THE ORIGIN AND HISTORY OF EXTINCT LAKE CALVIN

BY

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CONTENTS

ILLUSTRATIONS

CHAPTER I.

INTRODUCTION.

Problem stated.—The unusual width of the valley of Cedar river, together with the regular and distinct line of bluffs between West Liberty and Columbus Junction suggested to Calvin as early as 1874[1] the possibility of the existence of a former glacial lake in the region. Udden, some years later, in 1899, while working on the geology of Muscatine county, arrived at the same conclusions, mapped the ancient shore lines, wrote a description of the lake site and named the old "fossil" lake, 'Lake Calvin,'[2] in honor of its discoverer, Dr. Samuel Calvin, then director of the Iowa Geological Survey. Since Udden's work, however, was confined to Muscatine county, the entire site of the extinct lake had never been mapped and described. Furthermore, conclusive evidence of Lake Calvin's existence had not been presented and a discussion of the inlet and outlet of the lake were wanting entirely. Progress in Pleistocene geology, especially in the recent interpretation of the gumbotil[3] and the development of the theory of its origin, also demanded a reconsideration of the lake problem. With these considerations in mind, the writer undertook the necessary work, the results of which are incorporated in this report. The problem of the writer's investigations thus resolved itself into the following points:

1. to establish without a doubt either the existence or non-existence of Lake Calvin,
2. to carefully map and describe the exact and complete extent of the ancient lake, if such existed,
3. to account for the lake's origin and to trace out fully the lake's history if there was a lake,

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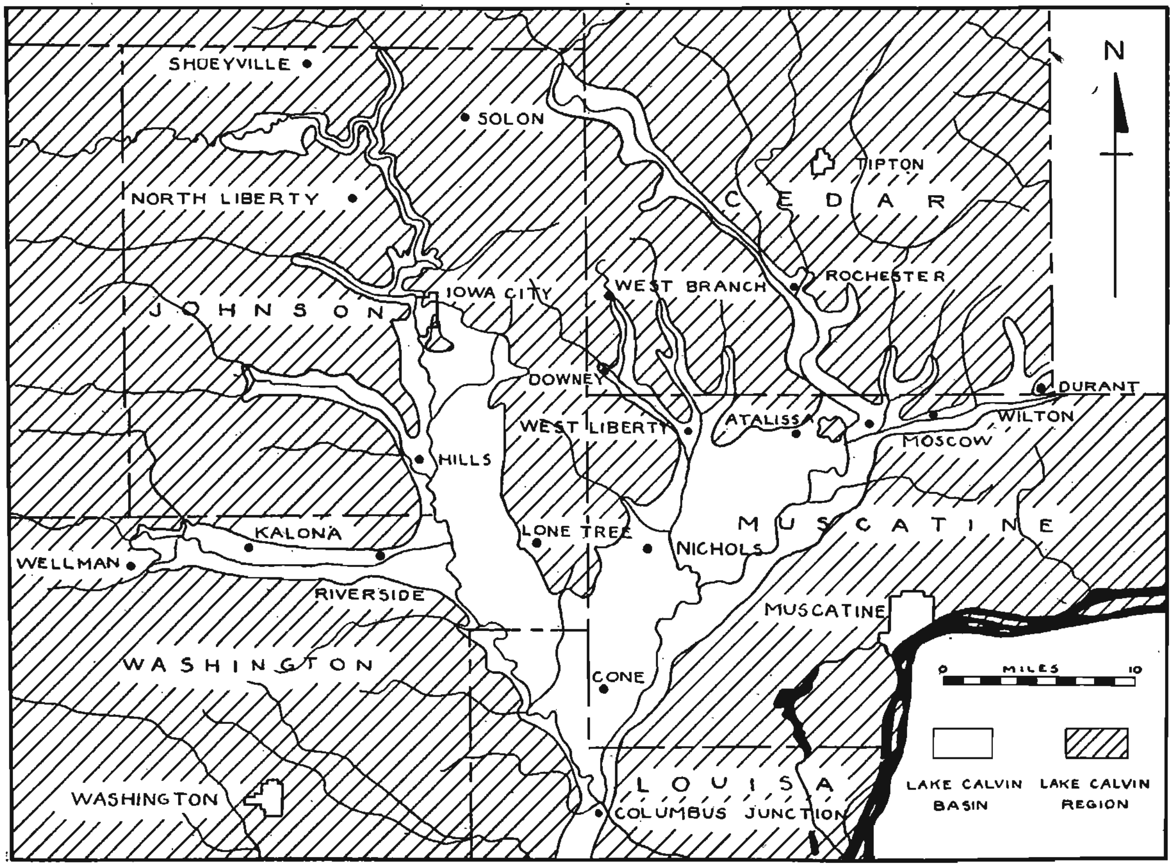
1 Calvin's report to President Thatcher of the State University of Iowa, 1874. Partly reprinted in Udden's report on the "Geology of Muscatine County": Iowa Geological Survey, Vol. IX, pp. 352 and 353, 1899.

2 Udden, J. A., Geology of Muscatine County: Iowa Geological Survey, Vol. IX, p. 357, 1899.

3 Kay, George F., Gumbotil, a New Term in Pleistocene Geology: Science, New Series, Vol. XLIV, Nov. 3, 1916. Reprinted in Iowa Geol. Survey, Vol. XXVI, pp. 217 and 218 1915.



Map showing the location and extent of extinct Lake Calvin.

4. to test the gumbotil hypothesis by seeing whether the presence of a Lake Calvin was in harmony with or detrimental to the gumbotil idea.

Location of extinct Lake Calvin.—Geographically, extinct Lake Calvin lies in the southeastern part of Iowa. The site of this former expense of water, as can be seen from Plate VI, is confined chiefly to an area lying roughly parallel to Iowa and Cedar rivers, from Iowa City and Moscow in Johnson and Muscatine counties respectively, in the north, to Columbus Junction, Louisa county, in the south. Physiographically, the area under discussion is a distinct unit, being bounded on the east by the Illinoian plain and on the north, west and south by the Kansan uplands.

Lake Calvin Basin Defined.—The Lake Calvin basin is limited to that area which was actually the site of the former glacial body of water as compared to the surrounding region which it was necessary to consider for a complete and a clearer understanding of the problem. The latter is termed the Lake Calvin region. The relation between the two is made clear by referring to Plate VI. It is the intention of the writer to confine his theme, as much as possible, to the Lake Calvin basin.

General Characteristics of the Basin.

Topography and relief.—The Lake Calvin basin is an extensive lowland surrounded on all sides by drift uplands rising above it to the height of eighty to one hundred feet. Having been the site of a former lake, its topography is more or less that of a monotonous plain with but little relief. This flat

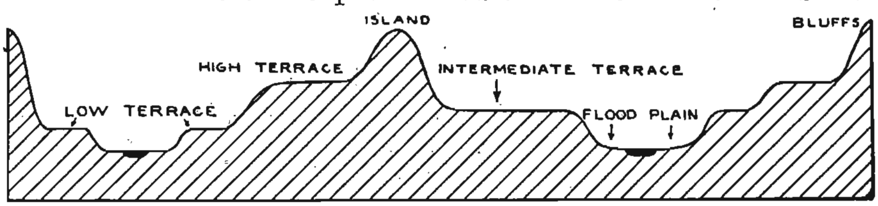


FIG. 6.—Generalized cross-section of the Lake Calvin basin.

stretch of country has an elevation of about 680 feet above sea level in the northern extremity and slopes gently southward at a rate of two and one-half to three feet per mile for a distance of about twenty-five miles, where it has an elevation of 620 feet. The surface of this level plain, however, is not without some relief as a cross section of the region shows. (Figure 6.)

Geology.—Deeply buried beneath the unconsolidated Pleistocene sands, clays and tills are the indurated strata of limestone, dolomite, sandstone and shale belonging to the Silurian, Devonian, Mississippian and Pennsylvanian systems. Exposures of bedrock are lacking in the lake basin proper with the exception of some in the valley walls of Iowa and Cedar rivers north of Iowa City and Moscow respectively, and in the arm-like extension of the lake along English river in Washington county.

Drainage in the lake basin.—The Lake Calvin basin lies in the drainage systems of Iowa and Cedar rivers, which empty into Mississippi river a little northeast of the village of Oakville, Louisa county. Old Mans creek, English river, Whiskey Run, Davis and Goose creeks may be mentioned as the most important tributaries of Iowa river, while Wapsinonoc and Mud creeks form the chief affluents of the Cedar. On the whole, the natural drainage of the lake basin is very incomplete. The courses of the master streams, especially that of Cedar river, are marked by various sloughs, abandoned channels, marshes and crescentic ponds.

Culture in the lake basin.—As might be expected, the Lake Calvin basin is primarily an agricultural district in which corn is the most important crop raised.[4] Because of the sandy soil in the vicinity of Moscow and Conesville, the raising of watermelons and cantaloupes has developed as a specialized truck farming industry. Each year several hundred carloads of melons are shipped from these places. Next to truck gardening and the raising of ordinary crops, the raising and feeding of beef cattle and hogs is important. West Liberty, Wilton and Nichols have become the centers for the raising of pure bred hogs. Dairying is slowly developing with headquarters at West Liberty and Wilton. The only manufacturing of any importance is done at Iowa City where several factories have been established. In connection with the cattle raising indus-

4 U. S. Department of Agriculture, Soil Survey of Muscatine County, Iowa, pp. 9-22, 1916.

try, shipping is extensively carried on. No small village is without its small white stock yard.

With the exception of the numerous good roads in the region, the Chicago, Rock Island and Pacific railway forms the main means of communication between the numerous towns and villages. The main line of the Rock Island system traverses the region in an east-west direction and passes through the towns of Durant, Wilton, Moscow, Atalissa, West Liberty and Iowa City. A north-south line of this same system connects West Liberty and Nichols, Conesville and Columbus Junction. A sub-line extends south from Iowa City with a western branch to Riverside and Kalona and an eastern one to Lone Tree, Nichols and Muscatine. Still another spur connects Wilton and Muscatine.

The largest city on or at the border of the lake basin is Iowa City with a population of about 12,000 inhabitants. Manufacturing is carried on to some extent, but the city is noted for its being the seat of the State University of Iowa and the county seat for Johnson county. West Liberty, Columbus Junction and Wilton are of about 1,500 and 1,000 people and are chiefly commercial and residential towns. Towns of lesser importance are: Durant, Nichols, Riverside, Kalona, Conesville, Atalissa, Hills and Gladwin. In addition, numerous small trading centers are scattered over the region.

Field work.—Field work was conducted during the summer months of 1916 and 1917. Mapping of the lake formed the major part of the work during the first season, whereas the season of 1917 was devoted chiefly to the examination of cuts, the description of sections, the tracing of the temporary Illinoian Mississippi river channel, the studying of the inlet and outlet of the lake, and a careful inspection of the Illinoian drift and topography. A considerable amount of mapping and detailed work in the vicinity of Iowa City was done in the early spring of 1917. Whereas the work of the first field season was accomplished alone and on foot, the second was done largely with the aid of an automobile. During the month of June, 1917, the writer spent four days in the field with Dr. George F. Kay, studying the Illinoian drift, the peat and gumbotil deposits of Louisa county. A day was spent with Professor A. C. Trowbridge examining the outlet of the lake in the vicinity of Columbus Junction. During the month of August, 1917, the writer was accompanied in the field by Mr. Bert C. Gose of Simpson College. In addition, several local excursions and week-end trips were made during the fall of 1917 and the month of June, 1919, completing the necessary field work.

Although Lake Calvin lies almost entirely in Muscatine and Johnson counties, field work was not restricted to that area, but included to some extent the whole region in Iowa affected by the Illinoian ice sheet, which includes practically the entire southern half of eastern Iowa, or the following counties: Lee, Des Moines, Louisa, Jefferson, Henry, Muscatine, Washington, Johnson, Cedar, Scott, Clinton and Jackson.

Acknowledgments.—In connection with the field investigation of this problem, the writer wishes to express his appreciation to Dr. George F. Kay, Director of the Iowa Geological Survey, and to Professor A. C. Trowbridge, of the Geological Department of the State University of Iowa, for their field conferences. The writer also acknowledges his indebtedness to Professor Trowbridge for the supervision of the field work and for the examination and criticism of the manuscript. Thanks are due also to the other members of the Geological staff of the State University of Iowa for encouragement and for their keen interest in the problem. The writer also wishes to express his obligation to Dr. James H. Lees, Assistant State Geologist, for editing the manuscript of this report. Finally, great obligations are due to the Graduate college of the State University of Iowa for the granting of a fund of $100 for field research purposes.

CHAPTER II.

HISTORY OF PLEISTOCENE INVESTIGATIONS IN THE LAKE CALVIN REGION.

Although the history of Pleistocene investigation in the Lake Calvin region can be traced back as far as 1852 at the time when David Dale Owen published his "Report of a Geological Survey of Wisconsin, Iowa and Minnesota" no great progress had been made until about 1891 when W J McGee's classic report on "The Pleistocene History of Northeastern Iowa" appeared. Previous to this time, practically all of the work was devoted to the study of the indurated rocks, especially with the idea of developing the mineral resources of the state. It is true that Owen,[5] as early as 1849, noticed erratic bowlders scattered here and there over the surface. To explain their origin, he introduced the theory of strong ocean currents coming from the north and carrying floating ice over the land, which at that time was still submerged. This pioneer geologist was more interested in the Carboniferous and other systems than in the drift.

The work of Owen was followed by that of James Hall,[6] first state geologist of Iowa, and his assistants J. D. Whitney and A. H. Worthen. Hall busied himself primarily with the indurated rocks but gave some attention to the drift, which he believed had "been deposited under the influence of somewhat turbulent currents."[7] In Hall's report, Worthen described the geology of Washington county, including in his discussion loess and drift, the latter having been deposited by "Drift agencies."[8]

C. A. White[9] was the first state geologist of Iowa to give any detailed consideration to the Pleistocene. As early as 1858,

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5 Owen, D. D., Report of a Geological Survey of Wisconsin, Iowa and Minnesota, p. 144, 1852. Calvin, S., Proc. Iowa Acad. Science, Vol. V, p. 64, 1897.

6 Hall, James, and Whitney, J. D., Report of the Geol. Survey of the State of Iowa, Vols. I and II, 1858.

7 Idem. Vol. I, Part I.

8 Worthen, A. H., Geology of Iowa, Vol. I, pp. 241 and 248, published in Hall's report cited in 6.

9 White, C. A., Report on the Geological Survey of the State of Iowa, Vols. I and II, 1870.

glacial striae[10] were discovered by him near Burlington although no account of them was published at that time. Later he fully described the glacial deposits and recognized their origin, without, however, separating the various surface drifts into their respective ages. He described briefly the drift of Washington county, but dealt in more detail with the coal found in that and Muscatine counties.[11]

As early as 1887, Calvin[12] attempted to account for the origin of the loess, "the peculiar yellow clay, so well known in rainy weather at least, in the roads and fields near Iowa City."[13] Calvin recognized its connection with the great continental ice sheet and believed then that the loess represented the finest mud that was deposited in a lake. It was his contention that the surface was not all covered with ice but that "lakes of unfrozen water"[14] were hemmed in by ice barriers. It was not until later years that Calvin understood the eolian origin of the loess.

Ice furrows near Iowa City were described by Webster[15] as early as 1888. McGee[16] refers to these glacial scorings as being the only ones occurring in northeastern Iowa. In the same year, Shimek[17] described some of the fossils found in the loess at Iowa City and Witter [18] made some observations on the loess in the vicinity of Muscatine.

It was for W J McGee[19] to differentiate more than one drift sheet in Iowa. His detailed work in northeastern Iowa, which includes practically all of the Lake Calvin region, except that portion in Washington and Louisa counties, led him to believe that there were two distinct drift sheets in Iowa

10 Keyes, C. R., Glacial Scorings in Iowa, Iowa Geol. Survey, Vol. III, p. 154, 1893.

11 White, C. A., Report on the Geological Survey of the State of Iowa, Vol. I, 1870.

12 Calvin, S., Fragments of Geological History, Johnson County, Iowa Historical Record, 1-3, pp. 100-107, 1885-1887.

13 Idem, p. 106.

14 Idem, p. 106.

15 Webster, C. L., American Naturalist, XXII, pp. 408 and 409, 1888. Keyes, C. R., Glacial Scorings in Iowa: Iowa Geol. Survey, Vol. III, pp. 152 and 153, 1893.

16 McGee, W J, The Pleistocene History of Northeastern Iowa: U. S. Geological Survey, Eleventh Ann. Rept., Pt. I, p. 200, 1891.

17 Shimek, B., Notes on the fossils of the loess at Iowa City: Amer. Geol., Vol. I, p. 149, 1888.

18 Witter, F. M., Some Additional Observations on the Loess in and about Muscatine: Proc. Iowa Acad. Science, Vol. I, Part I, 1888.

19 McGee, W J, The Pleistocene History of Northeastern Iowa: U. S. Geol. Survey, Eleventh Ann. Rept., Pt. I, pp. 189-577, 1891.

separated by a forest bed. Both the "Lower" and the "Upper" till, as McGee named the two drift sheets, are represented in the Lake Calvin region. In addition to describing the two tills, this pioneer geologist also mentioned the terraces along Iowa and Cedar rivers and discussed in some detail the old Goose Lake channel which was occupied by Mississippi river during the Illinoian stage of glaciation. McGee did not confine his work to the Pleistocene deposits, but also included in his studies the indurated strata.

In 1892, Professor Witter[20] of Muscatine published an account of the first gas well in the drift, which was located in the northern part of Louisa county, and in the following year Keyes[21] described the glacial scorings found in the lake region.

In 1894, at the time that Mr. Frank Leverett of the U. S. Geological Survey was working on his newly discovered drift, the Illinoian, Francis M. Fultz[22] of Burlington, independently of Leverett, found evidence of the same younger till sheet in southeastern Iowa. Erratics of a jasper conglomerate were known to exist all the way from eastern Ohio to western Illinois and as far south as Kentucky. The presence of these Huronian erratics seemed to prove that the ice sheet had formerly extended as far south as Kentucky and as far west as Illinois, but at that time the idea that the great ice mass could have crossed the deep valley of the Mississippi and invaded southeastern Iowa seemed incredible. The finding of two of these foreign conglomerates, one by Leverett, and the other by Fultz, in Lee and Des Moines counties, as well as the discovery of terminal moraine deposits, the Sandusky bowlder ridge, in Lee county, were sufficient evidence to those geologists that Iowa had been invaded by an ice sheet from the east. It is interesting to note that at this time the Iowan and Illinoian ice invasions were believed to have been contemporaneous. In 1896 Fultz[23] discovered further evidence of the Illinoian ice incursion by finding gla-

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20 Witter, F. M., Gas Wells near Letts: Proc. Iowa Acad. Science, Vol. I, Part II, pp. 68, 69. 1890-1891; Amer. Geol., Vol. IX, p. 319, 1892.

21 Keyes, C. R., Glacial Scorings in Iowa: Iowa Geol. Survey, Vol. III, pp. 152-163, 1893.

22 Fultz, Francis M., Extension of the Illinois Lobe of the Great Ice Sheet into Iowa: Proc. Iowa Acad. Science, Vol. II, pp. 209-212, 1895.

23 Fultz, Francis M., Recent Discoveries of Glacial Scorings in Southeastern Iowa: Proc. Iowa Acad. Science, Vol. III, p. 61, 1896.

cial striae in the southeastern part of the state. In the same year, Bain[24] published his report on the Geology of Washington county. In this report Bain discussed the Kansan drift and the loess and treated in some detail the Washington and other preglacial channels found in that county. An attempt to explain the origin of the drainage system in the county was undertaken also.

McGee's work ushered in a period of detailed investigation regarding problems in the Pleistocene. In-so-far as the region under discussion is concerned, no names are so closely associated with the development of the surface geology as those of Calvin, Leverett and Udden. Calvin's report on the "Geology of Johnson County"[25] appeared in 1897. Calvin, then state geologist, carefully and fully described the Kansan and Iowan drifts of the county and called attention to "the rapidly widening alluvial plain upon which the river," the Iowa river, "enters after emerging from its canyon south of Iowa City."[26] He further directed attention to the fact that "this last plain attains a width of many miles" and finally unites with a "plain of similar character that includes the lower course of the Cedar river."[27] It was not until later that Calvin recognized this "rapidly widening alluvial plain" as the bed of an ancient extinct lake.

Leverett first recognized and separated the Illinoian drift sheet from an older drift covering in southeastern Iowa. Leverett recognized the new drift as early as 1894, but the term 'Illinoian' was not used by him at that time. It was introduced into literature by Chamberlin, then director of the Wisconsin Geological Survey. It appears, however, that Chamberlin credits Leverett with having named the new drift sheet. Leverett is the authority on the Illinoian drift. It was he who mapped and made the most extensive and detailed studies regarding this younger drift. The results of his investigations, covering a period of over ten years, were published in 1899 by the United

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24 Bain, H. F., Geology of Washington County: Iowa Geol. Survey, Vol. V, pp. 113-174, 1896.

25 Calvin, S., Geology of Johnson County: Iowa Geol. Survey, Vol. VII, pp. 33-116, 1897.

26 Idem, p. 45.

27 Idem, p. 46.

States Geological Survey as Monograph 38, entitled "The Illinois Glacial Lobe." During the course of Leverett's investigations, numerous articles were published by him regarding observations on the new drift, on the preglacial drainage of the area and on the interglacial intervals. Practically all of these earlier publications are embodied in his final treatise on the Illinoian drift cited above.

In the same year that Leverett's classic monograph appeared, Norton published a report on the "Geology of Scott County."[28] This report deals at length with the preglacial surface of the county and discusses in detail the Cleona channel, a tributary of the preglacial Mississippi river of Leverett. Norton also described the Nebraskan, the Kansan, the Illinoian and the Iowan drifts with their corresponding interglacial deposits.

The most noteworthy and practically the only contribution concerning "Lake Calvin" is that of Udden[29] who was the first geologist to describe and map the old "fossil lake". In his account of the lake, Udden carefully described the old lake bottom in Muscatine county as it was then known, accounted for its origin and named the lake "in conformity with precedents"[30] Lake Calvin, in honor of its discoverer, Dr. Samuel Calvin, then director of the Iowa Geological Survey. It may be mentioned at this point that the borders of this ancient lake have never been mapped except the parts in Muscatine county, although on the "Preliminary Outline Map of the Drift Sheets of Iowa" for 1904, published by the state survey, an extension of this lake appears in Johnson county as far north as Iowa City. In connection with Lake Calvin, Udden[31] and Meyers[32] described some diatomaceous deposits which the writers believed to have some bearing on the existence of the old lake.

Except for a mere mention or two in the publications listed below[33-38] no other description of this ancient body of water has

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28 Norton, W. H., Geology of Scott County: Iowa Geol. Survey, Vol. IX, pp. 391-519, 1899.

29 Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, pp. 246-388, 1899.

30 Idem, p. 357.

31 Udden, J. A., Diatomaceous Earth in Muscatine County: Proc. Iowa Acad. Science, Vol. VI, p. 53, 1899.

32 Meyers, P. C., Report on a Fossil Diatomaceous Deposit in Muscatine County, Iowa: Proc. Iowa Acad. Science, Vol. VI, p. 52, 1899.

33 Calvin's report to President Thatcher of the State University of Iowa, 1874. Partly re-

appeared since Udden's report with the exception of a short account by Calvin[39] in the Iowa State Atlas for 1904, published for the St. Louis Exposition, and a short popular article prepared by the writer[40] for the Iowa Alumnus.

The last two county reports dealing with the geology of part of the Lake Calvin basin were published in 1901. These reports are, "Geology of Louisa County" by Udden[41] and the "Geology of Cedar County" by Norton.[42] As in his other reports, Udden dealt with all the surface deposits, the Nebraskan, the Kansan and the Illionian tills, the loess and the terraces of Iowa and Cedar rivers, and described the old temporary Mississippi river channel of Illinoian time. It is strange to note, however, that although Udden had previously mapped and described Lake Calvin and undoubtedly knew that the old lake had extended into Louisa county, the term 'Lake Calvin' was not used by him in his report. It is true that in discussing the Iowa river lowlands, he mentioned the fact that the northernmost expansion of the lowlands constituted the south end of the West Liberty Plain, but he failed to state the origin of the plain.[43] That writer believed the terraces or the "higher lowlands" along Iowa and Cedar rivers, to have been built up, in part at least, at the time of the Iowan ice invasion.[44] This too, might lead one to suspect that he had perhaps changed his ideas regarding the West Liberty Plain, which he regarded in his Muscatine county report as

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printed in Udden's report on the "Geology of Muscatine County": Iowa Geol. Survey, Vol. IX, pp. 352-353, 1899.

34 Leverett, F., Illinois Glacial Lobe: U. S. Geol. Survey, Monograph XXXVIII, p. 96, 1899.

35 Anderson, Netta C., and Udden, J. A.; A Preliminary List of Fossil Mastodon and Mammoth Remains in Illinois and Iowa, by Netta C. Anderson, and on the Proboscidian fossils of the Pleistocene Deposits in Illinois and Iowa, by John August Udden, Augustana Library Publications, Number Five, pp. 31 and 32, 1905.

36 Norton and Others, Underground Water Resources of Iowa: Iowa Geol. Survey, Vol. XXI, pp. 56, 558 and 560, 1912. Also U. S. Geol. Survey, Water Supply Paper No. 293, 1912.

37 U. S. Department of Agriculture, Soil Survey of Muscatine County, Iowa, p. 22, 1916.

38 Alden, Wm. C., and Leighton, M. M., The Iowan Drift, A Review of the evidence of the Iowan Stage of Glaciation: Iowa Geol. Survey, Vol. XXVI, Annual Report for 1915, p. 136, 1917.

39 Calvin, S., Physiography of Iowa: Annual Report of the Iowa Weather and Crop Service for 1902. Reprinted in the Iowa State Atlas of 1904.

40 Schoewe, W. H., Lake Calvin, an Extinct Glacial Lake: Iowa Alumnus, Vol. XVII, No. 4, pp. 193-197, 1920.

41 Udden, J. A., Geology of Louisa County: Iowa Geol. Survey, Vol. XI, pp. 55-126, 1901.

42 Norton, Wm. H., Geology of Cedar County: Iowa Geol. Survey, Vol. XI, pp. 279-396, 1901.

43 Udden, Op. Cit., p. 61.

44 Op. Cit., p. 113.

being a lake deposit. Futhermore, in connection with his description of the Illinoian drift, Udden mentioned the fact that while the Illinoian ice sheet was building up its terminal moraine, Mississippi river was forced out of its channel and occupied a broad shallow valley which extends from the Iowa river border of the upland, south past Columbus Junction to Winfield and thence west to Skunk river. And then after stating that "The significance of this valley was first made clear by Mr. Leverett,"[45] Udden failed to make clear that this valley was the outlet of his "Lake Calvin" of Muscatine county. Whether Udden changed his views regarding the former existence of the Illinoian glacial lake is not apparent from this report.

Norton described the Kansan drift of Cedar county and outlined in detail the preglacial surface and the preglacial Stanwood channel, probably a tributary of the preglacial Cleona channel. Norton ascribed the terraces along Cedar river to the Iowan ice incursion.

Between 1901 and 1916 but very little, if any, progress along geological lines had been made in the lake district. The few publications[46-49] appended below add nothing new to the Pleistocene knowledge of the region, but deal simply with the already established facts regarding the glacial history of the lake basin.

The only important new contributions of recent date made in reference to the Pleistocene of the region are those of Leighton, then of the Iowa Geological Survey, and Alden of the U. S. Geological Survey. Leighton[50] established the fact that Iowa river north of Iowa City is post-Kansan in age and also that an old preglacial or at least a pre-Kansan valley extended in a northwest-southeast direction across the southern part of Johnson county south of Iowa City. Leighton attributed some of the terraces found along the river to the Iowan stage of glaciation.

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45 Op. cit., p. 109.

