrysts, show similar phenomena to greater or less extent.

Quartz crystals with clouded borders within, have been observed in a few instances, especially in rocks in which the flowage structure is well developed. When examined under the microscope with a relatively low power, the border of the quartz-grain appears to be similar to pen and ink stippling. When a higher magnifying power is used, this appearance is found to be due principally to minute cavities within the crystal, similar, in appearance, to the gas cavities so common in granitic quartz. Quite fantastic forms are sometimes produced —the inner margin of the border being scalloped with a great variety of forms. It is possible that such effects are in some way produced by the corrosive action of the surrounding magma. Gas bubbles or fluid inclusions are almost as common in the quartz of the porphyries as in that of the granites. They do not differ in any essential respect from those which have already been described. The quartz in the groundmass is in granular form, or produces granophyric and sphærulic effects by its intergrowth with the feldspars.

Iron Oxide.

This mineral is one of the most common found in the porphyries. Not a single specimen has yet been examined which does not contain considerable amounts of it. Generally it is found in the form of little grains which seem to be jet black and entirely opaque. The higher powers of the microscope often reveal regular crystallographic faces on the grains, all of which seem to indicate that magnetite is the variety most abundant. In many instances the iron oxide assumes quite different forms, the most common of which is long and rod-like in outline. This is especially noticeable in the spherulitic porphyries, in which case the rods are generally arranged parallel with the rays of quartz and feldspar-producing spherules. The microscope shows that such forms are not solid, but simply aggregates or rows of minute grains. In a few cases the larger grains of iron oxide seem to have had the power of collecting about them in a circular form multitudes of exceedingly small grains, which are so arranged that they form dark-colored rings around the central crystal (figure 1, plate xxvi). Immediately adjacent to the crystal there is a zone which is comparatively free from the smaller grains, but outside of this there is a dark border entirely encircling the central crystal. Such phenomena seem common in the porphyry from Gray mountain (No. 15682), but was noticed in only a few others, and in none so well developed. In some cases the outer circle only is visible, but this may be due to the particular place at which the spheroidal body was cut in making the thin section.

Iron oxide is so abundant that it is common to find great quantities of it along the roadside and in the fields concentrated by the surface waters during the rains. Being so much heavier than the associated clays of decomposition, the rain-water washes the latter away, leaving the former behind. Such masses of "black sand" are so frequent and so large that with a little care it may be gathered in many localities by the bushel. There can be no doubt but that it is simply the grains of iron oxide from the porphyry set free by decomposition. The magnet shows that a considerable amount of it is magnetic, but by no means all of it. It is quite possible, of course, that portions of it may have been changed from magnetite to hematite, or even to limonite, during the period of decompostion or subsequently by oxidation and hydration. Some of the iron oxide undoubtedly is titaniferous, as is shown by the occasional presence of leucoxene which has resulted from the partial decomposition of the iron oxide.

Fluorite.

This mineral is found filling cavities in many of the porphyries. The southern side of Shepherd mountain furnishes good examples. So also does the porphyry from the Taum Sauk region, in the vicinity where the lithophysæ are the most abundant. It is always in irregularly outlined grains, which have the customary cleavage well developed. It appears to have been formed after the openings in the porphyry were made. In a few cases only have crystallographic faces been observed, and then where only a portion of the cavity was not filled by the mineral. The amethystine color prevails in all the fluorites observed.

Epidote.

Epidote is a very abundant mineral in many of the porphyries. This is particularly true in the green porphyrites so abundant in the vicinity of Piedmont. The general arrangement of the epidote in these porphyrites is very peculiar. It is essentially a constituent of the groundmass, although in many instances it pervades the feldspar phenocrysts to so great an extent that they too have a decidedly green color. Not a single example of well-formed epidote crystals has been found, excepting a few very small slender crystals which are occasionally noted projecting from the borders of a larger mass. It is simply scattered through the groundmass in large and small irregular aggregations, composed of irregular grains which have no common orientation, and which are separated from one another. In this way it gives that peculiar dark green color to the body of the rock in which it occurs. The epidote, however, is not entirely confined to the green porphyries, but is found to a less degree in many of the others. Naturally it is found most abundant in the more basic varieties, provided they are sufficiently altered to permit of its having been formed. Thus, a red porphyry from Iron mountain has many minute grains of epidote scattered through the groundmass. The peculiar and excessive presence of this mineral in certain porphyrites, without its corresponding presence in others in the some locality and of similar composition, is interesting, but at the same time it is quite puzzling. A comparison of the chemical composition of the French mills and Piedmont rocks shown elsewhere indicates that they are remarkably similar in every respect, excepting that the former has nearly all of its iron in the form of ferric oxide, while the latter has its iron principally in the form of a ferrous oxide. The first is a red porphyry filled with gas cavities, and with the flowage structure well marked. It also has many black iron oxide grains, but very little epidote. The second has almost no grains of iron oxide, but is so rich in epidote that the whole rock has a green color. It is probable that the epidote is all secondary, but there is almost no evidence indicating from what minerals it originated.

Another remarkable feature is the almost total absence of chlorite and other secondary products so commonly associated with epidote, which has resulted from the alteration of the iron silicates. It is safe to say that there is not a hundredth part as much chlorite in the green porphyrites as there is in the biotite granites already described. The rocks themselves seem to be perfectly fresh and sound, as the extensive use of paving blocks from the Piedmont quarries bears witness. Further, the rocks obtained the farthest from the surface in the quarry are in no respect different from those close by, so that weathering has manifestly not produced all of the change. Yet regional metamorphism can hardly be called in, for the hills of green porphyrites are so intimately associated with hills of the ordinary red varieties, that it can scarcely be believed that the one could be so greatly affected by great dynamic forces, without the other being also affected in the same way. The hills containing the quarries at Piedmont are almost in contact with Clark mountain and another smaller one to the south and east, and with Finley mountain on the west. Yet each of these has the red porphyry, with little if any epidote. So it is, also, with each of the others—a hill of red porphyry is invariably close by the rocks which show no material alteration. Again, the green porphyrites themselves present no indications, outside of the epidote, of having been changed. There is no evidence of crushing, no cataclase structure in the groundmass, no indications of pressure which would ordinarily manifest itself in producing lamination. The only explanation which can be advanced for this phenomenon is to suppose that, for some reason, during the pre-natal period the iron in the magma—which, it must be remembered, is practically the same as in the other porphyries—was combined in such a form that the molecule was unstable under the conditions to which it was brought by the eruption and solidification, and that therefore a molecular rearrangement was set up, which resulted in the production of the epidote without the association of the common decomposition products, as chlorite. This would necessitate assuming the independent eruption of these hills, although they may have been remotely associated with the red porphyries. It is admitted that this conclusion amounts to nothing when tested by the rule of positive evidence, but is entirely dependent upon negative evidence.

Piedmontite.

In the examination of certain porphyries obtained from near Annapolis, a peculiar red constituent was observed which was thought to be Piedmontite, and this opinion was expressed as early as 1888*. Subsequent study of the rocks around Annapolis and the adjacent districts failed to reveal this mineral in quantities so large as was then hoped, although it occurs in a number of different places. The largest amounts are found at a small paving-block quarry almost immediately south of the

*American Geologist, Vol. I, p. 365. Minneapolis, 1888.

Annapolis depot. Here at various points throughout the rock small masses of radiating crystals occur, some of the groups being fully one-fourth of an inch across. They are dark reddish-brown in color, with a light red streak. Their hardness is fully equal to that of epidote. All attempts to isolate individual crystals failed, but granules were obtained, and thin sections were also made. Blowpipe tests were made with the borax bead, and also a bead made of a mixture of sodium carbonate and potassium nitrate, each of which gave a strong and positive reaction for manganese. Iron was also found to be present in considerable quantities. The reaction showed conclusively that the mineral has a much greater percentage of manganese than withamite, which according to the analyses of Heddle* has only 0.138 per cent of MnO. When examined under the microscope it was found to be strongly pleochroic, giving three different colors—a very rich wine-red when the plane of the light vibrations was parallel to the length of the ray-like crystals, a yellowish red in some instances when the vibration was transverse to them, and a greenish yellow in other instances; which is $\mathfrak{a}$ greenish yellow, $\mathfrak{b}$ rich wine-red, $\mathfrak{c}$ yellowish red. The fan-like mass of radiating crystals seems to present quite a diversity of orientation, for frequently the colors are not the same throughout a single ray. Numerous instances were observed in which a particular ray presented the richest wine-red color in one portion and the yellowish red in another, indicating that the optical orientation was not uniform throughout the whole length of the crystal. It is interesting to know that Missouri can now definitely claim to be one of the few places known where this rare manganese epidote occurs.

TEXTURE OF THE PORPHYRIES.

Few subjects have been discussed more by petrographers than that of the texture of the groundmass in porphyries, and perhaps few have been less fruitful in positive final results. The fundamental idea of porphyritic texture is, as already given, that the rock mass should consist essentially of pheno-

*Mineralogical Magazine, Vol. V, p. 15.

crysts of one or more minerals in a more or less fine-grained groundmass composed of the same or of different minerals. The various discussions on the subject have been brought forward by an attempt to determine definitely the exact condition of the groundmass. When the microscope reveals the texture practically the same in kind as that found in granite, but with the individual crystals so small that ordinary vision must be aided in order to detect them, the term micrograniti is usually applied. If the microscope discloses the peculiar arrangement of quartz and feldspar seen in graphic granite, the term micropegmatitic, or granophyric, is used. Again, if the quartz and feldspar crystals have arranged themselves radially around a common center, so that in thin sections their form resembles a circle, the texture is said to be spherulitic. But when the microscope fails to differentiate any definite forms possessed by the mineral crystals, and yet their existence is shown by their action upon polarized light, it is not so easy to find the proper term to express the conditions, because the exact character of such a mass cannot be determined. The term microfelsitic was proposed by Zirkel to cover textures of this kind, and is now widely used in the literature of petrography. More recently* there have arisen some objections to its use, inasmuch as it covers up facts which should be brought to light. At best it can only be used in a general way to avoid for any reason the use of more exact terms, in a manner somewhat similar to the way in which the name plagioclase is used in mineralogy. The term felsophyric, perhaps, is a little less objectionable, and may be applied to the finer-grained groundmass in these porphyries; all of which, it should be stated, are a little more coarsely crystalline than the porphyries with the typical microfelsitic groundmass of Rosenbusch.

The Missouri porphyries furnish many excellent examples of the micrograniti, granophyric, micropegmatitic and spherulitic textures. No particular portion of the region can lay exclusive claim to either of them, for each may be found widely

*Iddings: Bull. Philos. Soc. Washington, Vol. XI, pp. 445-464; also Cross: Ibid., pp. 411-444.

distributed. The first two are most common in the rocks intermediate in texture between the granites and the fine-grained porphyries, and have already been mentioned under the granites. From these coarse, intermediate varieties such textures may be traced into nearly all of the porphyries.

Spherulitic Texture.—The spherulitic forms are also common, and often appear in rocks which, macroscopically, seem to be too well crystallized to produce them. The Piedmontite-bearing porphyry near Annapolis, which has so many large phenocrysts of microcline, exhibits them well (figure 2, plate xxvi). This rock has an even fracture, so that it has been worked into paving blocks quite extensively. A rock of this kind would not be expected ordinarily to contain spherulites, but there is scarcely a better example of them in the whole country than it furnishes.

At different points on the northeast side of Pilot Knob a peculiar structure is noticed, which it was thought was only a well-developed case of the common spherulitic structure. But when thin sections are examined under the microscope with crossed nicols, the customary black cross, and other evidences of the radial arrangement of the constituent minerals, are not observed. As seen in the field, the rock mass is composed of a fine-grained groundmass, in which small spheres and spheroids are held. Some of the spheres are nearly two inches in diameter, and in the badly weathered portions may be often detached, for they resist decay to a greater degree than the groundmass. From the maximum size as given they pass down to balls of microscopic dimensions. On the weathered surfaces they stand out prominently, giving quite a rough and unique appearance to the rock. When examined with the microscope, the little balls are seen to have the iron oxide grains arranged radially in most instances—very much like the spherulites from Annapolis (figure 2, plate xxvi). There is also, quite often, a collection of iron oxide on the circumference of the balls, and not infrequently an extra amount in the centre, as though it had acted as a nucleus about which the matter was concentrated. The absence of the radial arrangement of the quartz and feldspar in the spherules may be probably accounted for by assuming that the examples studied have been subjected to molecular rearrangement, as is so often the case in rocks which have been affected by weathering or dynamic influences. Equally great changes have been observed in many of the granites near the surface and in many other rocks in different parts of the world. A slight molecular rearrangement would completely change the optical properties, so that the familiar black cross would be wanting. Somewhat similar phenomena have been observed in a few other places, but nothing so complete. A few of the more vitreous appearing rocks have portions which approach closely to the same kind of spherulitic formations as may be readily seen macroscopically. These formations apparently are produced by the spherical fracture caused by a contraction in volume, but still the radial nature of the matter is sometimes apparent. The spherulitic texture is known in many other parts of the crystalline area.

Trachytic Texture.—In some of the exceedingly fine-grained rocks are many minute lath-shaped feldspar crystals, resembling somewhat the feldspars in the diabases, only much smaller. It might well be called the micro-ophitic texture, for it closely resembles the ophitic texture. Or, it may be called the trachytic, being nearly the same as the texture so commonly designated by that term

Poecilitic Texture.—Another type of texture represented is the poecilitic. This term was introduced by Williams* to express a certain structure observed in the rocks of the Cortland series, from New York, in which a comparatively large crystal of one kind is more or less filled with irregularly oriented grains of another mineral. This, it will be remembered, is different from both the micrographitic and granophyric. In the former there is no regularity in the arrangement of mineral grains, each individual being independent of all others in orientation. In the latter both minerals have a certain regularity as though the

*Am Jour. Sci., Vol. XXX, p. 31, and Vol. XXIII, p. 139.

different grains of quartz belonged to the same quartz individual, and the different grains of feldspar belonged to the same feldspar crystal. But in the poecilitic texture of Williams, the parts of one mineral have a common orientation while those of the second do not. Many of the porphyries from Missouri present just such features. The same name has been used to designate this texture in the porphyries of the state,* and it will be retained on account of its being the only term which has been proposed that is applicable. In the description of the poecilitic texture it may be well to begin with certain forms already mentioned. By referring to plate xxii, figures 1 and 2, and to plate xxiii, figure 1, it will be seen that the different grains of quartz there represented have wide borders in which the feldspar grains are diversely oriented. Now if the central crystal can be imagined as removed without affecting the surrounding borders, there will appear a moderately fine-grained groundmass in which the quartz is of one individual crystal only, while the feldspar grains belong to many; or, in other words, the features are essentially those of the poecilitic texture (figure, 1 plate xxvii). The porphyries in many places have just such a texture, which without doubt is only a modification of the quartz enlargement process in which the central grain of quartz is left out. In the one case the central phenocryst helped to attract the quartz material around it, but did not have the power to exclude the feldspar matter; in the other case quartz material concentrated by its own molecular attraction, without the assistance of the central parent crystal.

Brecciated Texture.—Another phase is the brecciated texture. The term is used in its ordinary signification when applied to eruptive rocks. It consists of a texture produced by fragments of one kind of rock being embedded in a groundmass of a slightly different color. The porphyries everywhere in Missouri have such a texture. The fragments generally are composed of about the same kind of material existing in the groundmass, differing only very slightly in color. The weathered surfaces show the fragmental inclusions more plainly than

*American Geologist, Vol. I, p. 368. Minneapolis, 1888.

fresh fractures, for in some way the differences in color are intensified by exposure. Many instances have been noted in which fragments could be plainly seen on the weathered surface, but could not be distinguished in fresh surfaces. In size the fragments vary greatly. Some of them are of microscopic dimensions; others are more than a foot in diameter. Sometimes they are few and hard to distinguish; at other times it would seem that nearly half the volume of the rock is composed of them. Perhaps the locality in which they are most noticeable is to the southeast of Pilot Knob. There is scarcely a porphyry hill in this area which is not a good representative. Along the upper course of the ravine which is followed by the St. Mary road to the northeast from Ironton is a good locality for showing the phenomenon in an excellent way. In places by the roadside are thousands of fragments, some of which are from twelve to eighteen inches in diameter. Intimately associated with the larger ones are countless myriads of small fragments, which indicate that the sorting power of water had not acted upon them. The different hills to the north of the gravel road from Ironton to Fredericktown, in the same township, also contain large numbers of the fragments.

Flowage Texture.—This is produced by the movement or flowing of the lava material after it has become quite viscous, but before it has become rigid. In this way are produced marks similar to those on slag from a furnace, or lines on candy which has been worked as it was cooling. Solid or gaseous inclusions of various kinds have in this way the flowage lines passing around them, often forming fantastic figures. The crystalline constituents, which are longer than wide, are generally arranged longitudinally with the flowage lines. The different kinds of materials in the rock mass are also usually spread out in broad bands, which often become thinner and thinner as the motion continues. In this way the banded appearance is produced which is so common in many effusive rocks; for every slight variation in color, or in constituents of any kind, is shown.

The Missouri porphyries have particularly good examples of flowage lines, both macroscopical and microscopical. A number of illustrations are introduced to represent these phenomena. Figure 1, plate xxviii, is from the south side of Cedar hill near Pilot Knob. Others show similar flowage lines around gas cavities and other inclusions, especially the rocks from French mills (Tp. 32 N., R. V E., Sec. 21). Figure 2 is from a small hand specimen taken from the first porphyry hill east of Annapolis, near the old May quarry. It represents the flowage lines very perfectly. Specimens were obtained near the Heywood place already mentioned, but about one-fourth of a mile away, on the hill in which are the manganese mines, and probably represents a facies of the rock at the mines. Plate xxix, is from a specimen taken on Captain creek, just east of the King farm (Tp. 32 N., R. VI E., Sec. 19). Figure 1, plate xxx shows the microscopic appearance of the same kind of rocks when only slightly magnified. It will be noticed that the flowage lines pass around each inclusion. Fig. 2, plate xxx, is mentioned in discussing the fragmental inclusions, but it also represents the flowage lines very well in certain parts. It is from the west side of the hill forming the south bank of the "Shut-in," two and one-half miles east of Ironton. Nothing, it would seem, could represent the flowage lines better than this does, as they pass in and out around the fragmental inclusions and the phenocrysts of quartz and feldspar. In all cases where the flowage structure is noticeable, the lines of flowage are seen to pass around the included fragments. This feature is shown both in hand specimens and in microscopic sections. Plate xxix is from a specimen in which a few fragments are included. On one of these the number is painted in white on an artificial black background, covering the fragment entirely. The flowage lines are seen to pass around it. Another prominent one is near the center of the picture and is crossed by a dark shadow. Plate xxx, figure 1, is a photograph of an entire thin section, and has a number of inclusions scattered through it, all of which have the wavy lines passing around them as is well shown.

These are even better represented in figure 2, plate xxx. One large fragment is shown with a number of small ones.

Particular attention should be given to the quartz phenocrysts which chance to be on the border line of the fragments. They are partly embedded in the fragment and partly in the adjacent groundmass, indicating that both fragment and groundmass were somewhat pasty at the time the fragment was included, so that a yielding could take place. It will be noted that the fragment itself has phenocrysts of quartz and feldspar; and further, that it has the wavy flowage lines well developed. Some of the inclusions carry quartz phenocrysts, and the wavy lines in the groundmass curve around or pass over them. Plate xxvii, figure 2, represents the microscopic characters highly magnified, especially that part along the border between an inclusion on the right and the main groundmass on the left. The inclusion contains phenocrysts of quartz and feldspar, and is in every respect an ordinary quartz-feldspar porphyry. The adjacent groundmass likewise contains phenocrysts. It also has the banded appearance produced by the flowage texture. It has many small lath-shaped feldspar microliths, so well represented in the groundmass in figure 2, plate xxx. It need not be assumed, however, that this fragment with its peculiar trachytic texture necessarily came from a distance, for very probably it was formed close by, where it became enclosed in the other material. In another instance is an inclusion of a very fine-grained porphyry which is embedded in an unusually fine-grained groundmass. It will be seen that the fragment has its borders rounded by the corrosive action of the surrounding magma, which evidently took place before solidification. The little feldspar phenocryst b^1 (figure 15), within the fragment, shows that the latter belongs to the feldspar porphyries.

It will be seen from the foregoing that the fragments were most likely embedded in the lava material of the rock-mass before it became solidified. There are different methods by which volcanic breccia is produced. The explosive action of the volcano forces into the air portions of the lava, which thus become cooled and solidified. The fragments formed fall back upon the outflowing lava and become entombed within it. Some of them may be entirely redissolved ; others, of course, are not, depending upon the varying size and the varying temperature of the lava. Again, the surface of the lava mass may have a crust formed on it by cooling, which may become broken up by subsequent flows and the fragments inclosed in the new material, thus producing a brecciated structure similar to that described. There are, also, other ways by which such inclusions may be produced. Inclusions are very common in all volcanic rocks and have been described by many writers. By comparing the brecciated rocks of Missouri with those described recently by Iddings from Obsidian cliff, in Yellowstone National park, no essential differences are seen.

Scoriæ and Lithophysæ.— Of scoriaceous structure and lithophysæ few examples occur. Instances of this structure, however, have been found much more frequently than was expected. One of the best is at the French mills on Marble creek. Here the whole hillside is covered with fragments which contain many gas cavities, and around which the flowage lines pass. Another place where such cavities may be observed is along the eastern side of the long porphyry hill south of the Munger mills, in the extreme northeast corner of Reynolds county (Tp. 33 N., R. IV E., section 1). The rock is a red, fine-grained variety which was apparently, originally, a glass. The cavities are generally larger than those in the porphyry at the French mills. Still a third place where gas cavities occur, and one which may be easily reached is at the falls on the east fork of Black river (Tp. 33 N., R. II E., Sec. 16). On the west side of the stream there is a belt of porphyry in which the gas cavities are very numerous. The majority of them have been partly or wholly filled with secondary quartz, so that when the rock is freshly broken it presents a spotted appearance, the white quartz contrasting sharply with the terra cotta color of the groundmass. On account of the quartz resisting decay more than the matrix, the weathered surfaces of the porphyry are covered by little projections, giving the rock a decidedly warty appearance. This scoriaceous porphyry has many included fragments, as is well shown in thin slices of the rock. On the opposite side of the stream the gas cavities also may be seen in the porphyry—some of them being much larger than any found on the other side. They are not so completely filled with secondary quartz, and, on the whole, form better material for museum specimens. The gas cavities in volcanic rocks usually are confined to the upper layers, and of necessity render the rocks more susceptible to the weathering agents. This is undoubtedly the reason why more examples of the scoriaceous porphyry cannot be found in Missouri. The three localities mentioned are by no means the only places where such material occurs.

CLASSIFICATION OF THE PORPHYRIES.

With reference to their chemical and mineralogical properties, the porphyries may be divided into two great classes, the porphyries proper and the porphyrites. The former include all those which have quartz, orthoclase or microcline phenocrysts, and the red varieties which have no phenocrysts. The latter embraces all those which have prominent phenocrysts of one or more varieties of the triclinic feldspars. The distinction between the two kinds is readily made macroscopically, for the porphyrites have the peculiar green color due to the epidote which is so evenly disseminated through the rock mass. They are also quite sharply separated geographically in nearly all cases, for there are but few instances in which the two kinds grade into each other.

Porphyrites.—Within the division of the porphyrites themselves there is little variation that may be traced readily macroscopically, for all of them are nearly the same color, have the same general appearance in texture and an equal abundance of the feldspar phenocrysts. But when examined microscopically it is seen at a glance that there is a considerable difference in the amount of quartz in the groundmass, and in some other minor particulars. The porphyrite at Piedmont is perhaps as acidic as any found, and yet it has only 68.61 per cent of silicic acid. The groundmass in this rock seems to be fully one-half quartz. Could some of the others have been examined chemically, there is no doubt but that their silica contents would have fallen below this, and this possibly would have given rise to subdivisions of the group. But as not a single instance has been observed of phenocrysts of any of the ferro-magnesian minerals, the common subdivisions of this group cannot now be made.

Porphyries.—By this term is meant the assemblage of all the different kinds of acid porphyries not included with the porphyrites. They all present in color some shade of red, excepting here and there one which is nearly black. There is a great diversity of texture and of the character of the phenocrysts. It does not seem advisable to again divide the porphyries into the quartz-porphyries and the quartz-free porphyries, for the quartz phenocrysts come and go with such apparent ease that it would only lead to confusion in attempting to study the rocks in the field. Very often, too, the two minerals, quartz and orthoclase, are found intimately associated as phenocrysts, so that for a majority of the porphyries the separation would be entirely unnatural and artificial. There are places, it is true, where the feldspar crystals are the only phenocrysts, and such rocks might well be called orthoclase-porphyry. It is much more in accord with the field conditions, however, to make four divisions based entirely upon texture, and then subdivide with reference to a mineralogical composition. In this way the orthophyres, usually given by themselves, will be a division of the microgranites.

As regarding the texture, then, the porphyries readily fall into four classes, which may be named, respectively, micro-granite, granophyre, felsophyre and vitrophyre. All of these may have phenocrysts of quartz, orthoclase or microcline, or, as is often the case, none of them may show porphyritic crystals.

Microgranite.—As used here, this term includes all the porphyries which have a groundmass sufficiently coarsely crystalline to admit of the accurate and easy recognition of the mineral constituents with the microscope, provided they have the arrangement with reference to each other common to such constituents in granite. In other words, if the groundmass has the granitic texture, and is sufficiently coarsely crystalline to admit of the easy identification of its constituents with the microscope, the rock will be called a micro-granite, independent of its phenocrysts. Rocks of this description are very abundant, and they constitute at least three-fourths of all the porphyries. Some of them with almost no phenocrysts grade directly into the granites. Others with prominent phenocrysts pass into the granite porphyries and through these into the granites, as already pointed out. All of the coarser porphyries belong here—those which have been worked for paving blocks in so many places, and many more which might equally well be utilized in the same way. Occasionally there occurs a considerable area of microgranite which has no phenocrysts, or if any, those of feldspar only. Such rocks may be called orthophyres in allusion to the prominence of the feldspar constituent. They are found on the summit of Knob Lick and among the finer grained varieties over an area to the south of that point. There are also a number of quarries along the railroad between Knob Lick and Mine la Motte which are opened in the same kind of rock. Farther south on both sides of the Little St. Francois are other locations. The same irregularity marks the position of the orthophyres in many other places, for they are liable to be found anywhere throughout the whole crystalline area. Yet when observed, they rarely are traceable any considerable distance; one side of a hill or a small exposure will be a true orthophyre, and, perhaps, not more than ten rods away the rock assumes the characteristic features of a quartz porphyry.

Granophyre.—This term is used to embrace all the rocks which have the granophyric or micropegmatitic texture, whether or not prominent phenocrysts of any kind are present. The larger part of the granophyres have already been described under the granites, as their general microscopic properties associate them with that group rather than with the porphyries.

It was stated that many of them had prominent phenocrysts and consequently were closely related to the division of porphyries. The granophyres are especially abundant along the borders between the granites and porphyries, and sometimes occupy large areas; but in general they are confined to smaller areas and comparatively narrow belts between the two kinds of rocks mentioned.

Felsophyre.—This term is applied to that particular division of the porphyries that has a groundmass which, while being holocrystalline, as is shown by its action on polarized light, is so crypto-crystalline in its general character that it is difficult or nearly impossible to determine definitely anything with reference to the nature of the crystalline constituents. The felsophyres have about the same relation to the microgranites that the latter have to the granites proper. They pass into the microgranites so gradually that often it is almost impossible to locate the dividing line. Some of the best examples of quartz porphyry have the felsophyric groundmass, and many rocks have nearly the same groundmass, but without phenocrysts of any kind.

Vitrophyre.—A rock of this character has a glassy groundmass, but otherwise is about the same as the felsophyre. The ancient porphyries have but few instances of glass in the groundmass, for the processes of devitrification have almost entirely obliterated all traces of glass, which undoubtedly was once present. Many of the Missouri porphyries bear within themselves very good evidence of their primitive glassy character. Only a few have been found in which there is now any glass, and in those cases it is possible that thinner sections and higher magnifying power would show that it is usually the felsophyric texture which the rock possesses. One instance of the above is a glass-like rock, filled with the flowage lines, which is found near and around the summit of the porphyry hill east of Annapolis. Judged both macroscopically and microscopically, it would appear that this rock has a considerable amount of glass. But the main part of the hill is more coarsely crystalline. Another illustration is the red porphyry containing the gas cavities, which occurs in the extreme northeastern part of Reynolds county. This rock is remarkably compact and flinty in its general appearance, has the glassy look and fracture, and when examined in thin sections under the microscope is seen to have a remarkably fine-grained ground mass, portions of which affect polarized light, but other portions of which seem to be entirely dark between crossed nicols. A third example is a portion of the rock covering the hill on which the Methodist church in Arcadia stands. In places the mass is very glassy, although in great part it is decidedly crystalline. A few other instances are known in which the rocks are partly glassy, but the three mentioned are the best examples.

GEOGRAPHIC DISTRIBUTION AND GENERAL CHARACTER OF THE PORPHYRIES.

It will be seen that the porphyries are widely scattered through the crystalline area, and that they are much more abundant than any other rock types. It will further be seen that they are relatively more abundant to the west than to the east. While the granites occupy the outlying portions in the east, from the north all the way round to the south, the porphyries occupy a similar position on the west. There are certain geographic peculiarities in the different porphyries which would almost make it possible for the practiced eye to distinguish between samples from different places, and to tell approximately the localities of such samples. These differences are principally confined to variations in color, and yet they are of such a nature that it is almost impossible to define them accurately. The different shades of terra cotta, red, brown and other colors exhibited by rocks, can hardly be expressed. The texture, also, has certain variations which are noticeable, but which are not measured in degrees of coarseness or fineness; neither do they come under the different class names adopted for designating the different kinds of texture. But the difference is comparable to the differences between granites from separate localities, all of which have the granitic texture well developed, but none of which are exactly alike.

In the central area the porphyries are characterized by a terra cotta, reddish-brown or dark brown color, with some shade of the terra cotta strongly predominating. They may or may not have phenocrysts, may be banded or plain, fine-grained or relatively coarse. Shepherd mountain is almost entirely composed of the banded variety, the alterations in color being due to the unequal distribution of the light-colored feldspathic material. As already pointed out, this banded appearance is probably due to the flowage of the lava. It is to be noted that not only Shepherd mountain, just mentioned, but generally the banded layers are parallel to the great lateral seams which dip with the hillsides. These bands are so noticeable at Shepherd that the fragments and boulders by the roadside and along the streets of Ironton show them very plainly.

The large porphyry area in the Taum Sauk region shows a very similar rock. The bands are here noticeable in many places, and the rock often contains the blisters, or lithophysæ, in greater abundance than is found in any other part of the district. Everywhere the flowage lines and the fragmental inclusions are found. Cedar hill is another example. From bottom to top the unusually fine-grained porphyry is filled with the flowage lines, and near the top the brecciated character of the rock is especially prominent. Buzzard mountain, to the east, is especially noteworthy on account of the great abundance of the fragmental inclusions which its porphyry contains. They are more abundant in the southern than in the northern part. All of Pilot Knob, excepting a small portion at the summit, is likewise composed of a fine-grained porphyry with the flowage structure plainly marked in places. The character of the rocks to the east and south of Shepherd mountain and Pilot Knob is quite the same in general as in the case of those hills. The color remains unchanged in the main, as do the frequency of the flowage and banded structures. The quartz and feldspar phenocrysts, and the included fragments, are quite as noticeable. These conditions are maintained for miles in every direction. The porphyry near Bismarck is scarcely distinguishable from that around Hogan, over twenty miles away; that on the head waters of the east fork of Black river does not differ materially from the porphyry adjacent to Fredericktown, thirty miles to the east. This persistency in character is remarkable, and argues very strongly for a common origin of the porphyries. It is true, there are slight local differences, but none which are not exceedingly local. Farther away, on the extreme borders, are found slightly greater differences, but even then the character of the rocks is so similar to those in the central part that it is very striking.

The porphyries around the western border, with but one exception, have their feldspar phenocrysts unusually well developed. Many of the crystals are also quite large, and generally contrast in color with the background much more strongly than do the average feldspar crystals in the central area. Little Pilot Knob (Tp. 38 N., R. I E., Sec. 31), for example, is composed of a rock filled with light-colored feldspar phenocrysts, many of which have assumed a light green color on account of the epidote developed secondarily in them. The whole rock also has a slight greenish hue caused in the same way, especially on the northern part of the hill. The porphyry in the partially distinct area in Shannon county, to the southwest, is very similar to that in the northeast. Portions of it are of the ordinary, red kind and cannot be distinguished from the porphyry in the central area. But other portions are filled with the light gray or light green feldspar phenocrysts which are common to the northeast.

Passing farther to the south, are found two distinct types: the green porphyries and the red porphyries, with a few examples of a somewhat intermediate group which is quite similar to those already mentioned at Little Pilot Knob. Aley mountain is, perhaps, the best example of this. Placed side by side, specimens from Little Pilot Knob and from Aley mountain can scarcely be distinguished, although they are so far apart.

Some of the red porphyries in the southern part are especially interesting on account of their wonderfully brecciated character. This is particularly true of the porphyry composing Clark mountain, of portions of Gad hill, and of a number of other places to the southwest of the latter place. The porphyrites are found in the first hill, west of Des Arc, on the first large hill east of the same town, which extends for miles to the south and east, in the big hill north of Piedmont in which the paving-block quarries were located, and in a few other smaller hills in that vicinity. No other rocks of that character have been found in the state. They are characterized macroscopically by their greenish color, which seems to be caused by the epidote which is so evenly scattered through the groundmass. Along with the green color comes the light feldspar phenocrysts, which gives a slightly mottled appearance. The feldspars are all, or nearly all, triclinic, some of which seem to be much more basic than would be expected in so acid a rock.

In perhaps a dozen different places quarries have been opened in the porphyrites, some of which have been quite extensively worked. They seem to be filled with seams about the same as in the ordinary porphyries, so that the rock is not suitable for dimension stone.

In the vicinity of Annapolis the distinguishing features of the rocks are the great abundance of the large microcline phenocrysts and the spherulitic character of the groundmass, as well as the occasional presence of the rare manganese epidote, or piedmontite. The feldspar phenocrysts are abundant in nearly all the porphyries to the east and to the north of Annapolis, and are so different from any others known that they are almost distinct. To the southeast and east there is no particular characteristic which would especially distinguish between the porphyries here and in the main central area. They produced the same variations in texture, color, and the mineralogical character of their phenocrysts, common to other localities.

ROCKS INTERMEDIATE BETWEEN THE GRANITES AND PORPHYRIES.

As already stated, there is a great class of rocks in Missouri which, in their structural relations, occupy intermediate positions between the granites and porphyries, and which have been variously designated as granite porphyries, granophyres, or coarse-grained micrograuites. Sometimes these rocks are located between the granite and porphyry areas, and seem to be a connecting link between them. At other times they are in contact only with the granite or with the porphyry, in which cases the graduations are traceable in one direction only.

Early in the course of field work, it was decided to advance as a working hypothesis the idea that the granites and the porphyries belong practically to the same general period of eruption, and that in many cases, from a particular magma a granite was produced in one portion and a porphyry in another. It was not thought that this was true in every case of contact between the two rocks, but that it probably was in a majority of cases. Since it was produced the hypothesis has been strengthened by many observations, and it is now offered as the most probable explanation for the intimate relations of the two kinds of rocks. It is recognized that similar relations between the well-crystallized rocks and those of porphyritic or glassy texture have been discovered in many different places, and described by different writers. In fact, the literature on this subject is quite voluminous. The instances of such graduation in Missouri are so numerous and furnish such beautiful examples that it is thought they will prove of interest; and, further, a description of the granites and porphyries is incomplete without a detailed account of the graduations.

Beginning with the southern part of the western margin of the largest granite area, there is along this boundary a marked juncture of the granite and porphyry nearly all the way from the St. Francois river below the Silver mines to the vicinity of Stono, a distance of nearly twenty miles. Back from the river a short distance on the bluff there is a fine-grained granite, which gradually changes into a coarse-grained porphyry, the transition sometimes occupying fifteen or twenty feet, and again as many inches. In the field it is not always possible to recognize the limits of either of the two rocks. Usually there is a change in color, the reddish porphyry shading into a much lighter granite. The difference in color, in fact, is the best single criterion to be governed by. The line of union can thus be traced from the bluff by the river, in a northerly direction, with comparative ease to the level land to the northwest. At one point, just below the Wiley house, it was thought that the change was made within such narrow limits that a large specimen could be obtained, which would show the two textures. Accordingly, the drill and blast were resorted to, and a suite of specimens were gathered, some of which were fifteen inches long. But when these sections were made, it was found that those thought to be porphyry were well-crystallized granite. However, the graduation was very decided from the red part of the specimen over into the porphyry which was near by.

Across the almost level ground to the northwest of Silver mines for some distance the contact was traced, although the soil covering interfered so much that accurate observations could be made only occasionally. To the east of the line there is a high point near the river (section 3) which is very instructive. The base of the hill is a well-crystallized granite, and corresponds to the granite of the surrounding valley in texture, in color, in mineralogical composition, in fracture, and in mode of weathering. On ascending the hill, but little change is noticed until half way to the top, where it is quite evident that the texture becomes finer, the color a deeper red, and the fracture more like that of the prophyries. At the summit the change is complete, and the red rock there is so filled with fracture seams that it proved impossible to obtain even a good hand specimen of the regulation size without a portion of its surface being weather-stained on account of seams. On the side over-looking the river there is a precipitous bluff nearly 100 feet high. The face of the bluff is filled with vertical seams exactly as is common with porphyry bluffs. The texture of the porphyry here is that of an average microgranite, which by no means is as coarse as is found in many other microgranites.

A partial chemical analysis was made by the St. Louis Sampling and Testing Works of two specimens, one obtained on the southeast hill-side, which is a typical granite (No. 15006), and the other at the summit (No. 15007).

Cab. No.	SiO_2.	Al_2O_3	CaO.	Na_2O.	K_2O.
15006	73.98	14.32	1.04	4.56	3.32
15007	74.12	13.82	1.41	5.25	3.80

The result shows that the two are very closely related chemically. In this case the change is very gradual—so much so that no decision can be made to within fifty feet as to the location of the dividing line. To the northwest the porphyry extends down the hillside further than either on the south or southeast. The next point of especial interest is where the division line crosses Rock creek (section 9). Years ago a prospector sank a shaft twenty feet deep in the porphyry, about fifty feet from the boundary. It is locally known as the Klein shaft. The material in the dump gave evidence of considerable variation in the crystallization within, so the water was baled out and the walls of the shaft examined to nearly the full depth. Three or four feet below the surface, on the north and east walls, the rock appeared to be more coarsely crystalline than the rest. The microscope shows that it is a moderately fine micropegmatite. The other walls retain a crystallization similar to that of the surface for a depth of twelve to fourteen feet, when they also change into a micropegmatite. The most coarsely crystalline parts are at and near the bottom, and are on the north and east sides: *i. e.*, the sides toward the granite area. In crystallization, the rock varies from the micropegmatite to the granite, in which the crystals are usually long and slender. This, in reality, is quite like the other, only much more coarsely crystallized. A silica determination was made by McClurg and Bradford of two specimens, one (No. 15108) from three feet below the surface, which gave 70.15 per cent of SiO_2, and the other (No. 15119) from near the bottom of the shaft, which gave 69.51 per cent of SiO_2. The shaft permits an examination of the difference in crystallization through a vertical variation, and consequently is of great importance. Only one other instance has been found, excepting in the different quarries in the porphyry, and they are not located near the border line. This is a shallow prospecting shaft not more than six feet deep, located almost on the county line in the same township (section 6), on the first hillside south of Stout creek. It also shows that crystallization increases with the depth. Northwest of the Klein shaft the contact line is readily traced over the hills for a mile or more. Occasionally the base rocks are exposed so that any change is quickly noticed. It is surprising to find the apparent contact so sharp in places, but in reality, as has been repeatedly shown by the microscope, the change in crystallization is not so abrupt as the change in color. On reaching the banks of Stout creek, another excellent opportunity is afforded for observing the contact. On the south bank the bluff comes almost down to the water's edge, while a broad bottom land lies to the north. It is in the former place that the contact is found. Of four specimens gathered from near the line, one (No. 15038) is from the typical granite; another (No. 15039) is still from the granite side, but before the color has changed much; a third (No. 15040) is from the porphyry side, but near the line; and the last (No. 15041) from the typical porphyry of the bluff up-stream and about forty feet away—the whole range covering about fifty feet, measured nearly at right angles to the contact line. The following analyses made by Melville show the variation in chemical composition:

Number.	15038.	15039.	15040.	15041.
Loess at 100° C.	0.14	0.22	0.12	0.17
Loess on ignition	0.85	0.54	0 30	0.26
SiO_2	69.94	72.35	71.33	71.88
Al_2O_3	15.19	13.78	12.55	12.88
Fe_2O_3	1.88	1.87	3.75	3.05
FeO.	0.60	0.36	0.85	1.05
NiO.	trace	0.20	0.15	0.02
MnO	0.03	0.06	0.04	trace
CaO.	1.15	0 87	0.94	1.13
MgO	0.92	0.42	0.58	0.33
K_2O	4 29	4.49	4.20	4.46
Na_2O	3.95	4.14	4.52	4.21
P_2O_5	0.13	0.13	0.16	0.15
TiO_2	0.25	0.44	0.55	0.22
Totals	99.32	99.87	100.04	99.81

The greatest difference shown by these analyses is in the acidity of the first two, each of which is granite. It is quite possible that the acidity of the first had been partially altered, as the specimen was slightly decomposed, it being impossible to obtain perfectly fresh material without blasting. This difference is principally balanced by the excessive amount of Al_2O_3 in No. 15038. The otherwise almost identical composition of the four rocks can leave little doubt regarding their consanguinity.

Equally interesting results were obtained by an examination farther up the stream. About one-fourth of a mile above the place just mentioned, the bluff on the south rises into quite a prominent peak, nearly 300 feet above the water level. Corresponding with this rise in the surface there is a decrease in the degree of crystallization in the rocks along the creek. Specimens were obtained at different places which show that the rock is a granite. It is as coarsely crystalline as the ordinary granite, as the thin sections well show. The rock at the summit of the high hill is a typical porphyry, and finer grained than either of those of which analyses have been given. Here, in a vertical distance of 300 feet, the rock changes in crystallization from a fine-grained porphyry to a well-crystallized granite. It should be noted, however, that throughout all of this upper region the color and general appearance of the porphyry and its well-crystallized facies is similar, so that without close inspection the two kinds of rock would be called the same. The conditions on the bottom and to the north cannot be traced on account of the soil covering. Some distance above the high hill on the south a similar elevation appears on the north. The lighter colored granite touches the eastern base of this hill. The summit is a good porphyry. Toward the creek the decline is gradual rather than precipitous, and soil covers the greater part of the surface. Nevertheless the rocks are exposed here and there, and they show a gradual increase in crystallization towards the creek. At the water's edge the granite is well crystallized, although it possesses the color so characteristic of the porphyries.

The surface covering of soil and the overlying sandstone is so great that nothing of especial interest is noticeable between the points mentioned and Brewer creek. On the hillside (Tp. 34 N,, R IV E, Sec. 24) to the west of the Smith house, several fine examples of the contact are visible. Larger or smaller bluffs of the bared rock permit the tracing of the one kind directly over into the other. The variation in color is not so great as at Stout creek, and the change is apparently quite abrupt. Following the contact line farther, a number of good exposures occur on the north side of Brewer creek. To the north the line soon strikes another hill. Immediately west of the Sinz house, on the line between sections 10 and 11, an unusually good outcropping exists. A large ledge is exposed to view, which contains both granite and porphyry. As in many other instances, the large vertical seams pass directly from one rock to the other, just as though the two were one. There is no indication whatever of any line or division between them, but they appear to be one and the same rock mass. Of the different samples examined, one (No. 15366) was from the granite, one (No. 15368) from the porphyry about 30 feet away, and a third (No. 15367) midway between the two. The porphyry one is an exceedingly coarse-grained microgranite. A partial chemical examination by the St. Louis Sampling and Testing Works gave the following results:

Number.	15366	15367	15368
SiO_2	77.04	77.88	76.10
Al_2O_3	12.29	13.19	12.28

Here, again, the intermediate grade has a little the highest per cent of silicic acid, although the difference is so slight that it is entirely insignificant. The amount of aluminium oxide is even more constant, the figures for the two extremes differing only by one-hundredth of one per cent. The chemical evidence, therefore, strongly indicates a unity of origin of the granites and porphyries at this place.

