CHAPTER IV.

SYSTEMATIC GEOLOGICAL SURVEYING.

The two early attempts by the state of Iowa to establish a geological survey of her domains and to take inventory, as it were, of her mineral resources were abortive. The work ended before it had hardly begun. In both instances the abrupt and untimely termination of the investigations was brought about by circumstances entirely beyond the control of those directly engaged; it was due wholly to a peculiar weakness in the organic law originally providing for the organization. A quarter of a century elapsed before a third attempt was successful in starting geologic investigations.

The fitful histories of many of the geological surveys of the states of the Union a generation ago are strikingly alike. The brief, disconnected, often wholly unproductive courses which these surveys followed are all directly traceable to the same atrophic influences to which all of these early organizations appear to have been peculiarly subject. With the third effort to establish the geological survey of our state an attempt was made to remedy some of the most serious of the inherently weak provisions of the usual enabling act. The success with which this was accomplished is fully demonstrated by the fact that a continuous policy and an uninterrupted course of the work have now gone on for two decades. Since the beginning of the present geological survey of Iowa nearly every state in the Union, which has conducted systematic and satisfactory investigations, has adopted provisions in the organic law similar to those incorporated in the Iowa law.

During the twenty-five years which elapsed between the discontinuance of the work under White and the renewal of investigations by the present organization numerous attempts were made to have the several legislatures provide in some way for carrying on geologic work in the state; but all were without success. Finally, in the winter of 1892 a fellow of the Iowa

Academy of Science, resident of the capital city, after consultation with the various scientific men of the State and others interested in the development of the long neglected natural resources, took it upon himself to have a comprehensive bill introduced in both branches of the legislature and followed through to the final approval of the Governor.

Soon after the beginning of the sessions of the legislature a small pamphlet was placed in the hands of every member, and other public men, setting forth the principal reasons why the State should make suitable provision for the study and taking of a careful inventory of its mineral resources. Either in entirety, or in part, this pamphlet was copied in many of the newspapers throughout the state. Some of the arguments presented are worthy of reiteration here. Reference has only to be made to the great series of reports of the Survey to note how repletely the prophesies then made have been fulfilled.

In pointing out some of the advantages of a geological survey it was stated that at no period in the history of the State has Iowa felt more the need of a thorough geological survey of her domains than at this time (1892).[162] Not such a survey as is vaguely conceived by the majority of people, but one that is broad in its scope and far-reaching in its workings. A survey the primary aim of which is to set before the public the grand natural resources of the State, to encourage its material development, and to invite the investment of outside capital.

The desirability, through such a measure in diffusing knowledge of a most practical kind among the citizens of the State, is so manifestly prevalent that it is a matter of considerable surprise that steps towards its consummation were not taken long ago. To be sure, such a movement was twice started and twice it was rendered abortive after a brief career—the first time in the fifties, the second time more than twenty years ago. Both were hurried reconnaissances—one of the eastern half of the State, and the other of the western part. Being thus merely preliminary the results could not help being incomplete and inaccurate. During the last two decades much valuable information concerning the mineral wealth of the State has accumu-

[162]Proposed Economical Geological Survey of Iowa, Pamphlet, 8 pp., Baltimore, 1891.

lated, which would be of the greatest service when brought together in a connected way with other investigations. In the same period geology itself has made gigantic strides, particularly in regard to its relations to agriculture. Furthermore, the existing geological reports of Iowa (Hall and White) are not only meager and wholly inadequate in subject-matter, but their distribution is very limited. The population of the State having also very greatly increased, even this little amount of information is inaccessible to the majority of citizens.

As already intimated, the best results obtainable by a thorough geological investigation of the State's natural resources are only through a liberal appreciation of a survey's proper function. Among the subjects in most urgent need of careful consideration are the character and distribution of the different soils and their capabilities for agricultural purposes, the extent and value of the various deposits of coal, lead, iron and other ores, the distribution, properties and uses of the inexhaustible beds of valuable clays, the accurate determination of the areas of artesian-waters, the analysis of the many mineral-waters, the relative value and durability of the numerous kinds of building-stones, and other structural materials. Moreover, independent of the great scientific bearing of the work, both the immediate and future economic returns would be very great even if viewed from the purely financial angle.

The relations of geology and agriculture are daily becoming more intimate. Nowhere is this inter-dependence more clearly understood, and nowhere are the benefits more satisfactorily shown than in certain European countries. Some of the older states of the Union and especially those on the Atlantic border, are following the same line of work with most encouraging results. It is now almost universally conceded that a good geologic map of a region is practically also a soil-map. The proper appreciation of the close relations of the two sciences cannot fail to impress the truth of this statement. The marvelous conclusions arrived at in the mechanical analysis of soils by the geologists connected with the state bureaus of North Carolina and Maryland, for examples, are just being made public, and they promise completely to revolutionize existing agricultural

methods. "Worn out" lands, a short time ago perfectly worthless, suddenly become highly productive, in fact thoroughly rejuvenated, by treatment very simple and very inexpensive. Moreover, the work can be carried on with mathematical precision. The increase in the value of the land in one portion of a single county is enough to cover the cost of an elaborate survey for an entire year.

The greatest factor in Iowa's mineral wealth—the coal deposits—has been allowed to take care of itself. Not a single area in the entire State has ever been accurately mapped, and its extent, thickness and stratigraphical peculiarities made out. Surprising as it may seem, carefully made estimates show that more money is wasted in the State every year in poorly conducted researches after coal and other mineral deposits than would have annually supported liberally a survey. Throughout the state are to be seen numberless abandoned diggings most of them the fruitless attempts to obtain coal in places where success is as utterly hopeless as can be imagined. Everywhere deserted shafts tell of the useless expenditure and loss of capital which might easily have been avoided had some authoritative information concerning the geological structures of the particular localities been accessible. It is the same in the cases of natural-gas, rock-oil, copper, gold, and many other mineral substances. A properly conducted investigation largely obviates such blunders. It indicates the presence of valuable minerals in places where their existence is little suspected; and it also proves conclusively their absence in localities where they have been long sought in vain. Not less important than the intelligent guidance in the search for the workable mineral deposits is the development of new fields. In a hasty, purely scientific reconnaissance during the past season of certain portions of the central part of the State, extensive beds of the best quality of coal were encountered in places where its existence was not thought of. These are only a few instances out of many which go to show the great advantage of having such facts brought properly before the public.