46 Calvin, S., Present Phase of the Pleistocene Problem in Iowa: Bull. Geol. Soc. America, Vol. XX, pp. 133-152, 1909.

47 Norton and Others, Underground Water Resources of Iowa: Iowa Geol. Survey, Vol. XXI, 1912. Also U. S. Geol. Survey, Water Supply Paper No. 293, 1912.

48 Hay, O. P., The Pleistocene Mammals of Iowa: Iowa Geol. Survey, Vol. XXIII, 1913.

49 U. S. Department of Agriculture, Soil Survey of Muscatine County, Iowa, 1916.

50 Leighton, Morris M., The Pleistocene History of the Iowa River Valley North and West of Iowa City, in Johnson County, Iowa: Iowa Geol. Survey, Vol. XXV, pp. 105-181, 1914.

This same geologist in cooperation with Alden[51] of the U. S. Geological Survey discussed a "gumbo-like" clay found about two miles west of the village of Moscow in Muscatine county. Since the exposure of this "gumbo-like" clay is found so close to the bottom land of Cedar river, the writers did not consider it as being a super-Kansan upland gumbo.[52] These same writers also suggested the possibility that the terraces along Cedar river in the vicinity of Rochester, believed by Norton to be of Iowan age, might "have resulted from slackwater during the Illinoian stage" and that "Such slackwater must have occupied the valley as far up as Ivanhoe bridge southwest of Mount Vernon."[53]

As indicated under "Field Work" on page 59, the writer's field work was not restricted to the Lake Calvin basin, but included practically all the southern half of eastern Iowa. Although it is not the intention of the writer to trace the Pleistocene development of this region, yet it is thought that a word or two ought to be said at this time regarding the preglacial and glacial drainage of the streams, especially in reference to Mississippi river. Probably no other problem in glacial geology is more complex and more difficult to solve than that of the history of Mississippi river during the Quaternary period. It was the displacement of this stream during Illinoian times that gave rise to the formation of Lake Calvin. The most important work in connection with the drainage problem of Mississippi river has been done by; Leverett, McGee, Calvin, Fultz, Warren, Hershey, Udden, Norton, Bain, Keyes, Winchell, Lees, Sardeson, Trowbridge, Westgate, Grant, Claypole, Gordon, Carman and Soper. Although definite conclusions have been reached regarding certain portions of the master stream, yet on the whole, the history of the great river is still uncertain and unsolved. The more important contributions dealing with this complex problem are given in Appendix A.

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51 Alden, Wm. C., and Leighton, Morris M., The Iowan Drift, A Review of the Evidences of the Iowan Stage of Glaciation: Iowa Geol. Survey, Vol. XXVI, Annual Report for 1915, pp. 49-212, 1917.

52 Idem, p. 196.

53 Idem, p. 136.

CHAPTER III.

PRE-PLEISTOCENE GEOLOGY AND HISTORY OF THE LAKE CALVIN BASIN.

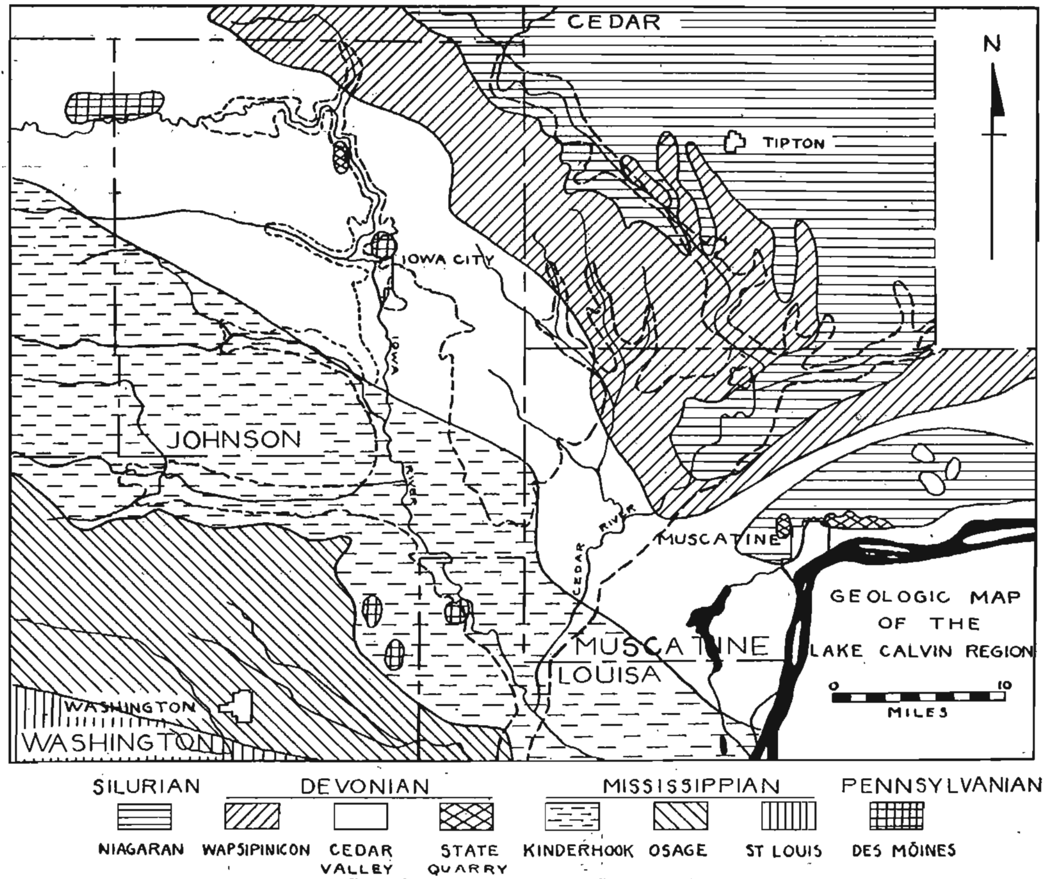
The Rock Formations.

General Statement.—The bedrock geology of the Lake Calvin basin has been determined mainly from the reports of the various counties in which the old lake lies. Outcrops of the indurated strata are extremely few in number and are practically limited to the northern border and to the English river arm of the lake bed. The rock consists mainly of limestone, dolomite, sand-

TABLE 1. CLASSIFICATION OF THE INDURATED ROCK FORMATIONS REPRESENTED IN THE LAKE CALVIN BASIN.

GROUP	SYSTEM	SERIES	STAGE	SUBSTAGE	ROCK
Paleozoic	Pennsylvanian	Des Moines			Sandstone, shale, coal
	Mississippian	Osage	Burlington	Lower Burlington	Limestone
		Kinderhook		Wassonville	Limestone
				Oölite Ledges	Oölitic limestone
				English River Gritstone	Sandstone
				Maple Mill	Shale
	Devonian	Upper Devonian	State Quarry		Limestone
			Cedar Valley		Limestone
			Upper Wapsipinicon	Upper Davenport	Limestone
			Lower Wapsipinicon	Lower Davenport	Limestone
				Independence	Limestone
				Otis	Limestone
	Silurian	Niagaran	Gower	Anamosa	Dolomite
				Le Claire	Limestone, dolomite

stone and shale and ranges in age from Middle Silurian to Lower Pennsylvanian. The accompanying table is a summarized



Geologic map of the Lake Calvin region.

classification of the strata of this portion of the state. See also certain other references[54] and Plate VII.

The Silurian System.

THE GOWER LIMESTONE FORMATION.

The Le Claire dolomite member.—The oldest formation of the bedrock in the lake basin is the Gower limestone of Niagaran or Middle Silurian age. This formation, which has been subdivided into the Le Claire and Anamosa dolomite members, attains a maximum thickness of about 120 feet. The Le Claire limestone, about ninety feet thick, is a hard brittle gray or bluish gray rock, in some places oxidized to a buff color. It consists of two phases, a subcrystalline and a crystalline variety. The former phase abounds in moulds and casts of fossils and has a vesicular texture. In many cases it has assumed a brecciated or conglomeratic nature and appears in mounds in which practically all signs of stratification are lost. It is only on the sides and upper surfaces of these mounds that the stratification again is visible. Not only do these beds dip in all directions and at high angles, the higher angles ranging between ten and thirty degrees, but the amount of dip varies considerably in short distances. The crystalline phase of the Gower limestone is pure brittle fine and close-grained dolomite of uniform texture and composition. The rock possesses a subconchoidal fracture and shows close laminations and evenness of bedding. Commonly the layers occur in tilted positions. As it weathers the surface of the Le Claire limestone, especially where it is heavily bedded, becomes deeply pitted with caverns.

The Anamosa dolomite member.—The Anamosa dolomite member has a thickness of thirty feet. It is a light buff, dully lustrous granular rock in which fossils are rare. This soft laminated vesicular dolomite with even and parallel bedding-planes weathers into thin detached laminæ.

Distribution.—The Gower limestone is limited in areal distribution to the northern and northeastern part of the lake bed. As may be seen from the geologic map, Plate VII, a tongue of

[54] Norton, W. H., Geology of Cedar County: Iowa Geol. Survey, Vol. XI, pp. 304-329, 1901. Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, p. 268, 1899. Calvin, S., Geology of Johnson County: Iowa Geol. Survey, Vol. VII, pp. 54-57, 1897.

this Silurian formation extends down into Muscatine county. Outcrops are found only along Cedar river north of the village of Rochester in the narrow finger-like extension of the lake. The best and most complete section showing both the Le Claire and the Anamosa members is to be seen at the Bealer quarries, located along Cedar river at Cedar Valley. Here about 116 feet of the Gower limestone formation is exposed.

The Devonian System.[55]

Formation and Classification.—The Devonian system is represented in the lake area by the Wapsipinicon, Cedar Valley and State Quarry limestones all of which belong to the upper part of the system. At the present time the Devonian rocks are classified as follows:

CLASSIFICATION OF THE DEVONIAN SYSTEM IN IOWA

	STAGE	SUBSTAGE
Upper	Missing	
	Lime Creek; 97-172 feet State Quarry; 40 feet	
	Cedar Valley; 60-150 feet Upper Wapsipinicon	Upper Davenport; 20-40 feet
	Lower Wapsipinicon	Lower Davenport; 20-35 feet Independence; 20 feet Otis; 10-30 feet
Middle	Missing	
Lower	Missing	

THE WAPSIPINICON FORMATION

Members.—The Wapsipinicon limestone is of such a variable character that it has been divided into the following four members:

Wapsipinicon { Upper Davenport, Lower Davenport, Independence, Otis }

55 Norton, W. H., Geology of Cedar County: Iowa Geol. Survey, Vol. XI, pp. 329-342, 1901. Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, pp. 268-303, 1899. Calvin S., Geology of Johnson County: Iowa Geol. Survey, Vol. VII, pp. 57-79, 1897.

The Otis member.—Lithologically and structurally the Otis limestone varies greatly from place to place. In general it may be described as a pure fine-grained hard, brittle brown to drab rock which breaks with a conchoidal or irregular fracture. The rock in places occurs heavily bedded, especially where it is cracked or fragmental, and in other localities it is thinly laminated. The Otis member, which attains a thickness ranging from ten to thirty feet, is not fossiliferous and contains some flint nodules.

The Independence member.—The Independence member in the lake region is an impure, argillaceous soft buff colored, speckled magnesian limestone which attains a thickness of twenty feet. In places the rock contains angular fragments of other limestones and of silica. At such places, it weathers to an earthy luster while its surfaces become pitted with angular cavities and roughened by protruding particles of sand which are left standing in relief. Locally, the limestone is so argillaceous that it breaks down into clay. This member also contains many siliceous nodules.

The Lower Davenport member.—The Lower Davenport member, often called the Fayette breccia, is an unfossiliferous hard compact, fine-grained whitish limestone which in many places is brecciated. The rock has a conchoidal fracture, is filled with siliceous nodules and in many places occurs in massive beds. Its thickness together with the Upper Davenport member is estimated to range from twenty to forty feet.

The Upper Davenport member.—The Upper Davenport limestone is a thickly bedded, highly fossiliferous, semicrystalline rock, tough and of a gray color. Brachiopod shells are so numerous in some parts of the member that the limestone may be said to be made up partly of coquina layers.

Distribution.—The Wapsipinicon limestone forms the country rock of the region adjacent to Cedar river and occupies a large part of the lake bed in Goshen, Pike and parts of Moscow and Wapsinonoc township. The various members belonging to the Wapsipinicon formation outcrop in the high bluffs along Cedar river from a point one mile north of the village of Moscow to a point about six miles northwest of the village of Rochester.

Other outcrops are found at various places along Sugar and Crooked creeks. In the quarries located on the island-like upland in sections 7 and 8, Moscow township, several feet of the Lower Davenport or Fayette breccia is exposed.

THE CEDAR VALLEY FORMATION.

The Cedar Valley limestone.—The Cedar Valley limestone now considered to be of Upper Devonian age consists of a series of limestones which vary greatly from place to place in color, texture, structure, clay and fossil content. In color the rock varies from a light bluish gray to dark gray, white or yellow. Texturally the limestone is hard, tough, compact and fine grained to soft and somewhat brittle and argillaceous. At places the layers are irregularly bedded, compact, massive and brecciated while elsewhere the strata occur in regular ledges cut by oblique joints. The beds are practically horizontal and yet on close examination of elevations of similar beds at the various quarries along Iowa river near Iowa City, it is seen that the strata have a dip to the south of approximately seventeen feet per mile. Locally, however, the dip may be greater. The rock, on the whole, is very fossiliferous, being filled with the shells of corals and brachiopods, yet there are certain beds in which fossils are rare or absent, especially in those portions which are brecciated. The Cedar Valley limestone is known to have a thickness ranging from sixty to one hundred and fifty feet. However, at no place in this region is its entire thickness exposed. Only fifty feet of this formation can actually be seen in the quarry faces along Iowa river. A typical section in the Cedar Valley limestone is to be seen at the Hutchison quarry located on the west bank of Iowa river just opposite Iowa City. This quarry exposes approximately thirty-two feet of rock in which thirteen distinct beds can be identified. The section is as follows.

HUTCHISON QUARRY SECTION, IOWA CITY

Bed		Feet
13.	Limestone, gray, thinly bedded	3 to 4
12.	Limestone, light gray, brecciated at places	6
11.	Limestone, upper Idiostroma layer	1 1/2
10.	Limestone, gray	1

9.	Limestone, light colored, with numerous *Idiostroma*	1 2/3
8.	Limestone, base of the Idiostroma bed, also birdseye coral	2 1/2
7.	Limestone, hard ledge, gray, with many *Acervularia* and other fossils	2 2/3
6.	Limestone, upper coral reef	2 5/6
5.	Limestone, light colored, few fossils	3
4.	Limestone, hard, bluish gray, separated from No. 5 by three inches of shale	1 1/6
3.	Limestone, bluish	1 1/3
2.	Limestone, hard, fine grained	2 1/3
1.	Limestone, coral reef	1
		31 2/3

Distribution.—The Cedar Valley formation is the bedrock for the southern portion of the Lake Calvin basin and underlies parts of the following townships in Muscatine county: Wapsinonoc, Goshen, Pike, Lake and Cedar, as well as the region bordering Iowa river in Johnson county north of the village of Hills. Practically all of the exposures are confined to the valley walls of Iowa river in Johnson county from Iowa City northward. Two small outliers of the limestones are to be found in the quarries of the small upland area located in sections 7 and 8, Moscow township, Muscatine county, and in the bluff line three-quarters of a mile due east of the village of Atalissa. At the latter locality, the rock is mostly hidden due to slump and overgrowth of vegetation.

THE STATE QUARRY BEDS.

in the lake basin are known as the State Quarry limestone. This formation, with a thickness of forty feet, outcrops in an area three-quarters of a mile by half a mile in extent along the west valley wall of Iowa river in sections 5 and 8, Penn township, Johnson county. The strata consists of a light grayish colored limestone varying in texture somewhat in the different beds. The uppermost layers are filled with the shells of numerous brachiopods, so that this rock may be described as a coquina limestone. The pores and other small openings in the rock are filled with abundant calcite crystals. The middle beds, which furnished the building stone for the Old State Capitol of Iowa, the present Administration building of the State University, are thickbedded, being as much as five feet thick, are well jointed and are highly fossiliferous. Towards the base of the exposures the beds are thinner and range from a few inches to one foot in thickness. Masses of chert bands are distributed irregularly throughout the formation and at places are crowded with imbedded remains of fish teeth. This formation rests unconformably on the Cedar Valley limestones.

The Mississippian System.[56]

Rocks represented.—By far the greater portion of the Lake Calvin basin is underlain by rocks belonging to the basal part of the Mississippian system. These rocks comprise soft greenish shales, fine-grained sandstones and lithographic and oölitic limestones, all of which belong to the Kinderhook and Osage series.

THE KINDERHOOK SERIES.

The Kinderhook series may be divided into four members as follows:

Kinderhook
- Wassonville limestone
- Oölitic limestone ledge
- English River gritstone
- Maple Mill shale.

The Maple Mill shale member.—This member is a nonfossiliferous greenish gray compact shale with a soapy or greasy luster. Small pale yellow cubes of iron pyrites are distributed throughout the shale. The rock breaks up into small regular rhomboidal blocks. Its thickness is estimated as 180 feet.

The English River gritstone member.—The English River gritstone is a soft fine-grained sandstone made up largely of angular quartz fragments of uniform size and shape. Intercalated with the sandstone are thin seams of shaly material. The bluish gray rock weathers to a dull yellow color. Near the upper part of the member is a thin layer in which the remains of fish teeth are found. Fossils in the form of casts occur, but not very abundantly. Above the sandstone, which has a thickness

[56] Calvin, S., Geology of Johnson County: Iowa Geol. Survey, Vol. VII, p. 79, 1897. Bain, H. Foster, Geology of Washington County: Iowa Geol. Survey, Vol. V, pp. 127-151, 1896. Udden, J. A., Geology of Louisa County: Iowa Geol. Survey, Vol. XI, pp. 71-93, 1901.

of ten feet, is a fine, compact grayish nonfossiliferous lithographic limestone from three to four feet thick. This is followed by a nonfossiliferous sandstone very similar in texture and composition to the gritstone below. Its color is soft blue or yellow and it is three feet thick.

The oölitic limestone ledge member.—This rock is a single ledge of white to yellowish limestone which is two or three feet thick and is composed of small spherical oölites imbedded in a matrix of calcareous material. Where it is leached the ledge appears as a porous yellowish rock. Fossils are fairly abundant.

The Wassonville limestone member.—The Wassonville limestone varies from an earthy magnesian to a moderately fine-grained limestone which is more or less arenaceous in places. Toward the base of the member, it occurs normally in thick ledges in which is found a gray chert which locally shows an oölitic structure. The limestone is fossiliferous and is approximately fifteen feet thick.

Distribution.—As indicated elsewhere, the rocks belonging to the basal part of the Mississippian system underlie the major portion of the lake bed basin. From the geologic map, Plate VII, it may be seen that except for a small outlier of Des Moines sandstone located along Iowa river north of Gladwin, Louisa county, the Kinderhook formation forms the country rock of the lake bed in Louisa, Washington and Johnson counties, south of the village of Hills, as well as a small portion of the southwest corner of Muscatine county. The various members of this formation outcrop only along the bluffs of English river westward from about Kalona to Wassonville.

THE OSAGE SERIES.

The Lower Burlington formation.—The Osage series is represented in the region by but one exposure of a buff arenaceous limestone, four inches thick. This lower Burlington limestone outcrops in the old railway quarry located in Washington county, township 77 N., range VIII W., section 16, where it caps about twenty feet of the Kinderhook formation.

The Pennsylvanian System.[57]

THE DES MOINES SERIES.

The Des Moines sandstone.—The Des Moines sandstone of Lower Pennsylvanian age is the youngest indurated rock formation known in the region. The rock occurs as small isolated outliers occupying old pre-Pennsylvanian erosional valleys, 140 feet deep or thereabouts and having a trend S. 30° E. Two of these sandstone outliers outcrop in the lake bed region, one of these being just north of Iowa City, the other north of Gladwin in Louisa county. The rocks belonging to the Des Moines series consist of sandstones interbedded with layers of shale and coal. The sandstone is a light yellowish, thinly bedded, medium-grained, iron cemented rock, rather porous and well jointed. At the Sanders quarry, located just north of Iowa City, where a thickness of twenty-six to thirty feet of the sandstone is exposed the rock is filled with numerous spheroidal limy concretions and with nodules of iron pyrites. The sandstone is interbedded with thin bedded layers of bluish black shales which differ in thickness from several inches to several feet. At places the shale beds are more numerous toward the top of the formation. Layers of coal, one-half inch to a few inches thick, are reported from both localities. In general the Des Moines sandstone and shale lie in horizontal beds. Locally, however, the sandstone and shale, as seen in North and South Sanders creek north of Iowa City, dip at an angle of five degrees in a direction N. 40° E. The formation rests unconformably on the Cedar Valley limestone.

History of the Indurated Rock Formations.

The history of the indurated rock formations or of the pre-Pleistocene geologic history of the Lake Calvin basin is recorded in the belted series of the rock formations which are found crossing the region in more or less roughly parallel bands having a northwest to southeast trend as is shown on Plate VII. This belted arrangement is due to the fact that after the strata had been formed, diastrophism set in, resulting in a slight tilting of the beds in a southwesterly direction.

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57 Calvin, S., Geology of Johnson County: Iowa Geol. Survey, Vol. VII, pp. 79-83, 1897. Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, pp. 303-317, 1899. Bain, H. Foster, Geology of Washington County: Iowa Geol. Survey, Vol. V, pp. 151-152, 1896. Udden, J. A., Geology of Louisa County: Iowa Geol. Survey, Vol. IX, pp. 93-95, 1901.

The oldest rocks outcropping in the area under discussion are exposed along Cedar river and belong to the Gower limestone formation of Middle Silurian age. The history of the region, however, does not commence with these oldest outcropping strata for lying north of the area are found still older rocks of Ordovician and Cambrian times and deep well records[58] reveal the presence of quartzite and slate which are believed to correspond in age to the Sioux quartzite of northwestern Iowa and to the Baraboo quartzite found in south-central Wisconsin, which rocks are considered to be Upper Huronian[59] in age.

The early history of the region seems to be as follows: A vast shallow sea extended over northeastern Iowa in which horizontal beds of sand and clay were deposited. The source of the material probably was the old unsubmerged igneous land mass in northern Wisconsin, Minnesota and Canada. After the sand deposited in this sea was finally converted into sandstone and later changed to quartzite, folding and uplifting occurred, resulting in a tilting of the beds to the southwest at an angle varying from three to seven degrees.[60] From other localities it is known that the newly elevated land surface underwent a long period of erosion, but that finally submergence again set in. The best evidence from well records seems to show that this submergence resulted in a widespread epicontinental sea in which sandstone and smaller amounts of limestone were deposited. The total thickness of these Cambrian deposits is as much as a thousand feet,[61] which indicates a long uninterrupted period of sedimentation.

This period of sandstone formation at last gave way to one during which calcareous and magnesian materials were the chief sediments deposited, for overlying conformably the Jordan sandstone, the upper one hundred feet or so of the Cambrian

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58 Norton, W. H., Underground Water Resources of Iowa: U. S. Geol. Survey, Water Supply Paper 293, Plates X and XI, pp. 293, 375, 447, 1912; Iowa Geol. Survey, Vol. XXI, Plates X and XI, pp. 68, 70, 450, 542, 1912; Thickness of the Paleozoic Strata of Northeastern Iowa: Iowa Geol. Survey, Vol. III, pp. 196, 197, 199, 1893.

59 Norton, W. H., Underground Water Resources of Iowa: U. S. Geol. Survey, Water Supply Paper 293, pp. 61-63, 374-375, 447 and 449, 1912.

60 Beyer, S. W., Sioux Quartzite and Certain Associated Rocks: Iowa Geol. Survey, Vol. VI, p. 75, 1896.

61 Norton and Others, Underground Water Resources of Iowa, U. S. Geol. Survey, Water Supply Paper 293, p. 63, 1912.

system, rests the Prairie du Chien formation consisting of the Oneota, New Richmond and Shakopee members. After about 250 to 300 feet of these sediments had been deposited, the sea withdrew and a great period of erosion at once set in, resulting in an almost complete removal at several places of the last formed group of strata.[62] The next formation to be laid down was the St. Peter sandstone, which has been believed by many to be of eolian origin,[63] but which now appears to be of marine derivation as pelecypods have recently been discovered in these strata at Minneapolis, Minnesota. The period of sedimentation did not stop with the St. Peter, but continued right on until at least about 400 feet of the Platteville limestone, Decorah shale and Galena dolomite had been laid down. Sedimentation then ceased for a while and erosion was the dominant process in operation. Soon, however, the sea encroached on the land again and the Maquoketa shale, with a thickness of 150 feet, was deposited.

As has been shown by Savage[64] seas covered northeastern Iowa during Silurian time. However, by far the greater part of the Silurian strata found in Iowa and in the region under discussion is of Niagaran or Middle Silurian age. As is indicated elsewhere, the rocks belonging to this age are the oldest strata exposed at the surface in the Lake Calvin basin. These rocks outcrop along Cedar river north of the village of Rochester in Cedar county. In all about 120 feet of Silurian sediments was laid down in the region.

As may be inferred from the typical Silurian section of New York,[65] the Upper Silurian is missing in Iowa and in this region. This fact gives rise to two alternative views: namely, that Iowa was land during Upper Silurian and Lower Devonian times, as seems to be indicated by the unconformity between the rocks of those two ages in northeastern Iowa; or that if the Cayugan, Helderbergian and Oriskanian seas did extend over the region

62 Trowbridge, A. C., The Prairie Du Chien-St. Peter Unconformity in Iowa: Proc. Iowa Acad. Science, Vol. XXIV, pp. 177-182, 1917.

63 Trowbridge, A. C., The Origin of the St. Peter Sandstone: Proc. Iowa Acad. Sci., Vol. XXIV, pp. 171-175, 1917. Sardeson, F. W., Minn. Acad. Nat'l Sci., Vol. IV, pp. 64-87, 1896. U. S. Geol. Survey, Folio No. 201, 1916. Dake, C. L., The Problem of the St. Peter Sandstone: Bull. School of Mines, Univ. Mo., Vol. 6, No. 1, Aug., 1921, pp. 210-216.

64 Savage, Thomas E., Geological Map of Iowa, 1905.

65 Chamberlin and Salisbury, Introductory Geology, p. 388.

those sediments were all removed before the Middle Devonian seas spread out over Iowa.

CLASSIFICATION OF THE NEW YORK AND IOWA SILURIAN

SERIES	NEW YORK	IOWA
Cayugan (Upper Silurian)	Manlius limestone Rondout waterlime Cobleskill limestone Salina beds	
Niagaran (Middle Silurian)	Guelph dolomite Lockport limestone Rochester shale Clinton beds	Gower dolomite Anamosa dolomite Le Claire limestone Hopkinton dolomite
Oswegan (Lower Silurian)	Medina sandstone Oneida conglomerate (and perhaps the Richmond beds)	Waucoma limestone Winston limestone

It is known that the Upper and Lower Silurian seas were restricted, whereas the Middle Silurian sea was widespread in America. This fact indicates also that there were shifting shore lines and that Iowa may well have been land during Upper Silurian times.

Resting unconformably on the Niagaran, thus indicating an erosional interval, lie the Wapsipinicon and Cedar Valley strata of Middle and Upper Devonian age. The rocks of these two formations are mainly limestones and attain a thickness of about 400 feet. The Wapsipinicon and Cedar Valley seas were teeming with life as is now testified by a large number of marine fossils found in the limestone. After about 400 feet of these sediments had been deposited, the sea withdrew and exposed the newly made surface to the elements of weathering and erosion. A long period of erosion seems to have taken place before the sea encroached again upon the land, for the State Quarry beds lie unconformably upon the deeply eroded surface of the Cedar Valley limestone. Conditions for marine life were exceptionally favorable during the State Quarry stage, for many of the State Quarry beds are practically coquina. Not only was the sea inhabited by corals and brachiopods similar to those of the previous seas, but also by thousands of fishes which, due to some unknown cause, suffered a sudden extinction as is now indicated by the fact that the cherty limestone beds of this formation are crowded with their teeth remains. How long this sea remained in the area can not be ascertained; however, suffice it to say that it remained sufficiently long for the deposition of at least forty feet of limestone.