From Brewer creek north no sharp lines are found. The granite crosses over the low land to the north, and strikes the hills which are almost continuous with those extending westward to Iron mountain. Every one of these, within the granite area, either is porphyry at the top and granite near the base, or is entirely porphyry that is closely allied to the granites in all its properties. A little to the east of Black mountain is a good instance of graduation. The granite is a deeper red than farther to the south, so that the change to be noticed in approaching Black mountain from the south or west is the appearance of quartz phenocrysts. This may attract attention even before the base of the hill is reached. Farther up the phenocrysts become more numerous, but the groundmass changes very slowly; and even at the summit, where the rock is porphyry, it would answer very well for a fine-grained granite if only the porphyritic quartz grains were absent. Still farther to the northward, even to Stono, it is immaterial whether the rock is called a granite or a porphyry. It varies slightly from place to place, but nowhere becomes a typical granite nor a typical porphyry. It is represented as a granite on the map, because, first, its texture would place it there as nearly as with the porphyries; and, second, because its fracture, its weathering products, especially the boulders, and its general characters, show that it is more closely allied to the granites than to the porphyries. These features prevail to the northeast of Stono for some distance, to the point where all of the crystallines become covered with the limestone which extends beyond the Doe Run lead mines. Borings and exposures made at this place show that the whole of this limestone is underlaid by granite, which, in all probability, joins the hills to the east of Stono.

The eastern limit of the granite area is not so well suited for studying contacts, except in isolated cases, for the boundaries are much oftener concealed beneath the sedimentary rocks. Numerous isolated examples occur of graduation from one rock into the other. Some of these have already been mentioned. No better example could be wished for than that furnished in different places around Knob Lick. To the north of the blue granite area the reddish or grayish granite gradually passes over into the porphyry which occupies the summit of the hill. It was not determined whether a similar gradation could be traced along the borders of the porphyry nearer the river to the north, or whether they have been erupted separately. To the south of Knob Lick probably a dozen or more places exist where the most gradual change occurs from the granites into the porphyries.

Near Fredericktown are a few examples which should be mentioned. On the eastern side of the first porphyry hill west of the town along the Ironton road there is a granite area covering a strip about forty rods wide, which extends south for nearly a mile. This is a granophyre, which is covered along the eastern side by limestone. Almost to a certainty can it be said that it is the same granite area of which small portions are exposed in different places in Fredericktown valley. But on the west it graduates directly into the porphyry. Nowhere is a sharp line shown as is often the case farther to the west. The graduation is even less marked toward the south. On the western side of the hill coarse microgranite is found, but the granophyric character does not seem to have been developed.

Across the Little St. Francois a few granite areas occur, one of which forms an excellent example. On the northwestern part of Matthews mountain is an exceptionally fine illustration. The granite (Tp. 33 N., R. VI E., Sec. 34) covers a space of a little more than ten acres. It reaches up into the porphyry hill, and all along the line gradually passes into porphyry in such a way that there is no indication whatever of its belonging to a separate eruption.

Another good illustration of the same phenomenon is furnished by the little granite area near Cornwall. At the east end of the hill the rock is the coarsest grained granite known in the State. From this it graduates into a finer and finer grained rock until it passes directly over into the porphyry. The change is so regular that for each distance of a hundred yards or less through the granite itself, a decided difference is noted.

Tin mountain is entirely made up of porphyry, and is an unusually steep hill. But on the east side from near the base, a ridge passes toward the east to a point almost opposite the Little Vine church. Along this comparatively level ground, near the east end of the ridge, and about one-third of a mile to the northwest from the church, is a small granite area which is entirely surrounded by porphyry. This was not examined minutely on all sides, but on the south it showed very plainly that it passed by degrees into the porphyry, and that the change was quite gradual, extending over two hundred yards or more.

At the place called the "Shut-in," east of Ironton, a small area of coarse granophyre occurs on the western side of the hill on the north side of the creek. The Ironton and Fredericktown road passes directly over it, but the strip here is so narrow that it may be easily overlooked. To the north it widens a little, but nowhere becomes very large. A little farther along, on the next hill to the northwest, near the north line of section 3, is a similar occurrence. The rock at both of these places appears to be a granite when examined macroscopically, but in reality both are coarse-grained granophyres. Each of these areas graduates directly into the porphyry. The rock at Graniteville is bordered by limestone on every side excepting the northeast. Here it joins the porphyry in the adjacent hill. The line of contact is so short that there is uncertainty regarding the exact relations between the two rocks, but it is most likely that they merge into each other. The contact is exposed only in two or three places.

On the south side of the little granite area belonging to the Pilot Knob company the gradation is less abrupt. To the south and southwest the granite borders the porphyry, but the change from one to the other takes place comparatively slowly, and occupies a space of 100 yards or more.

A few exceptions to the rule have already been pointed out, notably the granite porphyry at the Gabriel and Buford quarry, and certain granites in the Black river area. Reasons also have been given for believing that they were formed by separate eruptions. It is not to be understood that all the granites in the big area were brought to the surface at once; but rather that the granites and the porphyries were formed simultaneously and came from the same general magma, and consequently are of the same geological age. It is therefore useless to attempt to decide which is the older, the granite or the porphyry. This view is placed in contrast with the one that the two types of rocks are of two different periods, and possibly of different origins. From statements already made, it will be seen that there are good reasons for believing that many of the prominent porphyry hills are the result of different individual outbursts. In a similar way, different granite areas may also have resulted from a number of different eruptions.

Regarding the probable cause of the difference in texture of the granites and porphyries, it is sufficient to say that the greatest factors in producing a granitic crystallization are great pressure, and slowness of radiation of heat during the period of solidification, of which the latter doubtless has the strongest influence. It should be noted that, with the exception of the Black river rocks, which are likely independent eruptions, and two hills in the east, all the granites known are on relatively low ground. When the border line passes up a hillside, it rarely, if ever, extends to the summit of the hill. This is a very significant fact. If it is the result of great erosion, it shows that at this depth the crystallization is comparatively perfect. If the present porphhry hills could be leveled down to the altitude of the granites, the areas of the latter would doubtless be considerably widened. The evidence at the Klein shaft is directly in line. The diamond drill borings at Pilot Knob and Iron mountain do not especially strengthen this idea, but they by no means militate against it; for in many instances, if not in all, the porphyry at the bottom of the drill-hole is coarser than that at the surface. The extra erosion, therefore, would help to widen the granite fields, because, with the increased depth, the coarser the crystallization. Yet it is hardly probable that all the difference in crytallization expressed on the present surface is due to this cause alone. The topography of the country is such that it may be easily assumed that at the time of eruption only portions of the lava reached the surface. The crust or floor through which it was forced is now nowhere to be seen, yet it is not improbable that the granite lavas in general did not pass through this floor. Should this be correct, the porphyry hills are formed of the lava which reached the surface and formed variously-shaped volcanic mountains, or hills and monticules, the lava in which would connect directly with the deeper seated material, which of course would cool more slowly and under greater pressure. Subsequent erosion previous to Cambrian time could have removed portions of the crust, or possibly all of it, exposing the hidden rocks, which were sufficiently well crystallized to admit of their being called granites. With such varying conditions as these, the varying degrees of crystallization which are now absent could have been readily brought about.

ACKNOWLEDGMENTS.

For aid and assistance in the prosecution of the work on the crystalline rocks of the state, special acknowledgments are due to those who helped in the field. Mr. E. H. Lonsdale visited the northwestern part of the area, and also the outlying district in Shannon county. Mr. M. Z. Kirk spent one summer in the south and southeastern parts. Both of these gentlemen defined the boundaries of the crystalline rocks in the regions visited, and gathered hand specimens of different kinds of rock. Thanks are due to many citizens who aided in many ways. Prominent among these should be mentioned Mr. Richard Payne, of Madison county; Hon. Price Buford, Judge Fox and Mr. Frank Schulte, of Fredericktown; Hon. Thomas Beard and W. W. Haywood, of Ironton; Mr. Crain and Captain Searle, of Pilot Knob; Dr. Farrer and Surveyor Wilkinson, of Brunot. For advice and assistance, acknowledgment is also due Mr. Arthur Winslow, Prof. C. R. Van Hise, Prof. George H. Williams and Prof. J. P. Iddings. The illustrations reproduced from photo-micrographs were made with the assistance of Mr. E. S. Tucker, of the University of Kansas, and Mr. Merriam, of Madison, Wis. The colored figures are reproduced from water-color sketches made by Mr. Haworth.

EXPLANATION OF PLATES.

PLATE I. Map of crystalline area of Missouri.

PLATE II. Highlands of southeastern Missouri; St. Francois mountains, Arcadia.

PLATE III. Falls of Black river, showing solid porphyry, with numerous potholes (Tp. 33 N., R. II E., Sec. 16).

PLATE IV. Appearance of Psuedo-stratification in porphyry.

PLATE V. Horizontal and vertical jointing in granite quarry at Graniteville, Iron county.

PLATE VI. Granite bluff, showing seams cutting the rock into large quadrangular blocks; east bank of Black river, at falls.

PLATE VII. Porphyry bluff, showing vertical seams and columns, but absence of horizontal seams; French mills, on Marble creek (Tp. 32 N., R. V E., Sec. 21).

PLATE VIII. Tesselated surface of granite, Graniteville.

PLATE IX. Disintegration of granite, *in situ*.

PLATE X. "Elephant rocks;" boulders of disintegration; Graniteville.

PLATE XI. Juncture of stratified rocks and porphyry, Little St. Francois river, Fredericktown; line of separation coincides with the slope of the porphyry surface on the right.

PLATE XII. Diabase-porphyrite, showing feldspar phenocrysts, some of which are 3 inches long; from a 7-foot dike on south bank of Little St. Francois river (Tp. 33 N., R. VI E., Sec. 14).

PLATE XIII. Quartz-diabase-porphyrite; smaller phenocrysts are quartz; three largest feldspar (from No. 15001, Tp. 33 N., R. V E., sec. 10).

PLATE XIV. FIGURE 1. Thin slice of olivine diabase, showing augite, olivine and triclinic feldspar, X 60 (from 15566; Tp. 33 N., R. VI E., sec. 7). FIGURE 2. Plagioclase in an olivine diabase, polysynthetic twin (No. 15430, one mile west of Hogan).

PLATE XV. FIGURE 1. Glassy diabase-porphyrite, showing the light plagioclase crystals in a dark, glassy back-ground, X 30, (No. 15057); from big dike on left bank of river at the Silver mines. FIGURE 2. Melaphyre, showing relation of feldspar crystals to the glass of the groundmass, X 30, (No. 15011) Tin mountain.

PLATE XVI. FIGURE 1. Olivine diabase, X 10; augite in light pink, olivine in pale green, iron oxide in black, feldspar in white (No. 15262). FIGURE 2. Augite changing to hornblende, X 30, (No. 15052, Tp. 33 N., R. V E., sec. 4).

PLATE XVII. FIGURE 1. Melaphyre, showing augite crystal with a central core of glass filling the space of a negative crystal; section cut approximately parallel to the basal plane, so that the cleavage lines are plainly shown, X 30, (No. 15012) Tin mountain. FIGURE 2. Augite twin crystal with a solid border of dark hornblende around both members, X 20.

PLATE XVIII. FIGURE 1. Orthoclase phenocryst with granophyric border. FIGURE 2. Diabase-porphyrite, phenocryst of quartz badly corroded and with a rectionary rim formed around it, X 30.

PLATE XIX. FIGURE 1. Feldspar enlargements, central orthoclase crystal surrounded by a broad band of solid clear feldspar many times as large; parent crystal darker than the new growth, having been rendered partially opaque by decomposition; two parts are oriented exactly alike, X 44, (granite No. 364, Tp. 33 N., R. V. E., sec. 10). FIGURE 2. Orthoclase crystal showing secondary enlargement; parent phenocryst with its crystallographic faces well developed and its cleavage lines plainly shown, some of which pass through into the new portion, X 16, (from granite No. 364, Tp. 33 N., R. V E., sec. 10).

PLATE XX. FIGURE 1. Orthoclase crystal with a secondary zone partiallyenclosing it, the material of which is oriented with the parent crystal, which has been greatly corroded before the secondary growth took place (from No. 302, blue granite at Syenite). FIGURE 2. Twinned orthoclase crystal with granophyric border of secondary growth, in which the twinning is continued (from granite No. 15181, Tp. 33 N., R. IV E., sec. 11).

PLATE XXI. FIGURE 1 Corroded orthoclase crystal with a rod-like crystal within, the outer end of which has a granophyric secondary enlargement; larger crystal also with a slight enlargement around the lower part, X 30, (from granite No. 15180, Tp. 33 N., IV E., sec. 11). FIGURE 2. Typical micropegmatite (from granite at Shut-in east of Ironton).

PLATE XXII. FIGURE 1. Quartz porphyry, in which the quartz of the groundmass for a considerable distance is oriented with the central phenocryst, and with feldspar grains indenting the same, X 30, (from granite No. 15034, Tp. 33 N., R. IV E. sec. 1). FIGURE 2. Quartz-porphyry, in which the quartz of the groundmass for some distance around is oriented with the central crystal, shown in rhomboidal section, X 60, (from granite No. 15230, Tp. 33 N., R. IV E., sec. 32).

PLATE XXIII. FIGURE 1. Quartz crystal corroded into a shape similar to an anchor; quartz grains and quartz in the groundmass near by oriented with the central corroded crystal, X 60, (from granite No. 15230, Tp. 33 N., R. IV E., sec. 32). FIGURE 2. Quartz phenocryst with hornblende granules collected around it, X 30, (from granite No. 15496, west quarry at Skrainka).

PLATE XXIV. Polished specimen of granite-porphyry, showing numerous feldspar phenocrysts (from No. 15572, Gabriel & Buford quarries, southwest of Cornwall).

PLATE XXV. FIGURE 1. Orthoclase phenocrysts, corroded in a groundmass of very fine-grained porphyry, X 30, (from porphyry No. 15396, Tp. 33 N., R. III E., Sec. 6). FIGURE 2. Quartz-orthoclase porphyry, showing phenocrysts of quartz and orthoclase, all of which are rounded by magmatic corrosion, X 10, (from porphyry No. 15071, Tp. 33 N., R. IV E., Sec. 14).

PLATE XXVI. FIGURE 1. Grain of iron oxide in porphyry, with a belt of fine grains of the same mineral enclosing it, but leaving a narrow zone of colorless groundmass between the two, X 30, (from No. 15682, Tp. 31 N., R. V E., Sec. 32). FIGURE 2. Spherulitic texture, in which iron oxide grains are arranged radially around the center of the spherules, X 30, (from No. 15628, near Annapolis).

PLATE XXVII. FIGURE 1. Poecilitic structure in fine-grained porphyry, X 60, (from No. 15268, Tp. 34 N., R. III E., Sec. 26). FIGURE 2. Border line between an included fragment of quartz-orthoclase porphyry on the right and the fine-grained groundmass on the left; inclusion not water-worn (from same thin section as is shown in plate XXX, figure 2).

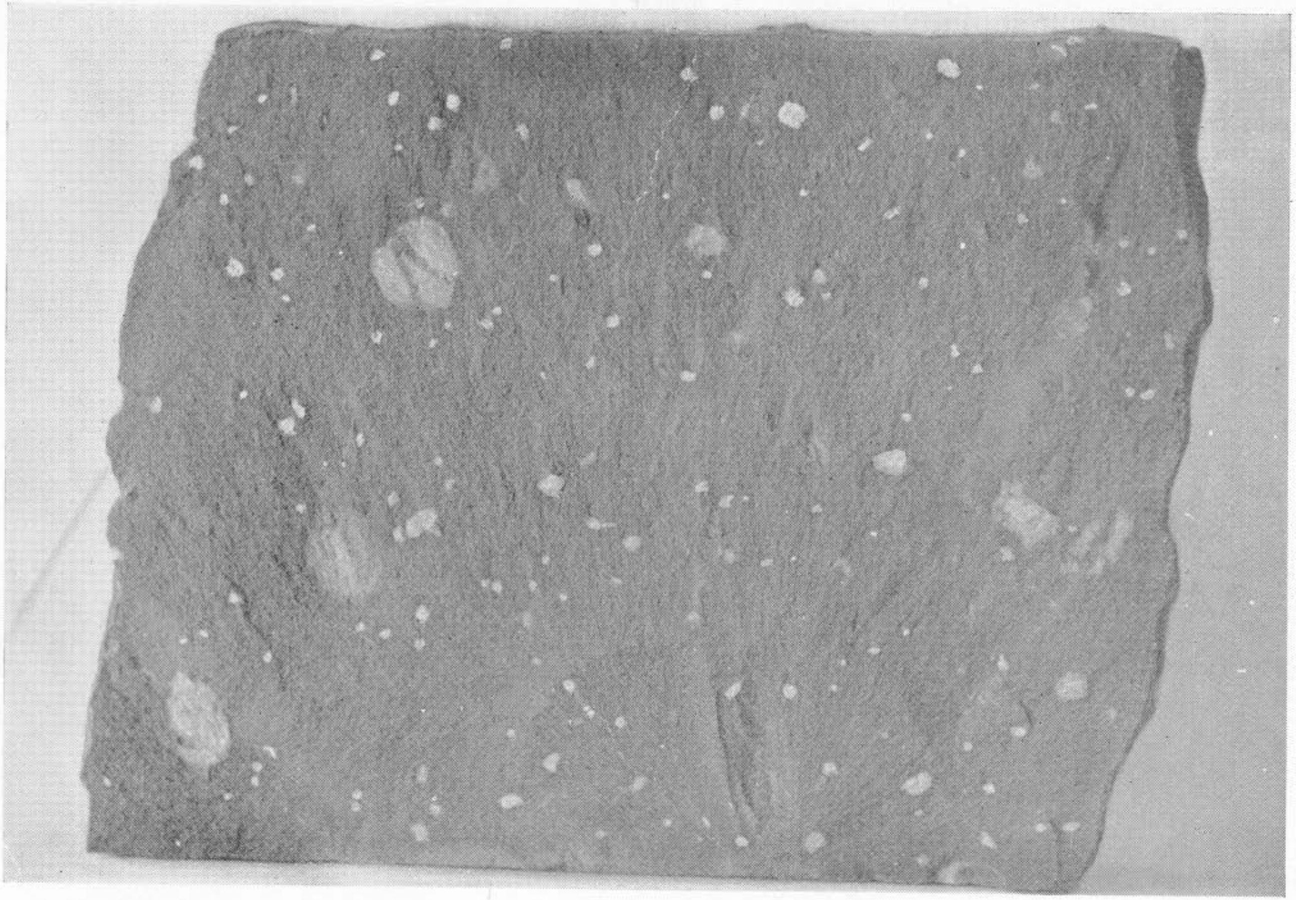
PLATE XXVIII. FIGURE 1. Brecciated porphyry, showing flowage lines well-developed (from south side of Cedar hill). FIGURE 2. Porphyry, showing banded structure due to flowage of magma (from porphyry hill in east edge of Annapolis, near the May quarry).

PLATE XXIX. Porphyry, showing flowage lines and included fragments (from No. 15552, Tp. 32 N., R. VI E., Sec. 19).

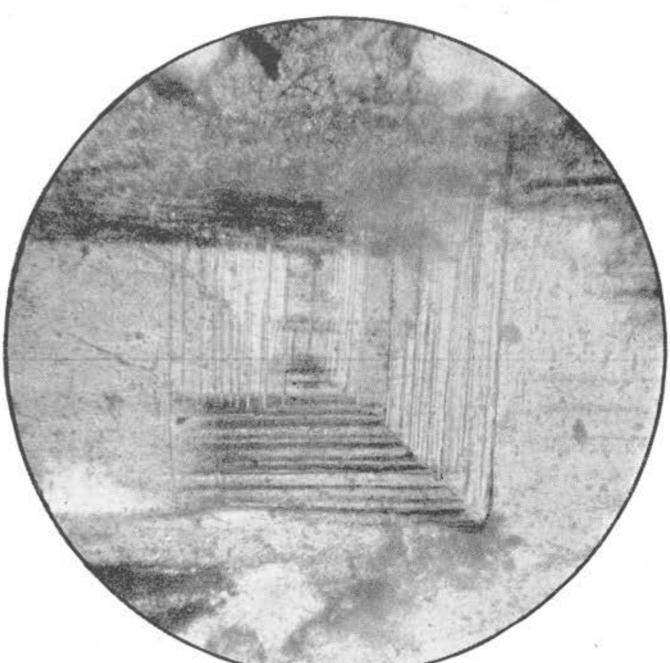
PLATE XXX. FIGURE 1. Thin section of porphyry, showing flowage lines, phenocrysts and included fragments, around which the flowage lines pass, X 8, (from No. 15552, Tp. 32, R. VI E., Sec. 19). FIGURE 2. Thin section, showing included fragment and many phenocrysts; particular attention is directed to the quartz grains around border of large included fragment, for they are partly embedded in it and partly in the groundmass, X 8, (from No. 15215, Tp. 33 N., R. IV E., Sec. 33).

PLATES.

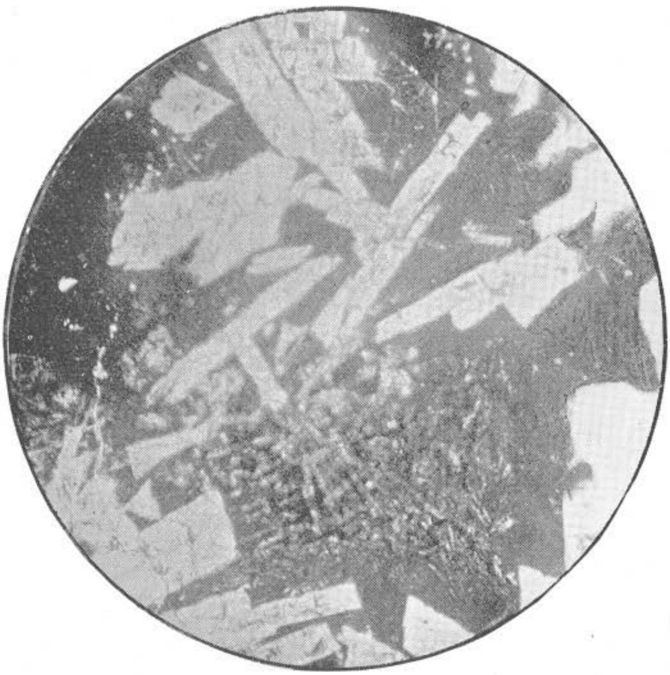
DIABASE-PORPHYRITE, SHOWING THE TEXTURE.



QUARTZ-DIABASE-PORPHYRITE.



THIN SLICES OF OLIVINE DIABASE.



GLASSY DIABASE-PORPHYRITE, AND MELAPHYRE.

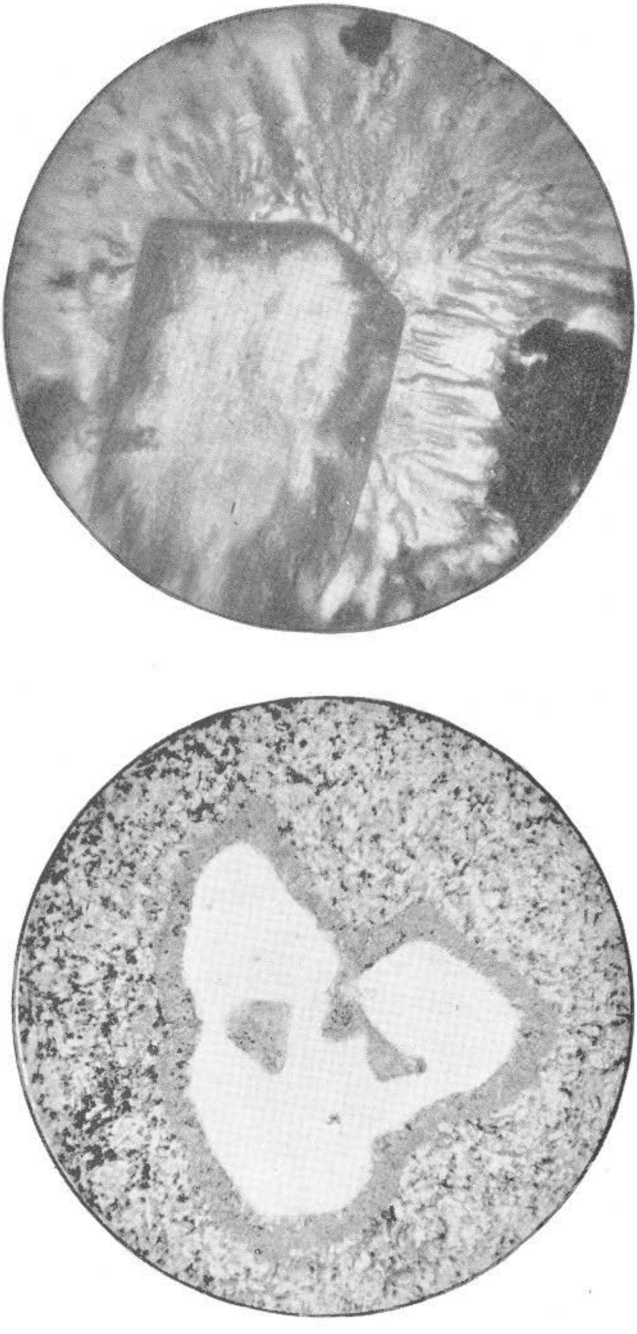
1.

2.

A. Hoen & Co. Lith.

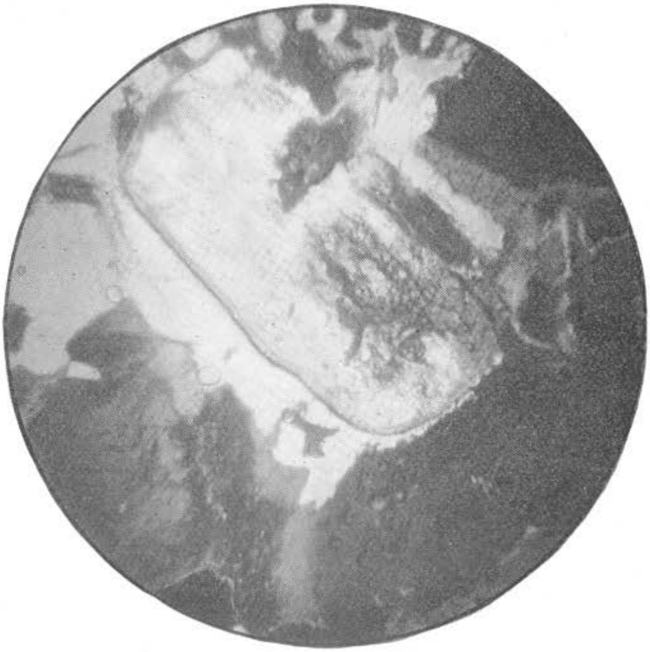
THIN SECTIONS OF DIABASE.

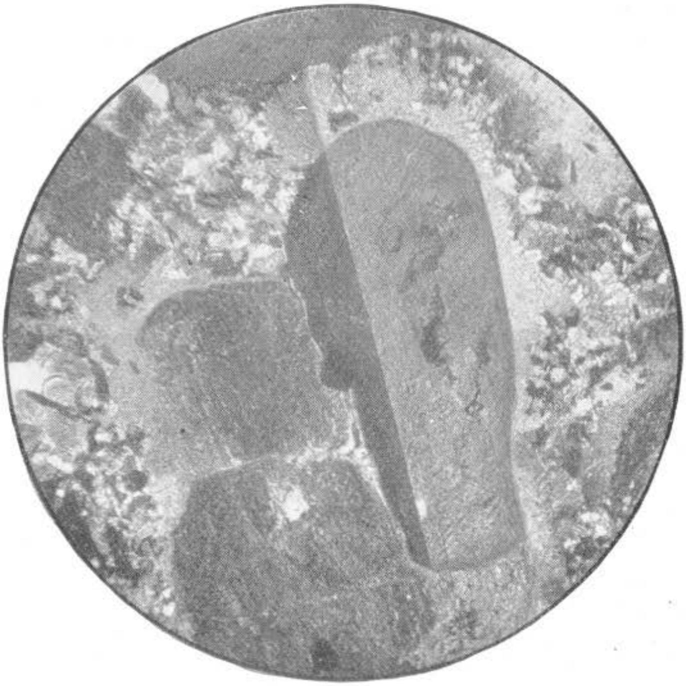
MELAPHYRE AND AUGITE TWIN.



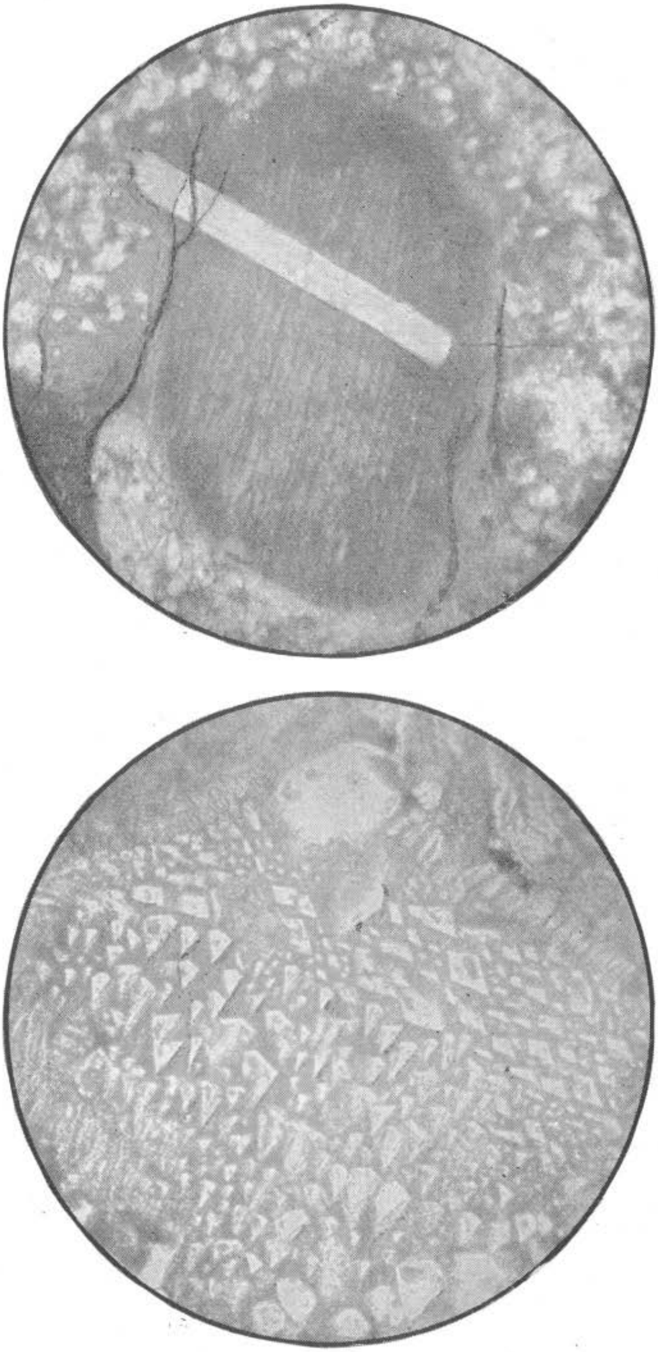
DIABASE-PORPHYRITE, PHENOCRYSTS.

FELDSPAR ENLARGEMENTS.

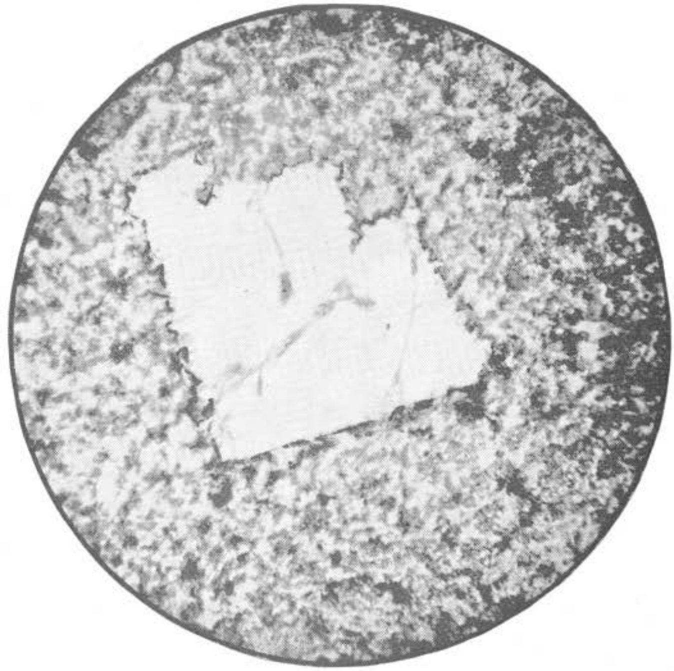


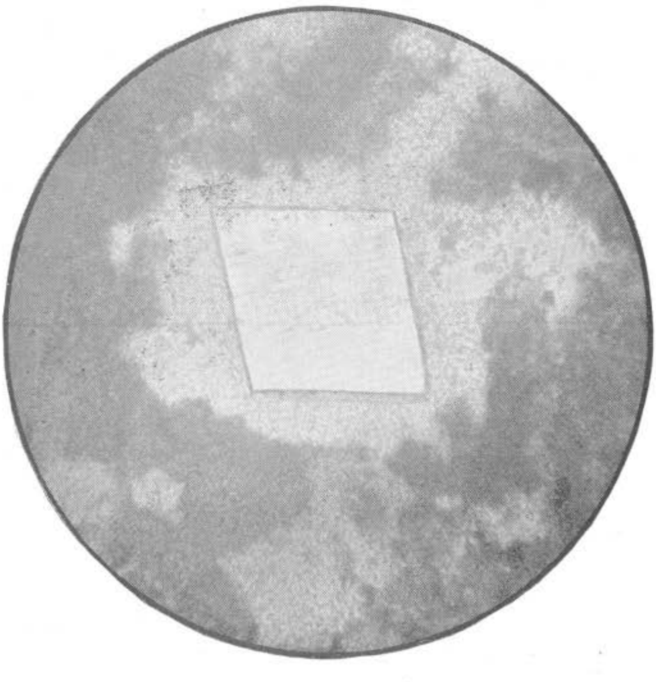


SECONDARY ENLARGEMENT OF ORTHOCLASE.

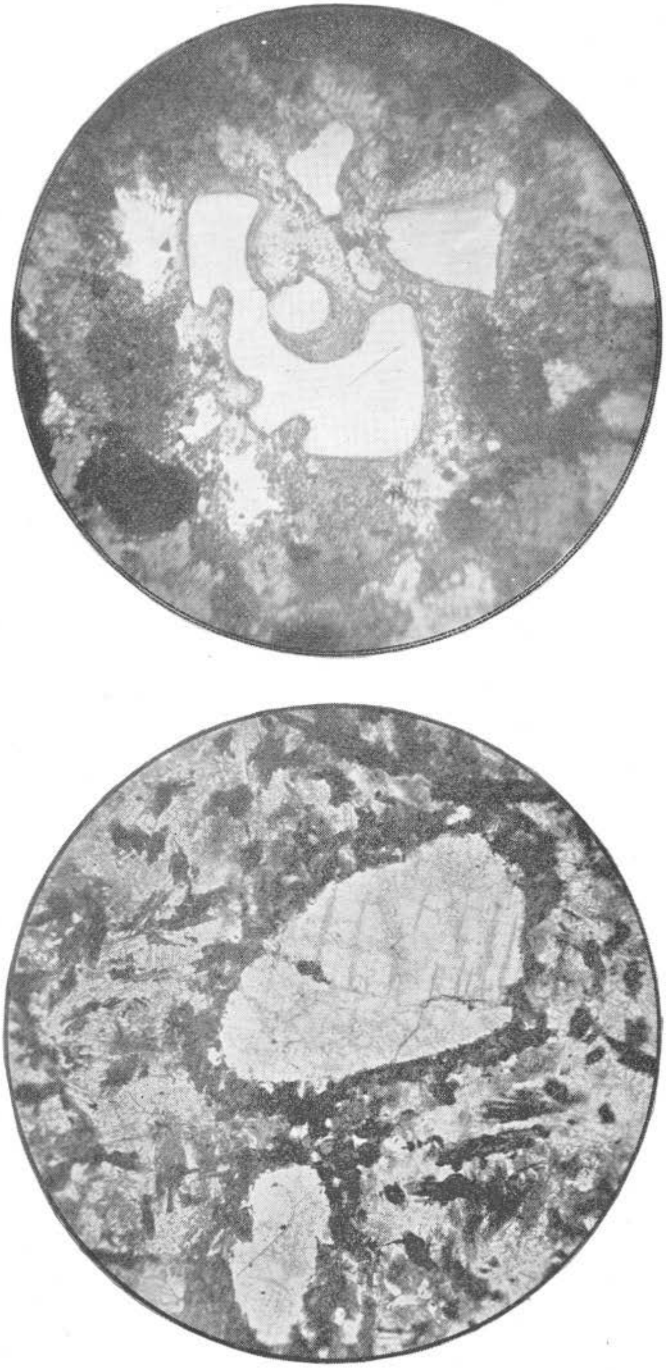


CORRODED ORTHOCLASE, AND MICROPEGMATITE.

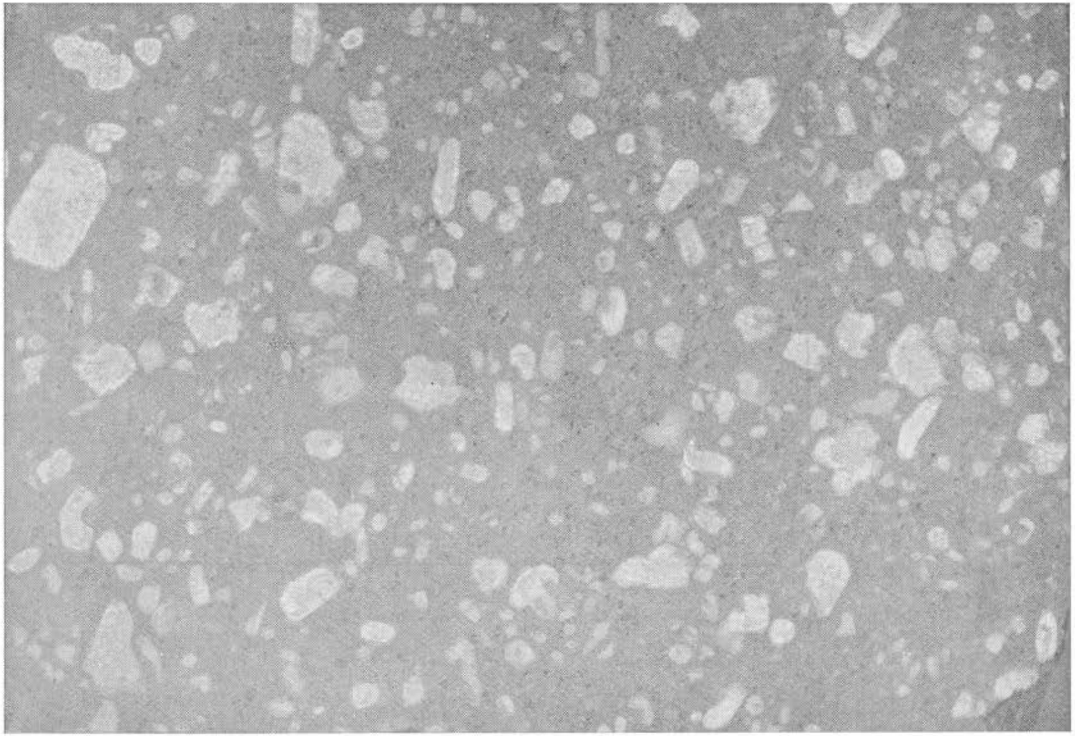




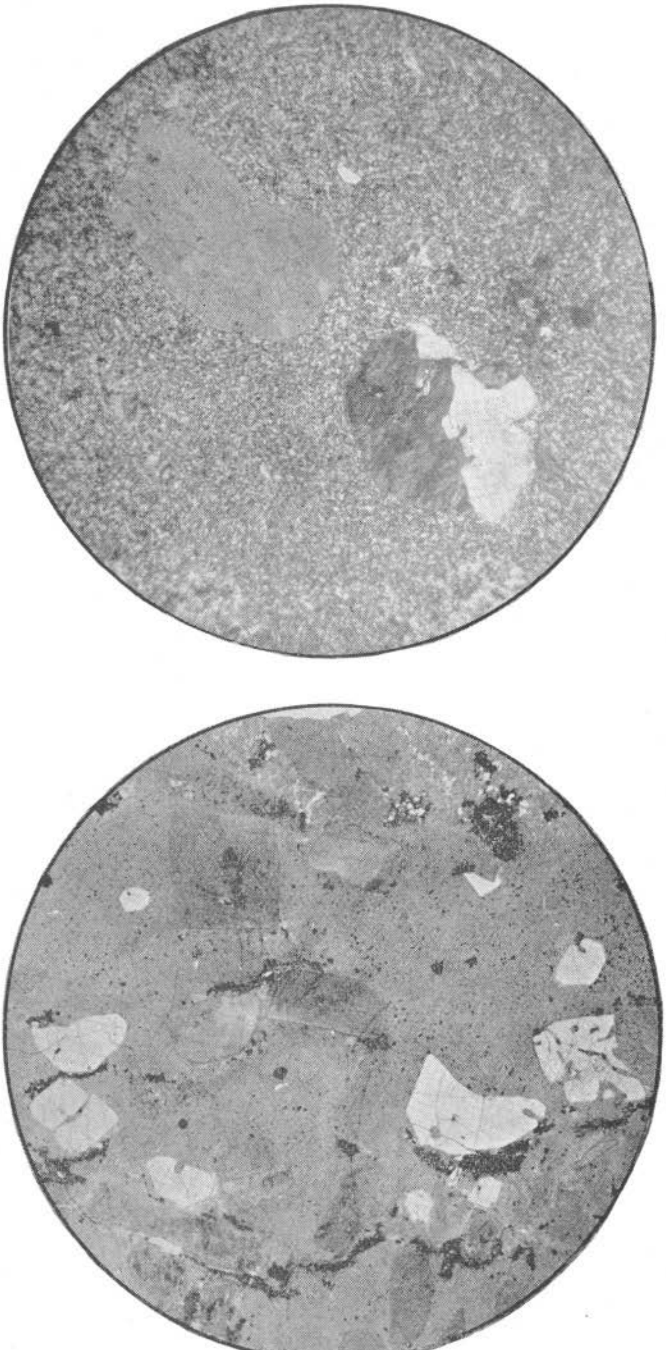
QUARTZ-PORPHYRY SECTIONS.



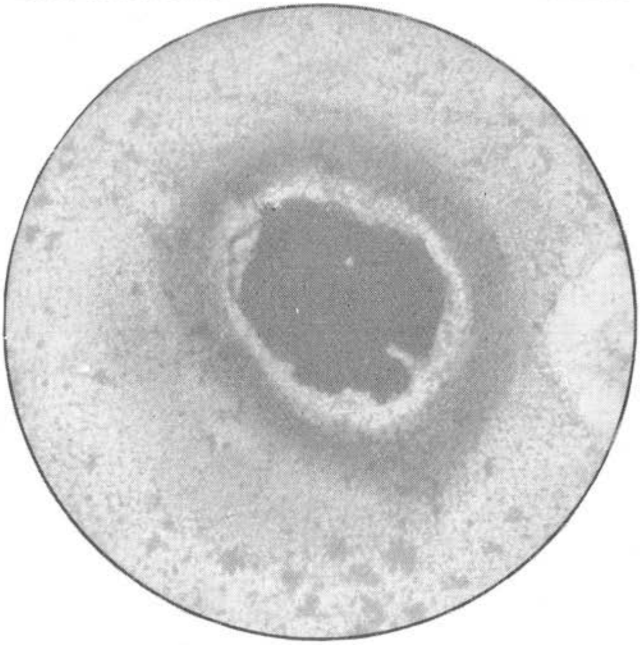
QUARTZ PHENOCRYSTS.

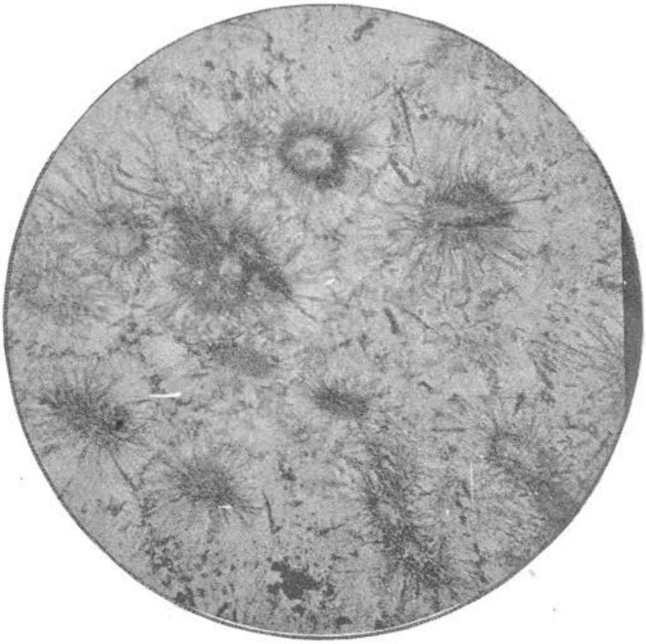


GRANITE-PORPHYRY, POLISHED SURFACE.