In the absence of extensive exposures of good building-stones in the immediate vicinity of many large cities of the State, ar-

chitectural materials must be in large part derived from other sources. Fortunately, in and about some of these places are inexhaustible supplies of good clays from which may be readily manufactured all the ordinary and ornamental products. These clays, as is well known, have diverse properties, certain ones being adapted better for particular purposes than others, while some may be used more advantageously in different ways. Hence the indiscriminate working of the deposits is not attended by the highest economic results, and often ends disastrously. This fact does not apply to a single locality but the entire State. Clay is constantly being put to a multitude of uses which were undreamed of a decade ago. Everywhere this material is becoming more and more important economically in the draining of farm-lands, in sewering, in paving, and in all kinds of building. There are still countless other ways in which it might be utilized with great profit. Manufactured clay-products are daily replacing other building materials, such as granites, and similar rocks, on account of its cheapness, its practically equal durability, and its great range of artistic effect with a requirement of less labor than is possible in the case of natural rock.

The building-stones of the State require the most careful investigation, for large amounts of money are sent to distant places for the same stone which exists in inexhaustible quantities at home, the chief difference being that the domestic rocks have not been sufficiently tested to separate the good from the poor qualities, and hence the use of inferior grades which may be to the casual eye identical with the best varieties has caused the whole group to fall into disrepute.

The sums annually expended in ill-provised and consequently fruitless seeking after artesian-waters, rock-oils, and natural-gas are something astonishing. Proper conduct in this regard calls for experience and geologic insight that extends beyond a single township, beyond the county, and even beyond the limits of the State.

From the foregoing it is manifest that in order to attain the highest and most speedy results in the development of the State's rich mineral resources a systematic effort must be made. Such an effort seems best effected through means of a thorough

and exhaustive survey—a geological survey in a broad sense. A glance at what sister states are doing in this direction serves to emphasize the proposition. Two score or more states have surveys in progress or have recently completed them. Missouri and Ohio have just inaugurated geological surveys for a third time. Georgia, North Carolina, Arkansas, and Texas have recently reorganized their geological bureaus. The majority of states having surveys in progress have recently greatly increased their appropriations for geological work. In Europe every country is now carrying on elaborate geological investigations. Brazil, India, Japan, New Zealand, and the African and Australian colonies are all prosecuting similar work. Canada and our Federal government also expend large sums annually in the development of the mineral wealth. Thus Iowa alone stands without any late authoritative information concerning her natural resources. Consequently beyond her borders there is a wide-spread impression that the natural sources of wealth are lacking.

It is apparent from a consideration of the statements thus set forth that, as every commonwealth in the Union has already concluded, the greatest strides in the development of the natural resources of a state are made through means of a properly conducted geological survey. The treatment of the various subjects from agricultural, economic and scientific angles would be of the greatest value to the citizens of the State, repaying many times the amount expended in conducting the investigations.

There are, thus, several independent and weighty reasons for the organization of a geological survey of Iowa.

For purely financial considerations a liberal appropriation cannot fail to prove a profitable investment.

The sums annually wasted in ill-advised and consequently fruitless search for coal and other minerals within our State far exceed the annual expense of a thorough and systematic geological survey. Thus a short time ago, in Mitchell county, a single capitalist expended in an utterly hopeless search for coal, during a single season, more money than would be required to prosecute a thorough survey of that county and to publish full reports of the results obtained. Other persons in the same and

adjoining counties have paid out amounts of money probably still greater in the aggregate. In Story county are to be seen numerous abandoned shafts, the total cost of which was at least two or three times as great as would be that of an exhaustive survey of the districts, including the preparation of maps and the publication of reports. It is about the same in at least thirty or forty other counties. Nor is coal the only *ignis fatuus*. Lead, gold, petroleum, iron, and other mineral substances have been sought for, at considerable expense, in localities where there is absolutely no reliable evidence of their existence in paying quantities.

A thorough geological survey of the State would conclusively establish the existence or non-existence of valuable minerals in every portion of our domain, and carefully prepared reports thereon, accompanied by suitable maps and sections, would not only indicate all localities in which such minerals actually occur, but also the approximate depth at which they lie; and judicious distribution of such reports and maps would cut off most of the constant serious drain upon our material resources occasioned by hopeless mining ventures.

A complete and systematic geological survey would reveal the previously unsuspected existence of valuable mineral deposits in numerous localities, and thereby add directly to the wealth of the State. The benefits derived from this single result have been found in several states, to be commensurate with the total cost of the survey.

Miners and prospectors are greatly aided by accurate information; and the farmer gets immediate financial returns, both by the advance in the price of the land and from the mineral wealth discovered. Commercial and manufacturing interests are enlivened.

The publication of facts illustrating resources would attract capital of brain, brawn, and gold from other and less favored localities. For nearly a quarter of a century Iowa has published nothing concerning her mineral and other resources; and since her admission to the Union, three small volumes and a few minor papers constitute the whole of her publications on these subjects. Compared with what our sister states have done, this is but a

meager showing. In consequence there is a feeling among influential classes beyond our borders that the natural sources of wealth are lacking in Iowa—that she is, as her scientific publications indicate, a starvling among the states. Among teachers in eastern institutions of learning, such an impression is common, if not general; and too frequently it is conveyed to pupils who might otherwise form most desirable and welcome additions to our population. This most misleading impression should be eradicated.

