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IOWA

GEOLOGICAL SURVEY

Annual report

VOLUME XXII

ANNOTATED BIBLIOGRAPHY

OF

IOWA GEOLOGY AND MINING

BY

CHARLES KEYES

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42-22

GEORGE F. KAY, STATE GEOLOGIST
JAMES H. LEES, ASSISTANT STATE GEOLOGIST

DES MOINES:
PUBLISHED FOR IOWA GEOLOGICAL SURVEY
1913

DES MOINES
ROBERT HENDERSON, STATE PRINTER
JOHN M. JAMIESON, STATE BINDER

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LETTER OF TRANSMITTAL.

IOWA GEOLOGICAL SURVEY.

To Governor George W. Clarke and Members of the Geological Board:

Gentlemen:

I have the honor to submit for publication an Annotated Bibliography of Iowa Geology and Mining by Dr. Charles Keyes.

This bibliography will serve the very useful purpose of making available and accessible to all students of geology the extensive and widely scattered literature of the geology of Iowa, a state which is one of the most important, geologically, in the entire Mississippi basin. The volume systematizes for a limited but typical area, data which have much more than a local bearing and which have also important general aspects.

In addition to the dictionary catalogue of the literature there are included most interesting historical chapters dealing with the development of knowledge of the geography and geology of Iowa from the early years of the seventeenth century to the present.

In the preparation of the Annotated Bibliography of Iowa Geology and Mining, the Survey has been particularly fortunate in having the services of Dr. Charles Keyes, who, for twenty-five years, has been a student of the stratigraphy not only of the Mississippi basin but of many other parts of America and also of the Old World. During the organization period of the Iowa Geological Survey he was for several years in active charge of the stratigraphic investigations in the state.

I take pleasure in recommending that the Annotated Bibliography of Iowa Geology and Mining be published as Volume XXII of the Iowa Geological Survey.

Yours very sincerely,

GEORGE F. KAY,

State Geologist.

PREFACE

During the last two decades much has been written on the geological features and the mineral wealth both of our own state and of the other states of the Upper Mississippi Valley.

The literature relating to the geology of Iowa is an extensive one. So voluminous and widely scattered is it that it is a matter of exceeding difficulty for any Iowa student to refer readily to more than a small part of that which has been published on any given subject. Some sort of synopsis of what is printed on the various localities and topics appears particularly needful at this time. This bibliography of Iowa geology is intended to meet this want.

In the preparation of the dictionary catalogue of the articles, memoirs and works bearing directly upon our State's material make-up and mineral resources the aim has been to include only those publications which are, in their character, strictly geological or which relate to the mining aspects of the subject.

As to exactly what titles should be included and what not has not always been an easy task to decide. In consequence, the criteria employed in making the selections of the subjects which should be properly included do not always, at first glance, appear to be the same in every case. A controling factor in all is the originality of the work reviewed. Many otherwise meritorious articles are omitted simply because they in no way contribute anything to our knowledge of the subject to which they relate. Thus a large number of titles, which ordinarily might be expected to be mentioned, are not found among the lists. Those pertaining wholly to methods of mining and to purely technological details are likewise omitted in this connection. They come properly elsewhere.

One of the most noticeable considerations connected with the bibliographical index is the fact that the literature is so widely scattered, and now so largely inaccessible to the people of the State. The last of the two earlier geological reports was issued nearly half a century ago. The copies were rather sparingly distributed, and during the period which has elapsed since their publication most of them have been lost, destroyed, or passed beyond the boundaries of the State. In the meantime the population has largely increased, so that even if the reports were all at hand the supply would be very inadequate.

A goodly number of references have appeared in the publications of learned societies and have had a limited distribution, a large share of which has been foreign. Many of the papers referring to the geological phenomena as presented in Iowa are found in the reports of other states; still others are scattered far and wide through various journals and serials, both in English and foreign languages; besides, there are many short articles, and more or less lengthy allusions included in the long list of publications printed by the Federal Government. A large majority of these descriptions are unknown to the people of the State, who, consequently, know not where to look for the information desired.

In the consideration of the literature of a subject the bibliographic matter may be arranged into four principal categories: (a) that which is strictly geological in its character; (b) that which is only incidental to geologic work; (c) that which is largely secondary in its nature, that is, forming important announcements of discoveries, or partaking of the character of criticism, notices, or reviews of work already done; and (d) that which is largely compiled from original sources with no additions of results of new investigations. References belonging to these four classes have received very different treatment, according to the importance of their bearing upon the subject.

Those of the first class comprise almost the entire list of references made. The more important titles of the second category have been included. The third and fourth classes have been omitted altogether.

In glancing over the titles herein enumerated, the majority of people probably will be impressed at once with the large number of references, and with the apparently extensive literature pertaining to the geology of Iowa. More careful perusal, however, will doubtless bring out the striking fact that many of the publications are purely scientific in character. The reason for this is not far to seek. For a long period of years scientific work in the state received little or no public aid or encouragement. Whatever work was carried on was done at private expense by scientific men who received no financial compensation for either the time or the money expended in prosecuting their researches. Thus, only the purely scientific results were placed before the world, while all the information of economic importance in the various lines of investigation was unable to be directed through those channels most likely to reach the people of the state. This information is, therefore, largely forgotten, or filed away in places now almost out of reach of the public. Nevertheless, the scientific work, done so generously by persons having no hope of financial reward or public aid, places the economic investigation of Iowa's natural resources upon a firmer basis than could possibly have been done otherwise without years of special labor.

The plan of the bibliography is essentially that of a dictionary catalogue, or bibliographical index. There are:

(1) An authors' list, in which is given the full title, volume, pages, and illustrations of the book or serial in which each article appeared, and place and date of publication. This is followed by a very brief synopsis of the contents of each article.

(2) A title index, in which the name of each article appears under each of its leading words. Then comes the name of the author and an abbreviated reference to its place of appearance.

(3) Subject entries and cross-references. These embrace under each topic, all references to any particular subject, as to each county, geological formation, zoological group, special subject, etc.; also those writings referring to the state in general. The names of authors, and abbreviated references to place and time of publication are given in all cases. Whenever additional information is wanted, reference can be made directly to the name of the author.

One of the principal advantages in the present scheme is that in no case is it necessary to turn back from title to title in order to obtain a full bibliographic reference. A worker upon any systematic group of animals, a particular geological formation, or a given area, finds all the articles upon the subject brought together.

The cross-references are arranged under the following principal headings, the classified list of the subjects being given below:

1. *General.*

Addresses; History; Biography; Bibliography; Education; Classification; Correlation; Mapping; Nomenclature; Surveys; Administrative Reports, etc.

2. *Regional.*

State in general; sections of the state; counties of the state.

3. *Economics.*

Ore-deposits; Origin; Lead; Zinc; Iron; Gold; Aluminum; Silver; Minerals.

Fuels; Coal; Lignite; Peat; Rock-oil; Natural gas.

Building materials; Granites; Quartzites; Limestones; Sandstones; Kaolins; Fire-clays; Shales; Brick-clays; Ballast-clays; Sands and Gravels; Cement rocks; Road material; Gypsum.

Soils.

Abrasive materials.

Minor minerals.

4. *Structural.*

Deformation; Sedimentation; Erosion; Rock-weathering; Glaciation; Eolation.

5. *Physiographic.*

Topography; Valleys; Rivers; Lakes; Plains; Altitudes; Climate; Rainfall.

6. *Stratigraphic.*

Geologic History; Geologic maps; Terranes; Geologic Formations.

7. *Paleontologic.*

Geographic Distribution; Geologic Distribution; Correlation; all larger zoologic groups; all larger botanic groups.

8. *Mineralogic.*

Minerals described.

9. *Underground Waters.*

Mine-waters; Artesian waters; Springs; Mineral waters; Phreatic waters; Well Waters.

10. *Petrologic.*

Rocks described; Rock-forming Minerals; Rocks, origin.

There are certain aspects in the history of the state that are not plainly brought out in a mere dictionary catalogue of the literature. A short chapter on the early geographic exploration of the region is one of these. A similar chapter treats of the character of the several geologic reconnaissances in the state.

The historical sketch of our mining in the state has a national bearing and presents many instructive phases. Its interest is not confined to the geological field alone. In the enumeration of results of geologic mining sundry advantages of systematically investigating the mineral resources of the state are pointed out. The comprehensive character of the work thus far conducted is indicated by the list of reports which have appeared in the first score of published volumes by the present Geological Survey.

Two general geologic sections of Iowa rocks are given. The first has been recognized in all recent publications of the Iowa Geological Survey. The second was constructed by the author of this volume and was recently published in Volume XIX of the Proceedings of the Iowa Academy of Science. The position and equivalence of all terranes or formations which are mentioned in the literature may be readily referred to the one or other of these sections.

CHAPTER I.

GEOGRAPHICAL EXPLORATION OF IOWA-LAND

In the country of which the present State of Iowa forms an integral part geographical exploration covers a period of about three centuries, reaching down to the very eve of Iowa's attainment of statehood. Forty years had not elapsed since the landing of Columbus on San Salvador before European adventurers had begun determinedly to turn their steps toward the interior of the North American continent. Singularly enough, expeditions from three widely different directions were almost simultaneously headed for the region now known as the Upper Mississippi basin.

The French, who under Cartier, had entered the St. Lawrence river, approached from the northeast. From the southeast the Spanish, led by De Soto, started from Florida and traversed the country to points in what are now Missouri and eastern Kansas. From the far southwest, Coronado, companion to Cortez, with a handful of conquestadores, having gone north from the City of Mexico to Sonora and the Grand Canyon of the Colorado in western Arizona, proceeded eastward to the Rio Grande. Seeking the fabulous City of Quivira, or the Gran Quivira, which was reputed to be 200 leagues northeast of Tiguex (near Albuquerque) he almost reached, before turning back in the summer of 1541, the southwestern corner of our State.

It was, however, a full century later before white-man's eyes actually rested upon Iowa-land. After his first entry into the region of the Upper Mississippi the struggles for its possession became inseparably linked with the fortunes and misfortunes of the three great European nations. For more than one hundred and fifty years prior to the beginning of the nineteenth century every tragic event of the Old World was reflected on these outskirts of civilization.

The first European to visit the Upper Mississippi valley appears to have been Jean Nicolet,[1] as was first shown recently by Shea.[2] In 1634,[3] at the request of Champlain, then governor of Canada, Nicolet left Quebec, passed up the St. Lawrence river, and finally discovering Lake Michigan, entered the Baye des Puans (Green bay) and ascended the Fox river to the portage-point between it and the Wisconsin river. It is important to note that this first established route of Nicolet to the Mississippi river continued for a period of more than 200 years to be a main path of exploration, travel and commerce to the West and to Upper Louisiana.

Before leaving Quebec Nicolet had heard of the existence of a powerful people in the Far West, who were without beards, shaved their heads, and otherwise appeared to resemble Taters, or Chinese. At any rate, our early explorer was fully prepared to meet the Chinese, as is indicated by his record. "At a distance of two days' journey from this tribe [Winnebagoes] he sent one of his savages to carry them the news of peace which was well received, especially when they heard that it was a European who brought the message. They dispatched several young men to go to meet the manitou, that is, the wonderful man; they come, they escort him, they carry all his baggage. He was clothed in a large garment of China damask, strewn with flowers and birds of various colors. As soon as he came in sight all the women and children fled, seeing a man carry thunder in both hands. They called thus the two pistols he was holding. The news of his coming spread immediately to the surrounding places; four or five hundred men assembled. Each of the chiefs gave him a banquet and at one of them at least one hundred and twenty beavers were served. Peace was concluded."[4]

According to Nicolet's own statement he would have reached the sea, or "Great Water," in three days longer sail, upon a great river. Such being the case historians have speculated on the actual reason of his turning back. It is now clear that he

[1]Relation de ce qui s'est passé en la Novvelle France, en l'anneé 1642 and 1643, Par. le R. P. Bartholemy Vimont, A Paris, MDCXLIV.

[2]Desc. and Explor. Mississippi Valley, p. 20, 1853.

[3]Sulte: Mélanges d'Hist. et de Litt., p. 426, Ottawa, 1876.

[4]Relation de que s'est passé en la Novvelle France, en l'anneé 1642 and 1643, Par le R. P. Bartholemy Vimont, A Paris, MDCXLIV.

misunderstood his early informants and mistook the meaning of the Algonquin words for great water to indicate the ocean[5] instead of a majestic river.

Nicolet had come fully prepared to enter Cathay in royal style. After dressing up in all his oriental finery, expecting to meet some gorgeous mandarin to whom he fancied his arrival had been announced, his disappointment must have been keen in the extreme when his shaven-headed hosts turned out to be only ordinary Sioux redskins instead of Asiatic potentates. At the misconception one hardly wonders. It reflects the prevailing notions of the day. With the aid of a little imagination and with no lack of willingness—one is always inclined to believe what one desires—it was easy to discern in the great water the sea that separates America from Asia, the North Pacific; and in the voyagers the Chinese, or Japanese. It was the opinion of Champlain, of the missionaries, and of the better informed colonists, that by pushing westward it would be comparatively easy to find a shorter road to China, by crossing America, than by that usually followed in rounding the Cape of Good Hope. Ever since the time of Jacques Cartier this idea had haunted the minds of men and they deceived themselves as to the real width of the American continent. They believed that it would be sufficient to penetrate two or three hundred leagues inland in order to find, if not the Pacific ocean, at least a bay or some great river leading there.[6] In this illusion lay the chief incentive to every western exploration of this time.

The first white men actually to view the "Great Water" and to set foot upon what is now Iowan soil appear to have been Pierre Radisson and Médard Groseilliers.[7] In the spring of 1655[8] these travelers, having spent the previous year around the shores of Lake Huron and having wintered with the Pottawattomies at the entrance to Green bay, determined to visit the Mascoutins, or Fire nation, and other tribes who dwelled to the southwest. Before the snow and ice were melted, he tells in concise language, how with one hundred and fifty of the In-

[5]Butterfield: Hist. Desc. of Northwest by John Nicolet, in 1634, p. 2, 1881.
[6]Jouan: Revue Manchoise, first quarter, 1886; Clarke's translation.
[7]Scull: Publications Prince Soc., No. 16, p. 147, Boston, 1885.
[8]Campbell: Parkman Club Pub., No. 11, Milwaukee, 1897.

dians these Frenchmen started westward on snow-shoes and traveled fully fifty leagues when they came to a great river near a point which appears to have been near the mouth of the Wisconsin river. Here they spent nearly a month making canoes and feasting. Radisson's narrative of this part of his travels is as follows:

"Att last we declared our mind first to those of the Sault, encouraging those of the north, that we are their brethren, & that we would come back and force their enemy to peace or that we would help against them. We made guifts one to another, and thwarted a land of allmost 50 leagues before the snow was melted. In the morning it was a pleasur to walke, for we could goe without racketts. The snow was hard enough, because it freezed every night. When the sun began to shine we payed for the time past. The snow sticks so to our racketts that I believe our shoes weighed 30 pounds, which was a paine, having a burden uppon our backs besides.

"We arrived, some 150 of us, men & women, to a river side, where we stayed 3 weeks making boats. Here we wanted not fish. During that time we made feasts att high rate. So we refreshed ourselves from our labours. In that time we tooke notice that the budds of trees began to spring, which made us to make more hast & be gone. We went up the river 8 days till we came to a nation called Pontonatenick & Matonenock, that is, the scrattchers. There we got some Indian Meale & corne from those 2 nations, which lasted us till we came to the first landing Isle. There we weare well received againe. We made guifts to the Elders to encourage the yong people to bring us down to the ffrench. But mightily mistaken; ffor they would reply, 'Should you bring us to be killed? The Iroquoits are every where about the river & undoubtedly will destroy us if we goe downe, & afterwards our wives & those that stayed behinde. Be wise, brethren, & offer not to goe downe this yeare to the ffrench. Lett us keepe our lives.' We made many private suits, but all in vaine. That vexed us most that we had given away most of our merchandises & swapped a great deale for Castors. Moreover they made no great harvest, being but newly there.

Besides, they weare no great huntsmen. Our journey was broaken till the next yeare, & must per force.''

The first ''landing isle'' is definitely identified with Prairie island above Lake Pepin.[9]

During the summer while his brother-in-law remained at Prairie island Radisson and a party of his Indian friends took a long hunting trip. Here are his own words:

''We weare 4 moneths in our voyage wthout doeing any thing but goe from river to river. We mett several sorts of people. We conversed with them, being long time in alliance w^th^ them. By the persuasion of som of them we went into ye great river that divides itselfe in 2, where the hurrons wth some Ottanake & the wild men that had warrs wth them had retired.[10]

There is not great difference in their language, as we weare told. This nation have warrs against those of the forked river. It is so called because it has 2 branches, the one towards the west, the other toward the south, w^ch^ we believe runns towards Mexico, by the tokens they gave us. Being among these people, they told us the prisoners they take tells them that they [the prisoners] have warrs against men that build great cabbans & have great beards & had such knives as we have had. Moreover they shewed a Decad of beads & guilded pearles that they have had from that people, w^ch^ made us believe they weare Europeans. They shewed one of that nation that was taken the yeare before. We understood him not; he was much more tawny then they w^th^ whome we weare.''[11]

There is no doubt that Radisson and his associate first reached the Mississippi river and gazed out upon the high bluffs of Iowaland at about where McGregor now stands. The travelers appear to have descended the river some distance and to have set foot on its west bank. They found the Indians in possession of mines of lead and zinc and the hills filled with alabaster (probably the translucent brittle stalactites with which the Dubuque district is now known to abound).

[9]Upham: Minnesota in Three Centuries, Vol. I, p. 141, 1908.

[10]Thwaites states that a large party of Hurons and Ottawas, while being driven before the storm of Iroquois wrath, had, a short time before Radisson's visit, settled on an island in the Mississippi river above Lake Pepin, but had finally proceeded up the Chippewa river to its source.

[11]Pub. Prince Soc., No. 16, p. 167, 1885.

It is, however, the west branch of the "Forked River", as Radisson calls the Mississippi, which has long puzzled historians. Thwaites[12] is of the opinion that it may have been the Iowa river. Richardson[13] in his sketch of "Muscoutin, a Remniscence of the Nation of Fire" considers it the Upper Iowa river. There appear to be good reasons for believing that this west fork was really the Missouri river.

Radisson's information on this point was manifestly hearsay. The notion derived by the French from the Indians before Radisson's visit was that there was a great river which flowed to the South sea. It was not until some years later that LaSalle proved that Marquette's great stream which was called the Riviére de la Conception and DeSoto's great river which he designated the Rio de la Espiritu Santo were only different parts of the same watercourse. On maps which appeared a decade or two later, la grande riviére is represented as forking about where the Missouri river enters; and the west branch ends abruptly somewhere in what is modern Texas, indicating that beyond that point its course was yet unknown. Franquelin's map of the Mississippi valley, published in 1864, shows this feature in a striking manner. On Hennepin's map of 1698 and others of that time the present Missouri river is continued westward and mingled with what is now called the Arkansas river.

The "Much more tawny" Indian prisoner from the Far West, which Radisson mentions, clearly indicates the Apache and the bearded men with which the latter carried on war correspond to the Spaniards of the Southwest. Radisson's surmises that they were Europeans was thus doubtless correct. His further description of the characteristics of the Apaches as he was told leaves little question that his informant had acquired his knowledge at first hands. The episode is significant in demonstrating the wide intercourse existing among the native races of the continent.

On the other hand, Upham[14] has recently tried to show that the "great river that divides itselfe in 2" and the "Forked river" are distinct streams, and to identify the first of these with the

[12]Coll. Wisconsin State Hist. Soc., Vol. XI, p. 70, 1888.
[13]John Brown Among the Quakers and Other Sketches, p. 68, 1897.
[14]Minnesota in Three Centuries, Vol. I, p. 155, 1908.

Illinois river, and the second with the Missouri river. From the internal evidence of the Frenchman's account it is not so evident, as the recent author states, "that Radisson and his companions went southeastward from Prairie island and hunted entirely on the east side of the Mississippi river, going by portages from one river to another until they reached the Illinois, 'the great river that divides itselfe in 2', so-called apparently because it is formed by the junction of the Des Plaines and Kankakee, each an important canoe-route." Upham appears to put considerable stress upon the statement of the Jesuit Relation of 1659-60, which relates that the Hurons and the Ottawas retreated thither and were kindly received by the Illinois tribes; and he intimates that during Radisson's hunting-trip might be learned all that the latter narrates of the "Forked river" and the people there and beyond.

At the time of Radisson's trip, and for a number of years after, Illinois tribes were occupying also the country west of the great river. Had the Frenchman gone southeastward from the Prairie island it would have taken him directly back to the country which he had just left; and it is not probable that this was his desire. His own statements seem to express curiosity to visit the country to the southwest of the Fox River district. His trip would naturally be directed to the southward, if not southwest, mainly in what is now Iowa and northern Missouri, where he would soon hear much of the anomalous watercourse.

So marvelous phenomenon as a "great river that divides itselfe in 2" would hardly apply to the coming together of two small creeks at the headwaters of such a stream as the Illinois river. As gleaned from other sources the report of the division of the great river must necessarily refer to its lower reaches and was a noteworthy fact known widely among the Indians. Under slight misconstruction on part of Europeans not thoroughly familiar with the native tongues, they could readily interpret the Indian words to indicate that far to the south the river actually separated into two distinct channels and thus flowed on to the ocean. Because of the fact that the main Indian route of travel to the Far Southwest was on the western branch of this river it was natural to suppose that the stream flowed in a southwest direction instead of eastward. It is a well known fact now that the Missouri river for a distance of 30 miles above its mouth actually flows to the northeast; thus apparently it is directed up-stream against the Mississippi river.

That the eastern Indians widely knew of this "Forked river" before Radisson's visit to the Mississippi valley is clearly indicated in his own account of his captivity some years previously among the Iroquois on the Mohawk river in what is now central New York state, when he incidentally mentions hearing of the great divided river from one of the tribe who had been in the far west.

A predecessor of Joliet and Marquette who, for a long time was thought[15] to have passed down the famous canoe-route of Indian travel, via Green bay, Fox river, and the Wisconsin river, to the "Great Water," is Father Renè Ménard, a Jesuit missionary who in 1660 came out from Quebec to Chequamegon bay, on the south shore of Lake Superior east of the present city of Duluth. Late investigations[16] appear to show that Ménard probably never actually reached the mouth of the Wisconsin river, but that he left the Lake Superior mission directly across country for the headwaters of this stream, down which he floated to the point of portage to the Black river, where he lost his life. This was in August, 1661. Ménard was on his way to visit the Huron nation then sojourning on the Black river. This nation recently driven from their eastern home by the Iroquois had, a short time before, reached Green bay, passed up the Fox river and down the Wisconsin river to the Mississippi, which they ascended to the Black river.[17] The aged Father was not with the Hurons at the time of their flight.

In 1669 Father Allouez who, for four years had had charge of the mission of the Holy Ghost at La Pointe, on Chequamegon bay, Lake Superior, returned to Sault Ste. Marie and Father Marquette took his place. Allouez longed to visit the Sioux country and see the great water which the Indians called the *Missi Sepe*. He says: "Ce sont peuples qui habitent au Couch-

[15]Winchell: Geol. Minnesota, Vol. I, p. 4, 1884; also, Neil: Minnesota Hist. Soc., Vol. II, p. 205, 1867.

[16]Campbell: Parkman Club Pub., No. 11, Milwaukee, 1897.

[17]Relations de Novvelle France, en l'anné 1663, p. 21, Quebec ed.

ant d'icy, vers la grande revière, nommé Messipi.'"[18] This appears to be the first mention in literature of the word "Mississippi."

Preceding Marquette by a full lenstrum in the Upper Mississippi basin was a Nicolas Perrot, one of the most capable and influental of all the French emissaries among the western Indians and one who rendered France great services in attaching them to her cause in the New World. Until recently little was known of this really remarkable *coureur de bois*. In 1864 his manuscript notes were found in Paris, covered with the accumulated dusts of more than two centuries, and published[19] by Father J. Tailhan, with copious explanations.

Perrot left the east sometime in 1665, and spent several months with the Pottawatomies around Green bay. In the spring of the following year he passed up the bay, entered Fox river, and visited the Outagamies, or Foxes, who dwelled above Lake Winnebago. Later he made a journey to the Mascoutins and Miamis who occupied the country around the headwaters of the Fox river and to the south. By Tailhan great importance is attached to this visit as it brought the French into friendly communication with the kindred of the Illinois, and gave them their first footing in the great valley of the Mississippi. Having obtained this footing, the further discovery and opening up of the country were only questions of time.[20]

Between the years 1665 and 1670 Perrot seems to have visited most of the western tribes, besides trading extensively with them. In the last mentioned year he made a trip to Montreal; but soon returned with St. Lusson's expedition to Sault Ste. Marie, he himself pushing on to Green bay. In May of 1671 he returned to the Sault in company with many Indian chiefs to complete the alliance with the French. From there Perrot returned to Quebec where he lived for ten years before again venturing back to the Mississippi River country.

Still another Jesuit missionary may have visited the Mississippi river before Marquette. Father Dablon who was sta-

[18]Relations de Novvelle France, en l'anné 1667, chap. xii, p. 23, Quebec ed.

[19]Memoire sur les Moeurs, Coustumes et Religion des Sauvages de l'Amerique Septentrionale, par Nicolas Perrot, Publié pour la primière fois par le R. P. J. Tailhan de la Compagne de Jésus, Leipzig et Paris, Librairie A. Franck, Albert L. Herold, 1864.

[20]Stickney: Parkman Club Pub., No. 1, p. 4, Milwaukee, 1895.

tioned in the Green Bay region for a time was a traveler of wide experience. He writes in 1670 of a great stream to the westward more than a league in width which flowed to the south more than 200 leagues. However, his information on this point may have been derived from hearsay.

At this time Father Marquette was in charge of the mission of the Holy Ghost, at La Pointe, on Lake Superior. He writes that "When the Illinois [tribes then living on the west side of the Mississippi river at the mouth of the Des Moines river] come to La Pointe they cross a great river which is a league in width, flows from north to south and to such a distance that the Illinois who do not know what a canoe is, have not yet heard any mention of its mouth." Thus Marquette also had definitely heard of the great stream which three years later he was destined actually to behold.

Marquette reached the Mississippi river in the summer of 1673. Soon after he had returned from his trip there was published a map of the new discoveries made by the Jesuit fathers in 1672. This map is especially noted by Parkman. On it is marked the route of travel of some missionary or traveler who had gone down the Wisconsin river to the Mississippi, down the latter to the mouth of the Des Moines and thence directly eastward to the Illinois river and the present site of Chicago. This route now appears to be intended for that of Marquette, the return path being incorrectly located.

Special interest attaches to the canoe-voyage in 1673 of Sieur Louis Joliet and Pere Jacques Marquette, who so long have been regarded as the discoverers of the Upper Mississippi river, and the first white-men to set foot on Iowa soil. On the 17th of June, these two travelers and several attendants entered the Mississippi river from the Wisconsin. Floating down the Great Water for several days they finally made a landing on the west bank. As shown by their maps the point was immediately above a large stream on which were located the Moingouena tribes, the present Des Moines river, and upon Iowa soil.

Along what is now the eastern boundary of our state Marquette graphically describes[21] the natural features, the animals,

[21]Jesuit Relations and Allied Documents, Vol. LIX, p. 109, Cleveland, 1900.

and the plants. As this is the first definite account of a circumscribed field of our land some of his paragraphs are reproduced from the translation. "Here we are, then, on this renowned River, all of whose peculiar features I have endeavored to note carefully. The Mississippi River takes its rise in various lakes in the country of the Northern Nations. It is narrow at the place where Miskous empties; its Current, which flows southward, is slow and gentle. To the right is a large Chain of very high Mountains, and to the left are beautiful lands; in various Places, the stream is Divided by Islands. On sounding, we found ten brasses of Water. Its width is very unequal; sometimes it is three-quarters of a league, and sometimes it narrows to three arpents. We gently followed its Course, which runs towards the south and southeast, as far as the 42nd degree of Latitude. Here we plainly saw that its aspect was completely changed. There are hardly any woods or mountains, The Islands are more beautiful, and are Covered with finer trees. We saw only deer and cattle, bustards, and Swans without wings, because they drop Their plumage in this Country. * * * When we reached the parallel of 41 degrees and 28 minutes, following The same direction, we found that Turkeys had taken the place of the game; and the pisikious, or wild cattle, That of the other animals.

"We call them 'wild cattle'. because they are very similar to our domestic cattle. They are not longer, but are nearly as large again, and more Corpulent. When our people killed one, three persons had much difficulty in moving it. The head is very large, The forhead is flat, and a foot and a half Wide between the Horns, which are exactly like Those of our oxen, but black and much larger. Under the Neck They have a Sort of large dewlap, which hangs down; and on The back is a rather high hump. The whole of the head, The Neck, and a portion of the Shoulders, are Covered with a thick Mane Like That of horses; It forms a crest a foot long, which makes them hideous, and, falling over their eyes, Prevents them from seeing what is before Them. The remainder of the Body is covered with a heavy coat of curly hair, almost Like That of our sheep, but much stronger and Thicker. It falls off in Summer, and The skin becomes as soft As Velvet. At that season, the savages Use the hides for making fine Robes, which they paint in various Colors. The flesh and the fat of the pisikious are Excellent, and constitute the best dish at feasts."

Referring to the landing on Iowa soil the venerable father continues: "Finally, on the 25th of June, we perceived on the water's edge some tracks of men, and a narrow and somewhat beaten path leading to a fine prairie. We stopped to Examine it; and, thinking that it was a road which Led to some village of savages, We resolved to go and reconnoiter it. We therefore left our two Canoes under the guard of our people, strictly charging Them not to allow themselves to be surprised, after which Monsieur Jollyet and I undertook this investigation—a rather hazardous one for two men who exposed themselves, alone, to the mercy of a barbarous and Unknown people. We silently followed the Narrow path, and, after walking About 2 leagues, We discovered a village on the bank of a river, and two others on a Hill distant about half a league from the first."

It is usually considered that the immediate mission of Joliet and Marquette's voyage was the discovery of the great river. The inference is mainly gained from perusal of the latter's journal. For a period of nearly two centuries Marquette's account of the journey was the only accessible information. Joliet's original notes and maps were lost through shipwreck when he had all but reached home. He prepared other descriptions and maps which he submitted to the Governor of Canada. It is no disparagement to the important services rendered by the brave Jesuit to state that it now transpires that Joliet was really the official commander of the expedition and that the priest accompanied him in a very secondary capacity.

There is sufficient honor accruing to Marquette and Joliet for laying the foundations of the French claims to the vast Louisiana country—the heart of the American continent. This was the practical result of their efforts, the consummation of whcih came in after years. That the real purpose of the expedition was entirely different from what Marquette's narrative would lead us to suppose is amply sustained by the contents of recently unearthed letters and documents of the time. Among these is a letter written by Frontenac, Governor of Canada, to Cobert, then Minister of State at Paris, on the return of Joliet to Quebec, clearly showing that the primary object of the exploration was the finding of the South sea and a feasible way by which to reach it. Exploration of the great river, it was fancied, would solve the puzzle.

In the spring of 1680, La Salle, who had established a post which he called Crève Cœur, on the Illinois river, near where Peoria now stands, sent one of his lieutenants, Accoult by name, to the upper Mississippi region. Accompanied by a father Hennepin and a single boatmen, Accoult floated down the Illinois river to its mouth and then ascended the greater river. He thus alludes to the Iowa part of the country: "The River Colbert (the Mississippi) * * * runs between two chains of mountains, very small here, which wind with the river, and in some places are quite far from the banks, so that between the mountains and the river there are large prairies where you often see herds of wild cattle browsing. In other places these eminences leave semi-circular spots covered with grass or wood. Beyond these mountains you discover vast plains, but the more one approaches the northern side ascending the earth did not appear to us so fertile nor the woods so beautiful as in the Illinois country."

The little company was soon captured by a war-party of Dakotah Indians, who carried them up Mille Lac. On reaching the falls of the Mississippi river the Recollet friar named them the Sault de St. Antoine de Padua. Although Hennepin's book of his travels had a wide circulation at the time of its appearance, there is really very little in it descriptive of Iowaland. After his release from the Indians Hennepin descended the great river to the mouth of the Wisconsin river, passed through Fox river and Green bay and returned to Montreal.

During the same year Du l' Hut (Duluth) who had been for several years in the government service in the Lake Superior region, passed over to the St. Croix river which he descended to the Mississippi. Here he heard of the captivity of three Europeans farther down the stream. He immediately sought them out and found Accoult's party, which he liberated and accompanied to the mouth of the Wisconsin river, and thence to the St. Lawrence. Little reference is made by this famous explorer to his trip along the Iowa border.

In 1681 Nicolas Perrot appears again to have entered the western fur-trading business. Two years later he was sent into the western country to get the support of the various Indian tribes with which he was acquainted, for an attack on the Iroquois. It appears proable that at this time[22] he established Fort St. Nicolas on the Mississippi river, a short distance above the mouth of the Wisconsin, and a little way below the present city of Prairie du Chien.

After reaching Green bay, as commandant, in 1685, Perrot passed on to the Mississippi, and up that stream, establishing the trading-post of Fort Antoine, on Lake Pepin. He immediately inaugurated extensive trading transactions with the Aiouez Indians, (Ioways), who then dwelt to the southwest. Four years later he formally took possession of the country for France. The same year he established another post nearly opposite the present city of Dubuque, and began the mining and smelting of lead-ore, in addition to his fur-trade. Perrot was active in this region until 1699, when he returned to the banks of the St. Lawrence, where he died about twenty years afterwards.

On Hennepin's map of the Mississippi region, which appeared in 1683, the great stream is designated as the Rivière de Colbert, after the French minister. So far as Iowa-land is concerned this map shows little. There are no streams represented as coming into the Mississippi from the west, and the great stream itself from the mouth of the Missouri southward is not represented. Along the Iowa part of the stream the course is perfectly straight. A range of mountains is represented on the west bank throughout the extent of the Iowa section.

Although Lahontan's "New Voyages to North America" which first appeared in 1788, passed through many editions, in several languages, some of his accounts of his geographic

[22]Stickney: Parkman Club Publications, No. 1, p. 12, Milwaukee, 1895.

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explorations in Canada have been lately believed to be entirely fictitious. Careful perusal of them seems to indicate that they have larger foundation in fact than these later assertions have claimed. There is little of strictly geographic value to Iowa, except that Lahontan appears to have been the first European to traverse the headwaters of the Des Moines river. This was in 1683. The celebrated Riviére Longe which is associated with Lahontan's name, and which is now generally regarded as applying to some stream of the fancy seems really to have some foundation for its usage. This traveler in the Upper Mississippi region took with him to France a sketch or map painted on a buffalo-skin by the Indians with whom he had come in contact. From these natives he evidently heard of the Columbia river running into the western ocean. The Upper Missouri river probably was a part of his Long river. In the light of more recent information bearing upon that time Lahontan's descriptions deserve careful examination anew before they are wholly condemned.

On the best and most accurate map published up to the year 1688, "Partie d'une Carte de l'Amerique Septentrionale, dressée par J. B. Franquelin, dan 1688, pour étre presentèe a Louis XIV", Iowa-land is still but meagerly represented. Rivière des Moingona is a term applied to the main stream; and its then unnamed main branch now called the Raccoon river is located. At the junction-point of the two streams is located the chief village of the Moingona Indians.

In 1695 Perrot began to have active competition in his fur-trading business and in mining in the vicinity of present Dubuque. Among others, a trader by the name of Le Gueur established a post on an island in the Mississippi river directly opposite the site of Dubuque's town.

The chief importance attached to the movements of Pierre Le Sueur in the Upper Mississippi valley lies in the fact of his establishing a new trade-route to the sea. He already had been in the region for nearly a score of years before his most famous exploit took place. In the interests of trade he appears first to have visited the country in 1683 in company with Per-

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rot.[23] Later, after he had been made commandant at Chequamegon bay, he located a trading-post, in 1695, on an island in the Mississippi river, above Lake Pepin, which prospered for a time. During his sojourn in the region he no doubt became widely acquainted with its great commercial possibilities.

Le Sueur went to France and obtained a commission from the King to open certain mines. In casting his fortunes with D'Iberville's expedition to settle the lower Mississippi region, it is suspected that his real purpose was to turn the new commercial acquirements at the headwaters of the great stream southward to the Gulf instead of permitting them to continue eastward to the St. Lawrence, as had been the custom for many years.

Early in April, 1700, Le Sueur, with twenty-five men, set out from Biloxi, to ascend the Mississippi river. When they reached the rapids above the mouth of the Moingona (Des Moines) river they were compelled to unload their boats and to drag them for a distance of seven leagues. Thus these famous rapids were very early recognized as serious obstacles to navigation. Le Sueur observed that on the west side of the rapids open prairies existed for a distance of at least ten leagues, and that the grass was like clover, supporting large numbers of animals. Some distance farther up-stream in the vicinity of the present city of Dubuque, the mines of Nicolas Perrot were encountered.[24] On the east side of the river the Galena river was designated as the Rivière a la Mine. Thus Le Sueur noted carefully the features along the entire eastern boundary of the present state of Iowa.

Le Sueur spent the winter on the Minnesota and Blue Earth rivers among the Ioway Indians. He is reported to have extracted a large quantity of copper-ore and to have sent 4,000 pounds of it down the river to the Gulf settlements. Geologists who have recently visited the locality of Le Sueur's alleged copper mine near the former site of his Fort l'Huilliers pronounce the green earth wholly unmetalliferous.[25] Historians

[23]Shea: Early Voyages Up and Down the Mississippi, p. 89, Albany, 1861.

[24]Mem. et doc. pour servir la l'histoire des origines Francaise des pays d'outremere, t. V, p. 412.

[25]Winchell: Geol. Surv. Minnesota, Vol. I, p. 18, Minneapolis, 1884.

have long speculated upon the fact that nothing more was ever heard of the ores the discovery of which was given so great an amount of distinction. The true explanation seems to be suggested in an official letter of the day recently unearthed in Paris, from the Intendant Champigny to the French minister[26] in which the former complains that "I think that the only mines that he (LeSueur) seeks in those regions are mines of beaver-skins."

The astuteness of this remark is all the more apparent when it is remembered that during the year previous Louis XIV. had ordered all the western trading-posts to be abandoned, and the traders and soldiers to return to Lower Canada in anticipation of war with England. While in France Le Sueur no doubt had early heard of the intended changes, and setting his wits together had looked ahead a little by securing a commission for mining, knowing full well that once in the abandoned territory he could secure furs just as well as before. Exported to France from Gulf of Mexico no question would be asked concerning the violation of the King's orders.

At this time the fur-trade was under the complete control of La Compagnie des Cent Associés of Montreal, and all pelts were sent eastward to this market. Le Sueur's fifteen years previous experience in the upper Mississippi region had doubtless convinced him that he could not conduct the business of buying and selling furs independently of this clique. The fact that along with his alleged cargo of green copper-earth, over which he made so much ado, he sent south several hundreds of fine beaver robes, besides many other rare and valuable pelts suggests that his "disappointment" in mining was amply appeased in other directions. Whether fur-trading and not mining was the real incentive for his expedition is not a matter of record; but Champigny's surmises, in the light of later information on the subject, seem quite plausible.

When Louis XIV. recalled to Lower Canada all French soldiers and voyageurs from the Upper Mississippi country in preparation for war with Anne of England there were four main lines of travel to the west. They were the Lake Superior

[26]MS. in Ministre des Colonies, t. XV, ch. xi, fol. 39, Paris.

route, the Wisconsin River route, the Illinois River route, and the Wabash River route. It was Le Sueur's particular mission to open up a new trade-way to the south.

With the settlements on the Mississippi river below the mouth of the Missouri as a center (Kaskaskia was established in 1695) exploration of western rivers went on rapidly. In the interests of trade Frenchmen ascended all the principal streams—the Arkansas, Red, Missouri, Des Moines, Iowa and Mississippi rivers. As early as 1703 a party of French attempted to reach the Spanish settlements on the Rio Grande in New Mexico by way of the Missouri river. Bienville, governor of Louisiana, states that there were in 1704 more than one hundred Frenchmen located on the Mississippi and Missouri rivers alone. In the following year one Laurain, with a number of companions, started up the Missouri river; and a year or two later a Nicholas de la Salle also ascended that stream with a large party. Beaurain thinks that the evidences of extensive early mining in the Osage country were the work of this party. About this time (1708) the French appear to have gone up the Missouri river as far as the mouth of the Platte, where the hostile attitude of the fierce Pamis (Pawnees) prevented further progress in that direction and at that time. After Iowa-land was first sighted by European on its east side it took a full half-century to reach by water the western border.

From this time onward for a full century, down to the very date of the purchase of Louisiana by the United States our principal river and the largest watercourse which Iowa can call all her own was the most important of all trade-routes between the Lower Mississippi markets and the northwest fur-country. On account of the presence of numerous marshes and lakes around the headwaters of the Des Moines, ladened canoes and even larger craft were able, in the spring of the year especially, to pass without portage from Hudson bay and Lake Winnipeg up the Red river of the North, thence by the Blue Earth and other streams into the Des Moines basin. Owing to the fact of a general lack of exact knowledge concerning the northwest country European map-makers were inclined to ascribe to Des Moines river an undue importance. Some of the maps of that day, as the Senex map of 1710, confound the Upper Missouri river with the upper reaches of the Des Moines. On the De l'Isle "Carte du Canada," published in Paris in 1703, the Des Moines river is displayed as the longest stream on the North American continent. The Mississippi drainage system is represented as a huge trident reaching up from the Gulf of Mexico. There are few or no tributaries shown. The Des Moines river forms the great central prong, much larger and longer than either of the other two—the Mississippi or Missouri rivers. The Des Moines river is the great middle river.

The importance of the Des Moines river as an early path of commerce is indicated in the history of the name. Marquette's name Moingouena refers only to the Indian tribes which he found dwelling near the mouth of the stream in 1673. On Joliet's map the river is caller the Ouacinatanas. This map was made in Montreal immediately upon his return from the explorations with Marquette in 1674. On another of his maps it is designated as Moengouena. It is probably the first map of the region which was based upon definite knowledge. From this period to the present time various names have been used and various spellings have been followed of the title which has survived. Some of the various spellings to be especially noted are De Moin, Des Moins, Demoin, Demoir, Demon and De Moyen.

The name Des Moines is the oldest European title known to our state. As applied to Iowa's leading natural feature, the one mainly instrumental in determining her boundaries as a state, the term has an unusual and complex origin, and an evolutionary history covering a period of more than two centuries. In the changes which the name has undergone is reflected the political vicissitudes of four great nations. Successively has French, Spanish, English and American influence dominated. In final form it is a beautiful, simple and euphonious name, apparently perfect French, and usually glibly translated into "of the monks." Its derivation from anything relating to the early missionaries is always puzzling. However, its monastical association appears never to have been nearer than the fertile imagination of a Philadelphia printer's clerk.

The first use of the Algonquin word Mikouang, corrupted to Moingouena, for the river appears to be different from the supposed still further corruption of a later date. After Joliet and Marquette's time the name was long used, and appeared on most maps of the region during a period of more than a hundred years. The name is still preserved in the hamlet of Moingona on the right bank of the Des Moines river in Boone county. Coues, following Nicollet, sums up the opinions of the supposed origin of the term from this source by saying that "The Indians called their place Moingona, Moingonan, or Mouingouinas—a word found in some form on very old maps. Later, the French clipped the word to Moin, calling the people Les Moins, and the river La Rivière des Moines, by spurious etymology. Traces of this history of the name survive in its various spellings."

Nicollet, a French engineer, who mapped the Upper Mississippi valley for the Federal government in 1835 and the following years and who was particularly inquisitive concerning the origin of geographic names states[27] that "The name which they gave their settlements was Monin-gouinas (or Moingona, as laid down in the ancient maps of the country), and is a corruption of the Algonquin word Mikouaug, signifying at the road. The Indians, by their customary elliptical manner of designating localities, alluded, in this instance, to the well-known road in this section of the country, which they used to follow as a communication between the head of the lower rapids and their settlement on the river that empties itself into the Mississippi, to avoid the rapids. This is still the practice of the present inhabitants of the country."

As a rule the English maps of the Upper Mississippi region, and the French maps based upon data obtained through Canadian sources previous to the relinquishment by France of all her American possessions to England and Spain in 1763, adhere to the name Moingona for the Des Moines river. The De l'Isle "Carte du Canada ou de la Nouvelle France," published

[27]Twenty-sixth Cong., 2nd Sess., Sen. Doc. 237, p. 20, 1843.

in 1707, and which was the work of two of the most distinguished cartographers of the time, the De l'Isle "Carte de la Louisiane et Cours du Mississippi," printed in Amsterdam in 1722, and the Senex "Map of North America," dated 1710, all have R. de Moingona. Towards the close of the Eighteenth century some of the cartographic sketches of the region, as the Winterbotham map of 1795, for example, which is practically a summary of the knowledge of the country previous to the explorations of Lewis and Clarke under the auspices of the United States government, have the name reduced to merely Moin.

After the year 1763, when Canada passed into control of England, and the French fur-trade was diverted mainly and permanently to the Lower Mississippi region, and when traders of other nationalities began to get a foot-hold upon the northwest business the new commercial adjustments brought about changes in geographical nomenclature. The Moingona tribes no longer dwelled at the mouth of the stream which bears their name, and the word no longer had to the traders a definite meaning. A new word of similar pronunciation but of different spelling and meaning appears to have taken its place—a word which meant much to all French voyageurs of the day. This title applied to a waterway designated it as the Middle River.

As already noted the Des Moines river was for a period of more than a century and a half the only uninterrupted path of canoe-travel between St. Louis and the Hudson bay and Saskatchewan fur-country. In the sense of a great middle trade-route the name has special significance. This distinction it enjoyed until the advent of the railroad. Even in the early days of Iowa's statehood the Des Moines river was considered a quite pretentious water-way. During spring floods steamboats from the Mississippi river service regularly came up so far as the Raccoon forks. Smaller steamboats plied between that point and the Lizard fork (Fort Dodge). In order to make the stream more suitable for boat-travel at all times an elaborate system of slack-water navigation was proposed, and begun with governmental aid. Careful surveys were made and sites for dams located at regular intervals. Several of these contructions were commenced, but only one was actually completed before the iron-horse appeared in the region and the whole undertaking was given up.

When Major Pike took his famous trip up the Mississippi river in 1805, he found De Moyen a name in general use, and he referred thus to it all through his narrative without comment. The editor of his Travels adding a vocabulary to the book translates the word as River of the Means. Since that day historians have been puzzled at the meaning. Without reference to the real trade conditions of the time it is quite meaningless.

The trade use of the title River de Moyen during the quarter of a century immediately preceding and following 1800 has a significance which appears to have generally escaped notice. We get a hint from Featherstonhaugh in regard to another and more familiar geographic title, the origin of which is even more abstruse than the term under consideration. In his "Excursion through the Slave States," in 1834-5, he states, concerning the name Ozark, now generally applied to the elevated and mountainous country lying in Missouri and Arkansas between the Missouri and Red rivers and the Mississippi and Neosho rivers, that "It was the custom of the French Canadians to abbreviate all their names. If they were going to the Arkansas mountains they would say they were going Aux Arcs, and thus these highlands have obtained the name of Ozarks from American travelers."

From what is known of the literature and custom of the same time it appears probable that our name Des Moines had an origin very much the same as Ozark and a number of other words. The phrase De Moyen with its pronounciation almost indistinguishable from that of the word as we now know it, means literally "from, or of, the middle"—country or river being understood. So the French voyageurs, on arriving from up-stream at the great trading-post of St. Louis, when speaking of that part of the region from whence they came, naturally replied in the usual abbreviated form "De Moyen." The great Middle country between the Mississippi and Missouri rivers and occupied by the great Middle river actually possessed a very appropriate title. The name De Moyen thus appears to have been attached to a definite geographic feature in the same way as was the title Ozark.

The special fitness of the title Rivière de Moyen, as signifying Middle river is shown on many maps. One in particular, made in 1720, by the Capuchin Père Le Grand, of Chalon, in the department of Saone, France, is a globe seven feet in diameter and now deposited in Dijon. A copy of the part referring to Iowa-land was some years ago made for Father Laurent, of Muscatine, by the public librarian of Dijon, and presented to the Iowa Historical Department.

Although in pronunciation almost identical with the earlier used terms De Moin and De Moyens the name Des Moines as signifying River of the Monks requires small consideration. This spelling and use appears not to have been adopted before the American occupation of the Louisiana country in 1803. Small wonder is it that the new-comers did not always at first grasp properly the strange names. Pike's editor seems to have been the first to introduce the name in this sense; and so places it on the map accompanying the Travels. During territorial days early settlers of Iowa were accustomed to account for the meaning by allusion to the trappist monks (Moines de la Trappe) living among the Indians of the American bottoms. Beltrami, an Italian traveler, who ascended the Mississippi river by steamboat in 1823, translates the name and calls the stream the Monk river, thus reflecting the association.

Thus from three words of very different meanings and quite distinct spellings, but of almost identical pronounciations Des Moins (corrupted from Moingona), De Moyen, and Des Moines (monks), the name of our chief river and capital city has been evolved.

Two other names of Iowa's chief river deserve mention in this place. One is Keosauqua, or Keoskawqua as it is lettered on "Galland's Map of Iowa" published in 1840. The principal town on the river at one time was Keosauqua, in Van Buren county.

Still another title for the stream is its earliest known Sioux name, Inyanshashawatpa, meaning Redstone river. The appropriateness of this term might not be readily inferred except by those quite familiar with all the features of the Des Moines valley. In Marion county, in the central part of the state, the river flows through a deep gorge of red sandstone. The bright, towering vermillion cliffs attract wide attention. In the days when the stream was the great highway to the northwest these mural shores were the wonder of all. Many a traveler has gone into ecstacies over their majestic splendor, and has speculated wildly upon their origin. Today the little, almost deserted, hamlet of Red Rock lies nestled under one of the most brilliantly colored of the canyon walls. The place was once an important landing for boats. A railroad now winds through the valley for many miles; but at the great red rock it makes a wide detour inland through deep ravines, and passes around this most interesting spot. The tourist just misses the most gorgeously picturesque bit of scenery to be found anywhere in all the Mississippi region.

When, in 1713, Louis XIV issued to a Paris merchant, M. Crozat by name, a patent which granted a monopoly of trade in all the Mississippi valley for a period of fifteen years, the direct results were in a commercial sense, negative. After a few years all rights were turned over to other interests. The greed for gold greatly stimulated exploration. The map of the Mississippi valley published by John Law, the famous Paris financier, in 1721, amply attests the wonderful progress in the geographic knowledge of the region during the previous two decades. At this time boats were continually passing on every river in Iowa-land.

For the next hundred years few important additions were made to the geography of the area now occupied by our state. When with the Peace of Paris, France in 1763, relinquished her control over all her vast colonial possessions in the New World, Canada and all territory east of the Mississippi river passed under British dominion, and all west of the great stream was ceded to Spain, two notable changes at once effected the development of the commercial interests of this region. The lucrative fur-trade of the Northwest which for so many years afterwards remained in the hands of the French, was entirely diverted from its long established eastern route to the St. Lawrence settlements to a course southward, down the Mississippi river. English adventurers from the colonies on the Atlantic sea-board pushed westward for the first time in numbers to and even beyond the confines of the newly acquired lands.

Prominent among these Englishmen, and first to leave a permanent record of his travels, is a Captain John Carver. With Iowa-land Carver's explorations have little to do. He passed up the Mississippi river from the mouth of the Wisconsin. Carver was the first person to bring prominently before the notice of the English-speaking races the vast resources of the Upper Mississippi valley. His story was one of the most widely read books of the day, as is attested by the fact that it passed through no less than twenty-three editions and was translated into the Dutch, French, and German languages.

The first actual settlement to be made on Iowa-land may be set down as Dubuque's mines, or simply Dubuque, as it was afterwards designated. Julian Dubuque began to build his own residence and other houses for his men and the lead smelter in 1788, at the mouth of Catfish creek at the south edge of the present city bearing his name. Here he continued to reside until his death in 1810. However, mining had been conducted more or less continuously for more than a century and a half prior to Dubuque's coming; and in the neighborhood there had been established a trading-post for over one hundred years.

With the purchase of the Louisiana country west of the Mississippi river from France there was at once inaugurated by the Federal government a series of exploratory expeditions. Of these the first and most important in its results was the Lewis and Clark expedition to the Columbia river.[28] These sturdy explorers, with 43 men, started from St. Louis on the 14th of May, 1804, and ascended the Missouri river to its source. The months of July and August were spent mainly on the western boundaries of present Iowa. In their journal is given the first full account of the features and products of this region ever published. They held many conferences with the Indians. Immediately below the mouth of the Big Sioux river one of the mem-

[28]Hist. of Exped. Lewis and Clarke to Sources Missouri River, etc., during years 1804-6, 2 Vols., Philadelphia, 1814.

bers of the expedition, Sergeant Floyd, died; and the place of his burial in Woodbury county, is known to this day as Floyd's bluff.

Speaking of the Big Sioux river, which now forms the northwest boundary of our state, it is stated, "Here began a range of bluffs which continue till near the mouth of the Great Sioux river, three miles beyond Floyd's. This river comes in from the north, and is about 110 yards wide. Mr. Durion, our Sioux interpreter, who is well acquainted with it, says that it is navigable upwards of 200 miles to the falls, and even beyond them; that its sources are near those of the St. Peter's. He also says that below the falls a creek falls in from the eastward, after passing through cliffs of red rock. Of this the Indians make their pipes, and the necessity of procuring that article has introduced a sort of law of nations, by which the banks of the creek are sacred; even tribes at war meet without hostility at these quarries, which possess a right of asylum."

In the following year Major Z. M. Pike made his famous expedition to the headwaters of the Mississippi river.[29] With twenty soldiers, in a keel-boat 70 feet long, he left St. Louis on August 9, 1805. In his journal he gives good descriptions of some of the physical features and of the entire eastern border of our state. The accounts of the Des Moines rapids, near Keokuk, and of the Mines of Spain at Dubuque are especially noteworthy. The rapids are described as follows: "20th August; Tuesday—Arrived at the foot of the rapids De Moyen at 7 o'clock; and, although no soul on board had passed them, we commenced ascending them immediately. Our boat being large and moderately loaded, we found great difficulty. The river all the way through is from 3-4 to a mile wide. The rapids are 11 miles long, with successive ridges and shoals extending from shore to shore. The first has the greatest fall and is the most difficult to ascend. The channel (the bad one) is on the east side in passing the first bars, then passes under the edge of the third; crosses to the west, and ascends on that side, all the way to the Sac village. The shoals continue the whole dis-

[29]Account of Expedition to Sources of Mississippi, etc., during 1805-7, 277 pp., Philadelphia, 1810.

tance. * * * The land on both sides of the rapids is hilly, but a rich soil.''

During the next decade the Federal government established forts at a number of points on the Mississippi river. Among those of greatest interest to Iowans are Ft. Crawford, on the present site of Prairie du Chien, Ft. Armstrong on Rock Island, Ft. Madison near the present city of that name, and Ft. Edwards at Warsaw, opposite Keokuk.

In 1817 the war department detailed Major Long to inspect these and other forts on the river and to determine sites for other forts. Long's notes are repeatedly referred to by Keating,[30] but they remained unpublished for nearly half a century, when Edward Neil secured them from Dr. James, the naturalist who accompanied Long on some of his expeditions. Neil published the account under the title of ''Voyage in a Six-Oared Skiff to Falls of St. Anthony.'' Later it was republished.[31]

When Gen. Louis Cass, governor of Michigan territory, returned from an expedition to the headwaters of the Mississippi river in 1820, he with his party went by boat down to the mouth of the Wisconsin river. At this point he left the mineralogist and narrator of the trip, Henry Schoolcraft. The latter spent some weeks in the lead region investigating the mines. This is the first scientific account of these ore-deposits.[32]

An expedition to the Rocky mountains was made by Major Long by way of the Missouri river from St. Louis in 1819.[33] The country on both sides of the river is described in some detail. At a point ten or a dozen miles north of the present site of Omaha, on the west side, near high banks called Council Bluffs (not Council Bluffs, Iowa) the party went into winter quarters, Long himself returning to St. Louis, where he remained until the following spring. Then going overland by the straightest lines possible he traversed the southwestern corner of our state to a point opposite the mouth of the Platte river. After leaving the valley of Grand river near the present Iowa border he

[30]Narrative of Expedition to Source of St. Peter River, etc., under Maj. Stephen H. Long, 2 volumes, Philadelphia, 1824.

[31]Coll. Hist. Soc. Minnesota, Vol. II, pp. 7-83, 1889.

[32]Narrative Journal of Travels through Northwest Region of United States to Sources of Mississippi River, etc., in 1820, Albany, 1821.

[33]Account of Expedition from Pittsburg to Rocky Mountains, performed in years 1819-20 (compiled by Edward James), 2 volumes, and atlas, Philadelphia, 1823.

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emerged upon the prairie which he thus describes: "Upon leaving the forest there was an ascent of several miles to the level of a great woodless plain. These vast plains, in which the eye finds no object to rest upon, are first seen with surprise and pleasure, but their great uniformity at length becomes tiresome. The grass was now about a foot high, and as the wind swept over the great plain, it appeared as though we were riding on the unquiet billows of the ocean. The surface is uniformly of that description not inaptly called rolling, and bears a comparison to the waves of an agitated sea. The distant shores and promontories of woodland, with here and there an insular grove, rendered the illusion more complete. Nothing is more difficult than to estimate by the eye the distance of an object seen on these plains."

Long's second expedition[34] to the upper Mississippi region in 1823, reached the great stream at Ft. Armstrong (Rock Island), and proceeded rapidly up that river to the Minnesota river. The account was written by Prof. W. H. Keating, of Pennsylvania University. So far as they relate to Iowa the geographic results are rather barren; although the writer makes some interesting geologic observations.

During the same year an Italian judge in exile, by the name of Beltrami, visited the northern region, passing up the Mississippi river in a steamboat "The Virginia." His notes on the features of the Iowa bank are rather full and of considerable interest.[35]

By an exploratory trip made in 1835 by G. W. Featherstonhaugh,[36] in the course of which that traveler passed along the eastern border of Iowa, little new information is added concerning the geographical features of the territory.

The summers of 1835 and 1836 were spent by George Catlin, the famous painter of Indian portraits, in the northwest. Part of this time was passed on Iowa soil. His description of his trip up the Des Moines valley is not without interest. One section in particular is prophetic. "The whole country that we

[34]Narrative of Expedition to Sources of St. Peters River, etc., made by Maj. Stephen H. Long, 2 volumes, Philadelphia, 1824.
[35]Pilgrimage in Europe and America, leading to Discoveries of Sources of Mississippi River, etc., 2 volumes, 1828 (London ed.).
[36]Rept. Geol. Reconnaissance, to Coteau des Prairie, 159 pp., Washington, 1836.

passed over was like a garden, wanting only cultivation, being mostly prairie. Keokuk's village is beautifully located on a large prairie on the bank of the Des Moines river. Dubuque is a small town of about two hundred inhabitants, all built within two years. It is located in the midst of the richest country on the continent. The soil is very productive, and beneath the surface are the great lead mines, the most valuable in the country. I left Rock Island about eleven o'clock, and at half past three I ran my canoe on the pebbly beach of Mas-co-tine Island. This beautiful island is so-called from a band of Indians of that name, who once dwelt upon it, is twenty-five or thirty miles in length, without a habitation on it, or in sight, and throughout its whole extent is one great lonely prairie. It has high banks fronting the river, and extending back as far as I could see, covered with a high and luxuriant growth of grass. The river at this place is nearly a mile wide. I spent two days strolling over the island, shooting prairie-hens and wild fowl for my meals. I found hundreds of graves of the red-men on the island. Sleep on in peace, ye brave fellows, until the white man comes and with sacriligious plowshare turns up your bones from their quiet and beautiful resting place! I returned to Camp Des Moines, musing over the loveliness and solitude of this beautiful prairie land of the West. Who can contemplate without amazement this mighty river eternally rolling its surging, boiling waters ever onward through the great prairie land for more than four thousand miles! I have contemplated the never ending transit of steamers plowing along its mighty current in the future, carrying the commerce of a mighty civilization which shall spring up like magic along its banks and tributaries.

"The steady march of our growing population to this vast garden spot will surely come in surging columns and spread farms, houses, orchards, towns and cities over all these remote wild prairies. Half a century hence the sun is sure to shine upon these countless villages, silvered spires and domes, denoting the march of intellect, and wealth's refinements, in this beautiful and far off solitude of the West, and we may perhaps hear the tinkling of the bells from our graves."

The various reports of the U. S. Army officers who have repeatedly traversed the Iowa territory during the third decade of the last century tend little to extend geographical knowledge. A notable exception is the account of Lieut. Albert Lea.[37] The natural resources are well set forth.

The years 1836 to 1843 were spent by J. N. Nicollet in mapping the Upper Mississippi valley[38] for the Federal government. Nicollet was a French engineer of high scientific and professional attainments. The map is most remarkable in its accuracy and detail. A high authority, Gen. G. K. Warren, expresses the opinion that it is "one of the greatest contributions ever made to American geography."

The subsequent contributions to Iowa geographical knowledge belong properly to the geological surveys.

[37]Notes on Wisconsin Territory, particularly with reference to the Iowa district, or Black Hawk purchase, Pamphlet, 53 pp., Philadelphia, 1836.

[38]Report Intended to Illustrate a Map of Hydrographic Basin of Upper Mississippi River: Twenty-sixth Cong., 2nd Sess., Sen. Doc. 237.

CHAPTER II.

GEOLOGIC RECONNAISSANCE.

In Iowa that particular phase of geologic inquiry which must always precede systematic investigations very closely coincided in point of time with the third quarter of the Nineteenth century. Prior to that period through a space of twenty-five years, the sundry observations made concerning the rock-formations of the State were incidental to the geographical explorations of the day. The various other results derived from the earliest definite inquiries started, were in no way connected with one another and they afforded little foundation for any subsequent investigations.

Singularly enough, although mining had been carried on for more than a century and a half previous to the first records in geology made within the area of the present state, the character and succession of the rock-layers containing mineral, and the relations of the one to the other excited almost no attention. Only occasionally was there even the faintest glimmer of the scientific trend in this regard. In after years these very subjects, in the Iowa field, became the themes of world-wide controversy and interest.

Several aspects of the geological reconnaissance-work had bearings that are more than State-wide. In the history of American geologic literature they assumed national import. The birth of modern stratigraphical geology dated from the first use of fossils to determine the relative succession of strata. The principle was soon definitely advanced in this country, first in Iowa fully thirty years before the New York geologists made known their use of the method.

Another noteworthy feature in this connection is the fact that the then new English classification of geologic formations, which has since been so generally adopted the world over, was, so far as its systematic subdivisions are concerned, first successfully fitted to the terranes of this continent in the Iowa part of the

Upper Mississippi valley. Moreover, the stratigraphic division-lines then proposed remain to-day essentially the same as when they were first drawn, a fact clearly indicative of the accuracy of the early observations, and attesting the wonderful scientific penetration of the pioneer workers.

A third consideration, and one of continental significance, is the remarkable parallelism thus early established between the general stratigraphic sequence of the Upper Mississippi valley and that of England. Of late years this great circumstance appears to have been largely lost sight of; yet the analogy remains as true to-day as it did then. In view of the fact that world-wide geologic correlations are now sought and that correlative methods more refined and more precise than fossil criteria are now possible of successful application, it seems likely that the Mississippi Valley succession of the later Paleozoic strata shall finally become the standard section for America rather than the New York section which has so long held dominance among scientific men.

To a very early period of geologic reconnaissance, or rather to pre-reconnaissance time, there is a bit of geologic work assigned which deserves special mention here. This is a certain old map and report published so long ago as 1752. As is well known the art of geologic cartography is barely a century old. In this country its most important precursor is Güttard's "Carte minéralogique ou l'on voit la nature du terrains du Canada et de la Louisiane," which illustrates a report on the mineral resources of New France, printed a short time prior to the loss of all that vast territory by the mother country. This work[39] was entitled "Mémoir dans lequel ou compare la Canada à la Suisse por rapport a ses minéreaux."

The first distinctive reference to the geologic composition of our Iowa-land appears to have been by General George Victor Collot, once governor of Guadaloupe, who, while traveling in America in 1793 in the interests of the French government, ascended the Mississippi river as far as Prairie du Chien. He noted[40] that between St. Louis and the point mentioned the

[39]Hist. de l'Acad. Royale des Sci., p. 189, pl. vii, Paris 1752.

[40]Voyage dans l'Amerique septentrionale ou description des pays arrosès par le Mississipi, l'Ohio, le Missouri et autres rivèires affluentes, T. I, p. 282, Paris, 1796.

"banks were composed of gray-stone, flint with which the Indians tip their arrows, or mill-stone, but most frequently of limestone."

On the first map of the United States colored geologically,[41] by William McClure, published in 1809, the great band of "alluvial deposits" is represented in the Mississippi valley as only reaching to the mouth of the Des Moines river. In a subsequent edition of this map issued eight years later, the great tract of secondary (Paleozoic) rocks touches the entire eastern boundary of present Iowa domain. The corrections on the second edition of the map and in the accompanying explanation, at least so far as the extreme western parts were concerned were due doubtless largely to the work of travelers in the West at that time. It was the irony of Fate that McClure's work, representing the last of the old régime should be covered so closely by that of his colleague's representing the first of the new.

The important part which our State has chanced to play in the founding of one of the great modern sciences is worthy of special record. In the history of that science as developed in the New World the circumstances surrounding the earliest discoveries deserve connected reiteration in a chapter all their own. They influenced the whole course of later geologic discovery. They seem destined yet to establish the standard systematic section for the entire American continent.

The scientific discoveries to which I allude were made in Iowa-land before Iowa was a state, before she was a territory, before she was hardly a part of the United States. It was in the earliest springtime of the last century, when our Nation was yet new, when the region was still remote and unknown, and when even the land itself was yet to receive its name.

For several reasons this pioneer scientific work is of exceptional historic interest. It was the first time that modern geological principles were successfully applied in this country. It was up to the time the boldest stroke at universal correlation of geological formations ever attempted by geologists. It was the first definite recognition of the two greatest geologic formations found on our continent. It was the first chronologic com-

[41]Trans. American Philos. Soc., Vol. VI, p. 411, Philadelphia, 1809.

parison of American Carboniferous rocks with those of the typical locality in the Old World. It furnished the clue to all subsequent investigations of the mid-continental region. It gave rise to a host of perplexing problems many of which are still unsolved. Where else in all the world have not the echoes of a century-long discussion long since died away? Singular is it that our Iowa should be the pivotal point.

When in England about a century ago, earth-study was made a modern science through William Smith's famous geologic discovery that the relative age and natural sequence of rock-layers were susceptible of accurate determination by means of the contained organic remains, America very early and from a wholly unexpected quarter furnished important aid in support of the newly established principles. The circumstances were long since all but forgotten. In the few casual references made to them in later years either their importance was misunderstood or familiarity with the attendant conditions was entirely wanting. As the first successful application of modern geological principles in the New World the episode must ever remain of great historic interest.

Singularly, this primal American effort to correlate by their faunal contents geologic formations widely separated geographically was not made in that portion of our continent which was most accessible and where it was most natural to expect it—that is, along the well-settled Atlantic border—but it was in the then remotest section of the Upper Mississippi valley. First fruits of research and observation were obtained in a region which was then perfect wilderness, but which now forms part of the great and populous state of Iowa. Moreover, these remarkable observations were made within a decade of the time when the novel method was originally announced in England. They antedated by fifteen years Samuel Morton's similar effort[42] on the Tertiaries of our Atlantic coast commonly regarded as the maiden attempt in America along these lines. By two decades they were in advance of the first work of that pioneer American paleontologist Lardner Vanuxem.[43] They anticipated by a full generation the famous investigations of Thomas Conrad and

[42]Jour. Acad. Nat. Sci., Philadelphia, Vol. VI, pp. 72-100, 1829.
[43]Jour. Acad. Nat. Sci., Philadelphia, Vol. VI, pp. 59-71, 1828.

James Hall in New York. Indeed they were the means of actually and correctly interpreting the true position and biotic relations of the Carboniferous rocks of the continental interior a half century before their geologic age was otherwise generally admitted. The Mississippian limestones, as the rocks are now called, remain today as compact and as sharply delimited a sequence of geologic terranes as they appeared when first recognized in that memorable summer of the year 1809.

This successful use in America of faunal criteria for purposes of solving problems of geologic correlation and of identifying geological formations was the first real ray of modern light to penetrate the stratigraphic darkness shrouding the New World. The happy application of these criteria was due directly to the keen scientific perception and peculiar reasoning of one who was never known as a geologist at all, but who was raised to fame through a wholly different channel of scientific activity. The name of this truly remarkable personage was Thomas Nuttall, botanist.

Nuttall's extensive travels in America were undertaken chiefly in the interests of his monumental works on North American plants and of his valuable contributions to American ornithology. On his first great trip, after traversing the southern shore of Lake Erie, and coasting by canoe Lakes Huron and Michigan, he entered Green bay, and, following that famous all-water route to the West which the Indians had used from time immemorial, ascended Fox river to the portage to the Wisconsin river down which latter stream he floated to its mouth near Prairie du Chien, thence down the Mississippi river to St. Louis. Subsequent trips took him far up the Missouri and Arkansas rivers.

On his Mississippi venture[44] besides garnering great quantities of interesting plants and taking voluminous notes on the birds, he appears to have made extensive collections of the fossils which he found throughout his path abundantly scattered through the limestones which in high cliffs bordered both sides of the great stream. In the course of his explanations of the geologic features of the region through which he passed Nuttall

[44]Obs. on Geol. Structure Miss. Valley: Jour. Acad. Nat. Sci., Philadelphia, Vol. II, pp. 14-52, Philadelphia 1821.

naively notes that he is "fully satisfied that almost every fossil shell figured and described in the *Petrifacta Derbiensia*" of Martin was to be found throughout the great calcareous platform of Secondary rocks exposed in the eastern Mississippi valley. Thus by means of fossils he parallels these limestones of the Mississippi river with the Mountain limestone of the Pennine range in Derbyshire, England, to which, several years later, Conybeare[45] gave the title of Carboniferous.

Along the Mississippi river, as we now know, Nuttall really encountered little else than rocks of Early Carboniferous age, so that his identifications of the fossils were doubtless with very few exceptions, correct. Moreover, at this date and for some time afterward the lower portion of the exposed stratigraphic sections, it must be remembered, was entirely undifferentiated, the great sequence of older beds which were subsequently separated from one another being jumbled together under the title of Transition group. It was not until more than a quarter of a century later that out of them in Britain Murchison and Sedgwich established the Cambrian, Silurian and Devonian systems.

Another important geologic correlation is to be credited to Nuttall. On his journey up the Missouri river in 1810, which he undertook with John Bradbury,[46] a Scotch naturalist, he reached the Mandan villages on the upper reaches of that stream. He makes especial mention of the Omaha villages situated below the mouth of the Big Sioux river. A short distance upstream from the last mentioned point he examined strata which by means of their fossils presumably, he referred to the Chalk division of the Floetz or Secondary rocks of northern France and southern England. This is the earliest definite recognition of beds of Cretaceous age in America. It preceded by a decade and a half the separation by John Finch of the newer Secondary rocks from the Tertiary section in the Atlantic states, and Lardner Vanuxem's and Samuel Morton's reference of the same deposits to the Cretaceous age. Thus also was another great succession of one of our main geologic periods discovered in a then remote part of our continent years before it was recognized in the East.