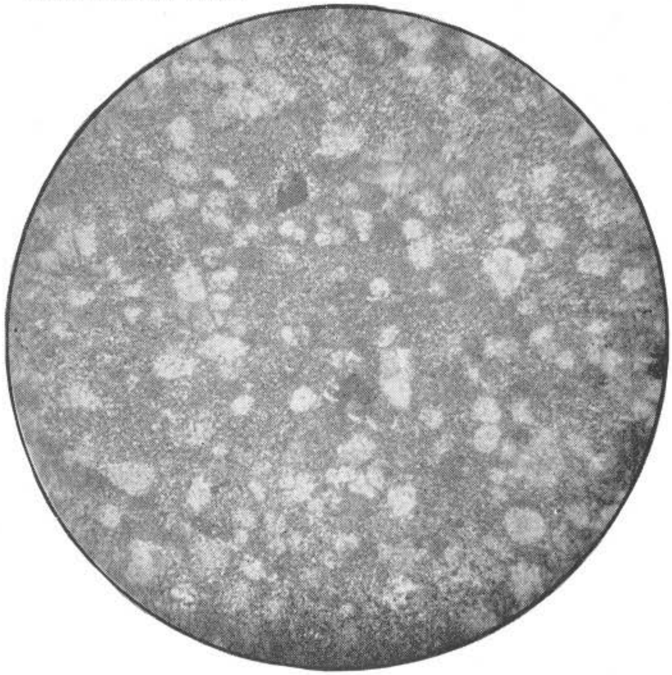


ORTHOCLASE PHENOCRYSTS, CORRODED.

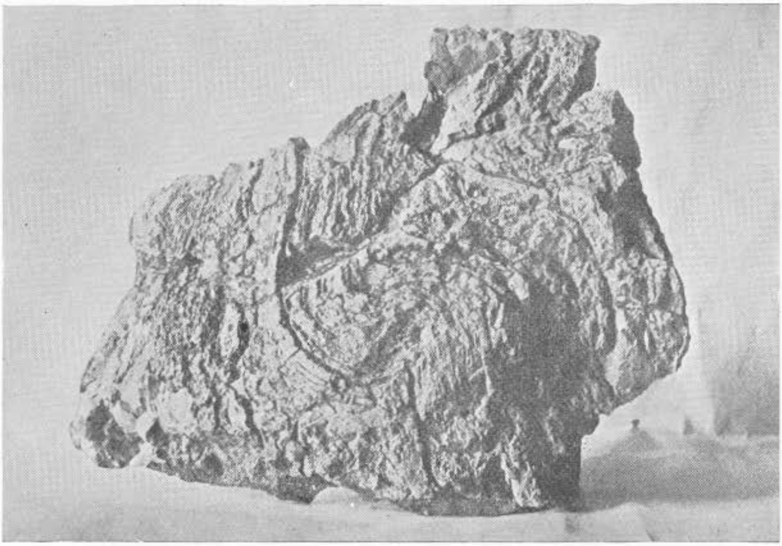




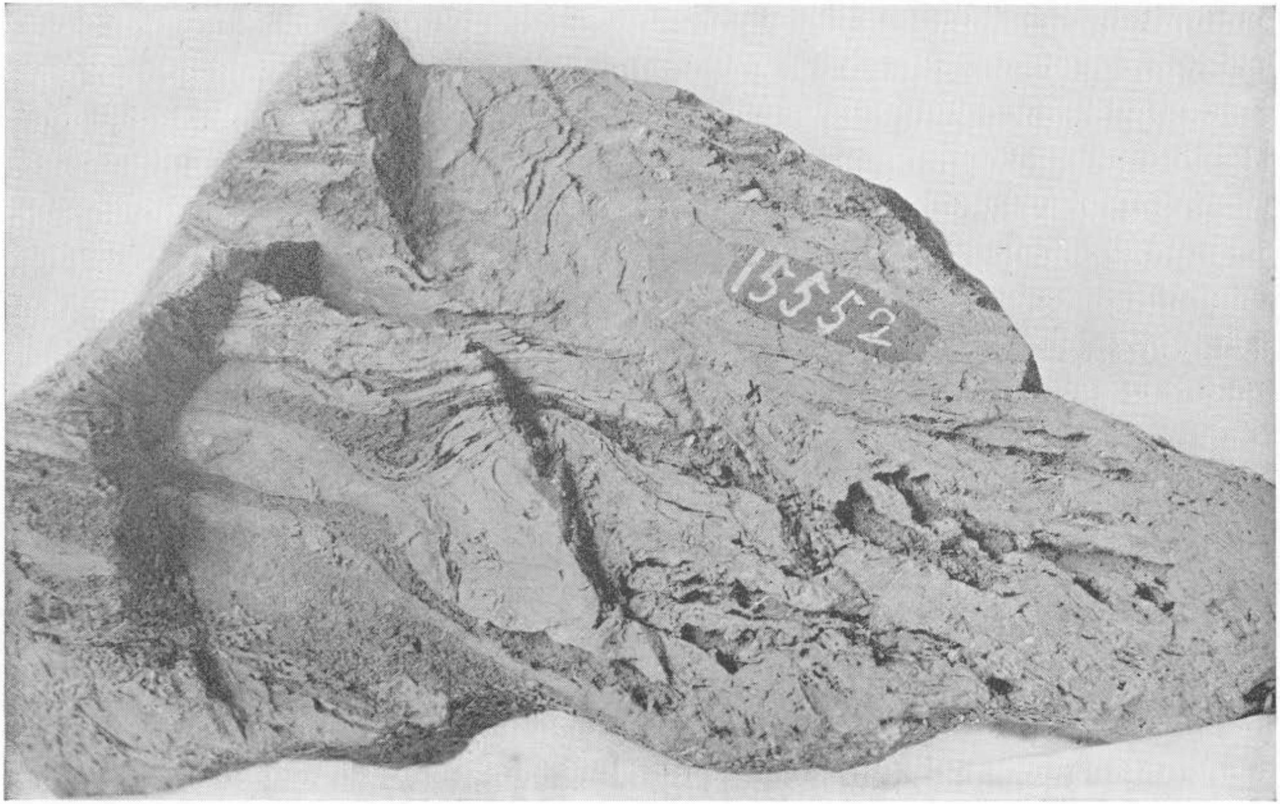
PORPHYRY SECTIONS, WITH IRON OXIDE.



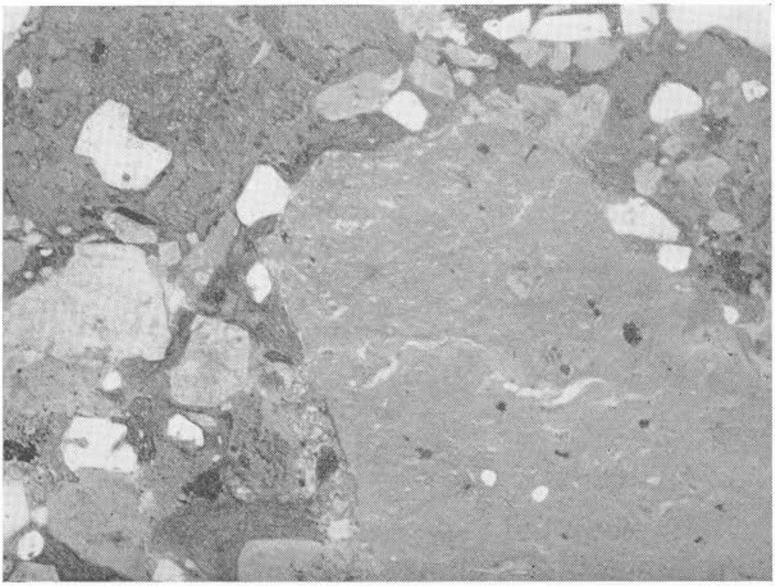
POECILITIC TEXTURE; AND INCLUSIONS.



BRECCIATED PORPHYRY, SHOWING FLOWAGE.



PORPHYRY, SHOWING FLOWAGE LINES.



THIN SECTIONS OF PORPHYRY, SHOWING FLOWAGE LINES.

DICTIONARY OF ALTITUDES OF MISSOURI

BY

CURTIS FLETCHER MARBUT.

DICTIONARY OF ALTITUDES

BY

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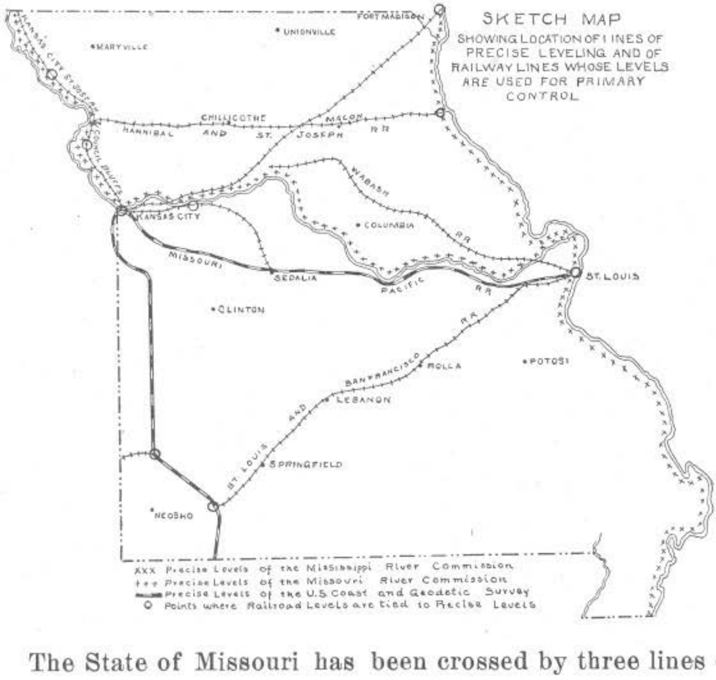
HYPSOMETRY OF MISSOURI.

An accurate knowledge of the elevations in the different parts of a region is of widespread scientific and practical interest. In the beginning of the inquiry regarding the hypsometry of Missouri, it was stated that "it was a subject which has never received exact investigation. The elevations of different points in the State were only approximately determined, and the distribution of the zones of equal altitudes was in no way defined. In connection with the detailed mapping it becomes necessary to know, with reasonable exactness, the relative elevations of various points in the State which are included within the areas mapped. The datum to which all such elevations are referred is the mean sea level. The primary base lines are the lines of precise leveling of the Mississippi and Missouri River Commissions along the respective streams, and the trans-continental line of the United States Coast and Geodetic Survey which traverses the State. The secondary base lines are the lines of leveling for the various railways, where constructed or surveyed throughout the State, as embodied in their profiles or level-books. As the methods by which railroad leveling is done are far less exact than the precise leveling of the government surveys, errors in the determination of altitudes frequently occur, and in order that their results may be used, the errors must be detected and eliminated." For these purposes, profiles or lists of elevations along all the various railroads have been obtained. These have been compared at their intersections, and any discrepancies which were detected were inquired into and corrected.

This having been done, and all the various lines adjusted, a network of lines of level throughout the State is obtained upon which to base all mapping with reasonable confidence.

The hypsometric features of the State have received more or less attention for several years past. During this period many valuable data have been brought together, and the work is now sufficiently complete to present the matter in tabular form, accompanied by a sketch map of the State on which are given the several lines of exact leveling. The adjustment of the various railroad levels of the different systems, and their reduction with reference to mean sea level through the lines of precise leveling, has resulted in many changes in the records as originally noted in profiles.



The State of Missouri has been crossed by three lines of precise levels, each run by a different organization, but all under the auspices of the United States government. The Mississippi River Commission has carried a line from tide water on the Gulf of Mexico, up the Mississippi river along the eastern border of the state. The Missouri River Commission has extended the line from one of the Mississippi River Commission benches, near the mouth of the Missouri river, up the latter stream across the state to Kansas City, and northward along the western boundary. The United States Coast and Geodetic Survey has run a line entirely across the state from St. Louis to Kansas City—this being part of a transcontinental line starting from mean tide-water of the Atlantic ocean, at Sandy Hook, New Jersey. From Kansas City a line has been carried southward along the western side of the state, and continued to Ft. Smith, Arkansas. The levels run by the two river commissions followed the rivers, and their bench-marks are generally located on or near the flood-plains of these streams, though in the most important towns and cities located on the river bluffs permanent bench-marks were established on the uplands. The elevations of various railroad tracks on bridges crossing these rivers, and of railway stations located near the lines of levels, were also determined. These are the only points established by the Federal organizations that are incorporated in the accompanying tables. They are not numerous, but each one is valuable as a check for a great many stations on a line of railroad, one of which is thus tied to a system of precise levels. In the following tables each station thus determined is noted.

The line of precise levels run by the United States Coast and Geodetic Survey from St. Louis to Kansas City followed the main line of the Missouri Pacific railway. From St. Louis to Jefferson City the bench-marks were located on bridges and other points on or near the track, but in no case, so far as is known, was the track at any station tied to the line of levels; but from the latter place westward this was done at most of the stations. Over the western part of the railroad, therefore, the elevations of all stations, unless otherwise noted in the table, are determined with a considerable degree of accuracy. The figures that are given, however, are the result of field computations only, and are subject to slight modification when finally revised.

From Kansas City southward, along the western boundary of the State, the line run by the Coast Survey follows the Kansas City, Fort Scott and Memphis railway from Kansas City to Harrisonville, in Cass county, on the Lexington and Southern division of the Missouri Pacific railway. From there to Carthage, Mo., the latter road was followed. From Carthage the St. Louis and San Francisco railroad was gone over through the main line to Monett, and thence southward over the Arkansas division of the same road to Ft. Smith, in Arkansas. This line was run during the season of 1894.

The elevations furnished to the Missouri Geological Survey by the Coast Survey and the Mississippi River Commission were referred to the St. Louis city directrix as a datum. In all cases 413 feet have been added to reduce them to the tide-water base. The elevations furnished by the Missouri River Commission are referred to mean tide of the Gulf of Mexico at Biloxi, Miss. According to the levels of the Mississippi River Commission, the St. Louis city directrix is 412.71 feet above mean tide. In each case 0.29 feet have been added to the elevations furnished by this organization, to refer them to the same datum as those given by the Coast Survey and Mississippi River Commission.

The elevation of the St. Louis city directrix, as determined by the levels of the Coast Survey, above mean tide of the Atlantic ocean, at Sandy Hook, New Jersey, is a little more than 413 feet; that of the Mississippi River Commission above mean tide on the Gulf of Mexico is 412.71 feet; so that 413 has been adopted merely to have a whole number, and also to strike a mean between these two determinations. The elevations, therefore, given in the following tables are to be considered in reality as referred to the St. Louis city directrix rather than to the tide-water; but that point is considered to be 413 feet above tide.

The elevations of points furnished by the Mississippi River Commission are not to be considered of the same value as those of their permanent bench-marks — the points here used being points on the railroad track at points which were not determined as accurately as the permanent benches. In a letter concerning this matter, the secretary of the commission says that they are probably within one-half foot of the correct elevation. There is no direct statement from the Missouri River Commission to the effect that the same is true of the points furnished by that organization; but since, as in the other case, these points are not permanent bench-marks, they may be considered in the same light.

The location of the lines of precise leveling is such that almost every railway within the State is tied directly to one of these at one or more points, and those that are not directly tied to the precise level lines are connected with them indirectly over a short distance of some other road. The determination by the precise level parties of the elevation of well-known points in the principal cities of the State, and the fact that the railroads center there, has been a favorable circumstance in furnishing two or three points for adjustment to these lines.

In tabulating the various elevations, two series have been made — one according to the railroad system, and the other alphabetically by towns. The arrangement of the stations under the roads on which they are located is adopted, in order that the data upon which the correction of the various railroad elevations is based may be given along with the list of elevations that were adjusted by the same data. The corrections were made not individually but in series, the same correction being in many cases applied to all the stations on one line of road. It appeared that in order to give the work its greatest value, the whole of the data should be given, so that in case more complete or different data should ever become available, it might be used intelligently. In the arrangement of the stations alphabetically, only the revised elevations are given, for convenience in general reference.

The collection of the railroad material used was begun by Mr. Leo Gluck, while an assistant on the corps of the Missouri Geological Survey. Most of the original profiles and lists of elevations were obtained by him before Mr. Marbut took up the work. Some of this material was copied by Mr. Gluck from the profiles of the roads in the offices of the chief engineers, and a considerable portion of the rest was prepared by the engineers themselves from their own data and sent to the Survey. At the time Mr. Marbut took up the subject the material was nearly all at hand. Nothing, however, had been done regarding the adjustment of the different lines, nor were the exact elevations of any of the roads at points of intersection with other lines calculated, except in a very few instances. Without these it would have been impossible to adjust the levels of the various roads and reduce them to a common datum. Additional information on these points was furnished by the chief engineers of the different roads, generally through correspondence. In all cases the attempt has been made not to allow any error to creep in with the later elevations (those of the railroad crossings), which might arise through a reference to a different datum, or from the earlier and later elevations being taken from a different series. When such has seemed to be the case, the matter has generally been referred back to the road with the request that particular attention be given it.

In the revision of the various railroad elevations, a few of the lines whose elevations seemed to be determined with considerable accuracy have been considered lines of reference, and the elevations on other roads crossing them have been made to conform to them. These roads are: The main line and the Lexington & Southern division of the Missouri Pacific railway; the main line of the St. Louis & San Francisco railway; the main line of the Wabash railway, from St. Louis to Brunswick; the Hannibal & St. Joseph railway, and the Kansas City. St. Joseph & Council Bluffs railway. The data upon which the elevations of the stations on these roads depend, and the weight of this in each case, are given in the note accompanying the list of elevations of each road.

The Chicago, Santa Fe & California railway may be considered in the same group, though no roads have been made to agree with it, excepting the St. Louis & St. Joseph and the

Hannibal & St. Joseph. In the latter instance another column of elevations of Hannibal & St. Joseph stations is given at the same time, in which the elevations do not agree with the Santa Fe figures; and where other roads are made to agree with the Hannibal & St. Joseph, the elevations of the latter list are used. The reason for not causing the elevations of the last mentioned road to agree with those of the Santa Fe is that from a comparison with those of the Wabash and Chicago, Burlington & Kansas City railways there is reason to believe that the figures of the Santa Fe line at its crossing of the Hannibal & St. Joseph track are not of the same series of elevations as those of the stations on the same road. The position of the crossing was given at a later date than the stations. The elevations of the stations agree very closely with the results of precise leveling at Kansas City and at Fort Madison, Iowa. In like manner the list of Hannibal & St. Joseph elevations agrees very well with the results of precise leveling at the opposite ends of the line at the cities of Hannibal and St. Joseph.

It would have been impossible to have done the work without the assistance of the chief engineers of the various railroads. This aid has been freely given, and in many cases extra effort has been made by these gentlemen to get the data into as good shape as possible before transmitting it. They have been patient and courteous, even under repeated requests for information. In no case whatever has any information asked for been refused, if it was possible to give it.

The Survey is under special obligations to the following gentlemen: Lieut. J. C. Sanford, secretary of the Missouri River Commission; Capt. Carl F. Palfrey, former secretary, and Lieut. Geo. A. Zinn, present secretary of the Mississippi River Commission; Prof. T. C. Mendenhall, formerly superintendent of the Coast and Geodetic Survey, and Gen. W. W. Duffield, present superintendent of the same organization. The following engineers: Mr. James W. Way, Missouri Pacific railway; Mr. L. F. Goodale, Chicago, Burlington & Quincy

lines in Missouri; Mr. Charles I. Brown, St. Louis & San Francisco; Mr. D. Boutecon, Kansas City, Ft. Scott & Memphis; Mr. James Dun, Atchison, Topeka & Santa Fe; Mr. W. S. Lincoln, Wabash; Mr. H. C. Draper, Chicago & Alton; Mr. B. B. Brayton, Chicago, Rock Island & Pacific; Mr. H. Fernstrom, Chicago, St. Paul & Kansas City; Mr. D. J. Whittemore, Chicago, Milwaukee & St. Paul; Mr. J. G. Collins, Kansas City, Pittsburg & Gulf; Mr. A. B. Thruston, Missouri, Kansas & Texas; Mr. A. C. Goodrich, Keokuk & Western; and Mr. H. G. Kelley, St. Louis & Southwestern.

From the following railroads no data could be obtained: Omaha & St. Louis, Quincy, Omaha & Kansas City, Kansas City, Osceola & Southern, St. Louis, Cape Girardeau & Ft. Smith, Greenfield & Northern, St. Louis & Hannibal, and that part of the Kansas City, Pittsburg & Gulf railway between Joplin and the state line of Arkansas. C. R. K.

MISSOURI PACIFIC SYSTEM.

MAIN LINE.

The elevations of the main line of the Missouri Pacific railroad are taken from the profiles of the road in the chief engineer's office in St. Louis. The profile elevations are given in feet above the city directrix of St. Louis, to which are added 413 feet of mean sea level. The revised elevations west of Jefferson City are those determined by the U. S. C. and G. Survey, and are the result of the field computations of the line run from Jefferson City to Kansas City in the summer of 1890. The elevation is that of the ground in the center of the track, excepting that at Kansas City, which is the top of the rail on A., T. & S. F. track, in front of center of Union depot.

East of Jefferson City, the railway elevations, determined by adding 413 feet to profile elevations, are checked at Grand avenue station, by the St. Louis City levels, which are 5 feet lower than the railway elevations. This amount is subtracted from each of the railway elevations from this point to Jefferson City, where the position of the ground between the rails, as determined by the Coast Survey, is 454.14 feet, while that of the top of rail, determined as before, is 454.50 feet. If correction were made for the height of the rail, the Coast Survey figures would be the same as the railway elevation. West of Jefferson City, no correction is made for top of rail, the Coast Survey determination alone being given (unless otherwise stated), which is of ground between the rails. In some cases the ground is built up in the middle of the track to very near the height of the rails, while in others it is level with the top of the tie.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
St. Louis directrix	413.00	413.00	St. Louis
St. Louis, Grand avenue (revised elevation determined by city street department)	458 80	458.34	"
Tower Grove	490.30	489.80	"
Howard	454.80	454.30	"
Cheltenham (revised elevation determined by city street department	452.30	452.60	"
Benton	469.90	469.40	"
Sutton	483.00	482.50	"
Laclede	459.50	459.00	"
Fairview	491.10	490.60	"
Webter	536.00	536.00	"
Glendale	598.70	598.20	"
Oakland	615.30	614.80	"
Woodlawn	635.20	634.70	"
Kirkwood	634.80	634.30	"
Rose Hill	617.00	617 00	"
Barrett	511.20	510.70	"
Meramec	428.20	427.70	"
Castlewood	430.00	430.00	"
St. Paul	439.90	439.40	"
Glencoe	435.90	435.40	"
Eureka	464.90	464 40	"
Allen	507.00	506.50	"
Pacific	463.50	463.00	Franklin

Location.	Altitude—mean sea level. R. R. elevat'n	Altitude—mean sea level. Revised elevat'n	County.
Gray Summit (top of hill)	636 00	635.50	Franklin
Labadie	494.30	493.80	"
Boles	483.50	483.00	"
South Point	488.50	488.00	"
Washington	490.00	489.50	"
Newport	495.90	495.40	"
New Haven	508.25	507.75	"
Etlah	510.70	510.20	"
Berger	511.20	510.70	"
Hermann	516.30	515.80	Gasconade
Gasconade	527.40	526.90	"
Morrison	527.70	527.20	"
Chamois	535.70	535.20	Osage
St. Auberts	539.20	538.70	"
Isbell	546.20	545.70	"
Bonnot Mills	544 30	543.70	"
Osage City	552.50	551.80	Cole
Jefferson City (revised elevation determined by the U. S. C. and G. S.)	555.00	454.14	"
Scott	587.00	587.11	Cole
Elston	685 00	684.58	"
Centretown	848.75	848.49	"
California	888.75	888.51	Moniteau
Moniteau	898.00	897.93	"
Tipton	922.00	921.35	"
Crossing, Boonville branch	924.90	924.25	"
Syracuse	913.00	913.98	Morgan
Otterville	713.75	714.93	Cooper
Smithton	887.50	887.43	Pettis
Sedalia	891.50	888.38	"
Dresden	821.25	820.83	"
Lamonte	863.50	......	"
Knob Noster	794.00	791.50	Johnson
Montserrat	799.75	798.23	"
Warrensburg	830.50	828.77	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Centreview	870.00	869.91	Johnson
Holden	848.00	849.24	"
Kingsville	904.50	907.71	"
Strasburg	844.00	846.42	Cass
Pleasant Hill	853.50	854.53	"
Greenwood	910.50	910.20	Jackson
Lee Summit	1042.00	1041.14	"
Little Blue	789.75	855.15	"
Crossing, C. & A.		1016.90	"
Independence	951.18	948.78	"
Springs	847.68	845.28	"
Rock Creek	750.00	752.25	"
Big Blue	746.00	748 00	"
Cecil	743.50	745.00	"
Crossing, C., M. & St. P	742.49	744.00	"
Kansas City	748.00	749.51	"

MISSOURI PACIFIC RAILWAY—LEXINGTON BRANCH.

The railroad elevations of stations on the Lexington branch of the Missouri Pacific railway were copied from a list of elevations referred to the St. Louis City directrix obtained in the chief engineer's office at St. Louis—413 being added to refer them to tide-water. The exact elevation of the point where this road leaves the main line at Sedalia was probably not determined. A condensed profile was examined, but the probable error in determining exact elevations from it is large. At the other end of the loop, however, the point of junction is believed to be accurately determined. By a comparison of profiles it was calculated that a point marked Pacific on the Lexington branch was the same as Independence of the main line. The elevation of the latter point (ground between the rails) was determined by the Coast Survey, to which were added 0.33 feet to cause the figures to read from top of rail.

Another check on these elevations is furnished by the Missouri River Commission at Wellington, and also at the bridge east of Wellington. These are the only checks that have been obtained. A correction of each elevation is made eastward from the most easterly of the Missouri River Commission's checks by the amount of that correction, though it is small (0.40 feet), and the railroad elevations may be considered as reliable over this part of the line as the revised elevations.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Lexington Junction (from condensed profile)	864.50	864.10	Pettis
Mile-post 190	877.50	877.10	"
B. M. 220, 9th pole east of 191st mile-post	874.50	874.10	"
Mile-post 191	887.50	887.10	"
Gentry	864.75	864.35	"
Mile-post 192	857.00	856.60	"
Georgetown	837.50	837.10	"
Mile-post 193	760.50	760.10	"
Mile-post 194	741.50	741.10	"
East end of bridge No. 117	730.75	730.35	"
Mile-post 195	767.50	767.10	"
Mile-post 196	830.50	830.10	"
Mile-post 197	832 75	832.35	"
East side of section-house	824.00	823.60	"
Mile-post 198	825.75	825.35	"
Mile-post 199	815.00	814 60	"
Hughesville, east end of depot	818.00	817.60	"
Mile-post 200	790.00	789.60	"
Mile-post 201	790.75	790.35	"
East side of bridge No. 118	765.50	765.10	"
Mile-post 203	808.50	808.10	"
Mile-post 204	775.50	775.10	"
Houstonia, east end of depot	749.50	749.10	"
Mile-post 205	767.50	767.10	"
Mile-post 206	745.50	745.10	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Mile-post 207	715.50	715.10	Pettis
County line, Pettis and Saline	667.00	666.60	
East side of bridge No. 120	657.50	657.10	Saline
Mile-post 209	722.50	722.10	"
Mile-post 210	706.75	706.35	"
Sweet Springs, east end of depot	674.75	674.35	"
Mile-post 211	674.50	674.10	"
Davis creek, east side of bridge No. 122	667.00	666.60	"
Mile-post 212	671.50	671.10	"
Mile-post 213	711.25	710.85	"
Mile-post 214	741.75	741.35	"
Mile-post 215	753.80	753.40	"
County line, Saline and Lafayette	757.50	757.10	
Mile-post 216	770.00	769.60	Lafayette
Mile-post 217	787.75	787.35	"
Mile-post 218	764.00	763.60	"
Mile-post 219	776.00	775.60	"
Concordia, east end of depot	783.25	782.85	"
Mile-post 220	792.00	791.60	"
Mile-post 221	805.25	804.85	"
Mile-post 222	846.50	846.10	"
Mile-post 223	801.50	801.10	"
Mulky creek, east side of bridge No. 123	743.00	742.60	"
Mile-post 224	742.50	742.10	"
Mile-post 225	793.25	792.85	"
Mile-post 226	749.50	749.10	"
Aullville, east end of depot	722.25	721 85	"
Mile-post 227	713.00	712.60	"
East end of bridge No. 124	714.00	713.60	"
Bridge No. 125, east side	720.25	719.85	"
Mile-post 228	723.75	723.35	"
Bridge No. 126, east side	727.25	726.85	"
Mile-post 229	742.00	741.60	"
Mile-post 230	765.50	765.10	"
Mile-post 231	810.50	810.10	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Higginsville, east end of depot	819.25	818.85	Lafayette
Mile-post 232	815.50	815.10	"
Mile-post 233	819.50	819.10	"
Mile-post 234	761.75	761.35	"
Bridge No. 128, east side	757.00	756.60	"
Page City, east end of depot	775.00	774.60	"
Mile-post 235	768.25	767.85	"
Bridge No. 129, east end	695.25	694.85	"
Mile-post 237	694.25	693.85	"
Mile-post 238	701.75	701.35	"
Trestle No. 130, east side	702.75	702.35	"
Bridge No. 131, east side	703.00	702.60	"
Mile-post 239	707.50	707.10	"
Trestle No. 132, east end	707.25	706.85	"
Trestle No. 134, east end	713.00	712.60	"
Mile-post 240	721.75	721.35	"
Mile-post 241	737.50	737.10	"
Bridge No. 138, east end	746.00	745.60	"
Mile-post 242	757.75	757.35	"
Trestle No. 139, east end	805.50	805.10	"
Trestle No. 139, west end	807.50	807.10	"
Lexington, east end of new depot	813.00	812.60	"
Road bridge over track, east side	815.50	815.10	"
Mile-post 244	803.75	803.35	"
Trestle No. 140, east end	757.75	757.35	"
Trestle No. 141, east end	712.75	712.35	"
Trestle No. 142, east end	692.50	692.10	"
Myrick	691.75	691.35	"
Mile-post 246	691.50	691.10	"
Mile-post 247	695.50	695.10	"
Mile-post 248	698.50	698.10	"
Trestle No. 144, east end	697.00	696.60	"
Trestle No. 145, east end	697.00	696.60	"
B. M. 259 U. S. B. M. 194, Mo. River Com	696.11	695.72	"
Trestle No. 147, east end	695.75	695.35	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
B. M. 260=U. S. B. M. 195, Mo. River Com	693.75	693.23	Lafayette. .....
Trestle No. 148, east end	692.50	692.10	" ....
Mile-post 250	695.50	695.20	" ....
Trestle No. 150, east end	705.25	705.05	" ....
Mile-post 251	714.00	713.90	" ....
Wellington, east end of depot	719.00	719 00	" ....
Trestle No. 151, east end	719.75	719.72	" ....
Trestle No. 152, east end	729.00	728.94	" ....
Trestle No. 153, east end	738.75	738.66	" ....
Trestle No. 155, east end	737.75	737.63	" ....
Mile-post 252	735.50	735.35	" ....
Trestle No. 156	712.00	711.82	" ....
Mile-post 253	696.75	696.54	" ....
Trestle No. 158, east end	696.75	696.51	" ....
Waterloo, east end of depot	700.50	700.23	" ....
Mile-post 255	710.00	709.70	" ....
Trestle No. 160	710.00	709.67	" ....
Napoleon, east end of depot	709.50	709.14	" ....
Trestle No. 161	711.00	710.61	" ....
Trestle No. 162	729.00	728.58	" ....
Mile-post 257	716.00	715.55	" ....
Trestle No. 164, east end	707.00	706.58	" ....
Levasy, east end of depot	711.00	710.49	Jackson ....
Mile-post 260	710.00	709.46	" ....
Trestle No. 165, east end	714.50	713.97	" ....
Mile-post 261	719.75	719.15	" ....
Trestle No. 166, east end	722.25	721.62	" ....
Mile-post 262	735.00	734.34	" ....
Mile-post 263	745.50	744.81	" ....
Buckner, east end of depot	749.50	748.78	" ....
Trestle No. 167, east end	739 75	739.00	" ....
Trestle No. 169, east end	734.50	733.78	" ....
Mile-post 265	737.00	736.19	" ....
Mile-post 266	740.75	739.91	" ....
Trestle No. 170, east end.	752.00	751 13	" ....

Location	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Lake City, east end of depot	750.50	749.60	Jackson
Mile-post 267	745.75	744.82	"
Mile-post 268	744.50	743.54	"
Bridge No. 173, Little Blue, east end	747.25	746.26	"
Mile-post 270	747.50	746.48	"
Mile-post 271	750.50	749.45	"
Mile-post 272	768.50	767.42	"
Trestle No. 175, east end	774.50	773.39	"
Mile-post 273	790.00	788 86	"
Pixley	814.75	813.58	"
Mile-post 274	815.75	814.55	"
Mile-post 275	889 00	887.77	"
Trestle No. 179, east end	973.50	972.24	"
Mile-post 276	983.25	981.95	"
Independence, east end of depot	998.50	997.17	"
B. M. 219	946.85	945.49	"
Independence, west side of station, main line.	950.50	949.11	"

MISSOURI PACIFIC RAILWAY—LEXINGTON & SOUTHERN DIV.

The railroad elevations were taken from the profiles in the chief engineer's office at St. Louis. The revised elevations were calculated by making certain corrections in accordance with the determinations of the U. S. C. & G. Survey. The elevations marked with the asterisk (*) were determined by that survey, and those of points between its results were changed by adding to or subtracting from the railroad figures. The Coast Survey determinations refer to the ground in the middle of the track in front of the stations. They are the result of field computations only, and are subject to a slight revision.

The railroad elevations on the profile are referred to the St. Louis city directrix as a base, and 413 feet have been added to refer the base to tide-water. These figures refer to top of rail, but all revised elevations refer to ground in middle of track in front of station.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Pleasant Hill, center of depot (from main line Missouri Pacific)	853.50	854.53	Cass
Bridge No. 1, Middle Big creek	853.50	854.00	"
Gowdy	852.50	853.00	"
Crossing, K. C., Ft. S. & M.	853.90	855.00	"
Bridge No. 2, South Big creek	859 50	860.00	"
Bridge No. 4	884.25	885.00	"
Ore	972.50	973.00	"
Bridge No. 8	984.50	984.00	"
Bridge No 10	940.50	940.00	"
Crossing, Osage division Missouri Pacific	918.50	918.00	"
Crossing, K. C., O. & S.	897.50	897.00	"
Crossing, K. C., Ft. S. & M.	896.00	896.00	"
Bridge No. 13, Muddy creek	872.50	872.00	"
Bridge No. 14, Glenn branch	896.00	896.00	"
Lone Tree (revised elevation is from U. S. C. & G. Survey determination)	874.50	874.00	"
Bridge No. 19, Tennessee creek	809.50	810.00	"
Bridge No. 21	810.25	811 00	"
Grand river bridge	803.50	805.00	"
Bridge No. 26.	799.50	801.00	"
Archie (revised elevation determined by U. S. C. & G. Survey)	831.00	833.00	"
County line, Bates and Cass	843 50	844.00	"
Bridge, Mormon creek	803.50	802.00	Bates
Bridge No. 32, Deer creek	835.50	832.00	"
Adrian (revised elevation determined by U. S. C. & G. Survey)	873.50	870.00	"
Bridge No. 38, Bone Fork creek	850.50		"
Bridge No. 40.	869.75		"
Passaic (revised elevation determined by U. S. C. & G. Survey)	876.50	863.00	"
Bridge No. 42, Wild Cat creek	866 50	853.00	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Bridge No. 44	904.50	891.00	Bates
Butler (revised elevation determined by U. S. C. and G. Survey)	862.50	849.00	"
Bridge No. 46	814.00	801.00	"
Bridge No. 48	840 50	827.00	"
St. Louis & Emporia railway (Mo. P.)	775.75	763.00	"
Monteith	774.50	771.00	"
Bridge No. 53	772.25	760.00	"
Bridge No. 55	770.50	758.00	"
Athol	775.25	763.00	"
Bridge, Marais des Cygnes river	771.50	759.00	"
Ovid, north end of switch	777.00	766.00	"
Bridge No. 62	795.50	784.00	"
Bridge No. 64	780.75	769.00	"
Rich Hill (revised elevation determined by U. S. C. and G. Survey)	806.50	795.00	"
K. C., Ft. S. & M. R'y.	806.50	795.00	"
Ft. Scott & Eastern R'y Jc	806.50	795.00	"
Bridge No. 68	806.75	795.00	"
Bridge No. 69, Muddy creek	782.50	771.00	"
County line, Bates and Vernon	818.50	807.00	
Bridge No. 72	800.50	789.00	Vernon
Bridge No. 75	808.50	797.00	"
Bridge No. 78, Willow branch	765.70	754.00	"
Arthur	778.50	767.00	"
Bridge No. 80, Little Osage river	761.50	750.00	"
Horton	782.50	772.00	"
Bridge No. 83	769.25	759.00	"
Bridge No. 85, Marmaton river	764.00	754.00	"
Bridge No. 88	776.50	766.00	"
Bridge No. 91	792.00	782.00	"
Bridge No. 93	820.50	810.00	"
Wales	849.50	839.00	"
Bridge No. 97	857.75	847.00	"
Nevada	870.25	860.00	"
Nevada and Minden railway	889.00	879.00	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Nassau	891.50	881.00	Vernon
Milo	890.00	880.00	"
Bridge No. 106	923.75	913 00	"
Sheldon (revised elevation determined by U. S. C. & G. Survey)	926.50	916.00	"
County line, Vernon and Barton	944 50	933.00	
Irwin (revised elevation determined by U. S. C. & G. Survey)	984.25	972.00	Barton
Bridge No. 109	981.00	969.00	"
Bridge No. 111	974.75	962.00	"
Bridge No. 113, Muddy creek	958.50	946.00	"
Lamar (revised elevation determined by U. S. C. & G. Survey)	976.75	964.00	"
Crossing K. C., Ft. S. & M. (revised elevation determined by U. S. C. & G. Survey)	964.75	951.00	"
Bridge No. 117	944.75	931.00	"
Bridge No 119	941.50	928.00	"
Bridge No. 121, Pettis creek	941.50	928.00	"
Carleton	956.50	943.00	"
Bridge No. 125	940.75	928.00	"
County line, Barton and Jasper	927.75	915.00	"
Bridge No. 127, Coon creek	926.25	914.00	Jasper.
Jasper (revised elevation determined by U. S. C. & G. Survey)	961.50	949.00	"
Bridge No. 129, Possum creek	943.50	931.00	"
Bridge No. 131	964.00	952.00	"
Bridge No. 134, Dry fork	938.00	926.00	"
Carytown (revised elevation determined by U. S. C. & G. Survey)	933.75	921.00	"
Bridge No. 137	976.50	964.00	"
Bridge No. 140, North fork	968.50	956.00	"
Carthage	986.50	974.00	"

MISSOURI PACIFIC RAILWAY—JEFFERSON CITY, BOONVILLE & LEXINGTON, AND BOONVILLE BRANCHES.

These railway elevations were copied from a list obtained in the chief engineer's office at St. Louis, and referred to the St. Louis city directrix, 413 being added to connect them with tide-water. As checks on these figures, the elevations of the main line of the Missouri Pacific were had at Tipton, where the Boonville branch crosses it—the elevation of Waverly determined by the Missouri River Commission and that of Myrick from the Lexington branch levels. There is some doubt here about exact location of points. "Myrick" is written opposite station 0 of the J.C., B. & L. line, but 0 may indicate the point at which this line departs from the Lexington branch, and this place is several hundred feet west of Myrick station. The exact elevation of this point, by the Lexington branch levels, is not known, but is assumed to be the same as Myrick. If 0 of the J. C., B. & L. line is Myrick, or at Myrick depot, there is an error of about one foot — the J. C., B. & L. line being about that much lower than the Lexington branch line. Elevations are top of rail.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Versailles	1020.50	1019.75	Morgan
Low Point	988.50	987.75	"
Glenstead	976.50	976.75	"
Akinsville	994.50	993.75	"
Fortuna	959.50	958.75	Moniteau
Crossing main line Mo. P.	925.00	924.25	"
Vermont	827.50	826.75	Cooper
Bunceton	772.75	772.00	"
Petersburg	679.75	679.00	"
Speed	659.25	658.50	"
Billingsville	649.00	648.25	"
Boonville, east end of depot	603.25	602.50	"

Location	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Boonville, western limit	598.70	597.98	Cooper
Bridge, Lamine river.	605.00	604.56	"
Turley	605 00	604.84	"
Bridge, Blackwater river	615.00	615.12	"
Head block, east of Blackwater depot	603.00	603.40	"
County line—Cooper and Saline	615.50	616.18	
Bridge, Salt fork	608.50	609.46	Saline
Bridge, Brush creek	613.50	614.74	"
Bridge, Salt fork	618.00	619.52	"
Napton	637.00	638.80	"
Bridge, Salt fork	635.00	637.08	"
Crossing C. & A. railroad	647.00	649.36	"
Bridge, Salt fork	653.45	656.09	"
Stanhope	663 00	665.92	"
Malta Bend	688.00	691.20	"
Grand Pass	661.75	665.25	"
County line—Saline and Lafayette	668.00	671.76	
Waverly	679.25	683.29	Lafayette
Edwards	673.00	676.50	"
Dover	677.10	680.23	"
Berlin	684.00	687.13	"
Bridge, Tobo creek.	683.25	686.48	"
Northrup, west switch	688 50	691.63	"
Myrick	688.22	691.35	"

MISSOURI PACIFIC RAILWAY—KANSAS & ARIZONA BRANCH.

The railway elevations for the Nevada & Minden, Kansas & Arizona and Lebanon branches, and St. Louis & Emporia and Ft. Scott & Eastern railways, were obtained from the profiles of these roads in the chief engineer's office at St. Louis. In all cases, the railway elevations were made to agree with that of the main line or branch from which it started. The same is true of the revised elevations. In the case of the Nevada & Minden railway, opportunity was presented for comparing its revised elevations with those of the main line of the K. C., Ft. S. & M. railroad at their crossing near Liberal. The N. & M. is checked by the Coast Survey levels at Nevada by way of the L. & S. division of the Mo. P. to the junction of the Nevada & Minden, and the K. C., Ft. S. & M. is checked by the Coast Survey determination of the elevation of that road at its crossing with the L. & S. division of the Mo. P. at Lamar. When the two roads are corrected to agree with these determinations respectively, and the correction applied to all the stations to their junction, they do not agree by about four feet. There are no means of determining which figure is the best, so they have not been changed. None of the other branches have any check beyond the starting point. Elevations are ground between the rails, excepting Lebanon branch, on which they are top of rail.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Holden station	848.00	849.24	Johnson
Point of departure K. & A. division	845.30	846.54	"
Bridge, Pine Oak creek	815.00	816.24	"
County line, Johnson and Cass	798.00	799.24	"
Bridge, Crooked creek	853.00	854.24	Cass
Bridge, Williams creek	909.00	910.24	"
Scheydler Gap	980.00	981.24	"
Harrisonville	910.25	911.49	"
Crossing, Mo. Pac. railroad	903.00	904.24	"
Bridge, Grand river	831.00	832.24	"
Freeman	852.50	853.74	"
Bridge No. 1, Pony creek	852.50	853.74	"
Bridge No. 2, Pony creek	863.00	864.24	"
Bridge No. 4, Pony creek	876.00	877.24	"
Bridge No. 6, Pony creek	895.00	896.24	"
State line	972.25	973.49	"

MISSOURI PACIFIC RAILWAY—NEVADA & MINDEN BRANCH.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Junction with Lexington & Southern.....	889.00	879.00	Vernon..........
Bridge No. 2......	878.00	868.00	" ....
Bridge No. 4..	804.00	794.00	" ....
Bridge No. 6..................	775.50	765.50	" ....
Bridge No. 11.....	778.00	768.00	" ....
Moundville..................	850.50	840.50	" ....
Bridge No. 17.......................................	843.00	833.00	" ....
Bridge No. 21.......	858.50	848 50	" ....
Bronaugh	897.00	887.00	" ....
Bridge No. 25.......................	887.00	877.00	" ....
County line, Vernon and Barton	880.50	870.50	....
Barton..	880.25	870.25	Barton...........
Bridge No. 32......................................	858.75	848.75	" ....
Bridge No. 37......................................	859.00	849.00	" ....
Pedro	902.00	892.00	" ....
Crossing K. C., F. S. & M........................	907.00	897.00	" ....
Bridge No. 39......................................	915.00	905.00	" ....
Bridge No. 41, Pigeon creek......	917.00	907.00	" ....
Crossing K. C., F. S. & M........................	977.00	967.00	" ....
Coal Spur...	974.00	964.00	" ....
Minden	960.00	950.00	" ....
State line, Missouri and Kansas.................	958.75	948.75	" ....

MISSOURI PACIFIC RAILWAY—LEBANON BRANCH.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Jefferson City (main line)	555.00	554.50	Cole
Russellville	879.50	879.00	"
Bridge, Morgan creek	702.50	702.00	"
Enon	691.00	690.50	"
Bridge, Enon creek	701.50	701.00	"
Bridge, South Moreau creek	711.30	710.80	"
Olean	746.50	746.00	Miller
Eldon	918.90	918.40	"
Aurora	913.00	912.50	"
Cooper	795.00	794.50	"
Bagnell, depot (1884)	579.50	579.00	"

ST. LOUIS AND EMPORIA RAILWAY.