The Devonian seas were followed by the invasion of the Mississippian sea which, judging from the thickness of the Mississippian system of rocks, about 500 feet, covered the region for a considerable length of time. Practically the entire sequence of Mississippian rocks is represented in Iowa, although the oldest formation, the Kinderhook, is the only one of these which aids in forming the bedrock of the Lake Calvin basin. That the Kinderhook sea extended farther north than is shown on the geological map, Plate VII, is shown by the small outliers of what were formerly known as the Sweetland Creek shale in Muscatine county near the city of Muscatine. These Sweetland Creek shales were formerly classified as Devonian on the basis of the fish teeth contained in them, since these are similar to those in the State Quarry beds. The fish whose remains are now found in the Sweetland Cheek shales, however, are now known to have lived in the Kinderhook seas and accordingly the strata are correlated with the Kinderhook. Sedimentation continued for some time, as several of the younger Mississippian formations are known to exist and to outcrop a little south of the southern border of the lake site.

After about 500 feet of sandstone, limestone and shale had been laid down, the sea again withdrew and erosion became active. Erosion seems to have progressed to a rather advanced stage as is indicated by the Iowa City and Louisa county sandstone outliers of Des Moines age, which occupy valleys in the Cedar Valley limestone which had been excavated to a depth of about 140 feet. Thus it appears that the region was deeply dissected before it was submerged beneath the Des Moines sea. It has been generally believed that this last submergence was in the nature of a shallow and restricted body of water occupying valleys rather than covering wide areas. The evidence for this belief seems to lie in the fact that wherever the Des Moines sandstone and shale is found, it is occupying valleys rather than high places. The Des Moines sea undoubtedly oscillated from time to time, as is shown by the interbedding of coal seams of nonmarine origin with the marine sandstone and shale. Finally the sea withdrew entirely and exposed the new surface, which seems never to have been submerged again. Whether younger deposits were laid down is not certain. If so, not only were they eroded away before Pleistocene time, but so also were practically all of the Pennsylvanian formations, excepting the few patches preserved in the valley north of Iowa City and the ones in Louisa and Muscatine counties. These patches of sandstone and shale were preserved because they occupied low places or valleys and hence were thus protected from erosion.

The finding of undoubted Cretaceous fossils[66] in the drift at various places, as at Iowa City, Mount Vernon, Cedar Rapids, Des Moines and Waterloo, has suggested to some the probability that the parent rock from which these fossils have been derived was not very far removed. The finding of a perfect slender belemnite[67] deeply buried in a clay seems to have strengthened the idea that the fossil must have been near to its original home, as it is believed that such a slender specimen could not have sustained transportation for a long distance without being shattered. Udden[68] also described two small deposits in Muscatine county, named the Pine Creek conglomerate, which he states may either belong to the Lafayette formation or be of Cretaceous age. Trowbridge, however, is of the opinion that these deposits are Aftonian.[69] Schuchert,[70] on the other hand, on his excellent maps of North American Paleogeography, does not extend the Cretaceous seas as far eastward as the Lake Calvin basin.

Subglacial Topography.

It matters little whether or not the Mesozoic seas inundated the region here discussed. The fact remains that before the

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66 Keyes, Charles R., Eastern Extension of the Cretaceous in Iowa: Proc. Iowa Acad. Science, Vol. I, pt. II, p. 21, 1890, 1891.

67 Norton, W. H., Geology of Linn County: Iowa Geol. Survey, Vol. IV, p. 168, 1894. White, C. A., Geology of Iowa, Vol. I, p. 98, 1870.

68 Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, pp. 303-316, 1899.

69 Personal Communication.

70 Schuchert, C., Paleogeography of North America: Bull. Geol. Soc. America, Vol. XX, pp. 94 and 95, 1908.

advent of the great continental ice sheets, at least before the Kansan ice invasion, eastern Iowa had been deeply dissected and probably presented a topography quite similar to that found in the famous Driftless Area of southern Wisconsin, and in the adjoining states of Minnesota, Illinois and Iowa.

A study of well records and outcrops of the indurated strata in the lake basin and in the surrounding counties of southeastern Iowa shows that the subglacial topography has a relief of 300 feet or so, and also discloses the presence of numerous large rock-cut channels which probably formed a drainage system of greater magnitude than now exists in the region.

As has been shown by Leighton,[71] Calvin[72] and Thomas[73] the bedrock surface beneath the drift covering in Johnson county has marked irregularities. "Over an irregular area in the central, northern and northeastern parts, and along the the extreme southern border of the county, bedrock is high, but between these two areas there is a northwest-southeast belt in which the bedrock surface is low."[74] The relief of the country was at least over 250 feet, for the highland bedrock surface has an average elevation of about 700 feet above sea level and in the lowland district bedrock is as low as 460 feet above sea level. This northwest-southeast trending lowland with a width of at least eleven miles crosses the Iowa river arm of the Lake Calvin basin south of Iowa City. "The north wall of the buried valley follows more or less closely the boundary between the Devonian and Mississippian formations."[75] This ancient valley undoubtedly extends diagonally across the northern portion of Louisa county and continues along the lowland underlying the Iowa-Cedar river valley of today, until it joins the ancient valley of the Mississippi.

Udden[76] has shown that the subglacial surface under the

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71 Leighton, Morris M., The Pleistocene History of Iowa River Valley, North and West of Iowa City in Johnson County: Iowa Geol. Survey, Vol. XXV (1914), pp. 110-112, 1916.

72 Calvin, S., Geology of Johnson County: Iowa Geol. Survey, Vol. VII, pp. 48, 90-91, 1897.

73 Thomas, A. O., Underground Water Resources of Iowa: Iowa Geol. Survey, Vol. XXI, p. 505, 1912. U. S. Geol. Survey, Water Supply Paper No. 293, p. 420, 1912.

74 Leighton, Morris M., The Pleistocene History of Iowa River Valley, North and West of Iowa City in Johnson County: Iowa Geol. Survey, Vol. XXV (1914), p. 111, 1916.

75 Idem, p. 111.

76 Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. XI, pp. 326, 327, and plate VII, 1899.

West Liberty Plain (the lowland area bordering Cedar river in Muscatine county) was low and that the valley now occupied by Mud creek lies over a buried valley. The region to the north of the lake bed appears to have been an upland. This ancient valley connected with the one to the south just described. There is a possibility also that the Washington channel[77] may have joined this general lowland area somewhere in the vicinity of Columbus Junction. The Washington channel, to which Bain[78] and Calvin[79] have called attention, extends diagonally across Washington county in a northwest-southeast direction, passing beneath the city of Washington. This ancient buried valley, as well as the one in Poweshiek county at Deep River,[80] may have some connection with the large buried valley underlying the famous Belle Plain artesian[81] basin which extends in a northwest-southeast direction through Tama, southwest Benton and northwest Iowa counties. In the northeast, the West Liberty subglacial lowland was joined by an ancient valley thought by Carman,[82] Norton,[83] Udden[84] and Leverett[85] to be the probable course of a preglacial Mississippi river. It is evident that the present course of Mississippi river between Princeton on the north and Muscatine on the south is of much more recent date than are portions of the river to the north and south of the two mentioned cities.[86] It has been suggested[87] that the preglacial

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77 Norton, W. H., Underground Water Resources of Iowa: Iowa Geol. Survey, Vol. XXI, p. 696, 1912; U. S. Geol. Survey, Water Supply Paper No. 293, p. 575, 1912.

78 Bain, H. Foster, Preglacial Elevation of Iowa: Proc. Iowa Acad. Science, Vol. II, p. 23, 1895; Geology of Washington County: Iowa Geol. Survey, Vol. V, pp. 159, 160, and fig. 9, 1896. Norton, W. H., Underground Water Resources of Iowa: Iowa Geol. Survey, Vol. XXI, p. 740, 1912. U. S. Geol. Survey, Water Supply Paper No. 293, p. 611, 1912.

79 Calvin, S., Notes on the Formations passed through in boring the deep well at Washington, Iowa: Amer. Geologist, Vol. I, pp. 28-31, 1888.

80 Bain, H. Foster, Geology of Washington County: Iowa Geol. Survey, Vol. V, p. 160, 1896. Stookey, S. W., Geology of Poweshiek County: Iowa Geol. Survey, Vol. XX, pp. 253, 254, 260, 265, 267, 1909.

81 Mosnat, H. R., Report on the Artesian Wells of the Belle Plain Area: Iowa Geol. Survey, Vol. IX, pp. 530-548, 1899. Stookey, S. W., Geology of Iowa County: Iowa Geol. Survey, Vol. XX, p. 179, 1910. Call, R. E., Iowa Artesian Wells: Iowa Weather and Crop Service, Vol. III, p. 4, March, 1892.

82 Carman, J. Ernest, The Mississippi Valley Between Savanna and Davenport: Illinois Geol. Survey, Bull. 13, pp. 58, 62 and 63, 1909.

83 Norton, W. H., Geology of Scott County: Iowa Geol. Survey, Vol. IX, pp. 413-415, 492-493, 1899.

84 Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, p. 327, 1899.

85 Leverett, Frank, The Illinois Glacial Lobe: U. S. Geol. Survey, Monograph XXXVIII, pp. 462-467, 1899.

86 Carmen, J. Ernest, The Mississippi Valley Between Savanna and Davenport: Illinois Geol. Survey, Bull. 13, p. 58, 1909.

87 Carman, Idem, p. 58.

valley of this mighty river extended up the Wapsipinicon river valley to the mouth of Mud creek from which place it extended roughly parallel to Mud creek in a southwest direction as far as Durant. That portion of the channel from the Wapsipinicon river to Durant has been called by Norton the Cleona channel.[88] Although the channel follows in a general way the course of Mud creek, it deviates at places from two to three miles to the south and to the east of it. Bedrock is not reached at 450 feet above sea level and "one well three miles north of Durant on the divide between Mud and Elkhorn creeks does not reach rock at 400 feet above sea level".[89] Well records show that the bluffs of the valley were rather steep, as the elevation of the rock surface has been found to differ as much as 250 feet within a mile. Several smaller tributaries of the Cleona channel have been mapped. From Durant the preglacial valley extends in a general direction past Wilton until it finally joins the lowland underlying the West Liberty Plain. It is not certain whether this ancient Mississippi entered the subglacial valley occupied by the present Mississippi river by way of a channel immediately south of the city of Muscatine or whether it pursued a course southward and finally followed the Iowa-Cedar river valley to the site of the buried valley at the debouchure of Iowa-Cedar river into the present Mississippi.[90]

Another large channel which undoubtedly was a tributary to the Cleona river is the Stanwood channel[91] whose course has been mapped and outlined by Norton. This ancient river flowed by Stanwood, Cedar county, then took a southerly direction, passing east of Tipton and flowing finally along the east side of the present Sugar creek valley. About two and one-half miles north of Lime City it turned southeast and near Durant joined

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88 Carman. Idem, p. 58. Norton, W. H., Geology of Cedar County: Iowa Geol. Survey, Vol. XI, p. 299, 1901; Geology of Scott County: Iowa Geol. Survey, Vol. IX, p. 493, 1899; Underground Water Resources of Iowa: U. S. Geol. Survey, Water Supply Paper 293, pp. 488-490, and fig. 5, 1912; Iowa Geol. Survey, Vol. XXI, pp. 587 and 588, and fig. 5, 1912.

89 Carman, Idem, pp. 58 and 59.

90 Carman, Idem, p. 58, and fig. 22. Leverett, F., The Illinois Glacial Lobe: U. S. Geol. Survey, Monograph XXXVIII, pp. 466 and 467, 1899.

91 Norton, W. H., Geology of Cedar County: Iowa Geol. Survey, Vol. XI, pp. 297-300, and fig. 17, 1901; Underground Water Resources of Iowa, U. S. Geol. Survey, Water Supply Paper 293, pp. 368-370, and fig. 4, 1912; Iowa Geol. Survey, Vol. XXI, pp. 441-443, and fig. 4, 1912.

the Cleona channel. "Measured from crest to crest, its width is at least seven miles at Tipton."[92]

On the west side, the West Liberty lowland area may have received a tributary by way of the upper Wapsinonoc valley. A buried channel has been discovered a little west of Downey where it lies deeply hidden under the drift covering.[93] This channel probably connects with the one lying in the upper northeast corner of Johnson county, between Solon and the present Cedar river.[94]

The above described channels undoubtedly all formed part of the vast drainage system of which the master stream probably was the preglacial Mississippi river. It has been sufficiently established that the present Mississippi river is at various places occupying a valley other than that of its own making. Gordon[95] and Leverett[96] have shown that the subglacial valley is much larger than the present one, whose average width is six miles and whose depth is 150 feet as compared to the width of six to fifteen miles and the depth of 250 feet of the former valley. Between Keokuk and Montrose the present valley of Mississippi river is comparatively recent. North of Montrose to Muscatine the river is occupying the ancient valley. From Muscatine to Princeton the river is again in a newly cut valley and from the latter city up to St. Paul, Minnesota, the mighty Father of Waters is occupying the ancient valley.[97]

Such is the surface of the Lake Calvin region beneath the thick covering of drift. Because it has been invaded by glaciers several times, the former highly dissected and rough topography is now everywhere obliterated and the surface has been made relatively smooth by a thick mantle of unconsolidated drift materials which are described in the following chapter.

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92 Norton, W. H., Geology of Cedar County: Iowa Geol. Survey, vol. XI, p. 299, 1901.

93 Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, p. 326, and plate VII, 1898. Calvin, S., Geology of Johnson County: Iowa Geol. Survey, Vol. VII, p. 91, 1897. Norton, W. H., Geology of Cedar County: Iowa Geol. Survey, Vol. XI, pp. 297 and 298, 1901.

94 Calvin, S., Geology of Johnson County: Iowa Geol. Survey, Vol. VII, pp. 90 and 91, 1897.

95 Gordon, C. H., Buried River Channels in Southeastern Iowa: Iowa Geol. Survey, Vol. III, pp. 244-249, 1895.

96 Leverett, F., The Lower Rapids of the Mississippi River: Proc. Iowa Acad. Science, Vol. VI, pp. 74-93, 1899; Preglacial Valleys of the Mississippi and its Tributaries: Journal of Geology, Vol. III, pp. 740-768, 1895; The Lower Rapids of the Mississippi River: Journal of Geology, Vol. VII, pp. 1-22, 1899; Old Channels of the Mississippi in Southeastern Iowa: Annals of Iowa Historical Quarterly, (3) Vol. V, pp. 38-51, 1901; Illinois Glacial Lobe: U. S. Geol. Survey, Monograph XXXVIII, pp. 460-477, 1899.

97 For a list of the more important contributions dealing with the drainage problem of Mississippi river, the reader is referred to Appendix A.

CHAPTER IV.

THE PLEISTOCENE DEPOSITS OF THE LAKE CALVIN REGION.

All the five great continental ice incursions now recognized in North America are represented, directly or indirectly, in the Lake Calvin region.

CLASSIFICATION OF THE PLEISTOCENE DEPOSITS IN IOWA.[98]

9. Wisconsin drift (of the Des Moines lobe)
8. (b) Peorian soil and weathered zone (of Leverett) at top of loess and beneath Wisconsin drift.
   (a) Main deposit of loess.
7. Iowan drift (of Iowa geologists)[99]
6. Sangamon soil, vegetal deposits and weathered zone (of Leverett) (including super-Illinoian "gumbo", or "gumbotil" of Kay) at top of Illinoian drift and beneath loess.
5. Illinoian drift (of Leverett)
4. Yarmouth soil, vegetal deposits, and weathered zone (of Leverett) (including super-Kansan "gumbo," or "gumbotil" of Kay) at top of the Kansan drift; also Buchanan gravel (of Iowa geologists) beneath Iowan drift and loess.
3. Kansan drift (of Iowa geologists)
2. Aftonian gravels, vegetal deposits, soil and weathered zone (of Chamberlin) (including super-Nebraskan "gumbo" or "gumbotil" of Kay) at top of Nebraskan drift.
1. Nebraskan drift (of Iowa geologists) (pre-Kansan or sub-Aftonian of Chamberlin)

The Nebraskan Drift.

Distribution.—In view of the fact that the region was visited

98 Alden, Wm. C., and Leighton, Morris M., The Iowan Drift, A Review of the Evidences of the Iowan Stage of Glaciation: Iowa Geol. Survey, Vol. XXVI, Ann. Rep't, 1915, p. 57, 1917.

99 The Iowan stage of glaciation has now been fully established by Alden and Leighton, see previous reference, pp. 49-212.

by more than one ice sheet, exposures of the oldest drift called the Nebraskan, sub-Aftonian or pre-Kansan, are extremely rare. Practically everywhere a thick mantle of younger drift masks the older and only at a very few places, as along the base of steep slopes and along stream courses, does the Nebraskan drift come to the surface. Its presence over widespread areas seems to be revealed, however, by the records of numerous wells scattered over the region.

Exposures of the pre-Kansan drift in the lake basin or the region surrounding it have been described by Udden in his Louisa County report.[100] However, when it is remembered that the earlier investigators did not know of gumbotil or use it to differentiate one drift from another but based their partition on color, texture and petrographic content of the deposits and on intervening stratified sands and gravels, it remains an open question whether the described drifts can be proved definitely to be Nebraskan. Some of Udden's exposures listed below were seen by the writer but in only two cases (10 and 11) does the writer feel confident that the drift belongs to the oldest stage of glaciation. The drift in the other outcrops may be either Nebraskan or Kansan.

EXPOSURES OF NEBRASKAN DRIFT CITED BY UDDEN.[101]

1. On the right bank of Honey creek near the south line of Sec. 21, Tp. 73 N., R. III W.
2. On the south bank of Smith creek near the center of the Se. ¼ of Sec. 35, Tp. 73 N., R. III W.
3. In the southwest bank of Smith creek near the southeast corner of Sec. 30, Tp. 73 N., R. II W.
4. In the south bank of Long creek near the center of Sec. 22, Tp. 74 N., R. IV W.
5. In the bank of the Muscatine North and South railroad cut, in the east bluff of Iowa river, in the Se. ¼ of Sec.9, Tp. 74 N., R. III W.
6. On the west bank of Iowa river at Wapello.

100 Udden, J. A., Geology of Louisa County: Iowa Geol. Survey, Vol. XI, pp. 55-126, 1901.
101 Idem, pp. 103 and 104.

7. On the west bank of Iowa river one mile north of Columbus Junction and farther north.
8. In the west bank of Cedar river two miles north of Columbus Junction.
9. In the railroad cuts in the bluffs of Mississippi river in Sec. 2, Tp. 75 N., R. III W.
10. Foot of the west bluff of Iowa river, along the wagon road in the Se. 1/4 of Sec. 21, Tp. 76 N., R. V W.
11. East bank of the Iowa, on both sides of the north line of Sec. 16, Tp. 76 N., R. V W.

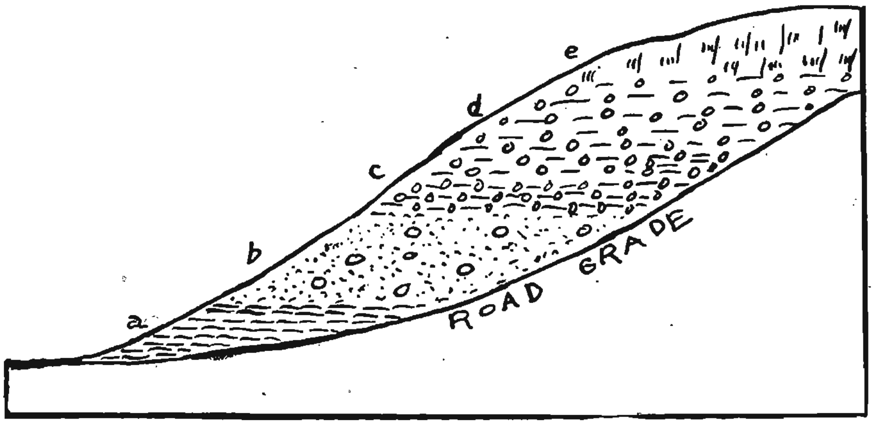

FIG. 7.—Relations of strata of drift seen on the south side of the road leading down the Iowa river bluff in the Se. 1/4 of sec. 21, Tp. 76 N., R. V. W. *a* Black, tough, leached silty soil (top of Nebraskan till ?); *b* tough bowlder clay with ferruginous joints, yellow above, grayish blue below (Kansan); *c* somewhat stratified and sandy, yellow till; *d* leached horizon (Sangamon; *e* loess. (After Udden.)

Udden, in describing the Nebraskan, makes the following statement regarding locality 10 and presents the figure (Fig. 7) given below. "In one instance there seems to be a soil horizon on its upper surface."[102] At the time of the writer's visit to the exposure, *a,* the black tough soil horizon, was not seen, due to heavy slump. However, *b, c, d,* and *e* were visible and *d* proved to be a typical gumbotil. Because of its topographic position and elevation, about 640 feet above sea level, the writer believes the gumbotil to be super-Nebraskan and the till beneath, Nebraskan. Two miles both north and south of this exposure undoubted Kansan gumbotil is found at 710 feet. Unless the present conception of the origin of the gumbotil is erroneous, no such big

102 Idem, p. 104, and fig. 8.

difference in elevation in the same gumbotil within such a short distance is permissible. The only outcrops of the Nebraskan drift in Muscatine county are found in the vicinity of Muscatine. No exposure of the oldest drift in Cedar county is reported although wells sunk over the Stanwood channel penetrate it.[103] Exposures of the pre-Kansan drift were not known to occur in Johnson county until 1916 when the writer discovered along the bluff line of the extinct lake a true gumbotil lying between two drifts. This gumbotil and the drifts are exposed in two road cuts, separated by about four-tenths of a mile. Midway between the two outcrops and at approximately the same elevation, the presence of the gumbotil is indicated by a strong flowing spring. As the upper drift is undoubted Kansan, the lower must be the Nebraskan. The two exposures are in West Lucas township in the southeast quarter of section 33. The first outcrop is the west bank of the cut along the road where it descends from the upland to the lowland in the extreme southeast corner of the section. The other exposure is four-tenths of a mile to the northwest of the first exposure. A third outcrop of what seems to be Nebraskan drift was discovered by the writer in the north bank of Davis creek, in the extreme southwest corner of section 36, Iowa township, Washington county. This till, which is dark, dense and bluish, is separated from a light pebbly fresh brown till by about twenty feet of highly oxidized and leached stratified sands and gravels which the writer believes to have been weathered during the interglacial interval separating the Nebraskan from the Kansan stage of glaciation.[104] This exposure lies 640 feet above sea level or approximately ten feet lower than the super-Nebraskan gumbotil in Johnson county. Because of its stratigraphic position and its close proximity either to the leached and oxidized sands and gravels in Washington county or to the super-Nebraskan gumbotil in Johnson county, the drift seen at the following places may be mentioned as probably being Nebraskan.

1. Johnson county, Liberty township, section 27, Ne. ¼, west river bank.

103 Norton, W. H., Geology of Cedar County: Iowa Geol. Survey, Vol. XI, p. 344, 1901.
104 Schoewe, W. H., The Interpretation of Certain Leached Gravel Deposits in Louisa and Washington Counties, Iowa: Proc. Iowa Acad. Science, Vol. XXVI, pp. 393-398, 1919.

2. Johnson county, Fremont township, section 24, Sw. ¼, east river bank.
3. Johnson county, Fremont township, section 25, Se. ¼, west part, east river bank.
4. Johnson county, Pleasant Valley township, section 23, Ne. ¼, northwest part, east river bank.
5. Washington county, Iowa township, section 23, Nw. ¼, northeast part, west bank of river.
6. Louisa county, Union township, section 6, northcentral part, south bank.
7. East bank of Iowa river on both sides of the north line of section 16, Tp. 76 N., R. V W. (Udden's exposure 11, see page 90.)

Character of the Drift.—The Nebraskan till in its unweathered state consists of a hard, dark brownish to blue-black, calcareous, compact, joint clay, which contains at places many fragments of wood. The till breaks into small angular to rhomboidal blocks. Where this till has been seen, most of the pebbles which are scattered throughout its mass are small and cobbles or bowlders are relatively few. At exposure 7 above, or 11 of Udden's outcrops, the clay appears to be without pebbles and finely laminated. Numerous cobbles and bowlders of all descriptions and sizes are to be found lying on the surface of the till, which in most cases forms a sort of bench. Many of these stones are striated and a large number of the granitic type are thoroughly disintegrated and break into thousands of pieces when stepped on. It is also noticeable that wherever these cobbles and bowlders occur, an unusual proportion of them are flattish or slablike.

The weathered phase of the pre-Kansan drift has been oxidized to a brownish color. It is not as compact as the unweathered phase and apparently does not differ from the weathered phase of any of the younger drift sheets. According to Udden, the Nebraskan drift "contains about twice as many fragments of local rocks"[105] such as the Kinderhook and Burlington formations, as do other drifts. Also accord-

[105] Udden, J. A., Geology of Louisa County: Iowa Geol. Survey, Vol. XI, p. 102, 1901; Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, see table on p. 336, 1899.

ing to the same observer, more greenstone hornblendic rocks as well as schists and a smaller proportion of dolomitic limestone and rocks common in the Keweenawan are found in the Nebraskan than in other drifts.

Thickness of the drift.—The maximum thickness seen, either of the fresh or of the weathered drift, is no more than ten feet. Due to heavy slumping, the thickness of the Nebraskan north of Gladwin at the outcrop in the west bluff of Iowa river, along the wagon road in the Se. ¼ of sec. 21, T. 76 N., R. V W., and at Indian lookout in Se. ¼ of sec. 33, West Lucas township, Johnson county, could not be ascertained, but a fair estimate of thirty to forty-five feet could not be overconservative. It appears that on the whole the Nebraskan drift is thin and is absent from the uplands except where the preglacial surface was low.[106] Even in the low places it was found sparingly.[107] According to Leighton[108] a study of well records in Johnson county gives the Nebraskan the following thickness: 15, 15, 25, 54, 86 and 122 feet. Udden[109] reports ten to twenty feet for the thickness of the drift in Louisa county, and Norton[110] reports a thickness of sixty-five feet in Cedar county.

The Aftonian Deposits [111]

The gumbotil.—The only true deposits of the first interglacial stage outcropping in the lake region are the super-Nebraskan gumbotils exposed at three places along the bluff line of Lake Calvin. The first two outcrops are in Johnson county in the southeast quarter of section 33 of West Lucas township. The third exposure is in Louisa county in the southeast quarter of section 21, Union township. This gumbotil,[112] which is believed to be the oxidized and leached pro-

106 Udden, J. A., Geology of Louisa County: Iowa Geol. Survey, Vol. XI, p. 103, 1901.

107 Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, p. 338, 1899.

108 Leighton, Morris M., The Pleistocene History of Iowa River Valley, North and West of Iowa City in Johnson County: Iowa Geol. Survey, Vol. XXV, pp. 169-181, 1914.

109 Udden, J. A., Geology of Louisa County: Iowa Geol. Survey, Vol. XI, p. 103, 1901.

110 Norton, W. H., Geology of Cedar County: Iowa Geol. Survey, Vol. XI, p. 344, 1901.

111 At the time of this writing the term Aftonian as the name of the first interglacial deposits is in question since doubt is being raised as to whether the type section of the Aftonian sands and gravels at Afton Junction is a true interglacial deposit.