[45]Outlines of Geology of England and Wales, p. 353, London, 1822.
[46]Travels in Interior of America in 1809-1811, London, 1817.

At the mouth of the Big Sioux river Nuttall fell in with an old trapper who described to him the great falls which blocked navigation at a distance of 100 miles up that stream, and who told him of the famous Indian pipestone quarries beyond.

The analogy established by Nuttall between the general Carboniferous section of Iowa and the upper Mississippi valley and that of northern England was one of the important geologic discoveries in America. Its great significance was pointed out by Owen a couple of decades later. Its historical value grows with the advancing years. In the final recognition of a standard Carboniferous section for this continent the sequence displayed in the Mississippi basin must prevail, since it is now generally conceded that the Appalachian succession of strata can never be considered as the typical development.

So conspicuously botanical in character are Nuttall's services to science that one can but wonder under what circumstances he could have obtained his keen insight into matters geological. Elias Durand said of him immediately after his death that "No other explorer of the botany of North America has personally made more discoveries; no writer on American plants, except perhaps Asa Gray, has described more new genera and species." Lists of his published memoirs and papers quite generally omit all reference to his recorded geological observations, probably because their importance would hardly be appreciated by writers in other fields of science. In the present connection our main interest centers on the transplanting so early to the interior of the American continent of William Smith's novel ideas concerning fossils. Brief reference to some of the early events in Nuttall's life seem to offer a clue.

Nuttall was born in Yorkshire, England, in the Mountain limestone belt and near the scene of Martin's labors on the Carboniferous fossils of Derbyshire. He was early apprenticed to the printer's trade and after a few years removed to London. There he followed his trade until at the age of 22 he set out for America in 1808. He appears to have been a printer of the Benjamin Franklin order, since while engaged at his trade he became proficient in knowledge of the sciences, Greek and Latin and kindred subjects. During the period of six or seven years he was in London he appears to have made the acquaintance of a number of the scientific men of the day. At least it is probable that at this time he acquired some familiarity with Smith's discoveries which were at that date attracting wide attention from English scientists. It is also quite possible that Nuttall gained much of his scientific information through setting up the types for those very memoirs which have since become geologic classics. It is not unlikely also that he even met Smith, since the latter is known to have been often in London at this time and to have taken up his permanent residence there several years before the printer-naturalist left his native country.

At any rate Nuttall had been in America scarcely a year before he was putting his geological knowledge to test. His familiarity with Martin's *Petrifacta Derbyensia* and Smith's principles clearly indicate that he must certainly have acquired his information at least several years previous. Then, too, his acquaintance with that pioneer American geologist, William McClure, for twenty years president of the American Philosophical Society at this period, should not escape notice. Two other papers, partly geological in nature but chiefly mineralogical in character, on the rocks and minerals of Hoboken and of Sparta, New Jersey, and the many keen observations on the rocks recorded in his journal of a trip from Philedalphia to Pittsburg attest his unusual intimacy with matters in geology.

Notwithstanding the fact that the brief memoir which Thomas Nuttall published on Iowa-land and the contiguous regions was the only one which he seems ever to have printed on strictly geological subjects so important are the principles set forth for the first time in this single, simple, short contribution to the literature of American terranal correlation that it places its author in the front rank among pioneer geologists not only of Iowa but of our Country. Although one of the foremost botanists of his day and an ornothologist of world-wide reputation his great service in first pointing out by method and by means the fundamental concepts of modern historical geology in America should not be forgotten.

In a canoe-trip to the falls of St. Anthony[47] which Major Stephen H. Long made in 1817, only incidental mention is made of any of the geological features along the course. This journal although unpublished for more than forty years, was made liberal use of by Keating in his narrative of Long's expedition to the sources of the St. Peter river.

Edwin James, who as geologist accompanied Long's expedition to the Rocky mountains,[48] only traversed the extreme southwestern corner of the Iowa tract. Incidentally, he called attention to the probable great importance of the coal measures of the region.

On the return of the Cass expedition[49] to the sources of the Mississippi river, in 1820, Schoolcraft, who was the narrator and mineralogist of the party, made a special side-trip from Prairie du Chien to the Dubuque lead-mines. Of these he gave the best detailed description up to that time and for a generation thereafter. This traveler had already investigated the lead-mines of Missouri and had published a full account of them, and the methods of mining and smelting.

As a result of his Iowa visit Schoolcraft, as it appears, originated the notion that the two mineral districts were genetically connected in some way. He fancied that the lead-bearing beds of the two widely separated districts were geologically in the same terrane. This formation he called the "Metalliferous Limestone." The statement was repeated as fact for many years afterwards. It is instructive as indicating the method of geologic correlation at that time. The idea was later elaborated from time to time until its necessary consequences had to be finally supported by the assertion that the ore-bodies were primarily deposited under the influence of favorable local currents on the floor of the Ordovician ocean. In some form or other this curious notion prevailed for more than two generations; and even at the present day it is seriously upheld.

Keating, who as mineralogist accompanied Long on the expedition to the sources of the St. Peter (Minnesota) river, in 1823, and passed through the northeastern corner of the state, adds

[47] Coll. Hist. Soc. Minnesota, 1860, pp. 9-15.

[48] Account Exped. Pittsburg to Rocky Mts., in 1819-20, Vol. I, 1823.

[49] Narrative Journal of Travels, etc., to Source of Mississippi River, Cass Exped., 414 pp., Albany, 1821.

nothing to the knowledge of Iowa geology.[50] Mention of his account is made here because of an error to which were committed many of his followers in the region for many years afterwards. In attempting to reconcile Conybeare's descriptions of English rocks with his own observations in the Mississippi valley he erroneously concluded that the lead-bearing rocks of Dubuque belonged entirely to the Carboniferous Limestone division, whereas none of them can be so classed .

Although Featherstonhaugh[50a] was United States geologist when he made his so-called geological trips to the Northwest he gave in the accounts of his travels little detailed information concerning the geologic features of the Iowa region through which he passed. This writer stated that the Galeniferous formation of Dubuque belonged to the Carboniferous Limestone. He connected the metalliferous rock of the region directly with the lead-bearing formation of southeast Missouri, thus following Schoolcraft. Above Rock Island rapids of the Mississippi river he noted the occurrence of bituminous coal; and at Keokuk he found geodes containing crystals of sulphret of lead. His elaborate discussion of Murchison's and of Sedgwick's rock-formation of England has no connection with the geology of the region which he traversed.

Between the years 1838 and 1839 Jean N. Nicollet, a French geographer, was engaged, under the auspices of the Engineering corps of the United States army, in preparing a detailed map of the Upper Mississippi valley.[51] According to the high authority of Warren,[52] this map is "one of the greatest contributions ever made to American geography."

Along with his geographic and engineering knowledge Nicollet possessed a keen appreciation of geological matters. He was quite familiar with fossils, and with Murchison's new classification of rock-terranes. His strictly geologic observations in Iowa

[50]Narrative Exped. Source St. Peter's River, etc., under Major S. H. Long, Vol. I, p. 195, 1823.

[50a]Geol. Rept. of examination made in 1834 of elevated country between Missouri and Red Rivers. 97 pp. 1835. (23d Cong., 2d Sess., House Ex. Doc. No. 115.)

Rept. of reconnaissance made in 1835 from seat of government by way of Green Bay and Wisconsin Territory to Chouteau du Prairie, elevated ridge dividing Missouri from St. Peters River, 168 pp., 1836.

[51]Rept. Intended to Illustrate a Map of Hydrographic Basin of Upper Mississippi River, Twenty-sixth Cong., 2nd Sess., Sen. Doc., Vol. V, pt. ii, No. 237, 177 pp., 1843.

[52]Rept. Pacific Railroad Survs., Vol. XI, p. 41.

were only incidental to his work in hand. He described quite fully the glacial drift, but did not touch upon its origin. The physiographic descriptions which he presented were notable productions.

Among the interesting facts noted were that the uplands bordering the Mississippi river above Keokuk were made up of Carboniferous, or Mountain, limestones (Early Carboniferous). The geodes of this region were described in some detail. A good detailed section of the rock-succession at Burlington was recorded. This was called the "Burlington Group", a term having priority by twenty years over Hall's similar title for the main limestone member only. Singularly enough the limestones of the Missouri river, at the mouth of the Platte river, were erroneously regarded as the same as those exposed at Burlington. The Coal Measures were mentioned as extending from the present Minnesota-line southward to the Arkansas river.

The calcareous rocks outcropping near the mouth of the Sioux river were pronounced to be Cretaceous in age. Samples examined under the microscope by Prof. J. W. Bailey, of West Point, were found to be composed largely of very minute shells like those occurring in the typical chalk. In the lead-region the main limestone was correlated with the Cliff limestone of Ohio, and the fossils contained were compared with the Trenton forms of New York. Coal fossils were collected on the Des Moines river at the Raccoon forks.

Nicollet made a special announcement[53] of his discovery of the "Cretaceous Formations of the Missouri River," but the main limestone member at the base of the section and which he observed near the mouth of the Sioux river, he mistook for Carboniferous limestone.

In the course of his examination of the mineral lands of the Dubuque region, in 1839, Owen[54] introduced several novel features into the consideration of the geological formations of the Mississippi valley. Four years later a second edition[55] of Owen's report appeared, together with the maps and plates which were

[53]Am. Jour. Sci., (1), Vol. XLV, p. 153, New Haven, 1843.

[54]Rept. Geol. Expl. Iowa, Wisconsin and Illinois, 26th Cong., 1st Sess., House Doc. No. 239, 161 pp., 1840.

[55]Twenty-eighth Cong., 1st Sess., Sen. Doc. 407, 191 pp., 1844.

omitted from the first edition. This volume contains the first complete outline of a classification of the geologic formations of Iowa in accordance with modern criteria.

In several respects Owen's work was especially noteworthy. By it were accurately paralleled for the first time in America the English systems, the names and lines of demarcation of which had been then just proposed by Phillips and which now are recognized throughout the world.

Murchison's Silurian system was defined[56] in 1835; as was also Sedgwick's Cambrian system.[57] Lonsdale's determination of the Devonian system was announced two years later.[58] Until 1848 American geologists west of the Appalachians following Featherstonhaugh were in the custom of calling all the strata beneath the coal measures, the Mountain limestone, or Carboniferous limestone. In the year mentioned De Verneuil[59] pointed out the fact that some of these limestones carried true Silurian fossils and, therefore, could not be properly termed Carboniferous in age.

Up to the time of the appearance of Owen's report (1844) Conrad[60] seems to have been the only American geologist who was at all inclined to recognize the new English classification. His application of it to the New York rocks was surprisingly unfortunate. While he was superintendent of the New York geological survey and the annual reports of the four districts were being published the attempt was made to harmonize the New York section with that of England. The effort was not so successful as it was hoped. Partly for this reason and partly perhaps on account of the fact that the New York geologists, after Conrad had left the survey, were carried away with the idea of establishing, out of the Paleozoic sequence, a "New York system," the final reports came out, in 1843, with Conrad's plans entirely abandoned. Moreover, the four geologists of the respective districts were hopelessly at variance as to the limita-

[56]Philosophical Magazine, (3), Vol. VII, p. 47, 1835.
[57]Ibid., p. 483.
[58]Proc. Geol. Soc. London, Vol. III, p. 281, 1837.
[59]Bull. Soc. géol. de France, t. II, p. 166, 1840.
[60]Jour. Acad. Nat. Sci. Philadelphia, Vol. VIII, p. 228, 1842.

tions of the different formations in different parts of the state, as Williams[61] points out in some detail.

When, then, the second and revised edition of the "Report of the Geological Exploration of Iowa, Wisconsin and Illinois" appeared, in 1844, Owen was the only geologist who had accepted the new English classification of rock-formations and who had accurately determined their stratigraphic delimitations in a definite section. His earlier subdivision of the "Cliff" limestone into three parts of Upper, Middle, and Lower, were here called the Upper Shell-beds, the Middle Coralline beds, and the Lower Lead-bearing beds.[62] These several divisions were, he astutely remarks, also distinguished by their contained fossils, and he enumerated and illustrated some of the most characteristic forms.

Immediately beneath the coal measures he described the Carboniferous limestones. Then came the Upper Shell-beds—the white limestones of the Red Cedar, Wapsipinicon and Rock rivers and of Iowa City, which he regarded as contemporaneously formed with the shell-beds of the Falls of the Ohio river. He had already referred the lower parts of this formation, the "knobs" in Kentucky, to the Devonian system of England and the Chemung terrane of New York.[63]

The Middle Coralline dolomites, carrying chain-corals and the brachiopod, *Pentamerus oblongus,* he assigned to the Upper Silurian system. The Lower Lead-bearing dolomites he placed without any hesitation in the Lower Silurian system.

The rocks of the Cambrian system, as they are now called, could not very well have attracted Owen's attention at this time, since, with the exception of a few unimportant outcrops near water-level in the Mississippi river, their areal distribution in this region was mainly outside of the section investigated. Four years later,[64] however, he was permitted to examine that part of the geological section for he announced that north of the mouth of the Wisconsin river there were magnesian limestones which

[61] Bull. 80, U. S. G. S., p. 57, 1891.
[62] Twenty-eight Cong., 1st Sess., Sen. Doc. 407, p. 32, 1844.
[63] Am. Jour. Sci., (1), Vol. XLV, p. 152, 1843.
[64] Thirtieth Cong., 1st Sess., Sen. Ex. Doc. No. 57, 1848.

were older than the lowest formations of the Ohio valley, a part at least corresponding to the Potsdam sandstone of the New York section, which he had previously compared[65] with the Cambrian section of Sedgwick.

During the years 1848-9 the rocks exposed along the Mississippi, Cedar, Iowa, Des Moines, and Missouri rivers were particularly examined by Owen. The results of these investigations were embraced in a large volume, published by the General Land Office in 1852.[66] Associated with him, as assistants in the work, were half a dozen men who afterwards became distinguished in the annals of American geology.

Owen was a man of remarkably keen geological insight. The acumen which, as a pioneer in a perfectly unknown country, he displayed in deciphering the problems presented would have done credit to any one even to-day. In this state and in Missouri and Minnesota I have personally in the field gone over much of his work and I have had repeated occasion to verify his recorded results in detail. I cannot but express the warmest admiration for his great skill in unraveling difficult problems, his remarkable accuracy of observation, and his sound geologic reasoning. In his method of investigation three features are conspicuously presented. His plan of correlating geologic sections by means of the combined methods of lithologic resemblance, stratigraphic continuity, and continuity of lithologic sequence, and of plotting the sections along exposed lines of streams preceded by a generation the general adoption of this method by American field-geologists. By half a century he anticipated modern geologic requirements, when he defined his terranes by clearly noting, as essential elements their topographic expression, their geographic extent, their lithologic character, their stratigraphic delimitation, their biotic definition, and their economic content. In soundness of logical deduction his generalizations stand every modern test. All of these characteristics are repeatedly displayed in the published results of his investigations in Iowa.

[65]Twenty-eighth Cong., 1st Sess., Sen. Doc. 407, p. 18, 1844.
[66]Rept. Geol. Surv. Wisconsin, Iowa and Minnesota, etc., 638 pp., Philadelphia, 1852.

One of the curious analogies which his keen penetration established was the remarkable parallelism existing between the sequence of Carboniferous limestones as displayed in Iowa and the succession as worked out by Phillips[67] in Yorkshire, England. The comparison clearly indicates the great influence of his English training in geology.

Very much as they are demarcated to-day Owen again delimited in Iowa and the Upper Mississippi valley the systemic groups of the rocks. Their areal distribution ascribed by him indicates closely the outlines now recognized in somewhat greater detail but determined many years afterwards. In Owen's determinations of Iowa stratigraphy several points should be particularly emphasized;

(1.) The present serial subdivision of the Paleozioc rock-sequence was distinctly foreshadowed; only the application of geographic names, which modern custom encourages, was lacking.

(2.) In his Upper Magnesian formation, which has since been found to embrace Ordovician and Silurian beds, the Maquoketa shales were not recognized.

(3.) The Cedar Valley limestones were closely correlated with the then new Hamilton section of New York state. Since Owen's day little progress has been made in the subdivision of this great succession of limestones.

(4.) With great nicity and detail was the Iowa section of the Early Carboniferous rocks differentiated. A notable feature was its separation into an upper series and a lower series at the horizon of the present Warsaw limestone. Sixty years afterward this same scheme was proposed as new and original in the most modern consideration of the subject by Schuchert[68] and by Ulrich.[69]

(5.) The geologic section along the Des Moines river from its mouth to the Lizard fork, at Fort Dodge, was one of the most detailed, most complete, and most accurate cross sections of the time. It stands to-day a model of exact stratigraphic correlation.

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[67]Geology of Yorkshire, p. 26, 1836.
[68]Bull. Geol. Soc. America, Vol. XX, p. 548, 1910.
[69]Ibid, Vol. XXII, pl. 29, 1911.

(6.) For the first time the remarkable marl hills at Council Bluffs and on the Missouri river were compared with famous similar deposits of the Rhine valley, in Germany, and here as there they are correctly called loess.

(7.) The Carboniferous limestones of the Missouri valley Owen regarded as the equivalents of the Early Carboniferous limestones of the Mississippi side of the state. In this he was mistaken; but the very fact of this error shows, as late investigations have thoroughly demonstrated, how closely, although so widely separated stratigraphically, the two maritime formations resemble each other. Owen had never seen the full Carboniferous section of the Missouri and Kansas region. He could not, while in Iowa, make the necessary investigations to work out in detail the stratigraphy, as it was later done, showing the intercalation of the great productive coal measures between two great barren measures. Nor had he at this time been able to visit places that would indicate to him that instead of the productive coal measures being only 100 feet in thickness, they were really, although not in Iowa, thicker than all the rest of the Paleozoic section of the region. Long years afterwards in the far-away Arkansas River valley Owen was permitted to make the very observations necessary[70] and to supply something of the missing-link to his complete effort. Yet still another half century was to pass before the exact stratigraphic equivalency of the section was to be determined beyond peradventure.[71]

(8.) Owen described the first organic remains new to science which had been found in Iowa rocks, and he beautifully illustrated them by his own drawings which are really works of art.

The first geologic inquiry publically undertaken by the State of Iowa was a reconnaissance of the eastern half of the domain. The Legislature of 1855 passed a law providing for a geological survey of the state and annually appropriating $2,500 for the biennial period. It was approved by Governor Grimes on January 23, 1855. Under the authority of this Act James Hall, of New York, was appointed state geologist, and J. D. Whitney,

[70]Rept. Geol. Reconnaissance, Part of Arkansas, pp. 17-141, Little Rock, 1858.
[71]Bull. Geol. Soc. America, Vol. XII, p. 173, 1901.

of Massachusetts, was selected for chemist. A. H. Worthen, afterwards state geologist of Illinois, was an assistant. The succeeding legislature appropriated $10,000.00 for the continuance of the work, and made provision for the publication of a report. Field-work was carried on during the three years of 1855-7.

Among the more important of the strictly geologic results may be mentioned:

(1.) The introduction of the New York classification of geologic terranes, and the New York formational nomenclature.

(2.) The application for the first time in the state of Murchison's plan of giving geographic names to the prominent rock formations.

(3.) The finding of the Maquoketa shales between the two great divisions of the Magnesian limestone of the northeastern part of the state.

(4.) The undertaking of a preliminary, but important, investigation of the lead deposits, by Whitney.

(5.) The construction of a detailed geologic cross section along the entire eastern border of the state, in which the tectonic and stratigraphic relations of the different formations are graphically represented. This section was continued southward to the Ohio river. The geographical names used to designate the Carboniferous terranes were local terms.

(6) The determination of the unconformable relation of the coal measures upon the beveled edges of all earlier formations was emphasized as new, although Norwood had, several years previously, demonstrated the fact elsewhere in the Upper Mississippi valley.

(7.) The general use of fossils in determining questions of geologic history was a feature displayed throughout the report; and the second part (volume) was devoted entirely to the description and illustration of the ancient organic remains.

(8.) The selection of small units for the detailed areal reports was manifested by the brief accounts of the geologic resources of six counties, showing at this early time that this political unit was the logical unit for the areal reports and maps of a state geological survey.

In introducing the New York classification Hall appears to have displayed the same intense prejudice against the new English scheme that he did a decade earlier in his eastern reports. There is no mention of the English system in his table of formations. The notation of some of them on the accompanying map appears to have been done by other hands.

For many years the New York formational names given by Hall to western terranes prevailed in the geologic literature of the region. Gradually they have been displaced as unsuitable, until at the present time only two or three of them remain.

A decade after the preliminary survey of the eastern half of Iowa was finished by Hall, a reconnaissance of the geology of the western half of the state,[72] by Charles A. White, was undertaken. Orestes St. John was appointed chief assistant geologist. For a period of four years $6,500.00 were annually appropriated by the Legislature to carry on the work. The results were published in two volumes.

Some of the more important scientific facts brought out in the course of the investigations were:

(1.) The establishment of the existence of unconformable relations between the St. Louis limestone and the older terranes.

(2.) The determination of the great extent and thickness of the coal-bearing formations of the state.

(3.) The detection of the occurrence of workable coal seams in the so-called upper coal measures (Missouri series) of the southwestern part of the state.

(4.) The proof of the great extent and thickness of the Cretaceous formations in northwestern Iowa.

(5.) The detailed determination of many stratigraphic features concerning the coal measures.

(6.) The outlining of the local geologic features of the western counties of the state.

After the discontinuance of the survey-work under White the State was long in getting into step again with her sister states. During this quarter of a century two especially notable efforts in geologic investigation were accomplished. Neither of them are properly termed reconnaissance; they were too mon-

[72]Rept. Geol. Surv. Iowa, 2 vols., Des Moines, 1870.

umental and monographical in character. Neither do they come in the class of public systematic inquiry. Yet they are both perhaps as well considered here between the two chapters relating to original geologic investigation.

In northeastern Iowa W J McGee had for a period of years conducted extensive examinations of the glacial deposits. The results were originally intended to appear in other form, but they grew so voluminous that they were finally incorporated in a great monograph and published by the Federal government.[73]

Along paleontological lines Charles Wachsmuth and Frank Springer conducted comprehensive studies on certain groups of fossils. The printed volumes already published form one of the most exhaustive contributions ever made to the literature of American science.[74]

Both of these efforts are not only highly creditable to the authors but they extend great honor to the State and the country. They would have reflected a much larger share of credit upon the State had they been accomplished under public auspices, instead of through private enterprise. Although aided in no way by the State these investigations are of the highest character scientifically and mark the first performances within the boundaries of Iowa of private research work of first rank in the domains of geology.

The great scientific value of McGee's "Pleistocene History of Northeastern Iowa" lies in the fact that there are recognized two distinct drift-sheets, indicating two glacial epochs, or two advancements of the continental ice-mass. Besides a large amount of detailed information concerning the geological formations of that part of the state there is presented in an exhaustive manner evidence of the dual character of the drift of Iowa. This testimony came at a time when it was generally held by the scientific world that there was strict unity of the great ice age.

At this time the theme was new and suitable criteria for correlating observations had yet to be formulated. The character of the phenomena presented were also unique in the annals of

[73]Eleventh Ann. Rept., U. S. G. S., pp. 190-577, 1893.
[74]Memoirs of Museum Comparative Zoology, 3 vols., Cambridge, 1895.

geology. McGee, himself, well expresses the conditions: "The most startling induction of geology, if not of modern science, is the glacial theory; but in the solution of the problem of these pages it is necessary to do more than assume the existence and action of the great sheet of ice hundreds or thousands of feet in thickness and hundreds or thousands of miles in extent. In order to explain the sum of the phenomena it is necessary to picture the great ice-sheet not only in its general form and extent, but in its local features, its thickness, its direction and rate of movement over each square league, the inclination of its surface both at the top and bottom, and the relation of these slopes to the subjacent surface of earth and rock; and all this without a single stria or inch of ice-polish, save in one small spot, in the whole tract of 16,500 square miles. It is necessary to conceive not only the mode of melting of the ice at each league of its retreat, but also every considerable brook, every river, and every lake or pond formed by the melting, both at its under surface and on its upper surface; it is necessary to restore not only the margin of the *mer de glace* under each minute of latitude it occupied, but, as well, the canyons by which it was cleft, the floe-bearing lakes and mud-charged marshes with which it was fringed, each island of ice, and each ice-bound lake formed within its limits. And it is not only necessary to reconstruct the geography of a dozen episodes, as does the anatomist the skeleton from a few bones, but to develop a geography such as civilized eye has never seen, and which could exist only under conditions such as utterly transcend the experience of civilized man. All this has been done. The trail of the ice monster has been traced, his magnitude measured, his form and even his features figured forth, and all from the slime of his body alone, where even his characteristic tracks fail."

In another connection the author notes that the "Two incursions of ice from the north have each spread a drift-sheet upon this district, and in each case only little of the drift can be ascribed to local origin. Probably ninety-five per cent. of both the earlier and the later till and of the associated stratified deposits came from areas north of Iowa. Boulders of small size, comprising many of hornblende-schist characterize the lower and older till, while the upper till has many large boulders of granitoid and gneissic rocks, usually occurring of all sizes up to 15 feet. Often much larger boulders are found, and one was measured having a diameter of 47 feet.

"A very remarkable feature of the early glaciation of this district is the absence of glacial striæ, except in one isolated locality, on the bed-rocks of a drift-covered country. Not all of the preglacial residuary clay was removed, and no glacial erosion of the underlying rocks took place. Between the first and second ice incursions forests grew on this area and their remains form a forest-bed of abundant logs and branches, with occasional peat accumulations, encountered by nearly every well of whole townships and traceable over several counties, lying between the lower and upper tills.

"The eastern part of the district is covered with loess, and the western border of the loess has a descent like a terrace ten to twenty feet or more, to the surface of the sheet of till which stretches thence westward upon the tract that was covered by the Minnesota and Iowa lobe of the ice-sheet while the loess was being deposited. Upon the till the loess occurs here and there forming ridges much higher than the surrounding land. These ridges, named paha, trend in parallelism with the movement of the ice-sheet, and were deposited, like the gravel and sand eskers of other regions, in ice-walled channels of glacial rivers during the departure of the ice."

This Pleistocene history may be summed up as follows: "Northeastern Iowa has been twice invaded by northern ice. The first ice-sheet was thick, pressed hard on the land, lay long, and slowly melted. It displaced the magnificent fauna of the Tertiary, few representatives of which survived its disappearance; and it was followed by a vast period of forest growth and soil accumulation. The second ice-sheet entered the territory very long after the first; it was only a few hundred feet in thickness at the most, ran quickly to its farthest limit, and quickly melted. Before its destruction it met the Iowa-Wisconsin ice-lobe, and behind the two a great lake formed which drained over the Iowa sheet; and as this sheet melted, rivers ran between the lobelets, lakes accumulated on its surface, and glacial mud gathered in the channels of the rivers and the basins of the lakes; and thus there was developed a combined topographic configuration and aqueo-glacial structure without parallel elsewhere on the known earth."

One feature of McGee's investigation is particularly noteworthy. For the first time he found extensive loess formations reposing between two till-sheets, thus recording the facts which are the main proofs of the complexity of the Glacial period. The circumstances surrounding this great discovery and Iowa's role in establishing the fact are briefly related.

Louis Agassiz's theory of continental glaciation was one of the most brilliant generalizations of modern science although it was neither so complete nor so widely applicable as was at first supposed. What was even more important to its scientific value than the bare statement of the conception itself was the recognition of the fact that there were not one but many glacial epochs in the earth's history. Of course Croll's hypothesis urged the necessity of successive glacial periods but it was soon shown that his astronomical dates were too far apart to account for the vicissitudes of the epoch which we are now mainly studying. So we have to go back to the testimony of the glacial deposits themselves for our fundamental data.

In the great world-wide controversy which warmly waged for more than a generation Iowa chanced to bear a conspicuous part. It was in Iowa that the first real evidences were found indicating the multiple instead of the unal character of the glacial epoch. They were Iowa men who made this great discovery. In Iowa were finally differentiated not one but five great glacial drift-sheets, or deposits, marking the successive advancements of the vast fields of northern continental ice. On Iowa men chiefly devolved the responsibility of first working out the complete and genetic relationships of these remarkable glacial till mantles.

In order fully to appreciate the genuine importance of the Iowa results bearing upon glacial complexity as opposed to glacial unity the facts leading up to the birth of the idea may be briefly reviewed. So early as 1870 Edward Orton observed peat-beds in the glacial deposits of Ohio and he rightly concluded that this feature indicated a warm interglacial epoch. He stated that evidence was at hand for the orderly arrangement of post-Tertiary deposits. This dual aspect of the glacial débris was further substantiated by Leverett, Chamberlin, Gilbert, McGee and others. In the prolix discussion which followed on the duality of the Glacial period the real facts were overlooked, or misinterpreted, and the possibility of a multiple instead of either a unal or dual Ice-age was lost sight of. Once suggested, the multiple hypothesis, about the year 1893, rapidly gained general acceptance among scientific men.

The arguments for a dual Glacial period and at the time of its proposal of a multiple Ice age were based mainly upon the fact of the presence in till sections of thin black soil streaks replaced here and there by thicker peat-beds. That there might be extensive inter-glacial sand or clay deposits was not thought of. Yet they were actually recorded and described a full decade prior to the time when their true significance was pointed out. Such an interglacial deposit clearly intercalated between two great till-sheets is the one on Capitol Hill, in Des Moines, described in detail by W J McGee and R. E. Call in 1882. It seems to be the first one ever recorded the stratigraphical relations of which were unmistakable.

The spot where the depositional proofs of the complexity of the Glacial epoch were first obtained is for several reasons of unusual interest. The section, originally well displayed, is now fast disappearing. It is also this section which later gave the first intimation of the eolian origin of the American loess-loams.

At this time and at this distance there are few of us who have any adequate appreciation of the great difficulties which the problem once presented. Still fewer of us there are who understand from direct experience what it really means actively and determinedly to contend on the battle-line of the unknowable. McGee was in position best to know intimately the intricacies of attempting to decipher the great glacial puzzle of that day.

The now famous geologic section under consideration is situated on the crest of Capitol Hill, at the south end of the State capitol grounds. As originally described in the American Journal of Science for 1882 (Vol. XXIV, p. 202) the exposure of deposits presents the following relations:

5. Till, light reddish buff clay, with pebbles......(feet) 7
4. Till, contorted and interstratified with loess......... 5
3. Loess, with numerous fossils 15
2. Till, dark red clay, with abundant pebbles.......... 6
1. Shale (Carboniferous) exposed 10

The important features especially to be noted are that: (1) The lower till (No. 2) represents what is now called the Kansan drift which was formed when the great continental glacier reaching southward to St. Louis and Kansas City, attained its greatest extent and thickness; (2) the loess members (Nos. 3 and 4), composed of fine loams, constitute the soil formations during a long interglacial epoch when the climate was not very different from what it is at the present day; and, (3) the upper till (No. 5) represents what is now known as the great Wisconsin drift-sheet.

At the time when these observations were made (1882) as already indicated, the possible complexity of the Glacial period was not yet even surmised. Possibilities of a second Glacial epoch were only vaguely being considered. The prolix and bitter controversy on the duality versus the unity of the Glacial period was just beginning. Under these circumstances it is not at all surprising that the facts presented were partially misinterpreted, and that their true significance was for a considerable time overlooked. Then, too, the prevailing theory of the origin of the loess tended to obscure the proper understanding of the accurately recorded data.

Notwithstanding the fact that both McGee and Call were inclined at the time to attach rather slight importance to their observations, and to regard the phenomena as indicating mere local advance of the ice-sheet it soon became manifest that the two till-sheets separated by a thick loess formation was impeachable testimony in support of two distinct and great ice movements within what was previously regarded as a single one. So far as is known this appears to the first and most important recorded evidence showing conclusively the complex character of the Ice age.

Of similar import was the somewhat later description of a great drift section several miles farther south on the Des Moines river. In a paper read before the Iowa Academy of Science in 1890, it was shown that there was still another thick member to be reckoned with below the loess. In later years the officers of the State Geological Survey have been inclined to regard it as representing the pre-Kansan Aftonian beds.

The Capitol Hill section is now one of the notable drift localities in America. During the past quarter of a century the place and vicinity have been visited by many of the most eminent scientists of the world.

As it is, our fellow Iowan barely escaped making one of the half dozen great geological generalizations or discoveries of the nineteenth century—the establishment of the fact of the complexity of the Glacial period.

In an entirely different field is the great effort of Wachsmuth and Springer on the "North American Fossil Crinoidea Camerata." Its main features may be briefly reviewed.[75] Although the work is first of all morphological in character from the foundation up, and the product of inquiries more thoroughly grounded in biological philosophy than any other work perhaps that has ever been issued on the fossil invertebrates in this country, it is also of such high utility in stratigraphy, especially in the great Mississippi basin, that it may be truly said no other one work has ever furnished so valuable criteria for the purposes of correct correlation of geological formations.

Of all fossil remains none are more admirably adapted to morphological study than those of the echinoderms. On account of their abundance, their peculiarities in geographic and geologic distribution, and their structure, the stalked feather-stars, or stone-lilies, are preëminent. With the skeletal parts composed of regular plates, or ossicles, definitely grouped and frequently highly sculptured, all structural changes are readily deciphered.

The introduction embraces an historical résumé of opinion and a full explanation of the terminology employed in descrip-

[75]Journal of Geology, Vol. IV, pp. 221-240, 1896.

tion. Special attention should be called to the clear and concise definitions given of the various structural parts. The terms should be universally adopted as they form by far the best collection ever proposed. American writers especially will need no appeal to at once use them not only to secure uniformity in nomenclature but precision of description. Heretofore the names of the various plates or groups of ossicles have been used in a rather haphazard way. Not only have different designations been given to the same part, but the same title has been repeatedly applied to structures widely separated morphologically.

The morphological part contains the full discussion of the data upon which the entire classification of the crinoids rest, of the genetic relationships of the various groups, and of the structural characteristics.

The plates in general are separated into "Primary" and "Supplementary" pieces. The former occur in every crinoid and comprise the ossicles represented in the early larva, the basals, the infrabasals, the various plates of the rays or arms, the orals, and the joints of the stem. The supplementary pieces, which make their appearance in the more advanced stages, but which are altogether unrepresented in some groups, comprise the remaining plates. The primary ossicles belong to the "abactinal" or to the "actinal" system. Those of the former include all the plates, connected with the chambered organ and axial cords; the others comprise those communicating with the mouth and the annular vessels surrounding it.

The stem is much more important than generally considered. It is composed of *nodal* and *internodal* joints, and continually increases in length in the growing crinoid by the production of new joints. The nodal plates in the Inadunata, Camerata, and a few of the Mesozoic and recent crinoids, are introduced directly beneath the proximal plate of the calyx, so that the uppermost joint for the time being, is the youngest joint of the stem. In the young Comatula, however, in which the top joint subsequently develops into a controversal, in the Mesozoic Millerocrinus and Apiocrinus, in the recent Rhizocrinus and Calamocrinus, and in all Ichthyocrinidae, forms in which the top joint in the early larva anchylose with the infrabasals, the new nodals are introduced below the top joint. The internodals are interposed between the nodal joints and increase continually in a downward direction during the life of the organisms *pari passu* with the formation of new nodal pieces. The stem matures from the root up, and remains permanently in a state of immaturity at its upper end. The maximum number of internodal joints varies among different forms. Sometimes there are many to the internode, as in the case of most species of Platycrinus, in Mespilocrinus and Rhizocrinus: sometimes only a very few; while Rhodocrinus, throughout its stem generally, has but one.

The cirri in Palæozoic crinoids are, as a rule, more formidable than in later forms, and in most of them they are confined to the lower part of the stem, often occuring only at the distal end. They are given off from the nodal joints, and are generally arranged singly, rarely in whorls as in recent forms.

It has been the general opinion that all Palæocrinoids are fixed forms, but this view is not now believed to be true. The facts appear to lead to the conclusion that at least many of the species in the later part of life were free for a portion of the time, as in the case of the recent Pentacrinidæ, in which the stem at some time at or near the maturity becomes separated from the root. The terminal end in most of the old crinoids tapers to a sharp point, but a root is rarely attached, while detached roots are found abundantly, but scarcely ever associated in the same stratum with the crown.

The real morphological relations of the Basals and Infrabasals is of particular interest. The latter term is adopted for the first plates in the base, and "basals" for the circlet next to radials. The basals of dicyclic crinoids always consist of five pieces; the infrabasals of five, rarely three. In monocyclic forms the base is divided into five, four, three and two pieces, or all five plates may be anchylosed, so as to form a single piece. Among the Camerata five basals are restricted to the Lower Silurian forms, four basals to those from the Upper Silurian and Devonian, three to those from Upper Silurian to the Lower Carboniferous, and two in only some forms from the Carboniferous. The diminution in number takes place in geological succession, and is the result of fusion of two or more of the original five plates, as is clearly seen in genera without an anal plate between the radials. In forms, however, in which an anal plate is represented and the basal disk is consequently changed from a pentagonal to hexagonal shape the case is somewhat more complicated, for a bisection of the plates in the hexagonal base would produce six basals instead of five. The introduction of the anal among all the monocyclic groups is accompanied with an increase in the size of one of the basals, there being no special basi-anal plate. In the tripartite base, the smaller plate—always the left antero-lateral one—doubles its size. In the quadripartite base the increase is towards the right of the posterior plate; while in the bisected base in which the left postero-lateral basal, and the anterio-lateral and the anterior one are fused, the two plates of the opposite side increase in size so as to correspond with the compound plate to the left. In dicyclic crinoids the introduction of the anal does not affect the arrangements of the infrabasals, and only slightly the form of the basals. In species with three infrabasals, one of the plates is always only one-half the size of the other two. This ossicle is, in the Ichthyocrinidæ and comatula larva directed toward the right posterior radial; but in the Inadunata its position is not constant. The basals of dicyclic crinoids are but little affected by the presence of the anal, only the upper angle of the posterior plate being slightly truncated.

When it was discovered several years ago, by Wachsmuth and Springer that among the Palæocrinidæ there is a regular alternation of the successive parts below the radials it was also found that the orientation of the stem in the monocyclic groups is reversed in dicyclic forms. In the former the sharp outer angles of the stem are radial; in the latter interradial. The central canal and the cirri are interradial in the first mentioned forms, but radial in others. The law is, however, applicable to its full extent only in species with pentangular or pentapartite stems, but it is concluded from analogy that the circular stem, wherever it occurs is also practically interradial in dicyclic crinoids and radial in monocyclic ones. However, on applying the rule to mesozoic and later crinoidæ it appears that in most of the so-called monocyclic forms, the orientation of the stem, central canal, and cirri agrees with the dicyclic type, the infrabasals being succeeded by a radial stem, as in those crinoids in which these plates are present but too small to be visible on account of being completely covered by the upper stem joint. Upon the strength of these observations, partly, these authors suggested that such forms either had small infrabasals hidden beneath the top stem joint, or those pieces had been represented in the larva. Other observations led to the same conclusion. In Extracrinus and in two species of Millerocrinus, the former belonging to the Pentacrinidæ, the latter to the Apiocrinidæ, two of the principal families of the Pseudomonocyclia, small infrabasals actually exist, and it appears very improbable that those plates should be present in genera of the same family, and even among species of the same genus, and absent in others, especially when the space which in some of them is occupied by small infrabasals, is vacant in others, and interradially disposed instead of radially as it would be if the space represented the axial canal. On applying these observations to the Comatulæ it was found that the outer angles of the top stem joint in the Pentacrinoid larva of the Antedon, and the angles of the centrodorsal in the mature animal, did not come under the rules laid down for the Monocylica, and this led to the conclusion that the Comatulæ also were built upon the dicyclic plan, and had infrabasals in early life. The predictions, which had been based exclusively upon palaeontological evidence were afterwards verified by the observations of Bury, who actually found infrabasals in the ciliated larva of Antedon. They consist of three unequal pieces, which in the Pentacrinoid stage are fused together with the top joint, so as to form with the latter one large plate with the five angles radial in position. A similar fusion evidently takes place among palæozoic Ichthyocrinidæ, in which the infrabasals are also coalesced with the upper stem joint, as is shown by specimens in which the stem is detached from the crown. These individuals are in the same condition morphologically, as the two species of Millericrinus figured by de Loriol, in which the infrabasals coalesce with the stem contrary to the other species of that genus, and allied forms having the infrabasals more or less completely fused with the top joint. As this structure prevents the formation of new joints directly beneath the calyx, it is contended, from the analogy, that in all forms in which the infrabasals coalesce with the stem, the new stem plates are introduced at some point beneath the top joint. The case is quite different in the Pentacrinidæ, where the youngest joint for the time being is the upper joint of the stem. Of the genera referred to this family, Extracrinus has small infrabasals persistent through life; while in Pentacrinus and Metacrinus no trace of these plates can be found in the adult; their stems are disposed interradially as in Extracrinus and other true dicyclic forms. That the plates are fused with the upper stem joint, is scarcely possible, as it would prevent the formation of new joints at the top; it is more probable as indicated by palæontological evidence that the infrabasals within the group, gradually diminished in size, and finally disappeared altogether. The structure of the Pentacrinidæ in this respect is very different from that of the Apiocrinidæ and Comatulæ, and it appears that crinoids in which the upper stem joint is the youngest, cannot be derived from types in which the upper joint is fused with the infrabasals. The latter therefore should be placed near the Ichthyocrinidæ and the Pentacrinidæ with, or close to the Inadunata.

These generalizations, so far as now known, meet with but two exceptions: the axial canal in the stem of Pentacrinus, contrary to that of Metacrinus and Extracrinus is interradially disposed; that of the monocyclic *Glyptocrinus fornshelli,* unlike that of the other species of the same genus, radially, so that the direction of the canals corresponds with the angles of the stem instead of alternating with them. This however does not invalidate the law, but simply points to the existence of the transition forms between the monocyclica and the dicyclica, as must have occurred at some time in the developmental history of the two groups if the one was evolved from the other.

The radials are less complicated in their morphological relations than the plates which they succeed. The term is now restricted to the first plate of each ray; and all succeeding pieces in a radial direction, whether free or incorporated into the calyx, are called brachials. In the earlier Inadunata and articulata but not in the Camerata so far as observed, the radials are frequently compound, being constructed of two segments, united by a horizontal suture, which in the organization of the crinoid corresponds to one plate. In most of the genera having compound radials the double ossicles, the two sections of which are called "infraradial" and "superradial," are confined to the right posterior ray, but they occur also in other rays but never in more than three, two of the radials at least being simple.

Recognizing the radials as practically a single plate in each ray, all plates above must be regarded as brachials to which pinnules may be attached. The terms costals, distichals and palmars are appropriately applied to the first, second and third orders of brachials respectively. When there are further divisions in the rays, the plates are designated as postpalmars, or as brachials of the fourth and fifth orders, and so on. A discrimination is also made between fixed and free brachials, the latter often being termed the arms. The arms are composed of one or two rows of plates. All biserial arms are uniserial in the young crinoid and gradually enter the biserial stage by an interlocking of the joints from opposite sides. In most of the families belonging to the Camerata the uniserial type is restricted to the Silurian, except in Hexacrinitæ. Among the Inadunata biserial arms occur only in a few genera found in the Kaskaskia, in the Coal Measures and in the Trias, but associated with the forms having the uniserial type. All Articulata, palæozoic as well as neozoic have uniserial brachial appendages.

The pinnules in a general way are repetitions of the arms on a small scale. When represented they spring alternately on opposite sides from every second joint and every joint bears a pinnule except in cases of a syzygy, in which the syzygyial plates must be counted in the alternation of the pinnules as one ossicle. Syzygies occur among Palæozoic crinoids either in successive series throughout the arm, as in the Heterocrinidæ and Belemnocrinidæ, or there is but one syzygy to each order of brachials, formed by the two proximal plates, as in Poteriocrinus, Dichocrinus, and in most species of Platycrinus. In Dichocrinus the various orders of brachials to the last axillary consist of two plates each, the first non-pinnulate, the upper bearing an arm instead of a pinnule. A similar arrangement occurs above the costals in most species of Platycrinus and it is quite evident that the plates in question, as in Dichocrinus for example, do form a syzygy. This, however, is not the case in such forms as *Platycrinus huntsvillæ* and a few other species. Here the first pinnule is given off from the proximal distichal, and the second on the same side from the first palmar. It shows clearly that the arm partakes of the alternation of the pinnules, and suggests that the armlets are enlarged pinnules. This is shown more conclusively by the structure of *Glyptocrinus dyeri.* While in most species of Glyptocrinus the second bifurcation takes place from the second distichal, that plate in *G. dyeri* gives off in place of an arm a large pinnule, more than twice as large as an ordinary one, which bending outward forms an angle as in the case of a true bifurcation. The second pinnule, which is somewhat smaller starts off from the fourth distichal on the opposite side as in the other species of the genus. All succeeding pinnules are small, and are given off alternately from successive joints.

The oral plates have been the subject of much controversy, but their identification in the different groups is now pretty well established. According to Wachsmuth and Springer the orals are not always represented in the adult. When present they surround the mouth or cover it. They may occupy the whole face of the vental disk or only its median portion. In the former case they rest upon the edges of the radials; in the latter against the perisome. In crinoids with a regular pentamerous symmetry they consist of five pieces interradially disposed, and form the center of the disk. When the symmetry is irregular they are pushed more or less to the anterior side. The former condition prevails among recent crinoids; the latter is the general rule among palæozoic forms. When asymmetrical, the posterior oral by the encroachment of the anal plates, is pushed between the four others, so as to attain a more or less central position. The plate is generally larger than the other four. The orals in all groups in which they are represented consist of five pieces. There is no such thing as an orocentral plate, as some writers have supposed. In some instances the orals seem to be wholly or partly resorbed; the former condition probably is the case among the Camerata, the latter in certain species of the Fistulata. In regard to the Ambulacra it is now generally admitted that the aperture in the tegmen of palæozoic crinoids is not the oral opening but the anus, and the mouth is subtegminal forming the center of radiation, which, however, is not necessarily the geometrical center. The ambulacra follow the grooves along the ventral side of the arms, and extend from the tips of the pinnules to the mouth. Their inner ends are either exposed upon the disk, or covered wholly or in part by plates of the tegmen. The upper face of the ambulacra is occupied by the food grooves, which are roofed over by the covering plates and frequently are boarded by side pieces. In recent crinoids the covering plates are movable from the tips of the pinnules to the entrance to the mouth; but in most palæozoic ones those of the disk are rigid, so far as known, often heavier, and larger than the intervening plates. The disk portions of the ambulacra in the Camerata, if tegminal form a component part of the tegmen, their plates being suturally connected with one another and with surrounding plates; those in the Fistulata rest upon the edges of large interradial pieces. When the ambulacra are subtegminal they enter the calyx by the arm openings, and follow the inner floor to the proximity of the mouth.

The "supplementary plates" comprise all calcareous particles between the basals and orals, and between the rays and their subdivisions. They are interradial, interaxillary or anal. The interradial plates which are separated into interbrachials and interambulacrals, comprise all pieces between the basals and orals interradially disposed, the former being confined to the dorsal cup; the interambulacrals occupy only the spaces between the ambulacra. The interaxillaries, which consist of the interdistichals and interpalmers are located within the axils of the second and third orders of brachials respectively. The anal plates are restricted to the posterior interradial area, and support the anal tube. Another system of supplementary plates occurs in the acrocrinidæ, between the basals and radials. In groups in which the arms are not entirely free from above the radials, the lower arm plates are incorporated into the calyx by means of interbrachials; and the orals are carried inward toward the actinal center by interambulacrals. The supplementary plates increase in number in the growing crinoid. They are undeveloped in the early larva and in the Laviformiæ. In the Fistulata they are represented only in the tegmen, except in the case of the anal piece. The plates vary exceedingly in form and character, being in some groups well developed and rigid, in others irregular and imperfectly formed or mere lime particles within soft tissues. The great variation in the structure of the plates formerly led to the belief that the rigid and regularly arranged pieces, so characteristic of the Camerata, did not belong to the same system as the irregular small pieces which unite the rays in recent forms. A distinction was also made between the ossicles of the tegmen. The heavy, rigid components of the palæozoic forms were called "vault" pieces the irregular smaller ones "disk" plates; and it was supposed that many of the older crinoids had a vault with a disk underneath. That they had two integuments was believed to be indicated by the condition of the ambulacra, which in recent crinoids are exposed, while in palæozoic types they are either completely subtegminal, or the food grooves are rigidly closed by immovable covering pieces. This supposition, however, has proved to be an illusion and to be based upon inaccurate observation. Even in species of Batocrinus and Dorycrinus, in which deception seemed to be almost impossible, it is ascertained from excellent material, that the tegmen consists of but one set of ossicles and that the plates are suturally connected and solid on the outside, but perforated and vesicular within. The condition of the ambulacra in camerate crinoids, whether tegminal or subtegminal, does not represent an essential structural feature, but is a natural consequence of differences in the form and construction of the tegmen in the respective groups and as such cannot be of much value from a morphological or classificatory point of view. Subtegminal ambulacra, as a rule, are most prevalent in species with high dome and bulging arm basis; while forms with a flat or depressed ventral surface generally have tegminal ambulacra. The two styles occur side by side among species of the same genus, and there exist all possible transition forms between the two extremes, *i. e.,* specimens in which the ambulacra are subtegminal at the median portions of the disk, and tegminal near the periphery. By comparing the younger individuals with the older, it appears that the covering of the ambulacra is produced in the growing animal by the gradual extension of the interambulacral areas along the lines of the ambulacra, either completely covering them, or leaving the portions next to the arm basis exposed. The ambulacra of the Camerata, therefore, are covered not by an element unrepresented in other groups, but by small superimposed plates passing out from the disk proper. These plates were quite small in the Silurian species, but change essentially until in the Carboniferous they frequently attain the large size and rigidness of the other plates in the tegmen. As to the closure of the mouth, it is now believed that it was subsequent to the introduction of the anal plate, by means of which the posterior oral was pushed in between the four others so as to close the opening.

The interbrachials and interambulacrals, in most of the Camerata, pass insensibly into one another, there being no line of demarcation by which they may be separated, except that produced by the arms, and it is difficult to understand how these plates can be distinct structures as is generally supposed. That their morphological relations are very close is conclusively shown by the fact that the very same plates which in the Actinocrinidæ and Batocrinidæ are strictly interbrachial, are in the Platycrinidæ and Hexacrinidæ partly interbrachial and partly interambulacral, and in the Cyathocrinidæ exclusively interambulacral. That the plates of the two hemispheres occasionally are interrupted (notably in Batocrinus, Catocrinus and Strocrinus, is readily explained by the large increase that here takes place in the number of arms, which prevents the development of interbrachials around the arm bases.

Essentially different is the ventral structure of the Fistulata, which have no interradial plates in the dorsal cup, the anal plate excepted, but which have these pieces extensively developed in the tegmen. Four of the interambulacral spaces are raised but little above the level of the arm bases, while the posterior area is extended abruptly upward, and is formed into a tube or sac of variable shape and size, rising beyond the tips of the arms. This sac, which may be regarded as a greatly extended anal area, probably lodged a large portion of the visceral mass. The sac is generally composed of longitudinal rows of hexagonal plates, and is often perforated by pores. The structure at the four other sides of the disk is rarely observed except among the Cyathocrinidæ in which it is probably more substantial than in other groups. In Cyathocrinus there are six plates, interradially disposed, resting against the inflected upper edges of the radials, the lateral margins being covered by the ambulacra. Four of them are large and of equal size, the two others, lying at the posterior side, are quite narrow and enclose a madreporite. The margins of the larger plates are roofed over in perfect specimens by numerous small irregular pieces, while the perforated plate is exposed to view.

Most of the Ichthyocrinidæ have interbrachial plates, which in some forms are large and massive, in others small; some are arranged regularly, others irregularly, but all are movable. The plates of the tegmen are very minute and irregularly arranged, the ambulacra are tegminal, and the mouth and food grooves are open. Thus there is among palæozoic crinoids a tegmen having all the characteristics of the disk in recent species, demonstrating conclusively that the disk as a ventral structure is not confined to the neocrinoids as generally supposed. Moreover, a careful study of the various tegmens in the different groups shows that there are represented among them all intermediate stages from the simplest disk to the most rigid and complicated "vault" of the Actinocrinidæ, and that the so-called vault is a highly modified form of the disk.

The anal plates bear a most important part in the phylogeny of palæozoic crinoids, and they are among the best criteria for purposes of classification. When present they occupy, in the Camerata, the median line of the posterior area so as to divide the interbrachial plates into two equal sets, and being in rows containing an odd number they have the effect, as it were, of breaking up the middle plate into two, as in cases where no anal plate is inserted between the sections. The anal plates vary considerably in their position and distribution, and, in some groups are absent altogether. As a rule they are largely represented in species with a stout tube or a lateral opening, and are wanting or are poorly developed when the anus is central.

Among the Fistulata the term "anal plates" has been applied to two ossicles of different origin, the one radial, the other interradial. The latter is the homologue of the first anal of the Camerata, and rests upon the truncated posterior basal. The other, which is not a supplementary plate but the lower section of the compound right posterior radial, performs anal functions only in certain genera. When both plates support the ventral sac as in most of the Poteriocrinidæ, the second, which is actually the first or lowest in point of position, is placed obliquely to the right of the other, without disturbing the orientation or the alternate arrangement with the basals. Both plates undergo many modifications, and the various phases as they occur in different geological stages, may be regarded as excellent criteria for generic separation. The earlier Camerata have neither a radi-anal nor a regular anal plate both of which make their appearance with the increasing size of the ventral sac. As this grows larger, the two posterior radials which previously were in contact laterally, part, and the anal piece is introduced to support the sac. Afterwards when the central sac attains still greater proportions, the supraradial is shifted to the right in a position almost directly above the right postero-lateral basal, so as to give to the infraradial which retains its place, a rather oblique direction. In the Poteriocrinidæ, in which the lower faces of the costals fill up the whole width of the radials, leaving no room for attachment, the lower plates of the sac enter the calyx. At the close of the Carboniferous, the sac becomes reduced again to its former significance, the anal plates generally disappear, and the two posterior radials meet again laterally. This interpretation of the origin of the anal piece (or plate x as it is frequently called) differs essentially from that given by the English writers on the crinoids who regard the plate as primitively derived from a brachial, which in time passed down from above into the dorsal cup. These authors also claim that in the older forms with a compound right-poster radial, such as in Iocrinus and Heterocrinus, the plate in question is supported by the supraradial and does not touch the infrabasal; but that, further, in Hybocrinus and Dendrocrinus, it passes down from above the radial and finally rests with its lower half between the two posterior radials, then being supported partly by the basals and partly by the infraradial; and that in Carabocrinus, Botryocrinus, and allied forms the said ossicle has sunk to a line with the radials. Evidently there have been confounded plates which are morphologically quite distinct. In the above genera the plate under consideration is represented only by Dendrocrinus, Carabocrinus, and Botrycrinus. The piece to which reference is made in Iocrinus, Heterocrinus and Hybocrinus is a plate of the vental sac, as is conclusively proven by Dendrocrinus, otherwise it must be admitted that the plate would be represented twice in the same specimen, by the true anal plate which rests upon the basals, and by the tube plate (of Iocrinus) which is supported by the supraradial. The anal area of Dendrocrinus is like that of Poteriocrinus, only that the supraradial of the former does not move away from the infraradial, as it does in the latter. This is not necessary in a form like Dendrocrinus in which the arm-facets occupy a comparatively small part of the radials and leave ample space for the support of the tube. In the Poteriocrinidæ, however, in which the upper surface of the radials is taken up completely by the costals, the foundation of the tube is not adequate to the width and the deficiency is manifestly made up by a shifting of the supraradial and the introduction of another plate for the support of the tube.

In the anal interradius, as it appears in the various families of the Camerata, a close agreement is found between the anal plate (x) and the tube plates of the Fistulata on one side, and the anal plate and interradials on the other. Admitting this, a more satisfactory explanation of the anal plates of the Fistulata is reached than that usually given. If it were true that what is known as Bather's plate x of Iocrinus passed down in later forms from above the supraradial to the basals, it would certainly require a partial revolution of the whole tube; but this is clearly disproved by the structure itself, which throughout its full length is composed of hexangular pieces, regularly arranged in longitudinal rows. Bather also regards the anals of the Camerata as morphologically distinct from those of the Fistulata, while there actually seems to be good grounds for believing that the plate x of the latter is homologous with the first anal in the Camerata, and also with the anal which for a time occurs in the larva of the Comatulæ; but that the Camerata have no radi-anal for the simple reason that they have no compound radials. The anals of the Icthyocrinidæ are arranged in a similar way to those in the Fistulata. Some of them have only a plate x represented, others only the radi-anal, still others both, and some of them have no anal plate at all. The Larviformia have neither the one nor the other, although they have frequently compound radials. The anal tube where it occurs, is inserted intermediate between the radials and orals.

The systematic arrangement of the crinoids as proposed by Wachsmuth and Springer is one that will require but few material changes for a century to come. Based entirely upon morphological principles, with a completeness and wealth of ontogenetic and phylogenetic data that are rarely obtainable among fossil organisms, the essential elements of classification are more firmly grounded than perhaps in any other group. No attempt in recent years towards a natural and rational orderly arrangement of a large and complex assemblage of organic remains has been so signally successful. Nor has the evolution of the groups in time and space been neglected. For classificatory purposes special emphasis should be placed upon a number of features. Of very great importance is the growth of the stem, whether the young joints are formed beneath the proximal ring of the calyx or beneath the top stem joint. Particular stress is also to be placed on the alternate arrangement of the stem with the lower ring of plates in the calyx, by which it is determined that by far the large majority of the neozoic crinoids are dicyclic and not monocyclic. Of exceptional significance are certain features in the Ichthyocrinidæ which clearly indicate affinities with the Apiocrinidæ, Bourgueticrinidæ, Eugeniacrinidæ, and Comatulæ, all five groups of which are placed together among the Articulata. All have a disk composed of small, irregular, and movable pieces, with open mouth and open grooves, all are dicyclic, but the infrabasals coalesce with the top stem joint, so as to prevent the introduction of new joints directly beneath the calyx. From the Articulata are excluded the Encrinidæ and Pentacrinidæ which are generally arranged with them. The infrabasals of the former of the two families are very small, or are resorbed in the growing animal, but they do not coalesce with the top joint which is therefore for the time being the youngest joint of the stem. The Pentacrinidæ have, through the Encrinidæ, close affinities with the Poterocrinidæ, and probably are their descendants, but if they really belong to the Inadunata as is now believed they represent somewhat abberant types, for the lower brachials take part in the calyx.

Not less important than the morphological contributions to a knowledge of the stemmed echinoderms are the advancements made in their classification, and it is safe to say that the systematic arrangement of the group is now practically settled for a century to come.

The three groups of stalked echinoderms, the cystids, blastoids and crinoids are regarded as orders of equal rank. The forms of the first are earliest in time and lowest in taxonomic position, and may be considered the ancestral types of the other two. The crinoid type itself is a very old one, dating from the Cambrian, in which it was already in a high stage of development. During the Ordovician the cystidian features almost wholly disappeared. The crinoidal group is remarkable for the persistency it has shown in preserving its pentamerous symmetry, and although the introduction of the anal plate was a disturbing element so great as to well-nigh produce a lasting bilateral arrangement, the former type was finally permanently retained.

The two primary groups of crinoids which were formerly almost universally accepted are abandoned. These are the Neocrinoidea and Palæocrinoidea. In their stead are recognized three principal subdivisions: Inadunata, Camerata and Articulata. It is particularly noteworthy that this ternate grouping of the crinoids is essentally the same as Wachsmuth originally proposed more than twenty years ago and that after being compelled by students of the recent forms to abandon it and to substitute others, a final careful survey, in the light of recent discoveries, of all crinoids both living and fossil, has clearly shown that the main subdivisions first suggested are essentially valid and are applicable to all known forms. The criteria for separating the crinoids into orders are briefly:

1. Condition of arms, whether free above the radials, or partly incorporated in the calyx.
2. Mode of union between plates of the calyx, whether movable or rigid.
3. Growth of the stem, whether new plates are formed beneath the proximal ring of the calyx or beneath the top stem joint.

The simplest forms of the Crinoidea Inadunata have the dorsal cup composed invariably of only two circlets of plates or three where infrabasals are present; there are no supplementary ossicles except an anal piece which is however not always present; the arms are free from the radials up. In the construction of the ventral disk two different plans are recognizable and upon these are established two subgroups—the Larviformia and Fistulata. The former has the disk in its simplest possible form, being made up of five large orals arranged in a pyramid; the second has the ventral side extended into a sac or closed tube, often reaching beyond the ends of the arms.

The Camerata are distinguished by the large number of supplementary pieces which bring the proximal arm plates into the calyx, thus enlarging the visceral cavity. All plates are heavy and immovable and the mouth and food grooves are tightly closed.

The Articulata have to some extent the incorporation of the lower arm plates with the calyx, but the plates are movable instead of rigid. The mouth and food grooves are open. The infrabasals are fused with the top stem joint which is not the youngest plate of the stalk. According to whether or not the pinnules are present two suborders are recognized: the Pinnata and Impinnata.

For the family distinctions the supplementary plates constitute excellent features for classification, and while of small importance physiologically, they form a good example of a truth which is met with everywhere in biology that characters of physiological value are not always of equally great utility for purposes of classification. Of prime import in this regard are the anal pieces.

Of the three groups of crinoids having ordinal rank, that constituting the Camerata is by far the most important. An analysis of the families is briefly as follows:

I. LOWER BRACHIALS AND INTERBRACHIALS FORMING AN IMPORTANT PART OF THE DORSAL CUP.

A. Interradials poorly defined.
Lower plates of rays more or less completely separated from those of other rays and from primary interradials by irregular supplementary pieces; anal interradius divided by a row of conspicuous plates; (dicyclic or monocyclic) ....RETEOCRINIDÆ

B. Interradials well defined.
1. Dicyclic.
a. Radials in contact, except at the posterior side....THYSANOCRINIDÆ
b. Radials separated all around ....RHODOCRINIDÆ

2. Monocyclic.
a. Radials in contact all around. Symmetry of the dorsal cup if not strictly pentamerous, disturbed by the introduction of anals between the brachials only ....MELOCRINIDÆ
Arms borne in compartments formed by partitions attached to tegmen; dorsal cup perfectly pentamerous; plates of calyx limited to a definite number .......................CALYPTOCRINIDÆ
b. Radials separated at the posterior side by an anal plate. First anal plate heptagonal, followed by a second between interbrachials ....BATOCRINIDÆ
First anal plate hexagonal, followed by two interbrachials without a second anal; arms branching from two main trunks by alternate bifurcation ...........................ACTINOCRINIDÆ

II. BRACHIALS AND INTERBRACHIALS ONLY SLIGHTLY REPRESENTED IN THE DORSAL CUP.

1. Dicyclic.
Radials in contact except at the posterior side........CROTALOCRINIDÆ

2. Monocyclic.
a. Radials in contact all around; base pentagonal......PLATYCRINIDÆ
b. Radials separated on posterior side by an anal plate; base hexagonal. Basals directly followed by the radials.......HEXACRINIDÆ
Basals separated from radials by accessory pieces.......ACROCRINIDÆ

While the morphological and classificatory chapters of the monograph on North American crinoids appeal more directly to palæontologists interested in the biological side of the subject, the descriptive part will be of greatest practical value to the stratigraphical geologists. This portion of the work is a complete revision of all Camerata known from this country up to September, 1894. Every species is fully and clearly described, compared with closely related forms, beautifully illustrated and referred to its proper geological horizon; the full literature of each and the localities where it occurs are also given. All the species have been redescribed from the most perfect material that could be found in all museums and private collections. The liberality shown Wachsmuth and Springer by those persons who possessed suitable specimens in placing them at free disposal is to be commended in the highest terms. It was the means of making accessible nearly all the type specimens known, and in fact, most of the crinoid material in the country. In addition there were the authors' own magnificent collections which contain more than nine-tenths of the known American species and over two-thirds of the European, of which many are represented by scores and even hundreds of individuals. These large collections gave new ideas regarding the limits of the different species and enabled a discrimination to be made between species and varieties, and between the young specimens and the adults, which led to the elimination of a large number previously recognized. The establishment of species on rational morphological grounds and not on trivial superficial or accidental characters which are relatively unimportant as classificatory criteria is a point of excellence which cannot be too highly praised, and one which should be the central consideration in the revision of the nomenclature of all groups of fossils as well as living organisms. That there has long existed a burdensome and extensive synonomy among crinoidal as well as all other classes of animals no one who has given the subject attention will for a moment question. The most casual consideration has rendered apparent the urgent necessity of a careful and complete revision of nearly all groups. The wide geographical distribution of many species and the concomitant changes of environment may readily be referred to as among the chief causes of local variation in species now living. Among fossil forms, however, there is in addition a greater factor of geological range which must be carefully considered. Notwithstanding the careful and conscientious labors of a large number of writers, little attention has been given in the description of species to these highly important factors which for the most part have been entirely overlooked. But the contributions to synonymy have not originated wholly in the manner mentioned. A still greater number of invalid names have come from a practice which cannot be condemned in terms too severe. It is the tendency to describe species, and genera also, from imperfectly preserved material, often from a single aberrant specimen, without making adequate comparisons with allied forms. This deplorable state of things, which in the natural course of events should be continually getting better with the advance of knowledge, appears of late years to have become so virulent that it is a serious question whether such work should not properly be ignored altogether. It will ever remain one of the crowning glories of Wachsmuth and Springer's efforts that they have shown no sympathy whatever with such work; and that with calm, untrammeled and truly scientific judgment they have relegated to oblivion such a large number of worse than useless specific names which have so long stood as a menace to progress in this field of palæontologic research. A full list of synonyms so far as they apply to the Camerata is given.

The preparation of the monograph occupied over seven years of continuous work, but this gives but a faint idea of the vast amount of labor involved. This work will be indispensable to all future writers on crinoids, as well as to the collector in the identification of his material. It embraces the whole literature on the subject and thus dispenses wth dozens of papers which are not accessible to the student. Besides it has the great advantage that the same terms are used throughout the whole work, and that these terms are clearly and accurately defined. The identification of the forms is facilitated by analytic tables for families and genera; and the species are arranged under the various genera in such a way that those most closely related are placed near one another.

CHAPTER III.

HISTORICAL SKETCH OF MINING

The early history of mining in the Upper Mississippi valley readily resolves itself into two quite distinct phases. One relates almost wholly to the development of the lead industry; the other to the growth of coal-mining. The first had a fundamental influence upon the early settlement of the region and the establishment of routes of commerce which persists even to the present day. To the second main phase economic importance came later.

Champlain's far-sighted policy of winning the good graces of the Indians of western Canada rapidly bore fruit. By means of it the fur-trade of the Northwest was long retained by the French, almost to the complete exclusion of all other nations. Before the middle of the Seventeenth century French missionaries had already penetrated to the head of the Great Lakes and to the Mississippi river. In rapid succession traders established, at advantageous points, suitable, and often fortified, depots. Because of a lack of proper waterways to the westward the Upper Mississippi region was long the halting place of French advancement; although occasionally the hardy *coureurs des bois* passed on into the unknown country beyond, even to the Rocky mountains.

It has been long commonly regarded that the first mining within the boundaries of our state was undertaken by Julian Dubuque. It has been related, that in 1788 he began mining lead-ores on the west bank of the Mississippi river, in northeastern Iowa, within the corporate limits of the present city bearing his name. Dubuque gave the place the name of "Spanish Mines," and the patent granted him by Spain eight years later thus distinguished the tract. The year 1788 is thus generally counted as the date of discovery of lead and zinc deposits in Iowa.

A century and a quarter has passed since Dubuque first began mining. It now appears than an even longer period had elapsed before Dubuque's time in which lead was taken out of Iowa-land. Moveover, the first knowledge and mining of lead in America belongs properly to the present Dubuque region. The circumstances surrounding this early development of the oldest industry of our State have at this time a special interest.

The mineral galena, the common ore of lead, occuring in bright sparkling masses, appears to have been known to the aborigines of the Mississippi valley long before the advent of white men. It is found in many tumuli of the so-called Mound-builders. It was brought in by the Indians to some of the very first French posts established in the region. In the first half of the last century the Sioux Indians of Minnesota and Iowa were accustomed to inlay with metallic lead in geometric designs their catlinite pipes. This was probably not a recently acquired accomplishment but had its origin in the long ago.

As early as 1634 Europeans had already penetrated nearly, or quite to the Mississippi river. In order to stimulate the hunting of the fur-bearing animals the French soon introduced the use of fire-arms among the Indians; and with it grew a strong demand for ammunition. As the traders garnered furs they also kept a sharp look-out for minerals suitable for moulding into bullets. Their Indian allies early conducted them to the district, long afterwards designated as the Dubuque country, where they found ample deposits of the mineral they so much sought. So rich proved the mines that they soon in fame surpassed even the fur-interests of the region.

The early history of lead-mining in northeastern Iowa is inseparably interwoven with that of southwestern Wisconsin and northwestern Illinois. Geologically there is only a single circumscribed field. The division of the lead-bearing country by the Mississippi river did not deter the early traders from dealing on both sides of the great stream. Even Julian Dubuque operated in Illinois as extensively as he did in Iowa.

The first white man to visit the lead region and to leave a record of his movements was a Frenchman by the name of Jean

Nicolet.[76] In the autumn of 1634, after having discovered Lake Michigan, this explorer entered Green bay, and passed up Fox river to the portage to the Wisconsin. Although he appears not to have actually passed over the portage or to have descended the latter stream to the Mississippi river, as Neil[77] and others have fancied, and thus reached the district in which the lead abounds, he seems to have made the Indians fully acquainted with the use of fire-arms. Whether he saw or even heard of lead among the Indians is not clearly recorded.

When, however, twenty years later (1655), Radisson and Grosseilliers[78] entered the region they visited among others the Mascoutin and other Indian tribes, in the vicinity of the present city of Dubuque. "In their country are mines of copper, of pewter, and of the lead. There are mountains covered with a kind of Stone that is transparent and tender, and like to that of Venice." This reference to pewter suggests that they also noted the occurrence of zinc. These travelers actually reached the Mississippi river and spent some time upon its banks.

Marquette and Joliet, in 1673, followed Nicolet's route to the grand portage of the Fox river, passed over to the Wisconsin river, thence down that stream to the Mississippi river and on to the latter's lower reaches. Marquette's Journal,[79] published sixteen years later, makes numerous references to the minerals of the Upper Mississippi valley. On his voyage down the great river he passed the lead region, where mining was perhaps going on, at least he must have had some direct knowledge of the location and product.

In 1687, Joutel[80] notes, that there were mines of lead in operation. Hennepin's map of the Upper Mississippi made the same year (1687) shows lead mines located near the present town of Galena, Illinois.

The evidence appears ample to sustain the contention that by the Indian fur-hunters and doubtless by many of the early French *voyageurs* who left no written record of their work, as

[76]Shea: Discovery and Exploration of Mississippi Valley, p. 20, 1853.
[77]History of Minnesota, p. 101, 1882.
[78]Colls. State Hist. Soc. Wisconsin, Vol. XI, p. 93, 1888.
[79]Jesuit Relations and Allied Documents, Vol. LVIII, p. 94, Cleveland, 1899.
[80]Journal historique, Paris, 1713.