The actual pecuniary value of the published reports of the survey ought fully to equal the total expenditure required for the prosecution of the survey and the publication of the reports. This is indicated by analogy with other states. Thus Ohio recently completed a geological survey at a cost of about $300,000. An edition of 20,000 copies of the final report was published and the sets sell readily at $15 each. These reports are nearly all distributed among the citizens of Ohio. Illinois has carried on a geological survey, and has expended something less than $200,000, in connection therewith. An edition of 3,000, or more, copies of each of the eight great volumes was issued, and all available sets readily bring from $30 to $40. These reports also are mainly in the hands of citizens of that state.

Even if not an immediately profitable financial investment. it is desirable that the State, as the guardian of public welfare, and as a patron of pure science which will ultimately become of practical value, should inaugurate any measure which will, with moderate outlay, increase, develop and diffuse knowledge among its citizens.

This proposition is too manifestly consonant with the principles governing intelligent statesmen everywhere to require extended discussion.

As an illustration of the benefits likely to accrue to an agricultural state from an intelligently conducted geological survey, it may be pointed out that the physical relations between geology and agriculture, though so intimate as to have exerted a most important influence on human development, are not yet understood; that science, in that particular field, has only reached the empirical stage, just as was once the case with as-

tronomy and chemistry; that less than half a dozen individuals have ever approached the subject with an adequate conception of its magnitude and importance; that so complex is the subject and so elaborate is the investigation demanded, that it is not likely to be reduced to an approximately exact science by individual enterprise and liberality, after the ordinary mode of development of the various branches of knowledge; and, finally, that geology has now reached such a stage that this subject is likely to be taken up by any geological survey not restricted, by definite legislation or predominant mineral wealth, to special geological questions.

In all European countries and in many of the Eastern states it is everywhere known that a good geological map of a district is a most reliable soil-map also; and that all experiments, calculations, or new departures succeed best where such maps are used as a basis. In some of these provinces wonderful results have been reached by geologists who have turned their efforts in this direction. By methods simple and costing but little, good crops have been raised on land which has long been regarded as perfectly worthless. Other lands in the same way have been made still more productive. What is even of greater importance, all danger of "exhausting" the soil is eliminated. The increased value of these lands in a single district has many times repaid the cost of the entire investigations and all the determinations of the geological and topographical features.

It is the province of the state to furnish its citizens with such information as is derived from a geological survey.

The existing accounts of the natural resources of Iowa are utterly inadequate. Being the results of hurried reconnaissances they are neither accurate nor complete. The cartography is miles wrong in many instances and in some cases new exposures indicating formations distinct from any recognized in either survey have since been discovered.

In the score of years that have elapsed since the preparation of the last report great strides have been taken by geology, particularly by that portion which relates to the superficial accumulations of earths, clays, loams, sands, etc., and which is hence of maximum importance in an agricultural state.

The last reports were published when the population of Iowa was far less than now, and were rather sparingly distributed. They are therefore totally inaccessible to the majority of the citizens of the State.

The bill for the geological survey, as it was originally drawn and as it passed both houses of the Legislature and was approved by the Governor, read as follows:

Section 1. There is hereby created and established a geological survey for the state of Iowa, which shall be under the direction and in charge of a geological board, which shall consist of the governor, the state auditor, the presidents of the State Agricultural College, the State University, and the Iowa Academy of Sciences.

Sec. 2. The duties of the geological board shall be to have oversight and full control of the survey, except as herein otherwise provided; to appoint a state geologist, and such expert assistants, recommended by the state geologist, as may be deemed necessary; to audit accounts; and to annually furnish for publication a report of the operations of the survey.

Sec. 3. The duty of the director, or state geologist, shall be to make a complete survey of the natural resources of the state, in all their economic and scientific aspects; including the determination of the order, arrangement, dip, and comparative magnitude of the various formations; the discovery and examination of all useful deposits, their richness in mineral contents, and their fossils; and the investigation of the position, formation and arrangement of the many different ores, coals, clays, building stones, glass sands, marls, peats, mineral oils, natural gas, mineral and artesian waters and such other mineral materials as may be useful, with particular regard to the value of the said substances for commercial purposes and their accessibility; also the careful noting of the characters of the various soils and their capacities for agricultural purposes; the growth of timber and other scientific or natural history matters that may be of practical importance and interest. A complete cabinet collection may, at the option of the board, be made to illustrate the natural products of the state; and the board may also furnish suits of minerals, rocks and fossils to colleges and public mus-

eums located within the state, provided the general state collection is not made to suffer thereby.

Sec. 4. It shall, further, 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 the work is completed, which maps shall embrace all such geological, mineralogical, topographical and scientific details necessary to make complete reports of the said districts. Whenever the information obtained warrants it, the results of any special investigation of agricultural or geological phenomena shall be brought together in a memoir or final report for publication accompanied by the proper illustrations and diagrams. On, or before, the first day of January of each year, the state geologist shall lay before the geological board a full report of the work of the preceding year, together with such minor reports and papers as may be considered desirable for publication. When occasion requires, important information may be issued in the form of special bulletins, for the immediate use of the people at large. From time to time items of general interest, or announcements of new discoveries, may be furnished to newspapers or periodicals for publication.