112 Kay, George F., Gumbotil, A New Term in Pleistocene Geology, Science, New Series, Vol. XLIV, Nov. 3, 1916; Pleistocene Deposits between Manilla in Crawford County and

duct of the drift, is a drab or ash-colored, thoroughly leached, hard and tough clay containing but few pebbles. The contained pebbles are small and consist of the more insoluble matter such as quartz, chert and quartzite; other constituents, however, as granites and basalts, are not entirely wanting. A microscopic analysis[113] shows that the gumbotil is made up of sixty to seventy-five per cent of minute, spherical, transparent grains of quartz and twenty-five to forty per cent of clay. When it is wet, the gumbotil breaks with a starchlike fracture and when it is dry its surface has a characteristic checkered appearance. A thickness of only about ten feet could be determined definitely at the exposures in Johnson county, due to heavy slumping, and only four feet at the third exposure. In Johnson county a brownish till sheet lies on top of the gumbotil and another lies beneath it, whereas in Louisa county it is overlain by a loess and underlain by a brown to yellowish sandy till. The gumbotil in Louisa county is believed to be Nebraskan rather than Kansan. Two miles to the north and at a similar distance to the south from the outcrop is another gumbotil lying at an elevation of 705 to 710 feet above sea level. At these places the gumbotil lies fifteen to twenty feet below the general level of the upland and is Kansan. As the elevation of the gumbotil in the southeast quarter of section 21 is about 640 feet, the original gumbotil plain, if all of the gumbotils are of the same age, has a slope of seventy feet in two miles or thirty-five feet per mile. Since it is believed that the plain on which the gumbotil was formed was essentially a ground moraine like that of the Wisconsin stage of glaciation in northcentral Iowa and that erosion was slight,[114] it is believed that a plain with a relief of thirty-five feet per mile is not in harmony with the idea of the origin of gumbotil.

A deposit which is possibly gumbotil has been reported by

Coon Rapids in Carroll County, Iowa: Iowa Geol. Survey, Vol. XXVI, p. 217, 1915; The Origin of Gumbitil, (with J. N. Pearce): Jour. of Geology Vol. XXVIII, No. 2, pp. 89-125, Feb.-Mar. 1920.

113 Dewey, Arthur H., The Pleistocene History of Lee County, Iowa. Unpublished thesis, Library, State University of Iowa, 1917.

114 Kay, G. F., Some Features of the Kansan Drift in Southern Iowa: Bull. Geol. Soc. of America, Vol. XXVII, pp. 115-117, 1915. Reprinted in Iowa Geol. Survey, Vol. XXV, pp. 612-615, 1914.

Leighton[115] as outcropping along the west bluff of Iowa river a few miles north of Coralville in section 33, Penn township, Johnson county. The writer in company with Mr. A. H. Dewey visited the section and found there what might be interpreted as a gumbotil, but due to the slumping of early spring, it was impossible to determine its thickness or whether it was in place.

Leached sands and gravels.—The only other visible evidence of this first interglacial interval is found in the following two places:

1. Washington county, Iowa township, section 36, extreme southeast corner, north bluff of Davis creek.
2. Louisa county, Union township, section 8, Nw. ¼, Sw. ¼, south wall of Goose creek.

At these places occur highly oxidized and leached stratified sands and gravels above which is fresh oxidized till, and, in the outcrop in Washington county, dense bluish compact unaltered till. The leaching and oxidation of these sands and gravels is believed to represent the time interval between the Nebraskan and Kansan stages of glaciation.[116]

Other interglacial deposits.—Aside from the above described interglacial deposits, numerous other sands and gravels, silts, soil bands and peat beds have been described in the various geologic county reports of the region as being Aftonian.[117] These deposits, most of which are lying at a considerable depth below the surface, are revealed in the logs of wells. Those in Louisa county range in thickness from two to ten feet, those in Muscatine from eight to fourteen feet and those in Johnson county from four to sixty-eight feet.

The Kansan Drift.

Distribution.—Except for the eastern border of the lake basin in Muscatine county and several small areas in the

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115 Personal communication to Dean G. F. Kay.

116 Schoewe, W. H., The Interpretation of Certain Leached Gravel Deposits in Louisa and Washington Counties, Iowa: Proc. Iowa Acad. Science, Vol. XXVI, pp. 393-398, 1919.

117 Calvin, S., Geology of Johnson County: Iowa Geol. Survey, Vol. VII, 1897. Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, 1899; Geology of Louisa County: Iowa Geol. Survey, Vol. XI, 1901. Norton, W. H., Geology of Cedar County: Iowa Geol. Survey, Vol. XI, 1901. Leighton, Morris M., The Pleistocene History of Iowa River Valley, North and West of Iowa City, in Johnson County: Iowa Geol. Survey, Vol. XXV, (1914), 1916.

northern portion of the lake region, the Kansan is the uppermost drift under practically the entire area. This drift is either exposed at the surface or it lies directly below a more or less heavy mantle of loess. As exposures may be seen almost everywhere along road cuts, along the valley walls of Iowa and Cedar rivers as well as along some of the smaller streams, no detailed locations need be cited.

Character of the drift.—Several phases of the Kansan drift sheet were noted; namely, the fresh or unaltered phase, the oxidized but unleached phase and the oxidized and leached phase. The unchanged till consists of a very compact, dense material of a bluish color in which the pebbles are predominantly small and which at places contains numerous fragments of wood. This phase of the Kansan till is rarely represented in the outcrops by a thickness of more than a few feet. Overlying the unoxidized and unleached material is a gray or yellowish to brownish sticky clay containing numerous striated and subangular pebbles, cobbles and bowlders of all descriptions. In most places the till is very sandy and in the vicinity of Columbus Junction an unusual amount of limestone is noticeable. Small rounded quartz, chert and greenstone pebbles also are numerous throughout this phase of the till. Large bowlders of granite, dolerite and basalt are in evidence practically everywhere. Some of these are highly weathered and crumble to pieces on slight pressure, whereas others are very hard and show no trace of alteration. It was noted that in Johnson, Louisa and Washington counties, among the gravels and bowlders lying on the surface of the Kansan drift within the lake basin near to the bluff line, a fair proportion are more or less slablike instead of having the characteristic subangular form. In Johnson county the Kansan drift is relatively free from large bowlders except locally as in the tributary gullies of Iowa river north of Iowa City where numerous large fresh bowlders of various kinds have been concentrated.[118] According to Udden[119] a larger proportion of diabase, granite and

118 Leighton, Morris M., The Pleistocene History of Iowa River Valley, North and West of Iowa City in Johnson County: Iowa Geol. Survey, Vol. XXV (1914), p. 119, 1916.

119 Udden, J. A., Geology of Louisa County: Iowa Geol. Survey, Vol. XI, p. 105, 1901.

other Keweenawan pebbles are found in the Kansan of Louisa county than in the Nebraskan, whereas the number of limestone and dolomite pebbles is the same in the two drifts.

Except for the absence of the calcareous constituents, the oxidized and leached zone of the Kansan drift is in all respects similar to that of the oxidized and unleached portion just described. It may be noted that very often the uppermost foot or two of the altered drift is very highly oxidized to a reddish brown color and is thus set off from the other portions of the drift. This thin zone is known as the "ferreto" zone.

Thickness of the drift.—The Kansan drift differs in thickness from place to place, being thinnest where it rests on bedrock. Where the drift was seen lying directly on the country rock in Morning Sun township, Louisa county, its thickness scarcely anywhere exceeds twenty feet and at the Interurban cut on the west side of Iowa river at Iowa City, its thickness is not quite eight feet. The maximum thickness of this till which was seen in the field is about sixty feet although well records in Johnson county, as shown by Leighton,[120] indicate a thickness of over 200 feet. Udden[121] reports a maximum of 100 feet for Muscatine county. In general the leaching of the Kansan drift has not penetrated farther down than five to thirteen feet,[122] whereas the oxidation as observed in the field has in many cases extended to a depth of sixty feet or more.

The Yarmouth Interglacial Deposits.

The Kansan gumbotil.—The second or Yarmouth interglacial stage is represented mostly by exposures of gumbotil and Buchanan gravels. Numerous well records throughout the region reveal also a soil and peat horizon. The Kansan gumbotil in its physical and chemical properties is in all respects similar to the Nebraskan. At most places the gumbotil is overlain by leached loess although a few outcrops show oxi-

120 Leighton, Morris M., The Pleistocene History of Iowa River Valley North and West of Iowa City in Johnson County: Iowa Geol. Survey, Vol. XXV (1914) p. 118, 1916.

121 Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, p. 339, 1899.

122 Alden, Wm. C., and Leighton, Morris M., The Iowan Drift: Iowa Geol. Survey, Vol. XXVI (1915), pp. 85-87, 1917.

dized Illinoian till above the gumbotil. Its thickness where it may be seen ranges from six to eleven feet. This small range of thickness, however, does not, in all probability, represent the entire development of this material, for in most instances the outcrops were either in shallow road cuts or else were hidden by more or less slumping. An average thickness of fifteen feet probably would not be far from correct, especially as that is the average thickness of the Kansan gumbotil in nearby counties.[123] In altitude the Kansan gumbotil plain ranges from 670 to 750 feet above sea level, being higher toward the western portion of the lake region.

The Buchanan gravels.—Most of the Buchanan gravels to be seen in the lake region are those described by Leighton.[124] Similar deposits are exposed in Iowa City on the north side of Brown street near Dubuque street, at the T-road in the center of section 16, West Lucas township, south of the city, and in the walls of the gully immediately south of the railroad tracks of the branch line of the Chicago, Rock Island and Pacific Railway where it crosses Iowa river.

The Buchanan deposits consist of highly oxidized and decayed stratified sand and gravel whose textural range is from fine sand to bowlders one foot or so in diameter. Many of the sands and gravels are of a highly reddish color and at places show crossbedding and contortion.[125] Calvin[126] has divided the Buchanan gravels into two phases, the upland phase and the valley phase, the former consisting of the coarser and bowldery material, the latter of the sand and finer pebbly gravel. Calvin regarded the Buchanan gravels as Kansan outwash, the upland phase having been deposited while the valleys were still filled with ice and the valley phase having been laid down in connection with the retreat of the ice

123 Dewey, Arthur H., The Pleistocene History of Lee County, Iowa, Unpublished thesis, Library, State University of Iowa, 1917.

124 Leighton, Morris M., Pleistocene History of Iowa River Valley, North and West of Iowa City in Johnson County: Iowa Geol. Survey, Vol. XXV (1914), pp. 120-124, 1916.

125 Idem, pp. 142-146; An Exposure showing post-Kansan glaciation near Iowa City, Iowa: Jour. Geology, Vol. 21, pp. 431-435, 1913. Alden, Wm. C., and Leighton, Morris M., The Iowan Drift: Iowa Geol. Survey, Vol. XXVI (1915), pp. 117-118, 1917.

126 Calvin, S., Geology of Buchanan County: Iowa Geol. Survey, Vol. VIII, pp. 201-253, 1898.

sheet.[127] Leighton[128], however, has come to the conclusion that Calvin's valley phase or terrace gravels represent Iowan outwash deposits.

Sand and gravel deposits in Muscatine county.—Deposits of highly oxidized coarse sand and fine pebbles, very similar to Calvin's valley phase of Buchanan gravels, are exposed in Muscatine county at the following four localities:

1. Goshen township, center of section 11, east road cut of north and south road.
2. Goshen township, southwest corner of section 9, road cut.
3. Goshen township, corner of south section line of section 10.
4. Wapsinonoc township, center of section 26.

With the exception of locality 4, all of the outcrops are in road cuts in the bluff line of the old lake. The deposits consist of highly ferruginous or brownish red coarse sand and fine pebbles. The pebbles are almost all well rounded and some are striated. The material is leached as is the underlying till. In all three of the exposures in Goshen township, the sands and pebbles are covered by a deposit of loess or loess-like clay most of which is leached. In section 9 the sandy material is covered by eight inches of sticky gray clay containing small chert pebbles, and in section 10 the underlying till, which is rather sandy at places, contains pockets of a similar very sticky leached clayey material containing quartz and chert pebbles. This clayey deposit may represent a gumbotil, a soil bed or a lake deposit. Only at two places, in sections 10 and 11, could the thickness of the sands and gravels be determined. In the former cut, four feet of sand is exposed, whereas in the latter exposure the thickness of the deposit ranges from ten to fifteen feet. In all four instances, the sand and pebbles were practically at the same height above the adjacent flat or terrace, namely twenty to thirty feet, or at an elevation of 685 to 695 feet above sea level. If these de-

127 Leighton, Morris M., The Buchanan Gravels of Calvin and the Iowan Valley Trains: Proc. Iowa Acad. Science, Vol. XXIV, p. 86, 1917.

128 Idem, p. 86.

posits are Buchanan gravels, then they correspond to Calvin's valley phase, as they are very much finer than the Buchanan gravel deposit of the interurban cut at Iowa City which is, according to Leighton,[129] the upland phase. From their topographic position it is clearly evident that these four deposits, although resembling the valley phase very closely, cannot be valley train deposits from the Iowan ice as Leighton[130] suggests for Calvin's valley phase. The presence of the sticky clay overlying the sands at one locality and the remarkable coincidence of elevation and height above the lowland or terrace suggest the possibility that the deposits may represent a highly oxidized beach deposit of a former body of water.

Other Yarmouth deposits.—Other and similar deposits representing Yarmouth times are described as occurring in Louisa, Cedar and Johnson counties. Udden[131] described a somewhat gravelly sand as well as soil bands which he found in Louisa county. Norton[132] reports one exposure in Cedar county which showed a dark red sand containing disseminated pebbles and Leighton[133] refers to the Buchanan gravels as being encountered in numerous wells in Johnson county.

The Illinoian Drift.

Distribution and character.—The Illinoian drift forms the surface material in those parts of Muscatine and Louisa counties which lie east and south of the lake basin. While it is characterized by a somewhat lighter yellowish color and a more sandy nature, the Illinoian drift to all other appearances closely resembles the Kansan and the Nebraskan drift sheets. Not only is the thickness of this drift less than the thicknesses of the other two, but leaching and oxidation have

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129 Leighton, Morris M., Pleistocene History of Iowa River Valley, North and West of Iowa City in Johnson County: Iowa Geol. Survey, Vol. XXV (1914), p. 120, 1916.

130 Leighton, Morris M., The Buchanan Gravels of Calvin and the Iowan Valley Trains: Proc. Iowa Acad. Science, Vol. XXIV, p. 86, 1917.

131 Udden, J. A., Geology of Louisa County: Iowa Geol. Survey, Vol. XI, pp. 105-107, 1901.

132 Norton, W. H., Geology of Cedar County: Iowa Geol. Survey, Vol. XI, pp. 366-367, 1901.

133 Leighton, Morris M., Pleistocene History of Iowa River Valley, North and West of Iowa City in Johnson County: Iowa Geol. Survey, Vol. XXV (1914), pp. 123, 169-181, 1916.

not progressed nearly so far. Where the drift has been examined, leaching has not been found to penetrate more than two or three feet although oxidation, at one place which was observed, has penetrated to a depth of thirty-nine feet. The Illinoian drift, on the whole, is very thin, at places being no more than two feet thick and in some places being lacking entirely. An average thickness for this drift where it has been observed is considerably less than thirty feet.

Sangamon Deposits.

Gumbotil and peat beds.—Deposits of gumbotil, peat and old soils register the third or Sangamon interglacial stage. The Illinoian gumbotil, in general, is in all respects, except thickness, similar to the Kansan and Nebraskan gumbotils. Its average thickness is but five feet. Outcrops are numerous on the slopes of the ravines which dissect the level Illinoian upland. Exposures of gumbotil are numerous also on both valley walls of the Iowa-Cedar river valley below Columbus Junction. At several places, as in the cut along the railroad tracks between Bard and Columbus Junction, on the line between sections 33 and 34, and in the north bluff of Iowa river, southwest corner of section 10, Port Louisa township, two and one-half miles north of Wapello, a soil or peat bed overlies the gumbotil. Most of the gumbotil at these places is highly carbonaceous. The peat bed in section 10 is five feet thick and the upper two feet is almost entirely woody. Fossil beetle remains were observed in the peat, but due to the poor state of preservation and the burning of the peat several years ago, their identity could not be ascertained. This peat horizon also has been described by Alden[134] and has been referred to by Udden.[135] Both of these writers are of the opinion that the peat is of Sangamon age. A comparison of elevations of the gumbotil along the valley walls and on the Illinoian upland, (see table 2, page 102, seems to indicate that a large sag existed over the present valley of Iowa-Cedar river after the retreat

134. Alden, Wm. C., and Leighton, Morris M., the Iowan Drift: Iowa Geol. Survey, Vol. XXVI (1915), p. 169, 1917.

135 Udden, J. A., Geology of Louisa County: Iowa Geol. Survey, Vol. XI, p. 109, 1901.

TABLE. 2. TABLE OF GUMBOTIL ELEVATIONS AND SLOPES OF RECONSTRUCTED GUMBOTIL PLAINS IN THE REGION OF THE IOWA-CEDAR RIVER VALLEY.

	Location	Topographic Position	Elevation	Difference in Elevation, Ft.	Distance Miles	Slope, Feet per mile, Reconst'd. Gumbotil Plain.
1	Section road between sections 25 and 30, 1 mile south of Columbus Junction	Upland	710			
2	Northeast corner of NW¼, section 35, 2½ miles east of Cairo	Upland	700	10	7.5	1.3
3	Center of NW¼, section 14, 1½ miles northwest of Oakville	Upland	650	50	12.5	4.
4	Intersection of road and Illinoian bluffs in section 22, 2 miles east of Fredonia	Valley walls	640			
5	East central part of section 5, Port Louisa township	Valley walls	620	20	5.5	3.6
6	North central part of NW¼, section 9, Port Louisa township	Valley walls	615	5	1.	5.
7	Northwest corner, section 15, 2½ miles north of Wapello	Valley walls	610	5	1.25	4.
8	West central part, section 23, 1½ miles northeast of Wapello	Valley walls	610	0	2.25	0.
9	South central part, section 31, 3¼ miles southeast of Wapello	Valley walls	600	10	3.—	3.3
10	Northeast corner along section road between Secs. 9 and 16, 2½ miles northeast of Elrick	Valley walls	610	10	3.25	3.
11	Northeast corner along section road between Secs. 15 and 22, 1¾ mi. northwest of Oakville	Valley walls	620	10	1.5	6.6
	1—4	Upland to valley walls	710-640	70	3.75	19.—
	2—7	Upland to valley walls	700-610	90	5.5	16.+
	3-11	Upland to valley walls	650-620	30	1.	30.

of the Illinoian ice sheet. Such a sag as must have existed if the gumbotil along the valley walls is Illinoian does not appear to be in harmony with the gumbotil hypothesis or with the existence of Lake Calvin. The table shows that the slope of the gumbotil plain when it is reconstructed from the three upland gumbotil outcrops ranges from one and three-tenths to four feet per mile and that the plain determined from the elevations of the gumbotil exposed along the valley walls has a slope of less than seven feet per mile. On the other hand, it is also seen that when all elevations are considered, a minimum slope of sixteen feet per mile is obtained. This figure is undoubtedly too small. There is a difference of thirty feet in the elevations of the two outcrops of gumbotil in sections 14 and 15, about one and one-half miles northwest of Oakville. The exposures are but one mile apart, the former being on the upland, the latter along the valley walls. At the other places where a similar comparison is made, the outcrops are separated by the Iowa-Cedar river valley which has a width of three and three-fourths to five and one-half miles, thus giving the low figures of sixteen and nineteen feet per mile indicated in the table. Since the slopes of the reconstructed gumbotil plains when they are considered independently are in perfect agreement but when treated collectively are not in harmony with the gumbotil hypothesis or with the existence of Lake Calvin, the writer has come to the conclusion that the gumbotil and peat exposed along the valley walls of the Iowa-Cedar river valley are not Sangamon in age. They may well represent Yarmouth deposits or possibly even those of the first interglacial stage. In this connection, it is suggested that a detailed study of the Iowa-Cedar river valley might prove of great value in the study of the origin of the gumbotils. Numerous exposures of soil bands and peaty deposits in Louisa and Muscatine counties are described by Udden[136] and Leighton and Alden[137] have described several outcrops of gumbotils in Louisa county.

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136 Udden, J. A., Geology of Louisa County: Iowa Geol. Survey, Vol. XI, pp. 109-111, 1901.

137 Alden, Wm. C., and Leighton, Morris M., The Iowan Drift: Iowa Geol. Survey, Vol. XXVI (1915), pp. 168-171, 1917.

The Iowan Drift.

Distribution and character.—Unlike the Kansan and Illinoian drift sheets the Iowan in the lake region does not constitute a continuous surface formation, but occurs in five lobate extensions of the main drift sheet in the northern portion of the region. Although they possess some characteristics of the typical Iowan drift plain, a question has recently been raised concerning all but the westernmost tracts[138] as to their ever having been covered by the Iowan ice sheet. Exposures of drift in this younger drift plain are rare, because little dissection has taken place since the deposition of the drift. The Iowan area is characterized by its youthful topography, its absence of a loess covering and the presence of huge coarse-grained granitic bowlders. The till itself is not distinctive. In contrast with the Kansan till, the Iowan till is more sandy and porous and has a yellowish color. Oxidation has penetrated but eight or ten feet and leaching on an average between three and five and one-half feet. This bowlder clay is characterized by a low content of calcium carbonate.[139] The unleached portion of the till is darker than the leached portion and from a bluish or drab gray to a slate color. On the whole, the fresh till is somewhat harder and denser than the oxidized portion. Many of the contained pebbles and bowlders exhibit a marked degree of freshness. The Iowan drift is thin, probably averaging no more than ten feet.[140]

The Peorian Interglacial Deposits.

Loess.—The fourth or Peorian interglacial stage is represented in the lake region by the widely known loess deposits. The loess consists of unstratified, usually yellowish to buff-colored siltlike material which is composed of very fine angular particles of quartz, feldspar, mica, and ferromagnesian and other minerals. The deposit is somewhat sandy, but pebbles are lacking from the typical loess. It can be easily detected

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138 Alden, Wm. C., and Leighton, Morris M., The Iowan Drift: Iowa Geol. Survey, Vol. XXVI (1915), pp. 177, 179, 180, 1917.

139 Calvin, S., Present Phase of the Pleistocene Problem in Iowa: Bull. Geol. Society of America, Vol. 20, p. 145, 1909.

140 Calvin, S., Iowan Drift: Bull. Geol. Society of America, Vol. 10, p. 113, 1899.

by its remarkable ability to stand in vertical faces for a long time after being exposed. The loess where it is unleached generally contains the fragile shells of small land snails and peculiar shaped calcareous nodules known by the name of "loess-kindchen." Cylindrical hollow tapering limonite concretions are common in the upper portion of the deposit, which in many places is completely leached of its calcium carbonate content. Practically nowhere has the leaching penetrated to a greater depth than eight to ten feet. The thickness of the loess differs from place to place from a probable maximum thickness of thirty feet to nothing more than a thin veneer. The loess is found not only on both the Kansan and Illinoian uplands, but is present also in the lake basin itself, although not to a great extent.

The Wisconsin and Post-Wisconsin Deposits.

Wisconsin terraces and valley train deposits.—The only deposits in the lake region which are known to represent the Wisconsin stage of glaciation are the sands and gravels of a few scattered terraces in some of the tributary valleys of the Mississippi, and the Wisconsin valley train deposit in the Mississippi gorge. Since these deposits, however, bear no intimate relation to the origin and history of Lake Calvin, a further discussion of them is not warranted. Future work may demonstrate that the terrace materials in the Iowa-Cedar valley between Columbus Junction and Mississippi river are associated with the Wisconsin stage of glaciation.

Recent deposits.—Post-Wisconsin deposits are the alluvium of the present flood plains of the rivers, some of the sand dunes bordering the stream courses and most of the upper soil deposits.

History of the Pleistocene Formations.

After the deposition of the last marine sediments, probably the Des Moines formation of the Pennsylvanian period, the region later occupied by Lake Calvin was subjected to a long interval of erosion. As a study of well records and outcrops of the indurated rock shows, the subglacial topography consists of a rough country traversed by numerous large drainage channels. Whether the first great continental ice sheet, the Nebraskan, advanced over a highly dissected region very much like the famous Driftless Area of southwestern Wisconsin and adjacent states or whether the region had been reduced again to one of low relief[141] has not been demonstrated. The fact remains that the lake region was invaded by the Nebraskan ice sheet and from the evidence of the Nebraskan gumbotil it is deduced that the region after the retreat of the glacier presented a level ground moraine topography similar to that of the Wisconsin drift plain in the northcentral part of the state.

The advent of the next ice sheet, the Kansan, was preceded by a very long erosion interval. During this stage, known in literature as the Aftonian interglacial stage, atmospheric weathering attacked the materials of the newly formed drift sheet and oxidized and leached the upper part of the drift until it became a tough, sticky drab colored gumbotil which now is ten to fifteen feet in thickness. Presumably contemporaneously with the formation of the gumbotil, the sands and gravels in Washington and Louisa counties which have been described above were leached and oxidized. The presence of soil bands and stratified sands and gravels has suggested to some that the Aftonian interglacial interval "was a time of luxuriant forests . . . an interval of moist climate and swollen streams."[142] From studies and discoveries in other sections of the country, it is known that during this mild interglacial stage such mammals as the elephant, the mastodon, the horse and the great stag roamed over the state.[143] After a prolonged period of weathering, diastrophic movements elevated the region and erosion became the dominant process causing the dissection of the original gumbotil plain.

The period of erosion was gradually followed by changes in the climate during which it became colder and colder until finally the lake region was invaded from the north by a second

141 Professor Trowbridge is of the opinion that the Nebraskan ice sheet advanced over a peneplain.

142 Calvin, S., Present Phase of the Pleistocene Problem in Iowa: Bull. Geol. Society of America, Vol. 20, p. 139, 1909.

143 Hay, O. P., The Pleistocene Mammals of Iowa: Iowa Geol. Survey, Vol. XXIII, 1913.

ice sheet, the Kansan. All the existing valleys were filled up with the glacial debris, the relief was reduced and a new ground moraine upon which new drainage courses were established was left by the retreating ice sheet. A long period of weathering followed during which fifteen to twenty feet of super-Kansan gumbotil was formed and the Buchanan gravels and sands were oxidized and leached. Another rejuvenation of the land set in, resulting in erosion and dissection of the gumbotil. It was during this time that the present course of Iowa river and undoubtedly that of the Cedar were established. That this, the Yarmouth interglacial stage, was of longer duration than the Aftonian seems to be indicated by the thicker layer of gumbotil formed during that time. Whether pronounced erosion again took place is difficult to state as records of post-Nebraskan, pre-Kansan erosion are not available. However, evidence[144] tends to show "that quite an amount of erosion had probably taken place in the surface of the Kansan before the Illinoian drift was deposited."[145]

For a third time, a period favorable for the formation of glaciers set in. This time, however, the entire lake region was not invaded by the oncoming ice sheet, which moved from the Labradorian center. Only the eastern portion of the area under discussion was traversed by an extension of the Illinoian glacier which pushed its way from the state of Illinois across the valley of Mississippi river into Iowa. It was the displacing of Mississippi river by the ice invasion which gave rise to the ponding back of the combined water of Mississippi, Cedar and Iowa rivers, forming Lake Calvin. The withdrawal of the Illinoian ice sheet was followed by a long period of gumbotil and peat formation. Due either to diastrophic movements or because of the proximity of the Lake Calvin region to the unaffected parts of the Mississippi river valley, erosion then set in and began to incise the recently formed gumbotil plain. It may be that during this stage of erosion Lake Calvin was finally drained and dissection of the lake basin was inau-

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144 Leverett, F., The Weathered Zone (Yarmouth) between the Illinoian and Kansan Till Sheets: Proc. Iowa Acad. Science, Vol. V, pp. 81-85.

145 Calvin, S., Present Phase of the Pleistocene Problem in Iowa: Bull. Geol. Soc. America, Vol. 20, p. 142, 1909.

gurated. This stage of nonglaciation which is known as the Sangamon interglacial stage, was followed by a fourth ice incursion, the Iowan, which affected only the northernmost part of the lake region. In connection with this ice sheet, terraces of sand and gravel were formed along some of the stream courses leading away from the melting glacier as well as in the lake basin. During the ensuing interglacial stage, the Peorian, loess was deposited over most of the region and dissection of the Iowan terrace began. The dissection may have been temporarily halted during the Wisconsin stage of glaciation by the ponding back of Iowa and Cedar rivers due to the filling up of the Mississippi valley by deposits of Wisconsin outwash materials. Erosion, however, soon became active again and caused the further removal of the Iowan terraces and the building up of the present flood plains of the rivers, a process which is still in operation.