Missouri Pacific, Junction	775.75	763.00	Bates
Bridge No. 4, Miami river	774.45	771.00	"
Bridge No. 7	818.75	805.00	"
Bridge No. 10	792.55	779.00	"
Bridge No. 13	786.55	773.00	"
Nyhart	786.55	773.00	"
Bridge No. 18	779.55	766 00	"
Bridge No. 21	779.05	766.00	"
Bridge No. 24, Marais des Cygnes river	783.05	770.00	"
Bridge No. 27, Walnut creek	783.05	770 00	"
Bridge No. 29	790.25	777.00	"
Foster	828.25	815.00	"
Bridge, Gillam creek	799.25	786.00	"
Bridge, Walnut creek	793.25	780.00	"
Wards	854.75	841.00	"
Yoakam	833.25	820.00	"
Kansas and Missouri line	809.75	796.00	"

KANSAS CITY & SOUTHWESTERN RAILWAY.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Cecil, main line Missouri Pacific	743.50	793.00	Jackson
Crossing, C. & A.	742.30	792.00	"
Crossing, Belt line	750.50	800.00	"
Crossing, K. C. & I. P.	751.75	801.25	"
Kansas City, 15th street	764.50	814.00	"
Manchester	754.75	804.25	"
Bridge, Blue river	750.50	800.00	"
Bridge, Blue river	758.50	808.00	"
Bridge, Brush creek	761.50	811.00	"
Crossing, K. C., C. & S (revised elevation taken from K. C., C. & S.)	793.50	843.00	"
Bridge, Indian creek	791.50	841.00	"
Red bridge	807.00	856.50	"
Martin City	870.50	920.00	"
State line, Missouri and Kansas	866.25	916.00	"

FT. SCOTT & EASTERN RAILWAY.

Connection with Lexington & Southern	806.50	795.00	Bates
Bridge, Mud creek	794.30	783.00	"
County line, Bates and Vernon	824.30	813.00	
Bridge, Willow creek	798.30	787.00	Vernon
Bridge, Reed creek	785.30	774.00	"
Metz	785.30	774.00	"
Bridge, Osage river	777.30	766.00	"
Wall Summit	865.40	854.00	"
Richards	846.05	835.00	"
Bridge, Cottonwood creek	806.30	795.00	"
Enoch	816.30	805.00	"
Bridge, Shiloh creek	794.30	783.00	"
State line, Missouri and Kansas	811.30	800.00	

ST. LOUIS, IRON MOUNTAIN & SOUTHERN—MAIN LINE.

The railway elevations of that part of the St. Louis, Iron Mountain & Southern line from St. Louis to Blackwell, were taken from the company's profile in the chief engineer's office at St. Louis. The datum point is 100 feet below the city directrix; 313 feet are added to refer to tide-water. The railway elevations were checked by the St. Louis city levels, at Stein street, in South St. Louis—these levels being 0.80 feet higher than those of the railway. This amount is added to each of the railway stations, from Ann street to Blackwell. From Blackwell to Hogan, the elevations were deduced from a profile in the Survey office, which was copied from the company's profile. The datum of the profile is the same as the list from St. Louis to Blackwell, and 313 has been added. The Stein street correction is carried southward from Blackwell, but reduced 0.10 feet at each station until it is reduced to zero at Blairsville. From there southward to the end of this part of the profile (Hogan), no correction is made. From Hogan southward to Poplar Bluff, the elevations were also copied from a list obtained in the engineer's office, to which is added 311, to make the stations read above tide-water, with the St. Louis directrix, as above, 413 feet A. T. This amount (311) was obtained by comparing these elevations with those on the profile from Blackwell to Hogan.

As before stated, the datum of this part of the profile is 100 feet below the St. Louis city directrix. On the profile, however, are inserted figures giving tide-water elevations of certain points which do not agree with any of the formerly accepted elevations of the St. Louis city directrix, and seem to have been determined from some other point. It is not known how these figures were obtained, and they have therefore not been used. The elevations of Neeleyville and State Line were read from the company's profile.

From Bismarck to Cornwall, on the Belmont branch, the railroad elevations were copied from the company's profile.

From Cornwall to Belmont they were taken from a list of elevations from the same source. They refer to tide-water, and have been corrected to read so that the St. Louis city directrix appears as 413 feet A. T. At Belmont the railroad levels are checked by the Mississippi River Commission levels of 1893, by which the railroad elevations are reduced 3.69 feet. This is distributed among the stations from Fredericktown to Belmont equally.

The elevations on the Cairo branch were checked by the main line figures at Poplar Bluff, and by the Belmont branch at the crossing at Charleston. The Jackson branch altitudes were compared with the Belmont branch station, where it joins the latter at Allenville. The Doniphan branch positions were compared with those of the main line at Neeleyville, the junction of the two. All elevations are of top of rail.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
St. Louis, Ann street	418.00	418.80	St. Louis
St. Louis, Dorcas street	418.55	419.30	"
Work-house	420.00	420.80	"
Mile-post 4	420.00	420.80	"
Mile-post 5	425.00	425.80	"
Carondelet	420.00	420.80	"
Mile-post 6	421.50	422.30	"
Stein street, city bench (revised elevation determined by city street department)	429.00	429.80	"
Docks	426.00	426.80	"
Mile-post 7	425.00	425.80	"
Bridge, River des Peres	421.00	421.80	"
Mile-post 8	421.00	421.80	"
Ivory	422.00	422.80	"
Barracks	418.50	419.30	"
Mile-post 10	417.00	417.80	"
Martigney creek	420 50	421.30	"
Mile-post 11	420.00	420.80	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Quarantine	417.00	417.80	St. Louis
Cliff Cave.	416.20	417.00	"
Mile-post 13	415.80	416.60	"
Mile-post 15	415.00	415.80	"
Mile-post 17	413.70	414.50	"
Meramec	414.50	415.30	"
Bridge, Meramec river	416.00	416.80	
Mile-post 20, from Plum street	414.50	415.30	Jefferson
Kimmswick	415.00	415.80	"
Sulphur Springs	410.00	410.80	"
Grand Glaze creek	412.00	412.80	"
Mile-post 24	411.00	411.80	"
Glenwood	411.00	411 80	"
Pevely	441.00	441.80	"
Baker	420.50	421.30	"
Crystal	422.00	422.80	"
Bailey	418.00	419.80	"
Mile-post 33	414.00	414.80	"
Hematite	437.00	437.80	"
Victoria	467.00	467.80	"
Mile-post 42	496.00	496 80	"
De Soto	497.00	497.80	"
Mile-post 44	567.00	567.80	"
Bridge, Big river	622.25	623.05	
Mile-post 51	591.00	591.80	St. Francois
Blackwell	592.00	592 80	"
Cadet	783.00	783.80	Washington
Mineral Point	864.00	864.65	"
Summit (top of hill)	985.00	985.55	"
Hopewell	898.50	899.05	"
Bridge, Big river, south end of trestle	775.05	775.35	"
Irondale	796.50	796.70	"
Scott switch	808.35	808.45	"
Blairsville	986.29	950.29	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Bismarck	1024.69	1024.69	St. Francois
Bridge, Charley creek	979.69	979.69	"
Iron Mountain	1076.60	1076.60	"
Middlebrook	1138.80	1138.80	Iron
Pilot Knob	951.00	951.00	"
Ironton	918.70	918.70	"
Bridge, south fork Stout creek	898.00	898.00	"
Arcadia	925.60	925.60	"
Tip Top (highest point of the track)	1198.00	1198.00	"
Hogan	889.50	889.50	"
Mile-post 100	778.50	778.50	"
Mile-post 101	762.00	762.00	"
Mile-post 104	693.00	693.00	"
Sabula	693.00	693.00	"
Annapolis	633.50	633.50	"
Mile-post 108	630.50	630.50	"
Bridge, Brushy creek	558.20	558.20	"
Bridge, Shaver branch	528.50	528.50	"
Mile-post 115	528.75	528.75	"
Bridge, Little Shaver branch	533.00	533.00	"
Des Arc	544.50	544.50	"
County line, Iron and Wayne	595.75	595.75	
Gad Hill	842.20	842.20	Wayne
Bridge, McKenzie creek	634.00	634.00	"
Irish Mountain Gap	634.00	634.00	"
Piedmont	501.00	501.00	"
Mill Spring	439.75	439.75	"
Bridge, Koon branch	418 50	418.50	"
Williamsville	392.50	392.50	"
Bridge, Hayne creek	394.50	394.50	"
Bridge, Black river	385.75	385.75	"
County line, Wayne and Butler	381.00	381.00	
Reeves	374.75	374.75	Butler
Mile-post 159	356 00	356.00	"

Location.	Altitude—mean sea level. R. R. elevat'n	Altitude—mean sea level. Revised elevat'n	County.
Hilliard.	356.00	356.00	Butler
Bridge, Black river.	357.00	357,00	"
Poplar Bluff	343.73	343.73	"
Neeleyville.	306.60	306.60	"
State line	296.90	296.90	"

ST. L., I. M. & S. R'Y—CAIRO BRANCH.

Poplar Bluff	343.73	343.73	Butler
Bridge, Black river	346.00	347.04	"
Ash Hills	333.83	333.78	"
Bridge, St. Francois river	339.40	339.30	
Dudley	355.00	354 85	Stoddard
Bridge, Lick creek	331 00	330.80	"
Dexter	374.97	374.72	"
Essex	301.00	300.70	"
Gray Ridge	298.00	297.65	"
Bridge, Castor river	307.50	307.10	"
Little River, depot	301.00	300.50	New Madrid
Sikeston	328.50	327.90	Scott
Bayou St. John	314.66	314.00	"
Bertrand	321.40	320.74	Mississippi
Charleston	324.25	323.59	"
Hough	319.50	318.84	"

ST. L., I. M. & S. R'Y—DONIPHAN BRANCH.

Neeleyville	306.60	306.60	Butler
Mile-post 4	306.10	306.10	"
Little Black river	308.10	308.10	Ripley
Varner	319.93	319 93	"
Mile-post 19	387.60	387.60	"
Doniphan	344.35	344.35	"

ST. L., I. M. & S. R'Y—BELMONT BRANCH.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Bismarck	1024.00	1024.69	St. Francois
Loughborough	920.00	920.69	"
DeLassus	890.00	890.69	"
Bridge, Wolf creek	832.00	832.69	"
Knob Lick	940.30	941.00	"
Bridge, Little St. Francois river (where track enters cut on south side)	739.00	739.69	Madison
Fredericktown	722.00	722.59	"
Cornwall	699.33	699.72	"
Marquand	570.00	570.19	"
Bessville	592.40	592.39	Bollinger
Glen Allen	458.00	457.79	"
Marble Hill	420.50	420.09	"
Laflin	387.10	386.49	"
White Water	365.00	364.19	Cape Girardeau.
Allenville	353.50	352.59	"
Delta	342.60	341 39	"
County line, Cape Girardeau and Scott	334.60	333.19	"
Morley	345.68	344.07	Scott
Blodgett	327.68	325.87	"
Diehlstadt	329.00	327.19	"
County line, Scott and Mississippi	327.68	325 67	"
Charleston	326.00	323.59	Mississippi
Crossing, Cairo branch St. L , I. M. & S	326.00	323.59	"
Crossing, St. L. S. W.	318.00	315.39	"
Henson	315.00	312.19	"
Belmont (revised elev. M. R. C. levels 1893)	313.00	310.00	"

ST. L., I. M. & S. R'Y—JACKSON BRANCH.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Allenville	353.50	352 59	Cape Girardeau.
County road (station 100)	339.50	338.04	"
County road (station 127)	357.70	336.24	"
Dutchtown	353 00	351.54	"
Gordonville	370.83	369.37	"
Jackson (depot)	429.50	428.04	"

ATCHISON, TOPEKA & SANTA FE SYSTEM.

CHICAGO, SANTA FE & CALIFORNIA RAILWAY—MAIN LINE.

The elevations of this line were copied from a list furnished by the chief engineer of the road, Mr. James Dun. They refer to mean sea-level, and are based upon the St. Louis city directrix as 413 feet. They were carried to Kansas City union depot through the Belt line. The elevations are top of rail at east end of depot. These figures, when corrected at Kansas City to agree with the Coast Survey determinations, are then carried by the railroad levels without other corrections to Ft. Madison, Iowa, where they agree with the Mississippi River Commission levels at that point to 0.444 feet. In both cases, that of the Coast Survey and the Mississippi River Commission, the St. Louis directrix is 413. The railroad profile (list) gives Ft. Madison as 521.831, which is corrected by subtracting 0.787, with a result of 521.044. The Mississippi River Commission elevation for Ft. Madison, St. Louis directrix being 413, is 107.6+413=520.600—the difference between the two lines being 0.444.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Dumas	558.798	558.011	Clark
Revere	674.723	673.936	"
Medill	705.340	704.553	"
Wyaconda	754.133	753.346	"
Gorin	701.083	700.296	Scotland
Rutledge	649.423	648.636	"
Baring	808.586	807.799	"
Kenwood	779 083	778.296	"
Hurdland	827.933	827.146	Knox
Gibbs	893.283	892.496	Adair
La Plata	914.574	913.787	Macon
Oliver	807.767	806.980	"
Elmer	731.809	731.022	"
Ethel	808.487	807.700	"
Hart	843.665	842.878	"
Bucklin	917.606	916.819	Linn
Crossing, H. & St. J	907.120	906.333	"
Marceline	858 633	857.846	"
Rothville	694.533	693.746	Chariton
Mendon	685.640	684.853	"
Dean Lake	659.923	659.136	"
Crossing, Wabash	680.853	680.066	"
Bosworth	748.825	748.038	Carroll
Newcomb	719.169	718.382	"
Carrollton	665.723	664.936	"
Palemon	680.433	679.646	"
Norborne	687.069	686.282	"
Hardin	693.723	692.936	Ray
Lexington Junction	694.799	694.012	"
Camden	708.723	707.936	"
Alfred	717.723	716.936	"
Sibley, low water in Mo. river (by Santa Fe)	683.890	....	Jackson
" " " (U. S. Eng.)	685.613	....	"
" high water " (Wallace)	723.013	....	"
"	783.723	782.936	"

Location.	Altitude—mean sea level. R. R. elevat'n	Altitude—mean sea level. Revised elevat'n	County.
Atherton	730.123	729.336	Jackson
Courtney	734 723	733.936	"
Crossing, C. & A	767.963	767.176	"
Big Blue Junction	747.523	746.736	"
Kansas City, union depot (revised elevation determined by the U. S. C. & G. Survey)	750.298	749.511	"

ST. LOUIS & SAN FRANCISCO RAILWAY—MAIN LINE.

The railroad elevations of all stations were copied from a condensed profile furnished by the company, on which the elevations of top of rail at stations were given in figures. The profile elevations were based upon the St. Louis city directrix, which at the time the road was built was supposed to be 428 feet A. T. The latest determinations make it about 413 feet A. T., and the elevations on the profile were reduced to that by subtracting 15 from each. The data for revising the railway elevations were obtained from the city levels of St. Louis and the levels of the U. S. Coast and Geodetic Survey.

Those points determined by the street department of St. Louis were reported by the street commissioner, and were referred to the city directrix as a datum. To each elevation, 413 was added to reduce to the tide-water datum. Those determined by the U. S. C. & G. Survey were furnished by the superintendent of the Coast Survey. They represent field computations only, and are subject to some revision. They refer to the ground in the middle of the road in front of the railway stations.

The elevation of the St. L. & S. F. track at Pacific was assumed to be the same as that of the Mo. P. Fractions of feet were dropped, and the elevations of the stations between Pacific and Tower Grove, a point determined by the city street department, were determined by adding 1 foot to each. Southwest of Pacific no check on the railroad elevations occurs until

Peirce City is reached. The Coast Survey elevation here is 3 feet less than the railway elevation. In going toward Pacific, three feet were subtracted from all stations from Peirce City to Lebanon, then two feet from stations between Lebanon and Arlington, then one foot to Coffeyton; beyond which the railroad elevations are unmodified to Pacific; from thence to St. Louis one foot is added.

The Coast and Geodetic Survey followed the Arkansas division of the St. L. & S. F. railroad from Monett southward to the state line, so the elevations of points on that division are corrected according to its work.

The railroad elevations on the Chadwick branch were not changed, excepting to agree with the present determination of the St. Louis directrix, on account of the lack of direct connection with the main line at Springfield. The railroad elevations refer to top of rail, and the Coast Survey elevations to ground in middle of track. The St. Louis street department elevations refer to top of rail also. There has been no attempt to correct for this small amount, about 4 inches, on account of the fact that railroad elevations are not exact enough to make the correction valuable.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
St. Louis, Grand avenue (revised from city levels)	460.00	*459.13	St. Louis
St. Louis, Chouteau avenue	471.00	....	"
Tower Grove (revised from city levels)	489.00	*488.00	"
Howard	454.00	455.00	"
Cheltenham	447.00	448.00	"
South Benton	465.00	466.00	"
Gratiot	468.00	469.00	"
Old Orchard	532.00	533.00	"
South Webster	603.00	604.00	"
Glendale	600.00	601.00	"
Oakland	605.00	606.00	"
Oak Ridge	603.00	604.00	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
South Kirkwood	613.00	614.00	St. Louis
Rose Hill	634.00	635.00	"
Meramec	425.00	426.00	"
Rankin	425.00	426.00	"
Southside	439.00	440.00	"
Mincke	441.00	442.00	"
Crescent	478.00	479.00	"
Eureka	460.00	461.00	"
Allenton	510.00	511.00	"
Pacific	462.00	463.00	Franklin
Catawissa	521.00	521.00	"
Robertsvillə	495.0C	495.00	"
Moselle	501.00	501.00	"
St. Clair	760.00	760.00	"
Anaconda	837.00	837.00	"
Stanton	865.00	865.00	"
Sullivan	966.00	966 00	"
Bourbon	947.00	947.00	Crawford
Coffeyton	1025.00	1024.00	"
Leasburg	1015.00	1014.00	"
Cuba Junct'on	1010 00	1009.00	"
Iron Ridge	1043.00	1042.00	"
Knobview	1055.00	4054.00	"
St. James	1083.00	1082.00	Phelps
Dillon	1085.00	1084.00	"
Rolla	1093.00	1092.00	"
Beaver	723.00	722.00	"
Newburg	706.00	705.00	"
Knotwell	694.00	693.00	"
Arlington	689.00	687.00	"
Jerome	694.00	692.00	"
Franks	970.00	968.00	Pulaski
Dixon	1189.00	1187.00	"
Hancock	1109.00	1107.00	"
Crocker	1128.00	1126.00	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Swedeborg	1116.00	1114.00	Pulaski
Richland	1142.00	1140 00	"
Stoutland	1168.00	1166.00	Camden
Sleeper	1219.00	1217.00	Laclede
Lebanon	1267.00	1265.00	"
Brush Creek	1304.00	1301.00	"
Phillipsburg	1424.00	1421.00	"
Conway	1405.00	1402.00	"
Niangua	1438.00	1435.00	Webster
Marshfield	1490.00	1487.00	"
Northview	1440.00	1437.00	"
Strafford	1481.00	1478.00	Greene
Lyman	1380.00	1377.00	"
Springfield	1348.00	1345.00	"
Nichols	1271.00	1268.00	"
Dorchester	1289.00	1286.00	"
Brookline	1288.00	1285.00	"
Republic	1314.00	1311.00	"
Billings	1369.00	1366.00	Christian
Logan	1375.00	1372.00	Lawrence
Aurora	1363.00	1360.00	"
Verona	1264.00	1261.00	"
Summit	1443.00	1440.00	"
Plymouth	1290.00	....	Barry
Peirce City (revised elevation determined by U. S. C. & G. Survey)	1200.00	1197.00	Lawrence
Berwick	1125.00	1122.00	Newton
Richey	1073.00	1070.00	"
Granby City	1032.00	1029.00	"
Neosho	1026.00	1023.00	"
Summit	1176.00	1173.00	"
Iron Switch	1097.00	1094.00	"
Dayton	962.00	959.00	"
Seneca	852.00	849.00	"

ST. LOUIS & SAN FRANCISCO RAILWAY—KANSAS BRANCH.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Peirce City (revised elevation determined by U. S. C. & G. Survey)	1200.00	1197.00	Lawrence
Wentworth (revised elevation determined by U. S. C. & G. Survey)	1232.00	1227.00	"
Talmage	1231.00	1226.00	Newton
Sarcoxie	1107.00	1104.00	Jasper
Reed	1120 00	1119.00	"
Knight	1087 00	1086.00	"
Carthage	941.00	940.00	"
Macy	1020.00	1019.00	"
Oronogo	936.00	935.00	"
Carl Junction	896.00	895.00	"
Smithfield	856.00	855.00	"
State line	846.00	845.00	"

ST. LOUIS & SAN FRANCISCO RAILWAY—SALEM BRANCH.

Cuba	1025.00	1009.00	Crawford
Halbert	722.00	706.00	"
Midland	724 00	708.00	"
Sankey	738.00	722.00	"
Steelville	760.00	744.00	"
Roswell	855.00	839.00	"
Eugenia	900.00	984.00	"
Highway	1025.00	1009.00	"
Keysville	905.00	889.00	"
Canal	878.00	862.00	"
Boaz	883.00	867.00	"
Sligo	895.00	879.00	"
Cook	901.00	885.00	"
Boscobel	1177.00	1161.00	"
Avery	1235.00	1219.00	"
Howe	1250.00	1234.00	"
Salem	1189.00	1173.00	"

ST. LOUIS & SAN FRANCISCO—CHADWICK BRANCH.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Springfield (main line)	1348	1345	Greene
Langston	1360	1347	"
Galloway	1169	1166	"
Gates	1161	1158	"
Cassidy	1237	1237	Christian
Summit	1342	1343	"
Ozark	1111	1108	"
Sparta	1389	1386	"
Chadwick	1375	1372	"

ST. LOUIS & SAN FRANCISCO—ARKANSAS & TEXAS BRANCH.

Plymouth	1290	....	Barry
Purdy (revised elevation by U. S. C. & G. S.)	1482	1482	"
Butterfield " " "	1534	1536	"
Exeter	1557	1555	"
Washburn (revised elevation by U. S. C. & G. S.)	1465	1463	"
Seligman " " "	1540	1537	"
State line " " "	1557	1554	"

ST. LOUIS & SAN FRANCISCO RAILWAY—BOLIVAR BRANCH.

Springfield (main line)	1348.00	1345 00	Greene
Ritter	1246.00	1243.00	"
Willard	1234.00	1231.00	"
Asher	1141.00	1138.00	"
Buckley	1178.00	1175.00	"
Graydon	989.00	986.00	Polk
Sac river	995.00	992.00	"
Wishart	972.00	969.00	"
Tremont	1137.00	1134.00	"
Bolivar	1068.00	1065.00	"

ST. LOUIS & SAN FRANCISCO RAILWAY—JOPLIN BRANCH.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Oronogo	938.00	935.00	Jasper
South Oronogo	915.00	912.00	"
Webb City	996.00	693.00	"
East Joplin	985.00	982.00	"
Joplin	984.00	981.00	"
Jackson	1021.00	1018.00	"
State line	945.00	942.00	

ST. LOUIS AND SAN FRANCISCO RAILWAY—GIRARD BRANCH.

Joplin	984.00	981.00	Jasper
Thoms	958.00	955.00	"
Carl Junction	896.00	893.00	"
Waco	905.00	902.00	"
State line	913.00	910.00	

ST. LOUIS & ST. JOSEPH RAILWAY.

These elevations were copied from a list furnished by Mr. James Dun, chief engineer of the road. They refer to mean sea level, and are for top of rail. He stated that "these elevations do not check up as closely as we would desire, and we have always used them with a little hesitancy." He also stated that the difference in elevation between Santa Fe track, top of rail, and C., M. & St. P. track, top of rail, at their crossing at Lawson is 22.3 feet. The railroad elevation of Lexington Junction is 697 feet, while the revised elevation of the C., S. F. & C. track at its station is 693.012. It is not known whether or not the point on the St. L. & St. J. track called Lexington Junction is at the Wabash depot or at the C., S. F. & C. depot or at the C., S. F. & C. crossing. The figures have been corrected to agree with the C., S. F. & C. depot, though by this correction they would agree pretty closely either with the C., S. F. & C. crossing, or with the Wabash depot, since the crossing is only 250 feet west of the station, and the Wabash depot is about the same distance away, and all on the flat bottom lands of the Missouri river flood plain. There is no check at the St. Joseph end.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
North Lexington	685.00	682.012	Ray
Lexington Junction	697.00	694 012	"
Richmond	812.00	809.012	"
St. Cloud	757.00	754.012	"
Swanwick	783.00	780.012	"
Hallard	965.00	962.012	"
Vibbard	1048.00	1045.012	"
Lawson	1058.00	1055.012	"
Converse	1080.00	1077.012	Clinton
Lathrop	1072.00	1069.012	"
Lyons	980.00	977.012	"
Plattsburg (C., R. I. & P.)	963.00	960.012	"
Searce	1017.00	1014.012	"
Tanner	887.00	884.012	"
Walker	903.00	900.012	"
Gower	936.00	933.012	"
Frazier	940.00	937.012	Buchanan
Agency	835.00	832 012	"
Bee Creek Junction	977.00	974.012	"
Matney	1005.00	1002.012	"
Connett	869.00	866.012	"
St. Joseph, all crossings	839.00	836.012	"

ST. LOUIS, KANSAS CITY & COLORADO RAILWAY.

A list of relative elevations of stations on this road was secured from Mr. Chas. I. Brown, the chief engineer. The true elevations were determined by comparing these relative elevations with the elevation of the Wabash railroad at Forsyth junction. They refer to mean sea level through the St. Louis city directrix as 413 feet A. T. The elevations are of top of rail.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Forsyth Junction	480.75	480.75	St. Louis
Skinker road	496.75	496.75	"
Forest City	499.75	499.75	"
Clayton	547.75	547.75	"
Fanita	524.75	524 75	"
Fargo	577.75	577.75	"
Olivette	595.75	595.75	"
Elmwood Park	595.75	595.75	"
Lackland	630.75	630.75	"
Ascalon	573.75	573.75	"
Bond	506.75	506.75	"
Vigus	455.75	455.75	"
Bonner	445.75	445 75	"
Creve Cœur	447.75	447.75	"
Mona	450.75	450.75	"
Drew	453.75	453.75	"
Gumbo	457.75	457.75	"
Stevens	457.75	457.75	"
Bonhomme	458.75	458.75	"
Centaur	459.75	459.75	"
County line. St. Louis and Franklin	468.75	468.75	
Port Royal	468.75	468.75	Franklin
St. Alban	469.75	469.75	"
Becker	479.75	479 75	"
Labadie	515.75	515.75	"
Villa Ridge	621.75	621.75	"
Derry	505.75	505.75	"
Union	545.75	545.75	"

KANSAS CITY, FT. SCOTT & MEMPHIS SYSTEM.

MAIN LINE.

The railway elevations herewith given, excepting certain railroad crossings, were compiled from a list which was furnished by the chief engineer of the road. The elevations of some of the railway crossings were given in two letters from the engineer, but they failed to agree by about three feet. He stated in the last letter that the elevations therein given are corrected elevations. The last ones sent are the ones used, but it is not certain that these are of the same series as the other elevations which were sent in at an earlier date. If they are not, then all the others are wrong, by at least the difference between the two series, for the revised elevations have been determined by correcting the elevations at the crossings to agree with what was considered fairly reliable data. At the crossing of the Mo. P. and the K. C., Ft. S. & M. roads at Lamar, there is a Coast Survey determination. At Nichols Junction the Memphis elevations are corrected to agree with the St. Louis & San Francisco railway elevations. East of Nichols there are no other checks.

The K. C., C. & S. railway is made to agree with that of the M., K. & T. at Clinton, the Mo. P. at Harrisonville and the main line of the K. C., Ft. S. & M. railway at Ash Grove. The elevations of Belton and Coleman were determined by the U. S. Coast and Geodetic Survey in the summer of 1894.

There is no check on the Current River railroad levels after it leaves the main line at Willow Springs. Elevations are top of rail.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Last Chance	867.50	862.00	Barton
Liberal	904.00	898.00	"
Crossing Mo. Pac	898.80	893.00	"
Iantha	996.50	991.00	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Lamar	942.80	937.00	Barton
Crossing Mo. Pac. (U. S. C. & G. S.)	956.80	951.00	"
Kenoma	971.50	965.00	"
Golden City	1031 50	1026.00	"
Lockwood	1093.50	1089.00	Dade
South Greenfield	948.50	945 00	"
Pilgrim	929.50	927.00	"
Everton	1039.50	1038.00	"
Emmet	1145.50	1144.00	"
Ash Grove	1048.50	1048.50	Greene
Bois D'Arc	1219.50	1219.00	"
Campbell	1280.50	1281.00	"
Nichols Junction (St. L. & S. F., checked by U. S. C. & G. Sur. at Peirce City and Purdy)	1267.30	1268.00	"
Springfield	1267.50	1268.00	"
Turner	1183.50	1194.00	"
Rogersville	1461 50	1462 00	Webster
Fordland	1606.50	1607.00	"
Seymour	1658.50	1659.00	"
Cedar Gap	1691.50	1692.00	Wright
Mansfield	1496.50	1497.00	"
Macomb	1512.50	1513.00	"
Norwood	1497.50	1498.00	"
Mountain Grove	1479.50	1480.00	"
Cabool	1260.50	1261.00	Texas
Sargent	1339.50	1340.00	"
Sterling	1499.50	1500.00	Howell
Willow Springs	1253.50	1254.00	"
Burnham	1341.50	1342.00	"
Olden	1245.50	1246 00	"
West Plains	965.50	966.00	"
Chapin	891.50	892.00	"
Brandsville	957.50	958.00	"
Koshkonong	910.50	911.00	Oregon
Thayer	936.50	937.00	"

KANSAS CITY, CLINTON & SPRINGFIELD RAILWAY.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Belton (U. S. C. and G. Sur.)	1135.00	1101.00	Cass
Raymore junction	1140.00		"
Crossing Mo. P.	864.90		"
Pleasant Hill	891.00		"
Coleman (U. S. C. and G. Sur.)	1027.00	1014.00	"
Crossing Mo. P.	900.00	896.00	"
Harrisonville	891.00	878.00	"
Dougherty	899.00	886.00	"
Garden City	924.00	911.00	"
Creighton	786.00	773.00	"
Urich	757.00	744.00	Henry
Hartwell	768.00	755.00	"
Clinton	778.00	765.00	"
M., K. & T. crossing (checked by U. S. C. and G. Sur. at Nevada)	767.00	754.00	"
Deepwater	748.00	736.00	"
Lowry City	881.00	871.00	St. Clair
Osceola	735.00	727.00	"
Vista	856.00	850.00	"
Collins	860.00	855.00	"
Humansville	918.00	914.00	Polk
Dunnegan Springs	931.00	929.00	"
Fair Play	1003.00	1003.00	"
Aldrich	905.00	907.00	"
Sharon	1110.00	1114.00	"
Walnut Grove	1183.00	1188.00	Greene
Phenix	1029.00	1034.00	"
Ash Grove	1043.40	1048.00	"

CURRENT RIVER RAILWAY.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Willow Springs	1253	1254	Howell
Hutton Valley City	1146	1147	"
Mountain View	1144	1145	"
Monitor	1049	1050	Shannon
Birch Tree	997	998	"
Bartlett	1037	1038	"
Winona	931	932	"
Low Wassie	815	816	"
McDonald	622	623	Carter
Cummings	518	519	"
Chicopee	477	478	"
Current river bridge	465	466	"
Chilton	438	439	"
Hunter	728	729	"
Grandin	595	596	"

KANSAS CITY, FT. SCOTT & MEMPHIS—JOPLIN BRANCH.

Joplin	1022		Jasper
Webb City	982		"
Belleville	870		"

KANSAS CITY, FT. SCOTT & MEMPHIS—RICH HILL BRANCH.

Hume	911	921	Bates
Sprague	929	939	"
Rich Hill	797	807	"
Mo. P. crossing at Rich Hill (U. S. C. & G. S.)	785.5	795	"
Carbon Center	784	794	Vernon

CHICAGO, BURLINGTON & QUINCY SYSTEM.

HANNIBAL & ST. JOSEPH RAILWAY—MAIN LINE.

The original datum for the Hannibal & St. Joseph railway levels was 100 feet below high water of 1851, at Hannibal, the latter being considered at that time to be 459.5 feet A. T. Later determinations made by the Mississippi River Commission place the elevation of that point at 469.94 feet, considering the St. Louis directrix to be 412.71; or by considering its elevation to be 413 the elevation (of the 1851 high-water mark) at Hannibal is 470 23. When this correction is applied to the list of railroad elevations and carried to a connection with the Kansas City, St. Joseph & Council Bluffs railway on the Atchison bridge, it agrees with the elevation of that road, the latter revised to agree with the U. S. Coast and Geodetic Survey determination of the elevation of the rails at the Union depot at Kansas City, and the Missouri River Commission's determination of the track at Corning, within 1.67 feet, the Council Bluffs road being higher by that amount. But when an attempt is made to check the Hannibal & St. Joseph elevations thus determined with those of the Chicago, Santa Fe & California railroad at Bucklin, and the Chicago, Milwaukee & St. Paul railroad at Chillicothe, or the Wabash at Macon, considerable difficulty is met with. The Santa Fe is a comparatively new road, and its engineering work appears to have been well done. Its elevations, when made to agree with the Coast Survey's determination of the elevation of its track at the Union depot, Kansas City, and carried across the State to Ft. Madison, Iowa, agree within less than a foot with the Mississippi River Commission levels. These levels have been considered as very reliable. But the fact that the Hannibal & St. Joseph levels agree very nearly as well with the results of precise leveling by the Government bureaus at the opposite ends of its line, indicates that its levels are reliable also.

In view of these considerations, two columns of revised elevations have been arranged—the first one giving the elevations revised so as to agree with the revised elevation of the Atchison bridge (from Kansas City and Corning through the K. C., St. J. & C. B.), and making that correction of the whole list; thus, the K. C., St. J. & C. B. elevation of the Atchison bridge is 798.27 feet A. T. (St. L. Dx =413); the H. & St. J. railroad elevation for the same point is 786.10 feet A. T., making a difference of 12.17 feet; 12.17 feet have therefore been added to the whole list of the H. & St. J. elevations, thus obtaining the first column of revised figures. The second column is obtained by placing the Chicago, Santa Fe & California elevation of the H. & St. J. road, at their crossing at Bucklin, on the H. & St. J. list opposite its proper place, and then distribute the difference between the various stations. A check at the Atchison bridge is the same as for the second column, eastward from Bucklin (the Santa Fe crossing). The next check is at Macon, where the H. & St. J. crosses the Wabash railroad. After applying the correction at Bucklin to make the H. & St. J. agree with the Santa Fe, and then carrying the same correction to Macon, there is a very close agreement with the Wabash levels. Just how much reliance should be placed in the Wabash levels north of Moberly cannot be stated.

East of Macon the next check is at Hannibal, which for lack of better information is considered to be the same as in the first column. In all cases where crossings are not grade-crossings, the correction is made for the difference in feet between the two tracks when comparing elevations.

All elevations refer to top of rail, and the St. Louis directrix is placed at 413 feet A. T. The latter comes in as a factor through the K. C., St. J. & C. B. at the Atchison bridge. The Coast Survey elevations were all referred to the St. Louis directrix as a datum, and 413 has in all cases been added.

The railroad elevations herewith given were obtained by adding 349.5 feet to a list of relative elevations furnished by the chief engineer of the road. The elevations of the railroad crossings and the distances between tracks at such places, as well as much comparative and critical information, have also been supplied from the same source.

Location.	Altitude—mean sea level.			County.
	R. R. elevat'n	Revised elevat'n		
Hannibal	460.4	472.57	472.57	Marion
Bear Creek.	579.4	591.57	591.57	"
Withers Mill	594.1	606.27	605.85	"
Summit	628.8	640.97	940.15	"
Bridge, South river	557.5	569.67	568.50	"
Palmyra	639.5	651.67	650.20	"
Palmyra Junction	638.8	650.97	649.15	"
Summit plateau	649.5	661.67	659.50	"
Woodland	667.0	679.17	676.70	"
Ely	721.0	733.17	730.35	"
Monroe	724.5	736.67	733.50	Monroe
Hunnewell (summit)	745.0	757.17	753.70	Shelby
Bridge, Salt river	651.5	663.67	659.85	"
Low point	630.4	642.57	638.00	"
Lakenan	719.0	731.17	726.70	"
Summit level	744.5	756.67	751.85	"
Shelbina	769.0	781.17	776.00	"
Lentner	780.5	792.67	787.15	"
Bridge, Crooked creek	750.6	762.77	756.90	"
Clarence	814.5	826.67	820.50	"
Anabel	825.9	838.07	831.65	Macon
Bridge, north fork of Salt river	764.5	776.67	769.50	"
Carbon	774.3	786.47	779.30	"
Crossing, Macon (revised elevation of second column figure is taken from Wabash railway levels)	854.5	866.67	859.40	"
Macon depot (summit)	857.0	869.17	862.40	"
Bridge, east fork of Chariton river	759.5	771.67	764.90	"
Summit	828.3	840.47	833.70	"
Bevier	770.5	782.67	775.90	"
Bridge, middle fork of Chariton river	738.5	750.67	743.90	"
Chariton	663.5	675.67	668.90	"
Bridge, Chariton river	681.7	693.87	687.10	"
New Cambria	811.1	823.27	816.50	"

Location.	Altitude—mean sea level.			County.
	R. R. elevat'n	Revised elevat'n		
Summit	836.7	848.87	842.10	Macon
Lingo	798.3	810.47	803.70	"
Bridge, Mussel Fork creek	768.5	780.67	774.00	
Bucklin	876.0	888.17	881.70	Linn
Crossing, C., S. F. & C. (second column revised to agree with the Santa Fe road)	873.5	885.67	879.33	"
Low point, east Yellow creek	740.5	752.67	746.43	"
St. Catherine	787.5	799.67	793.50	"
Brookfield	746.5	758.67	752.90	"
Laclede, B. & S. W. crossing	776.5	788.67	783.25	"
Bridge, Big Muddy creek	686.8	698.97	693.90	"
Meadville	719.5	731.67	726.90	"
Wheeling	728.5	740.67	736.10	Livingston.
Cream Ridge	726.5	738.67	734.20	"
Chillicothe	753.8	765.97	761.72	"
Crossing C., M. & St. P.,	737.5	749.67	745.70	"
Utica	728.3	740.47	736.70	"
Mooresville	911.0	923.17	919.60	"
Breckenridge	916.5	928.67	925.30	Caldwell
Nettleton	948.5	960.67	957.50	"
Hamilton	977.0	989.17	986.25	"
Kidder	1007.5	1019.67	1017.00	"
Cameron	1011.1	1023.27	1020.85	Clinton
Cameron Junction	1016.5	1028.67	1026.50	"
Crossing C., R. I. & P	1018.2	1030.37	1028.50	"
Osborn	1026.0	1038.17	1036.60	DeKalb
Stewartsville	950.2	962.37	961.05	"
Hemple	1030.0	1042.17	1041.20	Clinton
Easton	902.0	914.17	913.35	Buchanan
Saxton	870.5	882.67	882.10	"
Summit	960.7	972.87	972.55	"
St. Joseph	815.0	827.17	827.17	"
St. Joseph, junction Chariton br. C., B. & Q.	817.9	830.08	830.08	"

HANNIBAL & ST. JOSEPH RAILWAY—QUINCY BRANCH.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Palmyra Junction	638.8	650 97	Marion
North river	471.6	483.77	"
Moody	461.4	473.57	"
Bridge, Mississippi river at Quincy (St. L., K. & N W., over Wabash, to St. Louis directrix)	477.8	489.97	

HANNIBAL & ST. JOSEPH RAILWAY—ATCHISON BRANCH.

St. Joseph	815.00	827.17	Buchanan
Lake	810.50	827.67	"
Hall	793.10	805.27	"
Rushville	785.50	797.67	"
Bridge, Mo. river at Atchison (K. C, St. J. & C. B., checked by U. S. Mo. River Com. at Corning, and U. S. C. & G. S. at Kansas City)	786.10	798.27	

HANNIBAL & ST. JOSEPH RAILWAY—CAMERON BRANCH.

Cameron Junction	1016.5	1028.67	Clinton
Keystone	1030.5	1042.67	"
Turney	1038.5	1050.67	"
Lathrop	1059.0	1071.17	"
Crossing, Santa Fe	1060.3	1072.47	"
Holt	851.0	863.17	Clay
Kearney	817.0	829.17	"
Bridge, Fishing river	787.5	799.67	"
Robertson	862.0	874.17	"
Liberty	836.0	848.17	"
Junction, Wabash	724.1	736.27	"
Glen Arbor	739.7	751.87	"
Birmingham	723.5	735.67	"
Randolph	727.5	739.67	"
Harlem	725.0	737.17	"
Bridge, Mo. river at Kansas City	757.7	769.87	"

KANSAS CITY, ST. JOSEPH & COUNCIL BLUFFS RAILWAY—MAIN LINE.

A list of elevations, above the St. Louis city directrix, of the stations on the Kansas City, St. Joseph & Council Bluffs railway and its branches, was sent in by the chief engineer of the road. To these were added 413 feet for tide-water elevations. The figures thus obtained are in the column under "R. R. elevation."

The altitude of the Union depot at Kansas City was determined by the Coast Survey, and of the track at Rushville and Corning, by the Missouri River Commission. The railroad elevations were revised to agree with these. All elevations refer to top of rail.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Kansas City, Union depot (U. S. C. and G. S.)	749.82	749.51	Jackson
Bridge, Missouri river	770.32	770.02	"
Harlem	747.84	747.54	Clay
Parkville	753.92	753.62	Platte
Waldron	758.51	758.11	"
East Leavenworth	765.27	764.87	"
Beverly	770.29	769.79	"
Crossing, C., R. I. & P., Beverly	770.29	769.69	"
Weston	773.41	772.81	"
Iatan	790.97	790.27	"
Sugar Lake	795.29	794.49	"
Winthrop Junction	789.32	788.52	Buchanan
Crossing, H. & St. J.	788.99	788.09	"
Winthrop	788 16	787.26	"
Bridge Mo. river (Chicago & Atchison)	799.27	798.27	"
Crossing, C., R. I. & P.	788.79	787.69	"
Rushville (revised elevation determined by Mo. R. Com.)	798.79	797.63	"
Hall	804.29	803.03	"
Lake	824.29	823.93	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Crossing H. & St. J....	830.29	828.83	Buchanan.......
Round-house	828.29	826.73	" ....
Crossing, St. Joseph bridge	827.29	825.63	" ......
St. Joseph, Francis street depot	826.29	824.53	" ....
Amazonia	834.29	832.43	Andrew..........
Nodaway	831.08	829.12	" ....
Forbes	849.79	847.73	Holt............
Forest City	860.39	858.23	" ....
Napier	854.99	852.69	" ....
Bigelow	852.53	850 03	" ....
Craig	872.64	870.04	" ....
Corning (revised elevation by Mo. R. Com.)...	876.99	874.33	" ....
Nishnabotna	880.38	877.78	Atchison.........
Phelps	896.29	893.69	" ....
Watson	905.85	903.25	" ....

KANSAS CITY, ST. JOSEPH & COUNCIL BLUFFS RAILWAY—HOPKINS BRANCH.

Amazonia (top of rail)	834.29	832.43	Andrew..........
Savannah	1101.74	1099.88	" ....
Rosendale	914.26	912.40	" ....
Bolkow	928.87	927.01	" ....
Barnard	943.87	942.01	Nodaway........
Arkoe	981.20	979.34	" ....
Maryville	1038 24	1036.38	" ....
Pickering	1021.21	1019 35	" ....
Hopkins	1048.82	1046.96	" ....

KANSAS CITY, ST. JOSEPH & COUNCIL BLUFFS RAILWAY—TARKIO VALLEY BRANCH.

Location	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Corning	876.99	874.33	Holt
Fairfax	898.95	892.29	Atchison
Tarkio	918.78	916.12	"
Westboro	979.22	976.56	"
Northboro	1046.99	1044.33	"

KANSAS CITY, ST. JOSEPH & COUNCIL BLUFFS RAILWAY—NODAWAY BRANCH.

Bigelow	852.53	850.03	Holt
Mound City	879.68	877.18	"
Maitland	909.39	906.89	"
Skidmore	927.28	924.78	Nodaway
Quitman	914.70	912.20	"
Crossing, Omaha & St. Louis	943.39	940.89	"

ST. LOUIS, KEOKUK & NORTHWESTERN RAILWAY—MAIN LINE.

A list of elevations referred to the St. Louis city directrix was obtained from the chief engineer of the Burlington lines in Missouri. To these was added 413 to get the figures appearing in the first column. At Alexandria the Mississippi River Commission determined the elevation of the St. L., K. & NW. and the K. & W. roads at their junction, which is considered to be the location of the depot for both roads. The Commission also located the elevation of the junction of the H. & St. J. and St. L., K. & NW. railroad at West Quincy which is interpreted to be the same point as "Bridge Junction" on the list. The same authority determined the elevation of the "intersection of tracks near end of bridge" at Hannibal, which is considered to be the same point as "Crossing, Wabash railroad," in the list. At the junction of the St. L., K. & NW. with the Wabash at St. Peters, is another point whose elevation is well established.