Sec. 5. The reports contemplated in this act shall, under the direction of the board, be disposed of as follows: (1) To each of the present state officers and to each member of this Assembly who shall annually send his address to the geological board, one copy of each published volume; and to each member of any future Assembly, which shall authorize the publication of any report, one copy of such report shall be sent. (2) Twenty copies of each volume published shall be furnished to the State Library; ten copies to the State Historical Society, State University, State Agricultural Society and State Horticultural Board; two copies to each chartered college and normal school in Iowa; and to the libraries of each state institution, the Iowa Academy of Sciences, Davenport Academy of Sciences, and to the general offices of each railroad that has furnished aid to the survey. (3) One copy of each volume to each public library, to the libraries of academies or other educational institutions, to each scientific society in the state; to each first class library, to each scientific survey or organization issuing regular publications, beyond the

limits of the state; and to each geologist of national reputation, on receiving his written application therefor. (4) All remaining volumes, after retaining a sufficient number to supply future demands, shall be sold to persons making application for them at the cost price of publication of such volumes, the moneys thus accruing to be turned into the treasury of the state.

Sec. 6. For the purposes of carrying out the provisions of this act the sum of fifteen thousand dollars, or as much thereof as may be needed, is hereby annually appropriated.

Sec. 7. The members of the board shall be allowed the actual expenses attending the duties assigned them by this act. The salary of the state geologist and his expert assistants shall be fixed by the geological board. The necessary postage, stationery and office expenses of the state geologist shall be paid by the state as the expenses of other state officers are provided for. The expense of printing, engraving, binding and distribution of the reports of the survey shall be paid out of any moneys, not otherwise appropriated, in the state treasury on warrants of the state auditor approved by the geological board.

Sec. 8. All previous acts, or parts of acts, inconsistent with this act are hereby repealed.

Sec. 9. This act being deemed of immediate importance shall take effect and be in force from and after its publication in the Des Moines *Leader* and Iowa State *Register*, newspapers published in Des Moines, Iowa.

Prior to the initiation of the work of the present Iowa Geological Survey the progress of state organizations of this class generally had been seriously handicapped by conditions which not only invariably hampered continuous effort but which often were inimical to good scientific work. The frequent inability of so many of the state surveys to produce the creditable and satisfactory results demanded of them by the scientific world was, without exception, traced directly not to the shortcomings or remissness on part of the scientific corps, but to the constant and meddlesome political interference which actually prevented good continuous investigation.

In the framing of the new law establishing the Iowa Geological Survey, it was aimed to eliminate as many as possible of the in-

trinsic difficulties which prevent reasonable accomplishment. Advantage was taken of the experiences and rather wide acquaintance with the failures and vicissitudes concerning other states. Particular effort was made to guard against some of the most obvious legal defects of other state laws governing geological surveys. Of these the most vital safe-guards to the proper conduct of the bureau appeared to be:

Intrusting the appointive power of the survey personnel to scientific guidance rather than to political exigencies.

Provision for permanent annual appropriations of moderate size rather than for larger amounts for uncertain periods.

Establishment in the beginning of a continuous policy of scientific and economic investigation, rather than constant change from year to year.

Creation of complete individuality of the survey as an organization rather than as an appendage to some other state institution or state department.

Arrangement whereby the printing of the reports is provided for under the same conditions as the other state reports, but with the editorial supervision entirely under the direction of the survey, rather than publishing either entirely independently of the State, or as ordinary state documents.

Preparation and publication of reports containing only complete or permanent results rather than copious, undigested transcriptions of field-notes.

For the proper prosecution of the specific purposes for which the geological survey was established the controlling board early surpassed all expectations. The superiority of an *ex officio* board over an appointive board was demonstrated from the very beginning. Of the state officers, the Governor and the Auditor were the two most conversant with the details of all the state departments, were most interested in the good conduct of every state bureau, and most influential in the promotion of their welfare. At the time the present survey was organized these officials were elected every two years, but on alternate years. Their service, however, was usually for a period of four years rather than two.

The presidents of the State University and the State Agricultural College were likely to serve longer on the geological board than any of the other members, the term being about ten years. In their choice of a director for the survey, their approval of the working personnel, and of the general policy of the organization they have at all times the advice of some of the leading scientific men of the State. The fifth member of the Board—the president of the Academy of Sciences—changed every year; but as a representative of the most active scientific workers in the State and as the most distinguished Iowan among the scientific men of the nation he was in a unique position to pass judgment upon the qualifications of the geologic corps and the quality of the work proposed and performed.

Upon three of the five members of the geological board it would be almost impossible to bring disastrous political pressure to bear. After the various experiments along this line during the first year of the Survey's existence the organization has been remarkably free from all such attempts.

As a safe-guard against the interruption of the different lines of investigation undertaken by the survey, before their completion and against the consequent loss of a large part, if not all, of the results already accomplished the provision of an annual appropriation proved to be far more important than it was at first suspected. It insures permanency to the work. It enables work to be planned ahead. It serves as a check against hastily thrown together reports. It obviates the going before the Legislature every year or every two years to plead the life of the bureau. It makes more difficult unreasonable economies on part of a "reform" legislature.

The provision of perfect independence of the geological survey from all other institutions and state departments has many features to commend it. As a mere appendage of something else it is not possible to bring out the best work nor to accomplish maximum results. This is amply and repeatedly demonstrated by carefully comparing the manner, quality and quantity of the results obtained by the various state surveys under the two policies. There is really not another department of a state that

is doing or can do the particular line and grade of investigation that a well-organized survey does.

That the geological survey should have entire editorial control of the printing of its reports, including the selection of the paper, binding, styles of type, size of volume, and number and character of illustrations, is a more important provision than at first glance might seem. The contents of the reports are read by a more cultured and critical, as well as scientific, class of people than are the average state documents. The State can well afford at but slight additional cost, to have these reports present the most creditable appearance possible, conforming with the notions prevailing in all the civilized nations of the globe. Moreover, the reports reach a large professional and discriminating body of readers with whom a few mistakes may render the entire volume practically valueless. Technical correctness and completeness in such reports are as important as accuracy of statement in the subject-matter itself. The charging of the expense of the printing to the general printing fund instead of to the special survey fund works no hardship on the state.