CHAPTER V.

THE PHYSIOGRAPHY OF THE LAKE CALVIN BASIN.

Shape and Extent of Lake Basin.

Shape.—The shape of the basin formerly occupied by Lake Calvin when considered in its broad general outline is that of a huge letter "V" made irregular by numerous ramifications, which are found especially in the northern part of the lake site. The arms of the "V" extend in a direction parallel to Iowa and Cedar rivers and form its apex near the junction of the two streams at Columbus Junction, Louisa county. (See Plate VI, Map of Lake Calvin.)

Extent.—If we do not consider the numerous river-like irregularities north of Iowa City, West Liberty and Moscow as being part of the lake basin proper, the lengths of the Iowa and Cedar river arms of the "V" are twenty-eight and twenty-four miles respectively, with corresponding average widths of four and four-tenths and five and eight-tenths miles. The widest portion of the lake site is two and one-half miles south of Lone Tree where the two bluff lines are separated by a low flat stretch of country fourteen and two-thirds miles in extent. Of the three ramifications which may be considered as belonging to the main basin, the English river extension, which branches off the Iowa river arm in Washington county, is the largest. Its length and average width are fifteen miles and one-half mile respectively as compared to the length of ten miles and the breadth of somewhat over a mile of the Old Mans creek ramification, the northern branch of the Iowa river arm of the "V". The third of the secondary continuations of the lake basin is Wilton valley in Muscatine county. Its length may be considered as being that part of the valley lying between the villages of Moscow on the west and Durant on the east, a distance of eight and one-half miles. At the time of their greatest expansion, the waters of the lake covered an area of approximately 325 square miles or 208,000 acres, an area, as may be seen from figure 8, equal to about three-fourths of Muscatine county. Following the shore line of Lake Calvin during this stage of maximum development would have been equivalent to taking a journey of 475 miles, which is less by twenty-five miles than the distance between Chicago and Council Bluffs.

Uplands.—As indicated elsewhere, the extensive lowland area of the Lake Calvin basin is surrounded by uplands consisting of the Kansan, Illinoian and Iowan drift plains. Of these highlands, which rise eighty to one hundred feet above

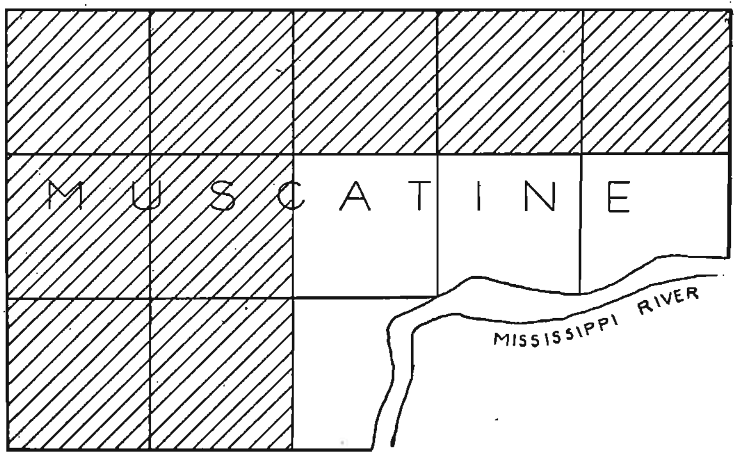
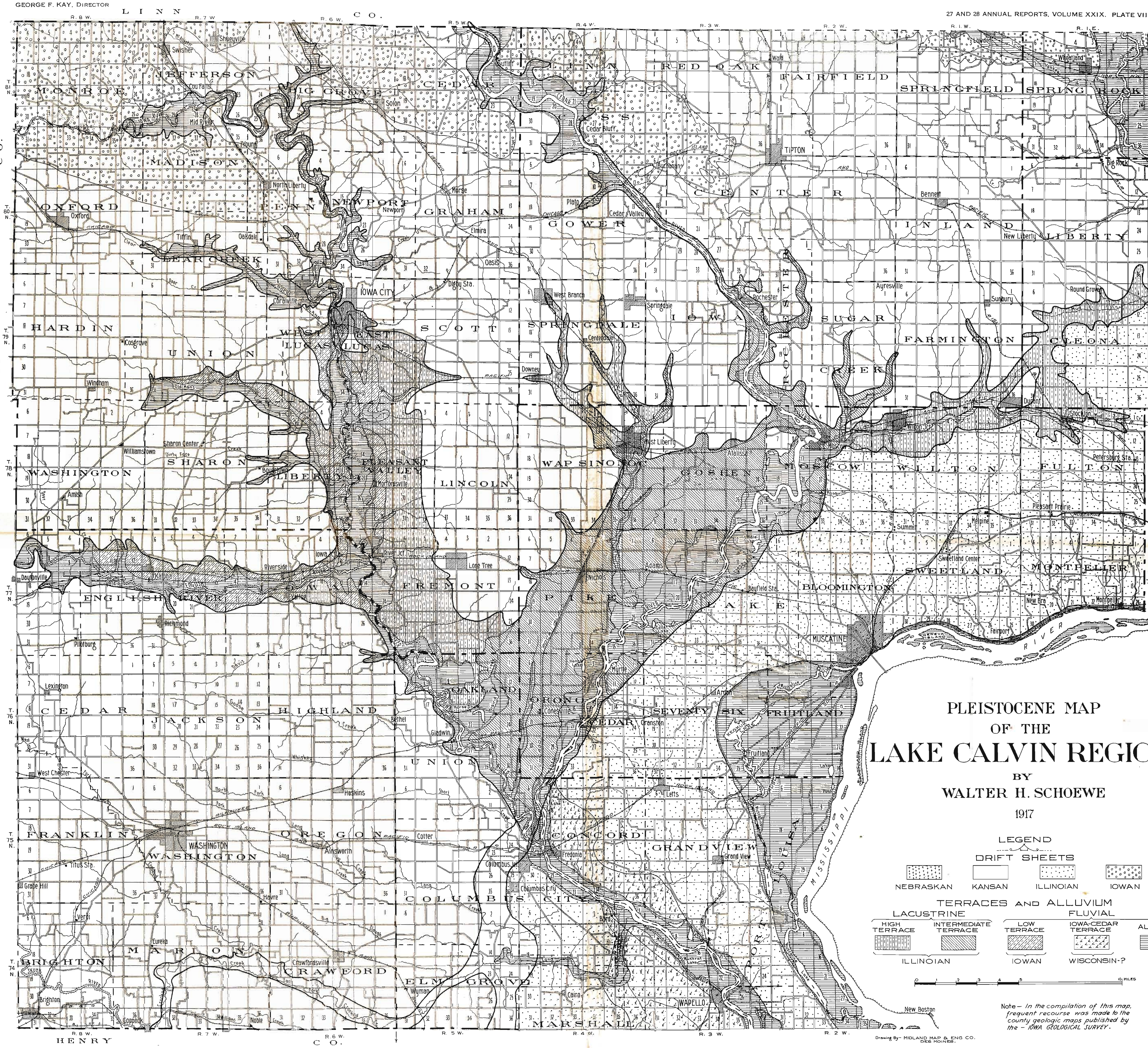


FIG. 8.—Diagram showing comparative areas of Muscatine county and the Lake Calvin basin. Cross-hatched portion represents the area of Lake Calvin.

the now dry lake floor, the Kansan has by far the greatest areal distribution. It includes, with the exception of two small areas, all of the region north and west of the lake basin. (See map showing the drift sheets in the Lake Calvin basin, Plate VIII.) The Iowan drift plain, which forms the two exceptions to the Kansan upland area just mentioned, borders the lake basin at its two northern extremities along Iowa and Cedar[146] rivers respectively. The more widespread Illinoian plain comprises the entire remaining area of the region south and east of the lake lowlands.

146 The Iowan age of the drift plain bordering on the eastern side of Cedar river and known as the Tipton Lobe of the Iowan drift sheet, has recently been questioned. See "The Iowan Drift" by Wm. C. Alden and Morris M. Leighton, Iowa Geol. Survey, Vol. XXVI, p. 179, 1916.


PLEISTOCENE MAP
OF THE
LAKE CALVIN REGION
BY
WALTER H. SCHOEWE
1917
LEGEND
DRIFT SHEETS
NEBRASKAN
KANSAN
ILLINOIAN
IOWAN
TERRACES AND ALLUVIUM
LACUSTRINE
FLUVIAL
HIGH TERRACE
INTERMEDIATE TERRACE
LOW TERRACE
IOWA-CEDAR TERRACE
ALLUVIUM
ILLINOIAN
IOWAN
WISCONSIN-?
Note— In the compilation of this map, frequent recourse was made to the county geologic maps published by the — IOWA GEOLOGICAL SURVEY.
Drawing By— MIDLAND MAP & ENG. CO. DES MOINES.
LINN CO.
IOWA CO.
SCOTT CO.
HENRY CO.
MISSISSIPPI
IOWA CITY
MUSCATINE
WASHINGTON
WAPELLO
TIPTON

View in northeastern Washington county, Iowa, showing mature erosion of the Kansan drift plain. Relief 100 to 150 feet.

The Kansan Upland.

Topography.—The Kansan drift plain, which comprises by far the greater portion of the highland bordering the lake basin, consists of a maturely dissected upland (Plate IX) whose general elevation lies between 840 feet above sea level in the northern and western parts of the lake region and 740 feet near the borders of the lake basin. Originally it was a somewhat gently sloping flat plain, but its surface today is deeply incised by an intricate dendritic system of valleys. Topographically, the region presents many diversities. As one approaches the larger stream valleys from the interstream areas, a gradual and orderly change from the uneroded, flat original drift plain to a rolling and finally rugged and rough type of country makes itself manifest. The only extensive area of the initial uneroded upland surface lies south of the English river valley in Washington county. Here the topography is practically in its original, unaltered state and forms wide flat-topped interstream divides. The valleys which have been cut into its surface are characteristically broad bottomed, open shallow swales whose long gentle slopes merge imperceptibly into the upland. At places the surface is still so flat and poorly drained that tiling has to be employed. At various other places, which are located at considerable distances from the larger streams and where the effects of running water have been but slightly felt, remnants of the original Kansan surface may still be preserved as narrow divides of limited extent and crenulated margins. Such erosional remnants are met as one travels over the lower Muscatine road between Iowa City and Downey, in the region lying east and north-east of Iowa City and extending up to Cedar river, and on the west side of Iowa river between Iowa City and Old Mans creek. Away from the uneroded remnants of the original plain and nearer the master streams the surface of the upland is more indented by the numerous ramifications of the arborescent drainage system, the broad-bottomed open swales with long gentle slopes are constricted to narrower, steep-sided valleys, the relief is greater until finally at the borders of the upland the streams have thoroughly dissected the region. Here maximum ruggedness and relief prevail. This is the border country of the river-like extensions of the lake basin, north of Iowa City and the village of Rochester, along Iowa and Cedar rivers respectively. Here the surface has been deeply incised into a complex rugged region of spurs, buttresses and abrupt convex-sloped hills, which lie between sharply cut steep-sided ravines and valleys which

FIG. 9.—View of the incised valley in the Kansan upland in section 36, Elm Grove township, Louisa county.

have a relief of sixty to one hundred and sixty feet and long winding even-crested ridges. Where the drift topography has been modified by loess only to a slight extent, this ruggedness becomes less pronounced. Although it is all reduced to slopes, the country is less deeply dissected, the slopes are gentler and the valleys wider and more open. Such is the characteristic rolling or undulating Kansan upland between the valleys of Old Mans creek and English river and that portion of the drift plain lying to the east of Iowa river south of a line passing through Iowa City and Rochester.

A departure from the usual normal type of topography is seen in Louisa county immediately west of the limits of the Illinoian drift plain. Extending in a southerly direction from the Iowa river border of the upland just north of Columbus Junction and paralleling closely the edge of the Illinoian drift sheet is a definite wide and shallow sag from one and one-quarter to one and one-half miles wide and thirty to sixty feet deep. This shallow incised valley, which rises ninety to one hundred and twenty feet above the level of Iowa river and which lies at an elevation of about 700 feet above sea level, in the vicinity of Columbus Junction, is more pronounced the farther south it is traced. At places it is occupied by streams, whereas other portions of it are still uncut by drainage channels. The photograph (Fig. 9), taken in section 36 of Elm Grove township, shows that the incised valley is cut thirty-five to forty feet below the general upland and is one mile wide. This place practically marks the divide between the north and south flowing streams developed in the sag.

Attention was first called to this abandoned channel by Mr. Frank Leverett of the United States Geological Survey who traced its devious course to Fort Madison, Lee county.

The Illinoian Upland.

Topography.—The Illinoian upland comprises that portion of the lake region east and south of the lake basin or lowland which lies between Cedar river, Mud creek and Mississippi river. Separated from the lowlands to the west by a line of bluffs seventy to one hundred feet in height, the Illinoian surface lies at an average elevation of 720 feet above sea level. In contrast to the Kansan highland whose general surface slopes gently to the south or southwest, the Illinoian upland is inclined in all directions so that its surface is drained to the north, west, south and east. Except for that part of the region lying north of Muscatine the divide between the drainage lines lies closer to the eastern edge of the upland than to the western border. Because of this, the northward and westward flowing streams are the larger and occupy the shallower and more open type of valley. South from the latitude of Muscatine, the watershed has shifted entirely to the east and now follows the bluffs of Mississippi river and forms the eastern edge of the upland plain. Here its crest ranges in elevation from 750 to 770 feet in the north to 680 feet above sea level in the south, in the latitude of Wapello. North and west of Muscatine, the height of land between Mississippi and Cedar rivers lies about midway between the two streams. The highest part of the plain is on the divide between Mud creek and Mississippi river in section 18, Fulton township, two and one-half miles southeast of Durant. At this place an elevation of 800 to 820 feet above sea level is attained.

Due to its varying width and proximity to master drainage lines, the Illinoian upland presents many diversities. One of the most noteworthy topographic features of the drift plain is the fringe of sand dunes which follows the western border of the upland south of Mosquito creek in Moscow township to the vicinity of Columbus Junction. This sandy undulating fringe is made especially conspicuous because of its abrupt termination at the southern extremity of the lake basin at Columbus Junction. South of the Junction no trace of a sand dune marking the limit of the Illinoian plain is to be seen. The dune-covered area is, as a rule, less than half a mile wide. However, at places such as the region two to three miles north of Bayfield, the dune topography extends inland from the edge of the drift plain for a distance of one mile to two miles. The average height of the sand knolls and ridges is twenty feet, but some of them reach heights of forty to fifty feet at those places where the sand covers larger areas. Numerous ponds, as the one seen on the right hand side of the following photograph (Fig. 10), are hemmed in among the dunes.

In contrast to the Illinoian drift plain of Lee and Scott counties, which is characterized by extensive areas of the original upland in the form of broad tabular interstream divides, the surface of the drift sheet in the lake region is more or less cut up into an undulating type of topography. Flat remnants of the uneroded surface are found only in that part of the drift plain south of Iowa-Cedar river and in the country forming the watershed between Mud creek, Cedar and Mississippi rivers north of Muscatine. In all directions from these flattish remnants or interstream areas the country is more and more cut up. The upper parts of these erosion lines are wide open swales or sags which, closer to the master streams, Mississippi and Cedar rivers, develop into deeper valleys until, finally, within a few miles of the main drainage lines, the whole topography is etched into a system of hills and valleys by the numerous ramifications of the dendritic stream courses. Thus everywhere along the eastern and southern border of the upland the bluffs of Mississippi river are cut into by young streams whose heads are 100 to 150 feet below the uplands. South from the latitude of Muscatine, in townships Seventy-Six of Muscatine county and Grand View and Port

FIG. 10.—Characteristic sand dune topography on the Illinoian border within the lake basin.

Louisa in Louisa county, the young valleys or ravines are very steep-sided, narrow and short and extend back into the upland on the average less than one mile. The streams occupying the valleys have high gradients. Because of the position of the divide relative to the master streams, the northward and westward flowing streams, as a rule, flow in more open and wider valleys than those pursuing the southerly and easterly courses. Such are the valleys especially in the northern tier of townships in Muscatine county. South of Mosquito creek, in Moscow township, Muscatine county, the valleys form the conspicuous feature of the landscape. They range from sixty to seventy feet in depth, and, together with the numerous sand dunes dotting the surface, present an unusual type of topography, one which is both constructive and destructive and which is particularly characteristic of this portion of the Illinoian drift plain.

The continuity of the Illinoian plain is broken in the southern part of the lake region at two places. At Columbus Junction, the northwest-southeast trending valley of Iowa-Cedar rivers divides the drift plain into two uplands which are separated by a valley three to five and one-half miles wide. The northfacing end of the upland south of the gap consists of steep undissected bluffs which rise one hundred feet or more above the valley floor. The bluffs on the opposite side of the valley range in height from forty-five to eighty feet, are gentler and some of them are fringed by a line of low sand dunes. The southern portion of the upland is redivided into north and south sections by the valley of Long creek. This valley is four and one-half miles south of Columbus Junction and is one-quarter to one-half mile wide and seventy to eighty feet deep. South of Long creek the western edge of the upland is marked by two parallel ridges which were considered by Udden[147] to be terminal moraines. These ridges, which are about one mile wide and which rise as high as fifty feet above the general surrounding level, are separated by a sag or depression one-half to one mile wide.

The Iowan Drift Plain.

Topography.—North Liberty Lobe.—The Iowan drift sheet forms a lobate upland area in the northern part of the lake region. The largest of the five tongue-like extensions of this drift sheet,[148] named the North Liberty Lobe by Calvin, enters the lake region in the northwestern part of Monroe township, Johnson county, and extends southeastward across the Iowa

147 Iowa Geol. Survey, Vol. XI, pp. 63 and 107, 1901.

148 The lobate character of the Iowan drift plain, with the exception of the North Liberty Lobe, has recently been questioned. See "The Iowan Drift" by Wm. C. Alden and Morris M. Leighton, Iowa Geol. Survey, Vol. XXVI, pp. 177, 179, 180, 1917.

View showing the flat surface of the North Liberty plain.

View showing the erosional topography of the Kansan. Taken near the border of the North Liberty plain.

river valley, the uppermost extremity of the lake basin, to a point one and one-half miles south of North Liberty. The topography of this area is in sharp contrast to the surrounding rough erosional Kansan plain, from which it is separated in the southern part by a fringe of rounded hills, termed "paha" by McGee. (Compare Plates X and XI.) Its surface is gently undulating and is scarcely scarred by the indentations of drainage lines. "Northwest of the village of North Liberty, just beyond the reaches of Pardieu creek, the surface is typically of the 'swell and swale' type. Farther northwest is a topography of unrelated elevations and depressions which has a relief of not more than twenty feet and slopes not greater than twelve degrees. One depression is occupied by a small pond of water while the others are of a slough character. Many undrained depressions exist in the northeast quarter of the plain, notable among which is Swan lake."[149] That portion of the Iowan plain lying south of Iowa river is practically unaffected by drainage except near its borders. The "somewhat higher and more billowy"[150] north lying portion is more highly cut up by young valleys and ravines whose depth where they join the Iowa river valley differs from eighty to more than 120 feet.

Shueyville Lobe.—A very much smaller extension of the Iowan plain, with similar surface characteristics, lies east of the North Liberty Lobe, to which it is connected. This plain is known as the Shueyville Lobe.

A question has recently been raised by Alden and Leighton as to whether the remaining tracts of so-called Iowan drift in the lake region, known respectively from west to east as the Solon, Tipton and Clinton Lobes, really belong to the Iowan drift plain.[151]

Solon Lobe.—The Solon Lobe as described by Calvin[152] "occupies a low plain when compared with adjacent loess-covered

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149 Leighton, Morris M., The Pleistocene History of Iowa River Valley, North and East of Iowa City in Johnson county: Iowa Geol. Survey, Vol. XXV (1914), p. 128, 1916.

150 Calvin, Samuel, Geology of Johnson County: Iowa Geol. Survey, Vol. VII, p. 42, 1897.

151 Alden, Wm. C., and Leighton, Morris M., The Iowan Drift, Iowa Geol. Survey, Vol. XXVI, pp. 177, 179, 180, 1917.

152 Iowa Geol. Survey, Vol. VII, p. 41, 1897.

areas which are in general highlands of moderate elevation." Its surface is smooth. Like the southern part of the North Liberty plain, the Solon lowland area is circumscribed by a belt of paha. Alden and Leighton in their thesis "The Iowan Drift", remarking on the Solon Lobe, state, "The writers have no definite evidence of the presence of Iowan drift in this area."[153]

Tipton Lobe.—The Tipton Lobe lies on the east side of Cedar river which it parallels southward within a mile to a mile and a half of Cedar Valley. The surface of this plain is divided by Baldwin creek into two topographically unlike parts. That part of the plain to the north and west of the creek "presents an exception to the usual undissected character of the Iowan surface"[154] and is in all respects similar to any of the Kansan upland topography bordering Cedar river. The remaining parts of the Tipton Lobe "compare with sufficient closeness to the normal Iowan drift plain."[155] Alden and Leighton "after considering everything, and especially the erosional character of the topography surrounding this area"[156] doubt if the Iowan ice ever covered the tract known as the Tipton Lobe.

Clinton Lobe.—Similarly, the Iowan age of the Clinton Lobe, which occupies but a very small area on both sides of Wapsipinicon river in the lake region, has been questioned by these same writers.[157]

Upland Remnants.

Moscow Remnant.—Two small isolated remnants of the Kansan upland occur within the lake basin. Of these, the larger and more conspicuous has an area of about one and one-half square miles and occupies practically all of section 7 and parts of sections 6, 8, 17, and 18 of Moscow township, as well as small portions of sections 12 and 13 of Goshen township, in Muscatine county. This island-like highland is separated from the main upland to the northwest by a distance of half a mile and rises

153 Iowa Geol. Survey, Vol. XXVI, p. 180, 1917.
154 Norton, Wm. H., Geology of Cedar County: Iowa Geol. Survey, Vol. XI, p. 372, 1901.
155 Idem, p. 372.
156 Iowa Geol. Survey, Vol. XXVI, p. 179, 1917.
157 Idem, pp. 177 and 179.

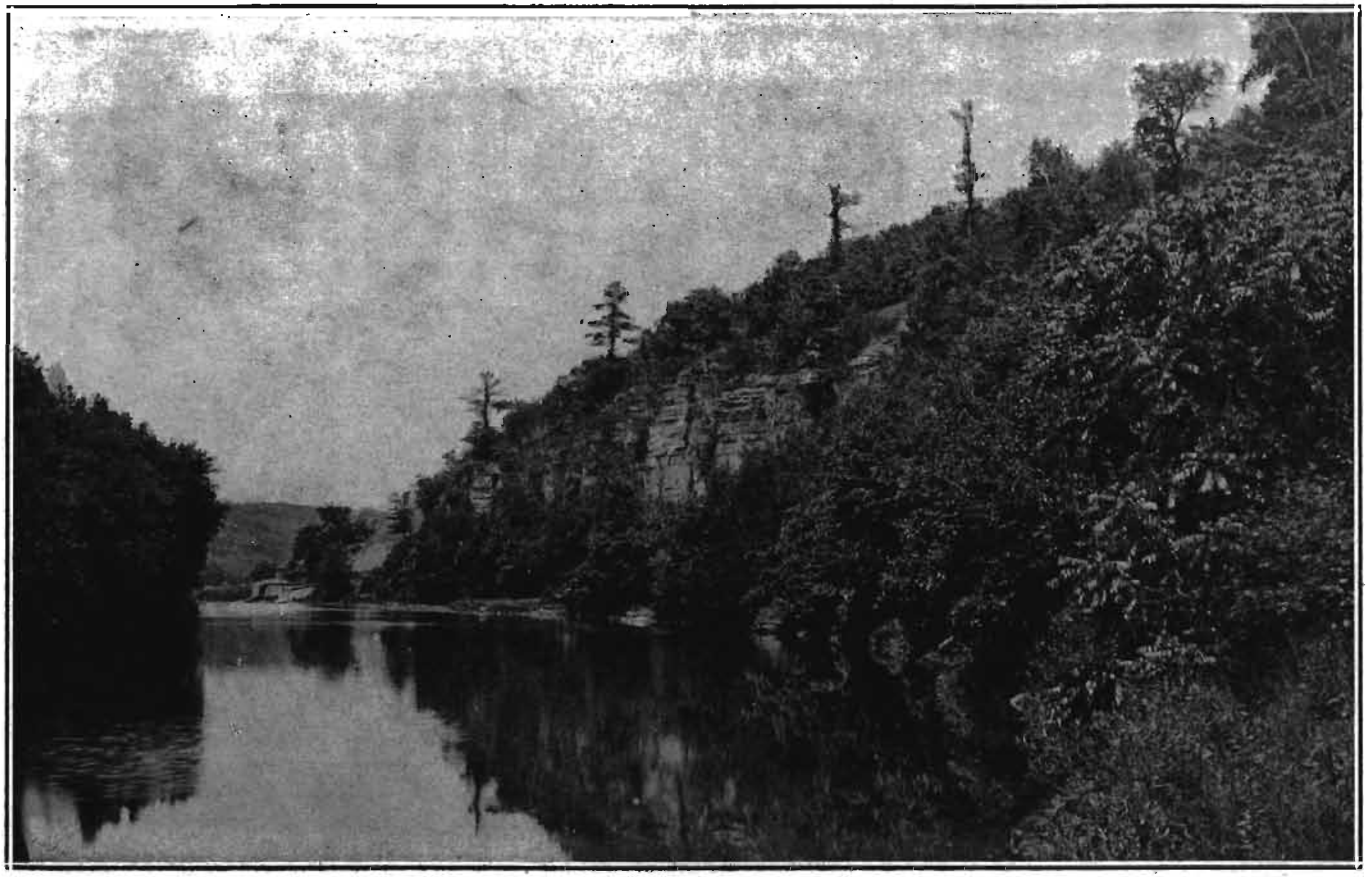
on the average seventy-five feet above the level surface of the surrounding plain, that is, the intermediate terrace. Its summit reaches an elevation of 760 feet above sea level at the school-house in section 7. This is 110 feet higher than the road at the base of the upland in section 8, about three-fourths of a mile directly east, and marks the highest point within the lake basin. The bluff-line on the north and east is cut into the Devonian limestone and is therefore very well defined. Where the slopes are not broken by quarries they have an average inclination of about seventeen degrees. Toward the south and especially toward the southwest, the border of the remnant is less conspicuous, due to the numerous sand dunes, and merges more gradually into the surrounding lowland. Sand dunes crown the summit.

Iowa City Remnant.—The Iowa City remnant of the Kansan upland is less well outlined than the one in the vicinity of Moscow. It extends southward as an isolated ridge from what is now Iowa Avenue in Iowa City as far as Kirkwood Avenue and its top is followed by the well-named Summit street. From Kirkwood Avenue the island spreads out in a general east-west direction, and has the appearance of a large railroad spike. Approximately one square mile is occupied by the remnant, whose maximum length and width are one mile and one-half mile respectively. It is separated from the main upland by the valley of Ralston creek, which is half a mile wide. The surface of the remnant is loess-covered and in Iowa City it is now modified by the works of man. The borders of the highland rise five to forty-five feet above the surrounding country and are well marked, especially as seen from the northeast, south and southwest.

The Bluff Line.

General.—Except for the river-like extension of the lake basin, the bluff line is conspicuous for two outstanding features: namely, its relative straightness and its smoothly curving or rounded outline at places of indention. Even in the narrower arms of the basin, there is indication of these characteristic features of the main lake border, rather than of the sharper sinuousities of meander scars. The bluffs are mainly cut in the unconsolidated drift materials of the various till sheets bordering the lake basin. Bedrock forms part of the bluffs in the western and southwestern end of the English river branch of the basin, along Iowa and Cedar rivers north of Iowa City and Moscow respectively, in the north and east faces of the bluffs of the island-like upland one mile west of Moscow and in a portion of the west facing slope of the isolated upland area in the southern part of Iowa City. The rock consists chiefly of Devonian and Mississippian limestone, although sandstone and shale of Pennsylvanian age form the bluffs at a few places. For a description and location of these rock formations the reader is referred to chapter III. Where the bluffs are cut into the country-rock they are exceptionally steep and even precipitous. (See Plate XII.)