The revised elevations were obtained by adding the amounts suggested by the various points named above and distributing the differences equally among the various stations between any two adjacent points. Elevations are *top of rail ;* and St. Louis directrix is 413 feet, A. T.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Keokuk	497 10	....	
Alexandria (M. R. Com.)	487.00	490.70	Clark
Gregory	481.10	485.10	"
Hardin	488.30	492.85	"
Canton	477.30	482.30	Lewis
LaGrange	475.30	480.80	"
Quincy, bridge junction	477.30	483.30	Marion
Hilton	467.30	475.30	"
Moody	467.30	477.70	"
Hannibal, crossing Wabash	477.30	482.90	"
Saverton	466.30	471.90	Ralls
Taylor	456.30	461.90	"
Busch	455.30	460.90	"
Ashburn	467.30	472.90	Pike
Love	455.80	461.40	"
Reading	453.30	458.90	"
Louisiana (So. end bridge C. & A.)	453.00	458.60	"
McIntosh	452.30	457.90	"
Clarksville	446.30	451.90	"
Kissinger	447.30	452 90	"
Annada	446.30	451.90	"
Dameron	441.90	447.00	Lincoln
Elsberry	443.80	449.40	"
Hurricane	438.30	443.90	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Foley	436.80	441.40	"
Winfield	440.30	445.90	"
Brevator	433.30	438.90	"
Old Monroe	438.50	444.10	"
Richfield	432.30	437.90	St. Charles
Groves	435.30	440.90	"
St. Peters (junction with Wabash)	441.80	447 40	"

CHICAGO, BURLINGTON & QUINCY R'Y—CHARITON BRANCH.

These elevations were obtained from the chief engineer of the road, who stated that he thinks the elevations were run from a Mississippi River Commission bench, at or near Burlington, Iowa. The railroad elevation in the list of the junction of this road with the H. & St. J. road at St. Joseph is 0.42 feet higher than the position of the same place through the K. C., St. J. & C. B. and the H. & St. J. railways from the Coast Survey's bench at Kansas City. To get the revised elevations 0.42 feet has been subtracted from each of the railroad elevations. There are no checks on these figures excepting the one at St. Joseph. All elevations refer to *top of rail.*

Location	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
State line, Missouri and Iowa	1097.95	1097.53	
Andover	1097.79	1097.37	Harrison
Bridge No. 55 A	1071.96	1071.54	"
Blythedale	1085.77	1085.35	"
Bridge No. 61 A	1035.86	1035.44	"
Bridge No. 66 A	1020 11	1019.69	"
Ridgeway	1058.86	1058.44	"
Gardner	1035.86	1035.44	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Summit (north of Bethany)	1021.86	1021.44	Harrison
Bridge No. 77 A	908.86	908.44	"
Bethany	916.86	916.44	"
Bridge No. 78 A, Big creek	865.14	864.72	"
Summit (west of Big creek)	1008.08	1007.66	"
Bridge No. 83 A	929.08	928.66	"
Bridge No. 86 B	963.97	963.55	"
New Hampton	956.03	955.61	"
Summit (west of New Hampton)	1053.32	1052.90	"
Albany	855.99	855.57	Gentry
Bridge No. 96 A, East Grand river	843.66	843.24	"
Bed of stream, East Grand river	827.46	827.04	"
Bridge No. 98 A, West Grand river	840 66	840.24	"
Crossing Wabash	840.16	839.74	"
Darlington	846.49	846.07	"
Flint	1043.25	1042.83	"
Summit, south of Flint	1111.16	1110.74	"
King City	1095.16	1094.74	"
Bridge No. 119 B, third fork of Platte river	948.66	948.24	DeKalb
Union Star	944.16	943.74	"
Summit, south of Union Star	1084.25	1083.83	"
Helena	1054.46	1054.04	Andrew
Summit, south of Helena	1065.67	1065.25	"
Crosby	870.36	869.94	"
Bridge No. 135 B, Platte river	951.36	850.94	Buchanan
Clair	847.86	847.44	"
Bridge No. 138 B, river 102	855.36	854.94	"
Bed of stream, river 102	825.66	825.24	"
St. Joseph	849.16	848.74	"
Junction with H. & St. J	830.50	830.08	"
Junction with H. & St. J. R. R. by Gov. levels	830.13	829.71	"
U. S. P. B. M. St. Joseph bridge	822.55	822.13	"

CHICAGO, BURLINGTON & KANSAS CITY RAILWAY—MAIN LINE.

Elevations in this list were furnished by the chief engineer of the road. They refer to tide-water and are of *top of rail.* The figures in the revised elevation column were obtained by adding the amount of difference between the railroad elevation of this road, and the revised, first column elevations of the H. & St. J. railroad at the crossing of these roads at Laclede. This, excepting the Wabash railway crossing, is the only check obtainable for these elevations. The elevation obtained by the H. & St. J. check at Laclede, when carried to the Wabash crossing, agrees with the Wabash elevation within 0.4 feet—the Wabash elevation being that much lower than the C., B. & K. C. figures. The Wabash elevations from St. Louis to Brunswick, on the main line of that road, were carefully re-run in the summer of 1890, and wherever reliable comparisons of these figures have been made with others, they (the Wabash) have proved to be very accurate. The Brunswick & Chillicothe branch levels were not re-run, but the C., B. & K. C. crossing is so near (8 or 10 miles) to the main line, that it seems fair to say that this elevation is probably correct. It does not, however, agree with the C., S. Fe & C. railway elevation of the same point, carried either over the Wabash from the Wabash-Santa Fe crossing, or over the H. & St. J. and C., B. & K. C. railways from the H. & St. J.-Santa Fe crossing, to the Wabash-C., B. & K. C. crossing. The elevations of these various roads at their crossings, and also the distances between their tracks where the crossings are not at grade, are given along with the various roads, and the difference can be determined from these. It is not considered necessary to correct the C., B. & K. C. elevations to agree with the Santa Fe elevations and place them in a second column, as in the case of the H. & St. J.

The revised elevations, as now given, are checked to agree with the first column, revised elevation of the H. & St. J. railroad at the crossing of these two roads at Laclede. Thus revised, they agree with the Wabash railroad elevation of the Wabash-C., B. & K. C. crossing. All elevations refer to *top of rail.*

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Mendota	882.	887.67	Putnam
Howland	979.	984.67	"
Unionville	1066.	1071.67	"
Lemons	1075.	1080.67	"
Pollock	942.	947.67	Sullivan
Boynton	876.	881.67	"
Milan	837.	842.67	"
Cora	788.	793.67	"
Browning	757.	762.67	Linn
Purdin	879.	884.67	"
Linneus	816.	821.67	"
Laclede, crossing H. & St. J., first column revised elevation	783.	788.67	"
Forker	775.	780.67	"
Sumner, crossing Wabash	679.	684.67	Chariton
Hale	759.	764.67	Carroll
Tina	703.	708.67	"
Bogard	846.	851.67	"
Carrollton	666.	671.67	"

CHICAGO, BURLINGTON & QUINCY R'Y—VILLESCA BRANCH.

These railroad elevations were obtained from the chief engineer of the road. There are no means of comparing them with those of any other road, so they have been placed in the revised elevation column after adding 0.30 feet to refer the figures to *top of rail* instead of *top of tie*, as they are in the first column.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Braddyville	955.25	955.55	Nodaway
Bridge No. 26 A, Nodaway river	952.10	952.40	"
Bridge No. 26 C	955.57	955.87	"
Bridge No. 28 A	957.41	957.71	"
Bridge No. 28 B	947.50	947.80	"
Clearmont	951.50	951.80	"
Bridge No. 30 A, Clear creek	936.63	936.93	"
Bridge No. 31 C, Muddy creek	931.60	931.90	"
Burlington Junction	938.54	938.84	"
Crossing Omaha & St. Louis R. R.	938 54	938.84	"

CHICAGO, BURLINGTON & QUINCY R'Y—GRANT CITY BRANCH.

These elevations are on the same basis as those of the Villesca branch. There have been added 0.30 feet to refer them to *top of rail.*

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
State line, Missouri and Iowa	1172.46	1172.76	
Irena	1166.43	1166.73	Worth
Summit, south of Irena	1153.43	1153.73	"
In depression, south of Irena	1119.78	1120.08	"
Summit, north of Grant City	1138.90	1139.20	"
Grant City	1133.95	1134.25	"
End of track	1131.43	1131.73	"

WABASH SYSTEM.

MAIN LINE.

Two lists of Wabash railway elevations between St. Louis and Brunswick were obtained by copying them from the company's profile. These lists are marked "old series" and "new series" respectively. In a letter Mr. W. S. Lincoln, the chief engineer of the road, states that the elevations given in the list marked "new series" were determined by leveling between St. Louis and Brunswick along the line of the road in the summer of 1890; those marked "old series" are the result of leveling at the time that the road was built. For the main line, therefore, from St. Louis to Brunswick, the "new series" has been adopted. The elevations on the list refer to the St. Louis city directrix as a datum. To each, 413.00 feet have been added to refer them to tide-water. These elevations are considered to be as reliable as any, excepting those determined by precise leveling by the Federal government. The list of revised elevations is the same as that of railroad elevations. There is no direct check on these levels by the government precise leveling, but indirectly through the Chicago & Alton railway from Clark, where that road crosses the Wabash to Glasgow, where the C. & A. levels are checked by the precise leveling of the Missouri River Commission. The Wabash levels agree very well with the government levels.

The elevations on the Ottumwa branch from Moberly to Macon (that being all that could be obtained) are the result of the old series of levels checked at Moberly by the new levels, and the same correction applied to all, both railroad and revised elevations. The elevations on the line of the Brunswick and Chillicothe branch are the result of the old series of levels checked at Brunswick by the "new series," as in the case of the Ottumwa branch. All elevations refer to *top of rail* and to tide-water, considering the St. Louis directrix to be 413.00 feet A. T.

Location.	Altitude—mean sea level. R. R. elevat'n	Altitude—mean sea level. Revised elevat'n	County.
St. Louis old Union depot, center	437.60	437.60	St. Louis
Jefferson avenue, east line	455.00	455.00	"
Grand avenue, east line	460.00	460.00	"
Boyle	495.00	495.00	"
Kings highway	483.25	483.25	"
Forest Park	476.00	476.00	"
Forsyth Junction	480.75	480.75	"
Rosedale	486.25	486.25	"
Olive street road, center	489.50	489.50	"
Cook avenue, center	516.50	516.50	"
Eden	536.50	536.50	"
Huntley	596.75	596.75	"
Normandy	621.00	621.00	"
Alderney	592.00	592.00	"
Woodstock	539.00	539.00	"
Ferguson	517.75	517.75	"
Crossing St. L., C. & W.	531.90	531.90	"
Graham	522.00	522.00	"
Bridgeton	564.75	564.75	"
Bonfils	463.25	463.25	"
Sands	454.50	454.50	"
St. Charles bridge	506.80	506.80	
Bridge, west end	492.50	492.50	
Depot	490.00	490.00	St. Charles
Elm Point	441.50	441.50	"
Bridge No. 78	439.75	439.75	"
Bridge No. 84	442.72	442.72	"
Dardenne	440.50	440.50	"
Junction St. L., K. & NW	447.40	447.40	"
St. Peter	447.00	447.00	"
Bridge No. 96, Billow creek	471.00	471.00	"
O'Fallon	535.70	535.70	"
Gilmore	554.50	554.50	"
Wentzville	624.00	624.00	"

Location.	Altitude—mean sea level		County.
	R. R. elevat'n	Revised elevat'n	
Foristell	699.25	699.25	St. Charles
Bridge No. 159	722.25	722.25	Warren
Wright	721.40	721.40	"
Bridge No. 175	753.00	753.00	"
Truesdale	853.30	853.30	"
Warrenton	816.50	816.50	"
Pendleton	910.90	910.90	"
Jonesburg	888.25	888.25	Montgomery
Bridge No. 233	881.50	881.50	"
High Hill	886.00	886.00	"
Bridge No. 247	858.00	858.00	"
New Florence	869.00	869 00	"
Montgomery	831.25	831.25	"
Bridge No. 273	798.25	798 25	"
Wellsville	818.70	818.70	"
Bridge No. 282	798.50	798.50	"
Martinsburg	802.70	802.70	Audrain
Bridge No. 297	811.60	811.60	"
Benton	820.00	820.00	"
Bridge No. 304	815.60	815 60	"
Mexico	801 00	801.00	"
Bridge No. 317, Salt river	755.30	755.30	"
Thompson	838.00	838.00	"
Bridge No. 331	852.00	852.00	"
Bridge No. 337	861.40	861.40	"
Centralia	883.80	883.80	Boone
Junction, Columbia branch	883.70	883.70	"
Bridge No. 353	860.20	860.20	"
Bridge No. 361, Silver creek	840.75	840.75	"
Sturgeon	855.25	855.25	"
Bridge No. 366	870.25	870.25	"
Clark	874.40	874.40	Randolph
Crossing, Chicago & Alton	874.30	874.30	"
Renick	879.20	879.20	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Bridge No. 389	877.75	877.75	Randolph
Bridge No. 392	883.00	883.00	"
Crossing, M., K. & T.	881.50	881.50	"
Moberly	878.60	878.60	"
Huntsville	808.00	808.00	"
Randolph Springs.	680.25	680.25	"
Bridge, East fork Chariton river	675.30	675.30	"
Clifton	731.00	731 00	Chariton
Bridge, Muncas creek	683.00	683.00	"
Bridge, Middle fork Chariton river	660.75	660.75	"
Junction, Glasgow branch	732.10	732.10	"
Salisbury	730.25	730.25	"
Bridge, Chariton river	647.30	647.30	"
Keytesville	643.25	643.25	"
Bridge, Mussel Fork creek	648.00	648.00	"
Dalton	648.25	648.25	"
Brunswick	652.50	652.50	"
Junction, Brunswick & Chillecothe branch	652.60	652.60	"

WABASH RAILWAY—DES MOINES BRANCH.

Moberly	878.60	878.60	Randolph
Cairo.	869.40	869.40	"
Jacksonville	868.20	868.20	"
County line, Randolph and Macon	865.40	865.40	
Excello.	875.30	875.30	Macon
Macon City	881.40	881.40	"
Macon City, under crossing H. & St. J	859.40	859.40	"

WABASH RAILWAY—BRUNSWICK & CHILLICOTHE BRANCH.

Location	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Brunswick	652.60	652.60	Chariton
Crossing, C., S. F. & C. (22.91 ft. above Wabash)	666.49	666.49	"
Triplett	670.72	670.72	"
Crossing, C., B. & K. C.	684.28	684.28	"
Cunningham	692.00	692.00	"
Sumner	686.58	686.58	"
Fountain Grove	676.30	676.30	Linn.
Bedford	678.78	678.78	Livingston
Crossing, C., M. & St. P. (25.1 ft. above Wabash)	775.70	775 70	"
Chillicothe	770 00	770.00	"
Crossing, Hannibal & St. Joseph R. R. (grade)	754.80	754.80	"
Sampsell	715.00	715.00	"
Lock Springs	725 00	725.00	Daviess
Carlow	732.00	732.00	"
Gallatin	754.00	754 00	"
Crossing, C., R. I. & P	754.00	754.00	"
Jameson	811.25	811.25	"
Pattonsburg	787.00	787.00	"

CHICAGO & ALTON SYSTEM.

MAIN LINE.

The elevation, given of the Chicago & Alton were copied from a list of elevations furnished by the chief engineer of the road. The datum of the railroad list is the level of Lake Michigan. The St. L., K. & NW. crossing at Louisiana is a grade crossing. The St. L. & H. runs over C. & A. at Bowling Green with 22 feet clear head room. The Wabash crosses the Cedar City branch at Mexico at grade, and the main line at Clark also at grade. The C. & A. crosses the M., K. & T. at Higbee at grade.

The Mo. P. crosses under C. & A. at Marshall with 22 feet clear head room. The A., T. & S. F. runs over C. & A. at Big Blue with 22 feet head room. The Mo. P. runs under C. & A. at Higginsville, and over it at Independence. The Belt line, Paola branch of the Mo. P., the C., M. & St. P. and K. C. Suburban all cross the C. & A. at grade in the Big Blue bottom east of Kansas City.

Elevations refer to top of rail.

There is an error in the railway figures of about six feet. It cannot be located exactly, but it lies somewhere between Glasgow and Higginsville. The levels are checked at Glasgow by the Missouri River Commission levels, and at Higginsville by those of the Mo. P. railway. The elevation of the C. & A. track at the Mo. P. crossing one mile east of Marshall cannot be made to agree with the Mo. P. figures. The C. & A. figures for that point are probably wrong.

Location.	Datum: Level Lake Michigan. R. R. elevation.	Mean sea level. Revised elevation	County.
Louisiana	−94.00	468.30	Pike
Crossing St. L., K. & NW.	−108.00	454 30	"
Bowling Green, crossing St. L. & H	317.00	879.30	"
Curryville	274.00	836 30	"
Vandalia	214.00	776.30	Audrain
Farber	216.00	778.30	"
Laddonia	228.00	790.30	"
Rush Hill	240.00	802.30	"
Littleby	261.00	823.30	"
Mexico	249.00	811.30	"
Centralia	327.00	889.30	Boone
Clark, crossing Wabash (revised elevation taken from Wabash levels, series of 1890)	312.00	874.30	Randolph
Higbee, crossing M., K. & T. (checked by Wabash levels, 1890)	325.00	880.00	"
Yates	291.00	854.00	"

Location.	Datum: Level Lake Michigan R. R. elevation.	Mean sea level. Revised elevation	County.
Armstrong	278.00	841.00	Howard
Steinmetz	237.00	800.00	"
Glasgow (U. S. Mo. R. C.)	102.00	664.99	"
Cambridge	64.00	626.00	Saline
Gilliam	269.00	829.00	"
Slater	306.00	865.00	"
Norton	136.00	694.00	"
Marshall	222.00	779.00	"
Crossing Mo. P.	154.00	711.00	"
Shackleford	202.00	759.00	"
Mt. Leonard	238.00	795.00	"
Blackburn	236.00	793.00	"
Alma	243.00	800.00	Lafayette
Corder	315.00	872.00	"
Higginsville	277.00	834.00	"
Crossing Mo. P.	277.00	834.00	"
Mayview	310.00	867.00	"
Odessa	374.00	930.00	"
Bates City	295.00	851.00	"
Oak Grove	311.00	867.00	Jackson
Grain Valley	229.00	786.00	"
Blue Springs	400.00	957.00	"
Glendale	210.00	767.00	"
Independence	367.00	924.00	"
Big Blue siding	192.00	750.00	"
Crossing Santa Fe.	185.00	743.17	"
Kansas City, Grand avenue	200.00	757.00	"

CHICAGO & ALTON RAILWAY—CEDAR CITY BRANCH.

Location.	Datum: Level Lake Michigan. R. R. elevation.	Mean sea level. Revised elevation	County.
Mexico..	249.00	811.30	Audrain ....
Crossing, Wabash..................................	249.00	811.30	" ....
Bryan..	277.00	839.70	Callaway.........
Aux Vasse......................................	318.00	880.70	" ....
McCredie.......................................	303.00	865.70	" ....
Callaway	219.00	781.70	" ....
Fulton	257.00	819.70	" ....
Carrington	320.00	882.70	" ....
Guthrie	300.00	862.70	" ....
New Bloomfield.................................	307.00	869.70	" ....
Hibernia.......................................	297.00	859.70	" ....
Crossing, M., K. & E...........................	—5.00	557.70	" ....
Cedar City.....................................	—5.00	557.70	" ....

MISSOURI, KANSAS & TEXAS SYSTEM.

MAIN LINE.

The railroad elevations here given were sent by the resident engineer of the road at Parsons, Kansas. To get the figures in the revised elevation column, the railroad elevations have been corrected so that they agree with the Wabash railway elevation at Moberly, the Chicago & Alton elevation of its crossing with the M., K. & T. railroad at Higbee, the determination of the elevation of the rail at the south end of the bridge at Boonville by the Missouri River Commission, the Mo. P. railway elevation of the crossing of the roads at Sedalia, and the U. S. Coast and Geodetic Survey's determination of the elevation of the road at the depot at Nevada. The differences have been distributed uniformly among the various stations between two adjacent controlling points. There is no check at Hannibal, since the Hannibal & St. Joseph elevation of the crossing of the two roads is not known, and so the Moberly correction (+9.50 ft.) is applied, increasing it 0.5 feet to make it a whole

number, to all stations north and east of Moberly. Elevations are top of rail, and refer to tide-water through the St. Louis directrix as 413 feet A. T.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Hannibal crossing (H. & St. J.)	471.00	481.00	Marion
Renselaer.	735.00	745 00	Ralls.
Huntington	827.00	837.00	"
Hassard	746.00	756.00	"
County line, Ralls and Monroe	745.00	755.00	
Monroe.	730.00	739.00	Monroe
Clapper	754.00	763.00	"
Stoutsville.	609.00	618.00	"
Gass.	752.00	761.00	"
Paris	666.00	673.00	"
Holliday	787.00	796.00	"
Madison	792.00	801.00	"
County line, Monroe and Randolph	754.00	763.00	
Evansville	748.00	757.00	Randolph.
Moberly	864.00	873.00	"
Crossing Wabash (revised elevation is from Wabash levels run in 1890)	872.00	881.00	"
Long siding	876.00	885.00	"
Elliott	861.00	870.00	"
Higbee	880.00	888.00	"
Crossing (C. & A. R. R.)	880.00	888.00	"
McDonald	770.00	777.00	"
County line, Randolph and Howard	762.00	768.00	
Russell	745.00	751.00	Howard.
Burton	674.00	679.00	"
Fayette.	658.00	661.00	"
Talbot	620.00	622.00	"
Estill	668.00	669.00	"
Franklin	634.00	635.00	"
Bridge, Mo. river, south end (M. R. C.)	611.54	613.00	
Boonville.	612.00	613.00	Cooper
Prairie Lick	696.00	697.00	"
Pilot Grove	836.00	836.00	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Harriston	860.00	859.00	Cooper
Pleasant Green	782.00	780.00	"
Sweeney	655.00	652.00	"
Clifton	730.00	726.00	"
County line, Cooper and Pettis	788.00	783 00	
Beaman	774,00	768.00	Pettis
Crossing, Mo. P. (checked through Mo. P. by U. S. C. & G. S. determination of Mo. P. track at Sedalia station)	911.00	904.00	"
Sedalia, Fifth street	907.00	900.00	"
Camp Branch	917.00	910.00	"
Green Ridge	905.00	897.00	"
County line, Pettis and Henry	903.00	895.00	
Windsor	894.00	886.00	Henry
Calhoun	771.00	762.00	"
Lewis	787.00	778.00	"
North Clinton, crossing, K. C., O. & S	791.00	782.00	"
Clinton	787.00	777.00	"
Crossing, K. C., C. & S	764.00	754.00	"
Ladue	754.00	744.00	"
Montrose	834.00	823.00	"
County line, Henry and St. Clair	879.00	868.00	
Appleton City	864 00	853.00	St. Clair
County line, St. Clair and Bates	839.00	827.00	
Rockville	777.00	765.00	Bates
County line, Bates and Vernon	740.00	727.00	
Schell City	761.00	748.00	Vernon
Harwood	855 00	842.00	"
Walker	861.00	847.00	"
Nevada (U. S. C. & G. S.)	874.00	860.00	"
Ellis	846.00	832.00	"
Deerfield	798.00	784 00	"
Crossing, K. C., P. & G	827.00	813.00	"
Clayton	824.00	810.00	"
State line, Missouri and Kansas	812.00	798.00	

CHICAGO GREAT WESTERN SYSTEM.

CHICAGO, ST. PAUL & KANSAS CITY RAILWAY—MAIN LINE.

The railroad elevations of stations on the Chicago, St. Paul & Kansas City railway were taken from the dispatcher's profile of the road, sent in by the chief engineer. The datum is mean sea level, and elevations are sub-grade, which is one foot below top of rail. The revised elevations were obtained by correcting the railway elevations to agree with the elevation of the K. C., St. J. & C. B. track at the junction of the two roads at the Francis street depot, St. Joseph, and also at their junction at Beverly. They are all top of rail, and refer to mean sea level through St. Louis city directrix as 413 feet A. T.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
State line, Missouri and Iowa	1066.00	1065.50	Worth
Athelstan	1069.00	1068.50	"
Sheridan	1043.25	1042.75	"
Parnell City	1028.00	1027.50	Nodaway
Ravenwood	1020.00	1019.50	"
Conception	988.00	987.50	"
Crossing, Wabash	977.80	977.30	"
Monastery	960.50	960.00	"
Guilford	946.00	945.40	"
Cawood	941.10	940.50	Andrew
Rea	1069.50	1068.90	"
Rush siding	932.00	931.30	"
Schuster	959.50	958.80	"
Savannah	1090.50	1089.75	"
Dean	887.00	886.25	"
Crossing, K. C., St. J. & C. B.	825.30	824.53	Buchanan
St. Joseph, Francis street	825.40	824 63	"
St. Joseph, Union depot	827.60	826.85	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Crossing, C., R. I. & P.	827.60	826.90	Buchanan
Crossing, H. & St. J	852.80	852.20	"
Crossing, C., R. I. & P.	852.60	852.00	"
Matney	1000.00	999.60	"
Bee Creek	973.00	972.70	"
Willow Brook	995.00	994.90	"
Faucett	950.00	950.00	"
Dearborn	881.00	881.10	Platte
Crossing, C., R. I. & P.	881.00	881.30	"
New Market	870.00	870.45	"
Woodruff	823.00	823.60	"
West Platte	793.30	794.05	"
Beverly Junction (K. C., St. J. & C. B.)	769.00	769.79	"
Bridge, Missouri river	818.80	818 80	"

CHICAGO, MILWAUKEE & ST. PAUL SYSTEM.

KANSAS CITY BRANCH.

The elevations here given were taken from a profile of the road furnished by the chief engineer, which gave the elevation of the various points on the road above Lake Michigan. To these figures 528 feet have been added for tide-water adjustments. The latter are the figures given in the column headed "railroad elevations."

The elevations of the various railroad crossings were supplied by the assistant engineer.

The best check that could be obtained upon the list of railroad elevations, as given in the first column, was that furnished by the Missouri Pacific railroad at its grade-crossing with the C., M. & St. P. in Big Blue bottoms, east of Kansas City. The elevation of the Mo. P. track at the crossing is 742.49 feet, considering the St. Louis directrix to be 413 feet A. T. By adding to this elevation the same amount (1.51 feet) as that added to the railroad elevation of Kansas City to make it agree with the U. S. C. and G. Survey's determination of the same place, there is obtained 744 feet for the elevation of the crossing. The C., M. & St. P. elevation at the crossing is 742 feet. Two feet have therefore been added to each of the Milwaukee stations within the State. When the elevation thus obtained of the Milwaukee track under the Hannibal & St. Joseph crossing is compared with the elevation of the same track determined by reference to the H. & St. J. elevations after the correction that has to be applied to the latter at St. Joseph, and is carried to the Milwaukee crossing, the elevations calculated from the two sets of data differ from each other by 2.33 feet—that determined from the H. & St. J. data being that much lower than that given from the Milwaukee data (carried through the Mo. P. to Kansas City). Elevations are *top of rail.*

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
State line, Missouri and Iowa	961.50	963.50	Putnam
Powersville	938.50	940.50	"
Lucerne	903.25	905.25	"
Newtown	868.00	870.00	Sullivan
Harris	856.50	858.50	"
Osgood	813.50	815.50	"
Crossing, Q., O. & K. C	786.90	788.90	"
Gault	787.12	789.12	"
Laredo	760.00	762.00	Grundy
Niantic	756.00	758.00	Livingston
Sturges	785.80	787.80	"
Chillicothe	777.20	779.20	"
Crossing H. & St. J. (22.7 ft. above H. & St. J.)	772.70	774.70	"
Crossing Wabash (24.7 ft. above W.)	773.10	775.10	"
Grand river	695.00	697.00	"
Dawn	699.00	701.00	"
Ludlow	735.00	737.00	"

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Braymer	753.00	755.00	Caldwell.
Cowgill	960 50	960.50	"
Polo	1005.00	1007.00	"
Elmira (low point)	879.00	881.00	Ray
Lawson	1075.00	1077.00	"
Crossing St. Joseph & St. Louis (23.5 ft. above St. J. & St. L.)	1077.00	1079.00	"
Excelsior Springs	939.50	741.50	Clay.
Mosby	763.00	765.00	"
Low point	760.00	762.00	"
Bement	931.15	933.15	"
Liberty	857.00	859.00	"
Crossing, H. & St. J	736.00	738.00	"
Minnaville	739.35	741.35	"
Randolph	744.50	746.50	"
Crossing, H. & St. J. (46.4 ft. higher than H. & St. J.) and Wabash (47.3 ft. above W.)	792.00	794.00	"
Thornton	792.00	794.00	"
Crossing, Mo. P	742.00	744.00	"
Crossing, C. & A	739.25	741.25	Jackson
Coburg	754.30	756.30	"
Independence, Dummy line crossing	783.90	785.90	"
Head block, Dummy line	786.00	788.00	"
Cable line, Fifteenth street	830.00	832.00	"
Head block of "Y" to K. C., Ft. S. & M	748.80	750.80	"

CHICAGO, ROCK ISLAND & PACIFIC SYSTEM.

SOUTHWESTERN DIVISION—MAIN LINE.

The railroad elevations here given were taken from a condensed profile furnished by the division superintendent of the road. The datum is not given on the profile, but it is known to be 107 feet below the low water in the Mississippi river at Rock Island. It is stated that according to Hayden's report of 1873, low water is 553 feet A T. Since this is rather indefinite, the relative elevations of the profile have been copied for railroad elevations. These are corrected by the elevation of the Hannibal & St. Joseph (first column) at the crossing of these two roads west of Cameron, and by the elevations of the K. C., St. J. & C. B. at Beverly, and also at Rushville. The point of departure of the branch going to Rushville could not be accurately determined, so it is not given. This branch is adjusted by the Council Bluffs road at Rushville. Elevations are of top of rail, and refer to mean sea level, through St. Louis city directrix as 413 feet A. T.

Location.	R. R. elevation.	Mean sea level. Revised elevation.	County.
State line, Missouri and Iowa	646.00	1086.37	Mercer
Princeton	385.00	825.37	"
Mill Grove	361.00	801.37	"
Spickards	346.00	786.37	Grundy
Tindall	339.00	779.37	"
Trenton	372.00	812.37	"
Q., O. & K. C. junction	370.00	810.37	"
Hickory Creek	340.00	780.37	"
County line, Grundy and Daviess	472.00	912.37	
Jamesport	531.00	971.37	Daviess
West Grand river	300.00	740.37	"
Crossing, Wabash	300.00	740.37	"
Gallatin	363.00	803.37	"
Altamont	563.00	1003.37	"
Winston	595.50	1035.87	"
County line, Daviess and DeKalb	578.00	1018.37	
County line, DeKalb and Clinton	585,00	1025.37	Clinton
Cameron	582.00	1022.37	"
Crossing, H. & St. J	590.00	1030.37	"
Perrin	588.00	1028.37	"
Plattsburg	508.00	948.37	"
Crossing, St. Louis & Santa Fe	505.00	945.37	"
Grayson	513.00	953.37	"

Location.	R. R. elevation...	Mean sea level. Revised elevation.........	County.
Edgarton	381.00	881.37	Platte
Platte river	351.00	791.37	"
Camden Point	386.50	826.87	"
Platte City	324.00	764.37	"
Beverly	320.00	760.37	"
Crossing, K. C., St. J. & C. B	330.00	769.69	"
Missouri river bridge	370.00	810.00	"

CHICAGO, ROCK ISLAND & PACIFIC RAILWAY—ATCHISON BR.

New Market	420.00	837.69	Platte
Wallace	648.00	1065.69	Buchanan
DeKalb	667.00	1084.69	"
Rushville	359.00	776.69	"
Crossing, K. C., St. J. & C. B. R. R	370.00	787.69	"
Winthrop,	338.00	....	"

ST. JOSEPH & IOWA RAILWAY.

Altamont	214.60	1003.37	Daviess
Munsen summit	244.30	1033.07	"
Grindstone creek	12 22	800 99	DeKalb
Weatherby	63.46	851.23	"
Duncan summit	103.30	892.07	"
Jones summit	132.30	921.07	"
Maysville	94.80	883 57	"
Amity	221.90	1010.67	"
Downing summit	245.90	1034.67	"
Clarksdale	86.27	875.04	"
Stockbridge	43.10	831.87	Buchanan
Wagenblast summit	116.10	904.87	"
Platte river	41.10	829.87	"
Leonard summit	190.10	978.87	"
South St. Joseph	34.50	823.27	"

KEOKUK & WESTERN RAILWAY.

The elevations herein noted are based upon the intersection of this line with the St. Louis, Keokuk & Northwestern railroad at Alexandria, a point which was determined by the Mississippi River Commission as 490.70 feet above tide level. This is the figure given in "Topographical Notes, 1892."

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Alexandria (revised elevation by M. R. C. "Topogr. notes, 1892")	487.20	490.70	Clark
Wayland	517.20	520.70	"
Fox river	512.20	515.70	"
Clark City	697.20	700.70	"
Ashton	717.20	720.70	"
Luray	715.20	718.70	"
North Wyaconda river	637.20	640.70	Scotland
Granger	807.20	810.70	"
South Wyaconda river	657.20	660.70	"
Pt. 42 miles west of Alexandria	787.20	790.70	"
Memphis	747.20	750.70	"
Crawford	737.20	740.70	"
Downing	857.20	860.70	Schuyler
Lancaster	937.20	940.50	"
Glenwood Junction	937.20	940.50	"
State line Missouri and Iowa	932.20	935.50	"

KANSAS CITY, PITTSBURG & GULF SYSTEM.

MAIN LINE.

These elevations were furnished by the chief engineer of the road. The datum is unknown. The revised elevations were determined by comparing with the revised elevations of the M., K. & T. railway at the crossing of these two roads near Cambria. The elevations refer to mean sea level through the St. Louis city directrix as 413 feet. Elevations are gound between the rails.

Location.	Altitude—mean sea level.		County.
	R. R. elevat'n	Revised elevat'n	
Grand View, junction, K. C., O. & S	909.00	1058.00	Jackson
West Line	728.00	877.00	Cass
Crossing, K. & A. division Mo. Pac	793.00	942.00	"
Crossing, K. C., C. & S	931.00	1080.00	"
Lisle	829.00	978.00	"
Drexel	850.00	999.00	"
Amoret	682.00	831.00	Bates
Worland, crossing, Mo. P	638 00	787.00	"
Hume, crossing, Carbondale br. K. C., F. S. & M.	744.00	893.00	"
Miller	675.00	824.00	"
Statesbury	636.00	785.00	Vernon
Richards	690.00	839 00	"
Crossing, Mo P	685.00	834.00	"
Cambria	664.00	813.00	"
Crossing, M., K. & T	664.00	813.00	"
Swartz	673.00	822.00	"
Oskaloosa	723.00	872.00	"
Burgess	738.00	887.00	Barton
Crossing, St. L. & S. F	746.00	895.00	"
Crossing, St. L. & S. F., main line	752.00	901.00	Jasper
Joplin, connection with Splitlog railway	811.00	960.00	"

ST. LOUIS SOUTHWESTERN RAILWAY.

This list is a copy of a list sent in by the chief engineer of the road, who states that the railway levels are corrected to agree with the Government figures at Bird Point. They do not agree with the Iron Mountain railway elevations at the crossing of the two roads. When they are corrected to agree with the Belmont branch elevations, they do not agree with those of the Cairo branch. Since they cannot be made to harmonize with these roads, the figures are given without change or attempted correction, merely for what they are worth.

Location.	Altitude—mean sea level—railroad elevation.	County.
Bird Point	338.00	Mississippi
Smithton	339.00	"
Crossing, Belmont Br. St. L., I. M. & S	336.00	"
East Prairie	327.00	"
Henderson mound	318.00	New Madrid
St. John bayou	317.80	"
LaForge	320.60	"
Ristan	320.60	"
Pawpaw junction	304.00	"
Como	304.00	"
Cut-off	301.00	"
Malden	310.70	Dunklin
Campbell	333.00	"
St. Francois river	315.50	"

ST. LOUIS SOUTHWESTERN RAILWAY—DELTA BRANCH.

Location.	Altitude—mean sea level. Railway elevation.	County.
Delta	356.00	Cape Girardeau.
Crossing, Cape G. & SW. R. R	356.00	"
Bridge, Blackwater river	358.50	
Randles.	349.00	Stoddard.
Whitewater river	350.50	"
Ardeola	333.00	"
Castor river (base of rail on bridge)	345.50	"
Day	348.00	"
Idalia	322.00	"
Crossing, Cairo Br. St. L., I. M. & S	322.00	"
Dexter	340.00	"
Birnie	317.00	"
Malden	310 70	Dunklin

ST. LOUIS SOUTHWESTERN RAILWAY—NEW MADRID BRANCH.

Pawpaw Junction.	304.00	New Madrid
New Madrid (M. R. C. 295)	292.00	"

MISSISSIPPI RIVER & BONNE TERRE RAILWAY.

The profile of the Mississippi River & Bonne Terre railway is in two parts, which are not connected with each other. The first part covers that part of the road from Riverside to the company's mill at Bonne Terre. The second part covers that part of the road from Doe Run to the Old St. Joseph & Desloge railway, about one mile south of Bonne Terre. The two parts of the new road are connected by a part of the old road, but the profiles do not show where the connection is made. The elevations of the northern end are, therefore, corrected to agree with those of the St. Louis, Iron Mountain & Southern railroad at Riverside, and the southern end to agree with the Belmont branch of the same system where it is crossed by the M. R. & B. T. line near Loughboro.

Location.	Altitude—mean sea level.	
	R. R. elevat'n	Revised elevat'n
Riverside Jc., Iron Mt. railway	446	446
Bridge, Joachim creek	398	398
Bridge No. 45, east side	439	439
Summit, in sand-cut	499	499
Junction, Crystal City railway	407	407
Mile-post 25.	395	395
Genevieve	421	421
Sugar creek	416	416
Plattin	436	436
Bridge No. 23	470	470
Mile-post 13.	811	811
Summit, 1000′ E. of mile-post 12	839	839
Bridge No. 14	709	709
Valle Mines	739	739
Mile-post 9	853	853
Summit, at north end of tunnel	936	936
Silver Springs	821	821
Mile-post No. 4.	654	654
Bridge, Big river.	638	638
Mill, Bonne Terre	796	796
Summit, south of Bonne Terre	917	917
Bridge, Big river	711	711
Flat river shaft	787	787
Bridge, Flat river	765	765
Summit, south of Flat river	1019	1019
Crossing, St. L., I. M. & S	885	885
Bridge, St. Francois river	872	872
Summit, south of St. Francois river	987	987
Doe Run	933	933

ALPHABETICAL LIST OF ELEVATIONS.