Elimination of all preliminary reports and mere transcriptions of field-notes and the publication of only matter of a permanent nature relieves the corps of the survey of a large amount of unnecessary and useless effort, and invokes the high appreciation of the scientific public. First drafts of reports are usually subject to such profound modification before they are finally brought into presentable shape that if published they soon become a source of great and constant embarrassment to all concerned. Moreover, with the public they are a source of no little confusion. If preliminary results of a scientific bureau are to be published at all they are best given in brief and popular form to the newspapers and periodicals.

When the geological board held its first meeting in July, 1892, for the purpose of initiating the work of the survey, its first duty was the selection of a director. The names of several persons were before it, some of them avowed candidates, but others wholly without knowledge of their consideration. The majority of the members of the board seemed to favor the author of the bill establishing the survey and him who was chiefly instrumental

in following it through the Legislature. The Governor finally resolutely objected on grounds of youth and politics; and the other members, in deference to his wishes and by way of compromise, concluded to ask Professor Samuel Calvin of the State University to act as head of the bureau. With his usual profound sense of the fitness of things and his exceptional magnanimity, Professor Calvin, after some two week's consultation with all parties concerned, refused to accept the post unless his former student and the real author of the bill, should be made chief assistant and be given the full and active charge of the organization, and he to retain his regular connection with the University. This plan being satisfactory, Professor Calvin accepted at the next meeting of the Board, the offer to serve as state geologist, Dr. Charles R. Keyes was then chosen assistant state geologist; and Professor G. E. Patrick was selected for chemist.

The organization of the geological corps, the plans of investigation, and the forms of reports were speedily worked out.

Ever since its first organization, the Iowa 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.

From the beginning, two classes of work have been recognized. One is denominated subject-work, the other 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 results.

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 naturally 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 stratigraphic 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 still others with still different substances of economic value. Each is found in a particular 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 a wholly 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 many:

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 deposits 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 kind of deposit may be taken up, and the results published long before all of the work in the counties containing the particular substances 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 intelligent interpretation of the phenomena observed in any one county, and to connect them with those seen in neighboring districts.

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, all 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.

In areal-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 of localities are set forth. Its di-

rect purpose, then, is to satisfy constant and ever increasing demands for reliable information in regard to given districts. 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-power; 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.

All 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. 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 areal 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 minature of the surface of the region is far superior to any ordinary atlas. It is invaluable not alone to the trained geologist, but it 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 the purposes mentioned, it affords 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.

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 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.

No feature in the investigation of the natural resources of the state is 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. 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 investiga-

tions 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 various scientific journals.

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.

The character, variety, and extent of the various investigations undertaken and completed during the two decades of uninterrupted activity are best indicated by a list of the reports already published and incorporated in the twenty-odd volumes. These are shown by the tables of contents here enumerated:

VOLUME I. FIRST ANNUAL REPORT, 1892.

480 Pages, 10 Plates, 26 Figures.

CONTENTS:

VOLUME II. COAL DEPOSITS.

BY CHARLES ROLLIN KEYES.

536 Pages, 18 Plates, 251 Figures.

CONTENTS:

VOLUME III. ANNUAL REPORT, 1893.

501 Pages, 4 Maps, 37 Plates, 34 Figures.

CONTENTS:

Thickness of the Paleozoic Strata of Northeastern Iowa; by William Harmon Norton.
Composition and Origin of Iowa Chalk; by Samuel Calvin.
Buried River Channels in Southeastern Iowa; by C. H. Gordon.
Gypsum Deposits of Iowa; by Charles Rollin Keyes.
Geology of Lee County; by Charles Rollin Keyes.
Geology of Des Moines County; by Charles Rollin Keyes.

VOLUME IV. ANNUAL REPORT, 1894.

467 Pages, 11 Plates, 6 Maps, 54 Figures.

CONTENTS:

Administrative Reports.
Geology of Allamakee County; by Samuel Calvin.
Geology of Linn County; by W. H. Norton.
Geology of Van Buren County; by C. H. Gordon.
Geology of Keokuk County; by H. F. Bain.
Geology of Mahaska County; by H. F. Bain.
Geology of Montgomery County; by E. H. Lonsdale.

VOLUME V. ANNUAL REPORT, 1895.

452 Pages, 14 Plates, 7 Maps, 72 Figures.

CONTENTS:

Administrative Reports.
Geology of Jones County; by Samuel Calvin.
Geology of Boone County; by Samuel W. Beyer.
Geology of Warren County; by J. L. Tilton.
Geology of Washington County; by H. F. Bain.
Geology of Woodbury County; by H. F. Bain.
Geology of Appanoose County; by H. F. Bain.

VOLUME VI. LEAD AND ZINC, ARTESIAN WELLS, ETC.

487 Pages, 28 Plates, 57 Figures.

CONTENTS:

Lead and Zinc Deposits of Iowa; by A. G. Leonard.
The Sioux Quartzite and Certain Associated Rocks; by S. W. Beyer.
Artesian Wells of Iowa; by W. H. Norton.
Relations of the Wisconsin and Kansan Drift Sheets in Central Iowa and Related Phenomena; by H. F. Bain.

VOLUME VII. ANNUAL REPORT, 1896.

550 Pages, 11 Plates, 11 Maps, 81 Figures.

CONTENTS:

Administrative Reports.
Geology of Johnson County; by Samuel Calvin.

Geology of Cerro Gordo County; by Samuel Calvin.
Geology of Marshall County; by S. W. Beyer.
Geology of Polk County; by H. F. Bain.
Geology of Guthrie County; by H. F. Bain.
Geology of Madison County; by J. L. Tilton and H. F. Bain.

VOLUME VIII. ANNUAL REPORT, 1897.