Illinoian Bluffs.—In spite of the meandering of Cedar river and the numerous places through which the streams of the upland descend to the lowlands, the eastern margin of the lake basin in Muscatine county is remarkable for its straightness. Starting from the southeast corner of section 32, Cedar township, the bluff, composed largely of Illinoian till, sand and loess, trends northeastward with a striking directness as far as the northcentral part of section 6 of Bloomington township. From here the bluffs swing in a smooth gentle curve northeastward to the southcentral part of section 28, Moscow township, continuing thence directly northward for two and one-half miles to the valley of Mud creek. From this place the line of bluffs follows in a more irregular outline the valley of Mud creek. The border of the lake basin just described forms the western margin of the Illinoian upland. Along practically its entire northeastward course of twenty-three miles, its top is covered by the rolling sand dunes previously described. The slopes are steep and range in height from one hundred feet or more in the south to seventy-five feet in the north. The base of the bluff is sharply defined from both the terrace and the flood plain, which abut against it. Along the margin of the lake basin eastward in the valley of Mud creek, the line of demarcation between upland and lowland is less pronounced than in the lake basin pro-



View showing the steep and rocky bluffs of the Lake Calvin basin along the Cedar river extension north of Moscow.

per. Nevertheless, a line of division can be drawn. On the south side of the valley, the lowland merges into the uplands in a fairly smooth curve. The north line of the bluffs, however, is more sharply defined, rising at places twenty-five to thirty feet above the terrace in the valley. In the small ramifications of the Wilton Valley arm of the lake basin, the bluff line is, as a rule, more or less indefinite and not more than fifteen feet high.

Bluffs of the finger-like extensions of the lake basin.—The bluffs are very pronounced and steep in the large finger-like ex-

FIG. 11.—View of the northern line of bluffs in section 18, Wapsinonoc township, Muscatine county.

tensions of the lake basin, as along Cedar river north of Moscow, in the Wapsinonoc valley north of West Liberty, up the valleys of English river and Old Mans creek and along Iowa river north of Iowa City. This is especially true where these bluffs are cut into solid rock. At many places the bluffs reach a height of seventy to eighty feet, although a rise of thirty to fifty feet[158] above the level of the river is more common.

Bluffs between West Liberty and Atalissa.—The northern bluff line between West Liberty and Atalissa in Muscatine county, although it is less abrupt and lower than the bluffs to the east or west, is nevertheless at most places very distinct

158 Leighton, Morris M., The Pleistocene History of Iowa River Valley, North and West of Iowa City in Johnson County: Iowa Geol. Survey, Vol. XXV, p. 157, 1914.

and sharply set off from the lowland to the south, called by Udden the West Liberty Plain.[159] (See Fig. 11.) The heights of these bluffs range from forty to fifty-five feet. As the map (Plate VIII) shows, this border is also somewhat more sinuous than the one which forms the western margin of the Illinoian upland or the line of contact between the Kansan drift plain and the lowland, south of West Liberty. Immediately west of Atalissa is a rounded peninsula-like projection of the bluff line rising forty to fifty feet above the surrounding level plain.

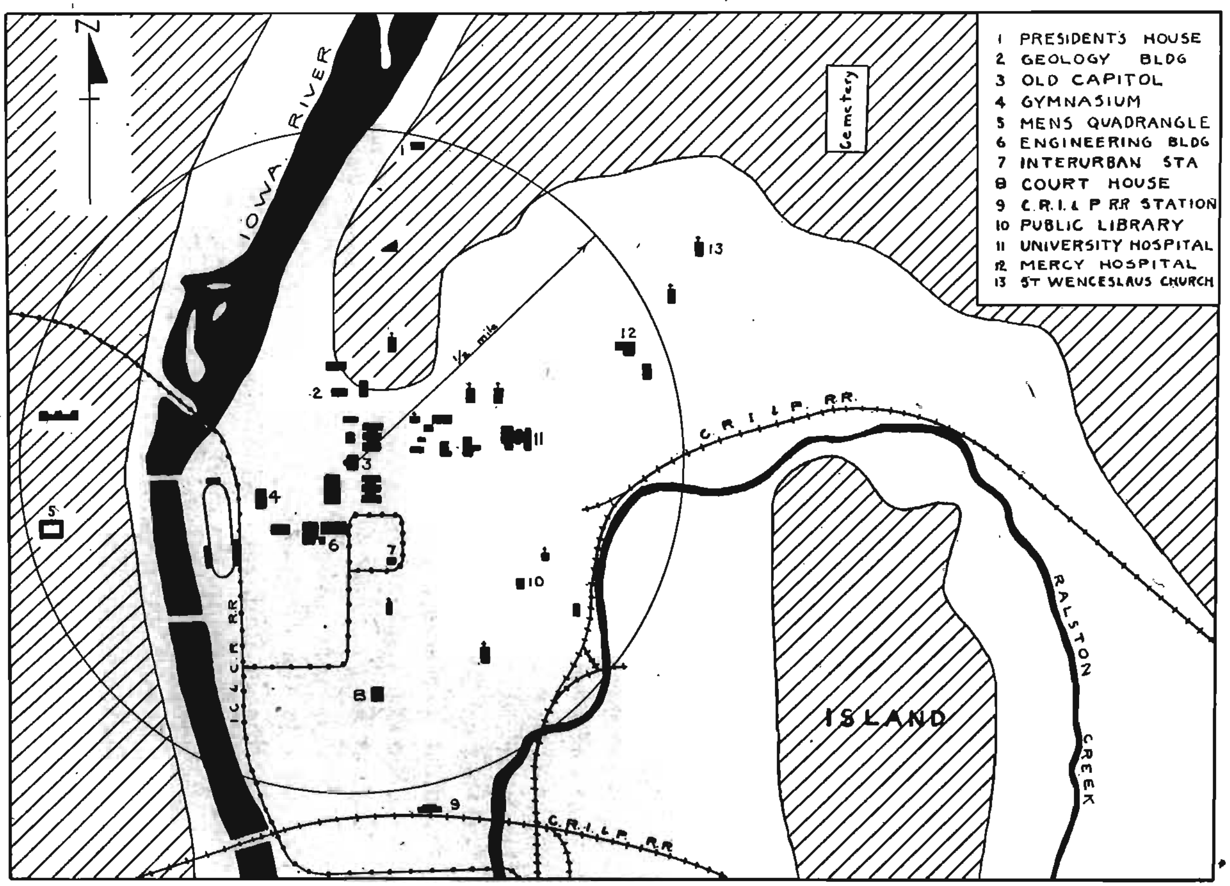
Kansan Bluffs in western Muscatine county.—As viewed from the West Liberty Plain the western bluff line extending southwestward from West Liberty in a relatively straight or gently rounded outline, has, especially in the vicinity of Nichols, an almost even sky line. The bluffs rise abruptly from the lowland and range in height from less than sixty-five feet two miles south of Nichols to ninety feet in section 26, Wapsinonoc township, and to thirty-five feet in the vicinity of West Liberty.

Kansan Bluffs in eastern Johnson county.—From the northwest corner of section 30, Pike township, Muscatine county, the bluffs continue their southwest course and extend into Johnson county for a little over half a mile to the southeast part of section 25, Fremont township. In this distance they maintain their sharp outline, but rise to progressively decreasing heights above the lowland. They are broken by a gap which extends to the corner of sections 23, 24, 25, and 26, but beyond this break the bluff line trends in a smoothly rounded curve to the southwest corner of section 27, although it is much less conspicuous and definite. Beyond the southwest corner of section 27, the bluffs again show their characteristic features, rise sharply forty feet above the lowland to the west and continue in a northerly direction practically to the southern limits of the village of Lone Tree. North of the village as far as section 31, Scott township, the bluff line presents much less definiteness of outline and also is lower,

159 Iowa Geol. Survey, Vol. IX, p. 257, 1899.

but maintains its relative straightness. The inconspicuousness of the border between lowland and upland is due in large measure to the numerous rolling tracts of dunes which mask the sharpness of the contact line. These dunes in many places cause a blending of the upland into the lowland and only from some distance on the lowland can the line of demarcation be recognized. Beyond section 31, Scott township, the line of bluffs shows its prominent features again, being easily traceable at first to the east and then to the west and north up to Iowa City. A very fine view of the bluffs, as well as of the lowlands, is to be had just east of Iowa City where, in sections 13 and 18 of East Lucas and Scott townships respectively, the old Muscatine road closely parallels on the north side the line of bluffs for over two miles. Even in Iowa City, in spite of the evenly paved streets, the walks and the buildings, a sharp break in the topography is in evidence and can be traced fairly distinctly throughout the city. (See Plate XIII.) Thus while walking up Dubuque street northward from the Methodist church, one can easily follow on the left hand side a sharp rise which separates the higher from the lower parts of the city. Just about at the intersection of Dubuque and Davenport streets, this topographic break swings off to the northeast as far as Dodge street, whence it turns gently southeast until it reaches the Upper or Old Muscatine road from which the fine view just referred to is to be had.

Kansan Bluffs south of Iowa City.—South of Iowa City the bluff line is very prominent and can be followed with ease. Its slope to the lowland or terrace is definite and steep and its sky line is uniform. At Indian Lookout, in section 34, West Lucas township, the bluffs rise 120 feet above the terrace, but are gradually lower in the direction of Iowa Junction where in section 10, Iowa township, Washington county, they have a height of only sixty-six feet. In the angle between Iowa and English rivers, the slope bordering the flat forms a very broad almost invisible curve without any suggestion of a projecting divide between the two streams. This same type of slope which is found also in the southern angle between the



MAP SHOWING LAKE CALVIN AT IOWA CITY

two streams, may be said to be characteristic of the bluff line between places of indentation.

From Iowa Junction the bluff line extends in a relatively direct line with a southeast trend to Columbus Junction in Louisa county. Between these two points the bluffs are about 140 feet high and for the most part are steep because of the lateral planation of Iowa river at their base.

Terraces.

General description.—At least three sets of terraces, a high set, an intermediate set and a lower one, occur in the Lake Calvin basin. Of these, the intermediate terrace, designated by Udden in his Muscatine county report as the West Liberty Plain,[160] is the most extensive and continuous. It comprises practically the entire higher lowland areas in Muscatine county and extends southward as far as Columbus Junction, Louisa county, occupying the higher land area in the triangle made by the junction of Iowa and Cedar rivers.

The uppermost or highest terrace is confined principally to the Iowa river arm of the lake basin. It forms the higher of the two terraces following the river southward from Iowa City to a point about one and one-quarter miles north of Gladwin in Louisa county. Except for several small remnants on the west side of the river, the terrace is continuous and is limited to the east side of the stream. Terraces presumably corresponding to this upper one are present in Mud Creek valley opposite Wilton Junction and on the higher land bordering the various branches of Wapsinonoc creek north and northwest of West Liberty.

The lower terrace is restricted to the narrow river-like extensions and to the western branch of the "V" of the lake basin. This terrace, with one exception, is not continuous but occurs in narrow linear remnants south of Iowa City and as "mere remnants at the bends of the stream"[161] north of Iowa City and possibly north of Moscow along Cedar river.

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160 Iowa Geol. Survey, Vol. IX, p. 257, 1899.

161 Alden, Wm. C., and Leighton, Morris M., The Iowan Drift: Iowa Geol. Survey, Vol. XXVI, p. 136, 1916.

THE INTERMEDIATE TERRACE.[162]

TOPOGRAPHIC FEATURES.

Area.—The intermediate terrace forms the major portion of the lowland in Muscatine and Louisa counties which was designated by Udden as the West Liberty Plain. The writer's investigation has led him to the conclusion, however, that the West Liberty Plain as described by Udden really consists of two lowlands or terraces, one designated in this report as the upper or high terrace and the lower of the two as the intermediate. The "two narrow extensions"[163] of Udden's West Liberty Plain the "one to the northwest, consisting of the bottom lands along Wapsinonoc, and another to the northeast, a rather ill-defined lowland drained by Mud creek"[163] form the two terrace remnants corresponding to the high terrace in the Iowa river arm of the basin. Furthermore the western portion of "the northernmost expansion"[164] of the Iowa river lowlands in Louisa county, which lies west of Prairie creek in Oakland township and which "constitutes the south end of the West Liberty Plain"[164] really forms the southern extremity of the upper or high terrace along Iowa river.

Topography.—The lowland or terrace, which is sharply set off from the surrounding drift uplands by a line of steep bluffs previously described, is traversed from north to south by Cedar river which has incised its valley twenty to forty feet below the general surface of the terrace. The vast plain is remarkable for its uniform width. For a distance of fourteen miles out of the twenty-two and one-half miles of its length, the terrace maintains an average width of four and three-fourths miles. On the west side of Cedar river, the intermediate terrace is continuous for its entire length from West Liberty or Atalissa in the north to the southeastern corner of section 18, Concord township, Louisa county, in the south, whereas to the east of the river, the terrace occurs in

162 In view of the fact that Udden's West Liberty Plain forms the major part of the intermediate plain and since a detailed description of it has been given in his Muscatine county report in connection with Lake Calvin and is therefore best known it was deemed advisable to consider this terrace first.

163 Iowa Geol. Survey, Vol. IX, p. 257, 1899.

164 Iowa Geol. Survey, Vol. XI, p. 61, 1901.

at least nine remnants. The largest of these remnants is the one on which the village of Moscow is situated and which can be traced for a distance of seven miles. All of the other remnants are very much smaller and have a width which in few places exceeds one mile.

Although without slope which is apparent to the eye, the terrace has a very gentle dip to the south. The surface of the plain lies approximately 660 feet above sea level in the northern extremity at West Liberty and slopes gently to the southern end of the terrace in Louisa county, eighteen miles distant. Here it has an elevation of 615 feet above sea level. Topographically, the intermediate terrace is still in its early youth for its surface is scarcely scarred by stream erosion. With the exception of the valley of Wapsinonoc creek, the few water courses developed on the terrace surface are more in the form of ditches five to eighteen feet deep and a few feet to a rod or two wide rather than well developed young valleys. The larger streams such as Wapsinonoc, Honey and Prairie creeks have developed larger sags which have on the average a width of one-fourth mile and a depth of twenty feet. To insure proper run-off on the plain, numerous drainage ditches have been dug and resort has been had to tiling. Although it is practically flat, the surface of the plain is not without some relief. Scattered over the entire area, but especially in the vicinity of the Cedar, there are stretches of low lying mounds or dunes of sand. Some of these are in the form of long winding and irregular ridges varying in height from ten to thirty-five feet. Their position on the plain is indicated on the map of Muscatine county published by the United States Bureau of Soils by the symbol, Ks, Knox fine sand.[165] A series of sand dunes in sections 12 and 13 of Goshen township and in section 7 of Moscow township, Muscatine county, occurs not only on the terrace but also covers the southeastern flank and a large part of the top of the island-like upland near Moscow which has previously been de-

165 U. S. Department of Agriculture, Bureau of Soils, Soil Survey of Muscatine County, Iowa, Soil Map, 1916.

scribed under the heading Upland Remnants. The dunes here average about twenty feet in height.

Bowlders on the terrace.—At several places large bowlders lie scattered over the surface, as well as along the base of the escarpment of the terrace. At the base of this escarpment in the northeast corner of section 7, Concord township, Louisa county, fifty or more large granite bowlders weighing perhaps on the average a ton each were noted. At this locality, Cedar river flows at the edge of the terrace. It is also worthy of remark in this connection that these bowlders are but half a mile west of the Illinoian bluffs. In the central part of section 34, Pike township, Muscatine county, a limestone bowlder lies on the surface of the terrace and in section 3 of the same township many bowlders are scattered on the escarpment slope as well as near its edge, high above the river or flood plain level. In the same section in the northwest corner of the northeast quarter along the escarpment slope and at its base are several granite and greenstone bowlders which have dimensions of one by one foot. These bowlders are two miles east of the Illinoian upland. Udden also mentions the finding of bowlders "near the south line of section 8, in Wilton township . . . and one near the center of the west line in section 2, in Moscow"[166] in Muscatine county.

Relation to other topographic features.—The intermediate terrace is sharply set off from the various drift uplands by a steep and well defined line of bluffs already described. In Fremont and Oakland townships of Johnson and Louisa counties respectively, the high and intermediate terraces are separated by a well outlined although somewhat sinuous escarpment. The surface of the terrace at the line of contact in Oakland township, especially in the lower halves of sections 3 and 10, is covered with dunes. Among the dune ridges, as in the northwest quarter of the southeast quarter of section 3, there are undrained depressions containing water. At the intersection of the road between sections 2 and 3 by the east and west road passing through the two sections, the upper

166 Iowa Geol. Survey, Vol. IX, p. 354, 1899.

terrace is forty feet above the intermediate terrace. The line of separation between the high and lower terraces in the vicinity of West Liberty is equally well outlined.

In sections 12, 13, 14, 23 and 27 of Oakland township, Louisa county, the intermediate terrace is separated from the high terrace by a large marshy slough or lowland about one mile wide. The terrace escarpment is sharply defined, is relatively free from irregularities and has an average height of thirty feet. Elsewhere the terrace is separated from the bottom lands of Iowa and Cedar rivers by a sinuous escarpment whose height ranges from twenty feet in the south to almost fifty feet in the north.

MATERIALS AND STRUCTURE OF THE INTERMEDIATE TERRACE.

General.—The study of the materials and structure of the intermediate terrace is practically limited to a score of exposures most of which are in the west escarpment of the terrace in section 13, Goshen township, Muscatine county. This lack of exposures is due to the extreme youthfulness of the topography and the slight relief of the region. Experience shows that in a region such as this, where the materials are fine unconsolidated sand, silts and gravels, where the wells are of the shallow and dug type, and where there is a vast amount of changing of ownership of the land, very little stress can be laid on well records gained from the people of the community. Most of the wells reported were about thirty feet deep and the material penetrated consisted principally of sand, although gravel and clay were at times mentioned. The deepest well in the area of the intermediate terrace is at Nichols and is recorded to have penetrated at least 250 feet[167] of unconsolidated material. The surface materials consist of fine yellowish to brownish or drab-colored loesslike silt and sands, the latter forming the sandy and dune areas previously described. Occasionally, a few scattered bowlders are found dotting the terrace surface.

167 Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, p. 355, 1899. Also U. S. Department of Agriculture, Bureau of Soils, Soil Survey of Muscatine County, Iowa, p. 23, 1916.

Material and Structure.—Practically the only clew as to the nature of the materials composing the intermediate terrace is to be found in the terrace escarpments facing Cedar river. Although the east facing escarpment of the modern valley of Cedar river has a length of thirty-five miles, cuts showing the materials of the terrace are limited practically to the northernmost five or six miles. Out of the nine outcrops exposed within these five or six miles, five occur within a distance of three-fourths of a mile in section 13 of Goshen township, Muscatine county. As far as could be ascertained from the few exposures seen, it appears that the terrace materials in the northern part of the plain are finer and less disturbed than those farther south. The following section in the western escarpment wall near the south line of section 8, Goshen township, Muscatine county, shows that the material is all finely stratified, not disturbed, and consists of fine-grained sand and some clay.

TERRACE MATERIALS, SECTION 8, GOSHEN TOWNSHIP. MUSCATINE COUNTY.

		Feet	Inches
A.	Loesslike clay	2	
B.	White, fine-grained stratified sand containing many small pebbles or grains, mostly of chert or quartz	2	
C.	Chocolate-colored fine-grained sand		3
D.	Iron oxide nodule layer		¼
E.	Fine laminated pebbleless clay or silt	1	
F.	White stratified fine-grained sand, containing some clay	2	
G.	Fine laminated fine-grained sand, laminæ one-fourth of an inch thick and of various colors as chocolate, brown, yellowish and white, exposed	2	
H.	Slump	25	

In the five exposures in section 13 of the same township, one mile south of the cut just described, the materials are similar to those mentioned. The sand is fine to medium-grained and has a dominant white color. The stratification is essentially horizontal and thin. Some cross-bedding and contortion of the beds occurs as is indicated by the lower bed No. H shown in the following diagram (Fig 12) and section.

		Feet	Inches
A.	Brown sandy soil	1	6
B.	Brown medium-grained sand, poorly stratified	3	10
C.	Yellow, light colored medium-grained sand, stratified	1½-2	
D.	Hard dark brownish medium-grained very resistant sand	1	
E.	Medium to coarse-grained light brown sand, cross-bedded		6
F.	Fine light yellow stratified sand		6
G.	Resistant brown sand, medium grained	1/3-2	
H.	Thinly bedded layers of brown and light yellow sand. Contorted layers an inch thick, exposed	2-3	
I.	Slump	30	

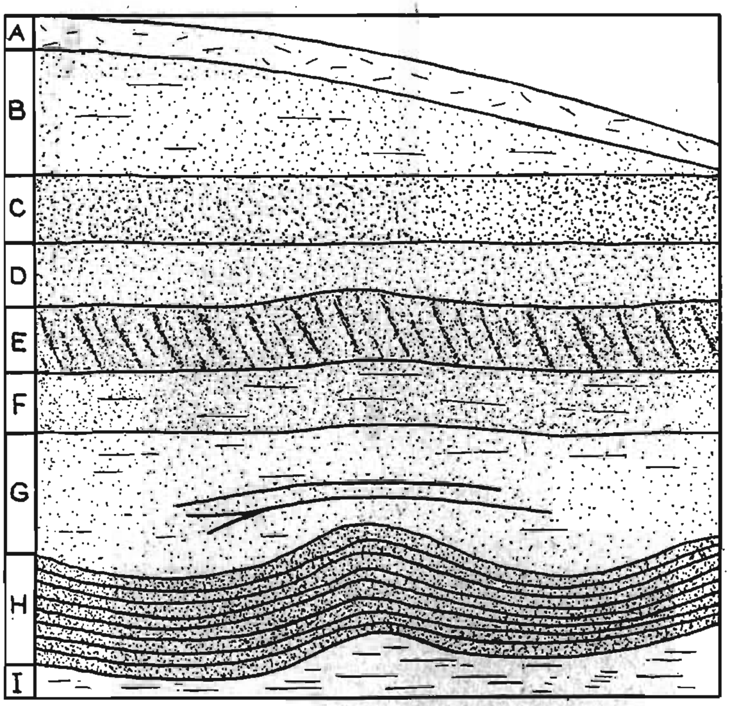

Fig. 12.—Diagram of exposure in the west terrace escarpment, southwest corner of section 13, Goshen township, Muscatine county. See the section above.

An idea of the prevailing fineness of the material may be had from the following photograph taken in the southeast corner of section 13, Goshen township.

In all of the exposures so far indicated, the material described forms the upper portion of the cuts, the lower half being hidden because of the heavy slump. However, on the opposite bank of the river east of the outcrops in section 13, in a gully four to five feet deep, in section 16, Moscow township, the sand is brownish and fairly coarse. Besides the sand, a gravel bed four feet thick and containing cherts, quartzites and other igneous rocks, is in evidence. The gravel is of low textural range and the diameter of the larger pieces does not exceed two inches. In elevation this gravel bed occupies a position corresponding to the lower five feet of the above

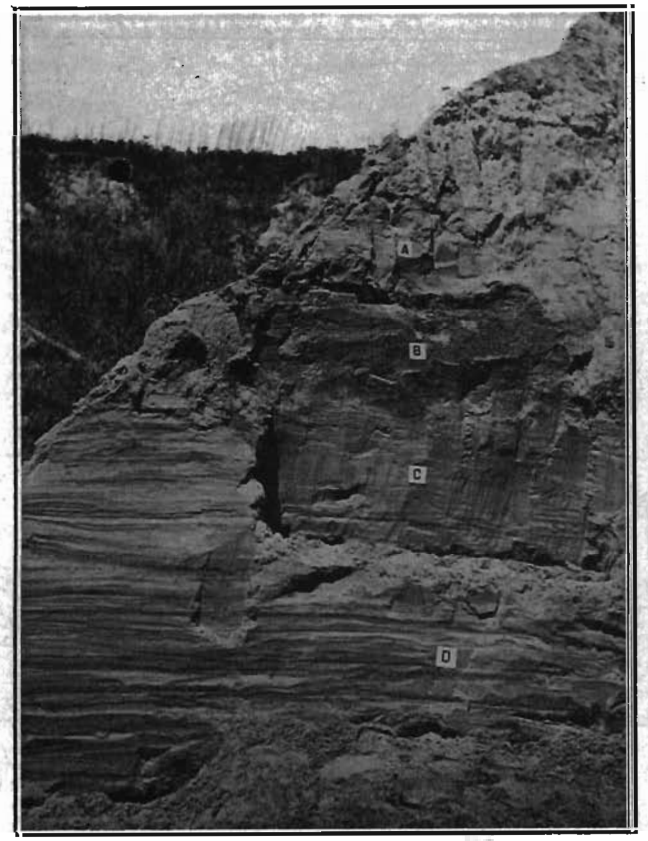

FIG. 13.—View of terrace material showing the fineness of the deposit.

described exposures in which that part is hidden from view by slump material. This great difference in the texture and color of the deposits as seen in the exposures on the west and east sides of Cedar river suggests that the two terraces may not be of the same age. This view is substantiated if one accepts the opinion of Udden[168] that the terrace on which Moscow is situated is younger than his West Liberty Plain. On comparing the elevation of the terraces at Moscow and on the west side of the river, it is found that there is a difference of four feet in elevation. The terrace at Moscow lies 654 feet above sea level and at Atalissa, five miles farther to the west,

FIG. 14.—View of the highly cross-bedded sands in the terrace in section 26, Goshen township, Muscatine county.

the elevation is 658 feet. This closeness of elevation suggests to the writer that there is but one terrace. Furthermore, Udden mentions in connection with his discussion on Lake Calvin "riffles of bowlders" in the bed of the river "at the old ford in section 36 in Goshen Township."[169] Also "On section 32, in Orono township, the river cuts into the gravel on the

168 Iowa Geol. Survey, Vol. IX, p. 361, 1899.
169 Iowa Geol. Survey, Vol. IX, p. 355, 1899.

plain bed."[170] Thus it appears that the base of the intermediate terrace is composed of coarser and more gravelly deposits than is the upper part.

The next exposure of terrace material south of the cuts in section 13, on the west side of the river, is in section 26 of the same township. Here, as in the other sections, the sand is prevailingly white and its stratification is on the whole very fine. Cross-bedding, lenses and unstratified thin sandy clay layers are in evidence. The cross-bedding dips to the east with an angle of about twenty-three degrees. See the preceding photograph. In this highly cross-bedded sand there are numerous thin layers of pebbles, the largest of which have a diameter under one inch. (Fig. 14.) In the exposure, a section of which follows, the uppermost crossbedded sand, No. D, shows more irregularity in its structure than the lower bed, No. G. Compare figures 14 and 15.

TERRACE MATERIAL, SECTION 26, GOSHEN TOWNSHIP.
MUSCATINE COUNTY.