Mills has suggested,[81] lead-ore was mined and smelted in a crude fashion in this region before the year 1650. This was about the same time that the actual mining of the mineral was undertaken in other parts of our country. Along the Atlantic border mining of lead-ore near Austinville, in Wythe county, Virginia, and at Middletown, Connecticut, commenced in 1650. In the same year lead-mining was first carried on in far away Pima county, Arizona. Thus, in the three most distant parts of our present National domain lead-mining was simultaneously begun.

Although Nicolas Perrot has been sometimes credited with the first discovery of lead-ore in the Upper Mississippi region, in 1682,[82] the mineral had already been mined there for a quarter of a century, and perhaps for a very much longer period before. Perrot had been in the upper Mississippi region since 1675, when he passed up the Fox river.[83] In the succeeding five years he appears to have visited most of the western tribes of Indians. In 1681 he was engaged in the district in trading. It may be that he discovered lead at this time. He probably was acquainted with its occurrence and mining several years before he actually began operations and built his trading-post below the mouth of the Wisconsin river, at a point which appears to have been nearly opposite the present city of Dubuque. This was in 1690; and at the same time he opened mines and erected a furnace.[84] His sudden determination, as record shows, to engage in mining after the Pottawatttamies had brought him samples of lead-ore from one of the small tributaries of the Mississippi river must have had other reasons than mere announcements of the discovery. Within three weeks after this occurrence he had built a post and had begun mining ore.[85] Franquelin's "Carte de l'Amerique Septentrionale," of 1688, already had mines located below the mouth of the Wisconsin river. According to the reports of the time "The lead was hard to work, because it lay between rocks and required blasting; it had very little dross and was easily melted."

[81]Boundaries Prov. Ontario, p. 6, Ottawa, 1877.
[82]Irving: Trans. American Inst. Mining Eng., Vol. VIII, p. 498, 1879.
[83]Stickney: Parkman Club Pub., No. 1, p. 5, Milwaukee, 1895.
[84]Colls. Wisconsin State Hist. Soc., Vol. XIII, p. 273, 1895.
[85]Parkman Club Pub., No. 1, p. 11, 1885.

During the same year lead was brought to Fort Crève Cœur, near the present site of Peoria, on the Illinois river, from the Indian mines on what is now known as the Galena river.[86] The earliest mining of lead on Iowa territory thus dates definitely back at least to the year 1690, and doubtless to a period before 1650.

Five years later one Le Gueur also located a trading-post on an island a few miles above Perrot's, where the lead from the neighboring hills was regularly brought.

By the end of the Seventeenth century lead-mining in the present Dubuque district had assumed considerable proportions on both sides of the river. This is well shown by the unusual activity displayed by Sieur Pierre le Sueur. As early as 1683, with the express view of establishing trade relations in the region, Le Sueur had, with Perrot, visited the Upper Mississippi country. After spending several years in exploratory effort.[87] in this region, he was finally, ten years later, made commandant at Chequamegon bay. His trading-post, built in 1695, on Isle Pelée, in the Mississippi river, above Lake Pepin, became, according to Charlevoix, the center of commerce for the western parts.

During his residence of a decade and a half in this region Le Sueur had become acquainted with its mining possibilities, particularly of the lead, copper and green-earth. First knowledge of the latter he perhaps derived from some associates of La Hontan, who in the winter of 1688-9, had gone up the mythical Rivière Longue—probably the present Cannon river and the upper reaches of the Minnesota river together—and doubtless had discovered the large deposits of green shales so prominently displayed at the mouth of the present Blue Earth river. The locality was in the country occupied by the Aiouez (Ioway) Indians.

At all events Le Sueur returned to France and succeeded in gaining from the King a commission to open the mines. Finally joining interests with D'Iberville, he got back with a numerous body of miners to the New World in 1699. The carpenter of

[86]Hunt's Merchant's Magazine, Vol. XVIII, p. 285.

[87]Shea: Early Voyages Up and Down the Mississippi, p. 89, Albany, 1861.

the expedition was named Penicaut, who was also the narrator. Margry[88] refers to Penicaut's account of the lead region as follows: "We found both on the right and left bank the lead-mines, called to this day the mines of Nicolas Perrot, the name of the discoverer." The Galena river is alluded to as the Rivière a la Mine; and a league and a half upstream was found a mine on the prairie. This was in August 1700.

The important point to note in the present connection is that the Le Sueur party found lead mines opened and in operation on the west bank of the Mississippi on what is now the site of the city of Dubuque. This was 80 years prior to the reputed first finding of lead in Iowa-land by the wife of Peosta, warrior of the Fox Indians, who eight later transferred her rights to Julian Dubuque.

Le Sueur wintered at the mouth of the Blue Earth river, where he built a stockade which he named Fort l'Huillier, after one of the King's chief collectors, who had assayed the ore in 1696. With the opening of spring, Le Sueur, having extracted a quantity of ore, placed 4,000 pounds aboard his boats, descended the Mississippi river and returned to France. He appears also to have discovered some lead-ore farther up the Mississippi river than any mines then opened, at a point which corresponds to the present site of the town of Potosi, Wisconsin. Here he extracted a quantity for his own immediate use.

Probably taking advantage of the information imparted by Le Sueur, as well as of that indicated on Hennepin's map of 1687, De l'Isle's map of Louisiana, published in 1703, notes the location of lead-mines at both the present sites of Galena and Dubuque. The "Map of North America," published in London, in 1710, by Senex, also records the presence of lead-mines on both sides of the Mississippi river at the Dubuque point.

The famous Crozat patents only incidentally effected the Upper Mississippi region, as all efforts at mining were confined to the Missouri district. These patents from Louis XIV were issued in 1712. In the present connection they are of interest only for the fact that they granted for a term of fifteen years a complete monopoly of trade and mining in Louisiana. Special

[88]Mèm. et doc. pour servir la l'histoire des origines Francaises des pays d'outremere, t. V, p. 412.

privileges applied to the discovery and operation of mines, among which, the rights were granted in perpetuity. Little advantage was taken of the patents by Crozat himself, no mining was begun, and he soon transferred his interests, in 1717, to the "Company of the West", which was at that time under the guidance of John Law.

Le Guis, in 1743, found a thriving mining camp on the present Galena river,[89] some twenty mines being in operation in this locality alone. Bauche's "Carte physique de Canada," published in 1752, has located upon it the Upper Mississippi lead-mines. Güttard[90] at this time described the mines as very rich.

At the end of the Seven-years' war between England and France, in 1762, the latter ceded to the former, Canada, together with all her possession east of the Mississippi river. A short time before France also turned over to Spain all of her possessions west of the river. A notable and immediate result was the complete diversion of the French trade of the Upper Mississippi region from its eastern course to the St. Lawrence to a southern direction. British traders pushed westward to the limits of the newly acquired English possessions and beyond.

In 1766, Jonathan Carver[91] reached the Upper Mississippi lead-field by the Wisconsin River route. He locates on his map important lead-mines at the Blue mounds, in Wisconsin, in the largest hill of which were extensive mineral deposits. In the chief town of the Sac Indians, large bodies of lead-ores were also noted. Carver returned by the Wisconsin river and the Great Lakes to Boston, and thence to England, where he made arrangements for another expedition to the interior of America. In 1774 all preparations being completed the party was about to set out, when England's trouble with the colonies compelled the abandonment of the project.

Previous to the year 1769 there had been, in the Mississippi valley, no individual concession of lead-lands granted. On July 5 of that year, one Martin Miloney Duralde filed an application for a tract three arpents wide and the usual (40 arpents) deep,

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[89] Wallace: Illinois and Louisiana under French Rule, p. 274, Cincinnati, 1893.

[90] Hist. de l'Acad. Royale des Sciences, Paris, p. 189, 1752.

[91] Travels through Interior Parts of North America, in years 1766-8, p. 47, Dublin, 1779.

along what is now the Galena river, across the Mississippi from the present site of the city of Dubuque. The grant was signed by Louis St. Ange de Bellerire, the captain-commandant of the Illinois; and by Joseph Labuxière "attorney of the attorney-general, judge, etc., of the royal jurisdiction of the Illinois for the French." In that day it was the custom for the Spaniards to confirm all French land-grants. Duralde appears never to have taken up his tract of lead-land, perhaps for reason of the fact that he soon found that it was located on English territory.

Although the first mining[92] within the limits of the present state of Iowa is commonly stated to have begun in the year 1788 and first operations ascribed to Julian Dubuque, Le Sueur, almost a century before, found lead-mining thriving on the west bank of the Mississippi, while both white-man and Indian had probably engaged in taking out ore from the district for more than half a century longer. Schoolcraft,[93] who visited the Dubuque lead-region in 1820, states that Dubuque's rich discoveries of lead-ores were made by the wife of Peosta, a warrior of Kettle Chief's band of Foxes. This reputed discovery has a tinge of romance as well as a dash of Twentieth Century business method.

As already stated, mining in the vicinity had been in progress for more than a hundred years and was in a very flourishing condition when Dubuque appeared upon the scene. He sought not only to mine lead as others were doing but he endeavored to control the industry. Born in Canada, of Norman parentage, he is described as a man of wonderful energy and singular popularity among the Indians. By divers machinations he secured from the full council of Fox and Sac Indians permit peacefully to operate the mines. Thereby he established a monopoly of all lead-lands on the west side of the Mississippi river. Later (in 1796) he had the Indian grant confirmed by Carondelet, governor of Louisiana, under the title of the "Mines of Spain." Soon, on the east side of the river, the entire lead-bearing districts of what are now Wisconsin and Illinois, were in the hands

[92]Leonard: Iowa Geol. Surv., Vol. VI, p. 15, 1897; also, Calvin and Bain. Ibid, Vol. X, p. 481, 1900.

[93]Narrative Journal of Travels to Northwest and Sources of Mississippi River, etc., p. 348, Albany, 1821.

of Dubuque's men. He built and operated the furnaces. He conducted extensive prospecting parties. He controlled the boats which carried the product down the river to market. In gaining absolute supremacy over the lead industry he displayed remarkable talent. For whatever lead-ores he purchased he established the rate. In market he fixed the price of the refined product. He tickled the fancy and touched the pride of the governmental powers by calling his properties the "Mines of Spain."

Dubuque continued actively in the business of mining and smelting of lead and of the buying and selling of furs until the day of his death in 1810. It was his custom to make two trips a year to St. Louis to market his various products. Until quite recently the ruins of two of his lead-furnaces were still visible in the city bearing his name—one on Eagle Point avenue, near Heeb's brewery, and the other between Main street and the Mississippi river. A third furnace was located south of the city-limits at the mouth of Catfish creek. His residence was nearby, in Kettle Chief's village. After Dubuque's death the Indians burned his house and destroyed all his improvements; but they continued to mine and smelt the lead-ores.

When, in 1803, Spain traded back Louisiana to France, who immediately sold it to the United States, the latter at once sent out exploring expeditions. With a small detachment of 20 soldiers Lieut. Z. M. Pike was dispatched to the Upper Mississippi region. Pike left St. Louis late in the summer of 1805. Of the two objects which he accomplished one was the investigation of the "lead tract," and the other was the pulling down of the British flags which were floating over a number of posts in that region. He found Dubuque "polite but evasive." While Dubuque received the distinguished visitor and his party with a salute from a field-piece, and lavishly entertained him, it was discovered that there were no horses with which to visit the mines which were said to be a considerable distance away. Consequently Pike who was ill at the time did not actually see the mines, and had to content himself with asking questions.[94] According to Dubuque's statement he annually produced from

[94]Exploratory Travels to Sources of the Mississippi, etc., p. 13, London, 1811.

20,000 to 40,000 pounds of lead. These figures were doubtless much too small; since from other authentic sources it is now known that during the last years of his life more than ten times this amount of the metal was shipped yearly to St. Louis, the greater part of it being transported by his own agents and received by his partners in the business, for at this time Auguste Chouteau had already acquired a half interest in the undertaking. The latter also had made an agreement, which both signed, to the effect that all of the Dubuque grant should pass to him at the death of the original grantee. In after years the Federal government refused to recognize the Chouteau claim, the ground taken being that both Indians and the Spanish governor Carondelet gave Dubuque simply permission to work the mines and that this permission was personal to him. There was in the Spanish grant no provision for a survey of the land, nor were other forms customary in making a valid grant followed. Dubuque's original request for "peaceable possession of the mines" was merely endorsed, "granted as asked" (conedido como so solicito.) Long litigation resulted which after being vigorously contested for over forty years and being carried up to the Supreme court of the United States, was finally decided, in 1853, in favor of the Government. This was not only Iowa's greatest case of mining litigation, but one of the famous suits of the country.

In 1807 the United States government announced a new policy respecting the development of the public mineral lands. Such lands were reserved; in Iowa 184, 320 acres being thus set aside. A system of leases was ordered, whereby individuals were permitted to extract mineral for a period of three or five years by paying to the Government a royalty of ten per cent.

During the years immediately following the promulgation of the new ruling large numbers of prospectors and miners entered the region; but they made agreements with the Indians rather than with the Government. It was not until 1816 that the Indian rights were definitely defined and the "tract five leagues square on the Mississippi river to be designated by the President" which the Indian treaty provided, was located in the lead region. The first leases from the Government were not executed until the beginning of 1822, when four miners from

Kentucky located 160 acres each. They were protected by a detachment of United States soldiers.

As the Government, after granting leases failed often to stand by the owners thereof continuous strife prevailed among the miners. Soon they began to pay little attention to the regulations, but carried on operations without license and with the aid of the Indians. Where there was one lease granted there were a score of unlicensed miners. So disastrous to all concerned was the experiment of leasing and so inconsequential was the revenue derived from this source that Congress finally, in 1846, abanoned the plan and a year later placed the lands on the market for sale.

Little wonder that during these years such remarkable industry was displayed by the "Indians," as was from time to time reported.

During the decade which elapsed between the date of Dubuque's death and the destruction of his properties in 1810, and Schoolcraft's visit to the lead-mines, in 1820, lead-mining seems not to have languished much. Nicholas Boiloin, a United States Indian agent who passed through the region in 1810, reported to the Government that the Indians were finding mining more profitable than hunting and were producing during that year 400,000 pounds of the metal. Doubtless many others than Indians, of whom no mention is made[95] were also engaged in mining. At any rate, a Henry Shreeve, in 1810, is reported to have returned from the Dubuque region to St. Louis with a boat-load of lead. It is also known that one George Jackson, a miner, who had come up the river from Missouri, established in the following year a lead-furnace on an island opposite the mouth of Catfish creek[96] (Dubuque's residence site), and took his product by boat to St. Louis. The next year he was joined by one John Miller. There were other white men engaged in this traffic at this time.

A few years later, in 1815, John Shaw began to make frequent trading trips up the Mississippi river from St. Louis. He is said often to have reached the lead region, and to have carried

[95]Coll. Wisconsin State Hist. Soc., Vol. XI, p. 252, 1888.
[96]Hist. LaFayette County, Illinois, p. 394, Chicago, 1881.

back considerable cargoes of metal, one of which contained nearly 150,000 pounds. In the following year George Davenport, who afterwards took up his residence near the Rock Island, conducted the first flat-boat ladened with lead to the Lower Mississippi markets.

Notwithstanding the fact that in 1819 on the east side of the Mississippi river the lead-industry was enjoying prosperity and receiving as newcomers a number of Americans, the west side was closed to their claims, because of the Government's ruling reserving that part of the district for the Indians. At this time Forsyth, the United States Indian agent for the Foxes and Sacs, notes in his journal[97] the extent of the mining. The number, situation, and quality of all the lead-mines between Apple creek and Prairie du Chien are as follows: "The first he places about 15 miles up Apple creek, 'a short mile' from the right bank; the next at Red Hawk's village, 'six miles above the Grand Macoutely' [Maquoketa] on the west side of the Mississippi, but this had been abandoned; the next, four miles up Fever creek [Galena river], on both sides of that stream, flat-boats being able to approach within a mile and a half of the mine, the fourth, six miles above the mouth of the Fever river, on the east side of the Mississippi; the fifth, Dubuque's mines, 'too well known to require any description'; the sixth, 15 miles above the Dubuque mines on the west bank of the Mississippi, six miles up the 'Little Macoutely creek'; the seventh, six miles above the Little Macoutely, but on the east side of the Mississippi; he adds that 'There are many other lead-mines on the Ouisconsin river, but my informant says he never was at any of them.' "

During this year, and for several years following, the flat-boats and keel-boats loaded with lead for St. Louis were frequent sights on the Mississippi river. One James Johnson's boats were particularly numerous.

Schoolcraft, who was the chief narrator of Governor Cass' exploring expedition sent out from Detroit to the Upper Mississippi region in 1820, was particularly attracted to the Dubuque lead-mines. His description of them is the first really intelligent

[97]Coll. Wisconsin State Hist. Soc., Vol. VI, p. 194, 1872.

one of which there is record.[98] Among many other interesting facts he states that:

"The district of country generally called Dubuque's lead-mines, embraces an area of about twenty-one square leagues. Commencing at the mouth of the Little Maquanquitous river, sixty miles below Prairie du Chien, and extending along the west bank of the Mississippi seven leagues, commencing immediately at the Fox village of the Kettle chief, and extending westward. This is the seat of the mining operations formerly carried on by Dubuque, and of what are called the Indian diggings. The ore found is the common sulphuret of lead, with a broad foliated structure and high metallic lustre. It occurs massive, and disseminated, in a reddish loam, resting upon limestone rock, and sometimes is seen in small veins pervading the rock, but it has been chiefly explored in alluvial soil. It generally occurs in beds or veins which have no great width, and run in a certain direction 300 or 400 yards,—then cease, or are traced into some crevice in the rock, having the appearance of a regular vein. At this stage of the pursuit most of the diggings have been abandoned and frequently with small veins of ore in view. No matrix is found with the ore which is dug out of the alluvial soil, but it is enveloped by the naked earth, and the lumps of ore are incrusted by an ocherous earth. Occasionally, however, some pieces of calcareous spar are thrown out of the earth in digging after lead, and I picked up a solitary specimen of the transparent sulphate of barytes, but these substances appear to be very rare. There is none of the radiated quartz, or white, opake heavy spar, which is so common at the Missouri mines. The calcareous rock upon which this alluvial formation, containing lead ore, rests, appears to be referable to the transition class. I have not ascertained its particular extent about the mines. The same formation is seen, overlaid by a distinct stratum of compact limestone, containing numerous petrifications, at several places between the mines and Prairie du Chien. The lead ore at these mines is now exclusively dug by the Fox Indians, and, as is usual among savage tribes, the chief labor devolves upon the women. The old and superannuated men

[98]Narrative Jour. Trav., etc., to Sources of Mississippi River, p. 343, Albany, 1821.

also partake in these labors, but the warriors and young men, hold themselves above it. They employ the hoe, shovel and pickaxe, and crow-bar, in taking up the ore. These things are supplied by the traders, but no shafts are sunk, not even of the simplest kind, and the windlass and bucket are unknown among them. They run drifts into the hills so far as they can conveniently go without the use of gunpowder, and if a trench caves in it is abandoned. They always dig down at such an angle that they can walk in and out of the pits, and I descended into one of these which had probably been carried down for forty feet. All this is the work of the Indian women and old men, who discovered a degree of perseverance and industry, which is deserving of commendation. When a quantity of ore has been gotten out, it is carried in baskets by the women to the banks of the Mississippi, and then ferried over in canoes to the island, where it is purchased by the traders at the rate of $2 for 120 pounds, payable in goods sold. At the profits at which these goods are usually sold it may be presumed to cost the traders from 75 cents to $1, cash value, per 100 weight. The traders smelt the ore upon the island, in furnaces of the same construction used at the lead mines of Missouri, and observe that it yields the same per centum of metallic lead. Formerly the Indians were in the habit of smelting their ore themselves, upon log heaps, by which a great portion was converted into what are called lead-ashes, and thus lost. Now the traders induce them to search about the sites of the ancient fires, and carefully collect the lead ashes, for which they receive $1 per bushel delivered at the island, payable in merchandise."

About this time (1822) a Moses Meeker was conducting important mining operations on the east side of the Mississippi river. Fifty years afterwards he recorded[99] his interesting experiences, and the facts of his connection with the early affairs of the mines.

A year later, 1823, the first steamboat from St. Louis arrived at the Dubuque mines. It was a vessel 118 feet long, and 22 feet wide, and 2,000 tons burden.[100] On board was a passenger by the

[99] Coll. Wisconsin State Hist. Soc., Vol. VI, p. 271, 1872.
[100] Beltrami: Pilgrimage in Europe and America, Vol. II, p. 127, London, 1828.

name of J. C. Beltrami, a former judge of a royal court in the ex-kingdom of Italy, who was on his way to St. Anthony's falls and the Northwest. He writes at some length of the lead industry on both sides of the river.[101]

During this year the Dubuque mines were producing over one-fourth of the total output of the district, or about 1,000,000 pounds of pig-lead.

In 1826 the United States superintendent of lead-mines, a Lieutenant Thomas, reported to Congress that during the year ending June 30, there were over 410 persons engaged in mining in the Fever River district (Illinois).

Notwithstanding the unsettled conditions of the mining industry on the west side of the Mississippi river the first attempts to regulate their relations among themselves were made by the miners in 1830. In June of that year a number of them met near Dubuque, and agreed, among other things, that "every man shall hold 200 yards square of ground by working said ground one day in six."

For a period of twenty years after Dubuque's death the lead-lands were generally regarded as private property, and little systematic mining was carried on there by white men. The miners and settlers who resided on the grant through permission of the Dubuque assigns and Indians were, in 1830, driven out and their cabins burned by the United States troops. The Government asserted its control to these lands as a part of the Louisiana purchase, but claimed that they still belonged, according to treaty, to the Indians, and that therefore they were not open to settlement. After the close of the Black Hawk war and the purchase of the lands from the Sacs and Foxes all claims of the former settlers were ignored by Congress and the lands sold in the regular way. In June 1833, the treaty went into effect, and all Spanish and Indian titles having been quieted large numbers of miners entered the district and began active operations in extracting the ores.

In an account of travels, published in 1833, Caleb Atwater,[102] who visited the Upper Mississippi region at this time, described

[101]Ibid., p. 163 et seq.

[102]Description of Antiquities Discovered in Western Country, etc., p. 355, Columbus, 1833.

the mining activities of the Dubuque district and brought away full statistics. He observed that the product "had to be carried to the Atlantic cities and had reduced the price of lead in all its forms one-half." In the mineral country it was selling at one cent a pound. He expressed the opinion that these are the richest lead mines in the known world.

Featherstonhaugh,[103] who undertook a canoe-trip down the Mississippi river, in 1835, stopped at Dubuque. He noted a marked difference between the character of the lead-ore of this region and that of Missouri. "When the present veins are exhausted, shafts will be sunk still deeper. There is in fact good reason to believe that the whole distance between the lead-mines of Missouri and those of Dubuque's is comprehended in the Galeniferous formation."[104] This notion of the continuity of the Missouri and Iowa lead deposits was one which seems to have been widely held at this time and for many years after. It appears to have originated a decade and a half previous in an argument by Schoolcraft.

Lea (Albert) states[105] that at this time a dozen steamboats plyed regularly between St. Louis and the lead-mines, the voyage taking three days.

The dozen or fifteen years following the close of the Black Hawk war and the throwing open of the Dubuque district to settlement, witnessed a tremendous development in the mining of lead-ores. During this period improved smelting methods, better transportation facilities, and the beginnings of the manufacturing of lead-products were some of the factors greatly stimulating the industry.

The old and crude log-furnaces and ash-furnaces began to be discarded. In 1834 a cupola-furnace was erected by Peter Lorimer at the mouth of the Catfish creek, in south Dubuque—the first structure of the kind built in the state. In the following year two others were constructed—one in the town of Dubuque and the other on the Little Maquoketa river. In this year, also, the first Scotch-Hearth furnace erected in America was built

[103]Rept. Geol. Reconnaissance to Coteau du Prairie, p. 158, Washington, 1836.
[104]Ibid., p. 159.
[105]Notes on Wisconsin Territory, particularly with reference to Iowa District, or Black Hawk Purchase, p. 16, Philadelphia, 1836.

midway between Dubuque and Mineral Point, Wisconsin. Soon after, the second in this country, and the first in Iowa, was erected on the Catfish creek, above Rockdale, in Dubuque county. This was the Watter's furnace; and it is still in operation (1912). This was followed by several others in the vicinity of Dubuque, of which the Brunskill and the Simpson were the best known.

The next few years in the Dubuque lead-region were marked by a rapid multiplication of modern furnaces. By 1840, when the census of Wisconsin was taken, there were in that state alone fifty smelters yielding over 15,000,000 pounds of metal.[106] Owen[107] gives the output of the Iowa part of the district for the preceding year at over 3,000,000 pounds of the refined product. The production of lead in the Upper Mississippi region contintinued to increase until it reached, in 1857, a total of more than a half million pigs (36,000,00 lbs.) Separate statistics for the Dubuque district do not exist. The lead receipts at New Orleans, during the two decades under consideration are instructive. The increase from 1836 to 1846 was from 295,000 to 785,000 pigs.[108]. Receipts then rapidly declined until 1857, when they fell to 18,000 pigs practically extinguishing the trade for that city.

During the later years mentioned lead-receipts at St. Louis also sank. In 1857, at that city and New Orleans together, only 200,000 pigs were shipped, a considerable part of which was from the Upper Mississippi region, but the production of the latter district and of Missouri amounted to more than 485,000 pigs,[109] showing the large output of the more northern country that was being shipped east by way of the Great Lakes instead of south, as formerly, by river.

Already, in 1852, the mines of the Upper Mississippi valley were producing annually over 26,000,000 pounds of metal; which amount was nine-tenths of the total production in the country for that year, and ten per cent. of the world's supply.

[106]Hunt's Merchants' Magazine, Vol. X, p. 552, 1840.
[107]Twenty-sixth Cong., 1st Sess., Ex. Doc., Vol. VI, p. 39, 1840.
[108]Hunt's Merchants' Magazine, Vol. XVI, p. 96, 1847.
[109]Hunt's Merchants' Magazine, Vol. XL, p. 244, 1858.

The first shot-tower in the United States was built at Herculaneum, on the Joaquin river, south of St. Louis, in 1809. Others were soon erected nearby, and in St. Louis. The shot-tower at Helena, on the Wisconsin river near the present town of Hillside, was established in 1833, and gave great impetus to the lead mining industry of the entire Upper Mississippi region. From this time on much lead went east to the markets as shot.

The main stimulus to the mining of lead during the quarter of a century immediately preceding the Civil war was due to betterment of transportation facilities from the Upper Mississippi country to the Atlantic sea-board. In 1841 newspapers of the day report a freight-rate for lead of 93 cents a hundred pounds from the river to the lake at Milwaukee, and a rate from the latter point to New York of 50 cents a hundred. This was a saving of 25 per cent over the New Orleans route. Later this rate was further reduced.

The early change of trade-routes in 1763, from the Dubuque lead-district from an easterly direction to Montreal to a southerly direction by the Mississippi river was wholly political in character. The change back a century later was strictly commercial.

As early as 1822 lead from the Dubuque district was again finding its way up the Wisconsin river to the Portage and thence down the Fox river to Green Bay. From the latter place it was carried by boat to Detroit.[110] Another forerunner of the new diversion of trade was the purchase, three years after its construction, of the Helena shot-tower by Buffalo, N. Y., merchants. Five years after, when the tolls on lead on the Erie canal were greatly reduced,[111] nearly 2,000,000 pounds of bar-lead and 2,614 kegs of shot reached New York in one year from Milwaukee alone.[112]

Another factor which contributed to the change in the routing of lead directly to eastern markets was the unsatisfactory condition of navigation at several points in the Mississippi river. Low water in the stream often prevented shipments from passing the Des Moines rapids for periods of two or three months.

[110] Philadelphia National Gazette, Oct. 19, 1822.
[111] Lapham: Wisconsin, p. 46, 1846.
[112] McLeod: Histtory of Wiskonsan, p. 216, 1846.

In this respect the year 1839 was particularly disastrous. Lack of good facilities for navigation on the Mississippi river might not have turned the course of trade; but being sorely felt by the tradesmen at the same time that other excellent routes were reaching out for business the transformation was rapid, complete, and for all time. The year 1847 may be taken as marking the loss of supremacy by the Mississippi route and the completed ascendency of the Great Lakes way in the lead-trade.

Still another factor joined in sounding the death knell of the southern route. This was the advent of the railroad. By 1850 railroad construction had already started out vigorously westward from the shores of the Great Lakes. Within a decade nearly 5,000 miles of road had been laid and placed in operation in the states of the Upper Mississippi valley. For securing a suitable tonnage the lead-district was one of the first objective points.

With the periods of great prosperity in lead-mining there have come at times declines. In 1846 the McKay tariff-bill, passed by Congress, whereby the prevailing duty of three cents per pound was reduced to 20 per cent. *ad valorem,* depressed the market for a short time. The output did not begin to sink until two years later.

In the next decade lead-mining was profoundly affected by the discovery of gold in California. For a time the mines were all but deserted by the men who fancied richer fields. The industry slowly recovered during a period of years. The mining of zinc-ores helped. In Wisconsin zinc began to reach market in 1860; in Missouri about ten years later. In 1880 the first zinc-ore mined on the west side of the river in the Dubuque district was shipped to Benton, Wisconsin. This was from the McNulty mines, at the head of Julian avenue. Since then many other old lead-mines have been reopened and worked for the zinc-ores which were left untouched when the lead was being taken out.

Later, with the fall in the price of silver and the consequent closing of many of the lead-silver mines of the Rocky Mountain region, attention was again directed to the soft-lead deposits of the Mississippi Valley. But the region to-day is more important as a zinc-field than as a lead producing district.

Beginning with the early days of its prosperity and continuing down to the present time the lead-region has been a constant interest to those who would know of the manner of the occurrence and origin of ore deposits. During the half-century a number of important descriptions of the lead-bearing formations have appeared. In 1835 Featherstonhaugh, the government expert, visited the Dubuque mines.[113] The United States geologist, D. D. Owen, investigated the field in 1839,[114] a revised edition of this report, with numerous illustrations, appearing four years later. This examination was preparatory to a plan for the sale of the public mineral-lands by the Federal government. It was one of the first, and at the same time the best scientific mineral inquiries undertaken in the country up to this time. This is the first real description of the geologic occurrence of the lead-ores, the detailed manner of extraction of the ores, and the location of the mines. As a result of his investigations Owen pronounced[115] the district surveyed as "one of the richest mineral regions, compared to its extent, yet known in the world."

Owen definitely associated the ore deposits with a particular geologic formation, probably the first serious attempt of the kind ever proposed in the country.[116] It was observed that the productive fissures (crevices) generally extended in an east and west direction.

In this year (1839) the four smelters at Dubuque produced about 3,000,000 pounds of the metal.

Owen noted[117] at this time that thousands of tons of zinc ores were lying on the dumps around the lead-mines; and he suggested ways of using this refuse. With keen scientific foresight he anticipated by a generation the commercial demands of the industry. In after years these rejected zinc-ores were gathered up and sent to the smelteries. Zinc-mining finally became more important than lead-mining.

[113]Rept. Geol. Reconnaissance to Coteau du Prairie, etc., p. 158, Washington, 1836.
[114]Twenty-sixth Cong., 1st Sess., House Rep. Doc., No. 239, 161 pp., 1840.
[115]Ibid., No. 407, p. 8.
[116]Schoolcraft's and Featherstonhaugh's previous attempts were merely guesswork, and not based upon broad observations and detailed correlations.
[117]Loc. cit., p. 51.

James Hodge, in 1842, visited the Upper Mississippi lead-fields, and gave [118] a concise account of his observations there.

By Owen the Chippeway Land district was also surveyed and reported upon in 1847.[119] Two years later he made a further report[120] on the geology of the Northwest, in which the Dubuque lead-mines are again described.

The investigations[121] of J. G. Percival, in 1854, were confined mainly to the Wisconsin part of the lead-field. This observer was the first correctly to recognize the presence of faults in this district, and their function in the localization of the ore-bodies.

In his "Metallic Wealth of the United States" J. D. Whitney gave the results of his professional examinations in the Dubuque region.[122] This outline was afterwards greatly elaborated successively in each of the three states of Iowa,[123] Wisconsin,[124] and Illinois.[125]

Whitney observed,[126] as early as 1855, the occurrence of considerable deposits of the carbonate and silicate of zinc in the Ewing mines, on the Little Maquoketa, a few miles northwest of Dubuque.

Actual mining of zinc-ores on a cemmercial basis was commenced in 1860 near Mineral Point, Wisconsin. The production steadily increased in the region, until the ores of this class became the principal mineral mined. The same year the first zinc-smelter in the West began operations at La Salle, Illinois. From that time to the present day this plant received its chief supplies of ores from the Dubuque district. Twenty years elapsed before zinc-ores were first mined for the market in Iowa.

White's inspection of the Dubuque mining district, in 1867,[127] notes signs of a decided revival of the lead-mining industry after a considerable period of stagnation.

118Am. Jour. Sci., (1), Vol. XLIII, p. 55, 1842.
119Thirtieth Cong., 1st Sess., Sen. Ex. Doc., No. 57, 134 pp., Washington 1848.
120Rept. Geol. Sur. Wisconsin, Iowa and Minnesota, 638 pp., 1852.
121Geol. Surv. Wisconsin, Ann. Rept., 1855; also, Ibid., Second Ann. Rept., 1856.
122Metallic Wealth of United States, pp. 403-417, Philadelphia, 1854.
123Geology of Iowa, Vol. I, p. 422, 1858.
124Geology of Wisconsin, Vol. I, p. 73, 1862.
125Geol. Surv. Illinois, Vol. I, p. 153, 1866.
126Geology of Iowa, Vol. I, p. 470, 1858.
127Rept. Geol. Surv. Iowa, Vol. II, p. 339, 1870.

Investigations in Wisconsin by Strong,[128] and by Chamberlin[129] refer only incidentally to the Iowa part of the mining-field.

Recently various members of the Iowa Geological corps examined in detail all the lead and zinc mines at present operating in the state. Calvin[130] described those of the Oneota limestone of Allamakee county. Leonard[131] gave a very complete general account. Calvin and Bain[132] summarized the present developments of Dubuque County deposits. Leonard[133] noted some new developments in Clayton county.

In the mineral industry the economical preparation of the ores for the artisan, after they have been extracted from the earth, is a process as important and as essential to general success as the mining itself. Especial interest attaches to the metallurgical treatment of the lead-ores as practiced in the Dubuque district for so many years from the fact that its history is really a history of lead-smelting in America. In the following notes on the subject the earlier descriptions of the methods are derived mainly from Schoolcraft, while the later phases are taken partly from Bain. On account of the long and intimate relationships of the Ozark and the Dubuque districts comparisons are instituted with the Missouri methods as described by Robertson. To these three sources of information reference may be made for fuller details.[134]

The primary object of ore-smelting being the separation of the pure metal from the dross the process is essentially a chemical one and the various metallurgical functions have for their result the same chemical reactions. In the case of the sulphide-ores of lead, or galena, the preliminary procedure is their oxidation, or "roasting" as it is technically termed, and this is followed by reduction. In details the method of arriving at these reactions varies with the purity and richness of the ores, the magnitude of the operations, the kind and quantity of available fuel, and the sort of necessary accessory materials used in the smelting, or fluxes.

[128]Geology of Wisconsin, Vol. II, p. 643, 1877.
[129]Ibid., Vol. IV, p. 365, 1882.
[130]Iowa Geol. Surv., Vol. IV, p. 103, 1895.
[131]Ibid., Vol. VI, p. 9, 1896.
[132]Ibid., Vol. X, p. 480, 1900.
[133]Ibid., Vol. XVI, p. 298, 1906.
[134]View of Lead Mines of Missouri, etc., New York, 1819. Iowa Geol. Surv., Vol. X, p. 589, 1900. Missouri Geol. Surv., Vol. VI, p. 199, 1894.

To accomplish these reactions on a large scale various types of furnaces are used. These several types are known as the Log-hearth, the Reverberatory, the Scotch-hearth, the Cupola, and a combination of some of these. During the early stages of the industry in the Dubuque district the simple log-hearth was used. With this primitive affair was smeltered the great bulk of the lead-ores prior to the year 1834. In Missouri this type was discarded some years sooner than in Iowa. In some shape or other it served in the region during a period of nearly two centuries. In reality it is only an improved form of camp-fire surrounded by a wall. Commonly the furnace was constructed on a steep hill-side. Three large logs were rolled into the enclosure the ends resting on the side-ledges. Small split-logs were then set up vertically around and the ore in masses of 15 pounds weight was piled on top, 5,000 pounds being regarded as a large charge. The whole was then covered with wood and the fire started. This was kept low, so that the ore could be thoroughly roasted during a period of about twelve hours. For a like period a stronger heat was maintained during which process the metal flowed out into a basin in front. Frequently the process was not complete within the usual time, when another period of twelve hours was required. Compared with modern practise the method was wasteful, only about fifty per cent of the metal in the ore being recovered.

After the accumulation of a considerable quantity of the ''lead-ashes'' the latter were broken up rather finely, washed, and put into the ash-furnace for further treatment. The ash-furnace was built of limestone usually, with a long sloping flue. It was arranged so as to receive the ashes of lead, or residue, from the log-furnace. Since these ashes were already more or less completely oxidized further roasting was dispensed with and the charge at once submitted to a moderately high temperature and reduced, the charred wood in the residue assisting. The broken and washed ashes were charged into the door at the far end of the furnace, with a quantity of sand or crushed flint in alternate layers, and as fast as well-heated were shoved further in until the full charge was made. After about two hours' time the furnace was ready for tapping. The slag was removed first, then the lead, on opposite sides of the furnace. As a general thing a good ash-furnace produced 25 tons of metal before it was discarded or rebuilt. Later it underwent improvement so that before its complete extinguishment in the business it often ran three times this quantity.

Another form of the reverberatory type of furnace, which was largely used and which was more effective than the ash-type, was what is widely known as the air-furnace. It was generally built of stone, sometimes of brick and lined with fire-clay. The hearth was commonly nine to ten feet long, and three to four feet in width at its widest part and had a slope of two inches to the foot towards the center. The grate was placed at right angles to the furnace and was two by five feet in size. Between it and the furnace a bridge of fire-brick was built, over which the flame passed.

The sulphide-ores were charged at the upper door of the furnace, a thousand or fifteen hundred pounds at a time. They were spread evenly over the hearth. The temperature was at first kept low, during which period partial oxidation of the ores took place. After a time, one or two hours, the heat was raised slightly, although not sufficiently to permit fusion. Reduction followed and the lead began to flow into the receptacle provided for the purpose. When the flow of metal began to diminish the operation was repeated, the attendant adding some of the ashes from the ash-pit for the double purpose of making the charge less liable to fuse and of aiding the reduction process by means of the partially charred wood in the ashes. The operation lasted ten to twelve hours, when the residue in the furnace was all oxidized and no more metal was obtainable from the earthy impurities remaining. The residual mass was then removed and a new charge introduced. The lead in the kettle was skimmed with chips of wood and cast into pigs. The process required the time of one attendant and one helper, and consumed about a cord and a half of wood. The recovery was between 80 and 90 per cent of the metal in the ores.

A crude form of the cupola-type of lead-furnace was introduced into the Iowa territory in 1834. The Lorimer smelter near the mouth of the Catfish creek, at the south end of Dubuque, one in the city of Dubuque, and one on the Little Maquoketa river were of this kind. They were soon supplanted by Scotch-hearths. It was, however, a great improvement upon the then existing furnaces, since there was a saving of 65 to 70 per cent of the metal or 50 per cent over the old log and ash-furnaces.

For small plants the Scotch-hearth is probably the most efficient and satisfactory type of furnaces, all things considered. The procedure depends upon the same principles as in the case of the reverberatory process, but the roasting and reducing are carried on simultaneously. The plant consists of a rectangular basin, the back and sides of which are carried up a foot or more, leaving the front and top open. The basin is kept full of molten lead, and on this the fuel and ores are charged. A blast of air plays on the surface, raising the temperature and oxidizing the ore, which is then reduced principally by the heated lead-sulphide which has not been oxidized, and also by the carbon. The lead flows off into the well in front of the basin.

The basin is always kept full of lead. If a furnace is being started, it is filled by melted pig-lead. An ordinary hearth holds about 2,500 pounds of ore. The residues from previous runs are added, with a little charcoal; then charges of mixed charcoal and crushed galena, 20 to 30 pounds at a time. The lead is gradually extracted by oxidation and reduction. A little lime may be added from time to time and the slag scraped off. The molten metal as it runs into the well in front of the furnace is ladled into moulds. Two men treat 3,000 pounds of ore during an eight-hour shift. The recovery is 80 to 90 per cent of the metal. Fifteen bushels of charcoal are consumed per shift.

Since the slags contain often as high as 30 per cent of lead they are run in a second hearth of similar construction as the first. In operation charcoal or coke is used, in the latter case the lead produced being slightly harder. The two hearths are run alternately, being fired sixteen hours and at rest eight.

The Scotch-hearth lead-furnace is an instructive illustration of how in some cases simple old-fashioned methods are best adapted to meet local conditions. As the Watters furnace, at Rockdale, is now operated there is a more perfect recovery at less cost than would be possible in the most improved and modern high-priced plant. Although the modern cupola-furnace is not now in operation in Iowa, it is probable that its establishment would be not only profitable but would very greatly stimulate mining. The type now generally used throughout the Missouri lead-fields would, on a somewhat smaller scale, fit the known local conditions in this state.

The smelting of the zinc-ores is a more elaborate process than that of lead. If it is to be accomplished profitably and with a saving of the valuable by-products it requires large investment. The old and common process of spelter-making with hand-rake reverberatory furnace for driving off the sulphur, and with coal-fired Belgian retorts for saving the metal, is not to be recommended, except where the proper fuel is abundant and cheap, and even then the loss of the sulphur is serious. The question of spelter-manufacturing in the Dubuque district has not been agitated for reason of the fact that the zinc sulphide-ores have not been as yet extensively mined. Very considerable bodies are now being exposed and it is merely a question of time when the subject will have to be passed upon. All indications point to the probability of the zinc blende mines becoming a notable feature of the region.

With the inevitable uncovering of large bodies of low-grade and complex ores it becomes necessary to concentrate and separate the metallic minerals before the ores are smelted. In the Dubuque region there are four principal classes of ores. These ores graduate into one another to a greater or less extent. They comprise the normal lead-ores (galena), dry-bone ores (smithsonite), mixed bone- and jack-ores, and mixed jack- and pyritiferous jack-ores (blende). The lead very rarely occurs in any considerable amounts so closely associated with the zinc minerals as to need separation by milling. The greater part of the lead-ores are very pure and only need to be washed free from the soft earth to be ready for charging in the furnace. In the general downward migration of the ore-materials there has been a marked concentration of the metallic sulphides in the zone above permanent water-level, which fact accounts partly for its freedom from impurities. The mineral is of nearly theoretical purity, ores from the Karrick mine assaying 86.43 per cent lead. It does not contain silver in more than a trace, although some of the ores from the Illinois field are said to yield silver enough to notably influence the price of the ores.

Whenever lead-ore occurs mixed with those of other metals, as at the Ahern mine of the Dubuque Lead Mining company, where it, together with marcasite, filled solution-cavities in a blue dolomite, and at the Pike's Peak mines, where some of the lead-ore is in intimate association with both blende and marcasite, it is readily removed owing to its high specific gravity. As this is between 7.4 and 7.6 the galena comes down on the screens of the first jig. Very little lead-ore has been yet jigged at Dubuque. It is commonly passed through the log-washer only.

The dry-bone ores, proper, occur, as does the galena, mainly in the upper weathered parts of the rock-section. They are commonly hand-sorted, washed with log-washers, and hand-picked. To a limited extent they are now being milled, and a considerable proportion of the ores of the region are marketed direct. Dry bone assumes a wide variety of forms from the clear translucent stalactitic variety, through honeycomb bone, to rock-bone. Analyses of the ores from the Cripple Creek mine yielded 47.3 per cent of metallic zinc, and 2.1 per cent of iron. The latter is in the form of the oxide as ochre or ocherous clay mixed with ore, and is completely removed by the washing.

The mixed bone- and jack-ores occur at and about ground-water-level. At the present time they are the ores most extensively mined. The iron exists partly as the sulphide and partially as the oxide. In milling the former is not completely separated. Nor is it possible to make a complete separation of the bone and jack, on account of the small difference in specific gravity.

The blende and blende-marcasite ores occur below water-level; these are the ores which will be most largely mined in the future.

The principal mill of the district is that of the Dubuque Ore Concentrating company. This custom-mill has a capacity of fifty to eighty tons in ten hours, the amount depending somewhat on the character of the ores. The ores are passed first through a 9x15 Blake crusher, then through 14x20 rolls, are elevated and then sized by means of a trommel-screen having half-inch round holes. The over-size from the screen goes to a second pair of rolls and back to the elevator. The undersize passes to a five-cell Cooley "rougher" jig, with 26x36 plungers, and 24x36 inch screens, which are grates with three-sixteenths-inch holes. The eccentrics are driven at 140 revolutions a minute and have a stroke of 3/8 to 3/4 inch. The tailings here are hoisted and laundered away. The middlings are drawn and re-ground by a third set of rolls. The re-ground material, with the fines which passed through the screens, is elevated and run over a second, six-cell, "cleaner" jig, with plungers and screens 24x36 inches. The screens are 4; 6; and 8-mesh. The eccentrics of the first three plungers make 200 revolutions a minute. The last three are driven 225 revolutions per minute. This plant uses 400 gallons of water per minute, a part being caught in a pond and run through in a circuit. The power for such a plant is properly about 45-H. P.; but in this plant both engine and boilers are considerably in excess of this. In running, two men are required in the jig-room, one at the engine, and two to three at the crusher.

Although the mining of iron-ores has never attained the position of an important industry within the limits of Iowa deposits of this metal attracted the attention of the first French explorers of the Upper Mississippi region. Jesuit maps published as early as 1672 locate "Mines de Fer" in the driftless area around the mouth of the Wisconsin river. Joliet's map of 1674 seems to indicate similar deposits on both sides of the great river at this point.

Until quite recently little use has been made of any of the iron-ores of the state. Owen,[185] while examining the mineral deposits of the Dubuque district, considered that large bodies of iron-ores occurred in this region, as extensive as those of Tennessee.

In 1857 Worthen reported good iron prospects in Henry county.[186] These were of Carboniferous age. Whitney[187] mentioned a number of workable iron-ore deposits in the northeastern part

[185]Twenty-eighth Cong., 1st Sess., Sen. Doc., Vol. VII, No. 407, p. 52, 1844.
[186]Rept. Geol. Surv. Iowa, Vol. I, p. 213, 1858.
[187]Ibid., p. 420.

of the state. White[138] noted a number of possible localities that might prove valuable in time.

Of late years there has been some new development of hematite and limonite ores in Allamakee county. These deposits were fully described by Calvin[139] in 1895.

In the normal course of national development the use of large fuel supplies belongs to a period when a country has become thickly populated, when the arts and manufacturing enterprises have attained great importance, and commerce has assumed large proportions. In America, however, mineral coal as a fuel appears to have been known at a very early day. How long before the advent of the European it was used is largely a matter of conjecture. Strangely enough its discovery belongs to the interior of the continent rather than to the Atlantic sea-board, where the first permanent European settlement took place, where it is now so extensively mined, and where it is known to be so widely distributed. In the Continental Interior the discovery of coal antedates that of the East by at least half a century; while in a limited way to be sure, its use by the Indians is now known to go back to a still more remote period.

Heretofore the discovery of coal in America has been dated back only to the beginning of the Eighteenth century. The earliest record in Pennsylvania is 1704, twenty years after the privilege of colonization was granted to Penn. Anthracite was not known in the Wyoming district of Pennsylvania until 1766; and its discovery in the Lehigh valley took place 25 years later. Virginia coals were mined for the first time near Richmond, in 1750; and at the close of the Revolutionary war they were shipped for the first time from that district to Philadelphia, New York and Boston.

In this country the earliest definite mention of the existence of mineral fuel in the form of coal appears now to be in the Upper Mississippi region. Jesuit missionaries, in the Assiniboine land, then in what is the state of Minnesota of today, make record of the occurrence of coal as early as 1659. In describing the Poualak (Assiniboine tribes) this statement occurs: "Comme le bois est rare & petit chez eux, la nature leur a appris

[138]Geology of Iowa, Vol. II, p. 336, 1870.
[139]Iowa Geol. Surv., Vol. IV, p. 97, 1895.

à faire du feu avec du charbon de terre, & a couvrir leurs cabanes avec des peaux." * * * * [140] It is also quite possible that the Ioway Indians of the northern prairies also made use of the lignite deposits of the region such as are found, for example, in Brown county, Minnesota, near the headwaters of the Des Moines river, and on the Big Sioux river in Plymouth county, Iowa.

When La Salle established in 1680, Fort Crève Cœur on the Illinois river, near the present site of Peoria, large coal-beds were discovered. Father Louis Hennepin, who was associated with La Salle at this time, states, in the journal of his travels, that at the place mentioned mineral coal exists. In an English edition[141] of his map of the Upper Mississippi region the location is clearly represented. That he was not mistaken is amply shown by subsequent developments.

In his letters regarding the natural productions found along the Illinois river, issued a few years later, La Salle also mentions the fact of the occurrence of coal at Crève Cœur. In a recent reprint of these letters by Margry,[142] among other instructive statements the following paragraph has a special interest in this connection: "Il y a aussy quantite d'ardoisieres et charbon de terre; quatre lieues plus bas, a droite, on trouve la rivvere des Pestigouki dans laquelle j'ay trouve un morceau de cuivre et une espece de metal que j'envoyay, il y a deuxans, a M. de Frontenac dont je n'ay point en de respouse, et que je croy de la bronze, si elle se trouve en mine."

Still another very early reference to the occurrence of coal in the Upper Mississippi valley is that of Le Gardeur de l' Isle. who writes in 1722 from Fort Chartres, near Kaskaskia, that he accompanied one Renault to the Illinois river to look after copper and coal mines.[143]

An Englishman, Capt. Phillip Pittman, who visited the Mississippi valley soon after the Peace of Paris, astutely infers

[140]Relation de ce qui s'est Passé de plvs Remarkable avx missions des Pères de la Compagnie de Iesus en la Novvelle France, en années six cent soixante ennoyée au R. P. Clavde Bovcher, A Paris, Sebastien Cramoisy, MDCLXI. "As wood is scarce and very small with them nature has taught them to burn coal in its place, and to cover their wigwams with skins."

[141]New Discovery of a Vast Country in America, etc., map, London, 1698.

[142]New Discovery of a Vast Country in America, etc., English ed., map, London, 1698. Mém. et doc. pour servier la l'histoire des origines Francaises des pays outremere; t. II, Lettres de Chavalier de la Salle et correspondance relative a ses entrepises, (1676-1685), p. 175, Paris, 1879.

[143]Coll. Wisconsin State Hist. Soc., Vol. XIII, p. 275, 1888.

from the great pieces of coal which he found constantly on the sand-bars up the river that there were coal-mines on the upper parts of the great stream.[144]

The French early knew of the coal which outcropped on the Missouri river a few miles above its mouth, at a point which they named La Charbonnière. Lewis and Clark make mere reference to it:[145] "At the distance of a few miles we passed a remarkable coal hill on the north side called by the French La Charbonnière."

Lieut. Z. M. Pike, on his trip to the sources of the Arkansas river, first passed up the Missouri and Osage rivers. "Six miles below St. Charles, on the south side, in front of a village called by the French Florisant, is a coal-hill, or as it is termed by the French, La Charbonnière. This is one solid sandstone hill which probably affords sufficient fuel for all the population of Louisiana."[146]

Long on his expedition from Pittsburg to the Rocky mountains, in 1819, also visited Charbonnière.[147] He also noted other coal deposits in going overland in a direct line from the mouth of the Missouri river to Council Bluffs. "The Chariton river originates near the De Moyen river of the Mississippi and traverses the region which is of great importance both on account of the fertility of its soil and its inexhaustible mines of coal. * * * These extensive beds of coal will be considered of great value and the necessities of the inhabitants will lead to their early exploration."[148]

The first distinct mention of the occurrence of mineral coal in Iowa appears to be that of Featherstonhaugh,[149] who, in 1835, descended the Mississippi river in a canoe, from Dubuque to St. Louis. At the mouth of Rock river, on both sides of the Mississippi, he reports the occurrence of bituminous coal deposits.

The same year Albert Lea investigated for the Federal government the resources of the Black Hawk Purchase,[150] comprising

[144]Present State of European Settlements on the Mississippi, etc., p. 7, London, 1770.

[145]Hist. Exped. Lewis and Clarke to Sources of Missouri, etc., during years 1804-6, Vol. I, Philadelphia, 1814.

[146]Explorations to Sources of Mississippi, etc., during 1805, 1806 and 1807, pt. ii, p. 126, Philadelphia, 1810.

[147]Exp. Pittsburg to Rocky Mts., etc., Vol. I, p. 70, 1823.

[148]Ibid., p. 97.

[149]Rept. Geol. Reconnaissance, etc., to Coteau du Prairie, p. 129, Washington, 1836.

[150]Notes on Wisconsin Terr., particularly with Reference to Iowa Dist. or Black Hawk Purchase, 53 pp., Philadelphia, 1836.

the present eastern Iowa, and noted the occurrence of coal in many places. In the Des Moines valley he records large coal deposits existing between the mouth of that river and the Raccoon forks.[151]

When Owen,[152] in 1839, visited Scott county, he found coal outcropping along Duck creek four miles northeast of Davenport, and he records the results of a chemical analysis of a sample collected there.

The Federal census for the year 1840 shows that 400 tons of coal were mined in Iowa during that year. This date may be regarded as marking the beginning of the commercial mining of mineral fuel in the state and the birth of one of her most important industries. Before this time, and also for a decade or two afterward, wood was so plentiful and so cheap that in this thinly populated region there was little demand for any other fuel. From the date mentioned there was a steady increase in the coal production of the state until it attained the present large proportions.

In his "Remarks on the Geology of the Upper Mississippi" Nicollet[153] says that shallow coal-basins frequently occur in Missouri and the south part of Iowa territory."

At the fifth meeting of the American Association for the Advancement of Science, in 1851, Owen read an "abstract" of his later report, in which he gives the first comprehensive view of the extent of the coal deposits of Iowa and Missouri. Among other important observations he notes that the coal-field of the states mentioned is a large, more or less circular basin, having an area of about 35,000 square miles. It is subdivided into three members, the lower one of which is stated to be composed of limestones chiefly and to have a thickness of perhaps 100 feet; the middle one, mainly comprising shales, has a thickness of about 75 feet; and the upper silicious sequence has a thickness of about 100 feet. The second, or middle member, is the coal-bearing portion, the individual coal-seams having a thickness of from a few inches up to four or five feet.

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[151]Ibid., p. 25.
[152]Twenty-eight Cong., 1st Sess., Sen. Ex. Doc., No. 407, p. 53, 1844.
[153]Am. Jour. Sci., (1), Vol. XLI, p. 181, 1841.

Owen's final report[154] on the geology of this region surveyed in several previous years, shows a fine cross section along the Des Moines river, in which numerous coal seams are displayed. Some coal out-crops are also noted on the Missouri river in the southwestern corner of the state.[155]

During the years 1855-1857 Hall, Whitney, and Worthen examined a large number of coal deposits in different parts of the state. Hall[156] gave a general account of the geology in which the coal measures are briefly mentioned. Whitney[157] described the chemical composition of the coals. Worthen[158] reported upon a trip up the Des Moines river; and on some of the counties in the southeastern part of the state.[159]

A decade later, White and St. John made a reconnaissance of all the coal-producing counties of the western half of the state.[160]

In 1879 a state bureau of mine inspection was established by act of the legislature. Since that time there has been kept a fairly complete record of the industrial features and development of coal-mining in the state.

During recent years a large number of articles have appeared relating directly to the geology and mining of coal. In the county reports of the present State Geological Survey have been given full details of the occurrences of coal and of the mines in operation. Two special reports on the coal deposits of the state have also been issued. The detailed history of coal mining in each of the various counties of the state has received the attention of Lees.[161]

[154]Rept. Geol. Surv. Wisconsin, Iowa and Minnesota, p. 105, 1852.
[155]Ibid., p. 133.
[156]Rept. Geol. Sur. Iowa, Vol. I, p. 123, 1858.
[157]Ibid, p. 397.
[158]Ibid., p. 147.
[159]Ibid., p. 183.
[160]Rept. Geol. Sur. Iowa, Vols. I and II, 1870.
[161]Iowa Geol. Surv., Vol. XIX, p. 525, 1909.

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, architectural 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 astronomy 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 museums 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 intrinsic 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 direct 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 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 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:

Administrative Reports.
Geological Formations of Iowa; by Charles Rollin Keyes.
Cretaceous Deposits of Woodbury and Plymouth Counties, with observations on their Economic uses; by Samuel Calvin.
Ancient Lava Flows in Northwestern Iowa; by Samuel W. Beyer.
Distribution and Relations of the Saint Louis Limestone in Mahaska County, Iowa; by Harry Foster Bain.
Annotated Catalogue of Minerals; by Charles Rollin Keyes.
Some Niagara Lime Burning Dolomites and Dolomitic Building Stones of Iowa; by Gilbert L. Houser.
Bibliography of Iowa Geology; by Charles Rollin Keyes.

VOLUME II. COAL DEPOSITS.

BY CHARLES ROLLIN KEYES.

536 Pages, 18 Plates, 251 Figures.

CONTENTS:

Chapter I.	Introduction.
Chapter II.	Origin of Coal.
Chapter III.	Carboniferous Basin of the Mississippi Valley.
Chapter IV.	General Geology of the Coal Region.
Chapter V.	Lithology of the Coal Measures.
Chapter VI.	Stratigraphy of the Coal Measures.
Chapter VII.	The Coal Beds.
Chapter VIII.	Description of the Coad Beds Now Operated in North Central Iowa.
Chapter IX.	Description of the Coal Beds in Central Iowa.
Chapter X.	Description of the Coal Beds of Southeastern Iowa.
Chapter XI.	Description of Coal B eds in Southwestern Iowa.
Chapter XII.	Description of the Coal Beds of the Outliers in Eastern Iowa.
Chapter XIII.	Composition of Iowa Coals.
Chapter XIV.	Waste in Coal Mining.
Chapter XV.	Coal Industry.

VOLUME III. ANNUAL REPORT, 1893.

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

CONTENTS:

Administrative Reports.
Work and Scope of the Geological Survey; by Charles Rollin Keyes.
Cretaceous Deposits of the Sioux Valley; by Harry Foster Bain.
Certain Devonian and Carboniferous Outliers in Eastern Iowa; by William Harmon Norton.
Geological Section Along Middle River in Central Iowa; by J. L. Tilton.
Glacial Scorings in Iowa; by Charles Rollin Keyes.

VOLUME IV. ANNUAL REPORT, 1894.

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

CONTENTS:

VOLUME V. ANNUAL REPORT, 1895.

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

CONTENTS:

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

487 Pages, 28 Plates, 57 Figures.

CONTENTS:

VOLUME VII. ANNUAL REPORT, 1896.

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

CONTENTS:

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:

Letter of Transmittal.
Preface.
Chapter I. Geographic Exploration of Iowa-land.
Chapter II. Geologic Reconnaissance.
Chapter III. Historical Sketch of Mining.
Chapter IV. Systematic Geological Surveying.
Chapter V. Annotated Bibliography.

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 STREAKS AND POCKETS OF SAND AND GRAVEL.
		Aftonian			0-40+	PEAT & FOREST 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			(40)	LIMESTONE, MOSTLY BRACHIOPOD COQUINA
		Lime Creek			(120)	MOSTLY SHALES (LOCALLY DEVELOPED FEATURES EACH LYING UNCONFORMABLY ON THE MIDDLE DEVONIAN.)
		Sweetland Creek			(20)	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
			New Richmond		20	SANDSTONE.
			Oneota		150	DOLOMITE.
CAMBRIAN	POTSDAMIAN OR SARATOGAN	St. Croix	Jordan		100	COARSE SANDSTONE
			St. Lawrence		50	DOLOMITE MORE OR LESS ARENACEOUS.
			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	THICK-NESS	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)
	TERTIARIC	LATE	*Pliocene*	Interval		Unconformity
		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 Coralville Rapid Solon	25 30 35 25	Limestones Limestones Limestones Limestones
				Interval		Unconformity
		MID	*Hamiltonian*	Fayette Independence Otis Coggan	75 20 10 15	Limestones Shales Limestones Dolomites
	SILURIC	LATE	*Goweran*	Bertram Anamosa LeClaire	35 60 70	Dolomites Dolomites Dolomites
		MID	*Niagaran*	Monticello Hartwick Colesburg Sabula	60 80 30 50	Dolomites Dolomites Dolomites Dolomites
	ORDOVICIC	LATE	*Maquoketan*	Brainard Atkinson Clermont Elgin	125 40 15 75	Shales Limestones Shales Shales
		MID	*Mohawkian*	Galena Decorah Platteville	225 30	Dolomites Shales Limestones
		EARLY	*Minnesotan*	Glenwood St. Peter	15 100	Shales Sandstones
	CAMBRIC	LATE	*Ozarkian*	Shakopee New Richmond Oneota	75 25 150	Dolomites Sandstones Dolomites
		MID	*Croixan*	Jordan St. Lawrence Dresbach Hinckley	100 50 150 600	Sandstones Dolomites Sandstones Sandstones
		EARLY	*Georgian*	Interval		Unconformity
AZOIC	HURONIC	LATE	*Siouan*	Hull Tipton Sioux	475 425 200	Porphyries Slates Quartzites

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Physiography, topography, altitudes, drainage.

Geological formations, general relations of strata, table of formations; Devonian system, Wapsipinicon stage, Cedar Valley stage, general section of the Cedar Valley limestone; geest; Pleistocene system, Kansan stage, Kansan drift, Buchanan gravels, Iowan stage, Iowan drift, loess, alluvium and terraces, Cretaceous material in drift; soils, deformations, unconformities; economic products, building-stones, limes, brick-clays, road materials, water-supplies, water powers.

Arey, Melvin F. Geology of Butler county. (Iowa Geol. Surv., Vol. XX, pp. 1-59, Des Moines, 1910.) The following topics are considered:

Introduction, location and area, previous geological work.

Physiography, topography, preglacial, Kansan area, New Hartford recessional moraine, paha, Iowan area, altitudes, drainage, Shell Rock river, West Fork of Cedar river, Beaver creek.

Stratigraphy, general relations of strata, table of formations; Devonian system, Middle Devonian series, Cedar Valley stage, exposures and sections, Upper Devonian series, Lime Creek shales, Owen beds, exposures and sections; Carboniferous system, Mississippian series, Kinderhook stage, exposures and sections; residual material; Quaternary system, Pleistocene series, Kansan stage, Kansan drift, Buchanan gravels, Iowan stage, Iowan drift, loess, soils.

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Physiography, topography, drainage.

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Physiography, topography, table of elevations, drainage.

Stratigraphy, general relations of strata, table of formations; Devonian system, Middle Devonian series, Cedar Valley limestone, Upper Devonian series, Lime Creek shales; Carboniferous system, Mississippian series, Kinderhook stage, Pennsylvanian series, Des Moines stage;

Mantle rock, residual materials; Quaternary system, Pleistocene series, Kansan stage, Kansan drift, Buchanan gravels, Iowan stage, Iowan drift, modified Iowan drift forms, bowlders, Iowan loess, alluvium, soils.

Economic products, building-stones, brick and brick making materials, sands, road-making materials, water-supplies, springs, wells.

Arey, Melvin F. Geology of Wayne county. (Iowa Geol. Surv., Vol. XX, pp. 199-236, Des Moines, 1910.) The various topics discussed include the following:

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Physiography, topography, table of elevations, drainage.

Stratigraphy, synoptical table; Carboniferous system, Pennsylvanian series, Des Moines stage, Appanoose formation, Pleasanton shales, Missouri stage; Quaternary system; Pleistocene series, Nebraskan stage, Aftonian interglacial stage, Kansan stage, secondary drift forms, gravels and bowlders, gumbo, loess, Recent series, alluvium.

Economic geology, soils, coal, clays, water-supplies, springs.

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Bain, H. Foster. Buried Mountains of the Prairies. (Midland Monthly, Vol. VI, pp. 20-26, Des Moines, 1896.)

Bain, H. Foster. Central Iowa Section of Mississippian Series. (American Geologist, Vol. XV, pp. 317-325, Minneapolis, 1895.) The lithology of the several members is described and the characteristic fossils of each are noted. The faunal affinities of part of the Kinderhook section to the Devonian are described.

Bain, H. Foster. Cretaceous Deposits of Sioux Valley. (Iowa Geol. Surv., Vol. III, pp. 99-114, Des Moines, 1895.) Besides the details of a geologic cross-section along the Big Sioux river the chalk-beds are especially described, and numerous sections are given. The Pierre formation is believed to be represented by 50 feet of black shales, the best exposures being south of Hawarden.

Bain, H. Foster. Distribution and Relations of St. Louis Limestone in Mahaska County, Iowa. (Iowa Geol. Surv., Vol. I, pp. 171-179, Des Moines, 1893.) Three narrow bands of the limestones are found crossing the county from northwest to southeast, in the valleys of the principal streams. The coal-measures are thus divided into five distinct fields. A cross-section shows the irregular character of the floor of the coal-measures of the region.

Bain, H. Foster. Dubuque Lead and Zinc Mines. (Mines and Minerals, Vol. XX, pp. 10-12, Scranton, 1889.) The occurrence, geology and nature of the ore-bodies are briefly characterized.

Bain, H. Foster. Geology of Appanoose County. (Iowa Geol. Surv., Vol. V, pp. 361-438, Des Moines, 1896.) The various topics discussed are:

Introduction, location and area, previous geological work.

Physiography, topography, table of elevations, drainage, origin of present topography.

Stratigraphy; geological formations, Carboniferous, Upper Carboniferous series, Des Moines stage, Appanooose beds, Chariton conglomerate, structure, faults, Scandinavian fault, Numa dome, deeper coal-seams; Pleistocene series, Kansan drift-sheet, loess-silt; alluvium.

Economic products, coal, coal-lands, character of the Mystic coal, mining methods, mines, clays, building-stones, water-supplies.

The Appanoose formation and the character of the Mystic coal seam are the most important features described that are of wide interest.

Bain, H. Foster. Geology of Carroll County. (Iowa Geol. Surv., Vol. IX, pp. 49-106, Des Moines, 1899.) In describing the various features the following are noteworthy:

Introduction, location and area, previous geological work.

Physiography, topography, Wisconsin drift-plain, Kansan loess-plain, drainage.

Stratigraphy, general relations, Carboniferous, Des Moines; Cretaceous, Dakota; Pleistocene, Kansan drift, loess, Wisconsin drift.

Economic products, coals, clays, Carroll, Manning; water-supplies, surface waters, artesian wells; soils, drift soil, loess soil.

Bain, H. Foster. Geology of Decatur County. (Iowa Geol. Surv., Vol. VIII, pp. 255-314, Des Moines, 1898.) There are described the following features:

Introduction, location and area, previous geological work.

Physiography, topography, table of elevations, drainage.

Stratigraphy, general relations of formations; Carboniferous, Des Moines, Missourian; Pleistocene, Kansan drift, loess and gumbo, alluvium, structure.

Economic products, coal, clays; building-stones, Grand river, De Kalb, Terre Haute, Davis City; limes. Forest trees and shrubs.

Bain, H. Foster. Geology of Guthrie County. (Iowa Geol. Surv., Vol. VII, pp. 413-487, Des Moines, 1897.) The features most fully described are:

Introduction, location and area, previous geological work.

Physiography, topography, drainage.

Stratigraphy, general relations of strata; Carboniferous, Des Moines, Misourian; Cretaceous, Dakota; Pleistocene, general relations, Kansan drift, Iowan loess, Wisconsin drift, alluvium.

Economic products, coal, Greenbrier mines; Stapes mine, Keeler, Burgess, Fisher, Dygert, Reese, Emery, White Ash, Harris, Clark, Fansler, Brushy Fork, Wales, Perkins, Burroughs, Anderson, Driscoll, Lonsdale mine; clays, Guthrie Center, Stuart, Panora, Jamaica; building-stones, sands, gravels, natural-gas, water-supplies, soils.

Bain, H. Foster. Geology of Keokuk County. (Iowa Geol. Surv., Vol. IV, pp. 255-311, Des Moines, 1895.) There are described in detail:

Introduction, area and location, previous geological work.

Physiography, topography, table of elevations, drainage.

Stratigraphy; general relations of strata; table of geological formations, deeper strata, standard section; Manhattan mill, Nugent and What Cheer typical outcrops; South

Skunk section, North Skunk section, South English section, geological formations, Mississippian, Augusta, Saint Louis, Springvale, Verdi, Pella, Upper Carboniferous, Des Moines, Pleistocene, drift, loess, alluvium; geological structure; cross-sections, North Skunk, South Skunk, Keota to Atwood, South English, North English to Hedrick; deformations, Manhattan anticlinal, Springvale anticlinal, South Skunk anticlinal; unconformities, pre-pleistocene, pre-coal measure.

Economic products; coal, What Cheer district, Delta district, Richland district, Sigourney district; clays, character and distribution, industries; building stones, Des Moines stage, Saint Louis stage, Augusta stage; soils; water-supply; water-power; road-materials; minerals; mineral paint; statistics.

Bain, H. Foster. Geology of Mahaska County. (Iowa Geol. Surv., Vol. IV, pp. 313-380, Des Moines, 1895.) The following topics are treated in detail:

Introduction, area and location, previous geological work.

Physiography, topography, table of elevations, drainage.

Stratigraphy, general relations of strata, classification of formations, deeper strata; typical sections, North Skunk river, South Skunk river, Des Moines river; geological formations, Mississippian series, Saint Louis; Upper Carboniferous, Des Moines; Pleistocene, drift, glacial striae, loess, alluvium; geological structure, cross sections, Harvey to Eddyville, Skunk river section, Atwood to North Skunk, North Skunk to Eddyville, Atwood to Harvey; deformations; unconformities, Saint Louis and Des Moines, Raven Cliff, drift and indurated rocks.

Economic products, coal-mines, Black Creek mines, Columbia mines, Rose Hill mines, Spring Creek mines, Oskaloosa mines, Leighton mines, Evans mines, Beacon mines, Muchakinock mines, Lost Creek mines, Cedar Creek mines, Coal Creek mines, coal lands; clays, character and distribution, industries; limes; building-stones; soils; water-supplies; water-powers; road materials; statistics.

Bain, H. Foster. Geology of Plymouth County. (Iowa Geol. Surv., Vol. VIII, pp. 315-366, Des Moines, 1898.) The various features described include the following:

Introduction, physiography, topography, drainage.

Stratigraphy, general relations of strata, geological formations; Cretaceous, Dakota, Colorado; Pleistocene, general description, summary, age of the bowlder clay, topographic development, alteration, physical character, stratigraphic relationships, résumé.

Economic products, coal, clays, cement, limes, water-supplies, soils.