427 Pages, 32 Plates, 6 Maps, 13 Figures.

CONTENTS:

Administrative Reports.
Mineral Production in Iowa in 1897; by S. W. Beyer.
Geology of Dallas County; by A. G. Leonard.
Geology of Delaware County; by Samuel Calvin.
Geology of Buchanan County; by Samuel Calvin.
Geology of Decatur County; by H. F. Bain.
Geology of Plymouth County; by H. F. Bain.
Properties and Tests of Iowa Building Stones; by H. F. Bain.

VOLUME IX. ANNUAL REPORT, 1898.

572 Pages, 13 Plates, 7 Maps, 56 Figures.

CONTENTS:

Administrative Reports.
Mineral Production in Iowa in 1898; by S. W. Beyer.
Geology of Carroll County; by H. F. Bain.
Geology of Humboldt County, by T. H. Macbride.
Geology of Story County; by S. W. Beyer.
Geology of Muscatine County; by J. A. Udden.
Geology of Scott County; by W. H. Norton.
Artesian Wells of the Belle Plaine Area; by H. R. Mosnat.

VOLUME X. ANNUAL REPORT, 1899.

666 Pages, 11 Plates, 11 Maps, 102 Figures.

CONTENTS:

Administrative Reports.
Statistics of Mineral Production in 1899; by S. W. Beyer.
Fossil Fauna of the Kinderhook Beds of Burlington; by Stuart Weller.
Geology of Lyon and Sioux Counties; by F. A. Wilder.
Geology of Osceola and Dickinson Counties; by T. H. Macbride.
Geology of Hardin County; by S. W. Beyer.
Geology of Worth County; by Ira A. Williams.
Geology of Dubuque County; by Samuel Calvin and H. F. Bain.

VOLUME XI. ANNUAL REPORT, 1900.

519 Pages, 12 Plates, 9 Maps, 43 Figures.

CONTENTS:

Administrative Reports.
Mineral Production of Iowa in 1900; by S. W. Beyer.
Geology of Louisa County; by J. A. Udden.
Geology of Marion County; by B. L. Miller.
Geology of Pottawattamie County; by J. A. Udden.
Geology of Cedar County; by W. H. Norton.
Geology of Page County; by Samuel Calvin.
Geology of Clay and O'Brien Counties; by T. H. Macbride.

VOLUME XII. ANNUAL REPORT, 1901.

511 Pages, 11 Plates, 6 Maps, 78 Figures.

CONTENTS:

Administrative Reports.
Mineral Production of Iowa in 1901; by S. W. Beyer.
Geology of Webster County; by Frank A. Wilder.
Geology of Henry County; by T. E. Savage.
Geology of Cherokee and Buena Vista Counties; by T. H. Macbride.
Geology of Jefferson County; by J. A. Udden.
Geology of Wapello County; by A. G. Leonard.

VOLUME XIII. ANNUAL REPORT, 1902.

446 Pages, 10 Plates, 11 Maps, 73 Figures.

CONTENTS:

Administrative Report.
Geology of Howard County; by Samuel Calvin.
Geology of Kossuth, Hancock and Winnebago Counties, by T. H. Macbride.
Geology of Mills and Fremont Counties; by J. A. Udden.
Geology of Tama County; by T. E. Savage.
Geology of Chickasaw County; by Samuel Calvin.
Geology of Mitchell County; by Samuel Calvin.
Report on the Lithographic Stone of Mitchell County; by A. Hoen.
Geology of Monroe County; by S. W. Beyer and L. E. Young.

VOLUME XIV. ANNUAL REPORT, 1903.

664 Pages, 38 Plates, 2 Maps, 132 Figures.

CONTENTS:

Administrative Reports.
Mineral Production of Iowa in 1902; by S. W. Beyer.
Technology of Clays; by S. W. Beyer and Ira Williams.
Chemistry of Clays; by J. B. Weems.
Selection, Installation and Care of Power Plants; by G. W. Bissell.
Geology of Clays; by S. W. Beyer and Ira Williams.
Tests of Clay Products; By A. Marston.
Mineral Production of Iowa in 1903; by S. W. Beyer.

VOLUME XV. ANNUAL REPORT, 1904.

560 Pages, 7 Plates, 10 Maps, 51 Figures.

CONTENTS:

VOLUME XVI. ANNUAL REPORT, 1905.

673 Pages, 8 Plates, 78 Figures, 14 Maps.

CONTENTS:

VOLUME XVII. ANNUAL REPORT, 1906.

622 Pages, 52 Plates, 44 Figures, 1 Map.

CONTENTS:

VOLUME XVIII. ANNUAL REPORT, 1907.

368 Pages, 16 Plates, 41 Figures.

CONTENTS:

Administrative Reports.
Statistics of Mineral Production for 1907; by S. W. Beyer.
Devonian Fishes of Iowa; by Charles R. Eastman.

VOLUME XIX. ANNUAL REPORT, 1908.

806 Pages, 22 Plates, 117 Figures.

CONTENTS:

Administrative Reports.
Statistics of Mineral Production for 1908; by S. W. Beyer.
Coal Deposits of Iowa; by Henry Hinds.
Fuel Values of Iowa Coals; by F. A. Wilder.
Analyses of Iowa Coals; by James H. Lees and A. W. Hixson.
History of Coal Mining in Iowa; by James H. Lees.
Coal Statistics; by S. W. Beyer.
General Section of the Des Moines Stage; by James H. Lees.
Carboniferous Section of Southwestern Iowa; by Geo. L. Smith.
Bibliography of Iowa Coals; by James H. Lees.
Peat and Peat Deposits in Iowa; by S. W. Beyer.
Bibliography of Iowa Peat; by James H. Lees.
Flora of Northern Iowa Peat Bogs; by L. H. Pammel.

VOLUME XX. ANNUAL REPORT, 1909.