		Feet	Inches
A.	Very fine silty soil, in places peaty, appearances of indefinite stratification	2	
B.	Pebbleless leached sticky clay, the upper one foot of which is of a chocolate color and grades downward into an ash-colored clay. At places the ashy clay grades down into an extremely fine-grained silt or sand which shows cross-bedding. Stratification extremely fine. Contact between this and underlying bed irregular	5-7	
C.	Whitish fine-grained stratified sand with some brownish interbedded layers. Stratification practically horizontal and wavy, at places, upper half is finely cross-bedded	1-3	
D.	A whitish and iron stained sand showing both highly cross-bedded and lens type of structure. Some lenses consist of a very fine clay or silt. Sand fine to coarse-grained, with many thin interbedded pebble layers	2-3	
E.	Chocolate-colored clay or silt, extremely fine and full of moisture		1.5
F.	Dark gray clay or silt, similar to E		1.5
G.	Whitish and iron stained cross-bedded sand, dipping east with an angle of 23 degrees. Sand full of thin coarse pebble layers	3	
H.	Whitish horizontally bedded sand with numerous small pebble layers, stratification fine; exposed	2-3	
I.	Slump material		

Between the cross-bedded divisions, D and G, there are two layers of an extremely fine clay or silt containing much moisture. The total thickness of this clayey material is three

170 Idem, p. 355.

inches. Overlying the stratified sands and separated from them by an irregular line of contact or erosional unconformity is a pebbleless leached sticky ash-colored clay which at places grades down into an extremely fine-graded silt or sand

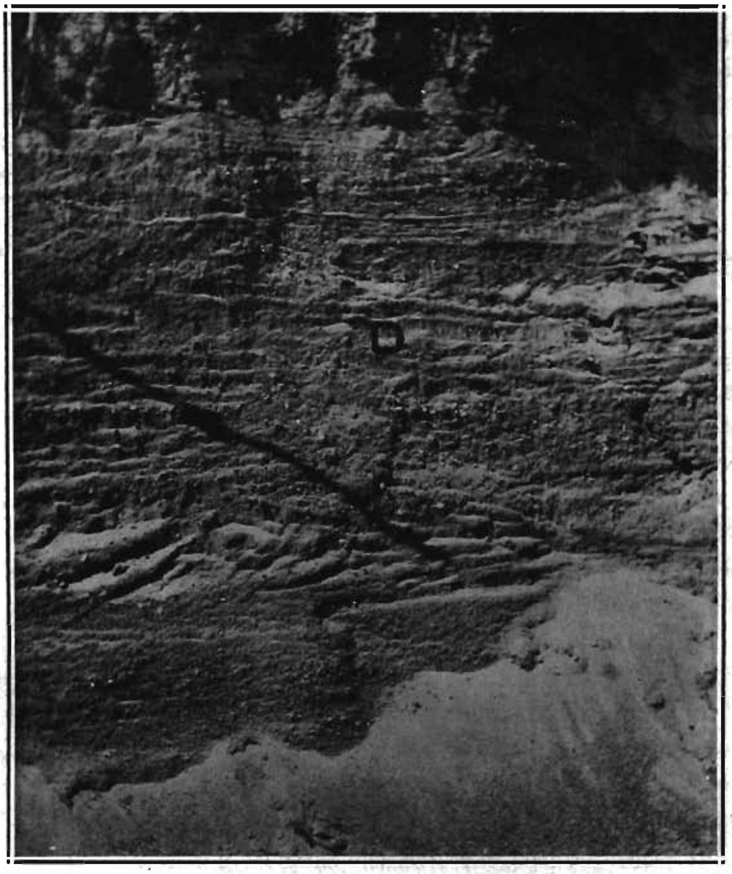

FIG. 15.—View of the irregular stratification of bed D in the same exposure as shown in figure 14.

which is very finely stratified and cross-bedded. This clayey deposit is presumably loess.

Other exposures showing the nature of the intermediate terrace deposit were seen on both banks of the recent Cedar valley as follows: (1) in sections 10 and 2 of Orono and Cedar townships respectively: (2) two and one-half miles northeast of Conesville and (3) in sections 13 and 2 of Oakland township.

in Louisa county. In sections 10 and 2 of Orono and Cedar townships the material consists of a fine to medium-grained brown sand containing numerous pebbles of low textural range. In section 2 no stratification is visible, whereas in section 10 the sands show cross-bedding. The deposit in the escarpment facing Prairie creek slough in the northwest corner of section 13, Oakland township, consists of very fine silt one-half a foot thick, overlying roughly stratified, brownish to red colored, fine-grained sand. Several other exposures which were visited reveal sands and structures which are similar to those described.

On page 361 of the Muscatine county report,[171] Udden states that "At Moscow the town is situated on a terrace which appears more recent than the West Liberty Plain. East of the railroad depot an excavation in this terrace, twenty feet deep, shows a structureless, yellowish surface sand two feet deep, resting on a white or gray sand rather free from gravel." As previously indicated, the writer is of the opinion that this terrace is a part of the intermediate terrace. If we consider the elevations, we will find that the terrace at Moscow is 654 feet above sea level and the intermediate plain at Atalissa, which is five miles to the west, is 658 feet above sea level. The material described by Udden does not differ essentially from that of the intermediate terrace. As the terrace is traced northward, it is found to be dune-covered, and on the west side of the river in section 26, Iowa township, Cedar county, the twelve foot exposure of extremely fine white stratified sand is overlain by a deposit of loess five to eight feet thick. Evidence of quiet water conditions is seen also in a terrace cut along a creek tributary to the Cedar in the southwest corner of section 22 of Iowa township. Practically all of the material is a fine stratified silt. The section is as follows:

TERRACE MATERIAL, SOUTHWEST CORNER, SECTION 22, IOWA TOWNSHIP, CEDAR COUNTY.

		Feet
A.	Brownish pebbleless loesslike clay	5
B.	Brownish, ash-colored silt or loess, extremely hard to penetrate. Iron mottled and containing pipe stems	5

171 Iowa Geol. Survey, Vol. IX, 1899.

		Feet
C.	Finely laminated ash-colored silt, iron stained layers	1-2
D.	Fine almost fatty laminated brown silt, interbedded with an ashy silt	1-2
E.	Ash-colored silt or clay, exposed to water level	3

Alden and Leighton in their report "The Iowan Drift"[172] indicate that some of the deposits of the terrace along Cedar river south of Rochester "may have resulted from slack-water during the Illinoian stage."[173]

THE HIGH TERRACE.

TOPOGRAPHIC FEATURES.

Historical.—The presence of at least two terraces in the Iowa river arm of the lake basin had been noted as early as 1891 by McGee.[174] However, from the map showing the surficial formations of northeastern Iowa accompanying McGee's classic monograph on the Peistocene History of Northeastern Iowa, it is apparent that the high terrace of this report was not recognized, although on page 432 McGee states: "The principal part of Iowa City, including the university campus, is on an elevated terrace of loess 60 feet above the river, and there is a narrow terrace just beyond the reach of the floods." The first part of McGee's description applies well to the high terrace of this report, for it lies about sixty feet above the river and also underlies most of Iowa City. Yet McGee's surficial map does not show it. His second terrace might correspond to the lower one as mapped and described in this report were it not for the following statement quoted from the same paragraph "and as the bottom lands expand below Iowa City they divide into terraces similar to and eventually merging with those of the Lower Cedar." It seems that McGee used the term "terrace" rather freely, for but two terraces, the high and the low, occur along Iowa river and these two eventually do unite with those of the lower Cedar. It appears also from the report on the "Geology of Johnson County"[175] that Calvin did not recognize two systems of terraces. No description of

172 Iowa Geol. Survey, Vol. XXVI, Report for 1915, 1917.

173 Idem, p. 136.

174 McGee, W J, The Pleistocene History of Northeastern Iowa, U. S. Geol. Survey, Eleventh Ann. Rep't., p. 432, 1891.

175 Iowa Geol. Survey, Vol. VII, 1897.

the upper one is found in his report and by comparing his surficial map with one showing the two sets of terraces as mapped by the writer, it is evident that at the time his report was written, in 1897, but one terrace was recognized. Hence, the mapping and describing of this important feature, the high terrace, appears for the first time.

Area.—By far the greatest development of the high terrace is confined to the east side of Iowa river, where it can be traced without interruption from Iowa City south to sections 10 and 15, Oakland township, Louisa county, a distance of nineteen miles. Throughout the middle portion of its extent, in Pleasant Valley township, Johnson county, the terrace maintains an average width of two miles. South of River Junction and Lone Tree the plain is wider so that a maximum width of almost six miles is attained three miles south of the above-mentioned villages. Still farther to the south, due to the encroaching of Iowa river, the terrace is restricted to a narrow neck less than half a mile wide connecting a somewhat wider portion in sections 3 and 10 of Oakland township, Louisa county. In sections 11 and 12, Pleasant Valley township, Johnson county, a narrow peninsular-like projection of the terrace extends westward for almost two miles. To the north of this hook, the high plain is marked by three indentations, the first of which is in section 7 and is made by the flood plain of a small tributary of Iowa river. The second indentation, which is in the form of a narrow valley and is occupied by the lower terrace, lies immediately to the north in sections 36 and 31 of East Lucas and Scott townships respectively. The third and largest irregularity consists of a well defined finger-shaped indentation, one and one-half miles long and half a mile wide. In the vicinity of Iowa City the terrace has a width of three miles.

On the west side of the river, the high terrace is not continuous, but occurs as small isolated remnants, the largest one of which is the valley of Old Mans creek, and occupies portions of sections 4, 5, 9, 15 and 16 of Liberty township and sections 31 and 32 of West Lucas township. Its width is between one-fourth and one-half mile and its length is four and one-half miles. This terrace is best developed in section 9 of Liberty township. Smaller remnants are found: (1) at the iron bridge crossing Iowa river to the city park at Iowa City; (2) on both sides of English river at the junction of the Iowa and English river valleys; and (3) in sections 16 and 17 of Union township, Louisa county.

The higher terrace rises distinctly above the lower one to the west, forming a very sharp and straight escarpment, which on the average is thirty feet high. Near Iowa City it lies sixty feet above Iowa river, while it is fifty feet high in the vicinity of Hills and thirty-two feet high in section 16, Oakland township, Louisa county. It has an elevation of 680 feet above sea level in the vicinity of Iowa City, but to the south it is lower, reaching a height of 670 feet near Hills, six to seven miles below Iowa City, and 660 feet two miles south of River Junction. In the lower two tiers of sections in Fremont township, Johnson county, the plain is again somewhat higher, approximating an elevation of 680 feet above sea level. From the elevations mentioned, is it apparent that the surface of the terrace has a much gentler slope—one and four-tenths feet per mile—than the intermediate terrace in Muscatine county. Immediately south of the island-like upland at Iowa City, but especially in sections 22, 23 and 26 of East Lucas township, the terrace border is bounded by low linear ridges of sand dunes. Dunes ten to fifteen feet high heighten the terrace escarpment of the peninsula-like extension of the main terrace in sections 1, 2, 11 and 12, Pleasant Valley township. Sand dunes are of common occurrence along the terrace margin south of River Junction.

Topography.—The most remarkable feature of the high terrace is its exceedingly straight border or escarpment where it is in contact with the low terrace. Where the flood plain of Iowa river abuts against it, as south of River Junction, the border is marked by numerous large irregularities of a type which is common to regions bordering courses of meandering streams. This straightness of the terrace margin where it is in contact with the lower terrace is not confined to the east side of the river, but occurs also on the west side and in the valley of Wapsinonoc creek north of West Liberty.

Topographically, the high terrace can be divided into northern and southern sections, the former including the area lying between Iowa City and the general latitude of Hills, the latter comprising all of the plain south of the above section. The northern section is characterized by a flat featureless surface in which the streams have cut but shallow and insignificant valleys. In sections 25 and 30, East Lucas township, the plain is especially flat as can be seen from the following photograph.

FIG. 16.—View showing the flat surface of the high terrace in section 25, East Lucas township, Johnson county.

The topography of the southern section is gently undulating. Compare figure 16 and figure 17. Its surface is marked by low elevations which in sections 13, 18, 19, 24, 25 and 36 of Pleasant Valley township rise twelve to fifteen feet above the general surface. Wherever the elevations are cut by roads they reveal a fine-grained sand without pebbles and undoubtedly they are dunes. Numerous undrained depressions, many of which are marshy and some of which contain ponds, were seen dotting the surface among the dunes. In sections 19, 24, 25 and 30 of Pleasant Valley township the surface of the terrace rises somewhat higher than the surrounding country. This led the writer to map it at first as a northwestward projection of Kansan upland. Closer examination, however, revealed the fact that the surface really consists of a series of broad and low elevations between which are undrained depressions. The material, as seen in the road and in the farm-yard in the northeast corner of section 30, consists of a fine-grained white to yellow structureless sand. Further work finally demonstrated a gentle break in the slope of the topography to the east of the supposedly tongue-shaped extension of the upland. Farther south, as in the lower tier of sections in Pleas-

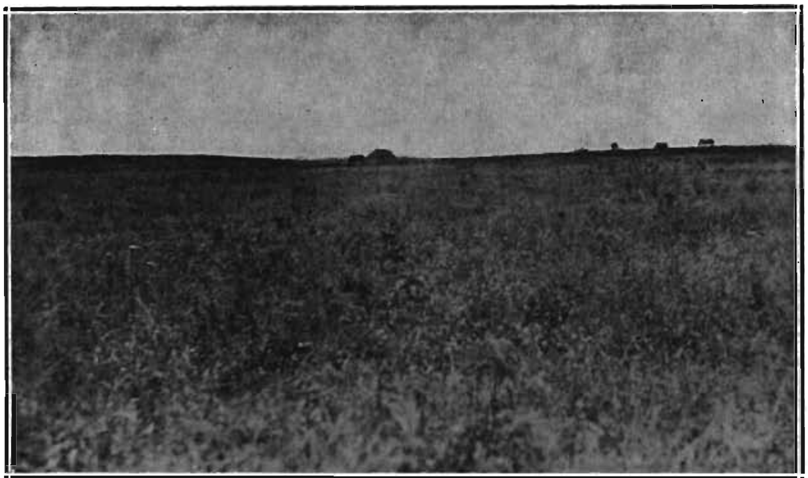

FIG. 17.—View showing the gently undulating topography of the high terrace, section 19, Pleasant Valley township, Johnson county. Compare with figure 16.

ant Valley township, the undulations are more pronounced, the dunes having a height of thirty to forty feet. Ponds are present between the undulations. Most of the dunes are not migrating but are under cultivation and at places are covered by groves of trees whose diameters measure as much as one and one-half feet. In general the undulations trend east and west.

Similar topography prevails south of the Chicago, Rock Island and Pacific railway tracks between River Junction and Lone Tree. The impression gained on viewing the topography is that the plain is the Kansan upland sloping gently west and southwest and the barometric elevations show this to be the case. The gentle upland slope was modified by some agency, which gave it the undrained-depression type of topography. This same impression is gained where the high and intermediate terraces come together in Muscatine and Louisa counties. In the center of section 33, Fremont township, Johnson county, there is a knoll somewhat higher than the surrounding land (Fig. 18), and the road which crosses it is very sandy toward the top of the ridge. To the south, the region lies forty to fifty feet lower, but rises again, however, to the same height at the edge of the terrace one mile distant. This knoll appears to

FIG. 18.—View showing the knoll on the high terrace in the center of section 33, Fremont township, Johnson county.

be the terminus of a high strip of country extending in a northwest direction through section 33 and the lower half of 29, into section 30.

Relation of the high terrace to other topographic features.—The high terrace is distinctly differentiated from the intermediate plain by a well defined escarpment which in section 3, Oakland township, Louisa county, reaches a height of forty feet. From the center of the western section line of section 11, Oakland township, to River Junction, the terrace is bordered by the present flood plain of Iowa river, with the exception of one locality. In sections 32 and 33, Fremont township, Johnson county, and sections 4 and 5 of Oakland township in

Louisa county, a small remnant of the low terrace joins the higher plain with a smoothly curving escarpment twenty feet high. It is in this part of the terrace lying south of River Junction that the sinuous border of the escarpment is found. The height of the high terrace above the flood plain differs from place to place. In the southern extension of the plain, in sections 9, 10, 15 and 16, Oakland township, where much of its prominence is lost, its surface lies between twenty-five and thirty feet above the flood plain. In section 4 of the same township, the escarpment bluff has attained a height of sixty feet. Twenty-five feet is the average height as far north as section 12, Fremont township, Johnson county, where the terrace bluff is forty feet high. North of River Junction, the high terrace is separated from the lower plain by the strikingly straight escarpment previously described. On the average, there is a vertical difference of thirty-five feet between the two surfaces.

On the west side of Iowa river, the larger terrace remnant in the valley of Old Mans creek is separated from the river flood plain by a steep bluff forty-eight feet high which gives it a height of thirty feet above the low terrace. Here, too, the characteristic straight escarpment is in evidence. The northern isolated remnant in the English river valley lies at least fifteen feet above the lower plain to the east and thirty-five feet above the bottom land of the river. The surface of the remnant on the south bank of the river is twenty-five feet above the low terrace.

MATERIALS AND STRUCTURE OF THE TERRACE.

Materials and structure.—An examination of all the exposures in the high terrace reveals the fact that most of the material is fine-grained, brown to white, horizontally bedded sand overlain by a deposit of loesslike clay which averages four feet in thickness. Sections in the northern part of the plain are extremely few in number. In the southwest quarter of section 24, East Lucas township, a few feet of horizontally bedded silt is exposed. Along Snyder creek, ten to fifteen feet of fine, horizontally stratified sand appears in the north bank of the creek at the crossing of the roads between sections 36 of East Lucas and 31 of Scott townships. The best outcrop of sands and silts is in the north bank of the wagon road cut between sections 13 and 24, Pleasant Valley township, two and one-half miles east of Hills and one mile east of a type section in the lower terrace to be described in the forthcoming pages. (See fig. 19.) The section follows:

FIG. 19.—View of an outcrop of fine sands and silts in the high terrace exposed in the north bank of the wagon road cut between sections 13 and 24, Pleasant Valley township, Johnson county.

TERRACE MATERIAL, HIGH TERRACE, TWO AND ONE-HALF MILES EAST OF HILLS.

		Feet
A.	Loesslike clay	2-3
B.	Extremely fine-grained, yellow to brown sand or silt. Stratification essentially horizontal, somewhat wavy. Lamination fine, lithological constituents uniform; exposed	3-7

Four cuts in the terrace surface in sections 31, 32 and 36 of the same township reveal the same type of fine horizontally bedded sands or silts. In these exposures, the stratification is horizontal and lacks the minor wavy undulations seen in the exposures east of Hills. It appears from the outcrop in the south bank of the creek in the northeast quarter of section 31 that the terrace is composed entirely of this fine-grained laminated material. Here the twenty feet of sand is exposed within two to three feet of the level of the rolling plain. Similar outcrops of fine silts are found in the center of section 4, Oakland township, Louisa county, four and one-half miles south of Lone Tree and in the south bank of the wagon road cut in the center of section 3 of the same township.

Only two exposures of the terrace material were seen in the terrace remnant in the valley of Old Mans creek. One of these is in a small gully in the terrace escarpment in the western part of section 10, Liberty township, five miles south of Iowa City. The materials are as follows:

TERRACE MATERIAL, SECTION 10, LIBERTY TOWNSHIP, JOHNSON COUNTY.

		Feet	Inches
A.	Brown to reddish fairly coarse-grained sand, grading into a whitish to grayish clay or silt, leached and structureless	17	
B.	Reddish to brownish black gumbo-like material, sticky when wet, practically free from grit. Material thoroughly leached. Surface uneven		½-13
C.	Buff to ash-colored clay, gritty, pebbleless, leached; exposed	2	

The relation of the gumbo-like material, B, to the other material is indicated in the diagram below, figure 20. The top

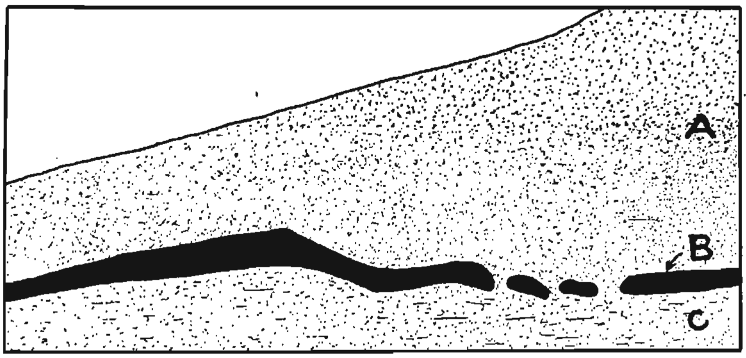

Fig. 20.—Diagram showing the relation of the gumbo-like material, B, to the material A and C.

of the terrace at this locality is thirty-two feet above the flat to the east, and the black sticky material, B, is fifteen feet above the flat. A similar gumbo-like clay outcrops one hundred yards to the southeast at practically the same level. Also the log of the well at the house two hundred feet or so north of the first outcrop indicates a black band having a thickness of six inches. This well is approximately sixty feet deep and the black layer is struck forty-five feet below the surface. The owner of the well also reported sixteen feet of gravel below the sticky material. The top of the terrace at the house is forty-eight feet above the lowland to the east, thus bringing the black layer about three feet above the lower flat or twelve feet lower than the deposit at the first described locality. Another exposure is half a mile farther to the southwest in a shallow ditch on the east side of the wagon road at the corner of sections 9, 10, 15 and 16. Four or five feet of leached sand and clay similar to those seen at the first locality is exposed here also. The layers, which are thinly laminated, show more or less irregular bedding, which, however, can be explained readily as being due to the settling of the material after the road was constructed. A deposit of four to five feet of loesslike clay lies over the sands. The surface of the terrace at these sections is flat.

Most of the outcrops seen south of the railroad tracks between River Junction and Lone Tree differ somewhat from those to the north. In addition to the fine-grained sands or silts of the northern exposures, the southern sections show layers of coarse-grained sand and fine pebbles. Cross-bedding also is more in evidence in the coarser material and it is noted that the cross-bedding is fine and variable in direction. It is further worthy of remark that the material is of low textural range, large pebbles being entirely absent. These cross-bedded layers are interstratified with the predominatingly finer horizontally bedded material. A typical section follows:

TERRACE MATERIAL, HIGH TERRACE, SOUTHWEST CORNER, SECTION 24, FREMONT TOWNSHIP, JOHNSON COUNTY.

		Feet
A.	Loesslike clay	4
B.	Medium to coarse-grained yellow to brown sand, very fine cross-bedding	1
C.	Very fine dense bluish sand with irregular lenses grading into a coarse-grained sand which is highly and finely cross-bedded; numerous small pebbles and pebble pockets	8
D.	Brown, horizontally stratified sand containing thin layers of very small pebbles, lower portion coarser grained and cross-bedded	12
E.	Dark brownish to blue-black joint clay containing much wood. Surface of till covered by bowlders of all descriptions of which many are in the form of shingle; exposed to water's edge	10

The cross-bedding of sand C, which is rather unusual for the high terrace deposits, is represented by the diagram, figure 21. It may be noted that a good many of the gravelstones, cobbles and bowlders which were seen lying between the stratified ma-

FIG. 21.—Detail of cross-bedding of bed C in the high terrace sands exposed in the southwest corner of section 24, Fremont township, Johnson county.

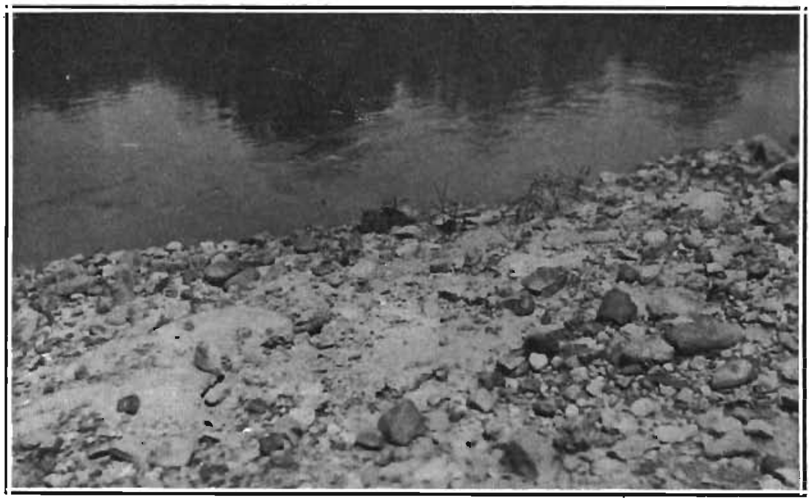

FIG. 22.—View of the slablike igneous bowlders lying on the surface of the till and beneath stratified terrace deposits in section 23, Iowa township, Washington county.

terials and the till in the various exposures along the bank of the Iowa river are flat or slablike. Not only is this true of the softer local limestone, but also of the harder igneous material. (See Fig. 22.)

THE WILTON VALLEY TERRACE.

Area and topography.—According to Udden, the terrace along the course of Mud creek up to Durant is a northeastern extension[176] of his West Liberty Plain, or the intermediate terrace of this paper. Because of the difference in the material of the two terraces and because of the interrupted profile of the gradient of their surfaces when these are connected, as illustrated in figure 23, the writer is of the opinion that the Wilton valley terrace is not an extension of the intermediate plain but rather a higher terrace corresponding to the high terrace in Johnson county. The terrace is continuous and can be traced eastward without a break on both sides of Mud creek, from sections 2 and 11, Moscow township, for a distance of over seven miles beyond Durant. The terrace is well defined and its surface is flat (see figure 24) and not obscured by sand

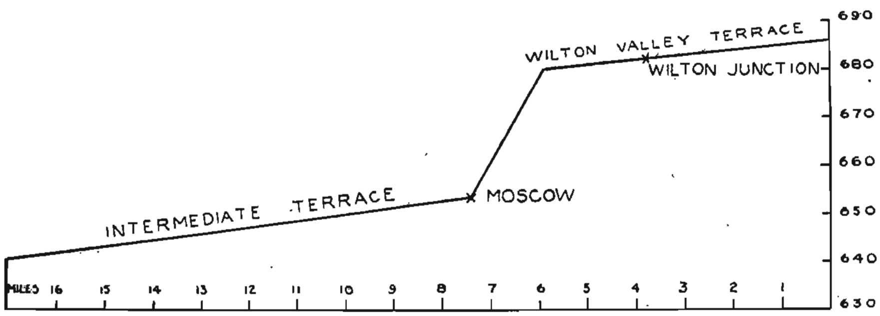

FIG. 23.—Diagram showing the interrupted profiles of the surfaces of the Wilton Valley and Intermediate terraces when the two are connected.

dunes. In width, the northern part averages half a mile, whereas south of the creek the terrace is three-fourths to one mile wide. Its surface, which lies thirty to forty-five feet above Mud creek, meets the valley walls in a gentle slope.

Materials and Structure.—Exposures in the terrace are fairly numerous. Good outcrops are to be had in almost every section through which Mud creek flows, from section 11, Moscow township, to the village of Durant. In general, the material composing the terrace is as follows:

176 Iowa Geol. Survey, Vol. IX, p. 257, 1899.

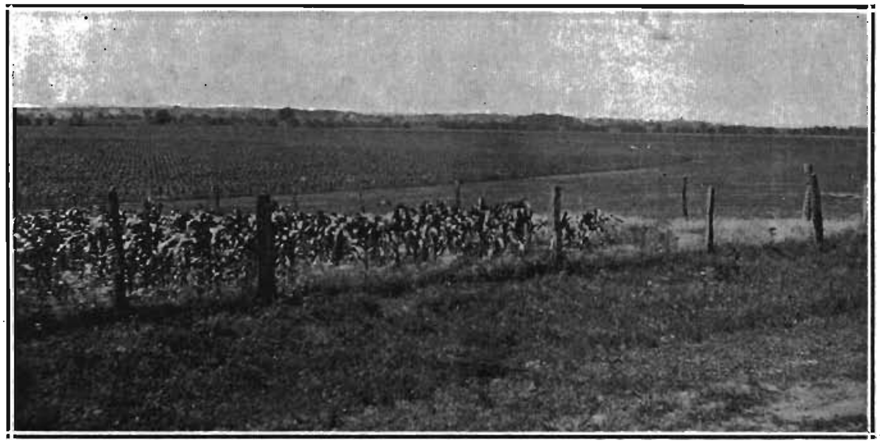

FIG. 24.—View of the Wilton Valley terrace showing its flat surface and the gentle slope of the valley walls. View taken one mile east of Wilton Junction.