Bain, H. Foster. Geology of Polk County. (Iowa Geol. Surv., Vol. VII, pp. 263-412, Des Moines, 1897.) Full descriptions include these subjects:

Introduction, location and area, previous geological work.

Physiography, topography, northern area, southern area, drainage, history of drainage, table of elevations.

Stratigraphy, geological formations, general relations of formations; Carboniferous, underlying formations, Greenwood Park well, base of coal measures, general character of coal measures, general cross-sections, section from Capitol hill to mouth of Beaver creek, section from Capitol hill to Walnut creek, detailed stratigraphy, Runnels-Carbondale districts, East Des Moines district, Berwick district, Altoona-Mitchellville district, Saylorville district, Polk City district, Commerce district, North Des Moines district, South Des Moines district, lower coal horizons, fauna of coal measures; Pleistocene, pre-Kansan drift, Kansan drift, loess, list of Pleistocene fossils, Wisconsin drift, alluvium, and terraces.

Economic products, coal, Runnels, Hastie, Manbeck, Carbondale, Northeast Des Moines, East Des Moines, Saylor, Polk City, North Des Moines, South Des Moines, Commerce; clays, Des Moines, Altoona, Polk City, Campbell, Bondurant; soils, gravels, building-stones, water-supplies, natural gas, and oil.

Bain, H. Foster. Geology of Washington County. (Iowa Geol. Surv., Vol. V, pp. 115-173, Des Moines, 1896.) The various topics considered in detail are:

Introduction, location and area, previous geological work.

Physiography, topography, table of elevations, drainage, English River, Davis creek, Goose creek, Long creek, Skunk creek, Crooked creek, origin of, drainage system.

Stratigraphy, general relations of strata, classification of formations; standard sections, Maple mill, Eckles quarry, Brighton, Leibs mine, deeper strata; geological formations, Mississippian series, Kinderhook, distribution, Wassonville limestone, English River gritstones, Maple Mill shales, correlations; Augusta limestones, Saint Louis formation, Springvale beds, Verdi beds, Pella beds; Upper Carboniferous series, Des Moines (Lower Coal Measures); Pleistocene, Kansan drift-sheet, striae, loess, alluvium; geological structure; cross-sections; English River, Cotters to Keota, Skunk River, Brighton to Washington; deformations; unconformities, drift and indurated rocks, Des Moines and Saint Louis, Saint Louis and Augusta.

Economic products, coal; clays, character and distribution, clay industries; building-stones, Saint Louis, Augusta, Kinderhook; soils, water-supplies, water-powers, road-materials.

Bain, H. Foster. Geology of Woodbury County. (Iowa Geol. Surv., Vol. V, pp. 241-299, Des Moines, 1896.) Detailed descriptions are given of the following:

Introduction, location and area, previous geological work.

Physiography, topography, table of altitudes, drainage, Missouri river, Big Sioux river, Perry creek, Floyd river, Little Sioux river, Maple river.

Stratigraphy, general relations of strata, classification of formations, general sections, pre-Cretaceous strata; standard sections, Sargeant's bluff, North Riverside, Cedar Bluff, Sand-pit; typical exposures, Prospect Hill, Riverside park, Floyd river; geological formations, Cretaceous, Dakota, Colorado; Pleistocene, pre-glacial deposits, glacial deposits, drift, loess, terraces, post-glacial deposits, alluvium; geological structure, general structure, cross-section.

Economic products, clays, character and distribution, clay industries, cement, building-stones, limes, sands and gravels, coal and lignite, water-supplies, soils.

Bain, H. Foster. Introduction [to Mineral Production for 1897.] (Iowa Geol. Surv., Vol. VIII, pp. 31-33, Des Moines, 1898.) Explanation is made of the initiation of the compilation, and its general use to the public.

Bain, H. Foster. Lead and Zinc Deposits of Upper Mississippi Valley. (Bull. U. S. Geol. Surv., No. 294, pp. 72-75, Washington, 1906.) This is a general discussion of the geology, occurrence, and relations of the ores of the entire region in which there are many references to Iowa. A brief account is given of the mines of the state. There is a map of the Dubuque district.

Bain, H. Foster. Loess Soils of Iowa. (Trans. Iowa Horticultural Soc., Vol. XXXI, pp. 185-191, Des Moines, 1896.) The surface deposits of the state are described in their relations to the soils, special emphasis being placed upon the rich character of the loess loams.

Bain, H. Foster. Machine Coal-mining in Iowa. (Mineral Industry, Vol. IV, pp. 195-200, New York, 1896.) The advantage of mining coal by machinery is discussed in detail, the character of the seams thus able to be operated upon is especially noted, and the machines used are described.

Bain, H. Foster. Mississippian Rocks of Central Iowa. (Proc. Iowa Acad. Sci., Vol. II, p. 174, Des Moines, 1895.) In a brief statement of the subdivisions recognizable in Mahaska, Marion, Keokuk and Washington counties several new formational names are introduced.

Bain, H. Foster. Preglacial Elevation of Iowa. (Proc. Iowa Acad. Sci., Vol. II, pp. 23-26, Des Moines, 1895.) The great depth of old river-channels noted in various parts of Iowa seems to indicate that in preglacial times the surface of the region was considerably higher than at present. To this circumstance may be ascribed the initiation of the present drainage-system.

Bain, H. Foster. Notes on Drift of Northwestern Iowa. American Geologist, Vol. XXIII, pp. 168-176, Minneapolis, 1899.) Certain moranic deposits are described, that appear to cover Kansan till.

Bain, H. Foster. Notes on Iowa Building-stones. (Sixteenth Ann. Rept., U. S. G. S., pt. iv, pp. 500-503, Washington, 1895.) Distribution of the best building-stones is mainly considered.

Bain, H. Foster. Origin of Certain Features of Coal-basins. (Journal of Geology, Vol. III, pp. 646-654, Chicago, 1895.) The probability of predicting lower thick seams from the character of basins in the higher seams is discussed and several examples are noted.

Bain, H. Foster. Peculiarities of Mystic Coal-seam. (American Geologist, Vol. XIII, pp. 407-411, Minneapolis, 1894.) The relatively great areal extent of basin is commented upon, and comparisons are made with other coal-fields of the state.

Bain, H. Foster. Portland-cement Resources of Iowa. (Bull. U. S. G. S., No. 243, pp. 147-165, Washington, 1905.) Suitable materials are reported from nearly every part of the state. The chalk deposits are described; also the principal non-magnesian limestones.

Bain, H. Foster. Properties and Tests of Iowa Building-stones. (Iowa Geol. Surv., Vol. VIII, pp. 369-416, Des Moines, 1898.) The discussion leads along the following lines:

Introduction, use of stone in building.

Essential properties of building-stones, strength, durability, external factors, mechanical effects, chemical effects, internal factors, color, workability, availability.

Tests of building-stones, test of strength, crushing strength with strawboard bearings, crushing strength with steel bearings, crushing tests of Iowa building-stones, test of durability, freezing tests on Marshalltown stones, absorption and specific gravity tests of Marshalltown stone, absorption tests of various stones, chemical analyses of Marshalltown stone, chemical analyses of various stones, microscopic examinations; general conclusions.

Bain, H. Foster. Relations of Wisconsin and Kansan Drift-Sheets in Central Iowa and Related Phenomena. (Iowa Geol. Surv., Vol. VI, pp. 429-476, Des Moines, 1897.) The features especially described are:

Definition of region.

Definition of term Wisconsin; early study of two drift-sheets in Wisconsin, later correlations, Kansan, recognition of an older drift, Iowan, McGee's studies in Iowa.

Des Moines lobe, early work, topography of lobe, drift, drift-border; kames, valley-trains, forest-beds, relations to loess; McGee and Call; recent work.

Outlying drift, general characteristics, disposition, leaching, ferrugination, topography of outlying drift, development of erosion-curves, river changes, resurrected river, correlation of outlying drift.

Time ratios.

There are especial discussions of erosion-curves, time-ratios, the general periods, and the classification of the Quaternary deposits of the State.

Bain, H. Foster. Report of Assistant State Geologist. (Iowa Geol. Surv., Vol. IV, pp. 29-30, Des Moines, 1895.) There is presented a summary of the field-work accomplished during the year 1894, and a list of the published results.

Bain, H. Foster. Report of Assistant State Geologist. (Iowa Geol. Surv., Vol. V, pp. 27-28, Des Moines, 1896.) Summary is made of the work accomplished during the previous year.

Bain, H. Foster. Report of Assistant State Geologist. (Iowa Geol. Surv., Vol. VIII, pp. 25-29, Des Moines, 1898.) The personal inspections and investigations of the year 1897 are summarized.

Bain, H. Foster. Report of Assistant State Geologist for 1898. (Iowa Geol. Surv., Vol. IX, pp. 25-27, Des Moines, 1899.) Summary of the investigations of the year is given.

Bain, H. Foster. Report of Assistant State Geologist. (Iowa Geol. Surv., Vol. X, pp. 28-30, Des Moines, 1900.) The work of the year 1899 is briefly outlined.

Bain, H. Foster. Samuel Calvin. (Journal of Geology, Vol. XIX, pp. 385-391, Chicago, 1911.) A brief sketch of his life is given.

Bain, H. Foster. Sigourney Deep-Well. (Proc. Iowa Acad. Sci., Vol. I, pt. iv, pp. 36-38, Des Moines, 1894.) A driller's log is given and the various strata are referred to the general geologic section of the state.

Bain, H. Foster. Structure of Mystic Coal-basin. (Proc. Iowa Acad. Sci., Vol. I, pt. iv, pp. 33-36, Des Moines, 1894.) This coal-seam is contrasted with others of the state, and as shown is one of relatively great extent. A notable feature is the associated limestones.

Bain, H. Foster. Western Interior Coal-field of America. Trans. North of England Inst. Min. and Mec. Eng., Vol. XLVIII, pp. 55-80, 1898.) Carboniferous stratigraphy of the Mississippi valley and the nature and extent of the coal-bearing rocks are described.

Bain, H. Foster. Western Interior Coal-field. (Twenty-second Ann. Rept. U. S. G. S., pt. iii, pp. 333-366, Washington, 1902.) The industrial aspect of the coal resources is chiefly considered.

Bain, H. Foster, and S. Calvin. Geology of Dubuque county. (Iowa Geol. Surv., Vol. X, pp. 379-651, Des Moines, 1900.) The following features are especially described: Introduction, location and area, previous geological work. Physiography, topography, drainage.

Stratigraphy, general relations of strata, synoptical table; Ordovocian system, Saint Peter sandstone, Trenton limestone, geological distribution, lithological and faunal characteristics, Galena limestone, Maquoketa shales; Silurian system, Niagara limestone; Superficial materials, residual materials, or geest; Pleistocene system, Kansan drift, Buchanan gravels, Kansan outwash in the driftless area, Iowan drift-loess, Wisconsin terraces; alluvium; summary of pleistocene history; calcareous tufa; deformations; unconformities.

Economic geology, soils; lead and zinc, historical sketch, geology, Saint Peter sandstone, Galena-Trenton, Maquoketa, Niagara, the ore deposits, ores and associated minerals, galena, cerussite, smithsonite, sphalerite, copper, pyrite and marcasite, limonite, wad, calcite and aragonite, gypsum, dolomite, barite, ore-bodies; vertical sheets, flats, pitches, disseminated bodies, cave-deposits, formation of crevices, enlargement of crevices, openings, ore-horizons, description of individual crevices, the timber range, Stewart Park range, Stewart and Bartlett lode, Stewart cave, Levens range, Dubuque cave, Sunflower, Patch diggings, Level, Kilbourne and Karrick, McGowan and Cunningham, Rake pocket, Julien Avenue crevices, Langworthy and Kelley, Rabbit Hollow mines, Center Grove mines, Pike's Peak, other crevices, mines away from Dubuque, origin of the Dubuque ores, ultimate sources of ores, table of analyses, localization of ore-bodies, concentration of ores; practical considerations; mining titles, Bonson rules, methods of work, prospecting, composition and treatment of ores, smelting.

Iron, analyses of Durango ore; limes, Eagle Point lime-works, Key City lime-works; clays, analysis of Maquoketa shales, brick-plants; pigments; road-materials; building-stones; artesian wells; cements; forestry notes.

Bain, H. Foster, E. C. Eckel and. Cement and Cement Materials of Iowa. (Iowa Geol. Surv., Vol. XV, pp. 33-124, Des Moines, 1905.) The following subjects are considered:

Introduction, production of cement in the United States, relation of domestic production and consumption to imports, uses of cement, scope of the report.

Materials and manufacture of Portland cement, the relation of Portland to other cements, classification of cements into simple cements, hydrate cements, carbonate cements, complex cements, pozzuolanic cements, hydraulic limes, natural cements, Portland cements.

Portland cement, its definition, composition and constitution, raw materials for Portland cement, general considerations, combinations of raw materials, origin and general characters of limestone, raw materials actually in use, argillaceous limestone, pure hard-limestone, soft limestone, chalk, fresh-water marls, alkali waste, blast-furnace slag, clays and shales, slate.

Factors determining the value of deposits for cement materials, methods and costs of excavation of the raw materials, cost of raw materials at the mill.

Methods of manufacture, preparation of the mixture for the kilns, drying the raw materials, grinding and mixing, dry methods, slag, limestone mixtures, wet methods, composition of the mixture, burning the mixture, theoretical fuel requirements, losses of heat in practice, actual fuel requirements and output, effect of composition on burning, character of kiln-coal, clinker-grinding, addition of gypsum, constitution of Portland cement.

Cement materials of Iowa, calcareous marls, chalk deposits, limestones, Ordovician limestones, Devonian limestones, Wapsipinicon limestone, Cedar Valley limestone, Lime Creek shales, Carboniferous limestone, Kinderhook limestone, Augusta limestone, St. Louis limestone, Des Moines formation, Missourian formation.

Relation to fuel and markets.

Cement plants in neighboring states.

Bain, H. Foster, and A. G. Leonard. Middle Coal-measures of Western Interior Coal-field. (Journal of Geology, Vol. VI, pp. 577-588, Chicago, 1898.) There are contrasted the conditions under which the sediments of the Des

Moines and Missouri series were deposited. A detailed and general section of the coal-bearing rocks of the central part of the state is given. The classification and correlation of the coal-measures of the state are discussed.

Bain, H. Foster, and A. G. Leonard. Middle Coal-Measures of Western Interior Coal-field. (Bull. Geol. Soc. America, Vol. X, pp. 10-12, Rochester, 1899.) This is an abstract of a paper of similar title.

Bain, H. Foster, and John L. Tilton. Geology of Madison County. (Iowa Geol. Surv., Vol. VII, pp. 489-539, Des Moines, 1897.) Detailed accounts are given of the following features:

Introduction; physiography, topography, table of elevations, drainage.

Stratigraphy, general relations of strata, classification of formations; geological formations; Carboniferous, Des Moines, Hanley section, St. Charles section, Patterson section, Raccoon River section, Missourian formation, Lincoln township section, Backbone section, South River section, Earlham section, Cedar Creek section, Winterset section, Tileville section; Pleistocene, Kansan drift; loess; alluvium.

Economic products; building-stones, Earlham district, Robertson quarry, Earlham Land Co., Nevitt quarry, Eureka quarry, Winterset district, Peru district, St. Charles-Truro district; road-materials, lime, clays, water-supplies, water-powers, coal.

Bain, H. Foster, J. E. Todd and. Interlœssial Till near Sioux City, Iowa, (Proc. Iowa Acad. Sci. Vol. II, pp. 20-23, Des Moines, 1895.) This unusual occurrence is fully described and illustrated by photographic prints. The best exposure is in Riverside park.

Bain, H. Foster, C. R. Van Hise and. Lead and Zinc Deposits of Mississippi Valley, U. S. A. (Trans. Inst. Mining Eng., XXIII, 376-434 (London), 1902.)

Balch, E. S. Glacierés or Freezing Caverns. (One Volume, pp. 88-89, Philadelphia, 1900.) The general causes of the formation of subterranean ice are discussed. The Decorah ice-cave is especially mentioned.

Ballast Clays.

Betterment of our public highways. C. R. Keyes. (The Annals of Iowa, Historical Quarterly, V, 372-379, 1902.)

Burnt clay for roads in west. C. R. Keyes. (American Monthly Review of Reviews, XXV, 72-74, 1902.)

Economic aspects of work in pure science. C. R. Keyes. (The Annals of Iowa, Historical Quarterly, V, 392-393, 1902.)

Barbour, E. H., Joseph Torrey, Jr., and. Recorded Meteorites of Iowa, with Special Mention of Last, or Winnebago County, Meteorite. (American Geologist, Vol. VIII, pp. 65-72, Minneapolis, 1891.) See Joseph Torrey and E. H. Barbour, 1891.

Barbour, Edwin H., Joseph Torrey, Jr., and. Winnebago County (Iowa) Meteorites. (Science, Vol. XV, p. 347, 1890.) See Torrey and E. H. Barbour, 1890.

Barris, W. H. Description of Some New Blastoids from Hamilton Group. (Geol. Surv., Illinois, Vol. VII, pp. 357-364, Springfield, 1883.) The following species from Iowa are described as new:

Elæacrinus obovatus.
Elæacrinus meloniformis.

Barris, W. H. Descriptions of New Crinoids and Blastoids from Hamilton Group. (Proc. Davenport Acad. Sci., Vol. IV, pp. 88-94, 1885.) Revised descriptions are given of the new species *Elaeacrinus obovatus* and *E. meloniformis.*

Barris, W. H. New Fossils from Corniferous Formation at Davenport. (Proc. Davenport Acad. Nat. Sci., Vol. II, pp. 282-288, Davenport, 1878.) The following genera and species are described as new:

Stereocrinus.
Stereocrinus triangulatus.
Stereocrinus triangulatus var. *liratus.*
Megistocrinus nodosus.

Rhynchonella intermedia.
Avicula (Pterinea) cancellata.
Gyroceras pratti.
Proetus davenportensis.

Barris, W. H. Notes on Our Local Geology, No. II. (Proc. Davenport Acad. Nat. Sci., Vol. III, pp. 163-168, Davenport, 1882.)

Barris, W. H. Our Local Geology. (Proc. Davenport Acad. Nat. Sci., Vol. VII, pp. 14-32, Davenport, 1900.) The lithologic characters and faunal features of the Devonian rocks are described.

Barris, W. H. Stereocrinus, Barris. (Proc. Davenport Acad. Nat. Sci., Vol. IV, pp. 102-104, Davenport, 1885.) Description is given of this new genus from the Devonian of Iowa.

Barris, W. H. Local Geology of Davenport and Vicinity. (Proc. Davenport Acad. Nat. Sci., Vol. II, pp. 261-269, Davenport, 1877.) A general sketch of the geology of the region is given with special reference to the fossils contained in the rocks.

Bartsch, Paul. Notes on Cretaceous Flora of Western Iowa. (Bull. Lab. Nat. Hist., State Univ. Iowa, Vol. III, pp. 178-182, Iowa City, 1896.) A collection of plants found in the Holman cut near Sioux City is identified and the species listed.

Baryte.

Annotated catalogue of minerals. C. R. Keyes. (Iowa Geol. Surv., I, 181-196, 1893.)

Decatur, Madison, Marion, Johnson, Bremer and Dubuque counties. C. A. White. (Geology of Iowa, II, 305, 1870.)

Geology of Dubuque county. S. Calvin and H. F. Bain. (Iowa Geol. Surv., X, 379-651, 1900.)

Basal line of delimitation of carboniferous in northeastern Missouri, present, C. R. Keyes. (American Geologist, X, 360-384, 1892.)

Base of our coal-measures, depositional equivalents of hiatus. C. R. Keyes. (Proc. Iowa Acad. Sci., VIII, 119-123, 1901.)

Bates, C. O. Analyses of Certain Clays used for Making Paving-brick for Cedar Rapids. (Proc. Iowa Acad. Sci., Vol. IX, pp. 61-63, Des Moines, 1902.) Results of 30 analyses of clays, from four different pits at Des Moines, are tabulated.

Beachler, Charles S. Keokuk Group of Mississippi Valley. (American Geologist, Vol. X, pp. 88-96, Minneapolis, 1892.) A short sketch of the Keokuk rocks is given, with an attempt at a correlation of the different beds in the several states of the upper Mississippi region.

Beds of carboniferous drift in bluffs of East Davenport. Tylor McWorther. (Proc. Davenport Acad. Nat. Sci., III, 129-130, 1882.)

Belle Plaine area, artesian wells. H. R. Mosnat. (Iowa Geol. Surv., IX, 521-562, 1899.)

Benton County.

Artesian wells of Belle Plaine area. H. R. Mosnat. (Iowa Geol. Surv., IX, 521-562, 1899.)

Artesian wells of Iowa. W. H. Norton. (Iowa Geol. Surv., VI, 113-428, 1897.)

Geological notes. J. D. Whitney. (Geology of Iowa, I, 260-266, 1858.)

Geology of Benton county. T. E. Savage. (Iowa Geol. Surv., XV, 125-225, 1905.)

Geology of quarry products. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

Underground water resources of Iowa. W. H. Norton. (Iowa Geol. Surv., XXI, 29-1214, 1912.)

Underground water resources of Iowa. W. H. Norton. (U. S. Geol. Surv., Water Supply Paper No. 293, 994 pp., 1912.

Benton county, geology. T. E. Savage. (Iowa Geol. Surv., XV, 125-225, 1905.)

Benton Formation.

Cement and cement materials of Iowa. E. C. Eckel and H. F. Bain. (Iowa Geol. Surv., XV, 33-124, 1905.)

Composition and origin of Iowa chalk. S. Calvin. (Iowa Geol. Surv., III, 211-236, 1895.)

Cretaceous deposits of Sioux valley. H. F. Bain. (Iowa Geol. Surv., III, 99-114, 1895.)

Geology of Plymouth county. H. F. Bain. (Iowa Geol. Surv., VIII, 315-366, 1898.)

Geology of quarry products [limes]. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

Geology of Sac and Ida counties. T. H. Macbride. (Iowa Geol. Surv., XVI, 509-548, 1906.)

Niobrara chalk. S. Calvin. (Journal of Geology, II, 755-756, 1894.)

Bertram limestone.

Certain devonian and carboniferous outliers in eastern Iowa. W. H. Norton. (Iowa Geol. Surv., III, 115-133, 1895.)

Geology of Jones county. S. Calvin. (Iowa Geol. Surv., V, 33-112, 1896.)

Geology of Linn county. W. H. Norton. (Iowa Geol. Surv., IV, 121-194, 1895.)

Sundry provincial and local phases of general geological section of Iowa. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 147-151, 1912.)

Bethany Limestone.

Bethany limestone at Bethany, Missouri. H. F. Bain. (Am. Jour. Sci., (4), V, 433-439, 1898.)

Bethany limestone of western interior coal-field. C. R. Keyes. (Am. Jour. Sci., (4), II, 221-225, 1896.)

Carboniferous formations of southwestern Iowa. C. R. Keyes. (American Geologist, XXI, 346-350, 1898.)

Carboniferous section of southwestern Iowa. G. L. Smith. (Iowa Geol. Surv., XIX, 605-657, 1909.)

Cement and cement materials of Iowa. E. C. Eckel and H. F. Bain. (Iowa Geol. Surv., XV, 33-124, 1905.)

Formational synonymy of coal-measures of Western Interior basin. C. R. Keyes. (Proc. Iowa Acad. Sci., VII, 82-105, 1900.)

Geological section along Middle river in central Iowa. J. L. Tilton. (Iowa Geol. Surv., III, 135-146, 1895.)

Geology of Dallas county. A. G. Leonard. (Iowa Geol. Surv., VIII, 51-118, 1898.)

Geology of Decatur county. H. F. Bain. (Iowa Geol. Surv., VIII, 255-314, 1898.)

Geology of Guthrie county. H. F. Bain. (Iowa Geol. Surv., VII, 413-487, 1897.)

Geology of Madison county. J. L. Tilton and H. F. Bain. (Iowa Geol. Surv., VII, 489-539, 1897.)

Geology of quarry products [limes]. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

Geology of Wayne county. M. F. Arey. (Iowa Geol. Surv., XX, 199-236, 1910.)

Note on correlation of Clarinda well-section with schematic section of Carboniferous. C. R. Keyes. (Iowa Geol. Surv., XI, 461-463, 1901.)

Report of assistant state geologist. A. G. Leonard. (Iowa Geol. Surv., VII, 29-30, 1897.)

Sundry provincial and local phases of general geological section of Iowa. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 147-151, 1912.)

Bethany limestone at Bethany, Missouri. H. F. Bain. (Am. Jour. Sci., (4), V, 433-439, 1898.)

Bethany limestone of western interior coal-field. C. R. Keyes. (Am. Jour. Sci., (4), II, 221-225, 1896.)

Bethany, Missouri, Bethany limestone. H. F. Bain. (Am. Jour. Sci., (4), V, 433-439, 1898.)

Betterment of our public highways. C. R. Keyes. (The Annals of Iowa, Historical Quarterly, V, 372-379, 1902.)

Beyer, Samuel W. Ancient Lava Flows in Strata of Northwestern Iowa. (Iowa Geol. Surv., Vol. I, pp. 163-169, Des Moines, 1893.) A petrographical description is given of a quartz-porphyry obtained at a depth below 755 feet in the Hull drill-well in Sioux county. Several of these old lava-flows were encountered between 755 and 1220 feet depths.

Beyer, Samuel W. Buried Loess in Story County. (Proc. Iowa Acad. Sci., Vol. VI, pp. 117-121, Des Moines, 1899.) Occurrence of a loess-sheet above the Kansan drift is regarded as the loess apron of the Iowan drift-sheet. The formation of appreciable deposits of fine pebbleless deposits by the winds is noted.

Beyer, Samuel W. Coal Statistics. (Iowa Geol. Surv., Vol. XIX, pp. 591-597, Des Moines, 1909.) The compilation includes the figures of the annual output since 1840, indicating a growth of from 400 tons in that year to 7,149,517 in 1908.

Beyer, Samuel W. Evidence of Sub-Aftonian Till-sheet in Northeastern Iowa. (Proc. Iowa Acad. Sci., Vol. IV, pp. 58-62, Des Moines, 1897.) Sections near Oelwein are described and a distinct drift-sheet is represented as underlying the Kansan drift.

Beyer, Samuel W. Geology of Boone county. (Iowa Geol. Surv., Vol. V, pp. 167-232, Des Moines, 1896.) The following features are especially defined:

Introduction, location and area, previous geological work.

Physiography, topography, table of elevations; drainage, Des Moines river system, terraces, age of Des Moines river; Beaver creek, Skunk river system, Squaw creek.

Stratigraphy, general relations of strata, table of geological formations, typical sections, Preston branch, the "Ledges," Honey creek, Moingona, Milford, Ogden well section, Boone deep-well section, geological formations, Des Moines stage, general sections, Pleistocene, Pre-Pleistocene, base-level, Lower till or Kansan, Upper till or Wisconsin, terminal moraine, alluvium.

Economic products, coal, Des Moines valley mines, Madrid district, Moingona district, Milford district, Boonesboro district, Fraser district, Squaw Creek mines, Angus mines, summary, chemical analyses of coal, coal-lands; building-stones; Pleistocene, clays, Boone clay-works, Boone Paving Co., Griffee pottery-works, Jacob Yegge yard, Slater yard, Everett yard; soil, road-materials, artesian waters, minerals.

Character and distribution of the forest trees and shrubs of Boone county, by L. H. Pammel.

Beyer, Samuel W. Geology of Hardin County. (Iowa Geol. Surv., Vol. X, pp. 243-305, Des Moines, 1900.) The following subjects are considered:

Introduction, location and area, previous geological work, historical résumé.

Physiography, topography, loess-Kansan, Iowan drift-plain, Wisconsin drift-plain, table of elevations; drainage, Iowa river system, Iowa proper, South Fork, other drainage systems.

Stratigraphy, general relations of strata, table of geological formations, Ackley well, geological formations; Carboniferous system, Mississippian series, Kinderhook, Pennsylvanian series, Des Moines; Pleistocene system, glacial series, Kansan, Iowan, loess, Wisconsin, history of drainage lines, terraces.

Economic products, coal, clay industries, Eldora, Gifford, Iowa Falls; building-stones, Kinderhook, Des Moines, Pleistocene; soils; road-materials, post-glacial gravels, indurated rocks; water-supplies, water-powers.

Beyer, Samuel W. Geology of Marshall County. (Iowa Geol. Surv., Vol. VII, pp. 197-262, Des Moines, 1897.) Detailed accounts are given of the following subjects:

Introduction, location and area, previous geological work.

Physiography, topography, table of elevations; drainage, Iowa river system, Iowa river, Timber, Linn, Minerva and Honey creeks, age of Iowa system; Skunk River system. Cleak lake, North Skunk and Snipe creek, terraces.

Stratigraphy, general relations of strata, table of geological formations, pre-Carboniferous strata, Marshalltown deep-well; standard sections, Le Grand, Woodbury mills, Rockton, Timber creek, Marshalltown; Mississippian series, Kinderhook, Le Grand beds, Marshalltown shales, Augusta, Saint Louis, Pennsylvanian series, Des Moines stage; Pleistocene, sub-Aftonian, Aftonian, Kansan, Buchanan, Iowan, loess, Wisconsin, Altamont moraine, post-glacial deposits, alluvium; geological structure.

Economic products; building-stones, mechanical and absorption tests, chemical analyses; clay industries, Marshalltown, Melbourne, Rhodes, Bromley, Gilman; limes, building-sands, moulding-sands, road-materials, coal, soils, water-supplies, water-powers.

Beyer, Samuel W. Geology of Story County. (Iowa Geol. Surv., Vol. IX, pp. 155-245, Des Moines, 1899.) The following subjects are especially considered:

Introduction, location and area, previous geological work.

Physiography, topography, general features, table of elevations, drainage, Skunk River system, Keigley branch, Squaw creek, Walnut creek, Ballard creek, Long Dick and Beaver creeks, Indian creek, Des Moines River system, Big and Four-mile creeks, Iowa River system, Minerva creek.

Stratigraphy, general relations of strata, synoptical table of formations, Nevada well-section, College well-section; geological formations, Carboniferous system, Mississippian series, Saint Louis stage, Pennsylvanian series, Des Moines stage; Pleistocene deposits, Kansan, Buchanan, Iowan, loess, Wisconsin, history of Skunk River system, remains of the mammoth, post-Wisconsin deposits; Skunk river anticlinal.

Economic products, coal; clays, coal measures, Pleistocene; building-stones, Saint Louis; soils, road-materials, building-sands, water-supplies, natural gas.

Beyer, Samuel W. Iowa's Iron Mine. (Eng. and Mining Jour., Vol. LXXIII, pp. 275-276, New York, 1902.) A description of the manner of occurrence, the character, origin and methods of mining of the iron ore in Allamakee county is given.

Beyer, Samuel W. Mineral production of Iowa in 1898. (Iowa Geol. Surv., Vol. IX, pp. 31-48, Des Moines, 1899.) Statistics are given of the output of raw materials for all classes of mineral industry. The figures are by counties.

Beyer, Samuel W. Mineral Production of Iowa in 1899. (Iowa Geol. Surv., Vol. X, pp. 41-58, Des Moines, 1900.) Full statistics are given according to the output of counties.

Beyer, Samuel W. Mineral Production of Iowa in 1900. (Iowa Geol. Surv., Vol. XI, pp. 37-53, Des Moines, 1901.) Detailed statistics by counties are given.

Beyer, Samuel W. Mineral Production of Iowa, in 1901. (Iowa Geol. Surv., Vol. XII, pp. 37-61, Des Moines, 1902.) Full statistics of the output for the year are given. The iron ores are especially considered.

Beyer, Samuel W. Mineral Production of Iowa, in 1902. (Iowa Geol. Surv., Vol. XIV, pp. 7-26, Des Moines, 1904.) Detailed statistics of the output for the year are given by counties.

Beyer, Samuel W. Mineral Production of Iowa, in 1903. (Iowa Geol. Surv., Vol. XIV, pp. 645-655, Des Moines, 1904.) Statistics are given for the year by counties.

Beyer, Samuel W. Mineral Production in Iowa, in 1904. (Iowa Geol. Surv., Vol. XV, pp. 15-32, Des Moines, 1905.) By counties statistics of the output of various minerals are given.

Beyer, Samuel W. Mineral Production in Iowa, in 1905. (Iowa Geol. Surv., Vol. XVI, pp. 17-36, Des Moines, 1906.) Statistics by counties of the output of mines are given for the year.

Beyer, Samuel W. Mineral Production in Iowa in 1906. (Iowa Geol. Surv., Vol. XVII, pp. 11-25, Des Moines, 1907.) Statistics by counties are given of the mine products of the year.

Beyer, Samuel W. Mineral Production in Iowa in 1907. (Iowa Geol. Surv., Vol. XVIII, pp. 11-28, Des Moines, 1908.)

Beyer, Samuel W. Mineral Production in Iowa in 1908. (Iowa Geol. Surv., Vol. XIX, pp. 1-20, Des Moines, 1909.) Statistics by counties are given of the mine-output of the year.

[Beyer, Samuel W.] Mineral Production in Iowa in 1909 and 1910. (Iowa Geol. Surv., Vol. XXI, pp. 1-28, Des Moines, 1912.) Statistics for each of the two years are given.

Beyer, Samuel W. Peat Deposits in Iowa. (Iowa Geol. Surv., Vol. XIX, pp. 689-730, Des Moines, 1909.) The following topics are discussed:

Introduction, peat defined, properties of peat, occurrence, mode of accumulation, peat plants, rate of growth of peat, composition of Iowa peat, heat-value of Iowa peat, methods of preparing peat for market, cut-peat, machine-peat, briquette-peat, uses of peat as a fuel, minor uses of peat, uses for other purposes, table showing location, acreage, depth and drainage of Iowa peat bogs, table showing location and description of samples of Iowa peat, table showing chemical and calorimetric analyses of Iowa peat.

Of special value are the carefully estimated figures on the acreage of peat deposits.

Beyer, Samuel W. Physical Tests of Iowa Limes. (Iowa Geol. Surv., Vol. XVII, pp. 91-150, Des Moines, 1907.) The aspects of the subject discussed are:

General considerations, white versus brown limes, white versus argillaceous or siliceous limes, slaking, setting and hardening, lime-mortars, sands.

Test of lime-mortars, high-calcium white limes, lime from Mason City, lime from Springfield, Missouri, magnesian and dolomitic limes, Eagle Point, Iowa, brown lime, Mason City brown lime, Maquoketa white lime (dolomitic), Excelsior white lime (dolomitic), new-process lime, Viola, Iowa, résumé.

Beyer, Samuel W. Report of Assistant Geologist for 1898. (Iowa Geol. Surv., Vol. IX, pp. 28-29, Des Moines, 1899.) The work of the year is reviewed.

Beyer, Samuel W. Report of Assistant Geologist. (Iowa Geol. Surv., Vol. X, pp. 36-38, Des Moines, 1900.) The work of the year on clays is summarized.

Beyer, Samuel W. Report of Assistant Geologist. (Iowa. Geol. Surv., XI, p. 35, Des Moines, 1901.) A brief statement is made of the work accomplished during the year on the clay deposits of the state.

Beyer, Samuel W. Sioux Quartzite and Certain Associated Rocks. (Iowa Geol. Surv., Vol. VI, pp. 67-112, Des Moines, 1897.) The phenomena described are chiefly as follows:

Introduction, area, topography.

Special area considered, geological formations, Niobrara chalk, Sioux quartzite, slates, relation of slate to quartzite, thickness of quartzite formation, diabase.

Petrographic description of eruptive rocks; olivine diabase, mineralogical composition, feldspar, alteration products, augite, alteration products, olivine, biotite, hornblende, apatite, magnetite, general alteration of the rock, chemical composition, structure.

Petrographic description of quartzite and slate; quartzite, mineralogical constitution; slates, mineralogical constitution, spotted slates.

Origin of quartzite and slates.

Age of quartzite formation.

Although mainly describing phenomena found just outside of the state, the article is the most important one yet published bearing upon the age, origin and character of the Iowa formation.

Beyer, Samuel W. Supplementary Report on Portland Cement Materials in Iowa. (Iowa Geol. Surv., Bull. No. 3, 36 pp., Des Moines, 1906.) This is a preliminary paper giving brief statement concerning some of the more important cement localities in the state.

Beyer, Samuel W., and I. A. Williams. Directory of Iowa Clay Workers. (Iowa Geol. Surv., Vol. XIV, pp. 621-643, Des Moines, 1904.)

Beyer, Samuel W., and I. A. Williams. Geology of Clays. (Iowa Geol. Surv., Vol. XIV, pp. 377-552, Des Moines, 1904.) The topics considered are:

Geological distribution of clays and shales, Saint Croix sandstone, Oneota limestone, Saint Peter sandstone, Galena-Trenton, Allamakee county; Maquoketa shales, Clayton county, Clinton county, Delaware county, Dubuque county, Fayette county, Winneshiek county; Silurian and Devonian, Cerro Gordo county, Floyd county, Franklin county; Carboniferous, Lower Carboniferous, Kinderhook, Des Moines county, Lee county, Washington county; Augusta, Saint Louis; Upper Carboniferous, Coal Measures, Adair county, Adams county, Appanoose county, Boone county, Dallas county, Decatur county, Des Moines county, Fremont county, Greene county, Guthrie county, Hamilton county, Hardin county, Humboldt county, Jasper county, Jefferson county, Keokuk county, Lee county, Lucas county, Madison county, Mahaska county, Marion county, Monroe county, Montgomery county, Muscatine county, Page county, Polk county, Poweshiek county, Scott county, Story county, Taylor county, Union county, Van Buren county, Wapello county, Warren county, Wayne county, Webster county; Cretaceous, Calhoun county, Montgomery county, Plymouth county, Pottawattamie county, Sac county, Sioux county, Woodbury county; Pleistocene, Pre-Kansan or Albertan, Kansan, Illinoian, Iowan, loess, red-clay.

Beyer, Samuel W., and Ira A. Williams. Geology of Quarry Products. (Iowa Geol. Surv., Vol. XVII, pp. 189-588, Des Moines, 1907.) The subjects treated at length are:

Notes on geological section of Iowa, Sioux quartzite, Cambrian sandstone, Prairie du Chien limestone, St. Peter sandstone, Platteville and Galena limestones, Maquoketa shales, Niagara limestones, Devonian system, Lower Carboniferous, Mississippian, Pennsylvanian series, Permian series, Cretaceous system, Pleistocene deposits.

Geology of Iowa quarry-products, Proterozoic, Sioux quartzite; Cambrian system, Potsdam series, Saint Croix sandstone; Ordovician system, Prairie du Chien limestone, Allamakee county, Clayton county, Dubuque, Fayette, Howard, Jackson, Winneshiek counties; Silurian system, Niagara limestone, Bremer, Buchanan, Cedar, lime, Clayton, Clinton, Delaware, Dubuque, Fayette, Jackson, Johnson, Jones counties, Stone City, Anamosa, State Quarry, Linn, Scott, Winneshiek counties.

Devonian system, Benton, Black Hawk, Bremer, Buchanan, Butler, Cedar, Cerro Gordo counties; Lime Creek shales, Chickasaw, Fayette, Floyd, Franklin, Howard, Johnson, Linn, Mitchell, Muscatine, Scott, Worth counties.

Carboniferous, Lower Carboniferous, Mississippian, Kinderhook limestone, Des Moines, Franklin, Grundy, Hardin, Humboldt, Marshall counties. Quarry industry, test of Le Grand stone. Tama county, Washington county; Osage limestone, Des Moines, Keokuk, Lee, Louisa, Van Buren, Washington counties; Saint Louis limestone, Des Moines, Hamilton, Henry, Humboldt, Jefferson, Keokuk, Lee, Mahaska, Marion counties; tests of stone, Pocahontas, Story, Van Buren, Wapello, Washington, Webster counties.

Upper Carboniferous, Pennsylvanian, Des Moines stage, Appanoose, Dallas, Davis, Guthrie, Hardin, Iowa, Jasper, Red-Rock sandstone, Lucas, Marion, Marshall, Muscatine, Polk, Wayne, Webster counties.

Missouri stage, Adair, Adams, Cass, Clarke, Dallas, Decatur, Fremont, Guthrie, Harrison, Madison counties. Analyses of shale and limestone of Mills, Montgomery, Page, Pottawattamie and Taylor counties; Permian system, Webster county; Cretaceous system, Calhoun, Cass, Guthrie, Pottawattamie, Plymouth, Woodbury and Sac counties. Pleistocene system.

Analyses of Iowa coals; analyses of limestone and chalks; analyses of clays, shales and marls; tests of Iowa building-stones, directory of Iowa limestone quarries by counties; directory of Iowa sandstone quarries by counties.

Beyer, Samuel W., and I. A. Williams. Materials and Manufacture of Portland Cement. (Iowa Geol. Surv., Vol. XVII, pp. 29-85, Des Moines, 1907.) The following topics are described:

Introduction.

Complex cements, classes of silicate cements, pozzuolanic, hydraulic, natural, Portland cements; Portland cement, definition, composition and constitution, raw materials for Portland cement, general considerations, raw materials actually in use, argillaceous limestone, pure hard-limestone, soft limestone, chalk, fresh-water marls, alkali waste, blast-furnace slag, clays and shales, slate.

Factors determining the value of deposits of cement materials, methods and cost of excavation of the raw materials, quarrying, mining, dredging, cost of raw materials at the mill.

Methods of manufacture, preparation of mixture for kiln, drying raw materials, percentage of water in raw materials, methods and cost of drying, grinding and mixing, dry-methods, wet-methods, composition of mixture, burning the mixture, summary of burning process, theoretical fuel requirements, losses of heat in practice, actual fuel requirements, and output, effect of composition on burning, character of kiln coal, drying coal, pulverizing coal, total cost of coal preparation, clinker grinding, addition of gypsum, constitution of Portland cement, testing of raw materials to determine availability for manufacture of Portland cement, methods of testing, analysis of limestone, process of analysis, treatment of siliceous residue, analysis of clays, interpretation of analysis, determination of hydraulic factor, calculation of cement mixtures.

Beyer, Samuel W., and I. A. Williams. Technology of Clays. (Iowa Geol. Surv., Vol. XIV, pp. 29-318, Des Moines, 1904.) The following topics are discussed at length:

Technology of clays, definition, origin, classification, primary residual clays, secondary clays, clays deposited in still water, deposited from running water, deposited by glacial action, deposited by wind.

Composition and chemical properties, kaolinite and pholerite, clay substance, properties of kaolinite, impurities of clays, silica, feldspar and mica, iron, lime, magnesia, alkalis, organic matter, uncommon constituents.

Physical properties of clays, raw clays, structure, color, fuel, slaking, strength, bonding-power, plasticity, shrinkage, porosity, specific gravity, fineness of grain, burnt clays, fusibility, fusibility defined, effect of chemical composition, effect of physical condition, methods of expressing, methods of measuring, table of Seger's cones, methods of preparing clay for fusion-tests, table showing fusion-temperatures for Iowa clays.

Processes in manufacture of clay wares, winning of raw material, surface digging, quarrying, mining, transportation of raw material in works, preparation of raw material, dry way, blake-crusher, rolls, disintegrators, dry-pans, ball-mills, wet method, wet-pan, pug-mill, soaking pit, screens, inclined stationary, inclined vibrating dunlap, formation of clay wares, manufacture of brick, soft mud, stiff mud, cutting-tables, repressing, dry-press, manufacture of drain-tile and building-block, manufacture of sewer-pipe, manufacture of pottery, wedging, jolly, stoneware glazing, salt, slip, bristol.

Properties of clays used in manufacture of foregoing classes of wares, soft-mud brick, stiff-mud brick, drain-tile and hollow-block, sewer-pipe, earthenware, stoneware, drying of clay wares, general consideration, practical consideration in drying clays, types of dryers, outside air-drying, the hot-floor, sewer-pipe or slatted floor, periodic or chamber dryer, continuous tunnel-dryer, direct, fuel for purpose, waste gases from other processes, indirect, radiation from heated brick-work, steam-heated surfaces, summary; burning of clay wares, combustion of fuel, general discussion, practical consideration, changes which occur in burning of clays, water-smoking, stage of oxidation, vitrification, types of kilns, intermittent kilns, updraft, temporary, English clamp, American scove, permanent, direct, rectangular, round, pottery, semi-muffle, muffle, downdraft, direct round, single stack, multiple stack, direct rectangular, single stack, multiple stack, muffle, continuous.

Beyer, Samuel W., and L. E. Young. Geology of Monroe County. (Iowa Geol. Surv., Vol. XIII, pp. 353-433, Des Moines, 1903.) The following subjects are considered:

Introduction, location and area, previous geological work.

Physiography, topography, general features, table of elevations, drainage, Des Moines river system, Cedar river, Coal creek.

Stratigraphy, general relations of strata, general features, table of formations, geological formations; Mississippian series, St. Louis stage; Pennsylvanian series, Des Moines stage, Monroe beds, Appanoose beds, Chariton conglomerate; Pleistocene deposits, pre-Kansan, Kansan, loess, recent.

Economic geology, coal, historical sketch, importance of the industry, coal-basins, Miller creek district, Smoky hollow, Foster district, Hiteman, Cedar creek mines, Hocking, Hilton, Bluff creek district, mining methods, system, ventilation and drainage, haulage, gaging and arrangement of bottom, pithead machinery, grading and loading, power-plants, transportation and markets, coal-tests, analyses, calorimetry; clays, building-stones, builders' and molders' sand, road-materials, soils, potable waters.

Forest trees and shrubs of Monroe county.

Bibliographic index of North American carboniferous invertebrates. S. Weller. (Bull. U. S. G. S., No. 153, 653 pp., 1898.)

Bibliography.

Annotated bibliography of Iowa geology and mining. C. R. Keyes. (Iowa Geol. Surv., XXII, 1913.)

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Bibliography of Iowa coals. J. H. Lees. (Iowa Geol. Surv., XIX, 659-687, 1909.)

Bibliography of Iowa geology. C. R. Keyes. (Iowa Geol. Surv., I, 209-464, 1893.)

Bibliography of Iowa peat. J. H. Lees. (Iowa Geol. Surv., XIX, 731-733, 1909.)

Epoch in history of American science. C. R. Keyes. (Annals of Iowa, Historical Quarterly, (3), II, 345-364, 1896.)

Iowa scientist and his work. C. R. Keyes. (Annals of Iowa, Historical Quarterly, IV, 383-392, 1900.)

Bibliography, annotated of Iowa Geology and mining. C. R. Keyes. (Iowa Geol. Surv., XXII, 1913.)

Bibliography of Iowa coal. J. H. Lees. (Iowa Geol. Surv., XIX, 659-687, 1909.)

Bibliography of Iowa geology. C. R. Keyes. (Iowa Geol. Surv., I, 209-464, 1893.)

Bibliography of Iowa peat. J. H. Lees. (Iowa Geol. Surv., XIX, 731-733, 1909.)

Bibliography of North American paleontology, 1888-1892. C. R. Keyes. (U. S. Geol. Surv., Bull. 121, 250 pp., 1894.)

Bierbauer, Bruno. Check List of Paleozoic Fossils of Wisconsin, Minnesota, Iowa, Dakota and Nebraska. (Bull. Minnesota Acad. Nat. Sci., Vol. III, pp. 206-247, Minneapolis, 1888.) Many of the species described from Iowa are listed.

Biographical sketch of Charles Wachsmuth. C. R. Keyes. (American Geologist, XVII, 131-136, 1896.)

Biography.

Biographical sketch of Charles Wachsmuth. C. R. Keyes. (American Geologist, XVII, 131-136, 1896.)

Elston Holmes Lonsdale, memorial. C. R. Keyes. (American Geologist, XXI, 264-265, 1898.)

Epoch in history of American science. C. R. Keyes. (Annals of Iowa, Historical Quarterly, (3), II, 345-364, 1896.)

Geological surveys of Iowa. C. R. Keyes. (Annals of Iowa, Historical Quarterly, (3), III, 111-121, 1897.)

Memorial of Charles Wachsmuth. C. R. Keyes. (Proc. Iowa Acad. Sci., IV, 13-16, 1897.)

Professor W. H. Barris. C. H. Preston. (American Geologist, XXVIII, 358-361, 1901.)

Samuel Calvin. H. Foster Bain. (Journal of Geology, XIX, 385-391, 1911.)

Samuel Calvin. George F. Kay. (Science, N. S., XXXIV, 106-107, 1911.)

W. J. McGee; Geologist, Anthropologist, Hydrologist. Charles Keyes. (Annals of Iowa; an historical Quarterly, XI, 1913.)

Bisbee, D. B. Nitrogen Compounds of Soil. (Proc. Iowa Acad. Sci., Vol. II, p. 66, Des Moines, 1895.) Explanation is made of the method of the determination of nitrogen, as developed in connection with the work on soils of the state undertaken by the Iowa geological survey.

Bissell, G. W. Selection, Installation and Care of Power-plants. (Iowa Geol. Surv., Vol. XIV, pp. 349-376, Des Moines, 1904.) The following subjects are explained:

Selection of power-plants, requirements: power-house; machinery, boilers, desirable types, shaking grate.

Specification for horizontal return tubular boiler 72 inches by 18 feet dimensions, material, tubes and braces, riveting construction, openings, castings, fittings, inspection and test.

Alternate specifications for boilers 66 inches by 18 feet, boiler feeding, cold feed-water, feed-water heaters, open, closed, advantages of open heater, construction of open heater, requirements of open heater.

Firing, analyses of Iowa coals, general characteristics of Iowa coals, calorific power of Iowa coals and other fuels, methods of firing.

Engines, proportions to be observed in selection, effective power calculated, foundation for engine.

Minor items, lagging of steam pipes, fitting self-oiling bearings, transmission belts, use of exhaust steam in heating drying room, ventilation.

Bissell, G. W. Selection of Power-Plants and Equipment for Stone Quarries in Iowa. (Iowa Geol. Surv., Vol. XVII, pp. 151-183, Des Moines, 1907.) The following topics are considered:

Introductory, power-house, machinery, boilers, table of dimensions for boilers, specifications for horizontal boilers 72 in. by 18 ft., dimensions, material, riveting, tubes and braces, supports, construction, openings, castings, fittings, inspection and tests, alternate specifications for boilers 66 and 60 in. by 18 feet, table showing capacities in horse-power of chimneys, boiler-feeding, use of cold-feed water, feed-water heaters, open heater, closed heater, advantages of open heater, requirements of open heater, firing, analyses of Iowa coals, general characteristics of Iowa coals, calorific power of Iowa coals and other fuels, cost of fuel and of steam, methods of firing, engines, proportions to be observed in selection, effective power calculated, size of engines, minor items, lagging of steam-pipes, oiling devices, belts, transmission of steam to drills.

Gas-engine power for quarries, tests of fuels, tests of producer gas-engines.

Black Hawk County.

Cretaceous fossils in drift. C. A. White. (Proc. American Association Adv. Sci., XXI, 187-192, 1873.)

Devonian fishes of Iowa. C. R. Eastman. (Iowa Geol. Surv., XVIII, 29-360, 1908.)

Geology of Black Hawk county. M. F. Arey. (Iowa Geol. Surv., XVI, 407-453, 1906.)

Hydraulic cement. C. A. White. (First Ann. Rep. State Geologist, 20-21, 1868.)

Water supplies at Waterloo, Iowa. W. H. Norton. (Water-Supply and Irrigation Papers, U. S. Geol. Surv., 148-155, 1905.)

Species of new genus Newberria from devonian noted. J. Hall. (Tenth Ann. Rep. State Geologist of New York, 91-102, 1891.)

Underground water resources of Iowa. W. H. Norton. (Iowa Geol. Surv., XXI, 29-1214, 1912.)

Underground water resources of Iowa. W. H. Norton. (U. S. Geol. Surv., Water Supply Paper No. 293, 994 pp., 1912.)

Black Hawk county, geology. M. F. Arey. (Iowa Geol. Surv., XVI, 407-452, 1906.)

Clay-slide at Boone viaduct, Boone, Iowa. A. W. Merrick. (Journal of Western Soc. Eng., XI, 332-339, 1906.)

Coal deposits of Iowa. C. R. Keyes. (Iowa Geol. Surv., II, 536 pp., 1894.)

Coal deposits of Iowa. H. Hinds. (Iowa Geol. Surv., XIX, 21-396, 1909.)

Coal mines at Boonsboro. C. A. White. (Second Ann. Rep. State Geologist, 142, 1868.)

General description. C. A. White. (Geology of Iowa, II, 259, 1870.)

Geology of Boone county. S. W. Beyer. (Iowa Geol. Surv., V, 167-232, 1896.)

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Description of new species of fossils. F. B. Meek and A. H. Worthen. (Geol. Sur. Illinois, III, 289-565, 1868.)

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Geology of Iowa county. S. W. Stookey. (Iowa Geol. Surv., XX, 151-186, 1910.)
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Synopsis of American paleozoic echinoids. C. R. Keyes. (Proc. Iowa Acad. Sci., II, 178-194, 1895.)

Transition forms in crinoids and description of five new species. Charles Wachsmuth and Frank Springer. (Proc. Acad. Nat. Sci. Phila., 224-266, 1878.)

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Geology of quarry products. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

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Geology of Boone county. S. W. Beyer. (Iowa Geol. Surv., V, 167-232, 1896.)

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Geology of Dubuque county. S. Calvin and H. F. Bain. (Iowa Geol. Surv., X, 379-651, 1900.)

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Geology of Louisa county. J. A. Udden. (Iowa Geol. Surv., XI, 53-126, 1901.)

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Call, R. Ellsworth. Artesian Wells in Iowa. (Science, Vol. XIX, pp. 310-311, New York, 1892.) A summary of the knowledge is presented concerning the localities where deep-borings for artesian-waters have been made.

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Call, R. Ellsworth. Sketch of Physical Geography of Iowa. (Annual Report of Iowa Weather and Crop Service, 1890, pp. 12-18, Des Moines, 1891.) A short account of the surface features of Iowa is given, with map of the chief hydrographic basins of the state.

Call, R. Ellsworth. Chemistry of Iowa Artesian Waters. (Monthly Rev. Iowa Weather and Crop Service, Vol. II, No. 2, pp. 1-5, Des Moines, 1892.) Results of analyses of the waters, as determined by different chemists, of various wells in the state are tabulated.

Call, R. Ellsworth. Fossils of Iowa loess. (American Naturalist, Vol. XV, pp. 585-586, Philadelphia, 1881.) Certain species found in the bluffs of the Missouri river are noted.

Call, R. Ellsworth. Iowa Artesian Wells. (Monthly Rev. Iowa Weather and Crop Service, Vol. III, No. 3, pp. 1-15, Des Moines, 1892.) This is a brief sketch of the conditions governing artesian flows, with geological notes of different wells throughout the state. An accompanying sketch-map shows the location of the chief wells.

Call, R. Ellsworth. Loess of North America. (American Naturalist, Vol. XVI, pp. 369-381, Philadelphia, 1882.) A number of references are made to the occurrence of loess in Iowa.

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Call, R. Ellsworth. Preliminary Paper on Artesian Wells in Iowa. (Monthly Review of Iowa Weather and Crop Service, Vol. II, No. iv, pp. 1-6, Des Moines, 1891.) Tables of the wells of the state, their location, depth and character of the waters are given.

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Call, R. Ellsworth, C. R. Keyes and. Quaternary Section Eight Miles Southeast of Des Moines, Iowa. (Proc. Iowa Acad. Sci., Vol I, pt. ii, p. 30, Des Moines, 1892.) Description is given of a section near the terminal moraine of the Wisconsin drift, near Des Moines.

Call, R. Ellsworth, W. J. McGee and. Loess and Associated Deposits of Des Moines. (Am. Jour. Sci., (3), XXIV, pp. 202-223, New Haven, 1882.)

Calvin, Samuel. Additional Notes on the Devonian Rocks of Buchanan County, Iowa. (American Geologist, Vol. VIII, pp. 142-145, Minneapolis, 1891.) A detailed description of the different beds belonging to the Devonian section, as found in Buchanan county, is given.

Calvin, Samuel. Aftonian Age of Aftonian Mammalian Fauna. (Proc. Iowa Acad. Sci., Vol. XVII, pp. 177-180, Des Moines, 1910.) The question discussed is why the remains are not older than the Aftonian. The bones are not abraded to the slightest degree.

Calvin, Samuel. Aftonian Gravels and their Relations to Drift-sheets in Region about Afton Junction and Thayer. (Proc. Davenport Acad. Sci., Vol. X, pp. 18-30, Davenport, 1907.) The evidence set forth shows two things: "First, in certain localities the Kansan ice rode over the older deposits without causing any break or disturbance, in which case the materials of the older formations occupy their proper stratigraphic relations to the newer Kansan till. Second, under certain conditions the glaciers of the Kansan stage plowed up the Aftonian and sub-Aftonian beds and incorporated masses varying from a few inches to many feet in diameter, in the great sheet of Kansan drift. The evidence probably warrants a third statement to the effect that, when all the facts are taken into account, there is no transition of Aftonian gravels to Kansan clays and nothing that argues contemporaneity of age."

Calvin, Samuel. Aftonian Mammalian Fauna. (Bull. Geol. Soc. America, Vol. XX, pp. 341-356, New York, 1909.) The deposits at the original locality are briefly described. Chief consideration is given to the larger relationships of the fossils recently discovered. Horses, elephants, and edentates make up the principal fanual elements.

Calvin, Samuel. Aftonian Mammalian Fauna, II. (Bull. Geol. Soc. America, Vol. XXII, pp. 207-216, New York, 1911.)

Calvin, Samuel. Apparent Anomalies of Stratification of Postville Well. (American Geologist, Vol. XVII, pp. 195-203, Minneapolis, 1896.) The peculiarities of the so-called Trenton limestone and the Galena dolomite are pointed out and discussed.

Calvin, Samuel. Buchanan gravels; an Interglacial Deposit in Buchanan County, Iowa. (American Geologist, Vol. XVII, pp. 76-78, Minneapolis, 1896.) The deposit is shown to be between the Iowan and Kansan till-sheets; and its peculiarities are fully described.

Calvin, Samuel. Buchanan Gravels; an Interglacial Deposit in Buchanan County, Iowa. (Proc. Iowa Acad. Sci., Vol. III, pp. 58-60, Des Moines, 1896.) These beds are described in detail. Large railroad gravel-pits are open in them.

Calvin, Samuel. Cedar Valley Quarry. (Eng. and Mining Jour., Vol. LXI, p. 544, New York, 1896.) The building-stones of this extensive quarry are described; and its geologic relations considered.

Calvin, Samuel. Composition and Origin of Iowa Chalk. (Iowa Geol. Surv., Vol. III, pp. 211-236, Des Moines, 1895.) The microscopic examination of the Iowa chalk shows that it is composed of two chalk-forming organisms in great abundance. The various forms recognized are listed and figured. Conditions under which the chalk was formed are discussed at some length.

Calvin, Samuel. Concerning Occurrence of Gold and some Other Mineral Products in Iowa. (American Geologist, Vol. XXVII, pp. 363-372, Minneapolis, 1901.) The author discusses the close relation existing between certain mineral products and the geologic formations.

Calvin, Samuel. Cretaceous Deposits of Woodbury and Plymouth Counties, with Observations on their Economic Uses. (Iowa Geol. Surv., Vol. I, pp. 145-161, Des Moines, 1893.) The general sequence of strata is described in detail and the several subdivisions are correlated with the general Cretaceous column of the Upper Missouri region. The chalk beds are referred to the Niobrara terrane.

Calvin, Samuel. Description of a New Species of Spirifera from the Hamilton Group, near Iowa City, Iowa. (Bull. Lab. Nat. Hist., Iowa State Univ., Vol. I, pp. 28-29, Iowa City, 1888.) *Spirifera urbana* is described as new.

Calvin, Samuel. Devil's Backbone. (Midland Monthly, Vol. VI, pp. 20-26, Des Moines, 1896.) Description is given of a picturesque bit of scenery in Delaware county.

Calvin, Samuel. Eighteenth Annual Report of State Geologist. (Iowa Geol. Surv., XIX, pp. xi-xv, Des Moines, 1909.) Brief statement is made of the work of the year.

Calvin, Samuel. Eighth Annual Report of State Geologist. (Iowa Geol. Surv., Vol. X, pp. 11-27, Des Moines, 1900.) A summary of the work of the year 1899 is given.

Calvin, Samuel. Eleventh Annual Report of State Geologist. (Iowa Geol. Surv., Vol. XIII, pp. 11-13, Des Moines, 1903.) The work of the year is briefly summarized.

Calvin, Samuel. Fifteenth Annual Report of State Geologist. (Iowa Geol. Surv., Vol. XVII, pp. 1-6, Des Moines, 1902.) Brief summary is given of the work of the year.

Calvin, Samuel. Fifth Annual Report of State Geologist. (Iowa Geol. Surv., Vol. VII, pp. 11-27, Des Moines, 1897.) Besides the administrative report the complex history of the glacial period is outlined, five glacial stages being recognized and also the same number of interglacial epochs.

Calvin, Samuel. First Annual Report of State Geologist for 1892. (Iowa Geol. Surv., Vol. I, pp. 3-5, Des Moines, 1893.) There is summarized the work of the several members of the geological corps during the year.

Calvin, Samuel. Fourth Annual Report of State Geologist. (Iowa Geol. Surv., Vol. V, pp. 12-25, Des Moines, 1896.) In the administrative report the work of the survey is briefly reviewed.

Calvin, Samuel. Geological Reconnaissance in Buchanan County, Iowa. (Bull. Lab. Nat. Hist., State Univ. Iowa, Vol. II, pp. 177-189, Iowa City, 1893.) The numerous exposures of Devonian strata chiefly are noted, and the organic remains characterizing the several layers are named. Certain peculiarities in the distribution of the outcrops are ascribed to uplift at the close of Silurian time.

Calvin, Samuel. Geology and Geologic Resources of Iowa—Formations and their Economic Values. (Mines and Minerals, Vol. XXII, pp. 560-561, Scranton, 1902.) Brief characterizations are given of the mining possibilities of several terranes.

Calvin, Samuel. Geology and Geological Resources of Iowa. (Proc. International Mining Congress, Fourth Sess., pp. 52-56, 1901.) An outline of the stratigraphy is given and the products of economic importance are referred to the different terranes.

Calvin, Samuel. Geology and Revelation. (Pamphlet, 27 pp., 1909.) The address was delivered before the members of the Okoboji Lakeside laboratory on Sunday, the fourth of July, 1909, and printed privately.

Calvin, Samuel. Geology of Allamakee County. (Iowa Geol. Surv., Vol. IV, pp. 35-114, Des Moines, 1895.) The following topics are discussed in detail:

Introduction, situation and area, previous geological work.

Physiography, topography; drainage, Oneota river, Village creek, Paint creek, Yellow creek.

Stratigraphy, general relations, geological formations; Cambrian, Saint Croix sandstone, distribution, thickness, lithological character; Ordovician, Oneota limestone, surface distribution, thickness, fauna, taxonomic relations, Saint Peter sandstone, general description, topographic features, distribution, fauna, Trenton limestone, general description, distribution and relations to drainage, fauna, Galena limestone, superficial deposits, soils, geological structure, deformations.

Economic products, building-stones, Saint Croix, Oneota, Saint Peter, Trenton, Galena, ornamental stones, limes, hydraulic limes and cements, clays, sands, glass sands, building sand, iron, mineral-paint, lead, galena, zinc, water-powers.

Forest trees of Allamakee county.

Of special interest among the subjects considered are the physiographic features of the region, the determination of the Oneota limestone, the character of the residual deposits; the formation of the iron-ores, and the occurrence of lead-ores in the Oneota formation.

Calvin, Samuel. Geology of Buchanan County. (Iowa Geol. Surv., Vol. VIII, pp. 201-253, Des Moines, 1898.) The subdivision of the report is as follows:

Introduction, situation and area, geological work in Buchanan county.

Physiography, topography, drainage.

Geological formations, general relations of strata; Silurian system, Niagara limestone; Devonian system, Independence shales, Fayette breccia, Cedar Valley limestone; Pleistocene, Kansan, Buchanan, Iowan, loess, post-glacial deposits; soils; deformations; unconformities.

Economic products, building-stones, limes, brick-clays, coal, road-materials, water-supplies, water-powers.

Calvin, Samuel. Geology of Cerro Gordo County. (Iowa Geol. Surv., Vol. VII, pp. 117-195, Des Moines, 1897.) Descriptions include the following features:

Introduction, situation and area, previous geological work.

Physiography, topography, Iowan drift-area, Altamont moraine, table of elevations; drainage, Lime creek, Shell Rock river, Willow creek, Calamus creek, Cold water creek, drainage of morainic area, sources of supply of Clear lake, drainage during Wisconsin time.

Geological formations, general description; Devonian system, Cedar Valley limestone, stratigraphical equivalents, typical exposures, Kuppinger quarry, Parker mill section, Lein quarry, Belding quarry, Mason City quarries, Portland section, exposure on Lime creek below Portland, sections at Nora Springs and Rockford, sections along Shell Rock river, sections along Lime creek above Mason City, section along interglacial channel, general section of Cedar Valley limestone, Lime Creek shales, Hackberry Grove section, Owen Creek exposures, general section of Lime Creek shales, Fauna of Lime Creek shales; Carboniferous system, Kinderhook; Pleistocene system, Kansan drift, Buchanan gravels, Iowan drift, Wisconsin drift, eskers and valley-trains, post-glacial deposits; soils; deformations; unconformities.

Economic products; building-stones, Kuppinger quarry, Belding quarry, Mason City stone quarry, Mason City quarry, other quarries in Cedar Valley limestone; quarries in Owen beds; value of quarry products, future of stone industry; limes, clays, Mason City Brick and Tile Co., Nelson brickyard, future of clay industry; peat, water-supplies, Mason City deep-well, water-powers.

Calvin, **Samuel**. Geology of Chickasaw County. (Iowa Geol. Surv., Vol. XIII, pp. 255-292, Des Moines, 1903.) The descriptions take up the following topics:

Introduction, geologic and geographic relations, area, previous geological work.

Physiography, topography, Iowan plain, rolling Iowan, pre-Iowan topography, shallow stream valleys, drainage, altitudes.

Stratigraphy, synopsis, synoptical table; Devonian system, general discussion, typical exposures, Gypidula Comis beds, Atrypa Occidentalis beds, Acervularia Profunda beds, Spirifer Parryanus beds, Idiostroma beds, lithographic beds, intermediate beds, upper yellow magnesian beds, general Devonian section; Pleistocene system, Kansan stage, Kansan drift, Buchanan gravels, Iowan stage, Iowan drift, Iowan bowlders, bowlders not superglacial, depth of Pleistocene deposits.

Soils.

Economic products, building-stones, limestones, granites, limes, brick-clays, road-materials, peat, limonite, water-supplies, water-powers.

Calvin, Samuel. Geology of Delaware County. (Iowa Geol. Surv., Vol. VIII, pp. 119-199, Des Moines, 1898.) Subjects discussed are:

Introduction. Physiography, topography, drainage.

Stratigraphy; Ordovician, Maquoketa shales; Silurian, Delaware stage, cliff-forming beds, non-dolomitic beds, fossils, chert-beds; Devonian, Wapsipinicon; Cretaceous, Rockville conglomerate; residual materials; Pleistocene, sub-Aftonian, Kansan, Buchanan gravels, Iowan drift, loess, alluvium, terraces; soils; deformations.

Economic products, building-stones, limes, clays, cement-rocks, iron-ores, road-materials, railway ballast, water-supplies, water-powers.

Calvin, Samuel. Geology of Howard County. (Iowa Geol. Surv., Vol. XIII, pp. 21-79, Des Moines, 1903.) The features chiefly described are:

Introduction, location and area, previous geological work.

Physiography, topography, general discussion, topography of loess-Kansan area, area occupied by Kansan drift, preglacial valley of Upper Iowa or Oneota river, mixed types of topography, topography of Iowan area, relative size of area, relative age of topographic forms, genesis of Iowan topographic forms, typical characteristics of Iowan plain, stream valleys in Iowan area, preglacial topography in Iowan area, other unusual types, drainage, drainage courses mostly preglacial, Upper Iowa or Oneota river, Turkey river, streams in southwestern part of county.

Stratigraphy, general description; Devonian overlap, synoptical table; Ordovician system; Galena-Trenton, distribution, characteristics, typical sections and exposures, cliffs in Albion township, section at Florenceville, section at Granger, Minnesota; Maquoketa or Hudson River shales, general characteristics, fossils, distribution, typical exposures, correlation and thickness; Devonian system, general description, relation to Maquoketa, horizon of lowest Devonian in Howard county, typical exposures, Productella beds, Acervularia beds, Stromatoporoid horizon, non-dolomitic beds preserving anomalous fauna, quarry-stone beds, dip of Devonian, general Devonian section; Pleistocene system, Kansan stage, Kansan till, Buchanan gravels, Iowan stage, Iowan till, Iowan loess, alluvium, thickness of Pleistocene deposits.

Soils, loess soils, alluvial soils, sandy and gravely soils, soils developed on Iowan drift.

Unconformities.

Economic products, quarry-stones, clays, limes, road-materials, water-supplies, water-powers.

Summary.

Calvin, Samuel. Geology of Johnson County. (Iowa Geol. Surv., Vol. VII, pp. 33-116, Des Moines, 1897.) The following subjects are treated in detail:

Introduction, situation and area, geological work in Johnson county.

Physiography, topography, Iowan drift-plains, Kansan drift-plains, topography of loess, river flood plains, lake-basins; table of elevations; drainage, Iowa river, Clear creek, Buffalo creek, Old Man creek, Pardieu creek, Rapid creek, Sander creek.

Stratigraphy, general relations of strata, synoptical table; geological formations, Silurian system, La Claire limestone, Anamosa limestone, Bertram and Coggan beds; Devonian system, Wapsipinicon stage, Otis and Independence beds, Fayette breccia, Cedar Valley stage, typical localities and exposures, general section, State Quarry limestone, State Quarry fish-beds, distribution, taxonomic relations; Carboniferous system, Kinderhook stage, Des Moines stage, Iowa City outlier, Anamosa outlier, fossils; Pleistocene system, Kansan drift, Glacial scorings, Iowan drift, loess, genesis of loess, fossils; alluvium, depth of Pleistocene deposits, pre-glacial surface; soils, drift-soils, alluvial soils, loess soils; deformations; unconformities.

Economic products, building-stones, Anamosa stage, Wapsipinicon stage, Cedar Valley stage, State Quarry stage, Des Moines stage, railway ballast and road materials, ornamental stone, flagging-stone; limes, sands; clays, River Junction, Oxford, Tiffin, Iowa City; minerals, water-supplies, water-powers.

Forest trees of Johnson county.

Occurrence of fossil fishes in the Devonian of Iowa.

The glacial deposits and the State Quarry formations are especially described.

Calvin, Samuel. Geology of Jones County. (Iowa Geol. Surv., Vol. V, pp. 33-112, Des Moines, 1896.) The following is a table of the contents of the report:

Introduction, situation and area, previous geological work.

Physiography, topography, drift-plains, loess hills, alluvial plains and river valleys, drainage.

Stratigraphy, general relations of strata; geological formations, Niagara series, Delaware stage, Le Claire stage, Anamosa stage, Bertram stage; Carboniferous series, Des Moines stage; geest; Pleistocene deposits, typical exposures, Castle Grove township, Monticello township, Richland township, Washington township, Cass township, Wayne township, Scotch Grove township, Clay township, Fairview township, Jackson township, Madison township, Wyoming township, Greenfield township, Rome township, Hale township, Oxford township; unconformities; deformations.