542 Pages, 42 Plates, 10 Maps, 42 Figures.

CONTENTS:

Administrative Reports.
Geology of Butler County; by Melvin F. Arey.
Geology of Grundy County; by Melvin F. Arey.
Geology of Hamilton and Wright Counties; by Thomas H. Macbride.
Geology of Iowa County; by Stephen W. Stookey.
Geology of Wayne County; by Melvin F. Arey.
Geology of Poweshiek County; by Stephen W. Stookey.
Geology of Harrison and Monona Counties; by B. Shimek.
Geology of Davis County; by Melvin F. Arey.

VOLUME XXI. ANNUAL REPORTS, 1910 AND 1911.

XVI + 1214 Pages, 16 Plates, 2 Maps, 7 Text Figures.

CONTENTS:

Administrative Report.
Mineral Production in 1909 and 1910.
Underground Water Resources of Iowa, by W. H. Norton and others.
Introduction.
Chapter I, Topography and Climate.

Chapter II, Geology.
Chapter III, Geologic Occurrence of Underground Water.
Chapter IV, Artesian Phenomena.
Chapter V, Chemical Composition of Underground Waters.
Chapter VI, Municipal, Domestic and Industrial Water Supplies.
Chapter VII, Mineral Waters.
Chapters VIII-XV, Underground Water Supplies of the State by Districts.

VOLUME XXII.—ANNOTATED BIBLIOGRAPHY OF IOWA GEOLOGY AND MINING.

BY CHARLES KEYES.

CONTENTS:

BULLETIN NO. 1, 1901.

525 Pages, 3 Plates, 220 Figures.

Grasses of Iowa, Part I; by L. H. Pammel, J. B. Weems and F. Lamson-Scribner.

SUPPLEMENTARY BULLETIN, 1903.

436 Pages, 270 Figures, 1 Map.

Grasses of Iowa, Part II; by L. H. Pammel, Carleton R. Ball and F. Lamson-Scribner.

BULLETIN NO. 2, 1905.

40 Pages, 1 Map.

Preliminary Report on Peat Resources of Iowa; by T. E. Savage.
Report on Tests of Iowa Coals Made by Government Coal Testing Plant at Louisiana Purchase Exposition, St. Louis, Mo., 1904; by T. E. Savage.

BULLETIN NO. 3, 1906.

36 Pages, 1 Figure, 1 Map.

Supplementary Report on Portland Cement Materials in Iowa; by S. W. Beyer.

GEOLOGICAL MAP OF IOWA, SHOWING THE SUPERFICIAL DISTRIBUTION OF THE INDURATED ROCKS THROUGHOUT THE STATE.

Lithographed in Colors. Scale, 8 miles to one inch. Sent free on request. Two editions—on light paper and folded; on heavy paper and mounted on rollers.

In the systematic geologic surveying there results a gradual evolution of geological sections of the rocks of the state. The section which has been widely used in the recent publications of the Iowa Geological Survey is given below. A second section, which has been constructed and published by the author of this volume, is also given. It will be found that the position and equivalence of the various terranes or formations to which reference is made in the bibliography may be readily understood by referring to the one or other of these sections.

A number of cases occur in which references are placed under formational names which are not used in the geological section published by the Iowa Geological Survey. In most of these instances the terms are in use outside the state and it is thought that the grouping of papers under those terms may facilitate the use of the literature dealing with the strata in question, even though the terms themselves may not be employed therein.

General Geological Section of Iowa Rocks, as adopted by Iowa Geological Survey.

SYSTEM	SERIES	FORMATION NAME	COLUMNAR SECTION	THICKNESS IN FEET.	CHARACTER OF ROCKS
QUATERNARY	PLEISTOCENE	Wisconsin		0 - 30 +	BOWLDER CLAY, PALE YELLOW VERY CALCAREOUS.
		Peorian			SOIL BAND
		Iowan		0 - 30 +	BOWLDER CLAY, YELLOW, WITH VERY LARGE BOWLDERS.
		Sangamon			SOIL, PEAT AND FOREST BEDS.
		Illinoian		0 - 100 +	BOWLDER CLAY, YELLOW.
		Yarmouth			SOIL, PEAT AND FOREST BEDS.
		Kansan		0 - 400 +	BOWLDER CLAY, BLUE, JOINTED, WITH INTERCALATED STREAMS AND POCKETS OF SAND AND GRAVEL.
		Aftonian		0 - 40 +	PEAT AFORESAID BEDS, SOIL BANDS, AQUEOUS GRAVELS.
		Nebraskan		0 - 30 +	BOWLDER CLAYS, DARK, FRIABLE.
CRETACEOUS	UPPER CRETACEOUS	Colorado		150	SHALES WITH SOFT LIMESTONES, IN PLACES CHALKY.
		Dakota		100	SANDSTONES.
PERMIAN		Fort Dodge		20	RED SHALES AND SANDSTONES.
				20	GYPSUM.
CARBONIFEROUS	PENNSYLVANIAN	Missouri		600	SHALES AND LIMESTONES.
		Des Moines		750	SHALES AND SANDSTONES WITH SOME BEDS OF LIMESTONE.
	MISSISSIPPIAN	St. Louis		100	LIMESTONE, SANDSTONE & MARLY SHALES.
		Osage or Augusta		265	LARGELY CRINOIDAL LIMESTONE, WITH HEAVY BANDS OF CHERT, SOME SHALE.
		Kinderhook		120	SHALE, SANDSTONE AND LIMESTONE, LIMESTONE IN PLACES OOLITIC.
DEVONIAN	UPPER DEVONIAN	State Quarry Lime Creek Sweetland Creek		(40) (120) (20)	LIMESTONE, MOSTLY BRACHIOPOD COQUINA MOSTLY SHALES (LOCALLY DEVELOPED PEATBEDS, EACH LYING UNCONFORMABLY ON THE MIDDLE DEVONIAN.) SHALE
	MIDDLE DEVONIAN	Cedar Valley		100	LIMESTONES, SHALY LIMESTONES, SOME DOLOMITE IN THE NORTHERN COUNTIES.
		Wapsipinicon		60 - 75	LIMESTONES, SHALES, AND SHALY LIMESTONES.
SILURIAN	NIAGARAN	Gower		120	DOLOMITE, NOT VERY FOSSILIFEROUS, LE CLAIRE PHASE EXTENSIVELY CROSS-BEDDED.
		Hopkinton		220	DOLOMITE, VERY FOSSILIFEROUS IN PLACES.
ORDOVICIAN	CINCINNATIAN	Maquoketa		200	SHALE, SHALY LIMESTONES, AND, LOCALLY, BEDS OF DOLOMITE.
	MOHAWKIAN	Galena		340	DOLOMITE IN PLACES, IN PLACES UNALTERED LIMESTONES
		Platteville		90	MARLY SHALES AND LIMESTONES.
	CANADIAN	St. Peter		100	SANDSTONE.
		Prairie du Chien — Shakopee		80	DOLOMITE
		Prairie du Chien — New Richmond		20	SANDSTONE.
		Prairie du Chien — Oneota		150	DOLOMITE.
CAMBRIAN	POTSDAMIAN OR SARATOGAN	St. Croix — Jordan		100	COARSE SANDSTONE
		St. Croix — St. Lawrence		50	DOLOMITE MORE OR LESS ARENACEOUS.
		St. Croix — Dresbach		150	SANDSTONE, WITH BANDS OF GLAUCONITE.
ALGONKIAN	HURONIAN	Sioux Quartzite		25	QUARTZITE.