Adrian	870
Agency	832
Akinsville	994
Albany	856
Alderry	592
Aldrich	907
Alexandria	491
Alfred	717
Allen	506
Allenton	511
Allenville	353
Alma	800
Altamont	1003
Amazonia	832
Amity	1011
Amoret	831
Anabel	832
Anaconda	837
Andover	1097
Annada	452
Annapolis	633
Appleton City	853
Arcadia	926
Archie	833
Ardeola	333
Arkoe	979
Arlington	687
Armstrong	841
Arthur	767
Ascalon	574
Ash Grove	1048
Ash Hills	334
Ashburn	473
Asher	1138
Ashton	721
Athelstan	1068
Atherton	729
Athol	763
Aullville	722
Aurora (St. L. & S. F.)	1360
Aurora (Mo. P.)	912
Auxvasse	881
Avery	1219
Bagnell	579
Bailey	420
Baker	421
Baring	808
Barnard	942
Barracks	419
Barrett	511
Bartlett	1038
Barton	870
Bates City	851
Bayou St. John	314
Beaman	768
Bear Creek	592
Beaver	722
Becker	480
Bedford	679
Bee Creek	973
Bee Creek Junction	974
Belleville	870
Belmont	310
Belton	1101
Bement	933
Benton (Mo. P.)	469
Benton (Wab.)	820
Berger	511
Berlin	687
Bertrand	321
Berwick	1122
Bessville	592
Bethany	916
Beverly (C., R. I. & P.)	760
Beverly (K. C., St. J. & C. B.)	770
Beverly (C., St. P. & K. C,)	770
Bevier	776
Big Blue	748
Big Blue Junction	747
Bigelow	850
Billings	1366
Billingsville	648
Birch Tree	998
Bird Point	338
Birmingham	736
Birnie	317
Bismarck	1025
Blackburn	793
Blackwell	593
Blairsville	950
Blodgett	326
Blue Springs	957
Blythedale	1085
Boaz	867
Bogard	852
Bois D'Arc	1219
Boles	483
Bolckow	927
Bolivar	1065
Bond	507
Bonfils	463
Bonhomme	459
Bonner	446
Bonne Terre	796
Bonnot Mills	544
Boonville (W. limit)	598
Boonville (M., K. & T.)	613
Boonville (Mo. P.)	602
Boscobel	1161
Bosworth	748
Bourbon	947
Bowling Green	879

Boyle	495
Boynton	882
Bradyville	956
Brandsville	958
Braymer	755
Breckenridge	925
Brevator	439
Bridgeton	565
Bronaugh	887
Brookfield	753
Brookline	1285
Browning	763
Brownsville	674
Brunswick	652
Brush Creek	1301
Bryan	840
Buckley	1175
Bucklin (C., S. F. & C.)	917
Bucklin (H. & St. J.)	882
Buckner	749
Bunceton	772
Burgess	887
Burlington Junction	939
Burnham	1342
Burton	679
Busch	461
Butler	849
Butterfield	1536
Cabool	1261
Cadet	784
Cairo	869
Calhoun	762
California	888
Callaway	782
Cambria	813
Cambridge	626
Camden	708
Camden Point	827
Cameron (C., R. I. & P.)	1022
Cameron (H. & St. J.)	1021
Cameron Junction	1029
Camp Branch	910
Campbell (St. L. S. W.)	333
Campbell (K. C., Ft. S. & M.)	1281
Canal	862
Canton	482
Canwood	940
Cape Girardeau	333
Carbon	779
Carbon Center	794
Carl Junction	893
Carleton	943
Carlow	732
Carondelet	421
Carrington	883
Carrollton (C., B. & K. C.)	672
Carrollton (C., S. F. & C.)	665
Carthage (Mo. P.)	974
Carthage (St. L. & S. F.)	940
Carytown	921
Cassidy	1237
Castlewood	430
Catawissa	521
Cawood	940
Cecil	745
Cedar City	558
Cedar Gap	1692
Centaur	460
Centertown	849
Centerview	870
Centralia (C. & A.)	889
Centralia (Wab.)	884
Chadwick	1372
Chamois	535
Chapin	892
Charlton	669
Charleston	324
Cheltenham (St. L. & S. F.)	448
Cheltenham (Mo. P.)	453
Chicopee	478
Chillicothe (C. M. & St. P.)	779
Chillicothe (H. & St. J.)	762
Chillicothe (Wab.)	770
Chilton	439
Clair	847
Clapper	763
Clarence	820
Clark	874
Clark City	701
Clarksdale	875
Clarksville	452
Clayton (M., K. & T.)	810
Clayton (St. L., K. C. & C.)	548
Clearmont	952
Cliff Cave	417
Clifton (M., K. & T.)	726
Clifton (Wab.)	731
Clinton (K. C., C. & S.)	765
Clinton (M., K. & T.)	777
Coburg	756
Coffeyton	1024
Coleman (U. S. C. & G. Sur.)	1014
Collins	855
Como	304
Conception	787
Concordia	783
Connett	866
Converse	1077
Conway	1402
Cook	885
Cooper	794
Cora	794
Corder	872
Corning	874
Cornwall	700
Courtney	734
Cowgill	960
Craig	870

Crawford	741
Cream Ridge.	734
Creighton.	773
Crescent.	479
Creve Cœur	448
Crocker	1126
Crosby	870
Crystal.	423
Cuba	1009
Cummings.	519
Cunningham	692
Curryville	836
Dalton	648
Dameron	447
Dardenne	440
Darlington	846
Dawn	701
Day	348
Dayton	959
Dean	886
Dean Lake	659
Dearborn	881
Deepwater	736
Deerfield	784
DeKalb	1085
DeLassus.	891
Delta (St. L., I. M. & S.).	341
Delta (St. L. S. W.)	356
Derry	506
Des Arc	544
DeSoto.	498
DeWitt.	652
Dexter (St. L., I. M. & S.).	375
Dexter (St. L. S. W.)	340
Diehlstadt.	327
Dillon	1084
Dixon	1187
Docks	427
Doe Run	933
Doniphan	344
Dorchester	1286
Dougherty.	886
Dover	680
Downing	861
Dresden.	821
Drew.	454
Drexel	999
Dudley.	354
Dumas.	558
Dunnegan Springs	929
Dutchtown	352
East Joplin	982
East Leavenworth	765
East Prairie*	327
Easton.	913
Eden	536
Edgarton	881
Edwards	676
Eldon	918
Elliott	870
Elm Point	441
Elmer	731
Elmwood Park	596
Elmira.	881
Ellis	832
Elsberry	449
Elston	685
Ely	730
Emmett	1144
Enoch	805
Enon	690
Essex.	301
Estill.	669
Ethel.	808
Etlah.	510
Eugenia	984
Eureka (Mo. P.)	464
Eureka (St. L. & S. F.)	461
Evansville.	757
Everton	1038
Excello	875
Excelsior Springs.	741
Exeter	1555
Fair Play	1003
Fairfax	892
Fairview.	491
Fanita	525
Farber.	778
Fargo	578
Faucett	950
Fayette	661
Ferguson	518
Flint	1043
Foley	441
Forbes	848
Fordland	1607
Forest City (K. C., St. J. & C. B.).	858
Forest City (St. L. K. C. & C.)	500
Forest Park	476
Foristell	699
Forker	781
Forsyth Junction	481
Fortuna	959
Foster	815
Fountain Grove	676
Franklin.	635
Franks.	968
Frazier.	937
Fredericktown	723
Freeman.	851
Fulton	820
Gad Hill	842
Gallatin (C., R. I. & P.)	803
Gallatin (Wabash)	754
Galloway	1166
Ganet	989
Garden City	911
Gardner	1035

Gasconade	527
Gass	761
Gates	1158
Gault	789
Genevieve	421
Gentry	864
Georgetown	837
Gibbs	892
Gilliam	829
Gilmore	554
Glasgow	665
Glen Allen	458
Glen Arbor	752
Glencoe	435
Glendale (C. & A.)	767
Glendale (Mo. P.)	598
Glendale (St. L. & S. F.)	601
Glenstead	977
Glenwood	412
Glenwood Junction	940
Golden City	1026
Gordonville	369
Gorin	700
Gowdy	853
Gower	933
Graham	522
Grain Valley	786
Granby City	1029
Grandin	596
Grand Pass	665
Grand View	1058
Granger	811
Grant City	1134
Gratiot	469
Gray Ridge	298
Gray Summit	635
Graydon	986
Grayson	953
Green Ridge	897
Greenwood	910
Gregory	485
Grindstone Creek	801
Groves	441
Guilford	945
Gumbo	458
Guthrie	863
Halberts	706
Hale	765
Hall (K. C., St. J. & C. B.)	803
Hall (H. & St. J.)	823
Hallard	862
Hamilton	986
Hancock	1107
Hannibal (H. & St. J.)	473
Hannibal (M. K. & T.)	481
Hardin (C., S. F. & C.)	693
Hardin (St. L., K. & NW.)	492
Harlem (H. & St. J.)	737
Harlem (K. C., St. J. & C. B.)	748
Harris	858
Harrisonville (K. C., C. & S.)	878
Harrisonville (Mo. P.)	912
Harriston	859
Hart	843
Hartwell	755
Harwood	842
Hassard	756
Helena	1054
Hematite	438
Hemple	1041
Henderson Mound	318
Henson	312
Hermann	516
Hibernia	860
Hickory Creek	780
Higbee (C. & A.)	888
Higginsville (C. & A.)	834
Higginsville (Mo. Pac.)	819
High Hill	886
Highway	1009
Hilliard	356
Hilton	475
Hogan	889
Holden	849
Holliday	796
Holt	863
Hopewell	899
Hopkins	1047
Horton	772
Houghs	319
Houstonia	749
Howard (Mo. P.)	454
Howes	1234
Howland	985
Hughesville	818
Humansville	914
Hume	921
Hunnewell (summit)	754
Hunter	729
Huntington	837
Huntley	597
Huntsville	808
Hurdland	827
Hurricane	444
Hutton Valley	1149
Iantha	991
Iatan	790
Idalia	322
Independence (C. & A.)	924
Independence (C., M. & St. P.)	786
Independence (Mo. P.)	949
Independence (Lexington br.)	997
Irena	1167
Iron Mountain	1077
Iron Ridge	1042
Iron Switch	1094
Irondale	797
Ironton	919

Irwin	972
Isbell	546
Ivory	423
Jackson (St. L., I. M. & S.)	428
Jackson (St. L. & S. F.)	1018
Jacksonville	868
Jameson	811
Jamesport	971
Jasper	919
Jefferson City	554
Jerome	692
Jonesburg	888
Joplin (St. L. & S. F.)	981
Joplin*	1022
Kansas City	750
Kansas City (Grand Ave.)	758
Kearney	829
Kenoma	965
Kenwood	778
Keokuk (Iowa)*	497
Keystone	1043
Keysville	889
Keytesville	643
Kidder	1017
Kimmswick	416
King City	1095
Kingsville	908
Kirkwood	634
Kissinger	453
Knight	1086
Knob Lick	941
Knob View	1054
Knob Noster	791
Knotwell	693
Koshkonong	911
Labadie (Mo. P.)	494
Labadie (St. L., K. C. & C.)	516
Lackland	631
Laclede (C., B. & K. C)	789
Laclede (H. & St. J.)	783
Laclede (Mo. P.)	459
Laddonia	790
Ladue	744
Laflin	386
LaForge*	321
LaGrange	481
Lake	823
Lake City	750
Lakenan	727
Lamar (K. C., Ft. S. & M.)	937
Lamar (Mo. P.)	964
Lamonte*	863
Lancaster	940
Langston	1357
LaPlata	914
Laredo	762
Last Chance	862
Lathrop (H. & St. J.)	1071
Lawson (C., M. & St. P.)	1077
Lawson (St. L. & S. F.)	1055
Leasburg	1014
Lebanon	1265
Lee Summit	1041
Lemons	1081
Lentner	787
Levasy	710
Lewis	778
Lexington	813
Lexington Junction	694
Liberal	898
Liberty (C., M. & St. P.)	859
Liberty (H. & St. J.)	848
Lingo	804
Linneus	822
Lisle	978
Little Blue	855
Little River	300
Littleby	823
Lock Springs	725
Lockwood	1089
Logan	1372
Lone Tree	874
Long Siding	885
Loughborough	921
Louisiana (C. & A.)	468
Louisiana (St. L., K. & NW.)	459
Love	461
Low Wassie	816
Lowry City	871
Lucerne	905
Ludlow	737
Luray	719
Lyman	1377
Lyons	977
McCredie	866
McDonald (K. C., Ft. S. & M.)	623
McDonald (M., K. & T.)	777
McFall	995
McIntosh	458
Macomb	1513
Macon (H. & St. J.)	862
Macon City (Wab.)	881
Macy	1019
Madison	801
Maitland	907
Malden	311
Malta Bend	691
Manchester	804
Mansfield	1497
Marble Hill	420
Marceline	858
Marquand	570
Marshall	779
Marshfield	1487
Martin City	920
Martinsburg	803
Maryville (K. C., St. J. & C. B.)	1036
Maryville (Wab.)	1168

Matney (C., St. P. & K. C.)	1000
Matney (St. L. & St. J.)	1002
Maysville	884
Mayview	867
Meadville	727
Medill	705
Memphis	751
Mendon	685
Mendota	888
Meramec (Mo. P.)	428
Meramec (St. L. & S. F.)	426
Meramec (St. L., I. M. & S.)	415
Metz	774
Mexico (C. & A.)	811
Mexico (Wab.)	801
Miami	622
Middlebrook	1139
Midland	708
Milan	843
Mill Grove	801
Mill Spring	440
Miller	824
Milo	880
Mincke	442
Minden	950
Mineral Point	865
Minnaville	741
Missouri City	630
Moberly (M., K. & T.)	873
Moberly (Wab.)	879
Mona	451
Monastery	960
Moniteau	898
Monroe (H. & St. J.)	733
Monroe (M., K. & T.)	739
Monteer	1050
Monteith	771
Montgomery	831
Montrose	823
Montserrat	798
Moody (H. & St. J.)	474
Moody (St. L., K. & NW.)	478
Mooresville	920
Morley	344
Morrison	527
Mosby	765
Moselle	501
Mound City	877
Moundville	840
Mount Leonard	795
Mountain Grove	1480
Mountain View	1145
Myrick	691
Napier	853
Napoleon	709
Napton	639
Nassau	881
Neeleyville	307
Neosho	1023
Nettleton	957
Nevada	860
New Cambria	816
New Bloomfield	870
New Florence	869
New Hampton	956
New Haven	508
New Madrid	295
New Market (C., R. I. & P.)	838
New Market (C., St. P. & K. C.)	871
Newburg	705
Newcomb	718
Newport	495
Newtown	870
Niangua	1435
Niantic	758
Nichols Junction	1268
Nishnabotna	878
Nodaway	829
Norborne (C., S. F. & C.)	686
Norborne (Wabash)	615
Normandy	621
North Clinton	782
North Lexington	682
Northboro	1044
Northrup (W. switch)	692
Northview	1437
Norton	694
Norwood	1498
Nyhart	773
Oak Grove	867
Oak Ridge	604
Oakland (Mo. P.)	615
Oakland (St. L. & S. F.)	606
Odessa	930
O'Fallon	536
Old Monroe	444
Old Orchard	533
Olden	1246
Olean	746
Oliver	807
Olivette	596
Ore	973
Oronogo	935
Osage	552
Osborn	1037
Oskaloosa	872
Osceola	727
Osgood	815
Otterville	715
Ovid	766
Ozark	1108
Pacific	462
Pacific (Jackson Co.)	949
Page City	775
Palemon	680
Palmyra	650

Palmyra Junction	651
Paris	675
Parkville	754
Parnell City	1027
Passaic	863
Pattonsburg	787
Pawpaw Junction	304
Pedro	892
Peirce City	1197
Pendleton	911
Perrin	1028
Petersburg	679
Pevely	442
Phelps	894
Phenix	1034
Phillipsburg	1421
Pickering	1019
Piedmont	501
Pilgrim	927
Pilot Grove	836
Pilot Knob	951
Pixley	814
Platte City	764
Platte River (St. J & G. I.)	828
Plattin	436
Plattsburg (C. R. I. & P.)	948
Plattsburg (St. L. & St. J.)	960
Pleasant Green	780
Pleasant Hill	855
Plymouth	1290
Pollock	948
Polo	1007
Poplar Bluff	344
Port Royal	469
Powersville	940
Prairie Lick	697
Princeton	1026
Purdin	885
Purdy	1482
Quarantine	418
Quincy	483
Quitman	912
Randles	349
Randolph (C., M. & St P.)	746
Randolph (H. & St. J.)	740
Randolph Springs	680
Rankin	426
Ravenwood	1019
Raymore Junction	1140
Rea	1069
Reading	459
Reeds	1119
Reeves	375
Renick	879
Renselaer	745
Republic	1311
Revere	674
Richards (K. C., P. & G.)	839
Richards (Ft. S. & E.)	835
Richfield	438
Rich Hill (Mo. P.)	795
Rich Hill (K. C., Ft. S. & M.)	807
Richland	1140
Richmond	809
Ridgeway	1058
Ristan	321
Ritchey	1070
Ritter	1243
Riverside Junction	446
Robertson	874
Robertsville	495
Rock Creek	752
Rockville	765
Rogersville	1462
Rolla	1092
Roseberry	992
Rosedale	486
Rose Hill (Mo. P.)	617
Rose Hill (St. L. & S. F.)	635
Rosendale	912
Roswell	839
Rothville	694
Rush Hill	802
Rush Siding	931
Rushville (H. & St. J.)	798
Rushville (C., R. I. & P.)	777
Russell	751
Russellville	879
Rutledge	649
Sabula	693
St. Alban	470
St. Aubert	539
St. Catherine	793
St. Charles	490
St. Clair	760
St. Cloud	754
St. James	1082
St. John Bayou*	318
St. Joseph (C. B. & Q.)	849
(C., St. P. & K. C.)	827
(K. C., St. J. & C. B.)	825
(St. L. & St. J.)	836
St. Louis (Union station, old)	438
directrix	413
Ann street	419
Chouteau avenue	471
Dorcas street	419
Stein street	430
Grand avenue (Mo. P.)	458
Grand avenue (St. L. & S. F.)	459
St. Paul	439
St. Peter	447
Salem	1173
Salisbury	730
Sampsell	715
Sands	454
Sankey	722
Sarcoxie	1104

Sargent	1340
Savannah (C., St. P. & K. C.)	1090
Savannah (K. C., St. J. & C. B.)	1100
Saverton	472
Saxton	882
Schell City	748
Scheydler Gap	981
Schuster	959
Scott	587
Searces	1014
Sedalia (M., K. & T.)	900
Sedalia (Mo. P.)	888
Seligman	1537
Seneca	849
Seymour	1654
Shackleford	759
Sharon	1114
Shelbina	776
Sheldon	916
Sheridan	1043
Sibley	783
Sikeston	328
Silver Springs	821
Skidmore	925
Slater	865
Sleeper	1217
Sligo	879
Smithfield	855
Smithton (Mo. P.)	887
Smithton * (St. L. SW.)	339
South Benton	466
South Greenfield	945
South Kirkwood	614
South Oronogo	912
South Point	488
South St. Joseph	823
South Webster	604
Southside	440
Sparta	1386
Speed	658
Spickards	786
Sprague	939
Springfield (K. C., Ft. S. & M.)	1268
Springfield (St. L. & S. F.)	1345
Springs*	845
Stanberry	991
Stanhope	666
Stanton	865
Statesburg	785
Steelville	744
Steinmetz	800
Sterling	1500
Stevens	458
Stewartsville	961
Stockbridge	832
Stoutland	1166
Stoutsville	618
Strafford	1478
Strasburg	846
Sturgeon	855
Sturges.	788
Sugar Lake	794
Sullivan	966
Sulphur Springs	411
Sumner	687
Summit (hilltop St. L., I. M. & S.)	985
Summit (St. L. & S. F.)	1343
Sutton	482
Swanwick	780
Swartz	822
Swedeborg	1114
Sweeney	652
Sweet Springs	674
Syracuse	914
Talbott	622
Talmage	1226
Tanner	884
Tarkio	916
Taylor	462
Thayer	937
Thompson	838
Thoms	955
Thornton	794
Tina	709
Tindall	779
Tipton	921
Tiptop	1198
Tower Grove (Mo. P.)	490
Tower Grove (St. L. & S. F.)	488
Tremont	1134
Trenton	812
Triplett	671
Truesdale	853
Turley	605
Turner	1194
Turney	1051
Union	546
Union Star	944
Unionville	1072
Urich	744
Utica	737
Valle Mines	739
Vandalia	776
Varner	320
Vermont	827
Verona	1261
Versailles	1020
Vibbard	1045
Victoria	468
Vigus	456
Villa Ridge	622
Vista	850
Waco	902
Waldron	758
Wales	839
Walker (M., K. & T.)	847
Walker (St. L. & St. J.)	900
Wall summit	854

Wallace	1066
Walnut Grove	1188
Ward	841
Warrenton	816
Warrensburg	829
Washburn	1463
Washington	489
Waterloo	700
Watson	903
Waverly	683
Wayland	521
Weatherby	851
Webb City* (K. C., Ft. S. & M.)	982
Webb City (St. L. & S. F.)	993
Webster	536
Wellington	719
Wellsville	819
Wentworth	1227
Wentzville	624
West Line	877
West Plains	966
West Platte	794
Westboro	977
Weston	773
Wheeling	736
White Water	364
Willard	1231
Williamsville	394
Willow Brook	995
Willow Springs	1254
Windsor	886
Winfield	446
Winona	932
Winston	1036
Winthrop (C., R. I. & P.)	788
Winthrop (K. C., St. J. & C. B.)	787
Winthrop Junction	789
Wishart	969
Wither Mill	606
Woodland	677
Woodlawn	635
Woodruff	824
Woodstock	539
Worland	787
Wright	721
Wyaconda	753
Yates	854
Yoakam	820

CHARACTERISTICS OF OZARK MOUNTAINS

BY

CHARLES ROLLIN KEYES

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CONTENTS.

INTRODUCTORY.

Missouri is divided into two nearly equal halves by the Missouri river, which flows from west to east across the state. The position of the stream is not due to chance, but to a variety of causes, which have combined to produce the effects presented. In general appearance, in surface relief, in drainage, in the character of the soils, in forestry, in lithological features, in geological structure and in many other particulars, the north and south portions of the state are strongly contrasted. There is probably no other similar district in the whole continental interior that presents in its several parts such a dissimilarity of characters and such striking peculiarities in features. North of the Missouri river there is a broad plain, with surface gently undulating, and inclined slightly to the south. The rivers flow in the direction of the general slant in shallow valleys, which present a wonderful parallelism to one another. The strata are very even and regular, but pitch at a low angle in the opposite direction to the slope of the surface. South of the principal river of the state rises a high, nearly level plateau, slanting gently from its central divide to the margin, which on one side is the Missouri river and on the other the low coastal plain of Arkansas. The rivers, after leaving the central area, flow in deep, narrow gorges. The strata are tilted moderately in the same direction as the general slope of the surface.

The last mentioned district is widely known as the Ozark country, and includes not only Southern Missouri, but also occupies Northern Arkansas and the eastern portion of Indian Territory.

The popular designation, Ozark mountains, is a name which has clung to the district ever since its earliest exploration. Although much of the area possesses a mountainous physiognomy, the appellation Ozark uplift has recently been proposed as a more expressive and a more appropriate title, geologically speaking. Still later, the term has been extended so as to cover all of the region in the two states and adjoining districts, which has been strongly affected orogenically. Notwithstanding the fact that it possesses marked topographical differences, widely different geological structure and very distinct lithological characters in its various parts, its several portions belong genetically to the same great unit of deformation. From the earliest time the district has been subjected to uprising or down-sinking. In all sections of its area it has experienced the effects of powerful dynamic forces—not at one time and in a set manner, but at various periods and in a variety of ways. Many and diverse results have been produced. They are expressed equally well in the geological construction and in the forms of relief.

The Ozark uplift is, in many respects, one of the most remarkable geological features of the entire North American continent. As the various parts are studied, new and unlooked for phenomena present themselves, and great complexity gives place to the great simplicity once universally ascribed to it. In general outlines it is a canoe-shaped elevation, broad and dome-like medially, but dying away into the surrounding country, to the east in Illinois and to the west in Indian Territory. Its major axis, which is over 500 miles in length, sweeps in a broad double curve west, then southwest, and again westward. Its maximum breadth is in the neighborhood of 200 miles; the areal extent is about 75,000 square miles. The highest parts are along a curved line, running nearly parallel to its northwest boundary. In elevation, this central divide is from 1400 to 1800 feet above the margin, and from 1800 to 2100 feet above mean tide.

PHYSIOGRAPHY.

GENERAL FEATURES.

The continental interior of North America is occupied by a wide undulatory plain stretching out from the base of the Appalachians to the foot-hills of the Rockies. For a distance of more than 900 miles in one direction and 1200 miles in another, this broad expanse of country has been practically free from orogenic disturbances, save in one spot. Only in a single place in the Mississippi valley, with its area of a million of square miles, or more than one-third of the whole United States, are there evidences of marked crustal movement. Otherwise the strata of the entire region are today nearly as even and as unwrinkled as when first laid down.

Aside from the Ozark region, the Mississippi basin may be properly regarded as a wide stretch of lowland, sloping gently in all directions from the margin toward the center and southward. Through the middle, for a distance of 1400 miles as the crow flies, flows the great river from which this region takes its name. A relief map of the United States shows that nearly two-thirds of the entire valley is below the contour line of 1000 feet. By following this river, the Minnesota and the Red River of the North, passage from the gulf of Mexico to Hudson bay may be made without going above the line mentioned.

The "Great Plains" form the western part of the region; the rolling praries of the Upper Mississippi the northern and median parts, the fertile valley of the Ohio and the Cumberland plateau the eastern section, and the coastal savannahs the southern portion. The latter is separated so sharply from the rest of the territory embraced by the Mississippi valley, that the whole may be considered as made up of two quite distinct districts. These present striking contrasts in topography, in drainage, in lithology, in structure, in stratigraphy, in age, and likewise in cultural features. The first is a vast shallow basin, with rolling, undulatory or hilly surface; the second is a boundless stretch of level country, gently inclined seaward. A more or less sharply defined escarpment forms the boundary line between the higher and the lower plains; and on a contour map of the United States this division feature is marked approximately by the 500-foot line. The larger is the Continental Interior basin; the smaller the Mississippi embayment. The two regions bear the same relations to each other in all essential particulars as do the Piedmont plateau and the Coastal plain of the Atlantic slope, which are so well known.

The water-ways of the basin are rapidly flowing rivers, moving often in rock-bound channels; those of the savannah are sluggish streams, meandering widely in their courses from escarpment to ocean.

The one comprises highly indurated masses, crystallines, limestones, sandstones and shales; the other soft, unconsolidated clastics, marls, clays, sands and gravels. With the first the incoherent strata are the exception; with the second the rule.

Stratigraphically, one is much more highly complicated than the other. The region of hardened strata has been irregularly deposited, has undergone some distortion, and has passed through many changes of continental elevation and depression. The district covered by soft beds is practically in the same condition as it was when the layers were first laid down, evenly reclined against an old continent, and is yet to undergo marked oscillation.

Regarding age, the first is very old; the second very young. The former represents the primitive continental nucleus and the ancient land extension which grew around it. In all respects it bears evidence of great antiquity. It is the Paleozoic continent. The organic remains contained in the beds are marvelously strange when compared with living animals of today. The second series of beds stands for the recent growth of the North American land area. It presents everywhere features of youth. It is the Neozoic enlargement of the continent. The fossils contained are all strikingly like modern organisms.

If the geological features of the two regions are so strongly contrasted, the cultural characters are even more so. The district of maturity is a prairie country; the home of mining, quarrying and manufacturing, the land of wheat and corn. The district of youth is a region of dense luxurious forests; the great cotton belt, an agricultural paradise.

On the whole, erosive agencies have not acted very vigorously since the deposits of the Mississippi valley were originally laid down. Through most of the long period, from the close of the Carboniferous age, when the beds were finally raised above the level of the waters of the shallow inland sea, to the present date, this vast region must have been nearly the same level lowland that it is today—a plain whose surface has remained nearly at base-level for ages, sometimes rising slightly, sometimes sinking a little, but never oscillating far, either one way or the other.

The contrasts of relief to be considered in the interior basin are not those between different parts of the plain itself, but those between the basin as a whole and region immediately around it. Beyond the boundaries in nearly every direction a mountainous physiognomy is presented. The Appalachians on the east and southeast, the Rockies on the west. the highlands of the great lake region northward, all stand out sharply against the country they surround. They all tell of powerful dynamic action which has been at work elevating broad stretches of territory—of continental movements on a grand scale.

In the central portion of the North American continent, lying within the Paleozoic area, but on the very border line between the old and new rocks, exists the only marked break in the continuity of surface and stratification. This is the Ozark uplift. The plain above which it rises has a gentle inclination to the east and south. On the northwestern margin, the elevation is about 400 feet higher than on the southeastern side. The general plane is a part of the great slope which rises gradually from the Mississippi river and extends to the foot of the Rockies. To the north and west, from the Ozark region, stretch away the prairies and "great plains" for a distance of 500 miles; to the east and south spread out the lowlands of the Mississippi embayment, which reach to the Gulf more than 400 miles away.

The southeastern flank of the Ozark region is much more abrupt than the opposite side, and forms the most striking topographic feature in the whole continental interior. It is an escarpment which begins near the Ohio river below Shawneetown, passes into Missouri, and then follows approximately the line of the St. Louis, Iron Mountain & Southern railroad southwestward to Little Rock, where it is deflected sharply, and thence extends directly westward into Indian territory. The eastern extremity of the escarpment is not so well marked as further west. Southeast from Iron Mountain the descent to the coastal plain is 1300 feet in less than 40 miles. At the west end, from Little Rock to the Indian territory line, the abrupt Ouachita ridges appear. The escarpment forms a part of the northern boundary of the Mississippi embayment; and at the same time it is the limit of the great cotton belt region. It marks off the unconsolidated clastics of the coastal plain from the indurated Paleozoic sediments of the interior, which have formed an impassable barrier against all encroachments of oceanic waters from the south, from the close of Paleozoic times to the present day.

The northwestern slope of the uplift is more gradual than the other, and finally merges into the general plain. The average gradient from crest to margin, a distance of 60 miles, is about 12 feet to the mile, or a fall of about 900 feet altogether.

The present drainage divide is a curved line running nearly parallel to the northern margin of the uplift. The structural axis, however, is much nearer the southern border, about midway between the latter and the drainage crest.

SURFACE RELIEF.

While there is simplicity and similarity in general make-up of the different portions of the Ozark uplift, the fundamental structural and topographical effects presented in the several parts are sufficiently distinct to enable several well-defined districts to be made out. This fact has been recognized both by the inhabitants and by those who have visited the region, and in consequence various names have been given to the different sections. The most prominent titles among those which deserve mention are Shawnee hills, located in the extreme east, chiefly in Illinois; St. Francois mountains, in eastern Missouri; the Ozark mountains proper, the Boston mountains, and the Ouachita system in the southwest. These various "mountain" systems, which define geographically the subdivisions of the uplift, are characterized by certain peculiarities, of which none are more striking than the various phases of topography. The extremities of the disturbed region are similar, and consist of a series of ridges which in a general way are parallel to one another. The middle is a typical high plateau, whose margins are deeply trenched by swift running streams.

Shawnee Hills.—Before it merges into the Mississippian plain, the Ozark plateau is broken up toward the eastward into a number of rather well-pronounced ridges. These ridges are cut across by the Mississippi river at various points between St. Louis and Cape Girardeau. Some of the more noteworthy anticlines are well exhibited at Selma cliff above the Ste. Genevieve, near Grand Tower and at Thebes. All of these ridges soon merge into the general upland and become inconspicuous. One of the elevations, however, attracts more attention than any of the others, and is called the Shawnee hills. This prominent range of hills has long been recognized as one of the most striking features of the landscape in Southern Illinois, where it extends in an easterly direction from Grand Tower. In the early references to this portion of the country, the hills were put down as the Oshawano mountains, so profoundly did they impress the early explorers and travelers. Schoolcraft, so late as 1821, has so designated them. Along the line of the Illinois Central railway, the crest of the divide is about 450 feet above the bed of the Big Muddy river, which washes the foot of the north flank, and is over 600 feet above river level at Cairo. Eastward, the ridge becomes less and less marked, crosses the Ohio below Shawneetown into Kentucky, and soon fades away altogether. Westward, the range of hills acquires greater prominence, and after crossing the Mississippi river, merges in Missouri into the outlying elevations of the Iron Mountain district. Where the ridge intersects the great stream, the strata are tilted and disturbed. "Grand Tower," Bald Bluff and the "Bake Oven" are among some of the more marked topographical features. The foot of the northern slope of the Shawnee range is marked by the short straight valleys of two streams flowing in opposite directions and parallel to the ridge. The southern, or longer incline, ends with the Ohio and Mississippi rivers.

St. Francois Mountains.—Southeastern Missouri has long been known as a highland district, but the title, St. Francois mountains, is of very recent application. The term is one which has been needed to designate the eastern part of the Ozark uplift in Missouri. It is a name which is peculiarly fitting, owing to its long association with the principal river and a county in the region.

The most striking peculiarity of the St. Francois group as distinguishing it from other parts of the general uplift, is the absence of any systematic arrangement of the surface features as the result of orogenic movements, and as is usually discernible in mountainous districts. Isolated peaks, large and small, constitute the prevailing type of topographic expression, and these rise one behind another with no regularity, often clustered here and there into groups of two or three, sometimes several in a row, forming a short irregular ridge. The hills or peaks rise 500 to 800 feet above the valleys which separate them, and have an elevation above tide level of 1200 to 1800 feet. No one elevation is conspicuously larger or higher than the others. The landscape presents to the view the more important ones, all about equally distant from each other, and beset or surrounded by small hills. The entire group is itself on the crest of the uplift, and stands out in marked contrast above the general surface of the plateau.

The valleys are, as a rule, broad and winding, though frequently they become narrow and tortuous, and in places even labyrinthine. Their surfaces are rolling, broken here and there by low mounds, or occasionally by prominent hills. No flood-plains of any consequence border the streams, except at isolated and widely separated points. Canyons occur, but they are quite short and not abundant. For the most part the sides of the hills are steep, and rise directly from the edge of the water-courses which wash their bases.

These are the main characteristics of the central portion of the crystalline area. On and beyond its borders the surface relief constantly changes, until a totally different set of topographic forms is met with, one which is more like that in other portions of the uplift.

Ozark Plateau.—The region with which the word Ozark has been most widely associated comprises southern Missouri and northwestern Arkansas. The term has also been applied to the extreme eastern part of the uplift, and even to the western extremity of the Ouachita system. The Ozark mountain region proper includes (1) a broad plateau which rises to a height of over 1500 feet above the tide level, and (2) a broad marginal zone so deeply trenched by water-courses as to make the term mountainous very applicable. In all its features, the district presents a marked contrast to the other portions of the uplift. In the plateau, the streams take their rise and flow in opposite directions down the general slopes in ever deepening trenches. The water-shed trends first westward from the granite peaks of St. Francois, and then bends southward in a broad, sweeping curve. While the crests of deformation and of drainage doubtless coincided originally, the erosional effects on the eastern or southern side of the uplift, owing to the steeper inclination, as well as an eating back of the old oceanic shore whose prolonged efforts resulted in the Mississippi escarpment, were much more vigorous than on the northern flank, and finally resulted in a wide separation of the water-shed and the top of the arch.

In the central part of the area is a seemingly boundless plain, the surface of which is gently rolling or billowy. The drainage divide is inconspicuous. Away from the crest the small water-courses unite with one another, and their valleys begin to deepen as they recede from top of the slope. The hills rise higher and higher, their sides become continually steeper and steeper, and the gorges often pass into true canyons with nearly vertical walls, at the foot of which are talus slopes reaching down to the edge of the swiftly-running waters. In times of freshet the smaller side-courses entering from the high ground leap over the precipice walls and form numberless cascades; or the torrential waters dash down the talus slopes till they mingle with the main stream. Everywhere the landscape is mountainous, and it continues to become more and more so until the margins of the uplift are reached. The tops of the narrow divides are for the most part on a level with the gentle slopes of the arch, and nowhere show any marked deviations in height from this horizon.

Boston Mountains.—This name has been used to designate a range of steep-sided elevations which form the water-shed in western and central Arkansas, between the White and Arkansas rivers. They extend nearly parallel to the latter stream half way across the state. The crest is from 1000 feet above sea-level in the eastern part to more than twice this height in the central and western portions, or from 600 to 800 feet above the waters which wash their bases. As remarked by Simonds, these mountains form a notable barrier, and are nowhere passed without marked ascent. They form a remarkable line of rugged elevations, rising nearly to a uniform height, and more or less abruptly truncated on the top. The northern flank of the mountains is somewhat more abrupt and broken than the southern, in many places forming a prominent escarpment, which is the most pronounced feature of surface relief in the region. Though broken at points, the escarpment follows the course of the White river for many miles, from beyond the point where the stream enters the state from the north to where it leaves the highland district and meanders through the Neozoic plain of the Mississippi embayment. The south face of the range slopes rather gently toward the Arkansas valley. The topography is strikingly one due to recent and profound erosion. The general upland is inclined southward at a low angle. Into this plateau the rivers have cut deep gorges and valleys, exposing undisturbed strata in considerable sections. On the steeper elevations the harder layers stand out prominently above the softer beds, forming impassable walls of various heights.

Ouachita Mountains.—South of the Arkansas river is a series of mountain ranges trending west from Little Rock into Indian territory. To the most southerly ranges Branner has given the name, Ouachita mountains; but more recently Griswold has extended the meaning so as to cover the entire number of ranges. The system consists of numerous anticlinal ridges which lie nearly parallel to one another. They rise from 500 to 1000 feet above the valleys on either side, and from 1600 to 2100 feet above the sea-level. The northern ridges are not so prominent as the southern, and in places do not even form noteworthy topographical features; but in passing southward each range becomes successively more rugged and more elevated above the valleys. Viewed from the lowland of the Mississippi embayment they stand forth, as aptly remarked by Hill, "as sharply and majestically upon the landscape as do the Rockies above the Colorado plain." The peaks are so prominent in many places as to receive special names.

The valleys between the mountains are broad and rather evenly rounded out. The surface is, as a rule, quite undulating. Occasionally an isolated peak of considerable height rises out of the basins. One of these, known as Pigeon Roost mountain, is reported by Griswold to be nearly 900 feet above the plain of the valley.

The majority of the ridges appear to rise to about the same height. This upland level may be regarded as a part of the Tertiary peneplain, which coincides with the general bowed surface of the whole Ozark uplift. In the north, where the strata are relatively undisturbed, the great planes of stratification are approximately parallel to the surface of the uplift, and erosion has not had an opportunity to produce widely different topographic forms. In the south, especially in the Ouachita district, where the Paleozoic strata were profoundly folded in pre-Tertiary times and the country afterward reduced to base-level, the upturned edges of the layers have widely different capacities for resistance. With the elevation of the Tertiary peneplain in this part of the country, great contrasts of relief were soon produced.

The marked structural differences existing in the elevated area south of the Arkansas river, as compared with that north of the stream, have given rise to the suggestion that the two districts are distinct units of deformation, and that the long slope of broad river valley forms the southern slant of the Ozark dome. The present configuration of the valley is certainly due partly to structural peculiarities, but it is also due largely to other conditions. On account of the existence of soft Coal Measure shales, the tract has succumbed to erosion agencies more rapidly than in the bordering district.

If the conclusions here presented be correct, the last great uplift of the region includes the territory both north and south of the Arkansas river. As a unit, the Tertiary peneplain was bowed up from the Red river to the Missouri.

DRAINAGE.

General Characteristics.—There are some peculiarities in the hydrography of the different parts of the Ozark uplift which are at once striking and interesting. In the first place, it is a region bordered by large streams. On the northern margin is the Missouri river. Cutting across a part of the eastern extremity is the Mississippi. In the south is the Arkansas river, separating in like manner a considerable portion of the western end. Still further to the south is another large water-way, the Red river. In the main, the subsidiary drainage is quaquaversal, the minor courses reaching the large marginal streams nearly at right angles. The southern side of the uplift being much steeper than the northern, the water-shed has been constantly pushed northward, until now there exists a wide divergence between it and the main structural axis.

Eastern Part.—In the extreme east, the Shawnee ridge presents a striking system of drainage. On the north side are two water-ways running at the base parallel to the main axis, but in diametrically opposite directions, and into them flow the subsidiary streams from the crest of the divide. Eastward is the south fork of the Saline river, which empties into the Ohio near Shawneetown. Westward is Orchard creek, which unites with the Big Muddy immediately below the point where that river turns abruptly from its long southerly course to the west. The latter stream continues its westerly direction until it cuts the Mississippi bluff above Grand Tower. Several of the minor ridges to the north also show similar though not so marked peculiarities of drainage.

The St. Francois highlands form the highest part of southeastern Missouri. Descending rather rapidly on all sides from the central area, the drainage becomes radical. The decline, excepting perhaps toward the west, is quite marked, in consequence of which stream erosion is energetic. This action is not so fast, however, as to form canyons, except in a few places; but the rate is sufficiently marked to prevent the forming of broad flood-plains. For the most part the valleys are wide trenches, with the flowing contours of the hills continuing down to the channels of the streams themselves.

Central District.—The Ozark region proper is a country in which the water-courses are cutting vigorously their channels not only at the surface but often underground, finally bursting forth as good-sized streams from the foot of some cliff. Everywhere after leaving the central plateau the rivers descend rapidly on both sides of the main divide. Deep gorges or canyons are formed, the walls of which are frequently perpendicular. Toward their mouths the streams come to lie deeper and deeper below the general level of the upland plain. The drainage-ways of the region are in great part of large size, in this particular being quite peculiar.

In the Boston mountains the character of the water-courses is very similar to that of those in the more central district, except, perhaps, the decline is not so marked on the south side. The drainage is also more quaquaversal—the White, Osage and Arkansas rivers receiving finally the waters of all other streams.

Western Portion.—In the Ouachita region the drainage is in the main in an eastern direction until the rivers issue from the Mississippi escarpment, where their courses are deflected so as to follow more closely the general slope of the coastal plain. The folding of the region has had a marked influence upon the character of the drainage. As elevation gradually took place the streams naturally followed the synclinal troughs, though subsequently they have undergone more or less change.

STRATIGRAPHY.

FUNDAMENTAL ELEMENTS.

The Ozark region is quite remarkable in having within such limited areas so wide a range of geological formations. In both the eastern and the western portions a cross-section constructed transversely to the main axis presents a complete succession from the oldest Archæan to the newest Quaternary, from the hardest crystallines to the most incoherent clastics, and from perfectly massive rocks to the most perfectly stratified sediments. There are represented a considerable variety of igneous masses belonging to different ages, a very complete section of the Paleozoic, and a rather full sequence of the later deposits which recline against the older strata. The first group includes chiefly abysmal rocks, with some intrusives. The former have been exposed partly by being forced to a position at or near the surface, and partly by profound erosion of the overlying stratified rocks—the crystallines for the most part occurring near the crests of the principal folds. The latter are shown at the surface in the form of dikes, in some cases outwelling. The second group embraces a very full representation of the great formations from the Cambrian to the Carboniferous. Some of these formations, however, are shown in comparatively small thickness. The third group forms an important succession of beds which, while now forming no part of the uplift, occur along its southern margin, and played an important role in the determination of the age of certain igneous masses.

Lithologically, the great bulk of the rocks which go to make up the uplift are limestones. Some sandstones are present, but few shales or other beds. The first of these components is largely of the magnesian variety, and covers the uplift from the Mississippi river to the Indian territory line. Sandstones of considerable thickness are intercalated, and the dolomitic series is overlain toward the margins by ordinary limestones, and in the western part of the area by shales.

CRYSTALLINE ROCKS.

During recent years information obtained in Missouri and the adjoining states concerning the ancient pre-Cambrian granite and schistose masses, upon which the sedimentary rocks were laid down, has indicated clearly that it lies very much nearer to the present surface in the Ozark region than in any portion of the immediately surrounding country. In the southeastern part of Missouri, in the Iron Mountain district, considerable areas of the oldest rocks have been brought to light through removal of the sediments which once covered them. For many miles outside of the limits of the large central areas, small peaks and bosses widely separated from one another are found peeping out from beneath the limestones. Beyond the main mass, fifty miles to the westward and along the crest of the uplift, other groups of crystalline hills have been exposed in the deep valley of Current river in Shannon county. At the western extremity of the dome in Indian territory, other old granite areas are also found. On the northern margin of the uplift a number of deep drill-holes have penetrated to the crystallines. It St. Louis county, at the Insane asylum, according to Broadhead, over 250 feet of granite were passed through in sinking a well which terminated at 3843 feet from the surface. In Franklin county, near Sullivan, granite is said to have been encountered at 1100 feet from the surface. At Kansas City, black mica schist was taken out as a diamond drill core from a depth of 2400 feet; and at Carthage, in the southwestern part of the State, porphyry is reported at 2000 feet.

The crystallines of the Hot Springs district are very different from the other igneous rocks of the uplift, and are in no way related to the fundamental complex. They are much more recent than those which go to make up the latter. Thus two primary classes of the crystallines which occur in the region may be recognized—the one embracing the older and the other including a younger group. The first are the Archæan granites and porphyries; and the second one the Cretaceous eleolite syenite.

Archæan.—As already stated, there are two places in the Ozark uplift which exhibit the older crystalline or Archæan rocks to good advantage, and these are at the opposite extremities of the elevated area. The best-known of these districts is in southeastern Missouri, in what is widely known as the Iron Mountain country. The peak from which the region takes its name may be regarded as the center of the crystalline exposures. The largest areas are in the immediate vicinity, and others of greater or less extent are scattered over a considerable range of adjacent territory. The igneous rocks of the district are in great part granites and porphyries, which are broken through in numerous places by basic intrusives. The acidic masses present a considerable variety, of which porphyritic phases greatly predominate. As a rule, all are some tone of red in color. They are fine-grained to coarse-textured, the components of some of the varieties being as much as two inches in length. They are compact, resist weathering influences well, and are jointed in such manner as to facilitate quarrying. The basic rocks also form a considerable series, which vary in structure from thoroughly holocrystalline to a pure glassy facies. They occur in numerous dikes and masses from a few inches to several hundred feet across, and cut the granites and porphyries alike. Usually the dikes are traceable but a short distance, chiefly on account of the heavy covering of decomposition products. The only other Archæan rocks which are known in the Ozark uplift are those found in the western part in Indian territory, immediately beyond the Arkansas boundary. They are chiefly granites, of which there are many varieties. These are cut by dikes of basic intrusive material, in a manner similar to that shown in the eastern area. There are a number of exposures, some quite extensive. Two of these areas are of considerable importance. The more northerly district was made known by Owen, and the more southerly by

Hill, who reports one ridge of solid granite more than 40 miles in length.

Cretaceous.—The younger igneous rocks of the region occur chiefly in central Arkansas, the principal areas lying between Little Rock and Hot Springs. They consist almost entirely of abysmal and intrusive rocks, the former represented by eleolite syenite and the latter by more basic dike materials. Although locally called granites, they differ both chemically and mineralogically from the older crystallines of Missouri and Indian territory. While the most important masses are confined to four limited areas, a large number of dikes are scattered over considerable territory. It is believed that these rocks were formed about the close of the Cretaceous.

SEDIMENTARIES.

As already stated, a rather full sequence of stratified rocks is represented in the Ozarks. The greater part of the region is occupied by magnesian limestones, with intercalated sandstones, to which Broadhead has recently given the name Ozark series. The exact geological age of all parts of the magnesian limestone is not known with certainty. A considerable proportion is without doubt Silurian, while another part appears to belong in the Cambrian. In the western part of the uplift the Carboniferous occupies a portion of the uplift, and around the western, northern and eastern margins the same rocks are found.

Algonkian.—Immediately overlying the Archæan in a number of places are found beds of conglomerates and slates. These are shown to best advantage, perhaps, on Pilot Knob. It has been thought that they represent the Algonkian of the Lake Superior region; but the area is so small, the situation so far removed from any other of this age, and detailed information regarding it so meager, that the recognition here of the Algonkian must be regarded as provisional.

Cambrian.—In the earlier geological reports of Missouri, great prominence was given to a succession of magnesian limestones lying between the horizon of the Trenton and the crystalline basement. By Swallow there were considered to be four thick limestones separated by sandstones. They were known as the first magnesian limestone, at the top, the first or saccharoidal sandstone, second limestone, and so on to the fourth magnesian limestone, at the bottom. The aggregate thickness of this "magnesian limestone" series was considered to be over 1200 feet. It was referred to the Calciferous as then understood. Since the appearance of Swallow's report, other work has been done in the region, and recently interest in the subject has been revived. More attention has been directed to the magnesian rocks in southeastern Missouri than anywhere else in the uplift, and although many new facts have been obtained, much additional information is necessary before satisfactory conclusions concerning the different parts can be drawn.

The igneous masses associated with the sedimentaries are known to be much the older. The relations of the two formations are of interest from a scientific standpoint, and of great importance from the practical side of the question. The eruptive rocks, as has been stated, are Archæan in age. Their upper surface was deeply eroded into hills and vales, which were even more pronounced than at present. When this old land surface began to be depressed after long subjection to sub-aerial influences, the accumulated debris was deposited around the old peaks and eminences. In early paleozoic times, the limestones and sandstones were laid down completely covering the old land area. Since that time, elevation above the sea level and a vigorous erosion has brought the crystallines to the surface again. The process has not gone far enough to remove all the strata from the old crystalline surface, as drill records show that granite and porphyry extend over a wide area a short distance below the present surface.

The sedimentaries of southeastern Missouri are regarded as partly Cambrian and partly Silurian. No distinctions have been yet made between the two. Heretofore but few fossils have been found in the Ozark limestones. Furthermore, those occurring were so poorly preserved that until recently no good material for systematic purposes had been secured. It is quite a remarkable fact that of all the forms obtained from these rocks, there had been none which had been certainly identified with species described from other districts. In every case where specific comparisons were made, more or less doubt was always expressed concerning the actual identity of the species. Of the many fossils mentioned in connection with the region, few of the references had been more than generic. None of the material ever collected in the eastern part, at least of the Ozark series, had ever had even the approximate horizon determined with any degree of exactitude; and this, together with the poor preservation of what had been collected, shows that little dependence could be placed upon the faunal evidence as a criterion in regard to the geological age of the several beds. It could only be said that some of the fossils appeared to be Silurian species, while others were decidedly Cambrian in aspect. In no case were the faunas which had been obtained extensive enough to warrant an exact arrangement of the succession. Although considerable information concerning the geology of the crystalline area had been obtained, there yet remained much detailed work in stratigraphy, which had to be done before an exact correlation of the various strata and of the faunal zones could be made in southeastern Missouri. What was true in respect to the fossils in the strata of the St. Francois region was equally applicable to those found in other portions of the uplift, except that in the latter locations they seemed even rarer.

The nearest region presenting rocks of similar age and lithological character, one which has been, moreover, thoroughly investigated and with which the Missouri section should be correlated, is northeastern Iowa. When this is done, it will be understood more clearly just how much, if any, of the Ozark series below the Saccharoidal sandstone should be placed in the Silurian and how much in the Cambrian.

Silurian.—The Silurian rocks, of well-determined age, which lie above the lower part of Ozark series of magnesian limestones, occur chiefly in the eastern part of the region.