Economic products, soils; building-stones, Gold Hill quarry, Champion quarry, Stone City quarry, Anamosa quarry, Gem quarry, State quarry, Johnellen quarry, other quarries of Stone City basin, Andrew Rummel quarry, Shope quarries, Dolby quarry, Carter quarry, Hale quarry, Clay quarry, Ballou quarry, other quarries in

Anamosa limestone; limes, clays, clay-works; building-sands, moulding-sands, road-materials, lead, water-supplies, water-powers.

Calvin, Samuel. Geology of Mitchell County. (Iowa Geol. Surv., Vol. XIII, pp. 293-352, Des Moines, 1903.) The features described in detail are:

Introduction, geological relations, topographical relations, causes of certain topographic phenomena, geographical relations, area; previous geological work.

Physiography, topography, drainage, altitudes.

Stratigraphy, general discussion, synoptical table; Devonian system, typical sections and exposures, Lewis lime-quarry, Chandler cliff section, rock exposures near Orchard, exposures near Mitchell, St. Ansgar exposures, Otranto exposures, exposures west of Cedar river, exposures on the Little Cedar, exposures near McIntire; Pleistocene system, Kansan stage, Kansan drift, Buchanan gravels, Iowan stage, Iowan drift, Iowan loess, supra-Iowan loess, Iowan terraces.

Deformations and unconformities.

Soils.

Economic products, building-stones, limes, lithographic stone, road-materials, clays, iron-ore, coal.

Water-supplies.

Water-powers.

Summary.

Calvin, Samuel. Geology of Page County. (Iowa Geol. Surv., Vol. XI, pp, 397-468, Des Moines, 1901.) The subjects considered in this connection are here enumerated:

Introduction, location and area, previous geological work.

Physiography, topography, drainage.

Stratigraphy, general relations of strata, synoptical table of geological formations; Carboniferous system, Missourian stage, general discussion, Keyes' divisions of the Missourian, correlations, typical sections, Hawleyville, Braddyville, Shambaugh mill, general dip of strata, Burlington Junction section, sections of limestones of Tarkio valley, relations of Tarkio limestones to Nodaway limestones, Linquist coal-horizon, deep drill-holes, Clarinda, Larrabee well, Grant township wells, Falk prospect-hole; Cretaceous system, Dakota stage; Pleistocene system, Kansan drift, relation to topography, materials forming drift, indications of age, residual gravel, loess, two beds of loess, flooded-valley deposits, characteristics, distribution, probable age, alluvium.

Deformations and unconformities.

Soils.

Economic products, coal, Ingraham mine, mines near Shambaugh, Linquist coal; building-stones, brick and tile, water-supplies, wells, springs, Dunbar mineral springs, water-powers.

Summary.

Calvin, Samuel. Geology of Winneshiek County. (Iowa Geol. Surv., Vol. XVI, pp. 37-146, Des Moines, 1906.) The various topics treated of are as follows:

Introduction, geographic and geologic relations, area, boundaries, relations to topographic areas, relations to distribution of geological formations, previous geological work.

Physiography, topography, preglacial topography, topographic effects of the several rock-formations, topography controlled by Pleistocene deposits, area of Kansan drift, Iowan-Kansan drift, Iowan-Kansan border, area of Iowan drift, topography due to recent shifting of mantle rocks, larger topographic features, Cresco-Calmar ridge, drainage basin of the Oneota, or Upper Iowa river, drainage basin of Yellow river, drainage basin of Turkey river, elevations, drainage, Oneota, or Upper Iowa river, Canoe creek, Bear creek, Ten-mile creek, Trout creek, Root river system, Turkey river, drainage of the Iowan plain.

Stratigraphy, general relations of the strata, synoptical table, new names used in synoptical table, Cambrian system, Oneota limestone, New Richmond sandstone, Shakopee limestone, Saint Peter sandstone, Trenton series, Platteville limestone, Decorah shale, Galena limestone, Maquoketa beds, Elgin beds, Clermont shales, Fort Atkinson limestone, Brainard shale, Silurian system, Niagara series, Hopkinton limestone, Devonian system, Middle Devonian series, Wapsipinicon and Cedar Valley limestones.

Mantle rocks, residual materials, Pleistocene system, glacial series, Kansan stage, Kansan drift, Buchanan gravels, deposits of uncertain age—possibly Kansan, Post-Kansan loess, Iowan stage, Iowan drift, Iowan sand terraces, Iowan loess, alluvium.

Soils, stony residual soils, loess-Kansan soils, Iowan drift soils, alluvial soils.

Unconformities, the great unconformity between Ordovician and Devonian, other unconformities.

Economic products, building-stone, Oneota, Platteville, Galena, Maquoketa, Isotelus zone, Fort Atkinson limestone, Niagara lime, clays, road-materials, water-supplies, water-powers, gold.

Caves, Glenwood cave, Decorah ice-cave.

Calvin, Samuel. Interglacial Deposits of Northeastern Iowa. (Proc. Iowa Acad. Sci., Vol. V, pp. 64-70, Des Moines, 1898.) With the recognition of several drift-sheets comes complexity of interglacial considerations. Buchanan gravels are described, but represent two interglacial intervals instead of one.

Calvin, Samuel. Iowan drift. (Bull. Geol. Soc. America, Vol. X, pp. 107-120, Rochester, 1899.) This till-sheet is compared with the other tills of the state. Its boundaries and features are described.

Calvin, Samuel. Iowan Drift. (Bull. Geol. Soc. America, Vol. XXII, pp. 729-730, New York, 1911.) Abstract.

Calvin, Samuel. Iowan drift. (Journal of Geology, Vol. XIX, pp. 577-602, Chicago, 1911.) The evidence is set forth showing that the till-sheet to which the name is applied is quite distinct from all others in the region. The nomenclature of all the glacial deposits of the state is fully discussed.

Calvin, Samuel. Le Claire limestone. (Bull. Lab. Nat. Hist., State Univ. Iowa, Vol. III, pp. 183-189, Iowa City, 1896.) The remarkable oblique bedding of this formation is decribed and its origin considered.

Calvin, Samuel. Le Claire Limestone. (Proc. Iowa Acad. Sci., Vol. III, pp. 52-58, Des Moines, 1896.) This is a detailed characterization of the formation as it occurs in Iowa.

[Calvin, Samuel.] Later Cretaceous in Iowa. (American Geologist, Vol. I, p. 337, Minneapolis, 1888.) A short note is made on the Cretaceous fossils found in the drift near Mt. Vernon, in Linn county.

Calvin, Samuel. Maquoketa Shales in Delaware County. (Proc. Iowa Acad. Sci., Vol. II, pp. 40-42, Des Moines, 1895.) Announcement is made of the fact that owing to a low fold trending northwest and southeast across the county some of the streams have cut through the Silurian strata exposing Ordovician shales.

Calvin, Samuel. New Horizons and Some New Localities for Friable Sandstone in which the Grains are enlarged by Secondary Deposition of Silica in Optical Continuity with the original Nucleus. (American Geologist, Vol. XIII, pp. 225-227, Minneapolis, 1894.) Many localities in northeastern Iowa are noted where the phenomenon is observable. The geologic horizon of the sandstone is the New Richmond formation of the Canadian series.

Calvin, Samuel. New Species and New Genus of Tubicolar Annelida. (American Geologist, Vol. I, pp. 24-28, Minneapolis, 1888.) This is an account and description of a worm found infesting the Devonian corals near Iowa City. The following genus and species are described as new:

Streptindytes.

Streptindytes acervulariae.

Calvin, Samuel. Ninth Annual Report of State Geologist. (Iowa Geol. Surv., Vol. XI, pp. 11-30, Des Moines, 1901.) The work of the previous year is summarized.

Calvin, Samuel. Niobrara Chalk. (American Geologist, Vol. XIV, pp. 140-161, Minneapolis, 1894.) The physical characters of the rock are noted and comparison is made with the English chalk. The areal extent in the state is estimated. This description refers to the Crill chalk or lime-stone and not to the Niobrara chalk proper.

Calvin, Samuel. Niobrara Chalk. (Journal of Geology, Vol. II, pp. 755-756, Chicago, 1894.) The character of the chalk is briefly noted.

Calvin, Samuel. Niobrara Chalk. (Proc. American Assoc. Adv. Sci., Vol. XLIII, pp. 192-217, 1895.) The stratigraphy of the formation is discussed and the foraminiferal origin of the chalk explained.

Calvin, Samuel. Notable Ride; From Driftless Area to Iowan Drift. (Proc. Iowa Acad. Sci., Vol. VII, pp. 72-77, Des Moines, 1900.) Along the Illinois Central railroad from Dubuque to Dyersville, a distance of 30 miles, is one of the most instructive trips for observing Pleistocene phenomena known, and one that should become famous.

Calvin, Samuel. Note on Difference between Acervularia Profunda, Hall, and Acervularia Davidsoni, Edwards and Haime. (Proc. Iowa Acad. Sci., Vol. I, pt. ii, pp. 30-32, Des Moines, 1892.) Characters of the two species at Independence, Iowa, and elsewhere, are given.

Calvin, Samuel. Note on Difference between Acervularia Profunda, Hall, and Acervularia Davidsoni, Edwards and Haime. (American Geologist, Vol. IX, pp. 355-358, Minneapolis, 1892.) A short statement is made of the difference between the two species.

Calvin, Samuel. Notes on Collection of Fossils from Lower Magnesian Limestone, from Northeastern Iowa. (American Geologist, Vol. X, pp. 144-148, Minneapolis, 1892.) Short characterizations of various fossils are given, and the following species, without figures, are described as new:

Straparollus claytonensis.

Straparollus pristiniformis.

Raphistoma multivolvatum.

Raphistoma paucivolvatum.
Cyrtoceras luthei.

Calvin, Samuel. Notes on Collection of Fossils from Lower Magnesian Limestone from Northeastern Iowa. (Bull. Lab. Nat. Hist., State Univ. Iowa, Vol. II, pp. 189-193, Iowa City, 1893.) There are described a number of new species and several others are identified.

Calvin, Samuel. Notes on Formations Passed Through in Boring Deep Well at Washington, Iowa. (American Geologist, Vol. I, pp. 28-31, Minneapolis, 1888.) Comments on the formations pased through in sinking a well at Washington are made.

Calvin, Samuel. Notes on Geological Formations of Iowa. (Pamphlet, World's Exposition at New Orleans, pp. 1-8, 1884.) This is a brief resumé of what is known of the geological formations of the State.

Calvin, Samuel. Notes on Geological Section of Iowa. (Iowa Geol. Surv., Vol. XVII, pp. 192-200, Des Moines, 1907.) The principal formations and subdivisions are briefly characterized.

Calvin, Samuel. Notes on Some Fossil Corals described by David Owen, in his Report of work done in Autumn of 1839, with Observations on Devonian Species *Phillipsastrea Gigas* of later authors. (American Geologist, Vol. XII, pp. 108-112, Minneapolis, 1893.) The nomenclature is discussed and the identifications considered.

Calvin, Samuel. Notes on Synonymy, Characters and Distribution of Spirifera Parryana, Hall. (Bull. Lab. Nat. Hist. State Univ. Iowa, Vol. I, pp. 19-28, Iowa City, 1888.) All the related species of *Spirifera parryana* described from the Iowa formations are considered to be synonyms of this species.

Calvin, Samuel. On Chert of Upper Coal Measures in Montgomery County, Iowa. (American Geologist, Vol. I, pp. 116-117, Minneapolis, 1888.) A brief comparison of the Iowa cherts with those of Ireland is made.

Calvin, Samuel. On Some Dark Shale Recently Discovered below Devonian Limestones, at Independence, Iowa; with a Notice of its Fossils and Description of New species. (Bull. U. S. Geol. and Geog. Sur. Terr., Vol. IV, pp. 725-730, Washington, 1878.) A short description of the rocks of the locality, with remarks on some of the fossils, is given. The following species are regarded as new:

Strophodonta variablis.
Strophodonta quadrata.
Orthis infera.
Rhynchonella ambigua.
Gypidula munda.

Calvin, Samuel. On Fauna Found at Lime Creek, Iowa, and its Relation to Other Geological Faunas. (Am. Jour. Sci., (3), Vol. XXV, pp. 434-436, New Haven, 1883.) This is a criticism on H. S. Williams' paper on the same subject, with additional notes and a description of *Spirifera macbridei,* regarded as new.

Calvin, Samuel. Physiography of Iowa. (Iowa Weather and Crop Service, Ann. Rept. for 1902, Appendix, pp. 3-11, Des Moines, 1903.) The surface relief and drainage features are described, and the distribution of the drift sheets is outlined.

Calvin, Samuel. Present Phase of Pleistocene Problems in Iowa. (Bull. Geol. Soc. America, Vol. XX, pp. 133-152, New York, 1909.) Five and probably six distinct drift-sheets are clearly differentiated in Iowa. So far as the age of ice is concerned the problems of this area are the problems of this continent. The relationships of the several drift-sheets are discussed.

Calvin, Samuel. President's Address: Work of Iowa Geological Survey. (Proc. Iowa Acad. Sci., Vol. XVI, pp. 11-18, Des Moines, 1909.) A summary of the chief results accomplished by the organization is given.

Calvin, Samuel. Relation of Cretaceous Deposits of Iowa to Subdivisions of Cretaceous proposed by Meek and Hayden. (Proc. Iowa Acad. Sci., Vol. I, pt. iii, pp. 7-12, Des Moines, 1893.) The Cretaceous deposits in the vicinity of Sioux City are described in detail.

Calvin, Samuel. Relation of Cretaceous Deposits of Iowa to Subdivisions of Cretaceous proposed by Meek and Hayden. (American Geologist, Vol. XI, pp. 300-307, Minneapolis, 1893.) The section on the Big Sioux River is described and the diastrophic movements during Cretaceous times are discussed.

Calvin, Samuel. Second Annual Report of State Geologist, for 1893. (Iowa Geol. Surv., Vol. III, pp. 19-27, Des Moines, 1895.) The summary of the work accomplished during the year includes also an outline of the results obtained by each of the assistants.

Calvin, Samuel. Seventeenth Annual Report of State Geologist. (Iowa Geol. Surv., XIX, pp. xiii-xiv, Des Moines, 1909.) Brief statement is made of the work of the year.

Calvin, Samuel. Seventh Annual Report of State Geologist. (Iowa Geol. Surv., Vol. IX, pp. 11-24, Des Moines, 1899.) Progress of the work during the previous year is reviewed.

Calvin, Samuel. Sixteenth Annual Report of State Geologist. (Iowa Geol. Surv., Vol. XVIII, pp. 1-5, Des Moines, 1908.) The work of the year is briefly noted.

Calvin, Samuel. Sixth Annual Report of State Geologist. (Iowa Geol. Surv., Vol. VIII, pp. 11-23, Des Moines, 1898.) The work of the Geological Survey for the year 1897 is reviewed.

Calvin, Samuel. Some Features of Channel of Mississippi River between Lansing and Dubuque, and their Probable History. (Proc. Iowa Acad. Sci., Vol. XIV, pp. 213-220, Des Moines, 1907.) The development of the Mississippi river valley is followed. Towards the close of Tertiary times the region is regarded as being more elevated, causing energetic erosion. At this time the Mississippi gorge was over 800 feet deep; this gorge was later partially filled by glacial debris.

Calvin, Samuel. Some Geological Problems in Muscatine County, Iowa. (Bull. Lab. Nat. Hist., State Univ. Iowa, Vol. I, pp. 7-18, Iowa City, 1888.) A description of certain rocks about Muscatine showing that they are Devonian instead of early Carboniferous in age. Numerous references to fossils are given.

Calvin, Samuel. Some Geological Problems in Muscatine County, Iowa, with Special Reference to Rectification of Supposed Kinderhook near Mouth of Pine Creek. (American Geologist, Vol. III, pp. 25-36, Minneapolis, 1889.) Special account is given of certain yellow sandstones in Muscatine county, formerly referred to the Chemung or Kinderhook, and they are now shown to be Devonian in age.

Calvin, Samuel. Some New Species of Paleozoic Fossils. (Bull. Lab. Nat. Hist., State Univ. Iowa, Vol. I, pp. 173-181, Iowa City, 1890.) The following species are described as new:

Terebratula iowensis.
Schizodus symmetricus.
Holopea grandis.
Straparollus lativolvis.
Straparollus bicarinatus.
Straparollus tricarinatus.

Calvin, Samuel. State Quarry Limestone. (Proc. Iowa Acad. Sci., Vol. IV, pp. 16-21, Des Moines, 1897.) The deposit seems to rest in marked unconformity upon the Middle Devonian formations.

Calvin, Samuel. Structure and Probable Affinities of Cerionites Dactylioides, Owen. (Proc. Iowa Acad. Sci., Vol. I, pt. iii, pp. 13-15, Des Moines, 1893.) The structure of the fossils is described in detail and an ideal restoration is made.

Calvin, Samuel. Structure and Probable Affinities of Cerionites Dactylioides, Owen. (American Geologist, Vol. XII, pp. 53-57, Minneapolis, 1893.) The nomenclature and zoological relations are discussed.

Calvin, Samuel. Summary of Discussion (on Oelwein Drift Section.) (Proc. Iowa Acad. Sci., Vol. IV, pp. 66-68, Des Moines, 1897.) The recognition of five distinct ice invasions, and of four interglacial intervals is emphasized. "Iowa is now classic ground for the study of Pleistocene deposits, and geologists the world over, if they would study these deposits to best advantage, must come to Iowa to do it."

Calvin, Samuel. Switzerland of Iowa. (Midland Monthly, Vol. III, pp. 403-414, Des Moines, 1895.) The scenery of the extreme northeastern corner of the state is described and illustrated.

Calvin, Samuel. Synopsis of Drift Deposits of Iowa. (American Geologist, Vol. XIX, pp. 270-272, Minneapolis, 1897.) The several till-sheets recently differentiated in the state are briefly characterized, and their boundaries indicated.

Calvin, Samuel. Tenth Annual Report of State Geologist. (Iowa Geol. Surv., Vol. XII, pp. 11-27, Des Moines, 1902.) The work of the year is summarized. Recent advancements in knowledge of the glacial deposits are noted.

Calvin, Samuel. Third Annual Report of State Geologist, for 1894.) (Iowa Geol. Surv., Vol. IV, pp. 19-26, Des Moines, 1895.) This is a summary of the results obtained during the year by the different members of the geological corps.

Calvin, Samuel. Twelfth Annual Report of State Geologist. (Iowa Geol. Surv., Vol. XIV, pp. 3-6, Des Moines, 1904.) Brief summary is given of the work of the year.

Calvin, Samuel. Two Unique Spirifers from Devonian of Iowa. (Bull. Lab. Nat. Hist., State Univ. Iowa, Vol. II, pp. 165-167, Iowa City, 1893.)

Calvin, Samuel, and H. F. Bain. Geology of Dubuque County. (Iowa Geol. Surv., Vol. X, pp. 379-651, Des Moines, 1900.) The following features are described:

Introduction, location and area, previous geological work.

Physiography, topography, drainage.

Stratigraphy, general relations of strata, synoptical table; Ordovician system, Saint Peter sandstone, Trenton limestone, geographical distribution, lithological and faunal characteristics, Galena limestone, Maquoketa shales; Silurian system, Niagara limestone; superficial materials, residual materials or geest; Pleistocene system, Kansan drift, Buchanan gravels, Kansan outwash in driftless area, Iowan drift, loess, Wisconsin terraces, alluvium, summary of Pleistocene history, calcareous tufa; deformations; unconformities.

Economic geology, soils; lead and zinc, historical sketch, geology, Saint Peter sandstone, Galena-Trenton, Maquoketa, Niagara, ore deposits, ores and associated minerals, galena, cerussite, smithsonite, sphalerite, copper, pyrite and marcasite, limonite, wad, calcite and aragonite, gypsum, barite, ore-bodies, vertical sheets, flats, pitches, disseminated bodies, cave-deposits, formation of crevices, enlargement of crevices, openings, horizons, description of individual crevices, Timber range, Stewart Park ridge, Stewart and Bartlett lode, Stewart cave, Levens range, Dubuque cave, Sunflower, Patch Diggings, Level, Kilbourne and Karrick, McGowen and Cunningham, Rake pocket, Julien Avenue crevices, Langworthy and Kelly, Rabbit Hollow mines, Center Grove mines, Pikes peak, other crevices, mines away from Dubuque, origin of Dubuque ore, ultimate source of ores, table of analyses, localization of bodies, concentration of ores, practical considerations, mining titles, Bonson rules, methods of work, prospecting, composition and treatment of ores, smelting.

Iron, analyses of Durango ore; lime, Eagle Point lime-works, Key City lime-works; clays, analysis Maquoketa shale, brick-plants; pigments; road materials; building-stones; artesian wells; cements.

Forestry notes.

The origin and character of the lead and zinc deposits are especially discussed. The dolomitization of the Galena limestone is described.

Calvin, Samuel. G. F. Kay. (Science, N. S., XXXIV, 106-107, 1911.)

Calvin, Samuel. H. F. Bain. (Journal of Geology, XIX, 385-391, 1911.)

Cambrian Period.

Artesian wells of Iowa. W. H. Norton. (Iowa Geol. Surv., VI, 113-428, 1897.)

Bibliography of North American paleontology, 1888-1892. C. R. Keyes. (U. S. Geol. Surv., Bull. 121, 250 pp., 1894.)

Correlation of Potsdam rocks in northeastern Iowa. C. D. Walcott. (Bull. U. S. Geol. Surv., No. 81, 187-188, 1891.)

Description of lower sandstone of the upper Mississippi (Potsdam). D. D. Owen. (Geol. Surv., Wisconsin, Iowa and Minnesota, 48-58, 1852.)

General account. W. J. McGee. (Eleventh Ann. Rep., U. S. Geol. Surv., 333-334, 1892.)

Geological formations of Iowa. C. R. Keyes. (Iowa Geol. Surv., I, 11-161, 1893.)

Geological map of Iowa. C. R. Keyes. (Annals of Iowa, Historical Quarterly, (3), I, 294-297, 1894.)

Geology of Allamakee county. S. Calvin. (Iowa Geol. Surv., IV, 35-114, 1895.)

Geology of Cerro Gordo county. S. Calvin. (Iowa Geol. Surv., VII, 117-195, 1897.)

Geology of Clayton county. A. G. Leonard. (Iowa Geol. Surv., XVI, 213-306, 1906.)

Geology of Henry county, T. E. Savage. (Iowa Geol. Surv., XII, 237-302, 1902.)

Geology of quarry products. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

Geology of Winneshiek county. S. Calvin. (Iowa Geol. Surv., XVI, 37-146, 1906.)

Lansing lead mines. A. G. Leonard. (Proc. Iowa Acad. Sci., II, 36-38, 1895.)

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Introduction, physiography, topography, general plateau, table of altitudes; drainage, Des Moines river, Indian creek, Bear creek, Chequest creek, Lick creek, Coates creek, Reed creek, Fox river.

Stratigraphy, general relations of strata, table of geological formations, description of typical sections, Bentonsport section, Kilbourne section, Edmonson well-section, Davis well-section, Miller well-section, Farmington section, Umphry well-section; geological formations; Burlington limestone, Keokuk limestone, Geode shales, Warsaw, Saint Louis, arenaceo-magnesian beds, brecciated limestone, compact and granular limestone, Farmington section, Reed Creek section, Rock Creek section, Chequest section, Kilbourne section; Des Moines stage, Farmington section, Business Corners, Ratcliff shaft, Overturff, Leifer, Fort Madison, School House, Hartman-Baker sections; Pleistocene, glacial deposits, blue clay, yellow clay, loess, alluvium; history of Des Moines river, ox-bow, terraces; geological structure, deformations, unconformities.

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PART FIRST (GEOLOGY).

Chapter I is a description of the physical geography of the State. (See J. D. Whitney, 1858.)

Chapter II treats of the general geology of the State, and the relations of the formations to those of the East.

Chapter III describes in detail the different geological formations of the State from observations made during the years 1855-1857.

Chapter IV deals with the geology of Des Moines valley. (See A. H. Worthen, 1858.)

Chapter V is a detailed account of the geology of certain counties in southeastern Iowa. (See A. H. Worthen, 1858.)

Chapter VI is an account of the geology of various counties in the central and northern part of eastern Iowa. (See J. D. Whitney, 1858.)

Chapter VII is a chemical and economical report. (See J. D. Whitney, 1858.)

PART SECOND (PALEONTOLOGY.)

Chapter VIII is made up of descriptions accompanied by illustrations of the numerous fossils of the different horizons as found in Iowa.

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Hamilton Formation. (*See Senecan Series.*) In nearly all of the early uses of the term the true Hamiltonian series as here indicated is not meant, but the Senecan series of which the Cedar Valley limestones are the chief representatives.

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Geology of Delaware county. S. Calvin. (Iowa Geol. Surv., VIII, 119-199, 1898.)

Geology of Des Moines county. C. R. Keyes. (Iowa Geol. Surv., III, 409-492, 1894.)

Geology of Dubuque county. S. Calvin and H. F. Bain. (Iowa Geol. Surv., X, 379-651, 1900.)

Geology of Emmet, Palo Alto and Pocahontas counties. T. H. Macbride. (Iowa Geol. Surv., XV, 227-276, 1905.)

Geology of Fayette county. T. E. Savage. (Iowa Geol. Surv., XV, 433-546, 1905.)

Geology of Franklin county. I. A. Williams. (Iowa Geol. Surv., XVI, 453-507, 1906.)

Geology of Grundy county. M. F. Arey. (Iowa Geol. Surv., XX, 61-95, 1910.)

Geology of Guthrie county. H. F. Bain. (Iowa Geol. Surv., VII, 413-487, 1897.)

Geology of Hamilton and Wright counties. T. H. Macbride. (Iowa Geol. Surv., XX, 97-138, 1910.)

Geology of Hardin county. S. W. Beyer. (Iowa Geol. Surv., X, 243-305, 1900.)

Geology of Harrison and Monona counties. B. Shimek. (Iowa Geol. Surv., XX, 271-483, 1910.)

Geology of Henry county. A. H. Worthen. (Geology of Iowa, I, 210-211, 1858.)

Geology of Henry county. T. E. Savage. (Iowa Geol. Surv., XII, 237-302, 1902.)

Geology of Howard county. S. Calvin. (Iowa Geol. Surv., XIII, 21-79, 1903.)

Geology of Humboldt county. T. H. Macbride. (Iowa Geol. Surv., IX, 109-154, 1899.)

Geology of Iowa county. S. W. Stookey. (Iowa Geol. Surv., XX, 151-186, 1910.)

Geology of Jackson county. T. E. Savage. (Iowa Geol. Surv., XVI, 563-649, 1906.)

Geology of Jasper county. I. A. Williams. (Iowa Geol. Surv., XV, 277-367, 1905.)

Geology of Jefferson county. J. A. Udden. (Iowa Geol. Surv., XII, 355-437, 1902.)

Geology of Johnson county. S. Calvin. (Iowa Geol. Surv., VII, 33-116, 1897.)

Geology of Jones county. S. Calvin. (Iowa Geol. Surv., V, 33-112, 1896.)

Geology of Keokuk county. H. F. Bain. (Iowa Geol. Surv., IV, 255-311, 1895.)

Geology of Kossuth, Hancock and Winnebago counties. T. H. Macbride. (Iowa Geol. Surv., XIII, 81-122, 1903.)

Geology of Lee county. A. H. Worthen. (Geology of Iowa, I, 187-188, 1858.)

Geology of Lee county. C. R. Keyes. (Iowa Geol. Surv., III, 305-407, 1894.)

Geology of Linn county. W. H. Norton. (Iowa Geol. Surv., IV, 121-194, 1895.)

Geology of Louisa county. J. A. Udden. (Iowa Geol. Surv., XI, 53-126, 1901.)

Geology of Lyon and Sioux counties. F. A. Wilder. (Iowa Geol. Surv., X, 85-184, 1900.)

Geology of Madison county. C. A. White. (Geology of Iowa, I, 305-308, 1870.)

Geology of Madison county. J. L. Tilton and H. F. Bain. (Iowa Geol. Surv., VII, 489-539, 1897.)

Geology of Mahaska county. H. F. Bain. (Iowa Geol. Surv., IV, 313-380, 1895.)

Geology of Marion county. B. L. Miller. (Iowa Geol. Surv., XI, 127-197, 1901.)

Geology of Marshall county. S. W. Beyer. (Iowa Geol. Surv., VII, 197-262, 1897.)

Geology of Mills and Fremont counties. J. A. Udden. (Iowa Geol. Surv., XIII, 123-183, 1903.)

Geology of Mitchell county. S. Calvin. (Iowa Geol. Surv., XIII, 293-352, 1903.)

Geology of Monroe county. S. W. Beyer and L. E. Young. (Iowa Geol. Surv., XIII, 353-433, 1903.)

Geology of Montgomery county. E. H. Lonsdale. (Iowa Geol. Surv., IV, 381-449, 1895.)

Geology of Muscatine county. J. A. Udden. (Iowa Geol. Surv., IX, 247-380, 1899.)

Geology of Osceola and Dickinson counties. T. H. Macbride. (Iowa Geol. Surv., X, 185-239, 1900.)

Geology of Page county. S. Calvin. (Iowa Geol. Surv., XI, 397-460, 1901.)

Geology of Polk county. H. F. Bain. (Iowa Geol. Surv., VII, 263-412, 1897.)

Geology of Pottawattamie county. J. A. Udden. (Iowa Geol. Surv., XI, 199-277, 1901.)

Geology of Poweshiek county. S. W. Stookey. (Iowa Geol. Surv., XX, 237-269, 1910.)

Geology of Sac and Ida counties. T. H. Macbride. (Iowa Geol. Surv., XVI, 509-548, 1906.)

Geology of Scott county. W. H. Norton. (Iowa Geol. Surv., IX, 389-519, 1899.)

Geology of southwestern Iowa. C. A. White. (Am. Jour. Sci., (2), XLIV, 119, 1867.)

Geology of Story county. S. W. Beyer. (Iowa Geol. Surv., IX, 155-245, 1899.)

Geology of Tama county. T. E. Savage. (Iowa Geol. Surv., XIII, 185-253, 1903.)

Geology of Van Buren county. A. H. Worthen. (Geology of Iowa, I, 221, 1858.)

Geology of Van Buren county. C. H. Gordon. (Iowa Geol. Surv., IV, 197-254, 1895.)

Geology of Wapello county. A. G. Leonard. (Iowa Geol. Surv., XII, 439-499, 1902.)

Geology of Warren county. J. L. Tilton. (Iowa Geol. Surv., V, 301-359, 1896.)

Geology of Washington county. H. F. Bain. (Iowa Geol. Surv., V, 115-173, 1896.)

Geology of Wayne county. M. F. Arey. (Iowa Geol. Surv., XX, 199-236, 1910.)

Geology of Winneshiek county. S. Calvin. (Iowa Geol. Surv., XVI, 37-146, 1906.)

Geology of Woodbury county. H. F. Bain. (Iowa Geol. Surv., V, 241-299, 1896.)

Geology of Worth county. I. A. Williams. (Iowa Geol. Surv., X, 315-377, 1900.)

Iowan drift. S. Calvin. (Bull. Geol. Soc. America, XXII, 729-730, 1911.) Abstract.

Iowan drift. S. Calvin. (Journal of Geology, XIX, 577-602, 1911.)

Nebraskan drift. B. Shimek. (Science, N. S., XXXIV, 28, 1911.)

New light on drift in South Dakota. J. E. Todd. (Proc. Iowa Acad. Sci., VI, 122-123, 1899.)

Notable ride, from driftless area to Iowan drift. S. Calvin. (Proc. Iowa Acad. Sci., VII, 72-77, 1900.)

Notes on drift of northwestern Iowa. H. F. Bain. (American Geologist, XXIII, 168-176, 1899.)

Old channels of Mississippi in southeastern Iowa. F. Leverett. (Annals of Iowa, Historical Quarterly, (3), V, 38-51, 1901.)

Pleistocene in vicinity of Sioux Falls, South Dakota. B. Shimek. (Bull. Geol. Soc. America, XXII, 730, 1911.)

Pleistocene deposits in Warren county, Iowa. J. L. Tilton. (Pamphlet, 42 pp., University of Chicago Press, 1911.)

Pleistocene of Missouri valley. B. Shimek. (Science, N. S., XXXI, 75-76, 1910.)

Pleistocene of vicinity of Omaha, Nebraska, and Council Bluffs, Iowa. B. Shimek. (Bull. Geol. Soc. America, XXII, 730, 1911.)

Pleistocene succession in Wisconsin. S. Weidman. (Science, N. S., XXXVII, 456, 1913.)

Present phase of pleistocene problems in Iowa. S. Calvin. (Bull. Geol. Soc. America, XX, 133-152, 1909.)

Principal soil areas of Iowa. W. H. Stevenson. (Bull. Iowa State College Exper. Station, No. 82, 373-388, 1911.)

Relation of Wisconsin and Kansan drift sheets in central Iowa and related phenomena. H. F. Bain. (Iowa Geol. Surv., VI, 439-476, 1897.)

Some pre-glacial soils. J. A. Udden. (Proc. Iowa Acad. Sci., V, 102-104, 1898.)

Study of portion of Iowan drift-border in Fayette county. G. E. Finch. (Proc. Iowa Acad. Sci., XIII, 215-218, 1906.)

Sundry provincial and local phases of general geologic section of Iowa. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 147-151, 1912.)

Synopsis of drift deposits of Iowa. S. Calvin. (American Geologist, XIX, 270-272, 1897.)

Topography and climate of Iowa. H. E. Simpson. (Iowa Geol. Surv., XXI, 48-66, 1912.)

Topography and climate of Iowa. H. E. Simpson. (U. S. Geol. Surv., Water Supply Paper No. 293, 45-59, 1912.)

Weathered zone (Yarmouth) between Illinoian and Kansan till-sheets. Frank Leverett. (Journal of Geology, VI, 238-243, 1898.)

Weathered zone (Yarmouth) between Illinoian and Kansan till-sheets. F. Leverett. (Proc. Iowa Acad. Sci., V, 81-86, 1898.)

Kaolin.

Annotated catalogue of minerals. C. R. Keyes. (Iowa Geol. Surv., I, 181-196, 1893.)

Geology of Lee county. C. R. Keyes. (Iowa Geol. Surv., III, 305-407, 1894.)

Kay, George F. Nineteenth and Twentieth Annual Reports of State Geologist. (Iowa Geol. Surv., Vol. XXI, pp. ix-xvi, Des Moines, 1912.) A summary of the work during the previous two years is given.

Kay, George F. Problems on Border-lines between Geology and other Sciences. (Proc. Iowa Acad. Sci., Vol. XVIII, p. 93, Des Moines, 1910.) Special attention is called to the need of coöperative work among investigators in the different fields of science in the State.

Kay, George F. Samuel Calvin. (Science, N. S., Vol. XXXIV, pp. 106-107, New York, 1911.) A brief sketch of his life is given.

Kenwood Shales (Independence).

Geology of Linn county. W. H. Norton. (Iowa Geol. Surv., IV, 121-194, 1895.)

Keokuk beds, origin of geodes of. F. M. Van Tuyl. (Proc. Iowa Acad. Sci., XIX, 169-172, 1912.)

Keokuk beds, origin of geodes. F. M. Van Tuyl. (Science, N. S., XXXVI, 569, 1912.)

Keokuk County.

Analyses of Iowa coals. J. H. Lees and A. H. Hixson. (Iowa Geol. Surv., XIX, 476-519, 1909.)

Artesian well at Sigourney. C. H. Gordon. (American Geologist, IV, 237-239, 1889.)

Artesian wells of Iowa. W. H. Norton. (Iowa Geol. Surv., VI, 113-428, 1897.)

Certain fossil plant-remains in Iowa herbarium. T. H. Macbride. (Proc. Davenport Acad. Sci., X, 153-162, 1907.)

Coal deposits of Iowa. C. R. Keyes. (Iowa Geol. Surv., II, 536 pp., 1894.)

Coal deposits of Iowa. H. Hinds. (Iowa Geol. Surv., XIX, 21-396, 1909.)

General geology. C. A. White. (Geology of Iowa, II, 267, 1870.)

Geology of clays. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XIV, 377-552, 1904.)

Geology of Keokuk county. H. F. Bain. (Iowa Geol. Surv., IV, 253-311, 1895.)

Geology of quarry products. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

History of coal-mining in Iowa. J. H. Lees. (Iowa Geol. Surv., XIX, 521-586, 1909.)

Mississippian rocks of central Iowa. H. F. Bain. (Proc. Iowa Acad. Sci., II, 174, 1895.)

Sigourney deep-well. H. F. Bain. (Proc. Iowa Acad. Sci., I, pt. iv, 36-38, 1894.)

Underground water resources of Iowa. W. H. Norton. (Iowa Geol. Surv., XXI, 29-1214, 1912.)

Underground water resources of Iowa. W. H. Norton. (U. S. Geol. Surv., Water Supply Paper No. 293, 994 pp., 1912.)

Keokuk county, geology. H. Foster Bain. (Iowa Geol. Surv., IV, 255-311, 1895.)

Keokuk Limestone.

Brachiopods from various localities in Iowa. J. Hall. (Nat. Hist. New York, Pal. VIII, 1-367, 1892.)

Brachiopods mentioned from Iowa. R. P. Whitfield. (Bull. American Mus. Nat. Hist., I, 39-97, 1882.)

Catalogue of types and figured specimens in paleontological collections of geological department, American museum of natural history; lower carboniferous to pleistocene, inclusive. R. P. Whitfield and E. O. Hovey. (Bull. American Mus. Nat. Hist., XI, pt. 4, 357-500, 1901.)

Cement and cement materials of Iowa. E. C. Eckel and H. F. Bain. (Iowa Geol. Surv., XV, 33-124, 1905.)

Central Iowa section of Mississippian series. H. F. Bain. (American Geologist, XV, 317-325, 1895.)

Cherts of Osage series of Mississippian system. F. M. Van Tuyl. (Proc. Iowa Acad. Sci., XIX, 173-174, 1912.)

Cherts of Osage series of Mississippian system. F. M. Van Tuyl. (Science, N. S., XXXVI, 569, 1912.)

Classification of lower carboniferous rocks of Mississippi valley. C. R. Keyes. (Pamphlet, Judd and Detweiller, printers, 1-24, Washington, 1892.)

Crinoids from Iowa. A. H. Worthen. (Geol. Surv. Illinois, VII, 264-322, 1883.)

Ctenacanthus spines from Keokuk limestone of Iowa. C. R. Eastman. (Am. Jour. Sci., (4), IV, 10-12, 1897.)

Description of beds at Keokuk. C. H. Gordon. (Proc. Iowa Acad. Sci., I, pt. i, 98-100, 1890.)

Description of fossil fishes. O. H. St. John and A. H. Worthen. (Geol. Surv. Illinois, VII, 53-264, 1883.)

Description of Iowa fossils. J. Hall. (Geology of Iowa, I, 606-667, 1858.)

Description of new fossils. A. H. Worthen. (Geol. Surv. Illinois, VIII, 69-154, 1890.)

Description of new species of crinoidea. J. Hall. (Boston Jour. Nat. Hist., VII, 251-328, 1861.)

Description of new species of crinoids. A. H. Worthen. (Illinois State Mus. Nat. Hist., Bull. No. 1, 1-39, 1882.)

Description of new species of fishes. O. H. St. John and A. H. Worthen. (Geol. Surv. Illinois, VI, 245-288, 1875.)

Description of new species of fossils. F. B. Meek and A. H. Worthen. (Geol. Surv. Illinois, V, 323-619, 1873.)

Description of new species of fossils from Iowa rocks. F. B. Meek and A. H. Worthen. (Geol. Surv. Illinois, II, 143-411, 1866.)

Description of some new species of invertebrates from paleozoic rocks of Illinois and adjacent states. S. A. Miller and W. F. E. Gurley. (Bull. Illinois State Mus. Nat. Hist., No. 3, 1-81, 1894.)

Fossil wood from Keokuk formation, Keokuk. S. J. Wallace. (Am. Jour. Sci., (3), XV, 396, 1878.)

General description. C. A. White. (Geology of Iowa, I, 210-215, 1870.)

Geology of clays. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XIV, 377-552, 1904.)

Geology of Des Moines county. A. H. Worthen. (Geology of Iowa, I, 202, 1858.)

Geology of Des Moines county. C. R. Keyes. (Iowa Geol. Surv., III, 409-492, 1894.)

Geology of Henry county. A. H. Worthen. (Geology of Iowa, I, 216-217, 1858.)

Geology of Henry county. T. E. Savage. (Iowa Geol. Surv., XII, 237-302, 1902.)

Geology of Jefferson county. A. H. Worthen. (Geology of Iowa, I, 237, 1858.)

Geology of Lee county. A. H. Worthen. (Geology of Iowa, I, 193-196, 1858.)

Geology of Lee county. C. R. Keyes. (Iowa Geol. Surv., III, 305-407, 1894.)

Geology of northeastern Iowa. W J McGee. (Eleventh Ann. Rept., U. S. Geol. Surv., 312, 1892.)

Geology of quarry products [limes]. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

Geology of Van Buren county. A. H. Worthen. (Geology of Iowa, I, 228, 1858.)

Geology of Van Buren county. C. H. Gordon. (Iowa Geol. Surv., IV, 197-254, 1895.)

Keokuk group of Mississippi valley. C. S. Beachler. (American Geologist, X, 88-96, 1892.)

Keokuk species of Agaricocrinus. C. H. Gordon. (American Geologist, V, 257-261, 1890.)

New bryozoans. E. O. Ulrich. (Geol. Surv. Illinois, VIII, 283-688, 1890.)

New species of fishes described. J. S. Newberry and A. H. Worthen. (Geol. Surv., Illinois, II, 9-134, 1866.)

New species of fishes from Iowa. J. S. Newberry and A. H. Worthen. (Geol. Surv., Illinois, IV, 246-374, 1870.)

New species of fossils from Iowa. A. H. Worthen and F. B. Meek. (Geol. Surv., Illinois, VI, 489-532, 1875.)

New species of polyzoans. A. H. Prout. (Geol. Surv. Illinois, II, 412-424, 1866.)

New species of sponges. E. O. Ulrich. (Geol. Surv. Illinois, VIII, 243-251, 1890.)

Observations on genus Archimedes. J. Hall. (Proc. American Assoc. Adv. Sci., X, 170-180, 1857.)

Observations on Keokuk species of Agaricocrinus. C. H. Gordon. (Proc. Iowa Acad. Sci., I, pt. i, 100-101, 1890.)

Origin of geodes of Keokuk beds. F. M. Van Tuyl. (Proc. Iowa Acad. Sci., XIX, 169-172, 1912.)

Osage vs. Augusta. S. Weller. (American Geologist, XXII, 12-16, 1898.)

Principal Mississippian section. C. R. Keyes. (Bull. Geol. Soc. America, III, 283-300, 1892.)

Sigourney deep-well. H. F. Bain. (Proc. Iowa Acad. Sci., I, pt. iv, 36-38, 1894.)

Some new American fossil crinoids. F. Springer. (Mem. Mus. Comp. Zool., XXV, 117-161, 1911.)

Synopsis of American carbonic calyptræidæ. C. R. Keyes. (Proc. Acad. Nat. Sci. Philadelphia, 150-181, 1890.)

Synopsis of American paleozoic echinoids. C. R. Keyes. (Proc. Iowa Acad. Sci., II, 178-194, 1895.)

Ueber das Carbon des Mississippithales. C. R. Keyes. (Neues Jahrbuch für Mineralogie, Geologie und Palæontologie. Jahrg. 1896, I, 96-110, 1896.)

Use of term Augusta in geology. C. R. Keyes. (American Geologist, XXI, 229-235, 1898.)

Variation of a gasteropod. C. R. Keyes. (American Geologist, III, 329-333, 1889.) Specimen from Keokuk is figured.

Wood. C. H. Gordon. (Proc. Iowa Acad. Sci., I, pt. i, 97-98, 1890.)

Keokuk limestone of Iowa, Ctenacanthus spines. C. R. Eastman. (American Jour. Sci., (4), IV, 10-12, 1897.)

Keyes, Charles. Aboriginal Use of Mineral Coal; and its Discovery in the West. (Annals of Iowa; an Historical Quarterly, Vol. X, pp. 431-434, Des Moines, 1912.) The lignites of the north are shown to have been used by the Aiouez Indians at the time of the earliest visits by the French.

Keyes, Charles. Administrative Report of Assistant State Geologist. (Iowa Geol. Surv., Vol. I, First Annual Rep., pp. 7-9, Des Moines, 1894.) This report contains summaries of the investigations carried forward on the coal deposits, clays, gypsum and of several reconnoissances in the state.

Keyes, Charles. Administrative Report of Assistant State Geologist. (Iowa Geol. Surv., Vol. III, pp. 29-38, Des Moines, 1894.) Short statements are made of the progress made in the personal investigations on the gypsum, coal, Sioux quartzite and areal work; and of the works of the various assistants engaged upon other topics.

Keyes, Charles. Administrative Report of Assistant State Geologist. (Iowa Geological Survey, Vol. IV, pp. 27-28, Des Moines, 1895.) The work of the year is summarized; and a brief statement is made of the publications issued during the year.

Keyes, Charles. Age of Certain Sandstones near Iowa City. (Proc. Iowa Acad. Sci., Vol. I, pt. ii, p. 25, Des Moines, 1892.) Owing to the recent discovery of fossils in the sandstones near Iowa City the suggestion is made that their age may be Kinderhook instead of Missourian as has been heretofore regarded.

Keyes, Charles. Alternation of Fossil Faunas. (Proc. Iowa Acad. Sci., Vol. XIII, pp. 199-201, Des Moines, 1907.) In the coal-measures of Iowa, Missouri and Kansas there is an alternation of faunas corresponding to the alternation of lithographic units. These have not been heretofore clearly distinguished.

Keyes, Charles. Aluminum in Iowa. (Proc. Iowa Acad. Sci., Vol. I, pt. ii, pp. 29-30, Des Moines, 1892.) Announcement is made of the establishment of a plant for the manufacture of aluminum in Franklin county.

Keyes, Charles. American Homataxical Equivalents of Original Permian. (Journal of Geology, Vol. VII, pp. 321-341, Chicago, 1899.) The lower part of the American section compared with the Russian sequence includes beds represented in Iowa. There are numerous references to Iowa rocks.

Keyes, Charles. American Species of Polyphemopsis. (Proc. Acad. Nat. Sci., Phila., 1889, pp. 299-302, Philadelphia, 1889.) This is a revision of the species that have been referred to this group of gasteropods.

Keyes, Charles. Annotated Bibliography of Iowa Geology and Mining. (Iowa Geol. Surv., Vol. XXII, Des Moines, 1913.) The list of publications relating to the geology of Iowa is brought down to the end of 1912.

Keyes, Charles. Annotated Catalogue of Minerals. (Iowa Geol. Surv., Vol. I, pp. 181-196, Des Moines, 1893.) The more important minerals are noted and their peculiarities described. The crystallographic features of several kinds are outlined. A notable occurrence of the sulphide of nickel is mentioned and photographs of the most perfect groups of crystals reproduced.

Keyes, Charles. Annotated Catalogue of Mollusca of Iowa. (Bull. Essex Inst., Vol. XX, pp. 61-83, 1889.) In addition to notes on the live mollusca of the State numerous references are made to the species collected in the loess; and a list of these species known to occur within the limits of the State is appended.

Keyes, Charles. Arkansan Series: A New Terrane of the Carboniferous in the Western Interior Basin. (Proc. Iowa Acad. Sci., Vol. VII, pp. 123-128, Des Moines, 1901.) The relative magnitude of the section of coal measures deposited in Iowa and that represented elsewhere by the unconformity-plane at the base are given in diagram. The term Arkansan-series is proposed for the exact depositional representation of the gap; and in Iowa the term Arkansan unconformity becomes a proper and useful title.

Keyes, Charles. Attachment of Platycerata to Palæocrinoids; and its Effects in Modifying the Form of the Shell. (Proc. American Philosophical Soc., Vol. XXV, pp. 231-248, Philadelphia, 1888.) A statement is made of the cases heretofore observed and of the opinions concerning the sedentary habits of Platyceras. There is also given a brief historical review, with remarks on the known examples. Detailed descriptions of numerous specimens recently found in which the gasteropods are attached to various species of crinoids; together with a list of the species of Platyceras which have been found attached are given. Four species are described as new.

Keyes, Charles. Attachment of Platyceras to Fossil Crinoids. (American Naturalist, Vol. XXII, p. 924, Philadelphia, 1888.) A preliminary Synopsis of the intimate associations of the two organisms is given.

Keyes, Charles. Bethany Limestone of Western Interior Coal-field. (Am. Jour. Sci., (4), Vol. II, 221-225, 1896.) The value of the Bethany limestone, the Winterset limestone of Iowa, as a guide-horizon limiting the productive coal-measures, or Des Moines series, above is emphasized. Synonym is discussed in detail.

Keyes, Charles. Betterment of our Public Highways. (The Annals of Iowa; Historical Quarterly, Vol. V, pp. 372-379, Des Moines, 1902.) In the immediate betterment of Iowa highways it is urged that by selecting for improvement the heaviest parts of a road first, since the worst stretches are often caused by the presence of the best material when burned of road-metal, five years would find every principal highway in a country as passable the year around as a paved street in a city, and at very little more cost than is now usually squandered on "working the roads."

Keyes, Charles. Biographical Sketch of Charles Wachsmuth. (American Geologist, Vol. XVII, pp. 161-173, Minneapolis, 1896.) To this biographical account of a distinguished Iowa scientist is added a complete list of his published memoirs on the crinoids. There is also a recent portrait reproduced.

Keyes, Charles. Bibliography of Iowa Geology. (Iowa Geol. Surv., Vol. I, pp. 209-464, Des Moines, 1893.) The plan followed is essentially that of a dictionary catalogue of the geological literature, comprising (1) an author's list with full titles of subjects and the place of publication, (2) a title index, (3) subject entries, and (4) cross-references. For convenience the whole is arranged alphabetically.

Keyes, Charles. Bibliography of North American Paleontology, 1888-1892. (U. S. Geol. Surv., Bull. 121, 250 pp., Washington, 1894.) Contains annotations on articles relating to Iowa and published during the period.

Keyes, Charles. Brick and Other Clays of Des Moines. (Proc. Iowa Acad. Sci., Vol. I, pt. ii, p. 29, Des Moines, 1892.) A brief statement of the clay industries at Des Moines is made.

Keyes, Charles. Burnt Clay for Roads in the West. (American Monthly Reviews of Reviews, Vol. XXV, pp. 72-74, New York, 1902.) The use of burnt gumbo for road improvement is shown to be cheap and lasting. Its use by Iowa railroads for ballast presents many commendable features. Singularly where highways are the worst the best clays for burning are found. The advantages of utilizing this road-metal are enumerated.

Keyes, Charles. Carbonic Column of the Rio Grande. (Proc. Iowa Acad. Sci., Vol. XVI, pp. 159-163, Des Moines, 1909.) Comparison is made with the stratigraphic sequence of the upper Mississippi valley.

Keyes, Charles. Carboniferous Echinodermata of Mississippi Basin. (Am. Jour. Sci., (3), Vol. XXXIII, pp. 186-193, New Haven, 1889.) This is a brief description of the lower Carboniferous rocks of the Mississippi basin, with suggestions as to the geological classification as indicated by crinoidal remains. A synopsis of the genera and the distribution of the species in the various formations are given; also a sketch of the evolution of the crinoids during this time.

Keyes, Charles. Carboniferous formations of New Mexico. (Journal of Geology, Vol. XIV, pp. 147-154, Chicago, 1906.) Serial comparison is made with the Iowa, Missouri, Kansas sections of the Carboniferous sequence. There are also other references to the Iowa formations.

Keyes, Charles. Carboniferous Formations of Southwestern Iowa. (American Geologist, Vol. XXI, pp. 326-350, Minneapolis, 1898.) The typical section of the Missouri series of eastern Kansas is shown to be fully represent-

ed in southwestern Iowa, with the exception of the Cottonwood formation and the Iola limestone. Nine terranes are thus for the first time in the state recognized.

Keyes, Charles. Certain Faunal Aspects of the Original Kinderhook. (American Geologist, Vol. XXVI, pp. 315-321, Minneapolis, 1900.) Since the Kinderhook section at Burlington has been pronounced to be mainly pre-Louisianian exceptions to the interpretations are taken. Other explanations to the anamalous assemblage of fossils and their vertical distribution are made. This later faunal correlation is shown to be closely in agreement with the stratigraphical interpretation.

Keyes, Charles. Certain Forms of Straparollus from Southeastern Iowa. (American Geologist, Vol. V, pp. 193-197, Minneapolis, 1890.) The generic characters of Straparollus and Euomphalus are discussed; and the various species found at Burlington are considered.

Keyes, Charles. Character and Stratigraphical Peculiarities of Southwestern Iowa Coal-fields. (Eng. and Mining Jour., Vol. LXXIII, p. 661, New York, 1902.) Special attention is directed to the Nodaway coal. Results of the chemical analyses of this coal are given, the samples being from the principal mines in this state.

Keyes, Charles. Classification of Crinoidea. (American Naturalist, Vol. XXIII, p. 153, Philadelphia, 1889.) A statement is made on the classification of the crinoids and the changes necessitated by the discovery of the ventral structure of Taxocrinus (from the Kinderhook, near Marshalltown, Iowa).

Keyes, Charles. Classification of Lower Carboniferous Rocks of Mississippi Valley. (Pamphlet, 24 pp., Washington: Judd and Detweiller, printers, 1892.) Sections and details of the lower Carboniferous rocks in southeastern Iowa are described; frequent allusion is made to the coal measures of the central part of the State.

Keyes, Charles. Coal deposits of Iowa. (Iowa Geol. Surv., Vol. II, 536 pp., XVIII pls., Des Moines, 1894.) As introductory, Chapter I takes into account the general aspect of coal and its relations to industrial activities of mankind.

Chapter II discusses the origin of coal-beds, the source of the carbonaceous materials, the conditions under which they were deposited, and the various strata usually associated with coal. Detailed references are made to the Iowa field as illustrating the different features.

In Chapter III the carboniferous basin of the Mississippi valley is especially considered with respect to its stratigraphical characteristics, its geotectonics, its local structures and its subdivisions. The productive coal-measures as a series of limited coal-basins are especially described.

The broader geological features of the coal-fields are considered in chapter III; and the stratigraphical relations of coal-beds to the other geological formations of the State are pointed out.

By way of contrast the lithological characters of the lower, or productive, coal-measures and of the upper, or barren, coal-measures are described separately. The relative development of the several kinds of rocks comprised in the coal-measures is considered with reference to the occurrence of coal-beds.

Under the title of "Stratigraphy of the Coal-measures" (Chapter VI) the general geological cross sections in different parts of the coal-fields are described, the form of the coal-basins is noted, the remarkable variability of the strata is emphasized, the significance of the unconformities is pointed out, typical vertical sections of the coal strata are given. The broader deformations are outlined, and the general conclusions are given regarding the local stratigraphy of the Iowa coal-measures. A special section on the nature of coal-horizons is intended to direct attention to certain features which are to be taken into account in prospecting and mining coal.

In Chapter VII, the descriptions of the coal-beds, the extent of individual coal seams is especially considered. The irregularities in original deposition, the effects of erosion in cutting out the coal, the interruptions owing to faulting and kindred features are noted in their bearings upon mining operations. Limitations to the mining of coal owing to insufficient thickness, and to excessive depths are described in all their various aspects. In the five succeeding chapters are given detailed descriptions of the coal-beds mined in North-central, Central, Southeastern, Southwestern and Eastern Iowa.

Composition of Iowa coals is considered in Chapter XIII. A large number of special chemical analyses are tabulated with special reference to the commercial properties and values of the different coals of the State.

A brief consideration of the waste in coal-mining is given in Chapter XIV. The most serious factors are inefficient methods of mining, lack of care in the removal of the coal, and the production of fine coal.

Chapter XV discusses the extent of the coal industry, the growth of production, the number of mines, the value of the product, the present territory supplied with Iowa coals, and the possible markets.

Keyes, Charles. Coal-floras of Mississippi Valley. (Science, N. S., Vol. XI, pp. 898-900, New York, 1900.) Something of the great richness of the coal-floras of the State is noted. It is estimated that there are 150 localities and 30 different horizons where coal-plants have been reported in Iowa. The recent finds of nodules bearing plant-remains finely preserved, similar to those of the famous Mazon creek, Illinois, of specimens preserving the woody structure to perfection, and immense slabs covered by ferns are mentioned.

Keyes, Charles. Coal Measures of Central Iowa; and Particularly in vicinity of Des Moines. (American Geologist, Vol. II, pp. 396-404. Minneapolis, 1888.) The sketch is accompanied by descriptions of sections of the geological formations near Des Moines, with references to the fossils in the middle coal measures. Incidental reference is made to the eastern extension of the Cretaceous in central Iowa.

Keyes, Charles. Coal Measures of Iowa. (Eng. and Mining Jour., Vol. LVII, pp. 269-297 and pp. 317-318, New York, 1894.) The Western Interior coal-field is described and the conditions under which the coal-beds were formed are discussed at length. A number of sketches illustrate the various features emphasized. The larger structural characteristics of the coal-measures are graphically represented.

Keyes, Charles. Collector; a Journal of Natural History. (Two Volumes, 144 pp., Des Moines, 1881-2.) Contains many short notes on Iowa geology.

Keyes, Charles. Comparative Values of Different Methods of Geologic Correlation. (Proc. Iowa Acad. Sci., Vol. X, pp. 105-107, Des Moines, 1903.) Attention is called to the application of several methods of correlation at once. This procedure was adopted in the course of geologic work in Iowa and Missouri. This paper is a summary of results.

Keyes, Charles. Complexity of Glacial Period and Iowa's Role in its Establishment. (Annals of Iowa, Historical Quarterly; Vol. XI, Des Moines, 1913.) A brief editorial describing McGee's work in connection with glacial studies in Iowa.

Keyes, Charles. Contribution to Fauna of Lower Coal Measures of Central Iowa. (Proc. Iowa Acad. Sci., Vol I, pt. ii, pp. 22-23, Des Moines, 1892.) Description and notes are given on three species, which, however, were previously described as new.

Keyes, Charles. Correlative Relations of Certain Subdivisions of Coal-Measures in Kansas. (American Geologist. Vol. XXV, pp. 347-353, Minneapolis, 1900.) The much discussed Kansas section of the Carboniferous rocks is compared with the sections of other parts of the western Interior coal-basin, including Iowa, and the bearing of the classifications thus represented upon other parts of the region is noted. Special attention is called to Swallow's early names for various subdivisions of the coal-measures.

Keyes, Charles. Cretaceous Formations of Iowa. (Proc. Iowa Acad. Sci., Vol. I, Part iv, pp. 25-26, Des Moines, 1894.) Announcement is made of the discovery of what appears to be Fort Pierre shales in Iowa, thus showing that four out of the five great terranes of the Cretaceous rocks of the Northwest are present in the state. The areal distribution and thickness of the several numbers, as shown by recent deep well-borings, are discussed.

Keyes, Charles. Crustal Adjustment in Upper Mississippi Valley. (Bull. Geol. Soc. America, Vol. V, pp. 231-242, Rochester, 1894.) From the recent investigations concerning the coal it is shown that there exist small faults the number and extent of which have never been fully realized. Sundry sketches illustrating the phenomena are introduced. Several distinct types are noted. In the case of many of the faults of small throw the stresses may have been superinduced by the diminution in bulk of lenticular coal-beds at horizons somewhat lower than those in which the dislocations are manifested.

Keyes, Charles. Des Moines River and origin of the Name. (Annals of Iowa: Historical Quarterly, Vol. III, pp. 554-559, Des Moines, 1898.) In the first decade following 1700 the present Des Moines river was thought to be the principal stream heading to the northwest fur-country. On the maps of the day it is represented as longer and larger than either the Mississippi or the Missouri rivers. It was possible for the French voyageurs to leave the Lower Mississippi by canoe or long-boat and proceed up the Des Moines through the Minnesota river and Red River of the North to Hudson Bay without getting out of their boats. The Sioux name of the Des Moines river is shown to be derived from the red sandstone cliffs in Marion county. Several early maps are reproduced.

Keyes, Charles. Depositional Equivalent of Hiatus at Base of Our Coal Measures. (Proc. Iowa Acad. Sci., Vol. VIII, pp. 119-123, Des Moines, 1901.) The true significance of the unconformable relations between the coal measures of Iowa and the underlying rocks has never been fully appreciated. By figures and diagrams it is shown that this stratigraphic gap is represented farther south by several thousands of feet of strata.

Keyes, Charles. Depositional Measure of Unconformity. (Bull. Geol. Soc. America, Vol. XII, pp. 173-196, Rochester, 1901.) The stratigraphy of the Western Interior coal-field is described, typical geological sections considered in the several states, and an exact correlation of their sections suggested. In the northern part of the field the unconformity at the base of the coal-measures is considered in its various phases. It is shown that the coal-measures of the region find greater development than in any other locality in America. In the Arkansas part of the coal-field 18,000 feet of sediments were deposited during the interval represented by the basal unconformity planes in Iowa. Diagrams accompany the paper.

Keyes, Charles. Depositional Phases of Eolation under the Stimulus of Aridity. (Proc. Iowa Acad. Sci., Vol. XVIII, pp. 101-103, Des Moines, 1911.) Special reference is made to the features of the Great Plains.

Keyes, Charles. Description of Two New Fossils from Devonian of Iowa. (Proc. Acad. Nat. Sci., Philadelphia., pp. 247-248, Philadelphia, 1888.)

Keyes, Charles. Devonian Hiatus in Continental Interior; Its Character and Depositional Equivalents. (Proc. Iowa Acad. Sci., Vol. IX, pp. 105-112, Des Moines, 1902.) Near the Osage river in southwestern Missouri the entire Devonian section is missing. The sections on either side are compared with the great Devonian sequence of Iowa.

Keyes, Charles. Devonial Interval in Missouri. (Bull. Geol. Soc. America, Vol. XIII, pp. 267-292, Rochester, 1902.) Comparison is made of the unimportant section represented in northern Missouri with the varied and extensive section of Iowa. A graphic correlation of typical sections from northern Iowa to Arkansas is made.

Keyes, Charles. Distribution of Certain Loess Fossils. (American Geologist, Vol. VI, p. 119, Minneapolis, 1890.) The geographic range of certain of the loess fossils found in Iowa, and the adjoining parts of the neighboring states is discussed.

Keyes, Charles. Diverse Origins and Diverse Times of Formation of Lead and Zinc Deposits of Mississippi Valley. (Trans. American Inst. Mining Eng., Vol. XXXI, pp. 603-611, New York, 1901.) Special reference is made to the formation of the lead and zinc deposits of the Dubuque region.

Keyes, Charles. Dual Character of Kinderhook Fauna. (American Geologist, Vol. XX, pp. 167-176, Minneapolis, 1897.) At Burlington and southward the two-fold character of the fauna of the Kinderhook beds is emphasized; and its significance in classification pointed out.

Keyes, Charles. Earliest Explorations of Iowa-land. (Annals of Iowa; an Historical Quarterly, Vol. X, pp. 265-272, Des Moines, 1912.) Accounts are given of several French explorers who visited the region now included within the boundaries of the state of Iowa before the appearance of Marquette and Joliet.

Keyes, Charles. Eastern Extension of Cretaceous in Iowa. (Proc. Iowa Acad. Sci., Vol. I, pt. ii, p. 21, Des Moines, 1892.) Announcement is made of the discovery of certain Cretaceous fossils in the drift near Des Moines; the probable eastern limits of the Cretaceous rocks in the state are discussed.

Keyes, Charles. Economic Aspects of Work in Pure Science. (The Annals of Iowa: Historical Quarterly, Vol. V, pp. 292-293, Des Moines, 1902.) Some of the advantages of applied geology are set forth with special reference to the utilitarian trend of scientific investigation by geological surveys.

Keyes, Charles. Elston Holmes Lonsdale, Memorial. (American Geologist, Vol. XXI, pp. 264-265, Minneapolis, 1898.) In the biographical sketch of Mr. Lonsdale his work in Iowa, while assistant geologist, is especially considered.

Keyes, Charles. Eolian Origin of Loess. (Am. Jour. Sci., (4), Vol. VI, pp. 299-304, New Haven, 1898.) Dust-storms on the Missouri river are described and are thought to be the direct origin of the loess deposits covering the bluffs. Observations are recorded on the western border of Iowa as far north as Council Bluffs. The rate of deposition is estimated; and the retention of the windborne materials is shown to be accomplished by the vegetation.

Keyes, Charles. Epoch in History of American Science. (Annals of Iowa, Historical Quarterly, (3), Vol. II, pp. 345-364, Des Moines, 1896.) There are given a brief account of their work, and biographical sketches of the late Charles Wachsmuth, and of Frank Springer, two of Iowa's most distinguished scientists, and authors of a monumental work on the fossil remains comprised in a monograph on the Crinoidea Camerata of North America. A portrait of each author and several pen-and-ink drawings showing characteristic forms which the authors had under consideration are given. A list of the authors' most important publications is appended.

Keyes, Charles. Fauna of Lower Coal Measures of Central Iowa. (Proc. Acad. Nat. Sci. Philadelphia, 1888, pp. 231-247, Philadelphia, 1888.) A brief sketch is given of the geological formations, together with notes on many of the fossils occurring in the rocks of the region. Three species are figured and described as new.

Keyes, Charles. First Recorded Use of Mineral Coal in America. (Scientific American, Supp., LXXIV, p. 34, New York, 1912.) Abstract is given of a more extended account under the same title.

Keyes, Charles. First Reported Use of Mineral Coal in America. (Eng. and Mining Jour., Vol. XCIV, pp. 27-28, New York, 1912.) The discovery of coal in the upper Mississippi valley preceded that in the east by 50 years. It was probably used by the Ioway Indians before the advent of Europeans.

Keyes, Charles. Formational Synonymy of Coal-Measures of Western Interior Basin. (Proc. Iowa Acad. Sci., Vol. VII, pp. 82-105, Des Moines, 1900.) A standard section of the geological terranes represented in the coal-measures of Iowa is given. To it are referred all the known formations. The recognized subdivisions are briefly described. A general cross section along the Missouri river from Kansas City to Council Bluffs is represented. The outcropping edges of the several terranes are drawn on a sketch-map of Iowa, Missouri, Kansas and Nebraska. A complete synonymic list follows.

Keyes, Charles. Fossil Faunas in Central Iowa. (Proc. Acad. Nat. Sci., Phila., pp. 242-265, Philadelphia, 1891.) The biological relations of the fossils are summarized; a general section of the rocks of the region and a list of the fossils found in the middle coal measures are given, together with notes and bibliographic references to many of the forms found in the rocks near Des Moines. A synoptical table of the genera and species thus far recognized is appended.

Keyes, Charles. Genesis of American Actinocrinoidæ. (American Naturalist, Vol. XXIV, pp. 243-254, Philadelphia, 1890.) This is a discussion of the evolution of sundry characteristic forms of crinoids, chiefly found in Iowa rocks.

Keyes, Charles. Genesis of Certain Cherts. (Proc. Iowa Acad. Sci., Vol. X, pp. 103-107, Des Moines, 1903.) It is stated that the evidence recently obtained indicates that the cherts of the Early Carboniferous formations of Iowa and Missouri were formed long after the rocks were laid down. The process of formation is analogous to that of ore-genesis under similar conditions, or through metasomatism.

Keyes, Charles. Genesis of Ozark Lead-Zinc Deposits. (Mining World, Vol. XXX, pp. 431-433, 481-485 and 543-546, Chicago, 1909.) Numerous references are made to the Iowa deposits of lead and zinc.

Keyes, Charles. Geographic Distribution of Lead and Zinc Deposits of Mississippi Valley. (Eng. and Mining Jour., Vol. LXXXVI, pp. 1004-1005, New York, 1908.) The localization of ore deposits in synclines appears to apply to the Dubuque region as well as in the Ozarks.

Keyes, Charles. Geological Age of Certain Gypsum Deposits. (American Geologist, Vol. XXX, pp. 99-102, Minneapolis, 1902.) Evidence is adduced for a Cretaceous age of the Fort Dodge gypsum. The assignment of a Permian age as recently advanced appears to be precluded by all direct testimony available; in fact a Permian age seems entirely impossible.

Keyes, Charles. Geological Formations of Iowa. (Iowa Geol. Surv., Vol. I, pp. 11-161, Des Moines, 1893.) The history of opinion regarding the various geological formations represented in the state is brought down to date. New personal observations are recorded. The Carboniferous terranes are especially considered and described, because of recent extensive field-work in this and neighboring states. A separation of the coal-measures into two divisions is made—the Des Moines and the Missouri. The stratigraphy of the coal-beds is discussed in considerable detail.

Keyes, Charles. Geological Map of Iowa. (Annals of Iowa, Historical Quarterly, (3), Vol. I, pp. 294-297, Des Moines, 1894.) This article is a brief popular statement

on the geological mapping methods being followed by the new survey. The significance of the various colors is also explained.

Keyes, Charles. Geological Mapping of Iowa. (Mon. Rev. Iowa Weather Serv., Vol. V, No. 2, pp. 4-6, Des Moines, 1894.) The construction of a geological map of the state is explained, and its service as a soil-index is pointed out. A properly constructed map thus puts in the hands of every citizen in every locality the means by which he may readily know just what mineral substances he may expect to find and for what it is useless to search.

Keyes, Charles. Geological Position of Trans-Mississippian Coals. (Eng. and Mining Jour., Vol. LXIX, pp. 528-529, New York, 1900.) A table indicates all the geological formations of the coal-measures of the region. In Iowa the terranal percentages of coal-production are calculated to be for the Cherokee shales 83.4 per cent., for the Appanoose limestones and shales 15.4 per cent., for the Marais des Cygnes 1.0 per cent., and for the Atchison shales 0.2 per cent. The coal-beds are also briefly described.

Keyes, Charles. Geological Structure and Relations of Coal-bearing Strata of Central Iowa. (Proc. Iowa Acad. Sci., Vol. I, pt. ii, pp. 27-28, Des Moines, 1892.) A summary is given of observations made along the Des Moines river, chiefly in the vicinity of Des Moines.

Keyes, Charles. Geological Survey of Iowa. (Annals of Iowa: Historical Quarterly, (3), Vol. III, pp. 111-121, Des Moines, 1897.) There are given brief accounts of the organization and work of the several attempts to carry on the geological surveys of the state. Portraits of former State Geologists accompany the sketch.

Keyes, Charles. Geology of Des Moines County. (Iowa Geol. Surv., Vol. III, pp. 409-492, Des Moines, 1894.) The principal features described are:

Situation and extent, previous work.

Physiography, surface relief, table of altitudes, drainage.

Stratigraphy, general geological relations, classification of formations, general section, standard section, Prospect Hill, Augusta, southwest corner of county, southwest of Danville, Mississippi river sections, Huron section, Dolbee creek section, Oak creek section, Patterson sections, Skunk River sections, Flint River sections, Knotty creek, Big Hollow, Pleasant Grove; geological formations, Mississippian series, Kinderhook, correlations of Kinderhook, useful deposits; Augusta, lower Burlington, upper Burlington, Montrose cherts, Keokuk limestone; St. Louis; upper Carboniferous or coal-measures, Des Moines; Pleistocene, general character, lower till, loess, terraces, glacial markings; geological structure, general arrangement; geological cross section, Mississippi river section, Skunk river section; unconformities.