GENERAL GEOLOGICAL SECTION OF IOWA ROCKS.*

ERAS	PERIODS	SUB-P.	SERIES	TERRANES	THICKNESS	ROCKS
CENOZOIC	QUATERNARIC	LATE	*Recent*	Alluvium	25	Clays, sand
		MID	*Pleistocene*	Wisconsin	30	Till
				Peoria	1	Soils
				Iowa	30	Till
				Sangamon	1	Soil
				Illinois	100	Till
				Yarmouth	1	Soil
				Kansas	200	Till
				Afton	40	Sand
				Nebraska	30	Till
		EARLY			10	Clays (geest)
						Unconformity
	TERTIARIC	LATE	*Pliocene*	Interval		
		MID	*Miocene*	Riverside	50	Sands
		EARLY	*Eocene*	Interval		Unconformity
MESOZOIC	CRETACIC	MID	*Coloradan*	Niobrara	150	Limestones
				Hawarden	125	Shales
				Crill	100	Limestone
				Woodbury	150	Shales
			Dakotan	Ponca	25	Sandstones
				Sergeant	75	Shales
				Nishnabotna	200	Sandstones
				Dodge	75	Shales
		EARLY	*Comanchan*	Interval		Unconformity
PALEOZOIC	CARBONIC	MID	*Missourian*	Atchison	300	Shales
				Forbes	25	Limestones
				Platte	125	Shales
				Plattsmouth	30	Limestones
				Lawrence	100	Shales
				Stanton	20	Limestones
				Parkville	100	Shales
				Thayer	75	Shales
				Bethany	50	Limestones
			Des Moines	Marais des Cygnes	300	Shales
				Appanoose	100	Limestones
				Cherokee	250	Shales
			Arkansan	Interval		Unconformity
		EARLY	*Mississippian*	St. Louis	100	Limestones
				Spergen	10	Limestones
				Warsaw	65	Limestones
				Keokuk	75	Limestones
				Burlington	125	Limestones
				Chouteau	50	Limestones
				Hannibal	75	Shales
				Louisiana	10	Limestones
				Saverton	60	Shales
				Grassy	50	Shales
			Chattanoogan	Interval		Unconformity

*Proc. Iowa Academy of Science, Vol. XIX, pp. 148-149, Des Moines, 1912.

ERAS	PERIODS	SUB-P.	SERIES	TERRANES	THICKNESS	ROCKS
PALEOZOIC	DEVONIC		*Chemungan*	Lime Creek	125	Shales
		LATE	*Senecan*	Lucas	25	Limestones
				Coralville	30	Limestones
				Rapid	35	Limestones
				Solon	25	Limestones
				Interval		Unconformity
		MID	*Hamiltonian*	Fayette	75	Limestones
				Independence	20	Shales
				Otis	10	Limestones
				Coggan	15	Dolomites
	SILURIC	LATE	*Goweran*	Bertram	35	Dolomites
				Anamosa	60	Dolomites
				LeClaire	70	Dolomites
		MID	*Niagaran*	Monticello	60	Dolomites
				Hartwick	80	Dolomites
				Colesburg	30	Dolomites
				Sabula	50	Dolomites
	ORDOVICIC	LATE	*Maquoketan*	Brainard	125	Shales
				Atkinson	40	Limestones
				Clermont	15	Shales
				Elgin	75	Shales
		MID	*Mohawkian*	Galena	225	Dolomites
				Decorah	30	Shales
				Platteville		Limestones
		EARLY	*Minnesotan*	Glenwood	15	Shales
				St. Peter	100	Sandstones
	CAMBRIC	LATE	*Ozarkian*	Shakopee	75	Dolomites
				New Richmond	25	Sandstones
				Oneota	150	Dolomites
		MID	*Croixan*	Jordan	100	Sandstones
				St. Lawrence	50	Dolomites
				Dresbach	150	Sandstones
				Hinckley	600	Sandstones
		EARLY	*Georgian*	Interval		Unconformity
AZOIC	HURONIC	LATE	*Siouan*	Hull	475	Porphyries
				Tipton	425	Slates
				Sioux	200	Quartzites