They are best exposed along the Mississippi river, between St. Louis and the mouth of the Ohio, and include the Trenton limestone, the Hudson shales and certain Upper Silurian limestones. Farther south, in northern Arkansas, strata thought by Williams to represent a part of this sequence are reported. It is beneath the Trenton in the eastern portion of the uplift that difficulty arises in attempting to fix the geological age of the beds, and in the present stage of investigation, the exact lines of demarkation cannot be drawn. As explicitly stated elsewhere, the Ozark series of Broadhead includes both Silurian and Cambrian instead of the latter alone, as finally announced by the author of the name. The limestones of the Ozark series cover a very large part of the region, and it is quite probable that a very considerable proportion of them will be found to be Silurian, not only in Missouri, but also in Arkansas. In the Batesville region, Trenton fossils have been recognized by Williams, and beneath the strata containing them are magnesian limestones and sandstones which are referred to the Calciferous. "Only the upper members, however, are regarded to be such, and the larger part remain to be studied." Below them and exposed to the north is a series which, according to Branner, passes into Missouri. Farther to the west, in the Ouachita district, the novaculite rocks have been considered to be largely Silurian.

Devonian.—The rocks of this age are exposed on the flanks of the uplift, principally in two places—one along the northern border of the eastern part, and the other in the western portion. In the former region the rocks consist largely of compact buff limestones, with some shale. They are exposed chiefly along the Mississippi and Missouri rivers, forming a narrow belt more than 200 miles in length, which extends up the latter stream from its mouth half way across the State. In southeastern Missouri the Devonian limestone has been called the Grand Tower formation. It was formerly referred to the Onondaga and Oriskany of the New York section. The fauna contained differs very considerably from most other Devonian faunas of the West. The rocks along the Missouri river have been termed the Callaway beds. They comprise heavy calcareous layers, above which are 30 feet or more of shale that is highly fossiliferous. The fauna is the typical "Western Hamilton," which is so characteristic of the Devonian rocks farther north in Iowa. The same faunas have also been observed in certain layers near Cape Girardeau. On the northwestern border of the uplift the Carboniferous beds overlay the magnesian limestones of the Ozark series, so that no strata between are open to observation. In the western district considerable doubt has been entertained concerning the existence of Devonian beds. The only layers which appear to have any affinities to strata of this age are in northern Arkansas and southwestern Missouri, where there is a band of black argillaceous material called the Eureka shale.

Carboniferous.—The Ozark uplift is almost completely surrounded by Carboniferous strata, and in addition the western half of the elevation is covered by beds of the same age. The lower part is in great part a fossiliferous limestone, which is easily recognizable, and which forms a platform that sharply cuts off all underlying rocks, regardless of age. Along the northern flank of the arch the subdivisions of the Lower Carboniferous are essentially the same as farther north and east in Iowa and Illinois. There are four members, the Kinderhook, Augusta, St. Louis and Kaskaskia, which altogether form the Mississippian series. In southwestern Missouri and the adjoining parts of the contiguous territory, the upper two members do not appear to be so well represented; at least until very recently the evidence as to their existence was so meager that it was not yet known with certainty whether or not they were present. Of late, however, both members have been recognized and characteristic fossils obtained. The Upper Carboniferous forms a broad belt of shales outside of the lower limestones. In western Arkansas a broad tongue of Coal Measures extends into the central part of the state. The formation was doubtless at one time much more widely distributed than at present, and covered a considerable portion of the uplift. At the present time small outliers are found nearly to the crest of the main elevation.

Cretaceous.—On the southern margin of the arch, resting against the abrupt escarpment of Paleozoic rocks, but forming no part of the uplift, is a variable series of clays, sands and chalks which stretch out for a long distance from the border of the more ancient deposits. The unconsolidated clastics represent a succession of depositions from repeated invasions of the great southern sea, whose waters beat against the old rocky shores, eroded it deeply, but were unable to pass the barrier, and finally retreated altogether to the limits of the present Gulf of Mexico.

Besides the Cretaceous, there are later Tertiary and Quaternary beds, which are found in the coastal plain. They consist chiefly of clays, sands and gravels.

GEOLOGICAL STRUCTURE.

GENERAL FEATURES.

Considerable detail has been entered into concerning the physiographic features of the region, for the reason that they are but the outward expressions of the inward structure. As has been stated, the Ozark uplift is a long, curved, canoe-shaped elevation, in general aspect a broad arch, wrinkled and folded in some places, but for the most part exhibiting no very pronounced effects of compression. The deviations from the common type of a simple swell are the result of orogenic movements, which have operated at different times, in different ways, and in different parts. Besides the general bowing, which was probably begun very early in the history of the region, numberless minor deformations have been imparted, which have tended to disguise somewhat the primitive simplicity of the broad fold. In some places little deformation is observable; in others the forces of compression have been quite effective, and there is noticeable a very marked series of wrinkles, with some faulting. This is the case of the Ouachita country, and in a much less degree at the eastern nose of the great ridge. In geological structure the subordinate districts of the uplift which have been defined are each as varied and as different as the types of surface relief represented.

PRINCIPAL PHASES OF STRUCTURE.

Shawnee Region.—As the eastern extremity of the Ozark uplift merges into the general level of the vast interior plain, it appears to resolve itself into a series of minor wrinkles, of which the most prominent forms the Shawnee hills. The Mississippi river cuts across these folds, exposing clearly the details of structure. Very marked inclinations of the strata are presented at certain points along the stream between St. Louis and the mouth of the Ohio. Attention has been called to these comparatively high dips by both Shumard and Worthen—the observations of the first writer having been made on the west side of the river, and those of the second on the east bank. In the main there is a close agreement as to the character of the different features.

Although for the most part the undulations are small in amplitude, the latter is in some cases so much as several hundred feet. The synclines are usually broader than the anticlines, and this appears to be a distinctive feature. The trend of the ridges is nearly east and west, but strict parallelism is not preserved. Toward the south more pronounced deformation is manifested than to the north. The principal anticlines are shown at Crystal City, Cliff, Grand Tower and Thebes. Faulting to some extent may accompany the folding, but the only place where this is likely to occur to any great extent is at Grand Tower. The dips observed in this vicinity are as high as 25 degrees. This is the point where the Shawnee ridge is cut by the Mississippi. The Thebes anticline is probably the sharpest of all. In Missouri it is also shown by a ridge of paleozoics which rises out of the flood-plain of the great river, and which extends inland a dozen or more miles before losing itself in the lowlands. The leading features of the region are shown in the geological section along the Mississippi, from St. Louis to Cairo.

St. Francois District.—The highlands of southeastern Missouri differ very markedly from other parts of the uplift in having old granitic rocks extensively exposed within their limits. This Archæan nucleus supports all the later rocks. It forms the central portion of the broad dome-like elevation, from which the sedimentary beds dip away in all directions. The granitic core having been in pre-Cambrian times an old land area around and upon which the sedimentaries were deposited, the strata originally had a slight seaward inclination, which, in direction, coincided approximately with the present dips. But the slant of the beds is much greater at the present time than when deposition took place, for the crystallines form the center of the upward movement. A general section transverse to the main axis of the uplift presents a central core of igneous rocks, which form the numberless peaks and minor elevations of the crystalline area. Upon the surface of these the magnesian limestones and various sandstones recline. Toward the border on the north, other paleozoic strata overlap and become attenuated as they approach the crest of the great arch. On the south the later clastics of the Mississippi embayment rest against the older rocks in a similar manner. The strata immediately above the crystalline rocks are usually sandstones of greater or less thickness.

The sedimentaries rest in marked unconformity upon the underlying crystallines. It is much more than an ordinary break in regular deposition, for the stratified beds were deposited upon an old eroded land surface, the relief of which was more broken and the extremes of altitude much greater than they are now. It is very remarkable that at the present time this old topography is being exhumed through erosion, and that merely a few remnants of the great mass of limestone which once covered the central granitic rocks now remain in the bottoms of the old depressions once occupied by the ancient waterways, whose courses coincided nearly with the present valleys. Drill-holes put down in many of the existing limestone valleys have passed completely through the stratified rocks, and have penetrated the crystallines beneath. This is shown at a number of points in the vicinity of Iron Mountain, Pilot Knob and elsewhere. The details of the juncture between the sedimentaries and crystallines are well shown in a number of places. Usually over the old surface of porphyry or granite is spread a bed of varying thickness of fragments and rounded water-worn bowlders of the crystalline rocks themselves, the whole mingled with granitic sand.

Central Plateau.—The median portion of the uplift, that part which most properly is entitled to the designation of Ozark mountains, presents great simplicity of structure. It is a broad spreading arch, with practically no minor deformations. Although erosion has been profound, the central crystalline core, if such exists, has nowhere been exposed, unless the small pegmatite area, recently discovered in Camden county, should prove to be a part of this igneous sub-structure. That the crystallines do exist not very far beneath the present surface is indicated by borings—one at Carthage, on the border of the Coal Measures, showing granite within 2000 feet of the surface.

The greater part of the region is occupied by the magnesian limestones and their associated sandstones. Against these rest younger strata, thinned out from their average thickness, until they are completely lost. In general structure, the region presents essentially the same simplicity as the St. Francois district, with the difference, perhaps, that erosion has not yet reached the granitic rocks upon which rest the sedimentaries. There is the same even bending of the strata, and the same gradual rise from the margins to the axis of the great anticline.

Boston Range.—In northwestern Arkansas the arrangement of the strata is essentially the same as in the plateau region. The same comparatively unwarped layers lie upon one another in regular sequence, and nearly in a horizontal position. Only in a few places are there marked dips. The mountainous aspect of the region is due rather to peculiarities of drainage and erosion than to special structural features. With large water-courses running on either side of the district, and in the same direction, a long narrow ridge has resulted. The channels of the main streams are now more than 1500 feet below the original surface of the general plateau, which may be regarded as once having existed about on a level with the present crest of the mountain.

Ouachita System.—This portion of the uplift differs very materially in structure from other parts of the Ozark region, in that it exhibits in a very noticeable degree the effects of mountain-making forces. It is, in fact, the only part of the uplift in which the action of compressive strains has been exerted to a marked degree. Griswold has given the region more detailed attention than any one else, and has recently shown that the strata have been folded much more than had been previously supposed. The system of mountain ranges present somewhat complicated relations in their several parts, and the salient features are dependent upon the phases of geological structure which exist. Some dislocation has been observed, of which reversed faulting is a prominent and anomalous phenomenon within the limits of the general uplift. It is a significant fact that this typical mountainous district is on the extreme margin of the dome, and also on the borders of what was once the limits of the broad southern sea, of which the present gulf of Mexico is the diminutive remnant. Passing from the confines of the coastal plain into the interior, the flexures rapidly lose their pronounced folded character and straighten out to approximate horizontality.

MINOR PHENOMENA OF DEFORMATION.

Jointing.—As one of the most evident results of crustal movement, jointing or cleavage of the rock masses is not the least important. It is exhibited to best advantage in the crystalline areas, particularly in the St. Francois district. Aside from the horizontal séries of cleavage planes which are doubtless due in part to contraction in the cooling of the molten masses, there are several vertical sets, the principal one of which has a general direction of northeast and southwest, or, more exactly, north 60 degrees east. These pass from one kind of rock mass to another without change of course, showing that they have arisen largely from orogenic strains. They correspond also in trend with the basic dikes which traverse the district. Similar joints are observed in other parts of the uplift, but they are not so prominent in the stratified rocks as in the massives. No regular system has yet been made out. In the lead and zinc districts, careful inquiry will doubtless reveal some definite arrangement of the joints. The beginning of crevices appears to depend upon these structures.

Faulting.—Both normal and reversed faults are represented. The latter are found in western Arkansas in the Ouachita district. The former are much more numerous, but are commonly of small throw. They occur throughout the region. A number of faults having a considerable displacement have been reported at various times, but reliable and satisfactory information concerning them appears to be wanting. Several faults of considerable extent are thought to occur in the neighborhood of Grand Tower on the Mississippi. The most noteworthy dislocation is found on the northern margin of the uplift at the mouth of the Illinois river. It has been called the Cap au Gris fault, taking its name from the old French voyageurs' designation of the sandstone headland which it produces on the Mississippi. In Missouri it is well shown on the river bluffs above Winfield, in Lincoln county. At this point the Devonian limestones, tilted at an angle of 75 degrees, rest against the horizontal strata of the Magnesian series.

In western Arkansas a number of very pronounced faults of the reversed order have been made out in the Ouachita ranges, where they accompanied the close foldings of the strata in that region. In some cases notable trust planes have been developed.

Intrusions.—The intrusive rocks differ very much from the granites and syenites, with which they are more or less closely associated, in being more basic. They form dikes of greater or less extent, and in a few cases well-defined bosses. As a rule, the former may be traced continuously only for short distances.

In the Archæan area of southeastern Missouri the dikes coincide in direction with the principal system of joints: that is, northeast and southwest. They consist chiefly of diabases, often with some glassy material. In no case known do they cut the stratified rocks overlying the crystallines. Fumarole action has been quite vigorous in some portions, but in others practically no metamorphic change has taken place in the neighborhood of the intrusions.

In the central region there is only a single point known which is likely to prove intrusive. It is in Camden county, Missouri; and the rocks appear to be a very acid granitic mass of the pegmatitic variety. Further examination of the field relations and the petrographical characters is necessary before it can be satisfactorily understood.

The intrusives of the elolite-syenite region of Arkansas penetrate not only the crystallines, but also the sedimentary beds above them. According to Kemp, the dikes are all small—the widest being not over four feet. They are scattered over an area whose limits are more than 40 miles from the large igneous masses with which they are believed to be closely connected genetically. Little or no contact metamorphism is noticeable. Farther west, in Indian territory, basaltic dikes are also reported in connection with the granites of that region.

Unconformities.—The physical breaks in the regular deposition of the strata in and around the Ozark uplift are important records in the geological history of the region. Several are as marked as are to be found anywhere in the continental interior.

The most noteworthy of all is between the Archæan crystallines and the Magnesian limestones, best shown perhaps in southeastern Missouri. On a rough old land surface the first sediments which accumulated within the limits of the state of Missouri were laid down. This plain of uneven deposition is apparent everywhere thoughout the St. Francois region. Its presence in the western part of the uplift is not well known.

In the Magnesian limestone or Ozark series, there has been observed a notable disparity in the arrangement of the strata at the base of the first or Saccharoidal sandstone, and this may mark the division line between the Cambrian and Silurian strata. Although best shown at Pacific, it is doubtless of more than local importance. The Silurian and Devonian appear to bear unconformable relations to each other, especially over the northern part of the district. Between the Devonian and Lower Carboniferous the physical break is very marked, particularly in southwestern Missouri, where a remarkable overlap occurs—the strata of the latter age, over a considerable area, resting directly upon the Magnesian limestones. Farther to the south and southwest the exact relations of the supposed Devonian and the Lower Carboniferous are not very clearly understood, but the two have been usually reported as conformable. In eastern Missouri the sequence of strata from the Devonian to the Lower Carboniferous appears ordinarily quite regular, with perfect transitions. But the rapid thinning out of the first-named beds in passing northward from the Missouri river indicates that some warping of the crust was experienced here.

In the Lower Carboniferous there is a widespread unconformity at the base of the Kaskaskia. In the eastern part of the uplift it is not shown clearly, but its position is indicated by the Aux Vases sandstone, which is so well exposed in the Mississippi river bluffs between Ste. Genevieve and Ste. Marys, and on the opposite side of the stream above Chester. North of the mouth of the Missouri this sandstone is not known; and its place is occupied by a lithologically identical sandstone of Coal Measure age, which rests upon the eroded surface of St. Louis limestone. The true significance of this great sandstone separating the St. Louis and Kaskaskia limestone does not appear to have been understood fully, especially when taken in connection with the absence of Kaskaskia rocks north of the Missouri river. There is an extension of limestone—the St. Louis—that, before the Coal Measures were laid down, was deeply eroded over a large part of its area, and over another adjoining portion having a great sandstone superimposed. This would point to the conclusion that the broad expanse of water which, during the deposition of the St. Louis beds, reached nearly to the present northern boundaries of Iowa, had retreated more than 400 miles to the southward. Dry land existed over a large part of the area formerly covered by the St. Louis waters, and bordering this continental mass, arenaceous deposits were laid down in the shallow littoral seas.

The line between the Lower and Upper Carboniferous is the most prominent physical break, next to the one at the base of the sedimentary column, that is represented in the whole Mississippi valley. The evidences of marked unconformity are everywhere plain on three sides of the uplift, as well as over a portion of its northern flank.

The other disparities in regular sedimentation are on the south flank, except in the case of the drift deposits, which reach the northern margin of the dome. The Cretaceous and also later depositions rest unevenly against the more indurated and older rocks.

PALEONTOLOGY.

From one end of the Ozark uplift to the other, the strata have been devoid of means by which the different terranes might be determined geologically. It is probably due largely to this fact that the rocks which go to make up the chief portion of the great dome have so long remained undetermined as to exact age. The scarcity of fossil remains in the magnesian limestones has been a striking peculiarity of the formation, and a point to which all who have worked in the region have drawn attention. Not only have fossils been scarce, but those which did occur were very poorly preserved, as a rule, their identity uncertain, and the horizons from which they had been taken not correlated with any degree of accuracy. Comparisons with forms of other districts had been few, and these had been attended with much doubt. These facts are admirably brought out in the paragraphs and table recently published in connection with the report on the lead and zinc deposits of Missouri. Of the forms from the Ozark series which had thus far been found, some were undoubted Silurian species, while others were believed to be Cambrian. Those known were almost entirely brachiopods and gasteropods—of three or four species chiefly—with a few cephalopods and trilobites. In the Ouachita region, graptolites, along with a few molluscan remains of the Lower Silurian, had been recognized.

The so-called Devonian shale of the western part of the uplift in Missouri and Arkansas is also nearly devoid of recognizable fossils, so that there is also some uncertainty as to the age of these beds. In the eastern portion of the Ozark ridge, both the Devonian and the Silurian as far down as the Trenton carry abundant fossils.

Around the margins of the dome, on the west, north and east, the Carboniferous beds are highly fossiliferous, and furnish extensive faunas at nearly all horizons.

On the southern border, the Cretaceous and later deposits supply fossils in considerable numbers.

MINERAL RESOURCES.

The Ozark uplift is a region of vast mineral wealth, the great body of which is as yet scarcely touched. The zinc deposits of southwestern Missouri and northwestern Arkansas are among the most important in the world. The lead of southeastern and southwestern parts of the former state and the northern portion of the latter can hardly be estimated in value. Iron has been an important product of the St. Francois district, and there are known at the present time more than a thousand localities in the eastern half of the uplift where workable deposits occur. Copper, cobalt and nickel are known, and the former has been worked. The most valuable manganese deposits in America are found on the southern slope of the great fold in northern Arkansas. Coal in abundance lies around the margins of the arch. Clays occur in exhaustless quantities, from the varieties used for common constructional materials to those from which are manufactured terra cotta, refractory products and china-ware. Building stone for all ordinary purposes abounds throughout the region, and the granites which occur in exhaustless quantities are surpassed by none. There are numberless mineral substances which are not yet worked on a commercial scale, but eventually many of these will doubtless be found to exist in sufficient quantities for profitable mining.

AGE OF THE UPLIFT.

Since the region where is now located the Ozark uplift was the first land to appear above the waters of the continental ocean, it has been heretofore the general opinion that certain portions—as for example the Archæan peaks of the St. Francois district—have remained above the sea level as an archipelago from pre-Cambrian times until the close of the Paleozoic, when all the surrounding area also became a land surface, and that the inference to be drawn is that the existing geographic features are very old. It is the purpose of the present brief review of the salient features of the uplift, not only to question the validity of the conclusions previously deduced, but to emphasize the fact that the Ozark uplift of today is essentially modern.

It is probable that from Archæan times the region has been one of constant oscillation, for the most part slight, perhaps, but at certain periods quite marked. Some of these changes in elevation are clearly defined, but the records of most of them are now obliterated. One of the most notable results of the warping of the earth's crust in this district, was as has been intimated, at the beginning of Paleozoic time, when the crystallines were subjected to profound subærial erosion. Another period of marked emergence was during Devonian times. A third occurred toward the close of the Lower Carboniferous, after the deposition of the St. Louis rocks. Still another closed Paleozoic deposition in the continental interior.

In post-Paleozoic times the oscillations of level have been manifestly not less marked than in the earlier periods. The most noteworthy, perhaps, was the rise of the land after the protracted submergence recorded by the Cretaceous. It is to this period that the intrusions of igneous rocks along the southern or coastal margin of the uplift in central Arkansas are assigned. Evidences of a subsequent lower level of the land surface are manifested in the peculiarities of the topographic forms in the plateau district, and in the relatively uniform evenness of the upland which is the Tertiary peneplain. Conclusions deduced from glacial investigations point to a depression, in very late geological times, of the surface of the continental interior below its present position. This carries with it the inference that since the close of the Tertiary, elevation has taken place. This is clearly indicated in the youthful topography now existing along the borders of the uplift. The water-courses have cut valleys in the general upland plain, and now flow in steep-sided or canyon-like trenches, which are ever deepening as the streams recede from their sources. Erosion is now going on vigorously. The rivers are carrying away the debris from their steep-sided banks as fast as formed, and are rapidly cutting lower and lower their confined and contracted channels, while their deepening gorges are being constantly carried back toward the crest of the great divide. The cycle of the last elevation is not yet ended, and the changes of level in the region are probably going on now as rapidly as they ever have in the past geological time, and as rapidly as oscillation of the land surface usually takes place.

COAL MEASURES OF MISSOURI

BY

GARLAND C. BROADHEAD.

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The area of the State of Missouri according to eleventh census is 69,415 square miles. The Ozark uplift in the southern part embraces about 36,000 square miles, or over one-half of the area. The Lower Carboniferous beds occupy a narrow, irregular belt extending from the northeastern to the southwestern corner of the state. They lie just outside of the Coal Measures, flanking them and dipping north and west beneath them. South of the Missouri river the width of the area increases. The Coal Measures occupy an area of 23,100 square miles, embracing most of north Missouri and the greater part of ten counties in southwest Missouri. The estimate is made from a careful calculation of the area of the coal fields from such data as have been accumulated and have been delineated on the various county maps.

In Illinois the Upper Carboniferous has been divided into the Lower and Upper Coal Measures. In Iowa and in Missouri there have been recognized until recently three divisions, the Lower, Middle and Upper. Swallow in his geological report, 1855, estimates the thickness of the Lower series at 140 feet and the Middle at 225 feet.

At the base of the productive Coal Measures is a sandstone which the Illinois Geological Survey has assigned to a division of the Kaskaskia group of the Lower Carboniferous. By Swallow it was termed the Ferruginous sandstone, for the reason that it is sometimes eminently ferruginous. In southwest Missouri it occurs in flaglike layers of a light brown color. Its iron component is distinct in the southwest part of Lawrence county; twenty miles southwest of Springfield it carries a good quality of limonite; while near the line of Greene and Lawrence counties it is a buff in color. In the southeast part of Dade county it contains the mineral chalcopyrite. In the vicinity of Joplin it again occurs; here the sandstone of the Lower Coal Measures is also found. In the absence of more conclusive evidence, the two are generally distinguished by the latter generally containing numerous small scales of mica, while the sandstones below the Coal Measures do not. The so-called ferruginous sandstone in the southwestern part of Cedar county is highly iron-stained; the same is partly so on Turkey creek in the same county, where it forms mural escarpments along the stream. South of Lamonte, in Pettis county, the rock is again found, a regular non-micaceous sandstone, very suitable for building purposes; and like characters are presented near the road from Boonville to Marshall, at the Collins farm near the west line of Cooper county. Around Marshall it occurs also, but is quite shaly. In Howard county, opposite Boonville, it presents a fine face of excellent building stone, as it also does at Collins quarry near Sweet Springs in Saline county. At Fulton, Callaway county, it is presented as a cherty conglomerate. On Bachelor creek in the northeast part of the district, the beds are irregularly stratified. In southern Illinois this sandstone is considered a division of the Kaskaskia group. Swallow thought that it might be the equivalent of the Millstone grit of England. Evidence of organic life has been observed in only one place, near Middle Grove, in Monroe county, where are found carbonized fragments of plants.

The sandstones of the Coal Measures are so very irregular in thickness and distribution that they cannot be traced for any great distance. Swallow speaks of the micaceous sandstone as occurring in Marion, Boone, Howard, Cooper, Lafayette, Henry, Bates and St. Louis counties. Its general character does not materially differ at its various outcrops, being a friable rock, of light brown or olive color. It may include certain heavily bedded brown sandstones, such as occur on Possum creek, four miles south of Butler, in Bates county. At the McLaughlin quarry, near Rockville, a grayish brown sandstone has furnished much good building material. At Nevada, Vernon county, it is both red and grayish brown in different beds. It occurs at many places on the Marmaton river, occupying most of the bluff north of Nevada. Near Clinton it is of a light brown color, and quite soft. Swallow refers the arenaceous beds opposite Dover to the micaceous sandstone. The outcrop projecting into the Missouri river several miles farther down may also be its equivalent. Near Knob Noster there is an exposure of a red and gray sandstone, but whether it should be assigned to the micaceous formation or to the Warrensburg beds, is yet an open question. The beds at White Rock, Carroll county, are probably the equivalent of the micaceous sandstone. They furnish good material for building purposes, and sometimes afford fine specimens of Calamites and Cordaites. Besides the above named localities, micaceous sandstones occur in the central part of Howard and the western part of Monroe counties. It has not been observed to be sufficiently continuous to allow of a definite geological boundary.

With a view of ascertaining the thickness of the Coal Measures of the State, the various outcrops were at first connected. The measurements made gave a result of 2065 feet as the thickness of the Coal Measures of Missouri, including 1270 feet of Upper Coal Measures and 795 feet of so-called Middle and Lower Measures. This work was revised and corrected subsequently, and it was found that about 1085 feet of a connected section of the Upper Coal Measures existed from near water-line at Randolph and Kansas City, to the highest rock at City bluffs, Nodaway county, on the Nodaway river. From this latter place for 20 miles west, no rocks are seen; also, from near Forest City in Holt county, to the northern part of the same district, there were no connecting beds, nor could the connection be obtained on the west side of the Missouri river. Concluding, from the already observed inclination of strata east and south, 50 feet were added for this interval. In Atchison there is a connected section of 180 feet. Adding these together, the Upper Coal Measures in Missouri have a thickness of 1315 feet.

The section which was first made gives 780 feet for Lower and Middle Measures along the Missouri river. The latter section gives 679 feet in Bates, Vernon and Barton counties; the boring at the Sandee well, Ray county, gives 644 feet. Considering the boring at Randolph as being opposite the bottom of the Bethany Falls limestone, the base of the Upper Coal Measures would be 27 feet below. One boring here gave 644 feet, the other 677 feet of Middle and Lower Coal Measures, and penetrated the Lower division at a depth of 552 feet. This would give 652 feet below the Upper Coal Measures. There would be then for the thickness of Lower and Middle Coal Measures, 652, 677, 644, 669, or an average of 664 feet, which, added to 1315 feet of the Upper Coal Measures, gives 1979 feet as the total thickness of the Coal Measures in Missouri, or in round numbers 2000 feet.

The Coal fields of Missouri occupy an area of 23,100 square miles. The Middle and Lower Coal Measures underlie an area of about 12,000 square miles, and the best coals may generally be reached, within a district of about two-thirds this size at depths less than 200 feet. The southern and eastern boundary of the Missouri coal field follows an irregular line from Jasper county in the southwest to Clark in the northeast, passing through Jasper, Barton, Dade, Cedar, Vernon, St. Clair, Henry, Benton, Pettis, Saline, Howard, Boone, Callaway, Audrain, Montgomery, Ralls, Monroe, Shelby, Knox, Adair, Schuyler, Scotland and Clark counties. Small outliers occur in Cooper, Lincoln, Pike, Marion, St. Charles and St. Louis counties.

The Ozark plateau on its eastern margin is 700 to 800 feet above the sea level. The Archæan peaks of the southeast are 1200 to 1800 feet above the sea. The unaltered sedimentary rocks surrounding them are but little over 1000 feet above the sea; but increase in elevation to 1500 feet in Webster, 1700 in Wright, and 1530 in Barry. Along the west State line the elevation is 800 to 1050 feet, reaching 1100 on the highest elevations. Cairo, Illinois, is 350 feet above the same datum line; southern Illinois 600 to 800 feet. In north Missouri, Jonesburg is a little over 800 feet, Centralia 873, Columbia 750, Keytesville 715, Schuyler county 1000, and Nodaway 1200 feet above the sea.

In eastern Missouri, in the ascending series succeeding the Ozark series (Magnesian limestones) there exists about 400 feet of Lower Silurian in the northeast, while Shumard has estimated over 600 feet of Lower and Upper Silurian in southeast Missouri. Westward these formations are last seen in Franklin county, and thinning westward on the north of the Misssouri river, are last seen in the eastern part of Callaway. In the western part of Montgomery county and eastern part of Callaway county the Devonian rests on a few feet of crinoidal limestone which may be of the age of the Upper Silurian. The Devonian is thinner in the Missouri bluffs of Boone county where it rests directly upon the Ozark series. In Cooper there are a few outliers of the Devonian, and on Muddy creek, Pettis county, the Cooper marble bed crops out 13 feet in thickness. Whether this is Devonian or not, is not determinable, since fossils have not been found. Further south and west no true Devonian has been found in Missouri. In all of the region in these directions, the Lower Carboniferous rests upon the Ozark series. If the formations lying beneath the Coal Measures of northwest Missouri, include only such as are seen in southwest Missouri, borings prosecuted in the northwest would probably not penetrate over 4000 or 4500 feet of strata, which might include 1500 feet of the Ozark series, 1000 feet of Lower Carboniferous and 1900 feet of Coal Measures.

If the measurements are correct, the Coal Measures in Nodaway county would be 500 feet below sea level, or 2250 feet below the summit of the Ozarks. East, west and north, from the time the Ozarks reared their peaks above the waters, there was a gradual depression of the surface beyond, becoming more so to the north and west, until, as the Ozarks continually rose, the distant oceanic floor gradually subsided until it received the Lower Carboniferous limestones in the deep seas. Then the sandstones in more shallow waters again slightly subsided leaving numerous marshy tracts with accumulating soil—the result of the drifting winds and waves of the early

Carboniferous period. On this soil there was a marvelous growth of vegetation, furnishing, in its decayed leaves and bark, the foundation for the coal beds of the future. Slight elevations and subsequent depressions beneath the waters and elevations again occurred, until the succession of various beds of fire-clay, shale, sandstone and limestone, amounting to 2000 feet of Coal Measures, was deposited. The boundary between the Upper and Middle Coal Measures may be considered an irregular line passing northwardly near Parkerville, Bates county, to Harrisonville, Cass county; northwestwardly to Kingsville, Johnson county, to Chaper Hill, Lafayette county, by the way of Odessa, Greenton, Richmond, Swanwick, Ray county, Mooresville, in Livingston county, five miles north of Chillicothe, to Gallatin, to Princeton and northeastwardly.

The following is a vertical section of the Coal Measures below the Atchison county beds. It is revised from a former section:

No.	Thickness.	Description.	Locality.
		UPPER COAL MEASURES.	
224	4	Limestone, porous, ferruginous................	City Bluffs ....
223	36	Shale, septaria in upper part..................	" ....
222	6	Septaria......................	" ....
221	48	Shales	" ....
220	2	Limestone, grayish blue......................	Quitman ....
219	2½	Shales, sandy.	" ....
218	1½	Limestone, pyritiferous..........................	Florida creek ....
217	....	Sandstone, thickness irregular.	Forest City...... ....
216	4⅔	Shales, blue and bituminous	Nodaway river.........
215	1	Coal, 4 to 16 inches.....................	" ....
214	17	Sandstone, with shales and plants.	White Cloud, Kas .....
213	4	Clay shale...	" " ......
212	4	Limestone, blue.................................	Rollins branch. ....
211	½	Limestone, fossiliferous.	Braddy, Iowa ....
210	4	Shales, brown, with nodular limestone........	Smith mill, Nodaway county..................
209	¾	Limestone, dark blue, fossils.....	Near Bridgewater .....
208	1	Shale, calcareous	" " ......
07	1½	Shales, blue and bituminous	" ......

No.	Thickness.	Description.	Locality.
206	1⅓	Limestone, blue, fossils............	New Bridgewater.....
205	2½	Shale, drab..	" ......
204	1⅓	Shale, green...	" ......
203	⅔	Shale, green, nodular............................	" ......
202	1⅓	Shale, yellow..	" ......
201	1	Limestone, course, rough, fossiliferous.	Bridgewater............
200	2½	Shale, with limestone concretions..............	" ....
199	2½	Limestone, ash blue, fossiliferous..............	" ....
198	2	Shale, blue..	" ....
197	2	Limestone, ash, blue and buff	" ....
196	3	Shale, brown, fossiliferous......................	" ....
195	4	Shale and sandstone...............................	" ....
194	1	Shale, bituminous, with thin coal seams......	" ....
193	3	Shale, sandy...	" ....
192	1¾	Limestone, grayish blue	Kunkles, Forest City...
191	½	Shale..	" " ....
190	½	Limestone, grayish, univalves..................	" " ....
189	½	Shale, blue	" " ....
188	1	Limestone, blue, cone-in-cone at top..........	" " ....
187	3	Shale, many Fusulinæ............................	Amazonia ....
186	15	Limestone, very fossiliferous	Forbes, Forest City....
185	5	Shale, blue and bituminous	" " ....
184	2	Limestone, fine-grained........................	" " ....
183	7	Shale	" " ...
182	5	Limestone, buff	Ohio mills........... ...
181	2	Sandstone..	Forbes to Forest City..
180	2	Shale.	" " ..
179	2	Limestone	Brockman branch .....
178	9	"	" .....
177	2	Limestone, drab, Fusilina..........	" .....
176	⅔	Limestone, ash-blue..............................	" .....
175	⅓	Shale	" .....
174	1½	Limestone, drab	" .....
173	15	Shale	" .....
172	3	Shale, bituminous, outcrop	" .....
171	5	Limestone, green, shaly, Fusilina..............	Mouth Nodaway river.
170	44	Concealed, probably shales......................	" "

No.	Thickness.	Description.	Locality.
169	2	Limestone, ashy, shelly	Mouth Nodaway river.
168	3	Shale, dark olive	Savannah
167	3	Limestone, drab-colored, with calcite	"
166	3	Limestone, nodular, shelly	"
165	3	Shale, dark	"
164	1	Shale, bituminous	"
163	1/3	Shale, Fusilina	"
162	1	Limestone, Fusilina	"
161	9	Shale, yellow, with limestone nodules	"
160	4 1/2	Limestone, brown, fossiliferous	"
159	5	Shale, argillaceous	Highest rock in Platte and Buchanan
158	1-6	Coal	Near Savannah
157	9	Sandstone, shaly	"
156	1/4	Coal	"
155	8 1/2	Shale, sandy	"
154	2	Limestone, Fusilina-bearing	"
153	9	Shale	"
152	9	Limestone, tough, with cross-laminated shales	Savannah
151	2	Shale	"
150	27	Limestone, drab and cherty	St. Joseph, Savannah.
149	3	Shale	" "
148	2	Shale, blue and bituminous	Mouth Nodaway river.
147	2 1/3	Limestone	" "
146	4	Shale	" "
145	8	Rocks concealed	" "
144	5	Shale, light-colored	" "
143	7	Limestone, fossiliferous, buff	St. Joseph, Amazonia.
142	....	Limestone, local	"
141	1/4	Coal, trace	Amazonia
140	6	Clay, dark	"
139	4	Shale, red	"
138	4	Shale, green	Savannah
137	7	Conglomerate, ferruginous	St. Joseph
136	42	Shale	Amazonia
135	4	Sandstone	St. Joseph
134	2	Shale and coal seams, including one foot of coal, separated by thin shale band; plants.	Hall Station
133	11	Shale	"

No.	Thickness.	Description.	Locality.
132	1	Limestone, sandy, ferruginous	Near St. Joseph
131	22	Shale	" "
130	6	Shale, red and green	" "
129	4	Shale, green and ocherous yellow	" "
128	4	Limestone, fossiliferous	" "
127	56	Shale	Iatan to Weston
126	2½	Shale, fossiliferous	Weston
125	21	Shale	"
124	⅔	Sandstone, rough, drab	"
123	1	Shale, bituminous, thin coal	"
122	6	Shale	"
121	18	Limestone	"
120	37	Shale	"
119	15	Sandstone, with calamites	Waldron
118	1	Coal, shaly	Above Waldron
117	4	Shale	"
116	15	Sandstone	"
115	3	Limestone, sandy, fossils	Weston
114	1	Shale	"
113	3½	Limestone, buff	"
112	13½	Limestone, gray, fossiliferous	"
111	5½	Shale, bituminous in center	"
110	4	Limestone, with univalves	"
109	19	Shale, with bituminous bands	"
108	18	Limestone, shaly partings; fossils	Plattsburg
107	1	Sandstone, calcareous	"
106	5	Shale, sandy	"
105	2	Shale	"
104	14	Sandstone, shaly	"
103	21	Sandstone, soft, buff and shaly	"
102	1	Conglomerate, ferruginous	"
101	3	Shale	Liberty, Kansas City
100	5	Limestone, ferruginous	" "
99	31	Shale, sandy	Near Gentryville
98	30	Limestone, gray, irregularly bedded	Independence
97	25	Shale, blue; ocher concretions	Kansas City
96	5	Limestone, bluish gray	" Cameron
95	2	Shales, blue and bituminous	" "

No.	Thickness.	Description.	Locality.
94	¾	Shale...	Kansas City
93	1	Shale, fossiliferous	Kansas City, Cameron.
92	1	Limestone	Parkville, Kansas
91	5	Shale, blue, fossiliferous	" "
90	9	Limestone, drab	Kansas City
89	5	Shale, blue and olive.	"
88	2	Shale, nodular, buff	"
87*b*	3	Limestone	"
87*a*	18	Limestone, oolitic	"
86	15	Shale	"
85*d*	1	Limestone, blue	"
85*c*	2½	Shale, blue	"
85*b*	⅓	Coal, with plants	"
85*a*	8⅔	Limestone and chert, blue	Independence
84	9⅓	Limestone, fine-grained, with calcite specks	Pleasant Hill.
83*b*	3⅔	Limestone, drab and blue	Liberty
83*a*	½	Shale, blue.	Gallatin
82	1	Limestone, concretionary, blue	Greenwood.
81*c*	1	Shale, blue	Liberty
81*b*	1½	Shale, bituminous	Gallatin
81*a*	2	Shale, clayey	Pleasant Hill.
80	4	Limestone, nodular, shelly	"
79	4	Limestone, oolitic	Bethany
78	21	Limestone.	"
77*b*	2	Shale, blue	Pattonsburg
77*a*	1⅓	Shale, bituminous	Kansas City
76*c*	1⅓	Limestone, dull blue	Liberty Landing
76*b*	½	Shales, argillaceous, blue	Kansas City
76*a*	½	Limestone, concretionary	"
75	2	Shale, blue	Liberty Landing
74	6	Limestone, ferruginous; oolitic in part.	Kansas City
73*c*	.....	Shale	Kansas City
73*b*	¼	Coal	Pleasant Hill
73*a*	12	Shale	Harrisonville
72	2	Sandstone, calcareous, and limestone	Pleasant Hill

Sections on the Missouri river, sections in Johnson county and the southwest Missouri sections differ in their relative thicknesses. The following is the section in Cass and Johnson counties, continued from the above:

No.	Thickness.	Description.	Locality.
71	....	Included in No. 72	
70	....	Included in No. 72	
69	129	Sandstones and shales	Strasburg
68	2	Limestone	Holden
67	9	Sandstones and shales	Johnson and Cass Cos.
66	17	Sandstones and shales	" "
65	13	Sandstones and shales	" "
64*b*	3	Shale, bituminous	Lexington
64*a*	1	Coal	Holden
63	⅓	Sandstone and shale	"
62	⅔	Sandstones and shale	"
61	1	Shale, dark and red	"
60	½	Shale, with nodular limestones	"
59	½	Coal	Strasburg
58	2	Shale	Holden
57	1	"	"
56	¾	"	Strasburg
55	4	Limestone	Holden
54	13	Sandstone and shale	"
53	10	" "	"
52	7	" "	"
51	½	Clay with streaks of coal	"
50	5	Limestone	Strasburg
49	1	Shale	Holden
48	1	"	"
47	3	Limestone, with Allorisma	Brush creek
46	7	Shale, bituminous	McClellan
45	½	Coal, slaty	Blackwater
44	1½	Coal	McClellan
43	3	Shale, "	"
42	90	Sandstone, 60 to 90 feet.	Warrensburg
41	4	Limestone	"
40	1	"	"
39	1	Shale, dark	"

No.	Thickness.	Description.	Locality.
38	2	Shale, bituminous	Warrensburg
37	3	Shale, dark	"
36	1½	"	"
35	1½	Coal	"
34	2	Clay	"
33	50	Shale, sandy	Knob Noster
32	½	Coal, shaly	"
31	13	Shale, sandy	"
30	3	Shale and clay	"
29	½	Limestone, bituminous	"
28	1	Shale, bituminous	"
27	1⅖	Coal	"
26	4	Clay	"
25	9	Shale	"
24	3	Limestone	"
23	1	Shale	"
22	1	Shale, bituminous	"
21	⅔	Coal	"
20	3	Shale	"
19	1½	Clay	"
18	1½	Coal	"
17	3	Shale	Clear fork
16	1	Shale, dark	"
15	4	Shale	"
13	5	Shale	"
12	18	Shale	"
11	10	Shale	"
10	4	Shale	"
9	3	Shale	"
8	4½	Coal	Clinton
7	5	Shale and fire-clay	Deepwater
6	6	Sandstone, white	Grand river
5	1	Coal	Clear fork
4	3	Fire-clay	"
3	1	Shale, and thin coal seam	"
2	2	Coal	W. part Pettis Co
1	10	Shale	" "
		Base of Coal Measures.	

The following is a general section of the rocks of southwest Missouri from the base of the Upper coal measures to the base of the Upper Carboniferous. The numbers correspond to those in the section of the Geological report for 1873–1874.

No.	Thickness.	Description.	Locality.
		Limestone on the hill-top is about the base of the Upper coal-measures.	
74	20	Limestone, blue and gray	Mulberry creek, Bates county
73	8	Sandstone	Mulberry creek
72	5½	Shale, brown, concretionary	"
71	2	Shales, siliceous	"
70	2	Coal, 20 to 34 inches	"
69	2	Fire-clay	Miami creek
68	11	Concealed	
67	8	Limestone, fossiliferous	Miami creek
66	9	Shale and thin limestone bands	"
65	5	Shale	"
64	4	Limestone, bituminous	"
63	1-6	Shale, brown	"
62	1⅓	Shale, bituminous	Near Butler
61	⅔	Shale, black, lustrous	"
60	1½	Shale, bituminous, soft.	"
59	⅓	Hard band	"
58	2	Shale, soft, bituminous	"
57	¾	Coal	Butler
56	25	Sandstone, fucoidal	"
55	2	Limestone, 2 to 4 feet	Ft. Scott
54	1	Shale, calcareous, buff	Ft. Scott, Kas.
53	4	Shale, bituminous	"
52	⅔	Coal	"
51	3	Fire-clay and shale	"
50	3	Limestone, with Fusilina, hydraulic	"
49	1	Limestone, nodular, crinoidal	"
48	3	Shales, bituminous and blue	"
47	1½	Coal	"
46	4	Fire-clay.	Moundville
45	1-6	Shale and sandstone	"
44	36	Shales and sandstones	"

No.	Thick-ness.	Description.	Locality.
43	1½	Limestone, bituminous, jointed................	Near Moundville ....
42	1½	Shale, calcareo-bituminous	Moundville..............
41	½	Shale, bituminous, hard........................	" ....
40	1	Shale	Ft. Scott, Kas .. ..
39	½	Limestone ("marble"), concretionary........	" " ....
38	1	Shale, bituminous	" " ....
37	⅔	Limestone, concretionary, dark...........	" " ....
36	3	Shale, bituminous, concretionary, "marble"	" " ....
35	2½	Shale, bituminous	" " ....
34	2½	Shale, bituminous	" " ....
33	1	Coal	S. of Moundville........
32	34	Mostly concealed, a few coal-seams............	" " ....
31	1½	Coal	" " ....
30	15	Concealed...	....
29	1	Limestone, reddish................................	S. of Moundville........
28	6	Shale and ironstone	" " ....
27	8	Shale, bituminous, and septaria................	" " ....
26	½	Coal, hard, slaty....................	" " ....
25	1½	Coal	" " ....
24	1½	Shale, bituminous in lower part	" " ....
23	3	Coal, 2 to 3 feet................	SW. Barton county .....
22	5½	Clay, with nodules and selenite	" " ......
21	4	Sandstone and shale...........	" " ......
20	6	Shale	" " ......
19	2	Shales, blue and bituminous	" " ......
18	1½	Coal, 18 to 24 inches..............................	" " ......
17	9	Clay, selenitic; thin coal-seams	SW. Bates county......
16	50	Sandstone, "Clear creek"....	E. Vernon county......
15	1	Conglomerate and iron ore......................	Near Lamar ....
14	1	Coal, 8 to 13 inches................................	Lamar ....
13	15	Sandstone..	" ....
12	6	Shale	" ....
11	½	Limestone, thin band	" ....
10	1	Coal..	" ....
9	15	Sandstone..	" ....
8	5½	Shale, semi-bituminous...........................	" ....
7	1	Coal.......	" ....