Building stones, Burlington township, Union, Augusta, Danville, Flint River, Pleasant Grove, Franklin, Yellow Springs, Huron, and Benton townships; clays, minerals, polishing materials, limes, road-metals, sands, waters and water-powers.

The geological mapping and reporting on Des Moines county was the first areal work completed by the new Iowa geological survey. A large part of the district, however, had been investigated several years previous, and the boundaries of the various geological formations and their delimitations determined.

Keyes, Charles. Geology of Lee County. (Iowa Geol. Surv., Vol. III, pp. 305-407, Des Moines, 1894.) The following features are discussed:

Introduction, area and location, previous geological work.

Physiography, surface relief, table of altitudes, drainage.

Stratigraphy, geological relations of formations, table of strata, general geological section, typical exposures; standard sections, Mississippi River sections, Skunk River sections, Des Moines River sections, other sections; geological formations, Mississippian series, Kinderhook shales, Augusta limestone, Lower Burlington limestone, upper Burlington limestone, Montrose cherts, Keokuk limestone, Goede bed, Warsaw shales, St. Louis limestone, Concretionary limestone, breciated limestone, white limestone; Upper Carboniferous, Des Moines shales; Pleistocene deposits, lower till, blue bowlder-clay, yellow bowlder-clay, loess, terrace formations; geological structure; general relations, geological cross section, Mississippi River section, Skunk River section, Des Moines River section; deformation of strata; unconformities, coal measures and Saint Louis limestone, drift and indurated rocks; coal, building-stones, limestones, sandstones, clay deposits, character and distribution, clay industries; sands, road-materials, macadam, gravels, clay; cements, lime, minerals, soils, waters, surface, artesian, mineral.

Keyes, Charles. Gigantic Orthoceratite from American Carboniferous. (Science, N. S., Vol. III, pp. 94-95, New York, 1896.) A short summary is given of the forms of Orthoceras known from the Carboniferous strata of the country, and attention is called to the recent finding in Guthrie county of a very large shell, probably originally over six feet in length. It is called *Orthoceras fanslerensis.*

Keyes, Charles. Glacial Scorings in Iowa. (Iowa Geol. Surv., Vol. III, pp. 147-165, Des Moines, 1894.) The known localities are listed where in Iowa glacial striæ have been observed; and the determined directions of the striæ are tabulated. A number of unusually fine striated surfaces newly discovered are described and several photographs are reproduced showing the ice-flutings and other markings.

Keyes, Charles. Growth of Iowa's Coal Industry. (Mon. Rev. Weather Serv., Vol. V, No. 12, pp. 5-7, Des Moines, 1894.) The growth of Iowa's principal mining industry is traced from the time when coal was first taken out of the ground for commercial purposes. The state's output is also compared with that of neighboring states. By counties the tonnage mined during the year previous to making the report on the coal deposits is tabulated. The production is also grouped according to the several sections of the state.

Keyes, Charles. Gypsum Deposits of Iowa. (Iowa Geol. Surv., Vol. III, pp. 257-304, Des Moines, 1894.) In describing the geological features of the region the unconformable relations with the coal-measures and St. Louis limestone are especially emphasized. The outcrops are considered in detail. Origin and geological age of the gypsum are discussed at some length; and the evidence adduced seems to point to a Cretaceous age. From similar shales further north Lesquereux described leaves which he assigned to the Dakota stage.

The composition, present uses and probable future uses of the gypsum are described; also the character of the beds, their extent and value; their general availability, the production and markets. The milling and preparation of the gypsum for market are entered into in considerable detail.

An important fact brought out is that the gypsum is a long basin having its main axis trending northeast and southwest instead of northwest and southeast as formerly supposed. Predictions of extensive deposits far beyond the known limits of the gypsum have since been fulfilled by the disclosures made by extensive boring explorations.

Keyes, Charles. Horizons of Arkansas and Indian Territory Coals compared with those of other Trans-Mississippian Coals. (Eng. and Mining Jour., Vol. LXXI, pp. 692-693, New York, 1901.) The industrial aspects of a knowledge of the exact stratigraphic horizons of the coal beds are emphasized. Differences between the southern and northern sections of the coal-measures are pointed out by diagrams.

Keyes, Charles. Iowa Coal Beds. (Mon. Rev. Iowa Weather and Crop Service, Vol. IV, No. 1, pp. 3-5, Des Moines, 1893.) The general geology, production and availability of the coal deposits of Iowa are described.

Keyes, Charles. Iowa Coal Beds. (Coal Trade Journal, Vol. XXXII, p. 133, March 1, 1893.)

Keyes, Charles. (Iowa Gypsum. (The Mineral Industry, Vol. IV, pp. 379-386, New York, 1896.) The industrial aspects of the Iowa gypsum interests are described at some length. Geology, chemical composition and extent of the deposits are considered. The present uses of gypsum and the methods of its preparation for market are also described. Photographs of the gypsum deposits are given.

Keyes, Charles. Iowa's Gypsum Deposits. (Mon. Rev. Iowa Weather and Crop Service, Vol. IV, No. 3, pp. 2-4, Des Moines, 1893.) The geology of the gypsum region is described, with special reference to the amount and availability of the gypsum deposits of the state.

Keyes, Charles. Iowa Mineralogical Notes. (Proc. Iowa Acad. Sci., Vol. I, pt. iii, pp. 19-22, Des Moines, 1893.) A description is given of certain recent finds of minerals in the state. Some unusually perfect crystals of pyrite are figured. The Keokuk millerites are described in detail. Announcement of the presence of eruptive rocks in northwestern Iowa is also made.

Keyes, Charles. Iowa's Contribution to Glaciology. (Annals of Iowa, Historical Quarterly, Vol. IV, pp. 394-396, Des Moines, 1900.) Statement of the part Iowans have played in advancing knowledge concerning the Great Ice Age. Particular attention is directed to the recent voluminous writings of Frank Leverett.

Keyes, Charles. Iowa Scientist and His Work. (Annals of Iowa, Historical Quarterly, Vol. IV, pp. 383-392, Des Moines, 1900.) An outline of the great work on glacial geology by Frank Leverett, an Iowan, is given, together with a biographical sketch and a portrait. The volume reviewed comprises some 800 pages and is regarded as one of the notable contributions to American geology. The subject matter covers mainly the southeastern part of the state.

Keyes, Charles. Iowa Volcano. (Mon. Rev. Iowa Weather and Crop Service, Vol. IV, pp. 5-6, Des Moines, 1893.) Eruptive rocks in northwestern Iowa are described.

Keyes, Charles. Kinderhook Stratigraphy. (Journal of Geology, Vol. VIII, pp. 315-321, Chicago, 1900.) Regarding the Iowa part of the memoir special attention is called to the great development of the shale beneath the limestone at Burlington as indicating a mingling of Devonian and Carboniferous faunal elements. By diagram the commonly recognized basal number of the Mississippian series is shown to fade out northward, leaving the supposed base in the middle of the great shale-section. The basal shale at Burlington represents much more than the Hannibal shale of Missouri.

Keyes, Charles. Lime Creek Fauna of Iowa in Southwestern United States and Northern Mexican Region. (Proc. Iowa Acad. Sci., Vol. XIII, pp. 197-198, Des Moines, 1907.) Comparison of certain Devonian faunas of southwestern United States is made with that occurring in the Lime Creek shales. A list of a score or more of the most characteristic Lime Creek species is given. The wide geographic relations of this peculiar fauna are discussed.

Keyes, Charles. List of Carboniferous Fossils from Des Moines. (Iowa Geol. Surv., Vol. VII, pp. 330-335, Des Moines, 1897.) The components of a remarkable fauna composed mainly of minute gasteropods are here enumerated. Only from one other locality is this assemblage of fossils reported.

Keyes, Charles. Lower Carbonic Gasteropoda from Burlington, Iowa. (Proc. Acad. Nat. Sci. Philadelphia, 1889, pp. 283-298, 1889.) This is an annotated list of the species of gasteropods found in the Kinderhook beds and Burlington limestone at Burlington, Iowa.

Keyes, Charles. Marked unconformity between Carboniferous and Devonian Strata in Upper Mississippi Valley. (Am. Jour. Sci., (4), Vol. XXXVI, pp. 160-164, New Haven, 1913.) Recent recognition for the first time of sections

in which the two groups of strata are seen in juxtaposition enables wide generalization to be made concerning the exact relationships.

Keyes, Charles. Memorial of Charles Wachsmuth. (Proc. Iowa Acad. Sci., Vol. IV, pp. 13-16, Des Moines, 1897.) A biographical sketch of one of the state's most distinguished scientists is given, with portrait.

Keyes, Charles. Methods of Determining Natural Resources of a Region. (Mon. Rev. Iowa Weather Serv., Vol. VI, No. 3, pp. 5-7, Des Moines, 1895.) The work of the geological survey is briefly outlined and some of the important results summarized. Among the things attained for the state are provisions of a suitable foundation for detailed and intelligent search for mineral wealth, the assurance of permanency and development of the resources already known, the establishment of an official guaranty respecting the natural wealth of the state, the formulation on a scientific basis of a standard by which the geological features of the region may be compared with those of other districts, and an advancement of agricultural and horticultural interests and the placing of them upon a firmer basis.

Keyes, Charles. Mid-Continental Eolation. (Bull. Geol. Soc., America, Vol. XXII, pp. 687-714, New York, 1912.) Origin of the Great Plains through eolation is discussed in its various phases. This region forms a vast area of deposition for the exported dusts of the western deserts. The features of the region are analyzed in accordance with eolic principles. Objections to the lacustran theory and the weaknesses of the fluvatile hypothesis are pointed out.

Keyes, Charles. Missourian Series of Carboniferous. (American Geologist, Vol. XXIII, pp. 298-316, Minneapolis, 1899.) A general section of the Upper Coal-measures of Missouri is given, with the grouping of the various strata into ten formations which are designated by special names. Southwestern Iowa is especially considered in this connection. Over 1,000 feet of strata are ascribed to the Missourian series in this part of the state. The upper part of the series is not represented within the limits of Iowa.

Keyes, Charles. Names of Coals West of the Mississippi River. (Proc. Iowa Acad. Sci., Vol. VII, 128-137, Des Moines, 1901.) A standard terranal classification of the coal-measures of the Western Interior region is given, to which are referred all the known coal-horizons. The three serial subdivisions recognized are Arkansan, Des Moines and Missourian.

Keyes, Charles. Naticoid Genus Strophostylus. (American Naturalist, Vol. XXIV, pp. 1111-1117, Philadelphia, 1890.) Some of the forms described are from Iowa rocks. The definition of the genus is based largely upon Iowa species.

Keyes, Charles. Natural Gas and Oil in Iowa. (Proc. Iowa Acad. Sci., Vol. I, pt. iii, pp. 15-18, Des Moines, 1893.) Statement is made of the various conditions necessary for a successful flow of natural gas and mineral oil and an application of the principles involved to Iowa.

Keyes, Charles. Nature of Coal Horizons. (Journal of Geology, Vol. I, pp. 178-186, Chicago, 1894.) The basin-shaped character of the coal deposits is analyzed and the cross sections in different directions compared. The various conflicting theories are thereby shown to be in harmony with one another. Diagrams accompany the explanations. The discussion is applicable particularly to the Iowa and Missouri coal-fields.

Keyes, Charles. Nether Delimitation of Our Carbonic Rocks. (Science, N. S., Vol. XXXVI, p. 569, New York, 1912.) Announcement is made of the finding of the unconformable juncture of the carboniferous and devonian rocks in Iowa.

Keyes, Charles. Nether Delimitation of Our Carbonic Rocks. (Proc. Iowa Acad. Sci., Vol. XIX, pp. 151-154, Des Moines, 1912.) The base of the carboniferous sequence in Iowa has never been open to inspection. Neither has the top of the devonian section been recognized with certainty. Recently recorded facts go to show that there is a marked unconformity in places between the two great rock-successions. The basal member of the carboniferous is the Grassy shale of Missouri heretofore regarded as Devonian in age. The Sweetland Creek beds of Muscatine county are the northward extension.

Keyes, Charles. New Conocardium from Iowa Devonian. (Proc. Iowa Acad. Sci., Vol. I, pt. ii, pp. 23-24, Des Moines, 1892.) Description is given of *Conocardium altum,* which is regarded as new.

Keyes, Charles. New Locality for Millerite. (American Geologist, Vol. XI, p. 126, Minneapolis, 1893.) Description of some unusually fine examples of the mineral recently found at Keokuk is given.

Keyes, Charles. "Nickel Ore" from Iowa. (Eng. and Mining Journal, Vol. LIV, p. 634, New York, 1892.) A statement is made in regard to the recent finds of the sulphide of nickel, or millerite, from Keokuk.

Keyes, Charles. North American Fossil Crinoidea Camerata. (Journal Geology, Vol. IV, pp. 221-240, Chicago, 1896.) This is an extended and critical review of Wachsmuth and Springer's monograph on the crinoids appearing in two large volumes and an atlas of 83 plates. To this are added certain personal observations and the discussion of sundry aspects of the subject of wide morphological interest. The subject matter is largely based upon material from Iowa.

Keyes, Charles. Northward Extension of Lake Valley Limestone. (Proc. Iowa Acad. Sci., Vol. XII, pp. 169-171, Des Moines, 1905.) Notice is taken of the occurrence of the typical Burlington (Iowa) fauna at Lake Valley and the recent finding of similar forms much farther north in the Magdalena mountains of New Mexico.

Keyes, Charles. Note on Carboniferous Fauna of Mississippi Valley in Rocky Mountain Region. (Proc. Iowa Acad. Sci., Vol. XI, pp. 258-259, Des Moines, 1904.) A comparison of the carboniferous fossils from the Rio Grande province is made with those occurring at Burlington, Iowa.

Keyes, Charles. Note on Correlation of Clarinda Well-section with the Schematic Section of the Carboniferous. (Iowa Geol. Surv., Vol. XI, pp. 461-463, Des Moines, 1901.) The record is shown to be that of a typical section of the Missourian series in which all the numbers recently named as belonging to that series are recognizable. Only the Iola limestone is missing, since it is known to thin out northward from Kansas City.

Keyes, Charles. Note on Distribution of Helicina Occulta. (The Nautilus, Vol. III, pp. 18-19, Philadelphia, 1889.) Notes are given on the distribution of these fossil forms recently found living in Iowa.

Keyes, Charles. Note on Nature of Cone-in-Cone. (Proc. Iowa Acad. Sci., Vol. III, pp. 75-76, Des Moines, 1896.) Recently a number of unusually fine specimens of this remarkable structure were obtained. They are shown to be crystalizations of calcic carbonate which have incorporated more or less clay as impurities. The structure is due therefore to the strong crystallizing process of the mineral calcite.

Keyes, Charles. Notes on Redrock Sandstone. (Proc. Iowa Acad. Sci., Vol. I, pt. ii, pp. 26-27, Des Moines, 1892.) Preliminary reference is made to the stratigraphical relations of an extensive sandstone formation in Marion county.

Keyes, Charles. Nous Avons Eu de Grandes Richesses Houillères. (La Chronique Industrielle, Trente-cinquiène Année, No. 102, pp. 1-2, Paris, 1912.) A brief history is given of the discovery, by the French, of coal in the Upper Mississippi valley.

Keyes, Charles. Observations on Classification of Mississippian Series. (American Geologist, Vol. XXII, pp. 108-113, Minneapolis, 1898.) Reasons are advanced for retaining the term Augusta in preference to that of Osage for a subdivision of the Mississippian series. The latter name is shown to be preoccupied several times.

Keyes, Charles. Occurrence of Natural Gas in Iowa; and its Probable Future. (Mon. Rev. Iowa Weather and Crop Service, Vol. III, No. 12, pp. 3-4, Des Moines, 1892.) A general account of the conditions necessary for a successful flow of oil and gas, and an account of how these conditions are satisfied within the limits of Iowa so far as is known, are given.

Keyes, Charles. Old Volcanic Eruption in Iowa. (Science, Vol. XXI, p. 132, New York, 1893.)

Keyes, Charles. Opinions Concerning Age of Sioux Quartzite. (Proc. Iowa Acad. Sci., Vol. II, pp. 218-222, Des Moines, 1895.) All the articles published on the Sioux quartzite are reviewed and summarized. The evidence upon which the varied opinions is based are weighed and compared with more recent personal observations. The conclusion reached is that the formation is Huronian in age.

Keyes, Charles. Origin of Anthracite. (American Geologist, Vol. XIII, pp. 411-415, Minneapolis, 1894.) The discussion of the subject is based upon a remarkable variety of coal known as the Mystic seam in southern Iowa. The coal is of bituminous variety but in all physical properties except hardness it would easily be mistaken for anthracite. A question arises as to the different modes of the origin of coal.

Keyes, Charles. Origin of the Great Plains. (Science, N. S., Vol. XXXIV, pp. 352, New York, 1911.) Their formation is ascribed to eolative influences chiefly. The other hypotheses are reviewed.

Keyes, Charles. Origine Eolienne du Loess. (Bull. de la Sociéte Belge de Géologie, de Palèontologie et d'Hydrologie, Tome XII, pp. 14-21, Bruxelles, 1901.) The origin of the loess deposits of the Missouri River valley

in Iowa and Missouri by wind-storm dusts is advanced, and the data upon which the argument is based are given.

Keyes, Charles. Orotaxical Correlation of Geological Terranes and Diastrophism. (Proc. Iowa Acad. Sci., Vol. XVI, pp. 153-157, Des Moines, 1909.) This is an application of local principles worked out in Iowa to general geological classification.

Keyes, Charles. Orotaxis: A Method of Geologic Correlation. (American Geologist, Vol. XVIII, pp. 289-302, Minneapolis, 1896.) The plan had its inception in the stratigraphic consideration of the Iowa coal-measures, and some of the illustrations are derived from this source.

Keyes, Charles. Ozark Lead and Zinc Deposits: Their Genesis, Localization and Migrations. (Trans. American Inst. Mining Eng., Vol. XL, pp. 184-231, New York, 1909.) In considering the localization of ore-bodies in synclines special note is made of the formation of the latter in Iowa of an unequal change in volume of the underlying rocks.

Keyes, Charles. Paleontology of Missouri, Part I. (Missouri Geol. Surv., Vol. IV, 271 pp., Jefferson City, 1894.) In the general chapter on the geological section numerous references are made to Iowa formations. The descriptions of the detailed cross section along the Mississippi river includes the Iowa boundary as far north as the Iowa river. Many Iowa fossils are described and illustrated.

Keyes, Charles. Paleontology of Missouri, Part II. (Missouri Geol. Surv., Vol. V, 266 pp., Jefferson City, 1894.) Many forms of organic remains from Iowa localities are described and illustrated.

Keyes, Charles. Paleozoic Fossils of Maryland. (Johns Hopkins University Circulars, Vol. XI, pp. 28-29, Baltimore, 1891.) A number of Iowa species are identified for the first time in the Appalachian region.

Keyes, Charles. Perisomic Plates of Crinoids. (American Geologist, Vol. VII, pp. 255-258, Minneapolis, 1891.) The discussion of the subject is based upon descriptions of certain Iowa forms.

Keyes, Charles. Permian Rocks of Eastern Russia. (Proc. Iowa Acad. Sci., Vol. VI, pp. 229-231, Des Moines, 1899.) The standard Carboniferous sections of eastern Russia and of the original Permian are compared with that of Iowa, Missouri and Kansas. A remarkable parallelism of formations is displayed.

Keyes, Charles. Platyceras Group of Palæozoic Gasteropods. (American Geologist, Vol. X, pp. 273-277, Minneapolis, 1892.) A revision of the group with special reference to the forms from Iowa, is outlined.

Keyes, Charles. Pre-Glacial River-channels of Central Iowa. (The Annals, Historical Quarterly, Vol. VIII, pp. 13-17, Des Moines, 1907.) Special description is given of Tertiary river-lines in the present Des Moines valley. Des Moines and Keokuk are noted. Sketches of the structure represented accompany the article and a sketch-map of the glacial deposits is given.

Keyes, Charles. Preliminary Note on Sedentary Habits of Platyceras. (Proc. Iowa Acad. Sci., Vol I, pt. ii, p. 24, Des Moines, 1892.) A preliminary account is made of the attachment of gasteropods to crinoids.

Keyes, Charles. Present Basal Line of Delimitation of the Carboniferous in Northeastern Missouri. (American Geologist, Vol X, pp. 380-384, Minneapolis, 1892.) A special bearing of the observations upon the rock-succession of southern Iowa is noted. It is predicted that a marked line of unconformity will be found to exist between the Devonian and Carboniferous strata of this region.

Keyes, Charles. Preservation of the Color in Fossil Shells. (The Nautilus, Vol. IV, pp. 30-31, Philadelphia, 1890.) Particular attention is directed to the original coloration of certain snail-shells from the loess of central Iowa.

Keyes, Charles. Principal Mississippian Section. (Bull. Geol. Soc. America, Vol. III, pp. 283-300, Washington, 1892.) The leading section along the Mississippi river, a historical consideration of the various terms applied to rocks and a detailed description of the different formations are given. A classification of the Mississippian series is proposed in accordance with the observations recently made.

Keyes, Charles. Probable Stratigraphical Equivalents of Coal-measures of Arkansas. (Journal of Geology, Vol. VI, pp. 356-365, Chicago, 1898.) The attempt is made to show that the enormously thick section of coal-measures displayed in Arkansas is not the equivalent of the coal-measures further north (Missouri and Des Moines series) as represented in Iowa.

Keyes, Charles. Process of Formation of Certain Quartzites. (Proc. Iowa Acad. Sci., Vol. I, Part iv, 29-31, Des Moines, 1894.) Thin slices of rock under the microscope show that the quartzite under consideration was formed by the secondary enlargement of the sand-grains, the added silica of the rock-grains being in optical continuity with them. Notice is also taken of the occurrence of diabase dikes in the Sioux quartzite beyond the Iowa boundary.

Keyes, Charles. Proposed Economical Geological Survey of Iowa. (Pamphlet, 8 pp., Des Moines, 1891.) Statement is made of the need of a geological survey of the state and of the various lines of work which especially require investigation, together with comparisons with other states; and an outline of how the work should be conducted is given. Portions appeared in various newspapers throughout the state.

Keyes, Charles. Redrock Sandstone of Marion County, Iowa. (Am. Jour. Sci., (3), XLI, pp. 273-276, New Haven, 1891.) There is described a section of a thick sandstone formation exposed on the Des Moines river in Marion county, showing a remarkable unconformity in the Cherokee shales. Extension of the sand-rock is pointed out and the opinions regarding its age considered.

Keyes, Charles. Relations of Devonian and Carboniferous in Upper Mississippi Valley. (Trans. St. Louis Acad. Sci., Vol. VII, pp. 357-369, St. Louis, 1897.) Results of a detailed comparison of fossil faunas of the Mississippian series in northeastern Missouri are also applicable to southeastern Iowa. The conclusions reached are partly the outcome of the observations made at Burlington.

Keyes, Charles. Relations of Missouri River Loess Mantle and Kansan Drift Sheet. (American Jour. Sci., (4), Vol. XXXIII, pp. 32-34, New Haven, 1912.) The loess mantles are believed to be eolian formed sheets interlocking with the ice formed glacial drift sheets. The materials of the first were derived from the southwest; those of the second from the northeast.

Keyes, Charles. Relations of Platyceras and Capulus. (American Geologist, Vol. III, pp. 6-9, Minneapolis, 1890.) The generic distinctions made are based upon forms collected mainly from the Mississippian rocks of southeastern Iowa.

Keyes, Charles. Remarkable Fauna at Base of Burlington Limestone in Northeastern Missouri. (Am. Jour. Sci., (3), Vol. XLIV, pp. 247-252, New Haven, 1892.) References are made to the rocks of southeastern Iowa.

Keyes, Charles. Remarks on Perisomic Plates of Crinoids. (American Jour. Sci., (3), Vol. XLI, pp. 247-248, New Haven, 1891.) The comments on the important morphologic memoir are based upon specimens from the rocks of Marshall and Des Moines counties.

Keyes, Charles. Review of Progress of American Invertebrate Paleontology for 1889. (American Naturalist, Vol. XXIV, pp. 131-138, Philadelphia, 1890.) A number of the important papers of the year relating to Iowa are reviewed.

Keyes, Charles. Review of Progress of American Invertebrate Paleontology for year 1890. (American Naturalist, Vol. XXV, pp. 327-333, Philadelphia, 1891.) Special notice is taken of several memoirs published during the year on Iowa geology.

Keyes, Charles. Revised List of Loess Fossils from Des Moines. (Iowa Geol. Surv., Vol. VII, p. 344, Des Moines, 1897.) A complete list of the forms thus far discovered in Polk county is given.

Keyes, Charles. Schematic Standard for American Carboniferous. (American Geologist, Vol. XXVIII, pp. 299-305, Minneapolis, 1901.) A table of formations constituting the Carboniferous sequence in the Mississippi valley is given and the various phases discussed.

Keyes, Charles. Sedentary Habits of Platyceras. (Am. Jour. Sci., (3), Vol. XXXVI, pp. 269-272, New Haven, 1888.) Notes are given on the habits of various species found in Iowa, especially those attached to crinoids.

Keyes, Charles. Serial Nomenclature of Carboniferous. (American Geologist, Vol. XVIII, pp. 22-28, Minneapolis, 1896.) Three of the four serial subdivisions of the Carboniferous are defined upon Iowa and Missouri delimitations.

Keyes, Charles. Sketch of Coal Measures of Iowa. (U. S. Geological Survey, Mineral Resources for 1892, pp. 398-404, Washington, 1894.) This is a concise account of the geological characters of the productive coal-measures of the state. The relations of the Iowa field to the great Interior coal-basin are noted. Thickness, variability, extent and character of individual coal-beds are particularly described.

Keyes, Charles. Sketch of Coal Deposits of Iowa. (Coal Trade Journal, Vol. XXXIII, pp. 954-957, New York, 1894.) The salient characters of the Iowa coal-bearing formations are considered and their commercial aspects are especially noted. The paper is illustrated by reproduced photographs showing the top-works of some of the most completely equipped mines.

Keyes, Charles. Sketch of Geology of Iowa. (Handbook of Iowa, World's Columbian Exposition at Chicago, pp. 18-28, Dubuque, 1893.) This is a popular résumé of what is known of the geological formations of the state. The various terranes are briefly characterized and their principal economic values pointed out.

Keyes, Charles. Soleniscus: its Generic Characters and Relations. (American Naturalist, Vol. XXIII, pp. 420-429, Philadelphia, 1889.) Description of the generic characters of the group is given, and several of the species belonging to the section are figured from Iowa.

Keyes, Charles. Some Fossils from Lower Coal Measures at Des Moines, Iowa. (American Geologist, Vol. II, pp. 24-28, Minneapolis, 1888.) A brief account is given of the relations of the coal horizons; with a list of 54 species of invertebrates and 2 of fishes found at Des Moines. The biological relations of the forms also receive notice.

Keyes, Charles. Some Physical Aspects of General Geological Correlation. (Proc. Iowa Acad. Sci., Vol. VI, pp. 131-154, Des Moines, 1899.) Diastrophism is the chief cause of sedimentary changes and its physical expression is the unconformity. For the major subdivisions of terranal sequence unconformity should therefore be the main criterion. The Iowa coal-measures form an admirable basis for outlining a general classification and the principles of geological correlation.

Keyes, Charles. Spanish Mines; an Episode in Primitive American Lead-Mining. (Annals of Iowa; an Historical Quarterly, Vol. X, pp. 539-546, Des Moines, 1912.) The financial methods of Julian Dubuque are recounted.

Keyes, Charles. Sphærodoma: a Genus of Fossil Gasteropods. (Proc. Acad. Nat. Sci. Phila., 1889, pp. 303-309, Philadelphia, 1889.) This is revision of the species formerly referred to Macrochilus; part of the species is placed under Soleniscus and others to the new genus Sphærodoma.

Keyes, Charles. Stages of Des Moines, or Coal-bearing, Series of Kansas and Southwestern Missouri, and their Equivalents in Iowa. (Proc. Iowa Acad. Sci., Vol. IV, pp. 22-25, Des Moines, 1897.) Subdivisions of the Des Moines series in Missouri are shown to be recognizable in the Iowa portion of the Western Interior coal-field. Their names are Cherokee shales, Henrietta limestones and Pleasanton shales. The last two terranes are more properly called in Iowa the Appanoose limestones and the Marais des Cygnes formation. These are briefly characterized.

Keyes, Charles. Stratigraphical Location of named Trans-Mississippian Coals. (Eng. and Min. Jour., Vol. LXXII, p. 198, New York, 1901.) A complete schematic section of the Carboniferous rocks of the Mississippi valley is given for the first time. The coal-beds known in each terrane are listed, with their localities.

Keyes, Charles. Stratigraphy of Carboniferous in Central Iowa. (Bull. Geol. Soc. America, Vol. II, pp. 277-292, Washington, 1891.) A full description is given of the various sections exposed along the Des Moines river in the central part of the state, with special reference to the lithological characters of the strata, and the stratigraphical relations of various beds. Several marked unconformities are described and illustrated and the leading faunal aspects of the region are tabulated.

Keyes, Charles. Structure of Coal Deposits of Trans-Mississippian Field. (Eng. and Mining Jour., Vol. LXV, pp. 253-254, and 281, New York, 1898.) In summarizing the salient facts concerning the geological features of the Western Interior coal-field the following topics are particularly discussed: Principal rock-series recognized, extent and thickness of the productive coal-veins, general geological structure of the coal region, character of the rocks, natural subdivisions of the productive measures, description of the coal-beds, thickness and availability of the coal-beds, prospects of coal outside of the surface areas occupied by the main-body of productive coal-measures and nature of the coal-pockets and outliers.

Keyes, Charles. Sundry Provincial and Local Phases of General Geological Section of Iowa. (Science, N. S., Vol. XXXVI, p. 569, New York, 1912). The urgent need of a radical revision in the nomenclature of Iowa formations is pointed out; and a working scheme is presented.

Keyes, Charles. Sundry Provincial and Local Phases of the General Geological Section of Iowa. (Proc. Iowa Acad. Sci., Vol. XIX, pp. 147-151, Des Moines, 1912.) Certain features of the stratigraphy of the state are briefly discussed in the light of recent advances of geological classifications. A careful revision of the nomenclature of the geological formations now recognized is needful. There should be a detailed study of some of the larger groups with a view of a more satisfactory subdivision. One of these sections is the Cedar Valley limestone. A time subdivision should apply only to the major groups and a space subdivision to the minor groups.

Keyes, Charles. Surface Geology of Burlington, Iowa. (American Naturalist, Vol. XXII, pp. 1049-1054, Philadelphia, 1888.) A sketch of the topography and surface geology of the district, with topographical map and cross sections is given.

Keyes, Charles. Synopsis of American Carbonic Calyptræidæ. (Proc. Acad. Nat. Sci., Phila., 1890, pp. 150-181, Philadelphia, 1890.) There are given full descriptions of the generic characters and relations of the genus Capulus found in the carboniferous rocks of America; also a tabular statement of the association of crinoids and gasteropods. The stratigraphical reference of all species found in the American carboniferous to their proper horizons is made, and all species are described in full, with bibliographic references. The memoir is illustrated by a plate of 22 figures.

Keyes, Charles. Synopsis of American Paleozoic Echinoids (Proc. Iowa Acad. Sci., Vol. II, pp. 178-194, Des Moines, 1895.) The principal species are from the Mississippi valley. Some unusually fine material is reported from Iowa rocks. An annotated list of the forms from the state is given. New species are described and figured.

Keyes, Charles. Taxonomy of Crinoids. (American Naturalist, Vol. XXX, pp. 292-295, Philadelphia, 1896.) A brief discussion is given of the zoological relations of the crinoids as brought out by Wachsmuth and Springer's monograph. The basis is chiefly Iowa materials.

Keyes, Charles. Thickness of Paleozoic in Mississippi Valley. (American Geologist, Vol. XVII, pp. 161-173, Minneapolis, 1896.) Special reference is made to the thickness of the coal-measures, which in Iowa is shown to be very much more than has been hitherto regarded. Sixteen hundred feet are suggested as the most reliable figures.

Keyes, Charles. Time-values of Provincial Carboniferous Terranes. (Am. Jour. Sci., (4), Vol. XII, pp. 305-309, New Haven, 1901.) The total thickness of the Carboniferous strata of the Mississippi valley is estimated at 25,000 feet. As the rocks are now subdivided into six series the time-ratio of their deposition appears to be very nearly equal, the Mississippian and Missouri being probably a little longer than the other.

Keyes, Charles. Two Remarkable Cephalopods from Upper Paleozoic. (Proc. Iowa Acad. Sci., Vol. III, pp. 76-78, Des Moines, 1896.) Descriptions are given of two rather remarkable fossils found recently in the Iowa coal-measures: They are *Nautilus ponderosus*, and *Orthoceras fanslerensis*. The latter was a shell which probably attained a length of six feet; and the former was 12 to 15 inches in diameter.

Keyes, Charles. Ueber das Carbon des Mississippithales. (Neues Jahrbuch für Mineralogie, Geologie und Palæontologie, Jahrg. 1896, Bd. I, pp. 96-110, Berlin, 1896.) There is given a classification of the terranes in accordance with the indications of the most recent investigations. The various subdivisions are briefly characterized. The foundation of the terranal sequence as recognized and named is the Iowa section.

Keyes, Charles. Use of Term Augusta in Geology. (American Geologist, Vol. XXI, pp. 229-235, Minneapolis, 1898.) The name was suggested for one of the principal stratigraphical subdivisions of the Mississippian series; it is not synonymous with the section covered by the time-unit Osage, as has been thought. The argument covers all the disputed points which have been brought up from time to time.

Keyes, Charles. Variation Exhibited by a Carbonic Gasteropod. (American Geologist, Vol. III, pp. 329-333, Minneapolis, 1889.) Great variation is shown in a single species from the Keokuk limestone. Outlines of specimens from Keokuk are given.

Keyes, Charles. Vertical Range of Fossils at Louisiana. (Proc. Iowa Acad. Sci., Vol. IV, pp. 26-41, Des Moines, 1897.) [with R. R. Rowley.] The range of the fossils in northeast Missouri is shown to have an important bearing upon the subdivisions of the Mississippian series to be recognized in Iowa.

Keyes, Charles. W. J. McGee; Geologist, Anthropologist, Hydrologist. (Annals of Iowa; an Historical Quarterly, Vol. XI, Des Moines, 1913.) There is given a brief account of his scientific work in general and in Iowa in particular.

Keyes, Charles. What the Iowa Geological Survey has been doing. (Mon. Rev. Iowa Weather Serv., Vol. V, No. 1, pp. 4-7, Des Moines, 1894.) A popular statement is given of the aims and work of the geological survey, of the manner in which the investigations are conducted, and of the industrial bearing of the work upon the industries of the commonwealth. A synopsis is given of the published results as shown in the first three volumes of reports.

Keyes, Charles. Work and Scope of the Geological Survey. (Iowa Geol. Surv., Vol. III, pp. 47-98, Des Moines, 1894.) A succinct statement is given of the organization and aims of geological surveys in general. A comprehensive plan of investigation and publication is outlined. The investigations nearing completion are reviewed. The lines of inquiry undertaken are described. A number of topics yet to be taken up are briefly discussed. There is given a synopsis of the reports.

Keyes, Charles, and R. Ellsworth Call. Quaternary Section Eight Miles Southeast of Des Moines, Iowa. (Proc. Iowa Acad. Sci., Vol. I, pt. ii, p. 30, Des Moines, 1893.) Description is given of a section near the terminal moraine in the vicinity of Des Moines.

Kinderhook at Burlington, Iowa, succession of fossil faunas. S. Weller. (Iowa Geol. Surv., X, 59-79, 1900.)

Kinderhook, certain faunal aspects. C. R. Keyes. (American Geologist, XXVI, 315-321, 1900.)

Kinderhook fauna, dual character. C. R. Keyes. (American Geologist, XX, 167-176, 1897.)

Kinderhook faunal studies; III, faunas of beds Nos. 3 to 7 at Burlington, Iowa. S. Weller. (Trans. Acad. Sci., St. Louis, XI, 147-214, 1901.)

Kinderhook faunal studies; II, Fauna of Chonopectus sandstone at Burlington, Iowa. S. Weller. (Trans. St. Louis, Acad. Sci., X, 57-129, 1900.)

Kinderhook faunas, northern and southern. S. Weller. (Journal of Geology, XIII, 617-634, 1905.)

Kinderhook, notice of new cœlacanth fish from Iowa. C. R. Eastman. (Journal of Geology, XVI, 357-362, 1908.)

Kinderhook Stage.

Geology of Cerro Gordo county. S. Calvin. (Iowa Geol. Surv., VII, 117-197, 1897.)

Geology of Des Moines county. C. R. Keyes. (Iowa Geol. Surv., III, 409-492, 1895.)

Geology of Humboldt county. T. H. Macbride. (Iowa Geol. Surv., IX, 109-153, 1899.)

Geology of Louisa county. J. A. Udden. (Iowa Geol. Surv., XI, 55-126, 1901.)

Geology of Marshall county. S. W. Beyer. (Iowa Geol. Surv., VII, 197-261, 1897.)

Geology of Washington county. H. F. Bain. (Iowa Geol. Surv., V, 113-173, 1896.)

Kinderhook stratigraphy. C. R. Keyes. (Journal of Geology, VIII, 315-321, 1900.)

Knight, Nicholas. Some Iowa Waters. (Proc. Iowa Acad. Sci., Vol. XV, pp. 109-110, Des Moines.) Results of several analyses are tabulated.

Knight, Nicholas. Some Recent Analyses of Iowa Building-stones; also of Potable Waters. (Proc. Iowa Acad. Sci., Vol. VIII, pp. 104-109, Des Moines, 1901.)

Knowlton, F. H. Report on Interglacial Earth from Iowa. (Eleventh Ann. Rept., U. S. G. S., pt. i, p. 493, Washington, 1891.) The material is regarded as mainly of vegetable origin.

Kossuth County.

Analyses of peat. Rush Emery. (Geology of Iowa, II, 399, 1870.)

Artesian wells of Iowa. W. H. Norton. (Iowa Geol. Surv., VI, 113-428, 1897.)

General description. C. A. White. (Geology of Iowa, II, 245, 1870.) The surface characters are briefly described.

Geology of Kossuth, Hancock and Winnebago counties. T. H. Macbride. (Iowa Geol. Surv., XIII, 81-122, 1903.)

Peat deposits in Iowa. S. W. Beyer. (Iowa Geol. Surv., XIX, 699-730, 1909.)

Underground water resources of Iowa. W. H. Norton. (Iowa Geol. Surv., XXI, 29-1214, 1912.)

Underground water resources of Iowa. W. H. Norton. (U. S. Geol. Surv., Water Supply Paper No. 293, 994 pp., 1912.)

Kossuth county, geology. T. H. Macbride. (Iowa Geol. Surv., XIII, 81-122, 1903.)

Kovarik, A. F. Decorah Ice Cave and its Explanation. (Scientific American Supplement, Vol. MCXC, p. 19158, New York, 1898.) The source of the freezing temperature is described at length.

Kuntze, Otto. Occurrence of Quenstedtite near Montpelier, Iowa. (American Geologist, Vol. XXIII, pp. 119-121, Minneapolis, 1899.) The occurrence, genetic relations and chemical characters are noted.

Lake Agassiz, glacial. W. Upham. (U. S. G. S., Mon. XXV, 87-110, 1895.)

Lake beds, old, of prairie region. S. J. Wallace. (Proc. Am. Assoc. Adv. Sci., XVII, 342-344, 1869.)

Lakes.

General remarks. C. A. White. (Geology of Iowa, I, 70-78, 1870.)

Geology of Cerro Gordo county. S. Calvin. (Iowa Geol. Surv., VII, 117-195, 1897.)

Geology of Johnson county. S. Calvin. (Iowa Geol. Surv., VII, 33-116, 1897.)

Geology of Osceola and Dickinson counties. T. H. Macbride. (Iowa Geol. Surv., X, 185-239, 1900.)

Geology of Sac and Ida counties. T. H. Macbride. (Iowa Geol. Surv., XVI, 509-548, 1906.)

Iowa lakes. C. A. White. (Second Ann. Rep. State Geologist, 151-163, 1868.)

Lakes of Iowa, past and present. C. A. White. (American Naturalist, II, 143-155, 1868.)

Lakes of Iowa, past and present. C. A. White. (Second Ann. Rep. State Geologist, 151-163, 1868.)

Megalonyx found in Mills county. J. E. Todd. (Proc. American Assoc. Adv. Sci., XXXVII, 202-203, 1889.)

Observations in vicinity of Wall lake. F. A. Wilder. (Proc. Iowa Acad. Sci., VII, 77-78, 1900.)

Old lake-beds of prairie region. S. J. Wallace. (Proc. Am. Assoc. Adv. Sci., XVII, 342-344, 1869.)

Some geologic aspects of artificial drainage in Iowa. G. G. Wheat. (Proc. Iowa Acad. Sci., XVII, 151-158, 1910.)

Lamellibranchs.

Carboniferous formations of Humboldt, Iowa. F. W. Sardeson. (American Geologist, XXX, 300-312, 1902.)

Central Iowa. C. R. Keyes. (Proc. Acad. Nat. Sci. Philadelphia, 231-247, 1888.)

Description of new species from Iowa lower carboniferous. F. B. Meek and A. H. Worthen. (Geol. Surv. Illinois, III, 289-565, 1868.)

Eastern Nebraska. F. B. Meek. (Final Report. U. S. Geol. Surv. Nebraska, pt. ii, 83-245, 1872.)

Evidence that fossiliferous gravels and sands of Iowa and Nebraska are Aftonian. B. Shimek. (Bull. Geol. Soc. America, XXI, 119-140, 1910.)

Fossil faunas in central Iowa. C. R. Keyes. (Proc. Acad. Nat. Sci. Philadelphia, 242-265, 1891.)

Kinderhook faunal studies; II, fauna of Chonopectus sandstone at Burlington, Iowa. S. Weller. (Trans. St. Louis Acad. Sci., X, 57-129, 1900.)

Kinderhook faunal studies; III, faunas of beds Nos. 3 to 7 at Burlington, Iowa. S. Weller. (Trans. Acad. Sci. St. Louis, XI, 147-214, 1901.)

List of carboniferous fossils from Des Moines. C. R. Keyes. Iowa Geol. Surv., VII, 330-335, 1897.)

New Conocardium from Iowa devonian. C. R. Keyes. (Proc. Iowa Acad. Sci., I, pt. ii, 23-24, 1892.)

New species from Burlington. A. Winchell. (Proc. Acad. Nat. Sci. Philadelphia, 225, 1863.)

New species from Burlington. C. A. White and R. P. Whitfield. (Proc. Boston Soc. Nat. Hist., VIII, 289-316, 1862.)

New species from lower carboniferous rocks of Iowa. A. H. Worthen and F. B. Meek. (Geol. Surv., Illinois, VI, 489-532, 1875.)

New species from carboniferous of Iowa. F. B. Meek and A. H. Worthen. (Proc. Acad. Nat. Sci. Philadelphia, XII, 447-472, 1860.)

New species from devonian at Davenport. W. H. Barris. (Proc. Davenport Acad. Nat. Sci., II, 282-288, 1878.)

New species from Iowa. A. H. Worthen. (Geol. Surv. Illinois, VIII, 69-154, 1890.)

New species of paleozoic fossils. S. Calvin. (Bull. Lab. Nat. Hist., State Univ. Iowa, I, 173-181, 1890.)

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Lead.

Description of deposits near Dubuque, occurrence of ore and mode of work. J. D. Whitney. (Geology of Iowa, I, 422-468, 1858.)

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Mineral production of Iowa in 1903. S. W. Beyer. (Iowa Geol. Surv., XIV, 645-655, 1904.)

Mineral production in Iowa in 1904. S. W. Beyer. (Iowa Geol. Surv., XV, 15-32, 1905.)

Mineral production in Iowa in 1905. S. W. Beyer. (Iowa Geol. Surv., XVI, 17-36, 1906.)

Mineral production in Iowa in 1906. S. W. Beyer. (Iowa Geol. Surv., XVII, 11-25, 1907.)

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Mineral production in Iowa in 1908. S. W. Beyer. (Iowa Geol. Surv., XIX, 1-20, 1909.)
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Origin of Iowa lead and zinc deposits. A. G. Leonard. (American Geologist, XVI, 288-294, 1885.)
Origin of lead and zinc ores of upper Mississippi valley district. G. H. Cox. (Economic Geology, VI, 427-448 and 582-603, 1911.)
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References to lead region of northeastern Iowa. J. D. Whitney. (Geol. Surv., Illinois, I, 153-207, 1866.)
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Spanish mines; an episode in primitive American lead-mining. C. R. Keyes. (Annals of Iowa; an Historical Quarterly, X, 539-546, 1912.)
Work and scope of the geological survey. C. R. Keyes. (Iowa Geol. Surv., III, 47-98, 1894.)

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Artesian wells of Iowa. W. H. Norton. (Iowa Geol. Surv., VI, 113-428, 1897.)

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Buried river channels in southeastern Iowa. C. H. Gordon. (Iowa Geol. Surv., III, 237-255, 1895.)

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Ctenacanthus spines from Keokuk limestone of Iowa. C. R. Eastman. (American Jour. Sci., (4), IV, 10-12, 1897.)

Description of new fossils. A. H. Worthen. (Geol. Surv. Illinois, VIII, 69-154, 1890.)

Description of some new speices of invertebrates from Paleozoic rocks of Illinois and adjacent states. S. A. Miller and W. F. E. Gurley. (Bull. Illinois State Mus. Nat. Hist., No. 3, 1-91, 1894.)

Extension of Illinois lobe of great ice-sheet into Iowa. F. M. Fultz. (Proc. Iowa Acad. Sci., II, 209-212, 1895.)

General description. (A. H. Worthen. (Geology of Iowa, I, 184-198, 1858.)

Genesis of American actinocrinoidæ. C. R. Keyes, (American Naturalist, XXIV, 243-254, 1890.)

Geology of clays. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XIV, 377-552, 1904.)

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Geology of quarry products. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

History of coal-mining in Iowa. J. H. Lees. (Iowa Geol. Surv., XIX, 521-586, 1909.)

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Keokuk beds at Keokuk, Iowa. C. H. Gordon. (Proc. Iowa Acad. Sci., I, pt. i, 98-100, 1890.)

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Pre-glacial river-channels of central Iowa. C. R. Keyes. (The Annals, Historical Quarterly, VIII, 13-70, 1907.)

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Review of progress of American invertebrate paleontology for year 1890. C. R. Keyes. (American Naturalist, XXV, 327-333, 1891.)

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Some new American fossil crinoids. F. Springer. (Mem. Mus. Comp. Zool., XXV, 117-161, 1911.)

Stratigraphy of St. Louis and Warsaw formations in southeastern Iowa. C. H. Gordon. (Journal of Geology, III, 289-311, 1895.)

Study of cherts of Osage series of Mississippian system. F. M. Van Tuyl. (Proc. Iowa Acad. Sci., XIX, 173-174, 1912.)

Surface geology at Keokuk. C. H. Gordon. (Report Dep. Nat. Hist. Northwestern Univ., 11-19, 1891.)

Surface geology of Keokuk. C. H. Gordon. (American Geologist, IX, 183-190, 1892.)

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Variation of gasteropod (from Keokuk). C. R. Keyes. (American Geologist, III, 329-333, 1889.)

Weathered zone (Sangamon) between Iowan loess and Illinoian till-sheet. F. Leverett. (Proc. Iowa Acad. Sci., V, 71-80, 1898.)

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Weathered zone (Yarmouth) between Illinoian and Kansan till-sheets. Frank Leverett. (Journal of Geology, VI, 238-243, 1898.)

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Lee county, geology. C. R. Keyes. (Iowa Geol. Surv., III, 305-407, 1894.)

Lees, James H. Bibliography of Iowa Coals. (Iowa Geol. Surv., Vol. XIX, pp. 659-687, Des Moines, 1909.) Complete author's and county lists of references are given.

Lees, James H. Bibliography of Iowa Peat. (Iowa Geol. Surv., Vol. XIX, pp. 731-733, Des Moines, 1909.) There is given a very full list of the publications on the subject.

Lees, James H. General Section of Des Moines Stage of Iowa. (Iowa Geol. Surv., Vol. XIX, pp. 598-604, Des Moines, 1909.) Three subdivisions are recognized: Cherokee shales, Appanoose beds and Pleasanton shales. The complete descriptive section embraces thirty-two numbers.

Lees, James H. History of Coal Mining in Iowa. (Iowa Geol. Surv., Vol. XIX, pp. 521-586, Des Moines, 1909.) The development of the mining in each of the coal-producing counties is fully considered. The historical summaries are especially complete in regard to early mining.

Lees, James H. Report of Assistant State Geologist. (Iowa Geol. Surv., Vol. XVII, pp. 7-10, Des Moines, 1907.) Summarizes the year's work; gives a list of exchange publications.

Lees, James H. Report of Assistant State Geologist. (Iowa Geol. Surv., Vol. XVIII, pp. 6-9, Des Moines, 1908.) The personal work of the year is reviewed.

Lees, James H., and A. W. Hixson. Analyses of Iowa Coals. (Iowa Geol. Surv., Vol. XIX, pp. 476-519, Des Moines, 1909.) The laboratory methods of analysis are described. A complete list of analyses of Iowa coals is compiled.

Leidy, Joseph. Fossil Remains of Caribou. (Proc. Acad. Nat. Sci. Philadelphia, Vol. XXXI, pp. 32-33, Philadelphia, 1879.) Announcement is made of *Rangifer caribou* from the loess, and *Cervus muscatinensis,* supposed to be extinct, from Muscatine, Iowa.

Leonard, Arthur G. Geology of Clayton County. (Iowa Geol. Surv., Vol. XVI, pp. 213-317, Des Moines, 1906.) The features described are here enumerated:

Introduction, location and area, previous geological work.

Physiography, topography, the driftless area, Iowan drift area, drainage.

Stratigraphy, general relations of strata, synoptical table, comparative table; Cambrian system, Saint Croix sandstone; Ordovician system, lower magnesian limestone, Saint Peter sandstone, Galena-Trenton limestone, Trenton limestone, lithological character, distribution and thickness, Galena limestone, distribution and thickness, Maquoketa stage; Silurian system, Niagara limestone, residual materials; Pleistocene system, Kansan stage, Kansan drift, Buchanan gravels, Iowan stage, Iowan drift, loess, terraces, alluvium; deformations; unconformities.

Economic geology; soils, building-stones, clays, limes, glass-sands, road-materials, lead; water-resources, water-power, clams.

Leonard, Arthur G. Geology of Dallas County. (Iowa Geol. Surv., Vol. VIII, pp. 51-118, Des Moines, 1898.) The topics treated are as follows: Introduction, situation and area, previous geological work.

Physiography, topography, table of elevations, drainage.

Stratigraphy, general relations of strata; standard sections, Booneville section, Van Meter section, Van Meters Mill section, Desoto section, Panther creek, Cottonwood, Redfield, County Line, Linden, Adel, Sugar creek, High Bridge, Dawson; Missourian Limestone sections, well-records.

Geological formations, Upper Carboniferous, Des Moines, Missourian; Pleistocene, Kansan drift, loess, Wisconsin drift, alluvium and terraces.

Geological structure, deformations, Redfield section.

Economic products; coal, Raccoon Valley mines, South Raccoon Valley mines, Middle Raccoon Valley mines, North Raccoon Valley mines, Des Moines River mines; clays, Van Meter, Adel, Redfield, De Soto, Minburn, Perry, Dawson, Madrid; building-stones, road-materials, natural gas, water-supplies, soils.

Leonard, Arthur G. Geology of Wapello County. (Iowa Geol. Surv.,Vol. XII, pp. 439-499, Des Moines, 1902.) The following features are described:

Introduction, location and area, previous geological work.

Physiography, topography, drainage.

Stratigraphy, synoptic table of geological formations, deeper strata; Carboniferous system, Saint Louis stage, Des Moines stage, coal measures; Pleistocene system, Kansan drift, loess, alluvium and terraces.

Unconformities.

Economic .products, coal, building-stone, clays, water-supplies, soils, and road-materials.

Leonard, Arthur G. Lansing Lead Mines. (Proc. Iowa Acad. Sci., Vol. II, pp. 36-38, Des Moines, 1895.) An unusual deposit is described. The novel features are the great extent of a vertically disposed galena-sheet, and its occurrence in the Oneota limestone, a geological horizon far beneath that in which the workable lead deposits of the region commonly occur. There are three to four inches of solid galena. An annual production of 400,000 pounds is attained.

Geol. Surv., Vol. VI, pp. 9-66, Des Moines, 1897.) The topics discussed are mainly as follows:

Leonard, Arthur G. Lead and Zinc Deposits of Iowa. (Iowa

Chief source of world's supply of lead and zinc, history of lead and zinc mining in Iowa.

Upper Mississippi lead and zinc region, limits and extent of area, general geological sketch of region, principal formations, Saint Croix sandstone, Oneota limestone, Saint Peter sandstone, Trenton limestone, Galena limestone, Maquoketa shales, Niagara limestone.

Mode of occurrence of lead and zinc deposits, ore deposits usually in area of disturbance, Iowa deposits an exception, lead and zinc deposits mostly in limestone, comparison of upper Mississippi mines with Missouri region.

Lead and zinc ores and associated minerals; lead minerals, glance, cerussite; zinc minerals, smithsonite, sphalerite; associated minerals, pyrite and marcasite, limonite, calcite, satin-spar, gypsum, dolomite; mode of occurrence of the Iowa ores, crevices, direction, extent, openings, mode of occurrence in crevices, as vertical sheets, in openings, vertical distribution of lead and zinc.

Special description of mines, Dubuque county mines, Clayton county mines, Buena Vista, Guttenberg, Allamakee county mines, Lansing, New Galena.

Origin of deposits, original sources of lead and zinc, localization of deposits, ocean-currents, surface decomposition, formation of crevices, filling of crevices, different views as to origin of the ore deposits, general ascension theory, lateral secretion theory, replacement theory, objections to ascension theory for Iowa deposits, proof of origin by lateral secretion.

General methods of working the mines, statistics.

The subjects of wide interest which deserve special consideration are the mode of occurrence and genesis of the ore deposits.

Leonard, Arthur G. Lead and Zinc Deposits of Iowa. (Eng. and Mining Journal, Vol. LXI, p. 614, New York, 1896.) Occurrence and mining of ores in the Galena limestone of the Dubuque district are considered.

Leonard, Arthur G. Lead and Zinc; Description of Mines of Iowa in Upper Mississippi Region. (Colliery Engineer, Vol. XVII, pp. 121-122, 1896.) The geologic peculiarities of the region are explained and the distribution of the ore-bodies is described.

Leonard, Arthur G. Natural Gas in Drift of Iowa. (Proc. Iowa Acad. Sci., Vol. IV, pp. 41-47, Des Moines, 1897.) The opinion is given that the gas is simply the product of the decomposition of vegetable remains buried in the drift.

Leonard, Arthur G. Occurrence of Zinc in Northeastern Iowa. (Proc. Iowa Acad. Sci., Vol. I, pt. iv, pp. 48-52, Des Moines, 1894.) Zinc mines around Dubuque are de-

scribed. The manner of occurrence, the geology and the character of the ores are especially noted. The development of zinc-mining in the district is said to date from 1880.

Leonard, Arthur G. Origin of Iowa Lead and Zinc Deposits. (American Geologist, Vol. XVI, pp. 288-294, Minneapolis, 1895.) The occurrence and manner of deposition are described and the various theories of formation are reviewed.

Leonard, Arthur G. Recent Developments in Dubuque Lead and Zinc Mines. (Proc. Iowa Acad. Sci., Vol. III, pp. 64-66, Des Moines, 1896.) The openings of some new mines are described.

Leonard, Arthur G. Report of Special Assistant. (Iowa Geol. Surv., Vol. V, p. 31, Des Moines, 1896.) A short statement is made of the work done on the lead and zinc deposits.

Leonard, Arthur G. Report of Assistant State Geologist. (Iowa Geol. Surv., Vol. VII, pp. 29-30, Des Moines, 1897.) The results of the season's work are noted.

Leonard, Arthur G. Report of Assistant State Geologist. (Iowa Geol. Surv., Vol. XI, pp. 31-32, Des Moines, 1901.) The results of the year are enumerated.

Leonard, Arthur G. Report of Assistant State Geologist. (Iowa Geol. Surv., Vol. XII, pp. 28-32, Des Moines, 1902.) Summary of the work done during the year is given.

Leonard, Arthur G. Report of Assistant State Geologist. (Iowa Geol. Surv., Vol. XIII, pp. 13-15, Des Moines, 1903.) The personal work of the year is summarized.

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Remarks on loess. F. W. Sardeson. (Proc. Iowa Acad. Sci., V, 11-12, 1898.)

Review of progress of American invertebrate paleontology for 1889. C. R. Keyes. (American Naturalist, XXIV, 131-139, 1890.)

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Richthofen's theory of loess in light of deposits of the Missouri. J. E. Todd. (Proc. American Assoc. Adv. Sci., XXVII, 231-239, 1878.)

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Significance of pleistocene mollusks. B. Shimek. (Science, N. S., XXXVII, 501-509, 1913.)

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Variation in succinidæ of loess. B. Shimek. (Proc. Iowa Acad. Sci., I, pt. iv, 111, 1894.)

Weathered zone (Sangamon) between Iowan loess and Illinoian till-sheet. F. Leverett. (Proc. Iowa Acad. Sci., V, 71-80, 1898.)

Loess and Illinoian till-sheet, weathered zone (Sangamon). Frank Leverett. (Journal of Geology, VI, 171-181, 1898.)

Loess, buried, in Story county. S. W. Beyer. (Proc. Iowa Acad. Sci., VI, 117-121, 1899.)

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Loess, more light on origin of Missouri river. J. E. Todd. (Proc. Iowa Acad. Sci., XIII, 187-194, 1906.)

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Loess of paha and river ridges. B. Shimek. (Proc. Iowa Acad. Sci., XV, 117-124, 1908.)

Loess of southwestern Iowa, certain aspects. O. W. Wilcox. (Journal of Geology, XII, 716-721, 1904.)

Loess, origine éolienne. C. R. Keyes. (Bull. de la Soc. Belge de Géol. de Pal. et d'Hydrol. T. XII, 14-21, 1901.)

Loess, remarks. F. W. Sardeson. (Proc. Iowa Acad. Sci., V, 11-12, 1898.)

Loess soils of Iowa. H. F. Bain. (Trans. Iowa Hort. Soc., XXXI, 185-191, 1896.)

Loess, theory. B. Shimek. (Proc. Iowa Acad. Sci., III, 82-89, 1896.)

Loess, variation in succinidæ. B. Shimek. (Proc. Iowa Acad. Sci., I, pt. iv, 111, 1894.)

Loess of Mississippi valley. B. Shimek. (Science, N. S., XXVII, 731, 1908.)

Lonsdale, Elston, H. Cement Materials in Iowa. (Proc. Iowa Acad. Sci., Vol. II, pp. 172-174, Des Moines, 1895.) A number of deposits suitable for the manufacture of Portland cement are briefly described.

Lonsdale, Elston H. Geology of Montgomery County. (Iowa Geol. Surv., Vol. IV, pp. 381-451, Des Moines, 1895.) The following subjects are considered in detail:

Introduction, situation and area.

Physiography, topography, hydrography, hypsometry.

Stratigraphy, general geological structure, classification of formations, general vertical sections, general cross sections, Carboniferous, upper Coal Measures (Missouri), general characters, description of typical sections, Stennett quarry, Fate quarry, Fox quarry, Smith and Fischer quarries, Milford Milldam section, Walnut Creek section, Climax quarry; descriptions of deep-drill holes, Red Oak deep-drillings, Rosacranz prospect hole, McCracken prospect hole, Villisca deep-drilling; stratigraphic features, bituminous deposits, lithological character, calcareous beds, argillaceous beds, arenaceous beds; Cretaceous, Nishnabotna sandstone (Dakota?), extent, age, description of typical exposures, Sherman township, Red Oak township, Grant township, Washington township, lithological features, arenaceous deposits, conglomerate materials, shale beds, flora, fauna, total thickness; Pleistocene, lower till, loess, alluvium.

Economic products, building-stones, limestones, sandstones, conglomerates, glacial boulders; clays and their adaptabilities, loess, Cretaceous shales, alluvium, Coal Measure shales, boulder clays, paint and ballast clays; clay industry, Red Oak, Villisca, Stanton; sands; coals, Westrope slope, Anderson prospect shaft; lime; road materials; soils; minerals; water-supplies and water-powers.

Lonsdale, Elston H. Upper Carboniferous of Southwestern Iowa. (Proc. Iowa Acad. Sci., Vol. II, pp. 197-200, Des Moines, 1895.) It is shown that recent deep-borings indicate a very much greater thickness of the section than has been heretofore generally estimated for Iowa. A thickness of at least 1,600 feet is claimed.

Lonsdale, Elston H. Southern Extension of Cretaceous in Iowa. (Proc. Iowa Acad. Sci., Vol. I, pt. iv, pp. 39-43, Des Moines, 1894.) Outliers and the main body are described. Details are given of the rocks in Montgomery county. Incidental notes are recorded of outcrops in Mills and Page counties.

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Louisa County.

Accretion of flood-plains by means of sand-bars. H. Simpson. (Proc. Iowa Acad. Sci., X, 54-56, 1903.)

Coal deposits of Iowa. H. Hinds. (Iowa Geol. Surv., XIX, 21-396, 1909.)

Gas well near Letts, Iowa. F. M. Witter. (American Geologist, IX, 319-321, 1892.)

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Geology of Louisa county. J. A. Udden. (Iowa Geol. Surv., XI, 53-126, 1901.)

Geology of quarry products. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

Nether delimitation of our carbonic rocks. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 153-156, 1912.)

Old channels of Mississippi in southeastern Iowa. F. Leverett. (Annals of Iowa, Historical Quarterly, (3), V, 38-51, 1901.)

Underground water resources of Iowa. W. H. Norton. (Iowa Geol. Surv., XXI, 29-1214, 1912.)

Underground water resources of Iowa. W. H. Norton. (U. S. Geol. Surv., Water Supply Paper No. 293, 994 pp., 1912.)

Weathered zone (Sangamon) between Iowan loess and Illinoian till-sheet. F. Leverett. (Proc. Iowa Acad. Sci., V, 71-80, 1898.)

Louisa county, geology. J. A. Udden. (Iowa Geol. Surv., XI, 53-126, 1901.)

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Kinderhook stratigraphy. C. R. Keyes. (Journal of Geology, VIII, 315-321, 1900.)

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Sundry provincjal and local phases of general geologic section of Iowa. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 147-151, 1912.)

Louisiana, vertical range of fossils. C. R. Keyes. (Proc. Iowa Acad. Sci., IV, 25-41, 1897.)

Loveland Clays (Kansan).

Geology of Harrison and Monona counties. B. Shimek. (Iowa Geol. Surv., XX, 271-483, 1910.)

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Lower carboniferous bryozoan, notice of new genus and species. R. P. Whitfield. (Bull. American Mus. Nat. Hist., XX, p. 469, 1904.)

Lower Coal Measures. (*See Des Moines Stage.*)

Lower magnesian limestone from northeastern Iowa, notes on collection of fossils. S. Calvin. (Bull. Lab. Nat. Hist., State Univ. Iowa, II, 189-193, 1893.)

Lower Magnesian Limestone. (*See Canadian Series.*)

Lower rapids of Mississippi river. F. Leverett. (Proc. Iowa Acad. Sci., VI, 74-93, 1899.)

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Lower strata of devonian series in Iowa. W. H. Norton. (Proc. Iowa Acad. Sci. I, pt. iv, 22-24, 1894.)

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Coal deposits of Iowa. C. R. Keyes. (Iowa Geol. Surv., II, 536 pp., 1894.)

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Fuel value of Iowa coals. F. A. Wilder. (Iowa Geol. Surv., XIX, 399-475, 1909.)

Geology. O. H. St. John. (Geology of Iowa, II, 77-95, 1870.)

Geology of clays. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XIV, 377-552, 1904.)

Geology of quarry products. S. W. Beyer and I. A. Wiliams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

History of coal-mining in Iowa. J. H. Lees. (Iowa Geol. liams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

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Lucas Limestone. Sundry provincial and local phases of general geologic section of Iowa. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 147-151, 1912.)

Lund, W. J. G., and John Coulter. American Lepidostrobus. (Botanical Gazette, Vol. LI, pp. 449-453, 1911.) The specimens are described from Warren county, Iowa.

Lund, W. J. G., and John M. Coulter. American Lepidostrobus. (Trans. Illinois Acad. Sci., Vol. IV, pp. 107-108, 1912.)

Lyon County.

Administrative report of assistant state geologist. C. R. Keyes. (Iowa Geol. Surv., III, 29-38, 1894.)

Buried mountains of prairies. H. F. Bain. (Midland Monthly, V, 291-296, 1896.)

Cretaceous deposits of Sioux valley. H. F. Bain. (Iowa Geol. Surv., III, 99-114, 1895.)

General description. C. A. White. (Geology of Iowa, II, 226-229, 1870.)

Geology of Lyon and Sioux counties. F. A. Wilder. (Iowa Geol. Surv., X, 85-184, 1900.)

Geology of quarry products. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

Glacial scorings in Iowa. C. R. Keyes. (Iowa Geol. Surv., III, 147-165, 1894.)

Glaciated rock-surfaces near Linn and near Quarry, Iowa, with table of bearings of glacial striæ in Iowa. W. H. Norton. (Proc. Iowa Acad. Sci., XVIII, 79-83, 1911.)

Opinions concerning age of Sioux quartzite. C. R. Keyes. (Proc. Iowa Acad. Sci., II, 218-222, 1895.)

Pleistocene of Sioux Falls, South Dakota, and vicinity. B. Shimek. (Bull. Geol. Soc. America, XXIII, 125-154, 1912.)

Process of formation of certain quartzites. C. R. Keyes. (Proc. Iowa Acad. Sci., I, iv, 29-31, 1894.)

Sioux quartzite and certain associated rocks. S. W. Beyer. (Iowa Geol. Surv., VI, 67-112, 1897.)

Sketch of geology of Iowa. C. R. Keyes. (Hand-book of Iowa, World's Columbian Exposition at Chicago, 18-28, 1893.)

Some variant conclusions in Iowa geology. J. E. Todd. (Proc. Iowa Acad. Sci., XIII, 183-186, 1906.)

Underground water resources of Iowa. W. H. Norton (Iowa Geol. Surv., XXI, 29-1214, 1912.)

Underground water resources of Iowa. W. H. Norton. (U. S. Geol. Surv., Water Supply Paper No. 293, 994 pp., 1912.)

Lyon and Sioux counties, geology. F. A. Wilder. (Iowa Geol. Surv., X, 85-184, 1900.)

Macbride, Thomas H. Certain Fossil Plaint-remains in Iowa Herbarium. (Proc. Davenport Acad. Sci., Vol. X, pp. 153-162, 12 plates, Davenport, 1907.) A number of fossils from the coal measures are described as new, and the microscopic structures noted.

Macbride, Thomas H. Geology of Cherokee and Buena Vista Counties. (Iowa Geol. Surv., Vol. XII, pp. 303-353, Des Moines, 1902.) The following topics are considered:

Introduction, location and area, previous geological work.

Physiography, topography, drainage.

Stratigraphy, table of geological formations; the Pleistocene deposits, Kansan drift, the loess, Wisconsin gravels, Wisconsin clays, alluvial deposits, margin of the Wisconsin drift.

Economic products, soils, brick and tile, gravels, water supplies, forestry notes.

Macbride, Thomas H. Geology of Clay and O'Brien counties. (Iowa Geol. Surv., Vol. XI, pp. 461-508, Des Moines, 1901.) The following subjects are described in detail:

Introduction, location, previous study of these counties.

Physiography, topography, constructional valleys, drainage.

Stratigraphy, synoptical table; alluvium, Wisconsin loess, Wisconsin gravels, Wisconsin clays, pre-Wisconsin sands, Kansan drift; Cretaceous sandstone.

Economic products, soils, sands and gravels, brick-clays, fuel, water-supplies.

Forestry notes for Clay and O'Brien counties.

Macbride, Thomas H. Geology of Emmet, Palo Alto and Pocahontas Counties. (Iowa Geol. Surv., Vol. XV, pp. 227-276, Des Moines, 1905.) The following topics are considered:

Introduction, location and area, previous geological work.
Physiography, topography, drainage.
Stratigraphy, formations represented, synoptical table, geological formations; Pleistocene series, the alluvium, Wisconsin gravels, Wisconsin drift, Buchanan gravels, Kansan drift, the blue clay, Pre-Kansan strata, sands, etc.; Carboniferous system, the Saint Louis limestone.
Economic products, clays, building-stones, gravels, water-supply, fuel, peat.

Macbride, Thomas H. Geology of Hamilton and Wright Counties. (Iowa Geol. Surv., Vol. XX, pp. 97-138, Des Moines, 1910.) The following topics are considered:
Introduction, location and area, previous geological work.
Physiography, topography, drainage.
Stratigraphy: synoptical table, Carboniferous system, Mississippian series, St. Louis limestone, Pennsylvanian series, Des Moines stage. Quaternary system, Pleistocene series, Kansan drift, Wisconsin drift, soils.
Economic products, limestones, sands and gravels, fuels, coal, brick and tile manufacturers, water-supplies.
Forestry notes.

Macbride, Thomas H. Geology of Humboldt County. (Iowa Geol. Surv., Vol. IX, pp. 109-154, Des Moines, 1899.) The following topics are discussed in detail:
Introduction, physiography, topography, drainage.
Stratigraphy, formations represented, synoptical table, geological formations, Mississippian series, Kinderhook, St. Louis, Upper Carboniferous, Des Moines, Pleistocene, Kansan drift, Wisconsin drift, soils.
Economic products, building-stones, limes, sands, clays, fuels, water-supplies, water-powers.
Forestry notes of Humboldt county.

Macbride, Thomas H. Geology of Kossuth, Hancock and Winnebago Counties. (Iowa Geol. Surv., Vol. XIII, pp. 81-122, Des Moines, 1903.) The following topics are briefly discussed:
Introduction, location and area, previous geological work.
Physiography, topography, drainage.

Stratigraphy, formations represented, synoptical table; Kansan drift, Wisconsin drift.

Soils.

Economic products.

Water supplies.

Forestry notes.

Macbride, Thomas H. Geology of Osceola and Dickinson Counties. (Iowa Geol. Surv., Vol. X, pp. 185-239, Des Moines, 1900.) The following subjects are considered in detail:

Introduction, location, previous geological work.

Physiography, topography, lakes, Spirit lake, Okoboji, East Okoboji, Gar lake, Center lake, smaller lakes, drainage.

Stratigraphy, formations represented, synoptical table, Kansan drift, Wisconsin drift.

Economic products, soils, sands, gravels, brick-clays, fuels, water-supplies.

Forestry notes.