No.	Thickness.	Description.	Locality.
6	35	Sandstone..	Lamar..................
5	1½	Shale	" ....
4	1	Coal..	Barton county....... ...
3	16	Shale	" ....
2	....	Chert beds..	" ....
1	....	Augusta limestone................................	" ....

Some of the last beds mentioned in the above section are well marked and readily recognized. They are the lowest portions of the Coal Measures in southwest Missouri, but cannot be closely correlated with the lowest beds of the Coal Measures in north Missouri. It is even probable that the beds of Barton and the sandstones of the southern part of Vernon lie below the lowest Coal Measures of the northern part of the State. In the section on Mulberry creek, coal is found about 110 feet below the Upper Coal Measures. Its position, therefore, must be either referred to the horizon of the Strasburg and Holden coals, or to the lower part of number 69 of the general section from Sedalia to Kansas City. Forty feet below the Mulberry coal there appears on Miami fork, and near Butler, a vein nine inches in thickness. The associated rocks would seem to indicate that it is nearly related to a coal thirty-seven feet below the Lexington coal, which, however, does not occur in Bates county. In Cass, Johnson and Henry counties it does not seem to be present, although the next limestone above it crops out north of Austin, in Cass county, and also on the Blackwater, in Johnson county.

The rocks between numbers 30 and 55 of the southwest section were termed the Fort Scott series by Swallow in his geology of Kansas, and this divison included about 150 feet of vertical thickness. They may be equivalent to known strata in northeast Missouri, but it has been impossible to correlate them with those rocks. They were first observed two miles north of Pleasant Gap, near the head waters of Panther creek, in Bates county; next, as the lowest rock, at Butler; then on

Shiloh creek, near the line of Bates and Vernon counties. They then extend in a southerly direction through Vernon. They occur also on Cottonwood creek, farther south on the Mound, west of Moundville, and trend toward the west into Kansas. The different rocks in this series are well exposed at Fort Scott, Kansas. Number 43 of this section is a heavy, tough, highly bituminous limestone, and is easily recognized. Other rocks in Vernon county and in the districts to the south consist chiefly of sandstones and shales, with thin coal seams frequently occurring in some localities. These beds nearly everywhere have a strong bituminous odor. The sandstones are adaptable for building purposes, and in the eastern part of Vernon and in Barton and Cedar counties they afford excellent material for grindstones and coarse whetstones. Remains of Lepidodendron and Sigillaria are occasionally found; also Sternbergia, and sometimes Calamites.

In the northeastern part of the State, as well as in the counties north of the Missouri, Kansas & Texas railroad, limestone often occurs in the lower and middle series. Some of these, Swallow regarded as hydraulic. They may be so, but tests have not as yet been made.

In the counties of Howard, Randolph, Linn, Sullivan and Adair, there is occasionally found a well-marked blue limestone, always rhomboidally jointed, which is a good guide to the rocks which are concealed and nearly related. Number 18, which is sixty-six feet higher in the series, is also well marked in these districts. It consists of red clay with nodules of red hematite.

From Johnson county northeastward the beds which are referred to the Lower Coal Measures do not differ much in their character or thickness, and the coals, as well as other rocks in the series, can be only approximately correlated; but southward the lower beds differ very much from those lying to the north. The northern beds consist of shales, sandstones, fire-clays and limestones, and the coals are separated chiefly by sandstones. The rocks of the southwest are often bituminous, the bitumen often oozing out in drops, like tar, upon the surface, and when freshly fractured the oily odor is quickly perceived. It would appear that the southwest series of sandstones in Vernon and Barton may occupy a position below the northeast series.

The beds at and contiguous to the base of the Upper Coal Measures are easily identified, and may be found along a varying zone often 20 miles in width, and which extends from the southwest to northeast.

The farthest point south where limestones of this horizon have been recognized was in the top of a mound (Tp. 38 N., R. XXXIII W., Sec. 5). This rock may be referred to number 74 of the general section. The next place north (Tp. 40 N., R. XXXIII, Sec. 11) is at a mound 95 feet above the plain below, and capped with limestone No. 74, which here abounds in *Productus nebrascensis* and *Lophophyllum proliferum*, both characteristic fossils of this rock. The hills in the next township north are also capped with limestones occupying the same geological position. There are also several isolated mounds six miles northeast of Butler, rising 120 to 140 feet above the plain, and also capped with limestones whose position is near the base of the Upper Coal Measures. Near West Point, Bates county, and occupying the highest land between the Miami fork of the Osage and Mormon fork of Grand river, there is a range of hills extending from the southern part of township 41 to Burdett, and including Upper Coal Measure rocks from numbers 74 to 80, inclusive.

It is at once apparent that the erosion in Bates county must have been vigorous since the Coal Measures were first laid down. It is thought that it is safe to say that in this district there has been eroded and borne away by the waters a very considerable portion of the Upper Coal Measures. In many of the counties where the Coal Measures occur, the mound feature of topography is presented. These characteristic hills are found wherever the strata, consisting of thick beds of shales and sandstone, are capped by hard limestones, and the natural result of erosion for ages is the formation of the mounds. Center knob at Kingsville, Johnson county, is capped by limestone, which forms the base of the Upper Coal Measures, and has a slope to the plains below of over 80 feet. A continuation of these beds extends northward along the western part of Johnson county, by the way of Blackwater, to Chapel Hill, Lafayette county.

From Chapel Hill to Lone Jack, in Jackson county, bed No. 78, or the Bethany limestone, is generally the highest rock seen in the hills at the head of the various branches of the Sniabar. This limestone is easily recognized wherever seen, from Bates to Mercer county. It is fine-grained, brittle, and when broken, light dove-colored. It is over 20 feet in thickness and is overlaid by from one to four feet of gray, oolitic limerock. It crowns the elevations at Pleasant Hill, in Cass county, but farther back more recent strata are found just beneath the surface. A few feet below it occurs the well-marked limestone No. 74, which has been considered to occupy the base of the Upper Coal Measures. It is only about nine feet below 78, and is the quarry rock taken out at Pleasant Hill. It is about six feet thick — the beds being from 12 to 16 inches in thickness, and very regular. The upper beds are a light gray, the lower blue and beautifully variegated, with fossils related to the Stromatoporids.

About 14 feet below No. 74, and separated from it by shales, is No. 72. Some years ago it seemed as if the layer was the base of Upper Coal Measures. But after further and more recent investigation the line has been placed somewhat higher at No. 74. The bed is recognized by its fossils, lithological features and thickness; and is found in Cass, Jackson, Clay, Caldwell, Daviess, Livingston, Mercer and Harrison counties. Nowhere is it a pure limestone. It is more calcareous in Cass, is not recognized in Jackson, is a calcareous sandstone in Clay, and in Mercer it merges into the underlying sandstones, and there it should properly be assigned. The sandstone beds are often shaly, and their general texture and character is uniform from southwestern to extreme northern Missouri.

On and near the Missouri Pacific railroad, near Strasburg, Cass county, sandstones numbers 65 to 69 include about 100 feet of vertical measurement. Only the upper beds are suitable for building purposes. Howe quarry, on the Blackwater, six miles north of Kingsville, is opened in this rock. It is too soft to be very valuable. At Pleasant Hill there are 100 feet of shale and sandstone below No. 72. At Harrisonville, and two miles southeast, it is thicker, and also contains many fossils. As has been stated, north of the Missouri river it loses its calcareous character, and the fossils are wanting. At Gillespie mill, on the east fork of Grand river, in Livingston county, sandstones numbers 66 to 69 crop out in a thickness of 86 feet. On the west fork of the same stream (T. 51 N., R. XXV W., Sec. 10) No 74 is exposed near the hilltop, and 160 feet below it is an outcrop of 51 feet of sandstone, with ten inches of coal just beneath. It is very probable that nearly all of the space between the limestone and bituminous vein is occupied by sandstone and shale. If so, there are 211 feet of such material. At Graham mill, on the east fork of Grand river, Livingston county, the sandstone alone is 113 feet thick.

One and a half miles south of Princeton, Grundy county, there are shown:

		Feet.	Inches.
1.	Limestone, ferruginous, No. 74	4	
2.	Shale, with thin limestone layers, containing fossils	1	
3.	Shale	4	
4.	Clay—ironstone, concretionary	......	4
5.	Shale, olive-colored	2	6
6.	Coal	....	6
7.	Shale	1	6
8.	Sandstone	1	2
9.	Shale, green	2	
10.	Coal	......	3
11.	Shale, dark blue	1	3
12.	Sandstone (exposed)	4	5

The coal seams of the above section are the same as those seen five miles south of Princeton, where the upper vein is eight inches thick, and is only separated from the lower by eight inches of shale. The equivalent of this coal is 13 inches thick, as shown at Missouri City, in Clay county; two to four inches thick near Lone Jack, in Jackson county; and three to four inches thick at Pleasant Hill, in Cass county, where it is separated from No. 74, which overlies it, by a few inches of shale. It thus seems that one of these coal-beds thins out to the southward. This coal and the associated limestone above (No. 74) are remarkable for their persistent uniform thickness and association for a distance probably of 150 miles. They also appear in the eastern part of Harrison county, and near Gallatin, Daviess county, where the limestone is eight feet in thickness.

The eastern-most extension of the Upper Coal Measure limestones south of the Missouri river is on the ridge extending from three miles north of Hopewell to Grady knob, southeast of Wellington. It is flanked on the east at its base by Little Sniabar, and on the west by Texas prairie. The surface rock on this ridge is No. 78, and 270 feet below it is the Lexington coal. On the west, beyond the Greenton valley, Texas prairie and Sniabar valley, it is twelve miles to the next hills on which Upper Coal Measure rocks appear. No. 78 continues high in these ridges. Still farther west, beyond the Little Blue, it is well developed on the creek just east and also northwest of Independence, and it lies at the foot of the bluffs at the edge of the Missouri bottoms. Under the bridge at Kansas City it is the lowest rock seen. At Blue Mills landing, on the Missouri river, Jackson county, the Bethany Falls limestone (78) is 112 feet above the river. On the Lexington and Greenton road, six miles south of Lexington, on the ridge above mentioned, there are about nine feet of No. 74, which here lies 148 feet above the Lexington coal. At Swanwick, Ray county, the same limestone (No. 74) occurs on the hilltop, 210 feet above the Lexington coal now mined in the shaft, while one mile north of Richmond the limestone is 160 feet above the seam. The discrepancy in thickness may be due to the varying thickness of the sandstone.

On Big creek, near Bethany, in Harrison county, a thick limestone occupies the bed of the stream, forming in at one point a waterfall; previous to correlating the section, the term "Bethany Falls" was adopted to designate this bed. The rock is well developed and easily recognized by its peculiar weathering and generally uniform thickness. On the Wabash railroad at Liberty landing its connected beds appear thus:

No.		Feet.
84	Limestone, 10 feet, shale, blue, clayey, 1 foot	11
83	Limestone, bluish gray, irregularly bedded	6
82	Lower part of above in an even layer	
81	Shale, bituminous	2½
	Shales, blue	2
	Limestone, nodular, dove-colored	4
79	Limestone, whitish, oolitic	14
78	Limestone, fucoidal, irregularly bedded	6
77	Shale, blue, clayey	1
76	Limestone, argillaceous, 1½ feet, shale, blue, clayey	2
	Limestone, concretionary	½
75	Clay-shale, blue	2½
74	Limestone, gray (exposed)	6½

The section above is similarly repeated at Pleasant Hill, Cass county, where the oolitic bed (No. 79) thickens to four feet. This latter stone is also seen near Princeton, in Mercer county, and near Mooresville, in Livingston county, where the Kirtley quarry has supplied a large amount of rock which has been used by the Hannibal & St. Louis railroad. At this quarry it is eight and one-half feet thick—occurring in very even layers from six to 32 inches thick. Other places worthy of note where these related beds occur are on Spring creek, in the northeast part of Sullivan county, and near Milan. The above will serve to show where the beds, near the base of the Upper Coal Measures, are to be found. Farther east are only found the Lower Measures, and westwardly, only the Upper division.

Table of Grouped Strata.

Group.	A. Top to 212		B. 212-188		C. 188-150		D. 150-108		E. 108-96		F. 96-72		G. 72 to Lex. C.		H. Lex. C. to base	
	ft.	p.c.	ft.	p.c.	ft.	p.c.	ft.	p.c.	ft.	p.c.	ft.	p.c.	ft.	p.c.	ft.	p.c.
Limestone	38½	.08	28½	.37	85	.47	72	.21	38	28	91	.52	27	.15	59	.08
Shale, calcareous	30	.08	2	.02	5	.03	12½	.03	......	......	3½	.02	2	.01	......	......
Shale, clayey	188	.50	18½	.24	48	.27	122	36	30	23	55	......	36	20	233	.39
Shale, sandy	8	.02	14	......	32	......	110	32	46	34	20	......	20	.11	39	.06
Sandstone	112	.30	13	......	3	......	15	.04	16	12	......	......	86	.50	218	.30
Shale, bituminous	......	......	......	......	3	......	6	.02	......	......	3	......	3	.01	21	.03
Coal	1½	.004	......	......	......	......	2	.001	......	......	......	......	1	.008	18	.03
Totals	310	......	43	......	200	......	400	......	154	......	154	......	175	......	588	

The figures are referred to the descriptive section along the Missouri river to the base of the Measures; the Lower division being variable at other places would make a slight difference. The footings also are different from the same cause, but the aggregate is approximately correct. The percentage of each is limestone 0.210, calcareous shale 0.020, argillaceous shale 0.350, sandy shales 0.143, sandstone 0.220, bituminous shale 0.011, and coal 0.018; the total thickness of coal a little over 24 feet, including about 4 feet in the Upper, or barren, Measures.

Group A of the above includes the highest rocks found in the State, which are all above No. 224 of the section of Upper Coal Measures. They have a strong resemblance to the Permian, and even might be so referred. These beds are only found in Atchison and the northern part of Holt county. Fifty feet below there occurs a three-inch seam of coal. The blue limestone at the base of group A is found at Forest City and in northeast part of Holt county. *Fusulina cylindrica* abounds throughout. The coal at Forest City and on the Nodaway, in Nodaway county, is near the lower part.

Group B includes the next rocks below Forest City, and in Holt county and in the southern part of Nodaway county. A small Chætetes and an Archæocidaris abound.

Group C contains two traces of coal and a 2-inch bed of tutenmergel (cone-in-cone), well marked near the upper part. The upper limestones cap the hills from near the mouth of Nodaway river as far as Ohio mills. They occur also at Howard mill, on Platte river in Nodaway county. The base is occupied by thirty feet of limestone, with a similar bed of cone-in-cone resting upon it. The limestone next below is the lowest seen at Dallas, and occupies the hilltops at Amazonia and St. Joseph, and retains this position to the south line of Buchanan county, being last seen high in the hills four miles above Weston. It crops out on Third fork of Platte river, in northeast part of DeKalb county, and on Niagara creek near Rochester, serving there as a guide to the coal 60 feet below. It is the highest rock on Island branch, Gentry county, and is well developed at the Lander quarry north of Savannah.

Group D. This includes two beds of bituminous shale and three thin seams of coal. The upper coal is seen in the bluffs near Hall Station, 12 miles below St. Joseph, on Niagara creek, Andrew county, on Third fork, in DeKalb county, and Island branch, in Gentry county. Another thin coal seam occurs three and one-half miles above Weston; 97 feet below it is another vein 9 inches thick.

Group E. The Plattsburg limestone is a name which was applied to the beds by Ulffers on account of the full exposure at Plattsburg, in Clinton county. It, probably, is more easily recognized than any other limestone of the Upper Coal Measures. Fossils are abundant, among which *Productus americanus* (Swallow) is very plentiful; also, many bryozoans, *Syntrilasma hemiplicata* and *Petalodus destructor* are found wherever this rock occurs. The lower beds are found in the western part of Clay county, thence to Plattsburg, to the northeastern part of Clinton and northwardly through DeKalb, Gentry and northeast portion of Harrison county. They are also well marked one mile above Waldron and at Union mills, Platte county. At Eudora, Kansas, fossils are abundant and well preserved.

Group F. Limestones abound in this section, the upper beds being found at Parkville; most of the subdivisions of this group occur at Kansas City and Independence. At a mill four miles north of Bethany, Harrison county, there are many fine fossils, referable to the upper beds, including Productus, Aviculopecten, Myalina, besides bryozoa and crinoids. Some of the fossils of the group present a strong Permian type. *Productus rogersi* is rarely found below this horizon. *Meekella striatocostata* is found here and in higher strata. *Myaline subquadrata* and *Aviculopecten carboniferus* abound. The latter, so far as known, is found only here and in group A. *Syntrilasma hemiplicata* has been reported from these beds. In former pages the rocks occurring near the base of this group were considered in detail. At Kansas City a great many fossils have been obtained, and some of the species at no other place in Missouri, among them *Conularia crustula*; No. 87 alone contains over forty species. Some of them have not been found in higher rocks in Missouri, but reappear in the so-called Permian of Kansas. No. 97 contains many rare and beautiful crinoids; also has tracks of several species of vertebrates. Upward of 250 species of organisms are reported from these rocks.

Group G. From the bottom of the previous to the Lexington coal is included here, its base passing northward through Trenton, Breckenridge, and thence northeastward. Sandstones represent over one-half of the group. *Chonetes mesoloba* is found here and below, but not above. A peculiar vermicular fucoid is found in limestone in Grundy county, and this is probably the lowest limit of *Terebratula bovidens*.

In Group H, all lying below the Lexington coal is included. *Chonetes mesoloba* and *Productus muricatus* abound, and may extend into Group G, but not above. Sandstones and shales comprise one-third of the rocks of the Coal Measures, and argillaceous shales also nearly one-third. Concretions of clay ironstone are of frequent occurrence, and of various degrees of purity. The concretions are generally flattened, and are often divided by calcareous veins which cut other calcareous concentric circles, forming "septaria." In size they range from one inch to four feet in diameter.

The Coal Measures of the state present certain disturbances. The prevailing dip of the series is to the northwest. Apparent undulations have been observed. In De Kalb county, on Grindstone creek, in the south part of township 58 N., range 30 west, the strata seem to be very much tilted and fractured. One-half mile distant, on Grand river, below Compton ferry, in Carroll county, there is a remarkable inclination of strata. A few miles north of Huntsville the Lower Carboniferous limestones protrude through the Coal Measures. In the eastern part of Howard county the rocks are very irregular, and the beds cannot be accurately traced.

The relation of Missouri rocks to the Kansas Coal Measures is of interest. The strata in northwestern Missouri and northeastern Kansas are very similar. In passing up the Kansas river to Topeka there is a marked similarity to the western Missouri beds. In Johnson county, Kansas, occur beds similar to those observed in this State. Southwardly in Miami and Anderson counties are both limestones and sandstones, the latter often containing an abundance of fossils, but the correlation is difficult. Between Osawattomie and Ottawa, *Syntrilasma hemiplicata*, *Productus punctatus* and bryozoans are abundant. It may be seen by this that these strata are equal to or above No. 96 of the Upper Coal Measures. In Woodson, Wilson and southward the rocks are chiefly sandstones, and may be referred to the Lower Coal Measures. A well-marked flagstone is easily traced from Pawnee, south of Ft. Scott, to near Chanute, Parsons and Oswego. The Ft. Scott series is the prevailing rock at Oswego. Near Thayer a coal-bed is worked having numerous ferns and other plant remains in the overlying strata. Passing from Woodson to Greenwood county and from Wilson to Elk, the sandy region of the Lower Coal Measures is replaced by the limestone region of the Upper Coal Measures, and in a distance of twenty miles the so-called Permian is reached. The approach to the latter formation from the Lower Coal Measures rises by a series of well defined terraces across the Upper Coal Measures. A Pinna of very large size is found in the Upper Coal Measures of Nodaway county, Missouri, also near the summit of the Coal Measures at Reese, Greenwood county, Kansas.

There is much which is of economic value in the Coal Measures. Beds of limestone suitable for building occur, but few are first-class stones for such purposes. Those that have given satisfaction are from the Kirtley quarry, near Mooresville, the stone being an easily-worked oolitic limestone. A similar bed at Kansas City has been used for ordinary purposes, for which it answers very satisfactorily. The upper bed at Lamders, two miles north of Savannah, is a hard, tough, strong limestone, which may also be obtained on Missouri bluffs in Buchanan and Andrew counties. A single layer of hard, bituminous limestone in Livingston county is also quite valuable. Probably the best layer, the one of most uniform thickness, and also of greatest strength, is the limestone (No. 74) at and near Pleasant Hill and Lone Jack. It is beautifully variegated, with a dark, winding fucoid. It is quite probable that a good hydraulic lime could be manufactured from certain beds, but no perfect tests have yet been made. At Amazonia, in Andrew county, limestone No. 150 has afforded a fair quality.

The sandstones of the Upper Measures are all too soft to be valuable as building materials. Those of the Lower Coal Measures have been much used. Near Meadville, in Linn county, there is a quarry of coarse sandstone, but it is too soft to be utilized in massive structures. The beds at White Rock, Carroll county, have been successfully quarried; also those at Warrensburg. From both of these places the rock has been shipped to many cities, and placed as a dressed stone in many of the larger buildings in Missouri and adjoining states. It alters but very slightly upon exposure. Other quarries are opened near Rockville and Butler, in Bates county.

The shales are useful for all of the more common articles; some are exceedingly valuable for making paving brick, but as yet they are little used for this purpose. Their usefulness has been proven in the brick made at Moberly, Higginsville, also in Nodaway county. Good beds of fire-clay abound as an under-clay to the coal beds of the Lower Measures. As such they have been successfully used for making fire-brick and retorts at St. Louis, Cheltenham, Fulton and Mexico, and a number of other places. In a test of eleven samples of refractory clays conducted by the New Jersey Geological Survey, the clay of Evens Mine at Cheltenham was second in the list. The others were from New Jersey, but undoubtedly Missouri has grades of clay just as good and in quantities inexhaustible. But little attention has been paid to the Carboniferous iron ores, owing chiefly to their limited outcrop. They are generally impure but are easily mined, and layers of coal are often found very near, thus making the mining of the two materials together practicable. The iron ores occur in regular layers, interstratified with coal and shale, and may include three varieties: the impure carbonate or clay ironstone, the red hematites and the limonites. They exist in the Lower Coal Measures as thicker layers and more frequent.

Thin bands of clay ironstone, not often over two inches in thickness, occur in the so-called Middle and Upper Measures, but rarely with two layers in close proximity. The Lower Measures often abound in bands and concretions which may sometimes reach four inches in thickness. In the latter division, where one seam is found, another commonly occurs a short distance above or below. Five miles south of Knob Noster on bluffs of Clear fork, the following section appears:

		Feet.
1.	Sandstone	1
2.	Limestone, bituminous	½
3.	Coal	1
4.	Fire-clay	4
5.	Shale, with two coal seams, 8 and 18 inches thick	31½
6.	Shale, inclosing ironstone concretions	4
7.	Ironstone, containing zinc blende	1
8.	Shale	1
9.	Ironstone	1
10.	Shales and sandstone	29
11.	Coal (exposed in the creek)	½

On the same stream, several miles north of Knob Noster, there are other outcrops of ironstone from six to ten inches in thickness. On Cedar fork, at the railroad crossing, one foot of coal is underlaid by several feet of the fire clay of a slight yellow tint. On the wagon road, one-half mile east, and also in the southern part of Knob Noster, and two miles northeast, the clay has become a rich yellow ochre, three to four and one-half feet thick, and seems to underlie the surface for at least five square miles, coal overlying it being, generally, fifteen inches thick. On Grand river, near Little Compton, in Carroll county, there are several beds of clay ironstone lying interstratified with soft clay shales. Within a vertical thickness of thirteen feet of shale the several ironstone layers aggregate a thickness of over two feet. Coal eighteen inches thick occurs in the hill above. Clay ironstone also appears in the

Grand river bluffs, not far from Brunswick. In the northwestern corner of Jasper county there is also found a two-inch band of clay ironstone containing some iron pyrites. On Cline Mound, Barton county, is a band of equal thickness of concretionary clay ironstone, breaking into smooth-jointed blocks, which are generally hollow. A short distance over it is a bed of ochre, while four seams of coal are shown in the hill above.

In section 10, township 33 north, range xxxiii west Barton county, a five-inch band of impure carbonate crops out. An analyses by Chauvenet gave insoluble silica 21.10, metallic iron 33.12 per cent. In the lower part of Timber hill, Vernon county, there appears a six-inch seam of clay ironstone. On the Marmaton, at other places above, and also a few miles from Nevada the ironstone is also seen. On Panther creek, west of Rockville, Bates county, broken and lenticular masses of clay ironstone occasionally crop out. In Henry county the overlying shales at the Jordan coal bank contain clay ironstone concretions. At Gilkerson there are at least two beds of ironstone, one of six inches thickness the other considerably thinner. At Jackson mill the ironstone is pyritiferous. Near Owens, Henry county, are large masses of concretionary ironstone often containing fossil plants.

Red hematites occur as open porous, as hard ores or as ochers. In Linn, Sullivan and Adair counties, there occur from 10 to 15 feet of soft, red shale, which in many places encloses hard nodules of ore sometimes as much as four inches in diameter. A fracture often exposes minute seams of lime carbonate, and sometimes fossils. Near Linneus, and on Locust creek, these nodules are abundant; also on Spring creek, three miles southwest of Laclede. The red shales are very abundant in the east part of Linn county, and might form a good paint. A nodule from near Linneus yielded 62 per cent of metallic iron. One and one-half miles north of Calhoun, in Henry county, three feet of red hematite of good quality, resting on three feet of brown ochre concretions occur just below the soil. At Calhoun, there appears two feet of red, sandy ironstone. The hematite bed north of Calhoun, apparently, underlies about ten acres of land. At Clinton and Calhoun there occurs a six-inch band of red hematite, containing brachiopods peculiar to the Lower Coal Measures. At Clinton it has a deep red color throughout. At Calhoun the inner portion of the ore has not completed its alteration, being ashen in color, while next to it is a band half an inch thick of red; then narrow, alternating bands of red and brown to the surface.

The limonites are either hard or soft, brown or yellowish, and of variable degrees of purity. The ocher bed at Knob Noster, above spoken of, underlies probably five square miles, and varies from a delicately tinted clay to an ocher and a richer ore, which may yield over 30 per cent of metalic iron. Beds of limonite are of common occurrence in the eastern part of Vernon and at many places in Barton. The best exposures have been observed in the southwestern part of Cedar county, where good ores and coal occur in the same locality. The section is:

	Feet.
1. Sandstone	28
2. Limonite, porous, yielding 55 per cent metallic iron	5
3. Limonite, soft, reddish brown, with coal plants containing well marked Sigillaria	1½
4. Ochre	7
5. Shale and sandstone	1⅝
6. Coal, good quality	½

These beds underlie the hill and are in a horizontal position. Other ores in Cedar county occur in a lower geological position. In Barton county, one mile west of Lamar, the upper coal seam is overlaid by an irregular bed three to twelve inches in thickness, which sometimes changes to a conglomerate of ironstone and sometimes to a sandy ocher. At other times it is a soft brown ore, with minute concretions alternating with bright yellow ochre. The latter, as analyzed by Chauvenet, gave 39.40 per cent of metalic iron, the results showing:

	Per cent.
Insoluble silica	31.51
Water	12.02
Peroxide of iron (Fe_2O_3)	56 29
Total	99.82

The brown cellular ores, abundant in many places, would give about the same result. In sections 18 and 19, township 33 N., range 33 W., the shales over the coal contain several concretionary bands and detached nodules arranged horizontally at regular intervals. The bands are from one to two inches thick, having an outer soft red or brown crust, and an interier hard shell of red hematite. Within it is either filled with ochre or is hollow. An analysis by Chauvenet gave the following results, with 44.24 per cent of metallic iron:

Insoluble silica	24.81
Water	11.90
Peroxide of iron	63.20
Total	99.91

A good quality of soft limonite has been observed in the northeastern quarter of section 23, township 33 N., range 33 W. The bed is two feet thick, occurring as broken strata over a space of about 800 square feet. Some of it is soft and shaly, while other portions are hard. Coal exists near by. Ochre beds occur in the bituminous shales of Vernon county. In Bates county, at several places in townships 38 and 39 N., range 31 W., are found large masses of cellular limonite. Beds of ochre, shales colored brown by presence of iron, and especially concretions of ochre, are often found in the Lower Coal Measures, as, for example, near Calhoun, in Henry county. Other localities to be mentioned are the Missouri bluffs below Carrollton, near Pleasant Hill and Strasburg, Cass county; also at Holden, in Johnson county.

The brown ochres particularly abound in some localities in the lower series. Red shales are found in the Upper Measures, and may be utilized as a material for paint. Such beds occur in Linn, Sullivan, Adair, Lafayette, Jackson, Platte, Buchanan and Andrew counties.

Bitumen is a substance which occurs in western Missouri, from Caldwell to Newton, a distance of 175 miles, in a district whose width in this state is from 25 to 40 miles, and about the same breadth in Kansas. On Fishing river, in Ray county, the upper sandstone of the Lower Coal Measures is saturated and blackened for a vertical thickness of 15 feet. The consequence was a boring for over 800 feet was made with no further sign of this material. Nearly opposite, in Jackson county, the sandstone is also in like manner saturated. The borings at Randolph also indicate about 35 feet of oily sandrock. Borings in Kansas City also indicate oil and gas in the same sandstone about 130 feet below the ordinary level of the river, and in a well at the St. James hotel, which extended 130 feet further down. In the Ridge well oil and gas, beginning about the same horizon as the last, are found 120 feet lower. In the boring made at the foot of the bluffs near the Union depot, Kansas City, bitumen was obtained at 180 feet below the surface. Several wells in this city have afforded sufficient gas for consumption on the premises. In the well at Wyandotte, Kas., bitumen appeared very near the surface. On the McCausland farm, near Higginsville, Lafayette county, the sandstones are so highly saturated with bitumen that borings were extended to a depth of 800 feet, but with no profitable result. The sandstone here is thick-bedded and soft, sometimes shaly. Swallow, reporting on this locality, states that the rock is traversed by east and west fractures filled with blue plastic clay. When first visited, this locality was regarded as Lower Coal Measures, but it seems probable that it may be higher in position and may even be equivalent to the beds just below the Upper Coal Measures and hence filling a valley of erosion.

On Mormon fork, in Bates county, a boring was made about the same time as the one near the Union depot, Kansas City. The hole began in the same sandstone as above named, but oil and tar were only found in the surface rock, with none below. In the western part of Cass county there is a tar spring, and west of Harrisonville and near Coleman, gas has been encountered in deep borings. From Cass county southward most of the sandstones and some of the limestones are very much saturated with bitumen. On fresh fracture most of them will emit a strong, bituminous odor. The coal also has that odor, and sometimes drops of bitumen appear on the surface. Some of the limestones at Rich Hill are very bituminous, and near the point of the elevation between the Marais des

Cygnes and the Marmaton the sandstone is quite black and highly saturated with bitumen. In the same vicinity limestones, which outwardly show no appearance of oil when freshly broken, have fossils which have their interiors filled with bitumen. Southward the waters are sometimes saturated with it, and in Vernon and Barton counties there are several tar springs. In Jasper and Newton counties the mineral occurs at the mines, and is often closely associated with the ores. There are several tar springs in Linn county, Kansas, and it has been found in wells at Ossawattomie; at Louisburg and Ft. Scott the wells have furnished a good deal of gas, while to the west of Iola, in Allen county, gas was also obtained.

In its northern extension the oil flows from the sandstone just below the base of the Upper Measures. It is found no higher in the series. But proceeding southward it is found throughout the base of the Coal Measures and in the mining regions in the Lower Carboniferous limestones. The sandstones in the Lower Coal Measures generally seem to be rendered more tough by its presence, and from north to south the rocks seem to have increased amounts. Although the beds are often blackened and liquid bitumen is found, it does not seem to be concentrated in sufficient quantity anywhere to pay for investigating. Its mere presence has caused deep wells to be sunk and thousands of dollars to be spent with no profitable result. The prerequisites do not appear to be present. There are no positive anticlinals in this district, as in Pennsylvania. Its greatest vertical range in Missouri may be placed at 600 feet, the average 300.

Bitumen in different parts of the world occurs along certain lines or meridians. Here it occurs along a line of northern Nebraska through Missouri, Kansas, Indian Territory and Texas, to the Gulf. The eastern oil fields occur along a line from Pt. Gaspe, Canada, to Nashville, Tennessee. Southward another band extends from Havana through St. Domingo, the Leaward and Windward islands to Trinidad, thence by Magdalena to Cape Blanco, Peru. In Europe, from Hanover through Gallicia, the Caucausus and the Punjaub. There are other lesser zones of the deposit, but the above are the most productive and their extensions parallel to great mountain chains.

There are a number of minerals found in the Coal Measures which deserve mention. Selenite is of frequent occurrence in the shales, being more often found as crystals imbedded in the under clay of the coal. In that position it is found near Columbia, Boone county, near Salisbury, in Chariton county, near Walnut creek, on the Missouri Pacific railroad, in Johnson; also, in Vernon and Barton counties, and in many other places.

Calcite is occasionally found as dogtooth spar, at or near Columbia, at the quarry at Amos, Jackson county, in a variety of nail-head spar and beutiful acicular crystals. On Grindstone creek, in DeKalb county, Panther creek, in Bates county and at Pleasant Hill, in Cass, both brown and whitish varieties are found. Aragonite in joints of the limestone (No. 74), in Lafayette county. Satin spar, of a beautiful silky lustre, occurs near Columbia, Boone county. Calcite also occurs as a parting to joints in the coal.

Baryte has been found in Jackson county, near Milan, in Sullivan county, and at Swanwick, in Ray county; also lining the fossils of the Upper Coal Measures.

Zinc blende has been found in limited quantity in septaria veins at Holden, on Walnut creek, Johnson county, in Platte county, and other places; also in a shaft near Greenwood, Jackson county. The same occurrence is shown at Amos, Jackson county, and at Lexington, Lafayette county. Ironstone concretions are often reticulated by a series of cracks which have been filled by calcite, which sometimes has associated with it zinc blende, as the northwestern corner of Saline county.

The pockets and outliers of Coal Measures are of special interest. Around the margin of the Lower division, where it rests upon the older rocks, are small basins and eroded valleys, in which are found occasional isolated deposits of coal, usually impure varieties of bituminous or cannel. Often a seam of soft bituminous shale is found without any coal, some few of them closely resembling true coal deposit. Coal with its associated shales and beds of fire clay are sometimes discovered. They vary in thickness from a few to 90 feet, and the inclination to the horizon would indicate that they were deposited at a time when the adjacent strata were considerably disturbed, or that a disturbance occurred soon after the coal was laid down. These deposits occur in valleys, or generally at a lower horizon than the general surface of the country, more often in narrow, eroded trenches, where the hillsides consist of rocks of much older age than the Upper Carboniferous. Although the seam may be 10, 20 or even 60 feet thick, it rarely extends very far horizontally. In Lincoln county, on Coon creek, such deposits are found in the valleys, also in the hollows tributary to the main valleys. They are more often found in the hollows or side valleys than elsewhere. The paleozoic rocks on Coon creek are of Lower Carboniferous age. In Callaway these coals also occur in eroded spaces, resting upon and against Lower Carboniferous strata. In Cole, Moniteau and Morgan there are also a number of such places, the coal resting on eroded valleys in the so-called second Magnesian limestone.

Farther southward these deposits occupy basins resting on the rocks of older age than the Coal Measures. In no instance have they been found occupying eroded spaces of Upper Carboniferous strata. These pockets must then be older than the beds of the regular Coal Measures. Probably at the beginning of the Upper Carboniferous age there was an unsettled condition existing and there were oscillations, tiltings and fractures of the earth's crust which prevented the forming of a continuous coal formation, or in other words the first coals formed in Missouri were disconnected shallow basins. Subsequent erosion washed away much of it, leaving it mainly in side valleys of larger streams. Some of these coal beds are drifted deposits. The erosion and transporting powers also carried along quantities of broken stone and clay, and in this way some seams are covered with chert of Lower Carboniferous age. In a coal bed near Versailles a band of such chert was noticed which appeared as if in almost the original place.

In central and southwestern Missouri depressions in the older rocks from 50 to 200 feet in diameter are often found, the material within the circle being often entirely fractured throughout, the rock outside remaining firm and solid. In such places it is common to find valuable deposits of lead and zinc, especially the carbonates of these ores, associated with broken rock and clay. Coal pockets sometimes fill areas which are somewhat analogous and zinc blende and iron pyrites are commonly found in small quantities with the coal, but rarely galena. This also serves to show that the lead and zinc may have been deposited contemporaneously with these pockets. Basins of coal are found also near the lead mines of southwest Missouri. In the valleys of Carterville and Joplin there are clay shale deposits which are apparently of Upper Carboniferous age. These circles form an interesting study and it remains in doubt whether an accurate theory of their formation can be formed.

The Upper Measures occupy a higher topographical position than the strata beneath, and at their last exposure to the eastward and southward they repose upon the Lower Measures. The latter, therefore, should be reached by deep shafts sunk upon the Upper Measures. The presumption would be that some of the lower coal beds would also be encountered. Some of them would likely be reached, but many become thinner, others entirely thin out, and if the recorded borings which thus far penetrated into upper, as well as well as the lower, strata are to be trusted, they go to show that most of the Lower coals become attenuated as they pass beneath the Upper Coal Measures, and some entirely thin out. Only by trial borings can a correct result be obtained. If, in the future, deep drilling is undertaken the work should be done with much greater care than is customary now, and the driller should be thoroughly competent, and in all cases an experienced party should have supervision of the work, and note carefully each sample as it is brought up.

As to the thinning of the coal seams where the Lower Measures underlie the Upper, the borings at Pleasant Hill penetrating through 550 feet of Lower Measures have recorded no seam thicker than 15 inches. But the drill was a common jump-drill. A diamond-drill might produce different results. The boring at Randolph also passed through no seam over 1½ feet in thickness. Other borings in Kansas City have penetrated to depths of 400 and 500 feet through 15 and 20 inches of coal. The boring at Bethany passed into 654 feet of Coal Measures, and the thickest coal was reported to be 16 inches. The well bored at the foot of the bluffs at Kansas City penetrated to the Lower Carboniferous at about 740 feet, but only thin coals were reported, the thickest 20 inches. In all of these borings, the Lower Coal Measures were penetrated without passing through any thick coal seams. Now, if these are correct records, it would go to show that the Lower Measures became thinner in passing beneath Upper Measures. In other words, the coal beds are thickest near the margins of the original coal swamp. If coals are thicker near the margin, it would also show that the carboniferous forests were more luxuriant around the margins of the wide-spreading, gentle inward-sloping basins of the coal marshes, than within the area, which would be a natural consequence of a better condition for plant and tree growth where the waters were shallow than where they were deep, for they would be deeper upon recession from the margin.

Some years ago, a well at St. Joseph was bored to a depth of 402 feet, passing through coal 22 inches thick at 103 feet, 18 inches at 223, and 32 inches at a depth of 350 feet. If these borings were rightly recorded, they show a considerable thickness of coal beneath the surface. This is the only marked exception. But bituminous shale may have been counted as coal. The Saunders well, in Ray county, penetrated 803 feet of strata, the lower 257 feet in Lower Carboniferous beds. In this, five feet coal was reported at 108 feet, but doubtless a part was bituminous shale. At 221 feet, four feet of coal was also recorded. Only one other stratum which included coal was noted. At Chillicothe a boring was extended to nearly 300 feet deep through beds of Lower Coal Measures. Six inches of coal were reported at 153 feet; only bands of black slate were reported from lower horizons, with two thin streaks of coal. There is no reason why good coal should not have been reached in this boring, unless the lower coals had become attenuated; otherwise the records were not correct. The last three borings were all made with the common drill, and under such circumstances it is easy to construct an imperfect or unreliable record.

The shales and sandstones are not generally fossiliferous. In the latter, especially in the Lower Measures, casts of Calamites, Sigillaria and Lepidodendron are sometimes found. Fine specimens of fossil fruit and Calamites have been obtained from the White Rock quarry in Carroll county, at Moberly, and at a few places in Vernon county. In sandy shales near the base of the Coal Measures on Drywood creek, Vernon county, half-way between Moundville and Deerfield, there has been obtained a number of specimens of a peculiar cup-shaped fucoid which Professor Lesquereux assigned to a new genus Conostichus, the two species being *C. broadheadii* and *C. prolifer.* A sigillaria in No. 123 at Weston, was also recognized occupying the same geological position near Winston in Daviess county. A similar one was also found in an ironstone bed in the southern part of Cedar county, near Jericho. In the sandstone quarry, near Warrensburg, a lone trunk of a coniferous tree was discovered having bark three-fourths of an inch thick. The bark was entirely converted to coal, while the interior was silicified.

Fossil plants occur abundantly in the lower beds of Henry county. Some ferns have been found in the shales at the foot of Timber Hill, Vernon county, near Coaltown, in Bates county, and Strasburg, Cass county; also in clay ironstone nodules at Holden, in Johnson county, and on Walnut creek, two miles east of Knob Noster. Limestone No. 85 at Kansas City and in Clay county contains beautiful impressions of fossil plants. Fossil ferns also occur in clay ironstone on Locust creek, west of Laclede, Linn county. They are abundant in shales associated with the coal at Hall station, Buchanan county, and at Rochester in Andrew county. In the bituminous shales of the Lower Coal Measures the fossils are often found composed entirely of iron pyrites. In the Upper series the interior of the fossil is often crystallized, both carbonate of lime and zinc blende being found. The latter mineral is also found in the cracked portions of the ironstone nodules at Holden, which contain fern impressions.

Fusulina abounds in the Lower Coal Measures, but is rare above all until high up in the Upper Measures, where it is even more abundant. Still higher it forms entire beds of rock in the so-called Permian at Kansas, as at Manhattan. Crinoid stems are commonly found, but the calyx is rare, and but a few localities afford good specimens. Number 97, in Kansas City, and other localities on Big creek, in Harrison county, furnish some specimens. They are of more frequent occurrence in the Upper Coal Measures. *Archæocidaris megastylus* occurs in the limestone over the Lexington coal; other species of this genus occur in the lower members of Group F, and in upper part of B. One specimen of fossil fish, a small species of Paleoniscus, has been discovered. It was found in bituminous shale overlying a lower coal near Knob Noster, Johnson county. Fish teeth are often found in both the limestones and the bituminous shales, and fish spines in the latter. The limestone overlying the Lexington coal also contains a peculiar fossil not elsewhere observed in Missouri. It may be referred to the Lower orders of animal life, probably to Cœlenterates, or even lower. A few specimens were obtained from bluffs of Marais des Cygnes, in Miami county, Kansas, five miles west of Osawattomie, where they merge in what seems to be a Stromatoporid. Quite a number were also obtained from near the head of Fancy creek, in Greenwood county, and westward toward Twin Falls. The Stromatopora may have only adhered to the other organism and not be a part, but the specimen appears very much as if both were one.

Chaetetes milleporaceus abounds in some of the Lower Coal Measure limestones, and apparently continuous reefs with an occasional Zaphrentis or Campophyllum or Syringopora. In the Upper Coal Measures, Chaetetes is found, but in smaller masses. *Campophyllum torquium* is especially characteristic of No. 90, at Kansas City. Bryozoans chiefly abound in the Upper division. Productus is prevalent throughout and includes about fourteen species. *Productus costatus* is common from the base up to the so-called Permian. A large variety occurs in the lower part of the Upper Coal Measures. The species *P. muricatus* has only been found in the Lower Coal Measures; the *P. splendens* is found from near the horizon of the Lexington coal to the top of the Coal Measures. *P. nebrascensis* and *P. norwoodi* were discovered only in the Upper Coal Measures, while *P. semireticulatus* is found from the base of the Coal Measures to the Middle Permo-carboniferous, where it assumes the broad, regular form of *P. calhounianus*. *Productus auriculatus* rarely occurs in beds of the Upper Coal Measures. *Spirifer (Martinia) planoconvexus* seems gregarious; *S. kentuckensis* is found throughout. *S. cameratus*, in the Lower Measures, slightly resembles the *S. striatus*; in the Upper Series its ribs are more angulated and fasciculated and it passes into the variety *S. kansasensis*. There may be three species of Meekella in the lower part of the Upper Coal Measures; the *M. striatocostata* found in Nebraska, at Hillsdale, and at the mouth of Big Nemaha. *Syntrilasma hemiplicata* is limited to the Upper Coal Measures.

Chænomya occurs in the last-named formation and in the Permian; the species *C. minnehaha* only in the former. Edmondia is found chiefly in the Upper Coal Measures. *Myalina subquadrata* occurs just below the lowest part of the same beds and at various higher horizons. Schizodus is noticeable chiefly in the Upper division and in the Permian. Species of trilobites are restricted to genus Phillipsia, which is apparently more rare in the Upper Coal Measures. *Conularia crustula* (White) has only been found in one thin shaly layer, high in the Kansas City bluffs. It was observed at one place in same formation of Montgomery county, Illinois, and was reported from New Mexico. Number 87, at Kansas City, abounds in fossils, including over 40 species.

INDEX.