Macbride, Thomas H. Geology of Sac and Ida Counties. (Iowa Geol. Surv., Vol. XVI, pp. 509-548, Des Moines, 1906.) The subjects discussed are:

Introduction, location and area, previous geological work.

Physiography, topography, drainage.

Stratigraphy, general relations of strata, synoptical table: Cretaceous system, Dakota sandstone, Colorado stage, Fort Benton shales; Pleistocene system, Kansan stage, Kansan drift, Buchanan gravels, Iowan stage, loess, Wisconsin stage, Wisconsin drift, Wisconsin gravels and gravel trains, alluvial deposits, soils.

Economic products, clays, gravels, limes, building-stones, coal, oil, gas, water-supplies, water-powers.

Forestry notes.

Macbride, Thomas H. Pre-Kansan Peat-bed. (Proc. Iowa Acad. Sci., Vol. IV, pp. 63-66, Des Moines, 1897.) The plants composing the peat are described.

McGee, W J. Additional Observations on Iowa Kames and Aasar. (Proc. Iowa Acad. Sci., 1875-1880, p. 25, Iowa City, 1880.) This is an abstract of a paper read before the Iowa Academy of Sciences, June 25, 1880.

McGee, W J. Complete Series of Superficial Geological Formations in Northeastern Iowa. (Proc. American Assoc. Adv. Sci., Vol. XXVII, pp. 198-231, Salem, 1878.) A description of the surface geology of northeastern Iowa is presented.

McGee, W J. Description of Quarries and Quarry Regions of Iowa. (Tenth Census of U. S., Vol. X, Report on Building Stones, pp. 256-265, Washington, 1883.) A résumé of the geological formations of Iowa, with special references to the leading building stones is given.

McGee, W J. Drainage System and Distribution of Loess of Eastern Iowa. (Bull. Philosophical Soc. Washington, Vol. VI, pp. 93-97, Washington, 1883.) An abstract of a general description of the drainage system is presented.

McGee, W J. Drainage System and Distribution of Loess of Eastern Iowa. (Pamphlet, pp. 1-14, Ft. Dodge, 1884.) A description of the general drainage system and topography, with explanations of the phenomena, are given.

McGee, W J. Geologist, Anthropologist, Hydrologist. Charles Keyes. (Annals of Iowa; An Historical Quarterly, XI, 1913.)

McGee, W. J. Ice Caves and Frozen Wells. (National Geog. Mag., Vol. XII, p. 433, New York, 1901.) The Decorah ice cave is described.

McGee, W J. Iowa Kames and Aasar. (Proc. Iowa Acad. Sci., 1875-1880, p. 19, Iowa City, 1880.) Abstract is given of a paper read before the Iowa Academy October 10, 1879.

McGee, W J. Notes on Geology of Part of Mississippi Valley. (Geological Magazine, (2), Vol. VI, pp. 353-362 and 412-420, London, 1879.) A description of the quaternary deposits of northeastern Iowa is included.

McGee, W J. Ovibos Cavifrons from Loess of Iowa. (Am. Jour. Sci., (3), Vol. XXXIV, pp. 217-220, New Haven, 1887.) Notice is given of a specimen of extinct Musk ox found near Council Bluffs, and its bearing upon the nature of the climate during the deposition of the loess.

McGee, W J. Pleistocene History of Northeastern Iowa. (Eleventh Ann. Rept. U. S. Geol. Surv., pp. 190-577, Washington, 1893.)

Chapter I is a very full description of the landscape and general topography of northeastern Iowa.

Chapter II forms a statement of the principles involved in the description of the geological history of the region, with full definitions.

Chapter III includes a general account of the stratified rocks of the state. A classification and description of the different formations are given, with the different kinds of disturbances recognized.

Chapter IV is a detailed account of the drainage and topography of the different quaternary formations.

Chapter V treats of the post-glacial phenomena, alluvium and terraces.

Chapter VI is a detailed account of the loess and its occurrence in different places.

Chapter VII is a description of the drift and an account of many well sections.

Chapter VIII considers the ice-markings—glacial striæ and surface moldings.

Chapter IX treats of the residuary products and the history indicated by them.

Chapter X is a general summary of the geological history as recorded in Iowa.

McGee, W J. Prairies: Itinerary from Kansas City, Missouri, to Chicago, Illinois. (International Cong. Géol., Compte Rendu, 5me Sess., pp. 449-452, Washington, 1893.) References are made to features of the southeastern part of the state.

McGee, W J. Relations of Geology and Agriculture. (**Trans.** Iowa State Horticultural Soc., Vol. XVI, pp. 227-240, 1881.) An address given before the society in which the bearing of agriculture upon geology is fully described with special reference to Iowa.

McGee, W J. Relative Position of Forest Beds and Associated Drift Formations in Northeastern Iowa. (Am. Jour. Sci., (3), XV, pp. 339-341, New Haven, 1878.) A number of sections at Farley are given, and special references are made to the forest-bed in Dubuque county.

McGee, W J. Superposition of Glacial Drift upon Residuary Clays. (Am. Jour. Sci., (3), Vol. XVIII, pp. 301-303, New Haven, 1879.) A section in Delaware county is described showing the relations of the two formations.

McGee, W J. Topographic Types of Northeastern Iowa. (Proc. American Assoc. Adv. Sci., Vol. XXXVII, pp. 248-249, Salem, 1890.) Abstract is made of more extended paper. Half a dozen distinctive types of topography are recognized.

McGee, W J, and R. Ellsworth Call. Loess and Associated Deposits of Des Moines. (Am. Jour. Sci., (3), Vol. XXIV, pp. 202-223, New Haven, 1882.) The topographic features of the region are outlined, with an accompanying sketch-map; the different sections of surface deposits are described in detail, with lists of fossils and a synoptical table showing the distribution of the fossils occurring.

McKissick Grove Shales (Atchison).

Carboniferous section of southwestern Iowa. G. L. Smith. (Iowa Geol. Surv., XIX, 605-657, 1909.)

McWorther, Tyler. Beds of Carboniferous Drift in Bluffs of East Davenport. (Proc. Davenport Acad. Nat. Sci., Vol. III, pp. 129-130, Davenport, 1882.)

Machine coal-mining in Iowa. H. F. Bain. (Mineral Industry, IV, 195-200, 1896.)

Macrouran decapod crustacean, Palæo-palæomon Newberryi, discovery of second example. R. P. Whitfield. (American Geologist, IX, 237-238, 1892.)

Madison County.

Analyses of coal. Rush Emery. (Geology of Iowa, II, 386-387, 1870.)

Coal deposits of Iowa. C. R. Keyes. (Iowa Geol. Surv., II, 536 pp., 1894.)

Coal deposits of Iowa. H. Hinds. (Iowa Geol. Surv., XIX, 21-396, 1909.)

Contribution to Madison county geology. F. A. Brown. (Proc. Iowa Acad. Sci., XIII, 203-206, 1906.)

General geological description. C. A. White. (Geology of Iowa, I, 305-316, 1870.)

Geological section along middle river. J. L. Tilton. (Iowa Geol. Surv., III, 135-146, 1895.)

Geology of clays. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XIV, 377-552, 1904.)

Geology of Madison county. J. L. Tilton and H. F. Bain. (Iowa Geol. Surv., VII, 489-539, 1897.)

Geology of quarry products. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

Results of recent geological work in Madison county. J. L. Tilton. (Proc. Iowa Acad. Sci., IV, 47-54, 1897.)

Short notes on geology. C. A. White. (First Ann. Rept. State Geologist, 70-73, 1868.)

Strata between Ford and Winterset. J. L. Tilton. (Proc. Iowa Acad. Sci., I, pt. iii, pp. 26-27, 1893.)

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Introduction, location and area, previous geological work.

Physiography, topography, table of elevations, drainage, history of drainage.

Stratigraphy, geological formations, underlying formations: Mississippian series, Saint Louis; Upper Carboniferous, Des Moines, Red-Rock sandstone; Pleistocene, Kansan drift, loess, alluvium.

Economic products, coals, mines, Pella, Otley, Dunreath, Morgan Valley, Swan, Coal Creek, White Breast Creek, Coalport, Knoxville, Flagler, O. K. Coal Company, Hamilton, Marysville; building-stones, limes and cements, clays, ochre, copper, lead and zinc; water-supplies, artesian wells, soils.

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Geology of Linn county. W. H. Norton. (Iowa Geol. Surv., IV, 121-194, 1895.)

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Niles, W. H., and Charles Wachsmuth. Evidence of Two Distinct Geological Formations in Burlington Limestone. (Am. Jour. Sci., (2), Vol. XLII, pp. 95-99, New Haven, 1866.) A short sketch is given of the Burlington beds, with list of the crinoids found in the upper and lower sub-divisions.

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Ninth annual report of state geologist. S. Calvin. (Iowa Geol. Surv., XI, 11-30, 1901.)

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Cretaceous deposits of the Sioux valley. H. F. Bain. (Iowa Geol. Surv., III, 99-114, 1895.)

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Northwestern Iowa, ancient lava-flows. S. W. Beyer. (Iowa Geol. Surv., I, 163-169, 1893.)

Northwestern Iowa, notes on drift. H. F. Bain. (American Geologist, XXIII, 168-176, 1899.)

Northwestern states, magnesian series. C. W. Hall and F. W. Sardeson. (Bull. Geol. Soc. America, VI, 167-198, 1895.)

Norton, William H. Artesian Wells of Iowa. (Iowa Geol. Surv., Vol. VI, pp. 113-428, Des Moines, 1897.) The subjects fully discussed are:

Introduction.

Definition and theory of artesian-wells, definitions, historical résumé, requisite conditions, illustrations of artesian areas.

Iowa field and its artesian conditions, geological structure, area of supply, conditions of supply, reservoir, conditions of transmission, permeable stratum, containing beds, fountain-head.

Records of wells, McGregor-Fairview section, Dubuque-Sioux City section, Clinton-Dunlap section, Davenport-Des Moines section, Washington-Des Moines section, wells of southeastern Iowa, wells of southwestern Iowa, flowing-wells in glacial drift.

Chemistry of artesian waters, interpretation of chemical water analyses, mineral ingredients of artesian waters, dissolved gases, dissolved solids, classification of artesian waters.

Qualities of artesian waters, therapeutics, sanitary, industrial.

Artesian waters as a public supply, adequacy, cost, purity, contract and some minor matters, art of drilling wells.

Bibliography.

The important feature which the results of this investigation emphasizes is the exact stratigraphic location of a great water bearing stratum throughout the state and the exact depths at which it may be reached.

Norton, William H. Certain Devonian and Carboniferous Outliers in Eastern Iowa. (Iowa Geol. Surv., Vol. III, pp. 115-133, Des Moines, 1895.) A number of isolated patches of the rocks are noted far beyond the margins of the main body of the strata of their ages. Sections accompany the descriptions. Fossils as determining factors are listed.

Norton, William H. Geological Section of Y. M. C. A. Artesian Well at Cedar Rapids. (Proc. Iowa Acad. Sci., Vol. II, pp. 194-196, Des Moines, 1895.) The detailed sequence of rock-layers is given and the various groups are referred to the general geological section of the state.

Norton, William H. Geology of Bremer County. (Iowa Geol. Surv., Vol. XVI, pp. 319-405, Des Moines, 1906.) The following subjects are fully considered:

Introduction, location and area, previous geological work.

Physiography, relief, table of altitudes, drainage, Cedar River valley, Wapsipinicon River valley.

Stratigraphy, general relations of strata, synoptical table, Ordovician system, Maquoketa stage, Silurian system, Niagara series, sections of the Niagara, Devonian system, Wapsipinicon stage, Lower Davenport sub-stage, Independence sub-stage, sections of the Wapsipinicon, Cedar Valley stage, sections of the Cedar Valley at Waverly, fish remains at Waverly, sections of the Cedar Valley north of Waverly, sections of the Cedar Valley about Frederika, geest, Pleistocene system, pre-Kansan stage, Kansan drift, sections of Kansan drift, topography of the Kansan drift, Denver loess-Kansan area, Buchanan gravels, Iowan stage, Iowan drift, loess, paha, distribution of the loess, preglacial topography.

Economic products, building-stones, crushed stone, lime, clay, soils, water-powers, water supply, section of Waverly well, section of Summer well.

Norton, William H. Geology of Cedar County. (Iowa Geol. Surv., Vol. XI, pp. 279-396, Des Moines, 1901.) The features described include:

Introduction, situation and area, previous geological work.

Physiography, relief, table of elevations, drainage, Wapsipinicon river, tributaries of the Wapsipinicon, Cedar river, terraces of the Cedar, tributaries of the Cedar, sinks, pre-glacial drainage.

Stratigraphy, general relations, synoptical table, deeper strata; Ordovician system; Silurian system, Niagara, Gower limestone, chemical analyses, sections of the Gower; Devonian system, Coggan, Otis, Independence, Lower Davenport, Upper Davenport, sections of Devonian; Carboniferous; Pleistocene, pre-Kansan and Aftonian, Kansan drift sheet, Kansan ferretto, Kansan topography, advance and retreat of the Kansan, Paha, Buchanan gravels, Iowan drift sheet, loess, remains of mammoth.

Economic geology, building-stone, limes, clays, road materials, sands, water-powers, soils.

The paha and its origin are especially discussed.

Norton, William H. Geology of Linn County. (Iowa Geol. Surv., Vol. IV, pp. 121-194, Des Moines, 1895.) The following subjects are considered:

Introduction, situation and area.

Physiography, drainage, topography, table of elevations.

Stratigraphy, general relations of strata, classification of formations, geological formations; Silurian *Pentamerus* beds, Coralline beds, Le Claire beds, Mount Vernon beds, Bertram beds, Coggan beds, sections of Coggan, Otis and Kenwood beds, relations of Coggan and Bertram beds; Devonian, Wapsipinicon stage, Otis beds, Kenwood beds, Fayette breccia, Cedar Valley limestone;

Carboniferous; Cretaceous; Pleistocene deposits, residuary clays, Kansan drift-sheet, east Iowan drift-sheet, pre-loess sands, valley drift, loess, preglacial erosion, terraces, distribution of Pleistocene deposits, central drift-plain, paha.

Economic products, building-stones, Mount Vernon beds, Stone City quarries, Waubeck quarries, Mount Vernon quarries, Coggan beds Bertram beds, Otis beds, Kenwood and Fayette beds, Cedar Valley limestone; drift-clays, character and distribution, loess; drift-clay plants in operation, Cedar Rapids, Marion, Lisbon and Mount Vernon, Center Point, Central City, Coggan; limes, Viola, Mount Vernon; sands.

Especially noteworthy features are the differentiation of the Late Silurian section and the Middle Devonian section, the discussion of the formation of the brecciation of the Fayette limestone, the description of certain Carboniferous outliers and the consideration of paha and its origin.

Norton, William H. Geology of Scott County. (Iowa Geol. Surv., Vol. IX, pp. 389-519, Des Moines, 1889.) There are described in detail these subjects:

Introduction.

Topography, constructional reliefs, Iowan drift-plains, Paha, Illinoian and Kansan drift-plains, fluvial plains, erosional reliefs, causes and conditions, Illinoian, Kansan, Drainage, Wapsipinicon river, Rock and Walnut creeks, Mud creek, other affluents of the Wapsipinicon, affluents of the Mississippi, Mississippi river, terraces, Rock Island rapids, history of drainage,

Stratigraphy, taxonomic relations; geological formations, Silurian, Gower stage, Le Claire stone, Anamosa stone, relation of Le Claire and Anamosa sections of Gower, Le Claire, Anamosa, intermediate type; Devonian, Wapsipinicon, Otis, Independence, Lower Davenport, brecciation of Lower Davenport, Upper Davenport, fauna of Upper Davenport, sections of the Wapsipinicon, Cedar Valley, general descriptions, sections;

Carboniferous, surface distribution, sections; geest; Pleistocene, taxonomic relations, pre-Kansan, Aftonian, Kansan, Yarmouth, Illinoian, Sangamon, Iowan, Iowan loess, red loam, loess sands, preglacial surface.

Economic products, coal; building-stones, Silurian, Devonian; limes; clays, Carboniferous, loess; road-materials, soils, water-supplies, artesian wells.

Table of wells.

Norton, William H. Glaciated Rock-surface near Linn and near Quarry, Iowa; with table of Bearings of Glacial Striæ in Iowa. (Proc. Iowa Acad. Sci., Vol. XVIII, pp. 79-83, Des Moines, 1911.) Finely ice-scored surfaces are described, together with the attendant phenomena.

Norton, William H. Notes on Some Strata of Devonian Series in Iowa. (Proc. Iowa Acad. Sci., Vol. I, Pt. iv, pp. 22-24, Des Moines, 1894.) Four stages of the Fayette breccia are noted. Kenwood, Otis and Coggan beds are distinguished.

Norton, William H. Occurrence of Megalomus Canadensis Hall, in Le Claire Beds at Port Byron, Illinois. (Proc. Iowa Acad. Sci., Vol. II, pp. 42-43, Des Moines, 1895.) Incidental allusion is made to the probable existence of the forms in Iowa.

Norton, William H. Report of Assistant Geologist. (Iowa Geol. Surv., Vol. V, pp. 29-30, Des Moines, 1896.) A brief statement is made of the progress in the investigation of the artesian waters.

Norton, William H. Report of Assistant Geologist. (Iowa Geol. Surv., Vol. VII, p. 31, Des Moines, 1897.) This is a brief statement of the work accomplished on artesian wells.

Norton, William H. Report of Assistant Geologist. (Iowa Geol. Surv., Vol. X, pp. 31-35, Des Moines, 1900.) This is a summary of the continued work on the artesian wells of the state.

Norton, William H. Report of Assistant Geologist. (Iowa Geol. Surv., Vol. XI, pp. 33-34, Des Moines, 1901.) The investigations on artesian wells during the year are noted.

Norton, William H. Report of Assistant Geologist. (Iowa Geol. Surv., Vol. XII, pp. 23-34, Des Moines, 1902.) Brief statement is made of the artesian work of the year.

Norton, William H. Report of Assistant Geologist. (Iowa Geol. Surv., Vol. XIII, pp. 17-19, Des Moines, 1903.) The work on artesian wells is reviewed.

Norton, William H. Thickness of Paleozoic Strata of Northeastern Iowa. (Iowa Geol. Surv., Vol. III, pp. 167-210, Des Moines, 1895.) The logs of a number of deep-well drillings are presented to show the relative development of the strata of different geologic periods in various parts of the state. In these wells the artesian water-stratum—the St. Peter sandstone—is sought.

Norton, Willian H. Underground Water Resources of Iowa. (Iowa Geol. Surv., Vol. XXI, pp. 29-1214, Des Moines, 1912.) The topics discussed are as follows:

Underground water resources of Iowa, introduction, topography and climate, geology, geologic occurrence of underground water, artesian phenomena, chemical composition of underground waters, municipal, domestic and industrial water supplies, mineral waters; underground waters of the Northeast district, Allamakee county, Black Hawk county, Bremer county, Buchanan county, Chickasaw county, Clayton county, Delaware county, Dubuque county, Fayette county, Howard county, Winneshiek county; underground waters of East-central district, Benton county, Cedar county, Clinton county, Iowa county, Jackson county, Johnson county, Jones county, Linn county, Muscatine county, Poweshiek county, Scott county, Tama county; underground waters of the Southeastern district, Davis county, Des Moines county, Henry county, Jefferson county, Keokuk county, Lee county, Louisa county, Mahaska county, Van Buren county, Wapello county, Washington county; underground waters of North-central district, Butler county, Cerro Gordo county, Floyd county, Franklin county, Hancock county, Humboldt county, Kossuth county, Mitchell county, Winnebago county, Worth county, Wright county; underground waters of Central district, Boone county, Dallas county, Greene county, Grundy county, Guthrie county, Hamilton county, Hardin county, Jasper county, Marshall county, Polk county, Story county, Webster county; underground waters of South-central district, Adair county, Appanoose county, Clarke county, Decatur county, Lucas county, Madison county, Marion county, Monroe county, Ringgold county, Union county, Warren county, Wayne county; underground waters of Northwest district, Buena Vista county, Calhoun county, Carroll county, Cherokee county, Clay county, Crawford county, Dickinson county, Emmet county, Ida county, Lyon county, Monona county, O'Brien county, Osceola county, Palo Alto county, Plymouth county, Pocahontas county, Sac county, Sioux county, Woodbury county; underground waters of Southwest district, Adams county, Audubon county, Cass county, Fremont county, Harrison county, Mills county, Montgomery county, Page county, Pottawattamie county, Shelby county, Taylor county.

Norton, William H. Underground Water resources of Iowa. (U. S. Geol. Surv., Water Supply Paper No. 293, 994 pp., Washington, 1912.) The topics discussed are the same as those of the Iowa report of the same title.

Norton, William H. Underground Waters of Eastern United States: Iowa. (Water Supply and Irrigation Papers, U. S. Geol. Surv., No. 114, pp. 220-225, Washington, 1905.) There is given a summary of the knowledge on the shallow waters; and the geologic horizons of artesian waters are described.

Norton, William H. Variation in Position of Nodes on Axial Segments of Pygidium of a Species of Encrinurus. (Proc. Iowa Acad. Sci., Vol. III, pp. 79-81, Des Moines, 1896.) It is noted that not a single segmental line of more than a score of species is unoccupied by tubercles.

Norton, William H. Water-Supplies at Waterloo, Iowa. (Water-supply and Irrigation Papers, U. S. Geol. Surv., No. 145, pp. 148-155, Washington, 1905.) Brief statement is made of the possibilities of artesian water-supplies for the city.

Norwood, J. G., and Henry Pratten. Notice of Producti found in Western States and Territories with Description of Twelve New Species. (Jour. Acad. Nat. Sci. Philadelphia, (2), Vol. III, pp. 5-22, Philadelphia, 1855.) A number of allusions are made to species occurring in Iowa.

Notable ride, from driftless area to Iowan drift. S. Calvin. (Proc. Iowa Acad. Sci., VII, 72-77, 1900.)

Note on carboniferous fauna of Mississippi valley in Rocky Mountain region. C. R. Keyes. (Proc. Iowa Acad. Sci., XI, 258-259, 1904.)

Note on correlation of Clarinda well-section with schematic section of carboniferous. C. R. Keyes. (Iowa Geol. Surv., XI, 461-463, 1901.)

Note on difference between Acervularia profunda, Hall, and Acervularia Davidsoni, Edwards and Haime. S. Calvin. (American Geologist, IX, 365-368, 1892.)

Note on difference between Acervularia profunda, Hall, and Acervularia Davidsoni, Edwards and Haime. S. Calvin. (Proc. Iowa Acad. Sci., I, pt. ii, 30-32, 1892.)

Note on distribution of Helicina occulta. C. R. Keyes. (American Geologist, III, 18-19, 1889.)

Note on Florencia formation. H. A. Pilsbry. (Am. Jour. Sci., (4) V, 232-233, 1898.)

Note on geological range of genus Receptaculites in American palæozoic strata. J. Hall. (New York State Cab. Nat. Hist., 16th Ann. Rep., App. D. 67-69, 1863.)

Note on nature of cone-in-cone. C. R. Keyes. (Proc. Iowa Acad. Sci., III, 75-76, 1896.)

Note sur le parallésme des roches des dépots paleozoiques de l' Amerique Septentrionale avec ceux de l' Europe, suivie d'un tableau des especes fossiles commones aux deux Continents, avec l' indication des étages on elles as recontrent, et terminée par un examen critique de chacune de ces éspeces. Ed. de Verneuil. (Bull. Soc. géol. de France, (2), t. IV, 646-710, 1847.)

Notes explanatory of section from Cleveland, Ohio, to Mississippi river, in southwest direction, with remarks upon the identity of western formations with those of New York. J. Hall. (Trans. Assoc. American Geologists and Naturalists, 267-293, 1842.)

Notes, on Aftonian mammals. A. O. Thomas. (Science, N. S., XXXVI, 570, 1912.)

Notes on collection of fossils from lower magnesian limestone from northeastern Iowa. S. Calvin. (American Geologist, X, 144-148, 1892.)

Notes on collection of fossils from lower magnesian limestone from northeastern Iowa. S. Calvin. (Bull. Lab. Nat. Hist., State Univ. Iowa, II, 189-193, 1893.)

Notes on cretaceous flora of western Iowa. P. Bartsch. (Bull. Lab. Nat. Hist., State Univ. Iowa, III, 178-182, 1896.)

Notes on "Cone-in-cone." C. A. White. (Am. Jour. Sci., (2), XLV, 400-401, 1868.)

Notes on distribution of timber in southwestern Iowa, with inferences concerning origin of prairies. J. E. Todd. (American Naturalist, XII, 91-96, 1878.)

Notes on drift of northwestern Iowa. H. F. Bain. (American Geologist, XXIII, 168-176, 1899.)

Notes on formations passed through in digging the deep-well at Washington, Iowa. S. Calvin. (American Geologist, I, 28-31, 1888.)

Notes on the fossil wood from Keokuk limestone, Keokuk, Iowa. C. H. Gordon. (Proc. Iowa Acad. Sci., I, 97-98, 1890.)

Notes on fossils of loess at Iowa City. B. Shimek. (American Geologist, I, 149-152, 1888.)

Notes on geological formations of Iowa. S. Calvin. (Pamphlet, printed at World's Exposition at New Orleans, 1-8, 1884.)

Notes on geological section of Iowa. S. Calvin. (Iowa Geol. Surv., XVII, 192-200, 1907.)

Notes on geology of part of Mississippi valley. W J McGee. (Geological Magazine, (2), VI, 353-362 and 412-420, 1879.)

Notes on geology of Johnson county. C. L. Webster. (American Naturalist, XXII, 408-419, 1888.)

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Notes on Iowa building-stones. H. F. Bain. (Sixteenth Ann. Rept., U. S. G. S., pt. iv, 500-503, 1895.)

Notes on local geology, No. II. W. H. Barris. (Proc. Davenport Acad. Nat. Sci., III, 163-183, 1882.)

Notes on lower strata of devonian series in Iowa. W. H. Norton. (Proc. Iowa Acad. Sci. I, pt. iv, 22-24, 1894.)

Notes on Redrock sandstone. C. R. Keyes. (Proc. Iowa Acad. Sci., I, pt. iii, 26-27, 1893.)

Notes on Rockford shales. C. L. Webster. (American Naturalist, XXII, 444-446, 1888.)

Notes on some fossil corals described by David Dale Owen in his report of work in autumn of 1839, with observations on devonian species Phillipsastrea Gigas of later authors. S. Calvin. (American Geologist, XII, 108-112, 1893.)

Notes on some points in structure and habits of palæozoic crinoidea. F. B. Meek and A. H. Worthen. (Proc. Acad. Nat. Sci., Phila., XX, 323-334, 1868.)

Notes on synonomy, characters and distribution of Spirifera parryana, Hall. S. Calvin. (Bull. Lab. Nat. Hist., State Univ. Iowa, I, 19-28, 1888.)

Notes on various glass-sands, mainly undeveloped. F. Burchard. (Bull. U. S. Geol. Surv., No. 315, 377-381, 1907.)

Notice of arrow points from loess in city of Muscatine. F. M. Witter. (Proc. Iowa Acad. Sci., I, pt. ii, 66-68, 1892.)

Notice of new cœlacanth fish from Iowa kinderhook. C. R. Eastman. (Journal of Geology, XVI, 357-362, 1908.)

Notice of new genus and species of lower carboniferous bryozoan. R. P. Whitfield. (Bull. American Mus. Nat. Hist., XX, 469, 1904.)

Notice of new species of Platycrinus and other fossils from Mountain limestone of Illinois and Iowa. A. H. Worthen. (Trans. Acad. Sci., St. Louis, I, 569-571, 1860.)

Notice of producti found in western states and territories, with description of twelve new species. J. G. Norwood and H. Pratten. (Jour. Acad. Nat Sci. Philadelphia, (2), III, 5-22, 1855.)

Nous avons lu de grandes richesses houillères. C. R. Keyes. (La Chronique Industrielle, Trente-cinquiène Année, No. 102, 1-3, 1912.)

Number and distribution of fossil species in paleozoic rocks of Iowa, Wisconsin and Minnesota. D. D. Owen and B. F. Shumard. (Proc. American Assoc. Adv. Sci., V, 235, 1851.)

Nuttall, Thomas. Observations on Geological Structure of Valley of Mississippi. (Jour. Acad. Nat. Sci. Philadelphia, Vol. II, pp. 14-52, Philadelphia, 1821.) Some general allusions are made to Iowa geology. By means of fossils early carboniferous and cretaceous rocks are recognized for the first time in Iowa-land and in America.

O'Brien County.

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Savage, T. E. Drift Exposures in Tama County. (Proc. Iowa Acad. Sci., Vol. VIII, pp. 275-278, Des Moines, 1901.) Two till-sheets are described.

Savage, T. E. Geology of Benton County. (Iowa Geol. Surv., Vol. XV, pp. 125-225, Des Moines, 1905.) The following features are described in detail:

Introduction, location and area, earlier geological work.

Physiography, topography, the Iowan-Kansan border, the Kansan area, the Iowan area, altitudes, drainage.

Geological formations, general relations of strata, table of formations; Middle Devonian series, Wapsipinicon stage, Coggan beds, Fayette breccia, Cedar Valley stage, general section of the Cedar Valley; Mississippian series, Kinderhook stage; Pleistocene system, Pre-Kansan stage, Kansan stage, Buchanan gravels, Iowan stage, loess; Post-Glacial deposits, alluvium, cumulose deposits, eolian deposits; soils; unconformities; deformations.

Economic products, building-stones, limes, road materials, sands, clays, copper, water-supplies.

Savage, T. E. Geology of Fayette County. (Iowa Geol. Surv., Vol. XV, pp. 433-546, Des Moines, 1905.) The consideration of the following topics is included:

Introduction, location and area, earlier geological work.

Physiography, topography, Iowan-Kansan border, area of Iowan drift, area of Kansan drift, table of altitudes, drainage.

Stratigraphy, general relations of strata, table of formations; Ordovician system, Galena-Trenton stage, Maquoketa stage, typical exposures, lower Maquoketa division, upper Maquoketa division, general section of the Maquoketa shales; Niagara series, Delaware stage; Devonian system, Wapsipinicon stage, Cedar Valley stage; residual materials; Pleistocene system, pre-Kansan stage, Aftonian stage, Kansan stage, Buchanan gravels; Iowan stage, Iowan loess, Iowan gravels; deformations and unconformities; soils.

Economic products, building-stones, limes, clays, sand, road-materials, cement materials; water-supplies; water-powers; lead, copper, gold.

Savage, T. E. Geology of Henry County. (Iowa Geol. Surv., Vol. XII, pp. 237-302, Des Moines, 1902.) The following features are described:

Introduction, location and area, earlier geological work.

Physiography, topography, table of elevations, drainage.

Stratigraphy, general relations of strata; Carboniferous system, Mississippian series, Keokuk limestone, Saint Louis limestone, Pennsylvanian series; Pleistocene system, Kansan drift, Buchanan gravels, Illinoian drift, loess, alluvium; deformations; unconformities.

Economic products, soils, coal, building-stones, limes, sands, clays, water-supplies.

Savage, T. E. Geology of Jackson county. (Iowa Geol. Surv., Vol. XVI, pp. 563-648, Des Moines, 1906.) The following topics are considered:

Introduction, location and area, earlier geological work.

Physiography, topography, alluvial areas, terraces, altitudes, drainage, Maquoketa river, Goose Lake channel, North Fork of Maquoketa river, South Fork of Maquoketa river, Lytle creek, Farmer creek, Bear creek, Prairie creek, Deep creek, Brush creek, Morts creek, Mill creek, other streams.

Stratigraphy, general relations of strata, table of formations; Ordovician system, Galena stage, typical exposures, Maquoketa stage, distribution, typical exposures, summary; Silurian system, Niagara series, Hopkinton stage, Gower stage; Devonian system; Carboniferous system, Pennsylvanian series, Des Moines stage, residual materials; Pleistocene system, Kansan stage, Kansan drift, Iowan stage, Iowan drift area, loess, distribution, post-glacial deposits, alluvium, eolian deposits; soils, loess soils, sandy soils, alluvial soil, residual soil; deformations; unconformities.

Economic products, soils, building-stones, Galena limestone, Maquoketa beds, Hopkinton stage, Gower stage, Des Moines sandstone, limes, sands, clays, Preston plant, Maquoketa plant, water-supplies.

Savage, T. E. Geology of Tama County. (Iowa Geol. Surv., Vol. XIII, pp. 185-253, Des Moines, 1903.) The following topics are considered in detail:

Introduction, location and area, earlier geological work.

Physiography, topography, general description, Iowan drift-plain, Kansan drift areas, flood-plains, elevations, drainage, Iowa river, Wolf creek, Deer creek, Salt creek, Richland creek, history of drainage.

Stratigraphy, general relations of strata; Devonian system, Cedar Valley limestone, Kinderhook stage, typical exposures; Des Moines stage; Pleistocene system, pre-Kansan drift, Kansan drift, Iowan drift, loess, postglacial deposits; unconformities; preglacial surface; soils.

Economic products, building stones, limes, sands, clays, water-supplies.

Savage, T. E. Preliminary Report on Peat Resources of Iowa. (Iowa Geol. Surv., Bull. No. 2, pp. 5-21, Des Moines, 1905.)

Savage, T. E. Report of Assistant State Geologist. (Iowa Geol. Surv., Vol. XV, pp. 12-14, Des Moines, 1905.) Brief statement is made of the personal work of the year.

Savage, T. E. Report of Assistant State Geologist. (Iowa Geol. Surv., Vol. XVI, pp. 13-15, Des Moines, 1906.) Personal work of the year is reviewed.

Savage, T. E. Report on Tests of Iowa Coals made at Government coal-testing Plant at Louisiana Purchase Exposition, St. Louis, Mo., 1904. Iowa Geol. Surv., Bull. No. 2, pp. 22-38, Des Moines, 1905.)

Savage, T. E. Toledo Lobe of Iowan Drift. (Proc. Iowa. Acad. Sci., Vol. X, pp. 123-129, Des Moines, 1903.) A long local extension of the drift-sheet is described.

Saverton Shales.

Geology of Des Moines county. C. R. Keyes. (Iowa Geol. Surv., III, 409-492, 1894.)

Geology of Louisa county. J. A. Udden. (Iowa Geol. Surv., XI, 53-126, 1901.)

Marked unconformity between carboniferous and devonian strata in upper Mississippi valley. C. R. Keyes. (Am. Jour. Sci., (4), XXXVI, 160-164, 1913.)

Nether delimitation of our carbonic rocks. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 153-156, 1912.)

Sundry provincial and local phases of general geologic section of Iowa. (Proc. Iowa Acad. Sci., XIX, 147-151, 1912.)

Schematic standard for American carboniferous. C. R. Keyes. (American Geologist, XXVIII, 299-305, 1901.)

Schematic section of carboniferous, note on correlation of Clarinda well-section. C. R. Keyes. (Iowa Geol. Surv., XI, 461-463, 1901.)

Science, American, epoch in history. C. R. Keyes. (Annals of Iowa, Historical Quarterly, (3), II, 345-364, 1896.)

Science, pure, economic aspects of work. C. R. Keyes. (The Annals of Iowa, Historical Quarterly, V, 392-393, 1902.)

Scientist, Iowa, and his work. C. R. Keyes. (Annals of Iowa, Historical Quarterly, IV, 383-392, 1900.)

Scope of the geological survey. C. R. Keyes. (Iowa Geol. Surv., III, 47-98, 1894.)

Scorings, glacial, in Iowa. C. R. Keyes. (Iowa Geol. Surv., III, 147-165, 1894.)

Scott County.

Account of paleozoic rocks explored by deep-borings at Rock Island and vicinity. J. A. Udden. (Seventeenth Ann. Rept., U. S. G. S., pt. ii, 829-849, 1896.)

Artesian well at Davenport. A. S. Tiffany. (American Geologist, III, 117-118, 1889.)

Artesian wells of Iowa. W. H. Norton. (Iowa Geol. Surv., VI, 113-428, 1897.)

Beds of carboniferous drift in bluffs of East Davenport. Tyler McWhorther. (Proc. Davenport Acad. Sci., III, 129-130, 1882.)

Coal deposits of Iowa. C. R. Keyes. (Iowa Geol. Surv., II, 536 pp., 1894.)

Coal deposits of Iowa. H. Hinds. (Iowa Geol. Surv., XIX, 21-396, 1909.)

Cretaceous drift-pebbles in northern Iowa. J. A. Udden. (American Geologist, XXIV, 389-390, 1889.)

Description of new blastoids from Hamilton group. W. H. Barris. (Geol. Surv., Illinois, VII, 357-364, 1883.)

Description of quaternary deposits. W. H. Pratt. (Proc. Davenport Acad. Sci., I, 96-99, 1876.)

Devonian fishes of Iowa. C. R. Eastman. (Iowa Geol. Surv., XVIII, 29-360, 1908.)

Diatomaceous earth in Muscatine county. J. A. Udden. (Proc. Iowa Acad. Sci., VI, p. 53, 1899.)

Geological notes. J. D. Whitney. (Geology of Iowa, I, 278-282, 1858.)

Geology of clays. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XIV, 377-552, 1904.)

Geology of quarry products. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

Geology of Scott county. W. H. Norton. (Iowa Geol. Surv., IX, 389-519, 1899.)

Geology of Scott county, Iowa, and Rock Island county, Illinois, and adjacent territory. A. S. Tiffany. (Pamphlet, 1-34, Glass and Hoover, printers, Davenport, 1885.)

History of coal-mining in Iowa. J. H. Lees. (Iowa Geol. Surv., XIX, 521-586, 1909.)

Lime-burning dolomites and dolomitic building-stones from the Niagara of Iowa. G. L. Houser. (Iowa Geol. Surv., I, 197-207, 1893.)

Local geology of Davenport. W. H. Barris. (Proc. Davenport Acad. Sci., II, 261-269, 1877.)

Mississippi valley between Savanna and Davenport. J. E. Carman. (Bull. Illinois Geol. Surv., No. 13, 96 pp., 1909.)

New crinoids from Buffalo. A. H. Worthen. (Geol. Surv. Illinois, VIII, 69-154, 1890.)

New crinoids from devonian. F. B. Meek and A. H. Worthen. (Proc. Acad. Nat. Sci. Philadelphia, XVII, 138-143, 1865.)

New fossils from devonian at Davenport. W. H. Barris. (Proc. Davenport Acad. Sci.. II, 282-288, 1878.)

Notes on lower strata of devonian series in Iowa. W. H. Norton. (Proc. Iowa Acad. Sci., I, pt. iv, 22-24, 1894.)

Notes on our local geology, No. II. W. H. Barris. (Proc. Davenport Acad. Sci., III, 163-183, 1882.)

Occurrence of Megalomus canadensis Hall, in Le Claire beds at Port Byron, Illinois. W. H. Norton. (Proc. Iowa Acad. Sci., II, 42-43, 1895.

Old channels of Mississippi in southeastern Iowa. F. Leverett. (Annals of Iowa, Historical Quarterly, (3), V, 38-51, 1901.)

Our local geology. W. H. Barris. (Proc. Davenport Acad. Nat. Sci., VII, 14-32, 1900.)

Preglacial soils. J. A. Udden. (American Geologist, XXI, 262-264, 1898.)

Preglacial valleys of Mississippi and tributaries. Frank Leverett. (Journal of Geology, III, 740-763, 1895.)

Professor W. H. Barris. C. H. Preston. (American Geologist, XXVIII, 358-361, 1901.)

Reference to coal. C. A. White. (Geology of Iowa, II, 274, 1870.)

Sanitary analyses of some Iowa deep-well waters. J. B. Weems. (Proc. Iowa Acad. Sci., IX, 63-70, 1902.)

Section of bluff at Sixth street, Davenport, W. H. Pratt. (Proc. Davenport Acad. Sci., III, 127-129, 1881.)

Some preglacial soils. J. A. Udden. (Proc. Iowa Acad. Sci., V, 102-104, 1898.)

Underground water resources of Iowa. W. H. Norton. (Iowa Geol. Surv., XXI, 29-1214, 1912.)

Underground water resources of Iowa. W. H. Norton. (U. S. Geol. Surv., Water Supply Paper No. 293, 994 pp., 1912.)

Weathered zone (Yarmouth) between Illinoian and Kansan till-sheets. F. Leverett. (Proc. Iowa Acad. Sci., V, 81-86, 1898.)

Scott county, geology. W. H. Norton. (Iowa Geol. Surv., IX, 389-519, 1899.)

Sea-bottom, inequalities in old paleozoic. J. E. Todd. (American Geologist, XV, p. 64, 1895.)

Second annual report of state geologist, for 1893. S. Calvin. (Iowa Geol. Surv., III, 19-27, 1895.)

Second annual report of state geologist. C. A. White. (Iowa Geol. Surv., 81-284, 1868.)

Secondary deposition of silica in optical continuity with the original nucleus, new horizons and some new localities for friable sandstone in which the grains are enlarged. S. Calvin. (American Geologist, XIII, 225-227, 1894.)

Section, general, of Des Moines stage of Iowa. J. H. Lees. (Iowa Geol. Surv., XIX, 598-604, 1909.)

Section, geological, along Middle river in central Iowa. J. L. Tilton. (Iowa Geol. Surv., III, 135-146, 1895.)

Section of Maquoketa shales in Iowa. J. F. James. (Proc. American Assoc. Adv. Sci., XXXVII, 250-251, 1890.)

Section of carboniferous, note on correlation of Clarinda well-section. C. R. Keyes. (Iowa Geol. Surv., XI, 461-463, 1901.)

Section of Iowa, notes on geologic. S. Calvin. (Iowa Geol. Surv., XVII, 192-200, 1907.)

Section of Iowa, sundry provincial and local phases of the general geological. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 147-151, 1912.)

Section of southwestern Iowa, carboniferous. G. L. Smith. (Iowa Geol. Surv., XIX, 605-657, 1909.)

Sedentary habits of Platyceras. C. R. Keyes. (Am. Jour. Sci., (3), XXXVI, 262-272, 1882.)

Sedimentation.

Accretion of floodplains by means of sand-bars. H. Simpson. (Proc. Iowa Acad. Sci., X, 54-56, 1903.)

Degradation of loess. J. E. Todd. (Proc. Iowa Acad. Sci., V, 46-51, 1898.)

Depositional phases of eolation under the stimulus of aridity. C. R. Keyes. (Proc. Iowa Acad. Sci., XVIII, 101-103, 1911.)

Inequalities in old paleozoic sea-bottom. J. E. Todd. (American Geologist, XV, p. 64, 1895.)

Is loess of aqueous origin? B. Shimek. (Proc. Iowa Acad. Sci., V, 32-45, 1898.)

Le Claire limestone. S. Calvin. (Bull. Lab. Nat. Hist., State Univ. Iowa, III, 183-189, 1896.)

Mid-continental eolation. C. R. Keyes. (Bull. Geol. Soc. America, XXII, 687-712, 1912.)

More light on origin of Missouri river loess. J. E. Todd. (Proc. Iowa Acad. Sci., XIII, 187-194, 1906.)

Relations of Missouri river loess mantle and Kansan drift sheet. C. R. Keyes. (American Jour. Sci., (4), XXXIII, 32-34, 1912.)

Segments of pygidium of a species of Encrinurus, variations in position of nodes. W. H. Norton. (Proc. Iowa Acad. Sci., III, 79-81, 1896.)

Selection, installation and care of power-plants. G. W. Bissell. (Iowa Geol. Surv., XIV, 349-376, 1904.)

Selection of power-plants and equipment for stone-quarries in Iowa. G. W. Bissell. (Iowa Geol. Surv., XVII, 151-183, 1907.)

Selenite.

Certain minerals of Webster county, Iowa. A. C. Spencer. (Proc. Iowa Acad. Sci., II, 143-145, 1895.)

Geology of Dubuque county. S. Calvin and H. F. Bain. (Iowa Geol. Surv., X, 379-651, 1900.)

Geology of Muscatine county. J. A. Udden. (Iowa Geol. Surv., IX, 247-380, 1899.)

Geology of Van Buren county. C. H. Gordon. (Iowa Geol. Surv., IV, 197-254, 1895.)

Geology of Webster county. F. A. Wilder. (Iowa Geol. Surv., XII, 63-235, 1902.)

Lead and zinc deposits of Iowa. A. G. Leonard. (Iowa Geol. Surv., VI, 9-66, 1897.)

Senecan Series.

Additional evidence of unconformity between Cedar Valley and Lime Creek stages of devonian of Iowa. (Science, N. S., XXXVI, 569-570, 1912.)

Analyses of lime. J. D. Whitney. (Geology of Iowa, 370-376, 1858.)

Brachiopods from various localities in Iowa. J. Hall. (Nat. Hist. New York, Pal., VIII, 1-267, 1892.)

Cement and cement materials of Iowa. E. C. Eckel and H. F. Bain. (Iowa Geol. Surv., XV, 33-124, 1905.)

Conocardium from Iowa devonian. C. R. Keyes. (Proc. Iowa Acad. Sci., I, pt. ii, 23-24, 1892.)

Description of devonian fossils from Iowa. James Hall. (Geology of Iowa, I, 476-516, 1858.)

Description of geological features along Cedar and Iowa rivers in eastern Iowa. D. D. Owen. (Rept. Geol. Surv., Wisconsin, Iowa and Minnesota, 77-90, 1852.)

Description of new blastoids. W. H. Barris. (Geol. Surv. Illinois, VII, 357-364, 1883.)

Description of new crinoids and blastoids from Hamilton group. W. H. Barris. (Proc. Davenport Acad. Sci., IV, 88-94, 1885.)

Description of new species of fossils. J. Hall. (New York State Cab. Nat. Hist., 13 Ann. Rept., App. F, 76-94, 1860.)

Description of new species of fossils. F. B. Meek and A. H. Worthen. (Geol. Surv. Illinois, III, 289-565, 1868.)

Description of new species of Spirifera from Hamilton group near Iowa City, Iowa. S. Calvin. (Bull. Lab. Nat. Hist., State Univ. Iowa, I, 28-29, 1888.)

Devonian fishes of Iowa. C. R. Eastman. (Iowa Geol. Surv., XVIII, 29-360, 1908.)

Dipterus in American middle devonian. J. A. Udden. (Journal of Geology, VII, 494-495, 1899.)

General description. C. A. White. (Geology of Iowa, I 184-188, 1870.)

General description of characters. James Hall. (Geology of Iowa, I, 85-88, 1858.)

Geology of Benton county. T. E. Savage. (Iowa Geol. Surv., XV, 125-225, 1905.)

Geology of Black Hawk county. M. F. Arey. (Iowa Geol. Surv., XVI, 407-452, 1906.)

Geology of Bremer county. W. H. Norton. (Iowa Geol. Surv., XVI, 319-405, 1906.)

Geology of Buchanan county. S. Calvin. (Iowa Geol. Surv., VIII, 201-253, 1898.)

Geology of Cedar county. W. H. Norton. (Iowa Geol. Surv., XI, 279-396, 1901.)

Geology of Cerro Gordo county. S. Calvin. (Iowa Geol. Surv., VII, 117-195, 1897.)

Geology of Chickasaw county. S. Calvin. (Iowa Geol. Surv., XIII, 255-292, 1903.)

Geology of Fayette county. T. E. Savage. (Iowa Geol. Surv., XV, 433-546, 1905.)

Geology of Howard county. S. Calvin. (Iowa Geol. Surv., XIII, 21-79, 1903.)

Geology of Johnson county. S. Calvin. (Iowa Geol. Surv., VII, 33-116, 1897.)

Geology of Linn county. W. H. Norton. (Iowa Geol. Surv., IV, 121-194, 1895.)

Geology of Mitchell county. S. Calvin. (Iowa Geol. Surv., XIII, 293-352, 1903.)

Geology of Muscatine county. J. A. Udden. (Iowa Geol. Surv., IX, 247-380, 1899.)

Geology of Scott county. A. S. Tiffany. (Geology Scott County, etc., 19-26, 1885.)

Geology of Scott county. W. H. Norton. (Iowa Geol. IX, 389-519, 1899.)

Geology of Tama county. T. E. Savage. (Iowa Geol. Surv., XIII, 185-253, 1903.)

Geology of Winneshiek county. S. Calvin. (Iowa Geol. Surv., XVI, 37-146, 1906.)

Marked unconformity between carboniferous and devonian strata in upper Mississippi valley. C. R. Keyes. (Am. Jour. Sci., (4), XXXVI, 160-164, 1913.)

New crinoids from Scott county. F. B. Meek and A. H. Worthen. (Proc. Acad. Nat. Sci. Philadelphia, XVII, 138-143, 1865.)

New species of fossils. J. Hall and R. P. Whitfield. (New York State Cab. Nat. Hist., 23d Ann. Rep., 223-239, 1873.)

New species of palæozoic fossils. S. Calvin. (Bull. Lab. Nat. Hist., State Univ. Iowa, I, 174, 1890.)

Notes on some fossil corals described by David Dale Owen in his report of work done in autumn of 1839, with observations on devonian species of *Phillipsastrea gigas* of later authors. S. Calvin. (American Geologist XII, 108-112, 1893.)

Paleontology of New York. James Hall. (Nat. Hist. New York, Paleontology, IV, 422 pp., 1867.) A number of references are made to fossils occurring in Iowa.

Preliminary notice of Newberria. J. Hall. (Tenth Ann. Rep. State Geologist of New York, 91-102, 1891.) Species from Iowa are noted.

Relation of Lime Creek shales to Cedar Valley limestone of Floyd county, Iowa. A. O. Thomas. (Science, N. S., XXXVII, 459, 1913.)

Stereocrinus, Barris. W. H. Barris. (Proc. Davenport Acad. Sci., IV, 102-104, 1885.)

Sundry provincial and local phases of general geologic section of Iowa. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 147-151, 1912.)

Two new species. C. R. Keyes. (Proc. Acad. Nat Sci. Philadelphia, 247-248, 1888.)

Two unique spirifers from devonian of Iowa. S. Calvin. (Bull. Lab. Nat. Hist., State Univ. Iowa, II, 165-167, 1893.)

Sergeant Shales.

Cretaceous of Woodbury county. C. A. White. (Geology of Iowa, II, 192-199, 1870.)

Description of Elk Point quadrangle. J. E. Todd. (U. S. Geol. Surv., Folio 156, 8 pp., 1908.)

Relation of cretaceous deposits of Iowa to subdivisions of cretaceous by Meek and Hayden. S. Calvin. (Proc. Iowa Acad. Sci., I, pt. iii, 7-12, 1893.)

Sundry provincial and local phases of general geologic section of Iowa. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 147-151, 1912.)

Serial nomenclature of carboniferous. C. R. Keyes. (American Geologist, XVIII, 22-28, 1896.)

Series, Arkansan, a new terrane of carboniferous in western interior basin. C. R. Keyes. (Proc. Iowa Acad. Sci., VII, 123-128, 1901.)

Seventeenth annual report of state geologist. S. Calvin. (Iowa Geol. Surv., XIX, xiii-xiv, 1909.)

Seventh annual report of state geologist. S. Calvin. (Iowa Geol. Surv., IX, 11-24, 1899.)

Shakopee Limestone.

Artesian wells of Iowa. W. H. Norton. (Iowa Geol Surv., VI, 113-428, 1897.)

Geological formations of Iowa. C. R. Keyes. (Iowa Geol. Surv., I, 23, 1893.)

Geology of Allamakee county. S. Calvin. (Iowa Geol. Surv., IV, 35-111, 1895.)

Geology of Clayton county. A. G. Leonard. (Iowa Geol. Surv., XVI, 213-317, 1906.)

Geology of quarry products. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

Geology of Winneshiek county. S. Calvin. (Iowa Geol. Surv., XVI, 37-146, 1906.)

Magnesian series of northwestern states. C. W. Hall and F. W. Sardeson. (Bull. Geol. Soc. America, VI, 167-198, 1895.)

Sundry provincial and local phases of general geologic section of Iowa. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 147-151, 1912.)

Shelby County.

Coal deposits of Iowa. C. R. Keyes. (Iowa Geol. Surv., II, 536 pp., 1894.)

General description. O. H. St. John. (Geology of Iowa, II, 171-174, 1870.)

Underground water resources of Iowa. W. H. Norton. (Iowa Geol. Surv., XXI, 29-1214, 1912.)

Underground water resources of Iowa. W. H. Norton. (U. S. Geol. Surv., Water Supply Paper No. 293, 994 pp., 1912.)

Sheppard, Charles Upham. Fall of Meteoric Stones in Iowa. (Am. Jour. Sci., (2), Vol. IV, pp. 288-289, New Haven, 1847.) Description is given of the fragments which fell in Linn county, February 25, 1847.

Sheppard, Charles Upham. Report on Meteorites. (Am. Jour. Sci., (2), Vol. VI, pp. 402-417, New Haven, 1848.) Additional notes are given on the Linn county fall, with chemical analyses and observations.

Shimek, B. Additional Observations on Surface Deposits in Iowa. Proc. Iowa Acad. Sci., Vol. IV, pp. 68-72, Des Moines, 1897.) The results of shallow borings in the northern part of the state are noted, and the relations of plants to the soils are considered.

Shimek, B. Aftonian Sands and Gravels in Western Iowa. (Science, N. S., Vol. XXVIII, p. 923, New York, 1908.) Preliminary announcement of the westward extension of the deposits is made.

Shimek, B. Aftonian Sands and Gravels in Western Iowa. (Bull. Geol. Soc. America, Vol. XX, pp. 399-408, New York, 1909.) Announcement of pre-Kansan deposits is made as occurring at numerous localities along the Missouri river.

Shimek, B. Distribution of Loess Fossils. (Proc. Iowa Acad. Sci., Vol. VI, pp. 98-113, Des Moines, 1899.) Comparison is made of the molluscan forms of the loess and those occupying the uplands of the region at the present time and the two are thought to be identical.

Shimek, B. Distribution of Loess Fossils. (Journal of Geology, Vol. VII, pp. 122-140, Chicago, 1899.) The subject of geographic range is discussed and a list of species collected at Council Bluffs is given.

Shimek, B. Eolian Origin of Loess. (Science, N. S., Vol. XXXIII, p. 467, New York, 1911.) Abstract.

Shimek, B. Evidence that Fossiliferous Gravels and Sands of Iowa and Nebraska are Aftonian. (Bull. Geol. Soc. America, Vol. XXI, pp. 119-140, New York, 1910.) A number of sections are described in detail and lists of molluscan and mammalian remains found in each are given. The conclusion is that the beds are distinctly of Aftonian age. A mild climate is postulated.

Shimek, B. Geology of Harrison and Monona Counties. (Iowa Geol. Surv., Vol. XX, pp. 271-483, Des Moines, 1910.) The following topics are noted:

Introduction, location and area, previous geological work. Physiography, topography, benches, list of elevations, drainage.

Stratigraphy, synoptical table, Carboniferous system, Pennsylvanian series, Missouri stage, fossils, coal, Quaternary system, Pleistocene series, Nebraskan stage, Aftonian interglacial stage, structure and composition, organic remains, mammalian fauna, Aftonian horses, other ungulates, proboscidians, elephants, mastodon, other proboscideans, edentata, mylodon, megalonyx, correlation, molluscan fauna, significance of Aftonian fauna, fossiliferous sections, sections in which no fossils are found, Snyder's Hollow section, Kansan stage, Loveland loess, bluish loess (post-Kansan), yellow loess, loess fossils, table of fossils and modern mollusca, terrestrial species, fresh-water species, genesis of the loess, recent series, alluvium, the bison in Iowa, sand dunes, mounds.

Economic products, soils and their products, building stones, clays, sand and gravel, road-materials, water-supply, water-powers and drainage ditches.

Meteorological record.

Botanical report: the prairies, types of prairies, the prairie flora, plants of dry prairies, plants of upland woods, plants of alluvial groves, plants of low grounds, marshes, etc., exposure to evaporation, evaporation,

rate of evaporation, contributing causes of prairies, tree-planting, plants in the Whiting grove, weeds, list of weeds and introduced plants.

Shimek, B. Genesis of Loess a Problem in Plant Ecology. (Proc. Iowa Acad. Sci., Vol. XV, pp. 57-64, Des Moines, 1908.) Relations of the plants to the formation of the loess are set forth. Incidentally the eolic hypothesis is strengthened.

Shimek, B. Is the Loess of Aqueous Origin? (Proc. Iowa Acad. Sci., Vol. V, pp. 32-45, Des Moines, 1898.) The habitat relations of the molluscan forms found in the loess are discussed. It seems evident that the loess materials originated largely or wholly in drift.

Shimek, B. Living Plants as Geological Factors. (Proc. Iowa Acad. Sci., Vol. X, pp. 41-48, Des Moines, 1903.) The constructive work of plants is considered, with special reference to the accumulation of the fine soils along the Missouri river. The origin of the loess is ascribed to the wind.

Shimek, B. Loess and its Fossils. (Bull. Lab. Nat. Hist., State Univ. Iowa, Vol. I, pp. 200-214, Iowa City, 1890.) An annotated catalogue of the species of mollusks found in the loess of Iowa is presented.

Shimek, B. Loess and its Fossils. (Bull. Lab. Nat Hist., State Univ. Iowa, Vol. II, pp. 89-98, Iowa City, 1890.) Additional notes are given on fossils found in the formation, with a general discussion of the climatic conditions during the deposition of the loess.

Shimek, B. Loess of Iowa City and Vicinity. (American Geologist, Vol. XXVIII, pp. 344-358, Minneapolis, 1901.) There is an annotated list of the loess fossils and of the allied forms now living in the locality. The living aquatic species are shown to be of rare occurrence in the loess.

Shimek, B. Loess of Iowa City and Vicinity. (Bull. Lab. Nat. Hist., Iowa State Univ., Vol. V, pp. 195-212, Iowa City, 1901.) The living and fossil species of the region are compared.

Shimek, B. Loess of Missouri River. (Proc. Iowa Acad. Sci., Vol. XIV, pp. 237-251, Des Moines, 1907.) No obstacle has presented itself more persistently in the way of those who have attempted to explain the formation of loess deposits by aqueous or glacial agencies than the presence of remains of strictly terrestrial mollusks in the deposits. The evidence of the fossils is discussed at some length.

Shimek, B. Loess of Paha and River Ridges. (Proc. Iowa Acad. Sci., Vol. XV, pp. 117-124, Des Moines, 1908.) Objections to the eolic hypothesis are answered.

Shimek, B. Loesses of Mississippi Valley. (Science, N. S., Vol. XXVII, p. 731, New York, 1908.) Evidence is presented to effect that a loess mantle followed the deposition of each drift-sheet.

Shimek, B. Nebraskan Drift. (Science, N. S., Vol. XXXIV, p. 28, New York, 1911.) Abstract.

Shimek, B. Notes on Fossils of Loess at Iowa City. (American Geologist, Vol. I, pp. 149-152, Minneapolis, 1888.) Brief notes are given on various species of gasteropods found in the formation.

Shimek, B. Pleistocene of Missouri Valley. (Science, N. S., Vol. XXXI, pp. 75-76, New York, 1910.) The glacial deposits near Council Bluffs are differentiated and briefly characterized. Loveland and Nebraskan are new names proposed for certain glacial deposits.

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Statistics in regard to Iowa coal product. J. H. Jones. (Rept. Mining Industry in the United States at 11th Census, 1890, 343-422, 1892.)

Stereocrinus, Barris. W. H. Barris. (Proc. Acad. Sci. Davenport, IV, 102-104, 1885.)

Stevenson, W. H. Principal Soil Areas of Iowa. (Bull. Iowa State College, Exp. Station, No. 82, pp. 373-388, Ames, 1911.) Four classes of soils are recognized in the state.

Stimulus of aridity, depositional phases of eolation. C. R. Keyes. (Proc. Iowa Acad. Sci., XVIII, 101-103, 1911.)

Stone-quarries in Iowa, selection of power-plants and equipment. G. W. Bissell. (Iowa Geol. Surv., XVII, 151-183, 1907.)

Stookey, S. W. Geology of Iowa County. (Iowa Geol. Surv., Vol. XX, pp. 151-186, Des Moines, 1910.) The following subjects are considered in detail:

Introduction, location and area, previous geological work.

Physiography, topography, loess topography, table of elevations, drainage.

Stratigraphy, table of formations, Devonian system, Cedar Valley stage; Carboniferous, system, Mississippian series, Kinderhook stage, Osage and St. Louis stages, Pennsylvanian series, Des Moines stage, Quaternary system, Pleistocene series, Nebraskan stage, Aftonian interglacial stage, Kansan stage, Iowan stage; loess; Recent series, alluvium; Preglacial surface.

Economic products, soils, water-supplies, limes, building-stones, clay-products, coal, meteorites.

Flora of Iowa county.

Stookey, S. W. Geology of Poweshiek County. (Iowa Geol. Surv., Vol. XX, pp. 237-269, Des Moines, 1910.) The following topics are discussed:

Introduction, location and area, history, previous geological work.

Physiography, topography, table of elevations, drainage.

Stratigraphy, table of formations; Carboniferous system, Mississippian series, Kinderhook stage, Saint Louis stage, Pennsylvanian series, Des Moines stage; Quaternary system, Pleistocene series, Nebraskan stage, Kansan stage, loess, recent series, alluvium.

Soils, drift soils, loess soils, alluvial soils.

Economic products, coal, clay products, water-supplies, analyses, record of strata.

Story County.

Artesian wells of Iowa. W. H. Norton. (Iowa Geol. Surv., VI, 113-428, 1897.)

Buried loess in Story county. S. W. Beyer. (Proc. Iowa Acad. Sci., VI, 117-121, 1899.)

Coal deposits of Iowa. C. R. Keyes. (Iowa Geol. Surv., II, 536 pp., 1894.)

Coal deposits of Iowa. H. Hinds. (Iowa Geol. Surv., XIX, 21-396, 1909.)

General reference to geology. C. A. White. (Geology of Iowa, II, 259-260, 1870.)

Geology of clays. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XIV, 377-552, 1904.)

Geology of quarry products. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

Geology of Story county. S. W. Beyer. (Iowa Geol. Surv., IX, 155-245, 1899.)

History of coal-mining in Iowa. J. H. Lees. (Iowa Geol. Surv., XIX, 521-586, 1909.)

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Sanitary analyses of some Iowa deep-well waters. J. B. Weems. (Proc. Iowa Acad. Sci., IX, 63-70, 1902.)

Tests of clay products. A. Marston. (Iowa Geol. Surv., XIV, 555-620, 1904.)

Underground water resources of Iowa. W. H. Norton. (Iowa Geol. Surv., XXI, 29-1214, 1912.)

Underground water resources of Iowa. W. H. Norton. (U. S. Geol. Surv., Water Supply Paper No. 293, 994 pp., 1912.)

Story county, buried loess. S. W. Beyer. (Proc. Iowa Acad. Sci., VI, 117-121, 1899.)

Story county, geology. S. W. Beyer. (Iowa Geol. Surv., IX, 155-245, 1899.)

Stratification, of Postville well, apparent anomalies. S. Calvin. (American Geologist, XVII, 195-203, 1896.)

Stratigraphic relations in southeastern Iowa, Salem Limestone. F. M. Van Tuyl. (Proc. Iowa Acad. Sci., XIX, 167-168, 1912.)

Stratigraphic relations in southeastern Iowa, Salem limestone. F. M. Van Tuyl. (Science, N. S., XXXVI, 569, 1912.)

Stratigraphical location of named trans-Mississippian coals. C. R. Keyes. (Eng. and Mining Jour., LXXII, 198, 1901.)

Stratigraphical pecularities of southwestern Iowa coal fields. C. R. Keyes. (Eng. and Mining Jour., LXXIII, 661, 1902.)

Stratigraphical, probable, equivalents of coal-measures of Arkansas. C. R. Keyes. (Journal of Geology, VI, 356-365, 1898.)

Stratigraphy.

Observations on geological structure of valley Mississippi. T. Nuttall. (Jour. Acad. Nat. Sci. Philadelphia, First series, II, 14-52, 1821.)

Some physical aspects of general geological correlation. C. R. Keyes. (Proc. Iowa Acad. Sci., VI, 131-154, 1899.)

Orotaxis: method of geologic correlation. C. R. Keyes. (American Geologist, XVIII, 289-302, 1896.)

Structure of Mystic coal-basin. H. F. Bain. (Proc. Iowa Acad. Sci., I, pt. iv, 33-36, 1894.)

Stratigraphy, Kinderhook. C. R. Keyes. (Journal of Geology, VIII, 315-321, 1900.)

Stratigraphy of carboniferous in central Iowa. C. R. Keyes. (Bull. Geol. Soc. America, II, 277-292, 1891.)

Stratigraphy of St. Louis and Warsaw formations in southeastern Iowa. C. H. Gordon. (Journal of Geology, III, 289-311, 1895.)

Streams, frozen, of Iowan drift-border. A. G. Wilson. (American Geologist, XVII, 364-371, 1896.)

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Structure of Mystic coal-basin. H. F. Bain. (Proc. Iowa Acad. Sci., I, pt. iv, 33-36, 1894.)

Study of cherts of Osage series of Mississippian system. F. M. Van Tuyl. (Proc. Iowa Acad. Sci., XIX, 173-174, 1912.)

Supplementary report on Portland cement materials in Iowa. S. W. Beyer. (Iowa Geol. Surv., Bull. No. 3, 36 pp, 1906.)

Sur les meteorites d' Amana. G. D. Hinrichs, (Comptes Rendus Acad. d Sci. d. Paris, t. CXL, 545-547, 1905.)

Surface Deposits. (*See Quaternary.*)

Surface deposits in Iowa, additional observations. B. Shimek. (Proc. Iowa Acad. Sci., IV, 68-72, 1897.)

Surface Features. (*See Physiography.*)

Surface Geology of Burlington, Iowa. C. R. Keyes. (American Naturalist, XXII, 1049-1054, 1888.)

Surface Geology of Raccoon river region. O. H. St. John. (Second Ann. Rept. State Geologist, 173-190, 1868.)

Sweetland Creek Beds (Grassy Shales).

Geology of Muscatine county. J. A. Udden. (Iowa Geol. Surv., IX, 347-380, 1899.)

Nether delimitation of our carbonic rocks. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 153-156, 1912.)

Notes on geological section of Iowa. S. Calvin. (Iowa Geol. Surv., XVII, 197, 1907.)

Sweetland creek beds. J. A. Udden. (Journal of Geology, VII, 65-78, 1899.)

Sweetland Creek beds. J. A. Udden. (Journal of Geology, VII, 65-78, 1899.)

Switzerland of Iowa. S. Calvin. (Midland Monthly, III, 403-414, 1895.)

Synonomy, formational, of coal-measures of the western interior basin. C. R. Keyes. (Proc. Iowa Acad. Sci., VII, 82-105, 1900.)

Synopsis of American carbonic calyptræidæ. C. R. Keyes. (Proc. Acad. Nat. Sci. Philadelphia, 1890, 150-181, 1890.)

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Synopsis of drift deposits of Iowa. S. Calvin. (American Geologist, XIX, 270-272, 1897.)

Table of bearings of glacial striæ in Iowa, glaciated rock-surfaces near Linn and near Quarry, Iowa. W. H. Norton. (Proc. Iowa Acad. Sci., XVIII, 70-83, 1911.)

Tables of Altitudes. H. Gannett. (Bull. U. S. Geol. Surv., No. 5, Iowa, 105-112, 1884. Bull. 160, Iowa, pp. 197-221, 1899. Bull. 274, Iowa, 300-332, 1906.)

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Geological notes. J. D. Whitney. (Geology of Iowa, I, 266-273, 1858.)

Geology of Tama county. T. E. Savage. (Iowa Geol. Surv., XIII, 185-253, 1903.)

Geology of quarry products. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XVII, 189-588, 1907.)

Present phase of pleistocene problems in Iowa. S. Calvin. (Bull. Geol. Soc. America, XX, 133-152, 1909.)

Toledo lobe of Iowan drift. T. E. Savage. (Proc. Iowa Acad. Sci., X, 123-129, 1903.)

Underground water resources of Iowa. W. H. Norton. (Iowa Geol. Surv., XXI, 29-1214, 1912.)

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Underground waters of Tama county. W. J. Miller. (U. S. Geol. Surv., Water Supply Paper No. 293, 508-513, 1912.)

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Carboniferous section of southwestern Iowa, G. L. Smith. (Iowa Geol. Surv., XIX, 605-657, 1909.)
Geology of Page county. S. Calvin. (Iowa Geol. Surv., XI, 397-460, 1901.)
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Taylor County.
Analyses of Iowa coals. J. H. Lees and A. W. Hixson. (Iowa Geol. Surv., XIX, 476-519, 1909.)
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Technology of Clays. S. W. Beyer and I. A. Williams. (Iowa Geol. Surv., XIV, 29-318, 1904.)
Temperature.
Topography and climate of Iowa. H. E. Simpson. (Iowa Geol. Surv., XXI, 48-66, 1912.)
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Tenth annual report of state geologist. S. Calvin. (Iowa Geol. Surv., XII, 11-27, 1902.)

Term Augusta in geology. C. R. Keyes. (American Geologist, XXI, 229-235, 1898.)

Terminal moraine of second glacial epoch. T. C. Chamberlin. Third Ann. Rep., U. S. Geol. Surv., 291-404, 1883.)

Terrace formation in Turkey river Valley in Fayette county. G. E. Finch. (Proc. Iowa Acad. Sci., VIII, 204-206, 1901.)

Terrane crètace des environs de Sioux City. J. Marcou. (Bull. Soc. géol. de France, (2), XXIV, 56, 1866.)

Terrane, new, of carboniferous in western interior basin; Arkansan series. C. R. Keyes. (Proc. Iowa Acad. Sci., VII, 123-128, 1901.)

Terranes, time-values of provincial carboniferous. C. R. Keyes. (Am. Jour. Sci., (4), XII, 305-308, 1901.)

Tertiary Period.

Description of Elk Point quadrangle, South Dakota-Nebraska-Iowa. J. E. Todd. (U. S. Geol. Surv., Folio 156, 8 pp., 1908.)

Geographic development of eastern part of Mississippi drainage system. L. G. Westgate. (American Geologist, XI, 245-260, 1893.)

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Geology of Lyon and Sioux counties. F. A. Wilder. (Iowa Geol. Surv., X, 85-184, 1900.)

Geology of Plymouth county. H. F. Bain. (Iowa Geol. Surv., VIII, 315-366, 1898.)

Preglacial elevation of Iowa. H. F. Bain. (Proc. Iowa Acad. Sci., II, 23-26, 1895.)

Some features of channel of Mississippi river between Lansing and Dubuque, and their probable history. S. Calvin. (Proc. Iowa Acad. Sci., XIV, 213-220, 1907.)

Sundry provincial and local phases of general geologic section of Iowa. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 147-151, 1912.)

Tests of clay products. A. Marston. (Iowa Geol. Surv., XIV, 555-620, 1904.)

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Tests of Iowa building-stones, properties. H. F. Bain. (Iowa Geol. Surv., VIII, 369-416, 1898.)

Tests of Iowa coals made by government coal-testing plant at Louisiana Purchase Exposition, St. Louis, Mo., 1904. T. E. Savage. (Iowa Geol. Surv., Bull. No. 2, 22-38, 1905.)

Tests of lithographic limestone of Mitchell county, Iowa, discussion of requisite qualities of lithographic limestone with report. A. B. Hoen. (Iowa Geol. Surv., XIII, 339-351, 1903.)

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Carboniferous formations of southwestern Iowa. C. R. Keyes. (American Geologist, XXI, 346-350, 1898.)

Carboniferous section of southwestern Iowa. G. L. Smith. (Iowa Geol. Surv., XIX, 605-657, 1909.)

Formational synonymy of coal-measures of western interior basin. C. R. Keyes. (Proc. Iowa Acad. Sci., VII, 82-105, 1900.)

Missourian series of carboniferous. C. R. Keyes. (American Geologist, XXIII, 298-316, 1899.)

Note on correlation of Clarinda well-section with schematic section of carboniferous. C. R. Keyes. (Iowa Geol. Surv., XI, 461-463, 1901.)

Sundry provincial and local phases of general geologic section of Iowa. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 147-151, 1912.)

Theory of loess. B. Shimek. (Proc. Iowa Acad. Sci., III, 82-89, 1896.)

Thickness of paleozoic in Mississippi valley. C. R. Keyes. (American Geologist, XVII, 161-173, 1896.)

Thickness of paleozoic strata of northeastern Iowa. W. H. Norton. (Iowa Geol. Surv., III, 167-210, 1895.)

Third annual report of state geologist, for 1894. S. Calvin. (Iowa Geol. Surv., IV, 19-26, 1895.)

Thirteenth annual report of state geologist. F. A. Wilder. (Iowa Geol. Surv., XV, 3-11, 1905.)

Thomas, A. O. Additional Evidence of Unconformity between Cedar Valley and Lime Creek Stages of Devonian of Iowa. (Science N. S., Vol. XXXVI, pp. 569-570, New York, 1912.) A new subdivision is suggested for the Lime Creek section.

Thomas, A. O. Fossil Burrowing-sponges from Iowa Devonian. (Bull. Iowa State Univ., Lab. Nat. Hist., Vol. VI, pp. 165-166, Iowa City, 1911.)

Thomas, A. O. Relation of Lime Creek Shales to Cedar Valley Limestone of Floyd County, Iowa. (Science, N. S., Vol. XXXVII, p. 459, New York, 1913.) A marked unconformity is shown to exist at the base of the shales.

Thomas, A. O. Some Notes on Aftonian Mammals. (Science, N. S., XXXVI, p. 570, New York, 1912.) New finds are recorded.

Thomas, A. O. [Underground Waters of] Johnson County. (Iowa Geol. Surv., Vol. XXI, pp. 504-514, Des Moines, 1912.) The features of the water-supply of the area are fully noted.

Thomas, A. O. [Underground Waters of Johnson County.] (U. S. Geol. Surv., Water Supply Paper No 293, pp. 419-427, Washington, 1912.)

Till, interlœssial, near Sioux City, Iowa. J. E. Todd and H. F. Bain. (Proc. Iowa Acad. Sci., II, 20-23, 1895.)

Tilton, John L. First Reported Petrified American Lepidostrobus is from Warren County, Iowa. (Proc. Iowa Acad. Sci., Vol. XIX, pp. 163-165, Des Moines, 1912.) The cones are described and the circumstances under which they were found are detailed.

Tilton, John L. First Reported Lepidostrobus is from Warren county, Iowa. Science, N. S., Vol. XXXVI, pp. 569, New York, 1912.) Abstract.

Tilton, John L. Geological Section along Middle River in Central Iowa. (Iowa Geol. Surv., Vol. III, pp. 135-146, Des Moines, 1895.) The detailed geological cross section displays almost the complete sequence of the Des Moines series. At short intervals the local successions are noted, together with the thicknesses of the several strata.

Tilton, John L. Geology of Warren County. (Iowa Geol. Surv., Vol. V, pp. 301-359, Des Moines, 1896.) The following aspects of the subject are treated in detail:

Physiography, descriptive physiography, general relations, drainage of region, streams of Warren county, general character of streams, escarpment-makers, escarpments, skyline, dip, explanation of physiography, immensity of erosion, table of elevations.

Geological formations, Pleistocene, alluvium, loess, drift; Carboniferous, general description, relations to underlying strata, conditions of deposition, relations to overlying strata, classification of formations, detailed cross-sections, South river, Whitebreast creek, Middle river, North river, southeast to northwest.

Economic products, coal, coal-horizons, lower group, upper group, intermediate horizons, statistics of coal production; water-supplies, rainfall, wells, surface wells, deep-wells; oil and gas; minerals; building-stones, clay-deposits, clay-working plants, pottery, brick, tiling, soil.

In this report the explanation of the present physiography of the whole state is especially discussed.

Tilton, John L. Origin of Present Drainage System of Warren County. (Proc. Iowa Acad. Sci., Vol. I, pt. iv, pp. 31-33, Des Moines, 1894.) Present river valleys are larger troughs than present streams require. The valleys are preglacial in origin. The bed-rock surface is very uneven.

Tilton, John L. Pleistocene Deposits in Warren County, Iowa. (Pamphlet, 43 pp., University of Chicago Press, Chicago, 1911.)

Tilton, John L. Pleistocene Record of Simpson College Well. (Proc. Iowa Acad. Sci., Vol. XVII, pp. 159-164, Des Moines, 1910.) The various formations passed through are discussed in detail.

Tilton, John L. Problems in Municipal Water-works for small City. (Proc. Iowa Acad. Sci., Vol. XII, pp. 143-150, Des Moines, 1905.) The various plans are compared and the climatic conditions discussed. Special reference is made to Indianola.

Tilton, John L. Results of Recent Geological Work in Madison County. (Proc. Iowa Acad. Sci., Vol. IV, pp. 47-54, Des Moines, 1897.) The geologic features of the district are outlined and some of the salient points described.

Tilton, J. L. Strata Between Ford and Winterset. (Proc. Iowa Acad. Sci., Vol. I, pt. iii, pp. 26-27, Des Moines, 1893.) The section along Middle river in Madison and Warren counties is described.

Tilton, John L. [Underground Waters of] Warren County. (Iowa Geol. Surv., Vol. XXI, pp. 999-1004, Des Moines, 1912.) The water-supplies of the area are fully described.

Tilton, John L. Underground Waters of Warren County. (U. S. Geol. Surv., Water Supply Paper No. 293, pp. 815-818, Washington, 1912.)

Tilton, John L., and H. F. Bain. Geology of Madison County. (Iowa Geol. Surv., Vol. VII, pp. 489-539, Des Moines, 1897.) Detailed accounts are given of the following features:

Introduction, physiography, topography, table of elevations, drainage.

Stratigraphy, general relations of strata, classification of formations, geological formations; Carboniferous, Des Moines, Hanley section, St. Charles section, Patterson section, Raccoon river section, Missouri formation, Lincoln township section, Backbone section, South River section, Earlham section, Cedar Creek section, Winterset section, Tileville section; Pleistocene, Kansan drift, loess, alluvium.

Economic products; building-stones, Earlham district, Robertson quarry, Earlham Land Co., Nevitt quarry, Eureka Springs; Winterset district, Peru district, St. Charles-Truro district; road materials, limes, clays, water-supplies, water-powers, coal.

Times of formation of lead and zinc deposits of Mississippi valley. C. R. Keyes. (Trans. American Inst. Mining Eng. XXXI, 603-611, 1901.)

Time-values of provincial carboniferous terranes. C. R. Keyes. (Am. Jour. Sci., (4), XII, 305-309, 1901.)

Todd, J. E. Description of Elk Point Quadrangle, South Dakota-Nebraska-Iowa. (U. S. Geol. Surv., Folio 156, 8 pp., Washington, 1908.) Incidental reference is made to the strata in the extreme western edge of Plymouth county.

Todd, J. E. Annual Deposits of Missouri River During Post-Pliocene. (Proc. American Assoc. Adv. Sci., Vol. XXVI, pp. 287-291, Salem, 1877.)

Todd, J. E. Charcoal Streak in Loess. (Proc. Iowa Acad. Sci., 1875-1880, p. 21, Iowa City, 1880.) Abstract is given of a paper read before the Iowa Academy of Sciences, June 24, 1880.

Todd, J. E. Evidence that Lake Cheyenne Continued till Ice Age. (Proc. American Assoc. Adv. Sci., Vol. XXXVII, pp. 202-203, Salem, 1889.) Evidence is brought forth to show that western Iowa and eastern Nebraska were occupied by a fresh-water lake before the deposition of the drift. Claw of Megalonyx is reported from Mills county.

Todd, J. E. Folding of Carboniferous Strata in Southwestern Iowa. (Proc. Iowa Acad. Sci., Vol. I, pt. i, p. 58, Des Moines, 1890.) Abstract is given of a paper read before the Academy, with a general section of the Upper Carboniferous rocks in southwestern Iowa.

Todd, J. E. Geology and Soils. (Proc. Iowa Hort. Soc., Vol. XVI, pp. 208-213, Des Moines, 1881.) The dependence of soil on the underlying rocks is described.

Todd, J. E. History of Drift Deposits of Iowa. (Proc. Iowa Hort. Soc., Vol. XVIII, pp. 316-327, Des Moines, 1883.) The different kinds of drift-soil are distinguished and their origins described.

Todd, J. E. Inequalities in Old Paleozoic Sea-bottom. (American Geologist, Vol. XV, p. 64, Minneapolis, 1895.) The depths at which the crystalline basement is encountered in various parts of Iowa are given.

Todd, J. E. Loess and its Soils. (Proc. Iowa Hort. Soc., Vol. XVII, pp. 263-270, Des Moines, 1882.) A popular discussion of the properties of the bluff soil is given.

Todd, J. E. More light on Origin of Missouri River Loess. (Proc. Iowa Acad. Sci., Vol. XIII, pp. 187-194, Des Moines, 1906.) The mass of loess is attributed to aqueous deposition; considerable portions will prove to be the work of wind.

Todd, J. E. New Light on Drift in South Dakota. (Proc. Iowa Acad. Sci., Vol. VI, pp. 122-130, Des Moines, 1899.) Incidental references are made to the glacial geology of northwestern part of the state.

Todd, J. E. Notes on Distribution of Timber in Southwestern Iowa, with Inferences Concerning Origin of Prairies. (American Naturalist, Vol. XII, pp. 91-96, Philadelphia, 1878.) Facts in southwestern Iowa are examined in the light of the different theories concerning the origin of the prairies.

Todd, J. E. Recent Alluvial Changes in Southwestern Iowa. (Proc. Iowa Acad. Sci., Vol. XIV, pp. 257-266, Des Moines, 1907.) Details are described of the alluvial fillings in Fremont county.

Todd, J. E. Recent Wind-action upon Loess. (Proc. Iowa Acad. Sci., 1875-80, p. 21, Iowa City, 1880.) Abstract of a paper read before the Iowa Academy of Science, June 24, 1880, is given.

Todd, J. E. Relation of Loess to Drift in Southwestern Iowa. (Proc. Iowa Acad. Sci., 1875-80, p. 19, Iowa City, 1880.) A general section of the surface deposits of southwestern Iowa is given.

Todd, J. E. Richthofen's Theory of Loess in Light of Deposits of the Missouri. (Proc. American Assoc. Adv. Sci., Vol. XXVII, pp. 231-239, Salem, 1878.)

Todd, J. E. Roots and Root-marks found in Loess. (Proc. Iowa Acad. Sci., 1875-80, 17, Iowa City, 1880.) Abstract of a paper read before the Academy is given.

Todd, J. E. Some variant Conclusions in Iowa Geology. (Proc. Iowa Acad. Sci., Vol. XIII, pp. 183-186, Des Moines, 1906.) Attention is called to the character of the folding of the Carboniferous rocks of Fremont county. The stratigraphic position of the chalk-rock of northwestern Iowa, the nature of the section in the Big Sioux river, the depth of the drift in Clay and O'Brien counties, and the position of the Altamont moraine in the northwest part of the state are discussed.

Todd, J. E. Striation of Rocks by River-ice. (American Geologist, Vol. IX, pp. 396-400, Minneapolis, 1892.) It is noted that planation and striation are often accomplished by floating river-ice armed with pebbles, producing phenomena identical with glaciated surfaces.

Todd, J. E., and H. Foster Bain. Interlœssial Till near Sioux City, Iowa. (Proc. Iowa Acad. Sci., Vol. II, pp. 20-23, Des Moines, 1895.) This unusual occurrence is fully described and illustrated by photographic prints. The best exposure is at Riverside park.

Toledo lobe of Iowan drift. T. E. Savage. (Proc. Iowa Acad. Sci., X, 123-129, 1903.)

Topographic types of northeastern Iowa. W J McGee. (Proc. American Assoc. Adv. Sci., XXXVII, 248-249, 1890.)

Topography.

Description of Elk Point quadrangle, South Dakota-Nebraska-Iowa. J. E. Todd. (U. S. Geol. Surv., Folio 156, 8 pp., 1908.)

General topography of Iowa. C. A. White. (Geology of Iowa, I, 29-35, 1870.) Descriptions of the general features, with tables of elevations, and profiles across the state are given.

Geology of Allamakee county. S. Calvin. (Iowa Geol. Surv., IV, 35-111, 1895.)

Geology of Appanoose county. H. F. Bain. (Iowa Geol. Surv., V, 361-437, 1896.)

Geology of Benton county. T. E. Savage. (Iowa Geol. Surv., XV, 125-225, 1905.)

Geology of Black Hawk county. M. F. Arey. (Iowa Geol. Surv., XVI, 407-453, 1906.)

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Geology of Clayton county. A. G. Leonard. (Iowa Geol. Surv., XVI, 213-317, 1906.)

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Geology of Dallas county. A. G. Leonard. (Iowa Geol. Surv., VIII, 51-118, 1898.)

Geology of Davis county. M. F. Arey. (Iowa Geol. Surv., XX, 487-521, 1910.)

Geology of Decatur county. H. F. Bain. (Iowa Geol. Surv., VIII, 255-314, 1898.)

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Geology of Dubuque county. S. Calvin and H. F. Bain. (Iowa Geol. Surv., X, 379-651, 1900.)

Geology of Emmet, Palo Alto and Pocahontas counties. T. H. Macbride. (Iowa Geol. Surv., XV, 227-276, 1905.)

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Geology of Jefferson county. J. A. Udden. (Iowa Geol. Surv., XII, 355-437, 1902.)

Geology of Johnson county. S. Calvin. (Iowa Geol. Surv., VII, 33-116, 1897.)

Geology of Jones county. S. Calvin. (Iowa Geol. Surv., V, 33-112, 1896.)

Geology of Linn county. W. H. Norton. (Iowa Geol. Surv., IV, 121-194, 1895.)

Geology of Louisa county. J. A. Udden. (Iowa Geol. Surv., XI, 53-126, 1901.)

Geology of Lyon and Sioux counties. F. A. Wilder. (Iowa Geol. Surv., X, 85-184, 1900.)

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Geology of Mahaska county. H. F. Bain. (Iowa Geol. Surv., IV, 313-380, 1895.)

Geology of Marion county. B. L. Miller. (Iowa Geol. Surv., XI, 127-197, 1901.)

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Geology of Plymouth county. H. F. Bain. (Iowa Geol. Surv., VIII, 315-355, 1898.)

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Geology of Sac and Ida counties. T. H. Macbride. (Iowa Geol. Surv., XVI, 509-548, 1906.)

Geology of Scott county. W. H. Norton. (Iowa Geol. Surv., IX, 389-519, 1899.)

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Geology of Van Buren county. C. H. Gordon. (Iowa Geol. Surv., IV, 197-254, 1895.)

Geology of Wapello county. A. G. Leonard. (Iowa Geol. Surv., XII, 439-499, 1902.)

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Geology of Winneshiek county. S. Calvin. (Iowa Geol. Surv., XVI, 37-146, 1906.)

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Mississippi valley between Savanna and Davenport. J. E. Carman. (Bull. Illinois Geol. Surv., No. 13, 96 pp., 1909.)

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Physiography of Iowa. S. Calvin. (Iowa Weather and Crop Service, Ann. Rept. for 1902, 3-11, 1903.)

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Tables of altitudes. H. Gannett. (Bull. U. S. Geol. Surv., No. 5, Iowa, 105-112, 1884. Bull. 160, Iowa, 197-221, 1899. Bull. 274, Iowa, 300-332, 1906.)

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Topography and climate of Iowa. H. E. Simpson. (Iowa Geol. Surv. XXI, 48-66, 1912.)

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Torrey, Joseph, Jr., and E. H. Barbour. Recorded Meteorites of Iowa, with Special Mention of Last, or Winnebago County, Meteorite. (American Geologist, Vol. VIII, pp. 65-72, Minneapolis, 1891.)

Torrey, Joseph, Jr., and E. H. Barbour. Winnebago County (Iowa) Meteorites. (Science, Vol. XV, p. 347, New York, 1890.) Reference is made to a fragment supposed to be a piece of meteorite. The authors claim it was not, and base their claims on the grounds of: Too low specific gravity, absence of metals and external crust, and chemical analysis.

Transition forms in crinoids and description of five new species. Charles Wachsmuth and Frank Springer. (Proc. Acad. Nat. Sci. Philadelphia, 224-226, 1878.)

Transitional drift. Clement L. Webster. (American Naturalist, XXIV, 1182-1185, 1890.)

Trans-Mississippian coals, geological position. C. R. Keyes. (Eng. and Mining Jour., LXIX, 528-529, 1900.)

Trans-Mississippian coals, horizons of Arkansas and Indian Territory coals compared. C. R. Keyes. (Eng. and Mining Jour., LXXI, 692-693, 1901.)

Trans-Mississippian coals, stratigraphical location. C. R. Keyes. (Eng. and Mining Jour., LXXII, 198, 1901.)

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Trilobites.

Description of new species. D. D. Owen. (Rept. Geol. Surv. Wisconsin, Iowa and Minnesota, App., Art. i, 573-577, 1852.)

Turkey River valley in Fayette county, Iowa, terrace formation. G. E. Finch. (Proc. Iowa Acad. Sci., VIII, 204-206, 1901.)

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Two remarkable cephalopods from upper paleozoic. C. R. Keyes. (Proc. Iowa Acad. Sci., III, 76-78, 1896.)

Two unique spirifers from devonian strata of Iowa. S. Calvin. (Bull. Lab. Nat. Hist., State Univ. Iowa, II, 165-167, 1893.)

Types and figured specimens in Paleontological collections of geological department, American museum of natural history; lower carboniferous to pleistocene, inclusive. R. P. Whitfield and E. O. Hovey. (Bull. American Mus. Nat. Hist., XI, pt. 4, 357-500, 1901.)

Udden, Johan A. Account of Paleozoic Rocks Explored by Deep-borings at Rock Island and Vicinity. (Seventeenth Ann. Rept. U. S. G. S., pt. ii, pp. 829-849, Washington, 1896.) The strata passed through in wells at Davenport are noted.

Udden, Johan, A. Diatomaceous Earth in Muscatine County. (Proc. Iowa Acad. Sci., Vol. VI, p. 53, Des Moines, 1899.) A deposit is reported associated with ancient peat under the loess. Fragments of the peculiar deposit are also found in Scott county.

Udden, Johan A. Dipterus in American Middle Devonian. (Journal of Geology, Vol. VII, pp. 494-495, Chicago, 1899.) The occurrence of the form in the rocks of Iowa is especially noted.

Udden, Johan A. Foraminiferal Ooze in Coal Measures of Iowa. (Journal of Geology, Vol. XI, pp. 283-284, Chicago, 1903.) A number of genera of Rhizopods are reported and vast numbers of individuals are said to extend throughout the Missouri section.

Udden, Johan A. Geology of Jefferson County. (Iowa Geol. Surv., Vol. XII, pp. 355-437, Des Moines, 1902.) There are described:

Introduction, area and location, earlier investigations.

Physiography, topography, flat uplands, upland slopes, terraces, bottom lands, table of elevations, drainage.

Stratigraphy, general relations of strata, underlying formations; Saint Louis, distribution and local sections, sections on Burr Oak and other creeks, on Walnut creek, Rocky branch, Turkey creek and adjacent ravines, Brush creek and Wolf creek, Cedar creek basin, Des Moines river basin, Springvale beds, Lower Verdi beds, Upper Verdi beds, Pella beds, geographical conditions, correlations; Des Moines, distribution and local sections, Walnut township, Lockridge township, Round Prairie township, Penn, Buchanan, Cedar, Black Hawk, Fairfield, Liberty, Polk, Locust Grove, Des Moines, thickness of the Des Moines, general character, correlations; table of fossils; erosion intervals; well-records; Pleistocene, associated gravels, bowlder clays, loess, alluvial deposits, Pleistocene fossils, geological structure, joints, glacial-scorings.

Economic products, building-stones, clay industries, coal, water-resources, soils.

Udden, Johan A. Geology of Louisa County. (Iowa Geol. Surv., Vol. XI, pp. 53-126, Des Moines, 1901.) The subjects discussed are as follows:

Introduction, location and area, earlier investigations.

Physiography, topography, Mississippi bottoms, Iowa river lowlands, east drift plain, table of altitudes, drainage.

Stratigraphy, general relations of strata, underlying formations; Mississippian series, typical sections, sections in bluffs and creeks north and east of Morning Sun, sections in Otter Creek basin, sections in Long Creek basin, sections on Clifton Creek and Iowa river, general section of subcarboniferous rocks, Maple Hill shale, English River gritstone (Chonopectus sandstone), "lithographic" limestone, Upper gritstone, Wassonville limestone, Lower Burlington limestone, main lower chert, Upper Burlington limestone, Montrose chert, upper shaly limestone, correlation, geographic conditions, Saint Louis limestone; Des Moines; subsequent history; Ozarkian and geest, table of well records; Pleistocene, Albertan, Aftonian, Kansan, Buchanan gravel and Yarmouth soil, Illinoian, Sangamon, loess, terraces and alluvium.

Economic products, Geological structure; joints; minerals; building-stones and macadam, clay products, natural-gas, gravels and sands, soils, water-supplies.

Udden, Johan A. Geology of Mills and Fremont Counties. (Iowa Geol. Surv., Vol. XIII, pp. 123-183, Des Moines, 1903.) The following subjects are discussed in detail:

Introduction, location and area, earlier investigations.

Physiography, topography, upland flats, upland slopes, lowlands and terraces, drainage, table of elevations.

Stratigraphy, general statement, deep explorations; Carboniferous, Missourian, exposures in and near bluffs of the Missouri in Mills county, exposures in and near the bluffs of the Missouri river in Fremont county, sections in the uplands east of Hamburg, scattered exposures, correlations, geographical conditions, fauna and flora, list of fossils; Cretaceous, erosion interval;

Pleistocene, ante-glacial silt, bowlder clay, gumbo, loess, fossil snails of the loess, alluvium, calcareous tufa, geological structure, ice-scorings.

Economic products, building-stones, coal, clay industries, water-supplies, sands and gravels, soils.

Udden, Johan A. Geology of Muscatine County. (Iowa Geol. Surv., Vol. IX, pp. 247-380, Des Moines, 1899.) The following subjects are dealt with in detail:

Introduction, location and area, earlier investigations.

Physiography, topography, Mississippi bottoms, West Liberty plain, Illinoian drift-plain, Kansan drift-plain, table of elevations, drainage.

Stratigraphy, general relations of strata, underlying formations, Silurian system; Devonian system, Fayette breccia and Cedar Valley limestone, Sweetland creek beds; Carboniferous system, Des Moines stage, Pine Creek conglomerate; preglacial erosion; Pleistocene, ante-glacial silt, glacial deposits, pre-Kansan till, Kansan till, Buchanan gravel and Yarmouth soil, Illinoian till, Sangamon soil and leached horizon, Lake Calvin, loess, terraces and alluvium; deformations; joints, earth temperatures; minerals.

Economic products, coal, building-stones, gravels, sands, clay industries, Fairport potteries, brick and tile, water supplies, natural gas, soils.

Udden, Johan A. Geology of Pottawattamie County. (Iowa Geol. Surv., Vol. XI, pp. 199-277, Des Moines, 1901.) The following topics are considered in detail:

Introduction, location and area, previous investigations.

Physiography, topography, flood-plains, uplands, table of elevations, history of drainage.

Stratigraphy, general statement, deep-explorations; Carboniferous, Missourian; Cretaceous; Tertiary erosion, well-records; Pleistocene, ante-glacial silt and sand, bowlder-clay, pre-Kansan, valley-drift gravel, gumbo, loess, terrace and alluvium, deformations, joints, ice-scorings.

Economic products, building stones, clay industries, water supplies, coal, road-ballast, soils.

Udden, Johan A. Occurrence of Rhizopods in Pella Beds in Iowa. (Proc. Iowa Acad. Sci., Vol. IX, p. 120, Des Moines, 1902.) Several species are identified in material from the St. Louis limestone of Jefferson county.

Udden, Johan A. Pine Creek Conglomerate. (Proc. Iowa Acad. Sci., Vol. VI, pp. 54-56, Des Moines, 1899.) Lithologically the bed resembles the Rockville conglomerate, and a rock of Cretaceous age found in Guthrie county. The suggestion is made that the Muscatine deposit may be also of the same age.

Udden, Johan A. Pleuroptyx in Iowa Coal measures. (Proc. Iowa Acad. Sci., Vol. IX, p. 121, Des Moines, 1902.) Remains of a batrachian are noted from the rocks of Jefferson county.

Udden, Johan A. Some Cretaceous Drift Pebbles in Northern Iowa. (American Geologist, Vol. XXIV, pp. 389-390, Minneapolis, 1899.) The original locality of the pebbles is thought to be to the north and not to the northwest where Cretaceous rocks are now exposed.

Udden, Johan A. Some Pre-Glacial Soils. (Proc. Iowa Acad. Sci., Vol. V, pp. 102-104, Des Moines, 1908.) South of the driftless area and beneath the Kansan till old soils are exposed in numerous localities. Between two of them is a fossiliferous loesslike bed. They attain a thickness of 16 feet in places.

Udden, Johan A. Some Preglacial soils. (American Geologist, Vol. XXI, pp. 262-264, Minneapolis, 1898.) A number of fossils were collected in Iowa.

Udden, Jon Andreas. Geology of Clinton County. (Iowa Geol. Surv., Vol. XV, pp. 369-451, Des Moines, 1905.) The following subjects are considered in detail:

Introduction, area and location, previous investigations.

Physiography, topography, Mississippi lowlands, Wapsipinicon lowlands, Iowan drift-plain, older drift-plain, Goose Lake channel, drainage, table of altitudes.

Stratigraphy, general relations of strata, underlying formations, data, older Clinton wells, the latest waterworks well, Pitch well, description of section; basal sandstones and shales; Saint Lawrence, Jordan and Oneota; Saint Peter, Galena and Trenton, Maquoketa shale; Niagara limestone, summary of the section.

Ordovician system, Maquoketa shale, exposures, thickness and geographical distribution.

Silurian system, Niagara limestone, areal extent, description by townships, Berlin, Bloomfield, Brookfield, Camanche, Centre, Deep Creek, Dewitt, Elden, Elk River, Hampshire, Liberty, Lincoln, Olive, Orange, Sharon, Spring Rock, Spring Valley, Washington, Waterford, Welton, divisions of Niagara, thickness of Niagara.

Carboniferous system, Des Moines stage.

Erosion intervals; geest.

Table of well-records.

Pleistocene system, pre-Kansas stage, Illinoian drift, Iowan drift, gravels of uncertain age, loess, alluvium.

Geological structure.

Minerals.

Economic products, clay industries, sands and gravels, building-stones; water-supplies; soils; quicklime; coal, lead and copper.

Ueber das Carbon des Mississippithales. C. R. Keyes. (Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie, Jahrg. 1896, I, 96-110, 1896.)

Ulrich, E. O. Paleozoic bryozoa. (Geol. Surv., Illinois, Vol. VIII, pp. 283-688, Springfield, 1890.) A number of species from Iowa are described as new.

Ulrich, E. O. Sponges of Devonian and Carboniferous Systems. (Geol. Surv. Illinois, Vol. VIII, pp. 243-251, Springfield, 1890.) Two species from Iowa are described as new.

Unconformity.

Arkansan series: new terrane of Carboniferous in the western interior basin. C. R. Keyes. (Proc. Iowa Acad. Sci., VIII, 123-128, 1901.)

Character of unconformability of Iowa coal-measures upon older rocks. C. A. White. (Am. Jour. Sci., (2), XLV, 331-334, 1868.)

Depositional equivalent of hiatus at base of our coal-measures. C. R. Keyes. (Proc. Iowa Acad. Sci., VIII, 119-123, 1901.)

Depositional measure of unconformity. C. R. Keyes. (Bull. Geol. Soc. America, XII, 173-196, 1901.)

Devonian fishes of Iowa. C. R. Eastman. (Iowa Geol. Surv., XVIII, 29-360, 1908.)

Devonian hiatus in continental interior; its character and depositional equivalents. C. R. Keyes. (Proc. Iowa Acad. Sci., IX, 105-112, 1902.)

Distribution and relations of St. Louis limestone in Mahaska county, Iowa. H. F. Bain. (Iowa Geol. Surv., I, 171-179, 1893.)

Geological formations of Iowa. C. R. Keyes. (Iowa Geol. Surv., I, 11-161, 1893.)

Geological reconnaissance in Buchanan county, Iowa. S. Calvin. (Bull. Lab. Nat. Hist., State Univ. Iowa, II, 177-189, 1893.)

Geological structure and relations of coal-bearing strata of central Iowa. C. R. Keyes. (Proc. Iowa Acad. Sci., I, pt. ii, 27-28, 1892.)

Geology of Benton county. T. E. Savage. (Iowa Geol. Surv., XV, 125-225, 1905.)

Geology of Black Hawk county. M. F. Arey. (Iowa Geol. Surv., XVI, 407-452, 1906.)

Geology of Buchanan county. S. Calvin. (Iowa Geol. Surv., VIII, 201-253, 1898.)

Geology of Cerro Gordo county. S. Calvin. (Iowa Geol. Surv., VII, 117-195, 1897.)

Geology of Henry county. T. E. Savage. (Iowa Geol. Surv., XII, 237-302, 1902.)

Geology of Howard county. S. Calvin. (Iowa Geol. Surv., XIII, 21-79, 1903.)

Geology of Jackson county. T. E. Savage. (Iowa Geol. Surv., XVI, 563-649, 1906.)

Geology of Jefferson county. J. A. Udden. (Iowa Geol. Surv., XII, 355-437, 1902.)

Geology of Johnson county. S. Calvin. (Iowa Geol. Surv., VII, 33-116, 1897.)

Geology of Jones county. S. Calvin. (Iowa Geol. Surv., V, 33-112, 1896.)

Geology of Keokuk county. H. F. Bain. (Iowa Geol. Surv., IV, 255-311, 1895.)

Geology of Lee county. C. R. Keyes. (Iowa Geol. Surv., III, 305-407, 1894.)

Geology of Mahaska county. H. F. Bain. (Iowa Geol. Surv., IV, 313-380, 1895.)

Geology of Marion county. B. L. Miller. (Iowa Geol. Surv., XI, 127-197, 1901.)

Geology of Muscatine county. J. A. Udden. (Iowa Geol. Surv., IX, 247-380, 1899.)

Geology of Page county. S. Calvin. (Iowa Geol. Surv., XI, 397-460, 1901.)

Geology of Story county. S. W. Beyer. (Iowa Geol. Surv., IX, 155-245, 1899.)

Geology of Van Buren county. C. H. Gordon. (Iowa Geol. Surv., IV, 197-254, 1895.)

Geology of Wapello county. A. G. Leonard. (Iowa Geol. Surv., XII, 439-499, 1902.)

Geology of Washington county. H. F. Bain. (Iowa Geol. Surv., V, 115-173, 1896.)

Geology of Webster county. F. A. Wilder. (Iowa Geol. Surv., XII, 63-235, 1902.)

Geology of Winneshiek county. S. Calvin. (Iowa Geol. Surv., XVI, 37-146, 1906.)

Gypsum deposits of Iowa. C. R. Keyes. (Iowa Geol. Surv., III, 257-299, 1895.)

Horizons of Arkansas and Indian Territory coals compared with those of other trans-Mississippian coals. C. R. Keyes. (Eng. and Mining Jour., LXXI, 692-693, 1901.)

Inequalities in old paleozoic sea-bottom. J. E. Todd. (American Geologist, XV, p. 64, 1895.)

Marked unconformity between carboniferous and devonian strata in upper Mississippi valley. C. R. Keyes. (Am. Jour. Sci., (4), XXXVI, 160-164, 1913.)

Nether delimitation of our carbonic rocks. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 153-156, 1912.)

Notes on Redrock sandstone. C. R. Keyes. (Proc. Iowa Acad. Sci., I, pt. ii, 26-27, 1892.)

Orotaxial correlation of geological terranes and diastrophism. C. R. Keyes. (Proc. Iowa Acad. Sci., XVI, 153-157, 1909.)

Redrock sandstone of Marion county, Iowa. C. R. Keyes. (Am. Jour. Sci., (3), XLI, 273-276, 1891.)

Relation of Lime Creek shales to Cedar Valley limestone of Floyd county, Iowa. A. O. Thomas. (Science, N. S., XXXVII, 459, 1913.)

Some physical aspects of general geological correlation. C. C. Keyes. (Proc. Iowa Acad. Sci., VI, 131-154, 1899.)

Stratigraphy of carboniferous in central Iowa. C. R. Keyes. (Bull. Geol. Soc. America, II, 277-292, 1891.)

Stratigraphy of St. Louis and Warsaw formations in southeastern Iowa. C. H. Gordon. (Journal of Geology, III, 289-311, 1895.)

Sundry provincial and local phases of general geologic section of Iowa. C. R. Keyes. (Proc. Iowa Acad. Sci., XIX, 147-151, 1912.)

Unconformable on underlying strata. J. Hall. (Proc. American Assoc. Adv. Sci., X, 51-69, 1857.)

Sweetland creek beds. J. A. Udden. (Journal of Geology, VII, 65-78, 1899.)

Time-values of provincial carboniferous terranes. C. R. Keyes. (Am. Jour. Sci., (4), XII, 305-309, 1901.)

Unconformity between carboniferous and devonian strata in upper Mississippi valley. C. R. Keyes. (Am. Jour. Sci., (4), XXXVI, 160-164, 1913.)

Unconformity between Cedar Valley and Lime Creek stages of Devonian of Iowa, additional evidence. A. O. Thomas. (Science, N. S., XXXVI, 569-570, 1912.)

Unconformity, depositional measure. C. R. Keyes. (Bull. Geol. Soc. America, XII, 173-196, 1901.)

Underground water resources of Iowa. W. H. Norton. (Iowa Geol. Surv., XXI, 29-1214, 1912.)

Underground water resources of Iowa. W. H. Norton. (U. S. Geol. Surv., Water Supply Paper No. 293, 994 pp., 1912.)

Underground Waters.

Description of Elk Point quadrangle, South Dakota-Nebraska-Iowa. J. E. Todd. (U. S. Geol. Surv., Folio 156, 8 pp., 1908.)

Sanitary analyses of some Iowa deep-well waters. J. B. Weems. (Proc. Iowa Acad. Sci., IX, 63-70, 1902.)

Sioux City water-supply. A. N. Cook and C. F. Eberly. (Proc. Iowa Acad. Sci., IX, 90-101, 1902.)

Underground water resources of Iowa. W. H. Norton. (Iowa Geol. Surv., XXI, 29-1214, 1912.)

Underground water resources of Iowa. W. H. Norton. (U. S. Geol. Surv., Water Supply Paper No. 293, 994 pp., 1912.)

Underground waters of eastern United States: Iowa. W. H. Norton. (Water-Supply and Irrigation Papers, U. S. Geol. Surv., No. 114, 220-225, 1905.)

Underground waters, chemical composition. W. S. Hendrixson. (Iowa Geol. Surv., XXI, 159-211, 1912.)

Underground waters, chemical composition. W. S. Hendrixson. (U. S. Geol. Surv., Water Supply Paper No. 293, 135-183, 1912.)

Underground waters of Buchanan county. M. F. Arey. (Iowa Geol. Surv., XXI, 333-338, 1912.)

Underground waters of Buchanan county. M. F. Arey. (U. S. Geol. Surv., Water Supply Paper No. 293, 281-285, 1912.)

Underground waters of Chickasaw county. O. E. Meinzer. (Iowa Geol. Surv., XXI, 339-341, 1912.)

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White, Charles A. Exogenous Leaves in Cretaceous Rocks of Iowa. (Am. Jour. Sci., (2), Vol. XLIV, p. 119, New Haven, 1867.) The note announces the discovery of exogenous leaves, and shows that the "Nishnabotna sandstone" is identical with the Dakota group.

White, Charles A. First Annual Report of Progress of State Geologist. (Pamphlet, pp. 1-4, Des Moines, 1867.) A statement of the work done during the year previous is given.

White, Charles A. First Annual Report of State Geologist. (First and Second Annual Report by the State Geologist, on Geological Survey of State of Iowa, pp. 5-8, Des Moines, 1868.) A short report is given of the work

carried on during the preceding two years, with a reprint of popular letters appearing in the various newspapers of the state.

White, Charles A. Geological Map Model of Iowa. (Geology of Iowa, Vol. I, p. 32, Des Moines, 1870.)

White, Charles A. Geological Map of State of Iowa. (Geology of Iowa, Vol. II, Des Moines, 1870.)

White, Charles A. Iowa Drift. (American Naturalist, Vol. II, pp. 615-616, Salem, 1869.) The derivation of the drift-material from the underlying rocks, by their disintegration and comminution, is shown.

White, Charles A. Lakes of Iowa; Past and Present. (American Naturalist, Vol. II, pp. 143-155, Salem, 1868.) The drift lakes, including the so-called "walled" lakes, are described, and the origin of the "walls" is explained. Also the bluff deposit of the Missouri river valley is shown to be the deposit of an ancient lake.

White, Charles A. Lakes of Iowa; Past and Present. (Second Ann. Rep. State Geologist, pp. 151-163, Des Moines, 1868.) A popular description of some of the lakes in Iowa is given.

White, Charles A. Note on "Cone-in-cone." (Am. Jour. Sci. (2), Vol. XLV, pp. 400-401, New Haven, 1868.) The mineral mentioned is from the lower coal measures of Iowa.

White, Charles A. Observations on Red Quartzite Boulders of Western Iowa; and their Original Ledges of Red Quartzite in Iowa, Dakota and Minnesota. (Proc. American Assoc. Adv. Sci., Vol. XVII, pp. 340-342, Cambridge, 1869.)

White, Charles A. Observations on Summit Structure of Pentremites, the Structure and Arrangement of Certain Parts of Crinoids, and Description of New Species from Carboniferous Rocks of Burlington, Iowa. (Boston Jour. Nat. Hist., Vol. VII, pp. 481-506, Boston, 1863.)

White, Charles A. Observations upon Geology and Paleontology of Burlington, Iowa, and its Vicinity. (Boston Jour. Nat. Hist., Vol. VII, pp. 209-235, Boston, 1860.) A detailed description is given of the rock-section at Burlington, Iowa, with table showing vertical range of the more important fossils. All below the oölite is referred to the Chemung (Devonian). Several species are described as new.

White, Charles A. Observations upon Drift Phenomena of Southwestern Iowa. (Second Ann. Rep. State Geologist, pp. 143-148, Des Moines, 1868.) A short account of the glacial scratches and drift materials is given.

White, Charles A. Observations upon Drift Phenomena of Southwestern Iowa. (Am. Jour. Sci., (2), Vol. XLIII, pp. 301-305, New Haven, 1867.) Special attention is directed to the glacial striæ upon rocks *in situ*.

White, Charles A. Occurrence of Later Cretaceous Deposits in Iowa. (American Geologist, Vol. I, pp. 221-227, Minneapolis, 1888.) Notes on certain fossils found in the drift in Hardin county are presented.

White, Charles A. Report of Geological Survey of State of Iowa. (Vol. I, pp. i-viii and 1-391, Des Moines, 1870.)

Introduction: Historical statement, popular explanations, and general classification of the Iowa rocks.

PART FIRST (PHYSICAL GEOGRAPHY AND SURFACE GEOLOGY).

Chapter I is a general account of the surface features of the state: Boundaries, general topography, drainage, springs, etc.

Chapter II forms a general description of the surface deposits of the state, with detailed accounts of the composition, distribution and origin of the drift, alterėd drift, alluvium and bluff-deposits (loess).

Chapter III treats of the soils of the drift, loess (bluff) and alluvium; and of the adaptability of the Iowa soils for the growth of the forest trees. Also, an explanation of origin of prairies.

Chapter IV is on the climate of Iowa. (See T. S. Parvin, 1870.)

PART SECOND (GENERAL GEOLOGY).

Chapter I describes the area, general characters, economic value and the fossils of the Archæan, Lower Silurian and Upper Silurian and their general subdivisions.

Chapter II gives an account of the Subcarboniferous; the general characters, economic value and fossils of the Kinderhook, Burlington, Keokuk and St. Louis limestones, together with sections and their minor subdivisions. Notes are also given on the unconformability of the coal measures upon older rocks and of the St. Louis limestone upon older formations of the Subcarboniferous group.

Chapter III: The lower, middle and upper coal measures are recognized by their general characters; and their economic value and fossil features are described. Also general observations are made on the Carboniferous rocks of Iowa, with some practical conclusions.

Chapter IV treats of the middle coal measures. (See O. H. St. John, 1870).

Chapter V. Earlier Cretaceous, Nishnabotna sandstone, Woodbury shales and Inoceramus beds are described; and their areas, lithological character, economic value and fossils noted.

PART THIRD (COUNTY GEOLOGY).

Chapter I is a general account of the geology of southwestern Iowa, with special descriptions of the geological features of seventeen counties.

White, Charles A. Report of Geological Survey of State of Iowa. (Vol. II, pp. i-viii and 1-435, Des Moines, 1870.)

PART FIRST (COUNTY GEOLOGY).

Chapter I deals of the geology of the middle region of western Iowa. (See O. H. St. John, 1870.) The physical features and general geology are described, with special reference to the post-tertiary, cretaceous and coal-measures. The general features of the following counties are briefly described, with numerous sections: Woodbury county, Monona, Harrison, Shelby, Crawford, Audubon, Sac, Ida, Calhoun, Carroll, Greene, Guthrie, Dallas, Polk, Boone, Webster.

Chapter II treats chiefly of northwestern Iowa. The general characteristics of the geology and material resources, and the geological features of the following counties are briefly described:
Pocahontas county, Palo Alto, Emmet, Dickinson, Clay, Buena Vista, Cherokee, O'Brien, Osceola, Lyon, Sioux, Plymouth.

Chapter III describes the middle region of northern Iowa, including the geology of the following counties:
Franklin county, Wright, Cerro Gordo, Hancock, Worth, Winnebago, Kossuth, Humboldt.

Chapter IV deals with the geology of the coal measures. A few preliminary notes and a rather full account of the geological features of the following counties are given: Webster county, Hamilton, Hardin, Boone, Story, Marshall, Polk, Jasper, Warren, Marion, Mahaska, Keokuk, Monroe, Wapello, Appanoose, Davis, Van Buren, Jefferson.

PART SECOND (ECONOMIC GEOLOGY).

Chapter I describes at length the peat formation of the state; also brief reference is made to the petroleum.

Chapter II describes in detail the gypsum deposits and related materials.

Chapter III gives an account of the building materials, especially the clays found in the eastern part of the state; also more or less brief mention of the limestone, fireclay, road materials, etc., with brief allusion to the artesian wells and mineral springs.

Chapter IV is chiefly a report of chemical work done by the Survey. (See Rush Emery, 1870.) This includes minerals, rocks, lead, clays, coals, waters, and peats.

Appendix A is a list of railroad elevations by chief engineers of the different railways.

Appendix B is a catalogue of Iowa Birds. (By J. A. Allen.)
Appendix C is an explanation of land surveys. (By C. W. Irish.)

White, Charles A. Report upon Invertebrate Fossils Collected in Portions of Nevada, Utah, Colorado, New Mexico and Arizona by Parties of Expeditions of 1871, 1872, 1873 and 1874. (Rept. Geol. and Geog. Expl. and Surv. W. 100 Mer., Vol. IV, pp. 1-219, Washington, 1875.) A number of species from Iowa are described as new.

White, Charles A. Second Annual Report of State Geologist on Geological Survey of State of Iowa. (Pamphlet, pp. 81-284, Des Moines, 1868.) A short sketch is given of the work done, with reprint of popular letters appearing in the various newspapers of the state.

White, Charles A. Sketch-Map of State of Iowa. (Geological Magazine, (1), Vol. VIII, p. 222, London, 1871.)

White, Charles A. Sketch of Geology of Southwestern Iowa. (Am. Jour. Sci., (2), Vol. XLIV, pp. 23-31, New Haven, 1867.) It is shown that the limestones of the region discussed belong to the upper and not to the lower carboniferous series, as has been supposed by some previous authors.

White, Charles A. Soils of Iowa and Their Origin. (Rep. Sec. Iowa State Agric. Soc., 1865, pp. 245-267, 1865.) A popular lecture was delivered before the society, September 29, 1865.

White, Charles A. Spontaneous Fission? in Zaphrentis. (Am. Jour. Sci., (3), Vol. V, p. 72, New Haven, 1873.) Special reference is made to specimens from the St. Louis limestone of Marion county.

White, Charles A. Trip to Great Red Pipestone Quarry. (American Naturalist, Vol. II, pp. 644-653, Salem, 1869.)

White, Charles A., and O. H. St. John. Descriptions of New Subcarboniferous and Coal Measure Fossils, collected upon Geological Survey of Iowa, together with notice of new Generic Characters observed in two Species of

Brachiopods. (Trans. Chicago Acad. Sci., Vol. I, pp. 115-127, Chicago, 1867.) Fourteen species of fossils are described as new from Iowa rocks.

White, Charles A., and O. H. St. John. Preliminary Notice of New Genera and Species of Fossils, by C. A. White and O. H. St. John. (Pamphlet, pp. 1-3, Iowa City, 1867.)

White, Charles A., and R. P. Whitfield. Observations upon Rocks of Mississippi Valley which have been Referred to Chemung Group of New York, together with Descriptions of new Species of Fossils from same Horizon at Burlington, Iowa. (Proc. Boston Soc. Nat. Hist., Vol. VIII, pp. 289-316, Boston, 1862.) Several species are described as new from Iowa.

Whitfield, R. P. Description of New Species of Crinoid from Burlington Limestone, at Burlington, Iowa. (Bull. American Mus. Nat. Hist., Vol. I, pp. 7-9, New York, 1881.) *Poteriocrinus jesupi* is described and figured as new from Iowa.

Whitfield, R. P. Discovery of Second Example of Macrouran Decapod Crustacean, Palæo-palæomon Newberryi. (American Geologist, Vol. IX, pp. 237-238, Minneapolis, 1892.) The form is described, and a detailed comparison is made with the type.

Whitfield, R. P. Fauna of Lower Carboniferous Limestones of Spergen Hill, Ind., with Revision of Descriptions of its Fossils hitherto Published, and Illustrations of Species from Original Type Series. (Bull. American Mus. Nat. Hist., Vol. I, pp. 39-97, New York, 1882.) A number of the species reported from Iowa localities are described.

Whitfield, R. P. Notice of New Genus and Species of Lower Carboniferous Bryozoan. (Bull. American Mus. Nat. Hist., Vol. XX, p. 469, New York, 1904.) *Dictyoretmon burlingtonensis* is described as new from Burlington.

Whitfield, R. P. Paleontology of Wisconsin. (Geol. Surv., Wisconsin, Vol. IV, pp. 163-349, Madison, 1882.) A number of species of fossils from Iowa localities are noted.

Whitfield, R. P. Recapitulation of Descriptions of Lower Carboniferous Crinoidea from the Hall Collection now in American Museum of Natural History, with Illustrations of Original Type Specimens not heretofore figured. (Mem. American Mus. Nat. Hist., Vol. I, pt. i, pp. 1-37, New York, 1893.) The original descriptions are reprinted with notes.

Whitfield, R. P., and J. Hall. Description of New Species of Fossils from Devonian Rocks of Iowa. (New York State Cab. Nat. Hist., 23d Ann. Rept., pp. 223-239, Albany, 1873.)

Whitfield, R. P., and E. O. Hovey. Catalogue of Types and Figured Specimens in Paleontological Collections of Geological Department, American Museum of Natural History; Lower Carboniferous to Pleistocene, inclusive. (Bull. American Mus. Nat. Hist., Vol. XI, pt. 4, pp. 357-500, New York, 1901.) Many of the forms are from Iowa.

Whitney, J. D. Chemistry and Economical Geology. (Geology of Iowa, I, 324-472, Albany, 1858.) The chemical composition and lithological characters of the various geological formations are noted with chemical analyses; also notes on the mode of occurrence of lead-ore in northeastern Iowa are given.

Whitney, J. D. County Geology. (Geology of Iowa, I, 259-323, Albany. 1858.) Detailed notices of the geology of the central and northern counties in the eastern part of Iowa are given.

Whitney, J. D. Geological Map of Lead Region in States of Wisconsin, Illinois and Iowa. (Geol. Surv. Wisconsin, Vol. I, Albany, 1862.)

Whitney, J. D. Geology of Lead Region. (Geol. Surv. Illinois, Vol. I, pp. 153-207, Springfield, 1866.) Numerous references to the occurrence of lead in northeastern Iowa are given.

Whitney, J. D. Physical Geography of Iowa. (Geology of Iowa, Vol. I, pp. 1-34, 1858.) A descriptive account of the surface features, soil and climate of Iowa is presented.

Wilcox, O. W. Certain Aspects of Loess of Southwestern Iowa. (Journal of Geology, Vol. XII, pp. 716-721, Chicago, 1904.) At Red Oak three loess-sheets are distinctly seen; the yellow, white, and red, overlying the Kansan drift sheet.

Wilcox, O. W. So-called Alkali Spots of Younger Drift-sheets. (Journal of Geology, Vol. XIII, pp. 254-263, Chicago, 1905.) These areas are found in small undrained basins. The effervescence is mainly compound of magnesian sulphates; and the soils are therefore not true alkali soils.

Wilder, Frank A. Age and Origin of Gypsum of Central Iowa. (Journal of Geology, Vol. XI, pp. 723-748, Chicago, 1903.) The manner of probable formation is discussed and the conclusion is reached that the age is Permian.

Wilder, Frank A. Geology of Lyon and Sioux counties. (Iowa Geol. Surv., Vol. X, pp. 85-184, Des Moines, 1901.) The principal topics discussed or described are the following:

Introduction, location and area, previous geological work.

Physiography, topography, table of elevations, drainage.

Stratigraphy, general relations of strata, table of geological formations; quartzite, quartz-porphyry; Cretaceous strata, Dakota sandstone, Benton shales; Pleistocene, loess, loess-covered drift, Buchanan gravels, Altamont moraine, eastern Lyon county, western Lyon county, Wisconsin, gravel-terraces, pre-Wisconsin course of Big Sioux, origin of the loess.

Economic products, Sioux quartzite, clays, cement, gravels, road materials, wells, coal, gas, soils, water-powers.

Flora of Lyon county.

Wilder, Frank A. Geology of Webster County. (Iowa Geol. Surv., Vol. XII, pp. 63-235, Des Moines, 1902.) The following subjects are discussed in detail:

Introduction, location and area, previous geological work.

Physiography, topography, drainage.

Stratigraphy, general relations of strata, table of geological formations; Carboniferous system, Mississippian series, relation of Saint Louis limestone to Coal Measures and gypsum, Pennsylvanian series, Des Moines stage, coal seams, Permian series, gypsum and associated deposits, well-data, records of prospect-holes, nature of gypsum beds, age of gypsum and associated deposits, origin of gypsum; Pleistocene system, Aftonian gravels, Wisconsin drift, old soils and gravels, Coon Mound Esker, Morainic belts, Pre-Wisconsin valley of the Des Moines; terraces.

Economic products, gypsum, composition and characteristics of gypsum, nature of Webster county gypsum, extent and availability, permanence of supply, distribution of gypsum in United States and markets, history of the gypsum-plaster industry in Webster county, nature of gypsum-plaster, nature of retarder, products of American gypsum-mills, gypsum as a fertilizer, gypsum as a basis for Portland cement, methods of hardening gypsum to imitate marble, chalcedony, hardening of cement plaster, gypsum as a basis for paint, mechanical processes in making hard-wall plaster, plaster of Paris, possible improvements in the manufacture of plaster; coal, analyses of Webster county coal, clays, building-stones, Portland cement, limes, road-materials, water-powers, water supplies, mineral paints, mineral springs, miscellaneous minerals, soils.

Gypsum industry of Germany, kinds of gypsum plaster used, stuck gypsum, estrick gypsum, porcelain gypsum, dunge gypsum (Land Plaster), processes of manufacturing the various kinds of gypsum plaster.

Preliminary tests of stucco and plaster.

The industrial aspects of the gypsum products are considered at length. There is also given a short review of the gypsum industry of Germany.

Wilder, Frank A. Gypsum Deposits of Iowa. (Bull. U. S. G. S., No. 223, pp. 49-52, Washington, 1904.) A brief summary is given of the geology of the gypsum area, with several sections. It is regarded as Permian in age.

Wilder, Frank A. Fourteenth Annual Report of State Geologist. (Iowa Geol. Surv., Vol. XVI, pp. 1-12, Des Moines, 1906.) The work of the year is reviewed. The peat deposits are especially noted.

Wilder, Frank A. Fuel Values of Iowa Coals. (Iowa Geol. Surv., Vol. XIX, pp. 399-475, Des Moines, 1909.) Samples from the five leading coal-producing counties are considered. The subjects of chemical analyses, boiler tests, gas-producing, coking, briquetting, and washing are especially described.

Wilder, Frank A. Observations in Vicinity of Wall Lake. (Proc. Iowa Acad. Sci., Vol. VII, pp. 77-82, Des Moines, 1900.) This is a body of water lying within the Altamont moraine and therefore has a special genetic significance.

Wilder, Frank A. Thirteenth Annual Report of State Geologist. (Iowa Geol. Surv., Vol. XV, pp. 3-11, Des Moines, 1905.) Brief summary of the work of the year is given.

Williams, H. S. Correlation Papers: Devonian and Carboniferous. (Bull. U. S. Geol. Surv., No. 80, pp. 1-279, Washington, 1891.) The rocks of Iowa are discussed in a general way, and their correlation with other formations in the Mississippi valley noted.

Williams, H. S. Equivalency of Lime Creek Beds. (Am. Jour. Sci., (3), Vol. XXV, p. 311, New Haven, 1883.) A short note in which statements made in a former publication are corrected.

Williams, H. S. Relation of Devonian Faunas of Iowa. (American Geologist, Vol. III, pp. 230-233, Minneapolis, 1888.) Observations on the Devonian rocks of Iowa are recorded.

Williams, H. S. Remarkable Fauna at Base of Chemung in New York. (Am. Jour. Sci., (3), Vol. XXV, pp. 97-104, New Haven, 1883.) Comparisons of fossils of the Lime Creek beds of Iowa are made with those of New York.

Williams, Ira A. Geology of Franklin County. (Iowa Geol. Surv., Vol. XVI, pp. 453-507, Des Moines, 1906.) The following features are fully described:

Introduction, location and area, earlier geological work.

Physiography, topography, Iowan drift area, Wisconsin drift area, moraines, Wisconsin drift plain, table of elevations, drainage, West Fork of Cedar river, Hartgrave creek, Otter creek, Spring creek, Mayne creek, Beaver creek, Iowa river.

Stratigraphy, general relations, table of geological formations; Devonian system, Lime Creek shales, Hackberry shales, Owen beds; Carboniferous system, Kinderhook, typical sections, Bailey creek, Otter creek, Mayne creek; Pleistocene system, Kansan drift, Buchanan gravels, Iowan drift, Wisconsin drift, gravel-trains and terraces, post-glacial deposits; soils.

Economic products, building-stones, Kinderhook limestone, Owen limestone, clay industry, Dows, Sheffield, sands, gravels, peat, water-supplies, water-powers.

Williams, Ira A. Geology of Jasper County. (Iowa Geol. Surv., Vol. XV, pp. 277-367, Des Moines, 1905.) The subjects discussed in detail include the following:

Introduction, location and area, history and previous geological work.

Physiography, topography, general features, Kansan drift area, Iowan drift area, Wisconsin drift area, elevations.

Drainage, meteorology, Skunk river system, Skunk river, Indian creek, Clear creek, Mud creek, Wolf creek, Prairie creek, Cherry creek, Squaw creek, Elk creek, North Skunk river, Snipe creek, Rock creek, Sugar creek, Des Moines River system, Camp creek, Walnut creek, Calhoun creek, Brush creek.

Stratigraphy, general relations of strata, table of formations, deep-well sections; geological formations, Mississippian series, Kinderhook and Saint Louis stages, Pennsylvanian series, Des Moines stage, coal measures, representative exposures, Red-rock sandstone; Pleistocene system, pre-Kansan deposits, Kansan stage, Iowan stage, loess, Wisconsin stage, postglacial sands and illuvium, soils.

Economic products, coal, Lynnville, Monroe, Newton, Prairie City, Vandalia, Colfax, Oswalt; clays, Lynnville, Monroe, Kellogg, Newton, Baxter, Colfax; building-stones, Lynnville, Rock creek, Kellogg, Murphy, Reasnor; sands, road-materials, ocher, ores of the metals, water-supplies, mineral waters, water-powers.

Williams, Ira A. Geology of Worth County. (Iowa Geol. Surv., Vol. X, pp. 315-377, Des Moines, 1900.) The following features are fully described.

Introduction, situation and area, previous geological work.

Physiography, topography, Wisconsin drift-area, Iowan drift-plain, drainage, Lime creek, Beaver creek, Winan creek, Willow creek, Shell Rock river, Elk creek, Goose creek, Deer creek.

Geological formations, general descriptions; Devonian system, Cedar Valley limestone, typical sections, Shell Rock river, Manly well, Lime creek, Lime Creek shales; Pleistocene system, Kansan drift, Buchanan gravels, Iowan drift, Wisconsin drift, alluvium.

Economic products, soils, building-stones, peat, water-supplies, water-powers.

Williams, I. A., S. W. Beyer and. Geology of Clays. (Iowa Geol. Surv., Vol. XIV, pp. 377-552, Des Moines, 1904.) The topics considered are:

Geology, distribution of clay and shales, Saint Croix sandstone, Oneota limestone, Saint Peter sandstone, Galena-Trenton, Allamakee county.

Maquoketa shales—Clayton county, Clinton county, Delaware county, Dubuque county, Fayette county, Winneshiek county.

Silurian.

Devonian—Cerro Gordo county, Floyd county, Franklin county.

Carboniferous—Lower Carboniferous, Kinderhook, Des Moines county, Lee county, Washington county; Augusta; St. Louis.

Upper Carboniferous—the coal measures, Adair county, Adams county, Appanoose county, Boone county, Dallas county, Decatur county, Des Moines county, Fremont county, Greene county, Guthrie county, Hamilton county, Hardin county, Humboldt county, Jasper county, Jefferson county, Keokuk county, Lee county, Lucas county, Madison county, Mahaska county, Marion county, Monroe county, Montgomery county, Muscatine county, Page county, Poweshiek county, Polk county, Scott county, Story county, Taylor county, Union county, Van Buren county, Wapello county, Warren county, Wayne county, Webster county.

Cretaceous—Calhoun county, Montgomery county, Plymouth county, Pottawattamie county, Sac county, Sioux county, Woodbury county.

Pleistocene—Pre-Kansan or Albertan, Kansan, Illinoian, Iowan, Delaware county, the loess, the red clay, the gumbo, burnt-clay ballast, Iowan loess.

Wisconsin—Buena Vista county, Clay county, Pocahontas county, post-Wisconsin.

Williams, Ira A., S. W. Beyer and. Geology of Quarry Products. (Iowa Geol. Surv., Vol. XVII, pp. 187-588, Des Moines, 1907.) The subjects treated at length are:

Notes on the geological section of Iowa, Sioux quartzite, Cambrian sandstone, Prairie du Chien limestone, St. Peter sandstone, Platteville and Galena limestones, Maquoketa shales, Niagara limestone; Devonian system; Lower Carboniferous or Mississippian, Pennsylvanian series, Permian system, Cretaceous system, Pleistocene deposits.

Geology of quarry products, Proterozoic group, Sioux quartzite, Cambrian system, Potsdam series, Saint Croix sandstones, Ordovician system, Prairie du Chien limestone, Saint Peter sandstone, Platteville limestone, Galena limestone, Maquoketa shales, Allamakee county, Clayton, Dubuque, Fayette, Howard, Jackson, Winneshiek counties.

Silurian system, Niagara limestone, Bremer, Buchanan, Cedar, Linn, Clayton, Clinton, Delaware, Dubuque, Fayette, Jackson, Johnson, Jones counties, Stone City, Anamosa, State Quarry, Linn, Scott, Winneshiek counties.

Devonian system, Benton, Black Hawk, Bremer, Buchanan, Butler, Cedar, Cerro Gordo counties, Lime creek shales, Chickasaw, Fayette, Floyd, Franklin, Howard, Johnson, Linn, Mitchell, Muscatine, Scott, Worth counties.

Carboniferous, Lower Carboniferous, Mississippian, Kinderhook limestone, Des Moines, Franklin, Grundy, Hardin, Humboldt, Marshall counties; quarry industry, test of Le Grand stone, Tama county, Washington county.

Osage limestone, Des Moines county, Keokuk, Lee, Louisa, Van Buren, Washington counties.

Saint Louis limestone, Des Moines, Hamilton, Henry, Humboldt, Jefferson, Keokuk, Lee, Mahaska, Marion counties, tests of stone, Pocahontas, Story, Van Buren, Wapello, Washington, Webster counties.

Upper Carboniferous, Pennsylvanian, Des Moines stage, Appanoose, Dallas, Davis, Guthrie, Hardin, Iowa, Jasper counties, Red Rock sandstone, Lucas, Marion, Marshall, Muscatine, Polk, Wayne, Webster counties.

Missouri stage, Adair county, Adams, Cass, Clarke, Dallas, Decatur, Fremont, Guthrie, Harrison, Madison counties. Analyses of shale and limestone, Mills, Montgomery, Page, Pottawattamie, Taylor counties.

Permian system, Webster county.

Cretaceous system, Calhoun, Cass, Guthrie, Pottawattamie, Plymouth and Woodbury, Sac counties. Pleistocene system.

Analyses of Iowa coals, analyses of limestones and chalks, analyses of clays, shales and marls, test of Iowa building stones.

Directory of Iowa limestone quarries by counties.

Directory of Iowa sandstone quarries by counties.

Williams, Ira A., S. W. Beyer and. Directory of Iowa Clay Workers. (Iowa Geol. Surv., Vol. XIV, pp. 621-643, Des Moines, 1904.)

Williams, Ira A., S. W. Beyer and. Technology of Clays. (Iowa Geol. Surv., Vol. XIV, pp. 29-318, Des Moines, 1904.) The following topics are discussed at length:

Technology of clays, definition, origin; classification, Ladd's, Buckley's, Orton's; primary or residual clays, secondary clays, clays deposited in still water, clays deposited from running water, clays deposited by glacial action, clays deposited by wind.

Composition and chemical properties, kaolinite and pholerite, clay substances, properties of kaolinite, impurities of clays, silica, feldspar and mica, iron, lime, magnesia, alkalis, organic matter, uncommon constituents.

Physical properties of clays, raw clays, structure, color, feel, slaking, strength, bonding-power, plasticity, shrinkage, porosity, specific gravity, fineness of grain, burnt clay, fusibility, fusibility defined, effect of chemical composition, effect of physical condition, methods of expressing, methods of measuring, table of Seger's cones, methods of preparing the clay for fusion tests, table showing fusion temperatures for Iowa clays.

Processes in the manufacture of clay-wares, winning of the raw material, surface digging, quarrying, mining, transportation of raw material to works, preparation of raw material; dry way, blake-crusher, rolls, disintegrators, dry-press, ball-mills; wet method, wet-pan, pug-mill, soaking-pit; screens, inclined stationary, inclined vibrating, Dunlap; formation of clay-wares, manufacture of brick, soft-mud, stiff-mud, cutting-tables, repressing, dry-press, manufacture of drain tile and building-block, manufacture of sewer-pipe, manufacture of pottery, wedging, jolly, stoneware-glazing, salt, slip, Bristol.

Properties of clays used in manufacture of foregoing classes of wares, soft-mud brick, stiff-mud brick, drain-tile and hollow-block, sewer-pipe, earthenware, stoneware; drying of clay-wares, general considerations, practical considerations in drying clays, types of dryers, outside air-drying, the hot-floor, sewer-pipe or slatted floor, periodic or chamber dryer, the continuous tunnel-dryer, direct, by fuel burned for the purpose, by waste gases from other processes, indirect, radiation from heated brick-work, radiation from steam heated surfaces, summary; burning of clay-wares, combustion of fuel, general discussion, practical considerations, changes which occur in burning of clays, water-smoking, stage of oxidation, vitrification, types of kilns, intermittent kilns, updraft, temporary, English-clamp, American scove, permanent, direct, rectangular, round, pottery, semi-muffle, muffle, downdraft, direct round, single stack, multiple stack, direct triangular, single stack, multiple stack, muffle, continuous.

Wilson, Andrew Gordon. Frozen Streams of Iowan Drift-Border. (American Geologist, Vol. XVII, pp. 364-371, Minneapolis, 1896.) Small streams freezing solid frequently over-flow in spring until several feet of ice are accumulated. The bearing of the phenomena on glacial work is discussed.

Wilson, Andrew Gordon. Subdivisions of Upper Silurian in Northeastern Iowa. (Proc. Assoc. Adv. Sci., Vol. XLIV, p. 137, 1896.) Five distinct terranes are recognized.

Wilson, Andrew Gordon. Upper Silurian in Northeastern Iowa. (American Geologist, Vol. XVI, pp. 275-281, Minneapolis, 1895.) Subdivision of the Silurian section of Iowa is discussed and five numbers are characterized lithologically and faunally. Four of these are essentially the subdivisions at present recognized.

Winchell, Alexander. Description of Fossils from Yellow Sandstone lying below Burlington Limestone at Burlington, Iowa. (Proc. Acad. Nat. Sci. Philadelphia, XV, pp. 2-25, Philadelphia, 1863.) A number of species and genera are described as new.

Winchell, Alexander. Description of New Species of Fossils from Marshall Group of Michigan and its Supposed Equivalent in Other States: with Notes on Some Fossils of Same Age Previously Described. (Proc. Acad. Nat. Sci. Philadelphia, Vol. XVII, pp. 109-133, Philadelphia, 1865.) Several species of fossils are noted from Burlington.

Winchell, Alexander. Marshall Group: A Memoir on its Geological Position, Characters and Equivalencies in United States. (Proc. American Philosophical Soc., Vol. XI, pp. 57-83, Philadelphia, 1869.) References to the correlation of the Kinderhook rocks of Iowa are made.

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Complexity of glacial period and Iowa's role in its establishment. C. Keyes. (Annals of Iowa; an Historical Quarterly, XI, 1913.)

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Geology of Dallas county. A. G. Leonard. (Iowa Geol. Surv., VIII, 51-118, 1898.)

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Witter, F. M. Additional Observations on Loess in and about Muscatine. (Proc. Iowa Acad. Sci., Vol. I, pt. i, p. 45, Des Moines, 1890.) Abstract of paper read before the Academy is given.

Witter, F. M. Geological Features near Muscatine. (Proc. Iowa Acad. Sci., 1875-1880, p. 16, Iowa City. 1880.) Brief notice of the loess and its fossils at Muscatine is made.

Witter, F. M. Gas wells near Letts, Iowa. (American Geologist, Vol. IX, pp. 319-321, Minneapolis, 1892.) Notes on natural gas-wells recently opened in Louisa county are presented.

Witter, F. M. Gas Wells near Letts, Iowa. (Proc. Iowa Acad. Sci., I, pt. ii, pp. 68-70, Des Moines, 1892.) Gas is reported as being found in a number of places near Letts, in Louisa county, and as furnishing supplies for a number of families.

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Cretaceous deposits at mouth of Big Sioux. F. B. Meek. (U. S. Geol. Surv., Terr., IX, p. xxv, 1876.)

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New Species. (Proc. Acad. Nat. Sci. Philadelphia, Vol. XVII, pp. 138-143, Philadelphia, 1865.) See F. B. Meek and A. H. Worthen, 1865.

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Geology of Sac and Ida counties. T. H. Macbride. (Iowa Geol. Surv., XVI, 509-548, 1906.)
Geology of Scott county. W. H. Norton. (Iowa Geol. Surv., IX, 389-519, 1899.)
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Weathered zone (Yarmouth) between Illinoian and Kansan till-sheets. F. Leverett. (Proc. Iowa Acad. Sci., V, 81-86, 1898.)

Young, L. E., and S. W. Beyer. Geology of Monroe County. (Iowa Geol. Surv., Vol. XIII, pp. 353-433, Des Moines, 1903.) The following subjects are considered:

Introduction, location and area, previous geological work.

Physiography, topography, general features, table of elevations; drainage, Des Moines River system, Cedar river, Coal creek, Des Moines river proper, Chariton river system.

Stratigraphy, general relations of strata, general features, table of formations; geological formations; Mississippian series, St. Louis stage, Pennsylvanian series, Des Moines stage, Monroe beds, Appanoose beds, Chariton conglomerate; Pleistocene deposits, pre-Kansan, Kansan, loess, Recent.

Economic geology; coal, historical sketch, importance of industry, coal-basins, Miller Creek district, Smoky hollow, Foster district, Hiteman, Cedar Creek mines, Hocking, Hilton, Bluff Creek district, mining methods, system, ventilation and drainage, haulage, caging and arrangement of bottom, pit-head machinery, grading and loading, power-plant, transportation and markets; coal tests, analyses, calorimetry; clays, building-stones, building and moulding sand, road-materials, soils, potable waters.

Youtz, L. A. Clays of Indianola Brick, Tile and Pottery Works. (Proc. Iowa Acad. Sci., Vol. III, pp. 40-44, Des Moines, 1896.) The composition of these clays is determined and a number of results of chemical analyses are given.

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Zinc and lead district, Mississippi valley. R. E. Davis. (Mining World, XXIV, 548-549, 1906.)

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Geology and geological resources of Iowa. S. Calvin. (Proc. International Mining Congress, Fourth Sess., 52-56, 1901.)

Geology of Allamakee county. S. Calvin. (Iowa Geol. Surv., IV, 35-111, 1895.)

Geology of Des Moines county. C. R. Keyes. (Iowa Geol. Surv., III, 409-492, 1894.)

Geology of Dubuque county. S. Calvin and H. F. Bain. (Iowa Geol. Surv., X, 379-651, 1900.)

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Lead and zinc deposits of Iowa. A. G. Leonard. (Iowa Geol. Surv., VI, 9-66, 1897.)

Lead and zinc deposits of upper Mississippi valley. H. F. Bain. (Bull. U. S. Geol. Surv. 298, 72-75, 1906.)

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Les principaux gisements de minerais de zinc des Etats-Unis d'Amérique. L. Demaret. (Revue universelle des Mines (4), VI, 221-256, 1904.)

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Occurrence of zinc in northeastern Iowa. A. G. Leonard. (Proc. Iowa Acad. Sci., I, pt. iv, 48-52, 1894.)

Ore deposits of southwestern Wisconsin. T. C. Chamberlin. (Geol. Surv. Wisconsin, IV, 367-568, 1882.)

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