A. Loesslike clay.

B. Stratified sand, usually fine-grained.

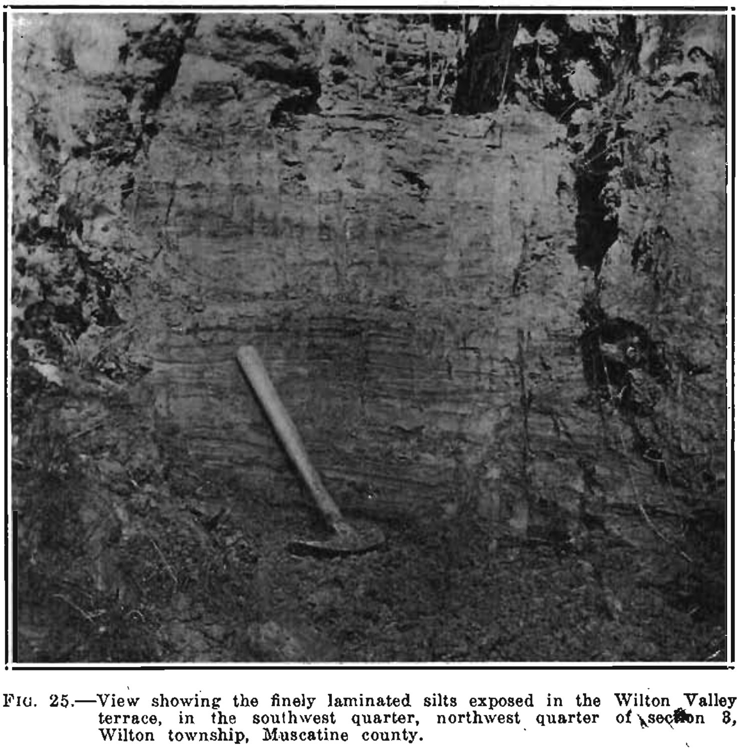

FIG. 25.—View showing the finely laminated silts exposed in the Wilton Valley terrace, in the southwest quarter, northwest quarter of section 8, Wilton township, Muscatine county.

C. Finely laminated silts or clays.

D. Stratified sand, more gravelly to the west.

The deposits seen in the various outcrops are of such a uniform character that they may be represented by the two following typical sections, one showing the prevalence of finely laminated silts or clays in the eastern half of the valley and the other showing a predominance of fine stratified sands in the western end of the valley. The type exposure of the laminated silts or clays is in the southwest quarter of the northwest quarter of section 3, Wilton township, three miles east of Wilton Junction. At this place Mud creek makes a sharp

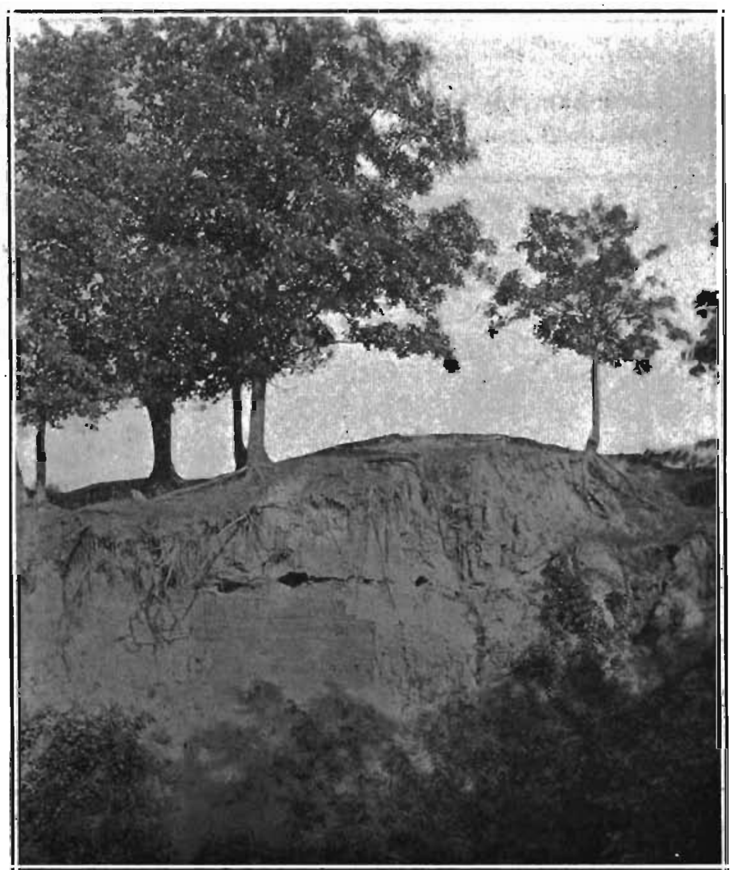

FIG. 26.—View showing the laminated silts of figure 25 exposed within a few feet of the terrace surface.

bend toward the north. The exposure is in the south and east bank of the terrace escarpment which rises thirty-five feet above the creek level. Figures 25 and 26 illustrate the materials at this place. The section is as follows:

TERRACE MATERIAL, WILTON VALLEY TERRACE.
Sw. ¼, Nw. ¼, SEC. 3, WILTON TOWNSHIP,
MUSCATINE COUNTY.

		Feet
A.	Loesslike clay	1-5
B.	Fine-grained thinly bedded yellow sand above the finely laminated silts or clays, laminæ about twenty to an inch	34

The sand, silts or clays are free from all pebbles. The stratification, which is extremely fine, is horizontal; however, minor undulations, as figure 26 shows, are in evidence.

The section typical of the terrace material in the west half of the valley is shown in the following photograph, figure 27. This outcrop is in the west bank of the wagon road cut between sections 11 and 12 of Moscow and Wilton townships respectively, one mile south and west of Wilton Junction. The terrace at this place is forty-six feet high and the outcrop is twenty feet above the creek.

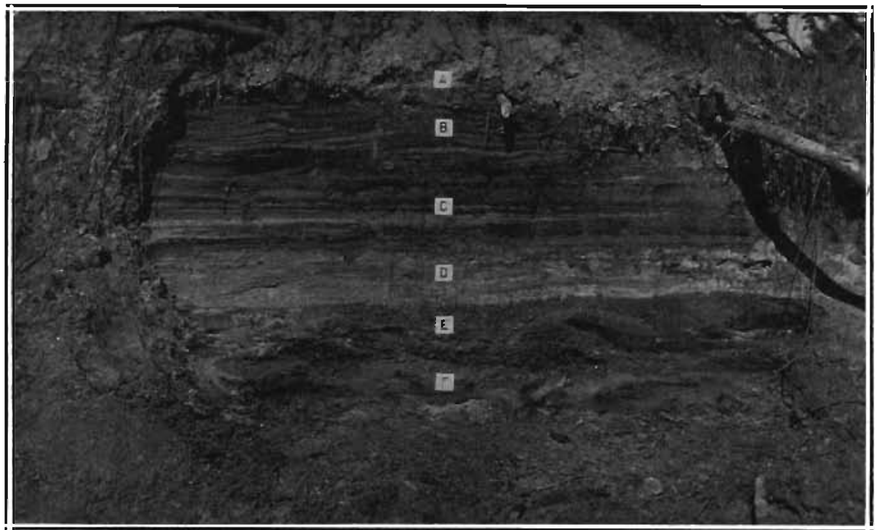

FIG. 27.—View showing typical outcrop of terrace deposits in the western half of the Wilton Valley terrace, section 11, Moscow township, Muscatine county.

TERRACE MATERIAL, WILTON TERRACE,
WEST HALF SEC. 11,
MOSCOW TOWNSHIP, MUSCATINE COUNTY.

		Feet	Inches
A.	Brown loess	2-3	
	Sandy and silty deposit with small gravel or pebble pockets	2-3	
B.	Finely laminated brownish sand to silt, no pebbles, bedding practically horizontal	1	
C.	White to brown sand, white sand fine-grained, few scattered pebbles; brown and lower sand coarser and containing numerous small pebble pockets	8	
D.	White fine-grained sand, occasional pebbles		
E.	Coarse brown sand, numerous pebbles		6
F.	Ash-colored silt, very fine, no pebbles, laminated; exposed		6

TERRACE REMNANT IN CEDAR COUNTY.

A remnant of what appears to be a high terrace is present in sections 13, 14, 23 and 24 of Iowa township, Cedar county, on the west bank of Cedar river. The top of this terrace remnant is flat and lies thirty-five feet above another terrace to the east which in turn is twenty feet above the water level of Cedar river. No exposure was seen in it and the only clew as to the nature of its material and structure is obtained from its sandy surface and an exposure of bedrock in the creek bed in section 14 where the high terrace meets the bluffs of the upland. This suggests a rock terrace partly covered over with loose sandy deposits. The terrace is only half a mile wide.

TERRACE NORTH AND NORTHWEST OF WEST LIBERTY.

The high terrace north and northwest of West Liberty along the course of West Branch or Big Slough creek and Wapsinonoc creek was mapped on the basis of topographic position. The town of West Liberty is built on this terrace, which rises about thirty feet above the intermediate plain. The terrace can be very readily traced up to the above-mentioned creeks but they have not incised their valleys sufficiently to reveal the nature and structure of the materials. The noteworthy feature of this terrace is its regular and straight border, a feature characteristic of the high terrace wherever it is in contact with the lower terrace. This terrace is Udden's other extension[177] of the West Liberty Plain.

177 Iowa Geol. Survey, Vol. IX, p. 257, 1899.

RELATIONSHIP OF HIGH TERRACES.

In the neighborhood of Hills, Johnson county, the high terrace has an elevation of 670 feet above sea level which agrees well with that of the western remnant in the valley of Old Mans creek. This height corresponds with that of the high terrace at West Liberty where the terrace, as recorded by the Chicago, Rock Island and Pacific Railway depot elevation, is 673 feet. The lower end of the Wilton Valley terrace, also in the same straight line, has an elevation of 670 feet. In sections 29 and 30 of Scott township, Johnson county, the elevation of the terrace is 680 feet above sea level. Five miles directly east, the northwest extremity of the high terrace north and northwest of West Liberty lies at 681 feet. Furthermore, the small remnant of the high terrace on the west bank of Iowa river at Iowa City, near the city park, is at 680 feet. Lastly, the two isolated remnants of the high terrace on both sides of English river lie at approximately 640 feet, which is also the approximate elevation of the terrace east of Iowa river at River Junction. Thus, it seems that in so far as elevations are concerned, there is some relationship between the high terrace and its remnants in Johnson county and the two high terrace remnants in Muscatine county.

THE LOW TERRACE.

Area.—The low terrace is confined to the western or Iowa river arm of the lake basin. Unlike the other two terraces, this terrace is not continuous, but is represented by remnants large and small. Its surface lies, in general, twenty feet above Iowa river or somewhat less above the bottom-lands and twenty to forty feet below the high terrace. Where it is in contact with the high terrace, as in Pleasant Valley township, Johnson county, the line of separation is regular, whereas its escarpment along the river or flood plain is more or less sinuous. Remnants of the terrace occur on both sides of Iowa river. Along the stream courses of Old Mans creek and English river south of Iowa city, the terrace is represented by "mere remnants at the bends of"[178] Iowa river. These 'mere remnants'

[178] Alden, Wm. C., and Leighton, Morris M., The Iowan Drift: Iowa Geol. Survey, Vol. XXVI, p. 136, 1917.

have been described by Leighton[179] and are at the following places.

1. West side of the valley of Pardieu creek about one mile below the North Liberty Plain in the west central part of section 29, township 80 north, range 6 west.
2. Along the north side of the ravine running parallel with the Cedar Rapids and Iowa City Interurban from Swisher to Cou Falls.
3. On the north side of the bend of Iowa river just north of Iowa City and on the west side of the tributary that dissects the valley wall.
4. Just above Mehaffey bridge, in the southeast quarter of section 32, township 81 north, range 6 west.

The remnants are all small, having an average length and width of one-fourth and one-eighth of a mile respectively and a height above the river of about thirty feet.

South of Iowa City the terraces are better developed and of greater dimensions. Half a mile south of the Iowa City limits in West Lucas township, the terrace is one and one-fourth miles wide and on the east side of the river in East Lucas township, sections 34, 35 and 36, it is approximately two miles wide. However, the average width of the low terrace in the Iowa river valley is about three-fourths of a mile. The largest parts of this terrace are that in the valley of Old Mans creek, where it is ten miles long and half a mile wide and that along the course of English river, where it is seventeen miles long and about a mile wide. Two insignificant remnants, one on each side of the river, are present at the intersection of Johnson, Louisa and Washington counties. It is possible that the low terrace is represented along Cedar river north of Cedar Valley, in Gower township, Cedar county.

Topography.—The surface of the low terrace is flat except where it is interrupted by a few shallow gullies of young streams.

Materials and Structure.—Exposures of materials are limited to the river banks. In contrast with the deposits seen in the high and intermediate terraces, the materials of the low terrace are coarser, contain more gravel layers, have a higher

179 Iowa Geol. Survey, Vol. XXV, pp. 134-138, 140, 141, 1914.

textural range and consist predominantly of sands with extremely little silt or clay. In structure there is also a difference. Whereas the high and intermediate terraces contain thinly and horizontally bedded deposits with minor cross-bedding, the prevailing type of structure of the low terrace is well developed cross-bedding and pocket-and-lens stratification. Of all the exposures observed, those at the following three places may be cited as the best and most typical:

1. Johnson county, Pleasant Valley township, center of the northeast quarter of section 33. The outcrop is in the east bank of a slough of Iowa river, one and one-half miles east of Hills and one mile southeast of a typical high terrace exposure. The terrace is twenty-one feet above water level and approximately 640 feet above sea level.
2. Johnson county, Liberty township, central part of the northeast quarter of section 27, one and one-fourth miles south of Hills. The materials are in the west bank of Iowa river.
3. Washington county, Iowa township, northeast corner of northeast quarter of section 33. The outcrop is in the southwest bank of Iowa river.

A composite description of the three outcrops follows. The upper three to six feet consists of loess or a brownish loesslike clay which overtops a fine to medium-grained highly cross-bedded sand which has a predominant dip to the south. This bed is two to four feet thick and numerous small granite, chert and limestone pebbles one inch in diameter are scattered through it. Pockets of laminated clay are visible locally. Beneath this layer of sand is a white sand which contains near its top small pockets of quartz, chert, greenstone and other pebbles. The sand also is cross-bedded and peppered with little pebbles. Its thickness is three feet. Beneath the white sand is a coarse, brown sand containing numerous pebbles which measure one inch in all three dimensions. Most of the sand is cross-bedded with a dip toward the south. Dip measurements read from twenty to thirty degrees. At places, as at the Washington county exposure, there is a change in the direction of dip of the cross-beds. Numerous fine gravelly layers are distributed throughout this sand in the form of pockets which pinch out laterally. Some horizontal as well as irregular or wavy bedded layers occur throughout the deposit. Beneath the stratified material, which is exposed within one to ten feet of the water's edge, is a dense bluish to black till whose surface is covered by many pebbles, cobbles and bowlders, a large proportion of which are slablike. (See fig. 22, page 155.) Laminated clays in the low terrace are exposed in the south bank of Ralston creek in the center of section 15, East Lucas township, south of Iowa City.

Another outcrop which calls for especial attention is the one in the southwest quarter of section 34, West Lucas township, about four miles south of Iowa City. The material is all stratified, is coarse and consists of sands and gravels. The deposit is exposed in a former gravel and sand pit of the Iowa City-Kalona branch of the Chicago, Rock Island and Pacific Railway. The terrace rises fifteen feet above the flood plain of Iowa river and is about one-eighth of a mile wide. A diagram and section follow:

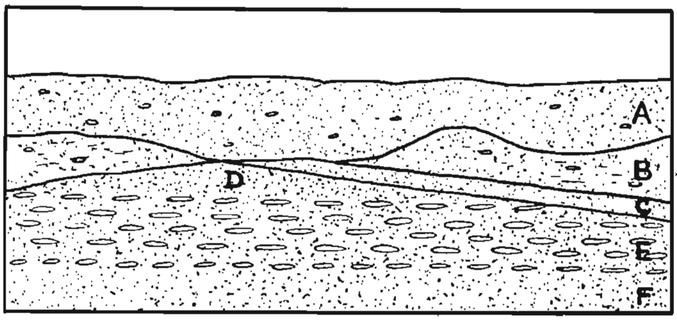

FIG. 28.—Diagram of the terrace materials seen in the low terrace in the Sw. ¼ of section 34, West Lucas township, Johnson county.

TERRACE MATERIAL, LOW TERRACE, SOUTHWEST QUARTER, SECTION 34, WEST LUCAS TOWNSHIP, JOHNSON COUNTY.

		INCHES
A.	Dark sand peppered with pebbles or small gravel, some well rounded. Occasionally large pebbles are found. Lower surface somewhat irregular	6-15
B.	Coarse sand lighter than above, stratified, containing few large pebbles; on the whole, pebbles smaller than in A	0-6
C.	Thin layers of coarse stratified sand, the upper half of which is blackish and contains a few pebbles; lower half of a brownish color	2-3
D.	A sand similar to B	0-5
E.	Coarse stratified gravel and sand. Gravel consists of igneous material and limestone in equal parts; textural range high, from small sand grains to bowlders nine by six by four inches. Many of the gravels are in the form of slabs or shingle. Some of the limestone slabs are	

	one-eighth to one-fourth of an inch thick, six to seven inches long and four inches wide. This slablike form is not confined to the limestone, but is common also to the harder igneous material	12-24
F.	Coarse stratified sand; exposed	1-2

The log of the well at the house immediately west of the outcrop shows that there is about two feet of soil followed by three feet of coarse stratified sand below which the gravel is encountered. The owner of the well also reported that where the water level in the terrace is reached, the sand is coarse but of uniform texture. According to this same farmer, the gravel lies at different distances below the terrace surface, generally not very far beneath it, however.

THE FLOOD PLAINS OF THE LAKE BASIN.

The flood plain of Cedar River.—The flood plains of the two master streams have different widths and are at different depths below the levels of the adjacent terraces into which the modern valleys have been cut. Their margins, however, are practically everywhere characterized by sinuous river-scarred escarpments. The bottom lands of Cedar river maintain a fairly uniform width of two and one-fourth miles to a point about three miles north of Cone where the valley is constricted to one and one-half miles. This width is maintained within two miles north of the Muscatine county line from which point to the junction of Iowa and Cedar rivers, the flood plain is no wider than half a mile. In the northern part of Muscatine county, in Goshen township, the bottom lands lie thirty-seven to forty-three feet below the intermediate plain. As the flood plain is traced southward, the difference between its surface and that of the intermediate terrace becomes less and less until in Orono township it is twenty-seven feet and in Louisa county but twenty feet. The flood plain in turn lies on the average five feet above the river. Its surface is characteristically flat, sandy and marshy and scarred by numerous abandoned river channels, old sloughs and ox-bow lakes. On the whole, the drainage is defective and most of the land is barely fit for agriculture.

The flood plain of Iowa river and its tributaries.—The flood plain of Iowa river and its tributaries is in all respects similar to that of Cedar river. The bottom lands of Iowa river are on the average twenty feet below the surface of the low terrace and thirty-two to forty-eight feet lower than the high terrace in the valley of Old Mans creek and forty to forty-five feet lower than the high terrace near River Junction. At other places, in sections 24, 25, 31 and 32, Fremont township, Johnson county, differences in elevation between the flood plain and the high terrace ranging between twenty-two and thirty feet are more common. A maximum vertical difference in height of sixty feet between the high terrace and the flood plain is reached in the center of section 4, Oakland township, Louisa county. The most conspicuous features of the Iowa bottom lands are the two large extensions of the flood plain into the high and intermediate terraces in Oakland township. The most easterly one, occupying parts of sections 11, 12, 13, 14, 15, 22 and 23, is especially noteworthy. On the west side it is bordered by the high terrace and on the north and east by the intermediate terrace, whose surface lies on the average thirty feet higher than the flood plain. Its outline or border is remarkably regular with no notable indentations. Its width is uniform and is a little more than one mile. The lowland, which is marshy and a favorite ground for duck hunters, is traversed by Prairie creek. Two crescentic ponds or lakes dot its surface, one in the northwest corner of section 13 and adjoining parts of sections 12 and 14, the other in the southeast corner of section 15, the southwest corner of section 14 and the northern part of section 23.

The average width of the Iowa river flood plain between River Junction and a point almost four miles north is two and one-half miles. Thence the bottom lands are narrower, having at first a width of one and one-half miles, then one mile and finally at Iowa City scarcely one-eighth of a mile. South of River Junction, the flood plain is two and one-half miles across, but is abruptly constricted to half a mile in sections 25 and 26 of Iowa township, Washington county. The flood plain widens again south of these two sections until finally a maximum width of three miles is attained in the first large indentation in Oakland township, Louisa county. Between the two large extensions of the Iowa river lowland, the flood plain is confined to a width of only one-fourth of a mile or less. South of Gladwin as far as the junction of the Iowa with the Cedar, the bottom lands range from one-third to one mile in width. The flood plains of the tributaries of Iowa river are insignificant and need no further comment.

CHAPTER VI.

EVIDENCE AND ORIGIN OF EXTINCT LAKE CALVIN.

Evidences of Extinct Glacial Lakes.

In a consideration of extinct glacial lakes, the most common evidences cited for their previous existence are generally those enumerated by Upham and listed as follows:

1. "Their channels of outlet over the present watersheds.
2. Cliffs eroded along some portions of the shores by waves.
3. Beach ridges of gravel and sand, often on the larger glacial lakes extending continuously through long distances.
4. Delta deposits, mostly gravel and sand, formed by inflowing streams.
5. Fine sediments spread widely over the lacustrine area."[180]

To these may be added several others as for instance, ice-rafted bowlders, bowlder walls, rounded shore lines between places of indentation and associated deposits along the shore lines.

Discussion and Interpretation of Features of the Lake Calvin Region.

Although the existence of Lake Calvin has been accepted by most geologists familiar with the Lake Calvin basin, absolute proof of the former lake's existence has never been presented. Udden's work was confined to Muscatine county and the evidences cited by him in his report on Lake Calvin[181] do not establish the certainty of the presence of the ancient lake, especially in the light of our present knowledge of the Pleistocene. Furthermore, doubt regarding Lake Calvin has been presented personally to the writer and has also been indicated elsewhere as may be seen from the following: "It is not known whether this gravel (a deposit in the intermediate terrace or Udden's West Liberty plain) is a sheet deposit formed along a delta front encroaching on a lake, or was deposited by a stream the width of the present plain or was laid down in long narrow

180 Upham, W., Lake Agassiz: U. S. Geol. Survey Monograph XXV, p. 195, 1895.

181 Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, pp. 350-357, 1899.

strips in the channel of an aggrading stream perhaps no larger than the Cedar of today.''[182] It has also been suggested that the sediments in the lake basin in Muscatine county were laid down ''by a stream which is supposed to have had its course through it (the intermediate terrace) with some lacustrine influence.''[183]

In view of the above opinions, it now becomes necessary to carefully and critically study all features found in the lake region which might throw some light on the question whether Lake Calvin did or did not exist. An unbiased analysis of such features ought then to show whether the Lake Calvin basin is to be attributed to:

1. lacustrine influence
2. alluvial influence
3. or a combination of 1 and 2.

With this view in mind, the following topics or features are presented for careful and critical study:

1. Theoretical considerations.
2. The Mud-Elkhorn creek valley.
3. The temporary Mississippi river channel of Leverett.
4. Laminated silts, clays and sands in the lake basin.
5. Terraces in the lake basin.
6. Rounded bluff lines in the lake basin.
7. Bowlders in the lake basin.
8. Certain gravel deposits in the lake basin.
9. The Illinoian upland within and without the lake basin.
10. A comparison of the width of the valley in and outside of the lake basin.

THEORETICAL CONSIDERATIONS.

Discussion.—Leverett[184] has conclusively demonstrated that southeastern Iowa was invaded from the east by the Illinoian ice sheet and that during this time Mississippi river must have been displaced. The blocking up of the valley by the ice sheet undoubtedly resulted in a ponding of the waters probably giving rise to a lake as the waters rose until finally an outlet or spillway was reached. As the mouth of Wapsipinicon river

182 Norton, W. H., and Others, Underground Water Resources of Iowa: U. S. Geol. Survey Water Supply Paper 293, p. 465, 1912; Iowa Geol. Survey, Vol. XXI, p. 560, 1912.

183 U. S. Department of Agriculture, Soil Survey of Muscatine County, Iowa, p. 22, 1916.

184 Leverett, F., Illinois Glacial Lobe: U. S. Geol. Survey Monograph XXXVIII, 1899.

was blocked by the Illinoian ice sheet[185] (Fig. 29) the waters of the Mississippi were dammed back as far as Maquoketa river from whence they escaped westward as far as Preston in Jackson county. At Preston, the Maquoketa river valley is connected from the south by the wide and well developed Goose Lake channel which extends southward for over nineteen miles to the valley of Wapsipinicon river. Due to the closing of the

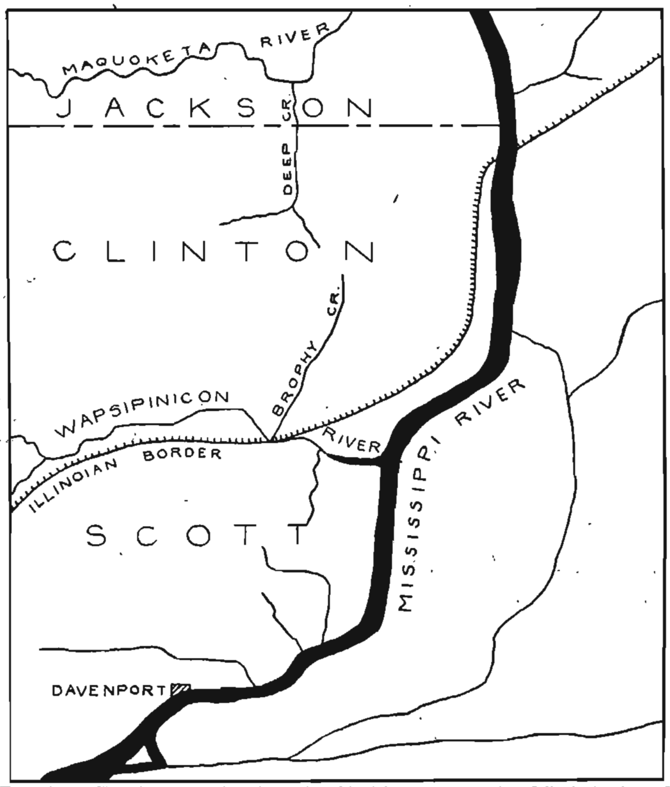

FIG. 29.—Sketch map showing the blocking up of the Mississippi and lower portion of the Wapsipinicon river valleys. (Modified after Carman)

mouth of that river by the ice barrier the combined waters of Mississippi, Maquoketa and Wapsipinicon rivers were forced westward to the mouth of Mud creek from whence the confined waters found their way southward over the low divide to Elkhorn creek and finally into Cedar river at Moscow. From here

185 Carman, J. Ernest, The Mississippi Valley Between Savanna and Davenport: Illinois Geol. Survey, Bull. 13, p. 62, and fig. 15, p. 38, 1909.

the four streams pursued a southerly course to Columbus Junction, Louisa county, where Iowa river added its waters to that of the others. Since the passage of these waters was still obstructed on the east by the ice wall of the Illinoian glacier and on the other sides by high Kansan bluffs they were still dammed back and must have risen until the level of the abandoned channel discovered and mapped by Leverett[186] was reached. As has been shown by Leverett[187] this ancient water-course can be traced southward, westward and eastward across several counties until it joins the present Mississippi river valley immediately below Fort Madison in Lee county. That the course of Mississippi river during the Illinoian stage of glaciation followed the course just outlined is not disputed. That the ponding of the combined waters of Mississippi, Maquoketa, Wapsipinicon, Cedar and Iowa rivers together with that of the melting ice sheet necessarily gave rise to a quiet body of water in the lake basin area or that aggradation kept pace with the increasing influx of water so that stream conditions existed all the time or that a combination of the two may have resulted is not so obvious.

Interpretation.—The fact remains that when the Illinoian ice sheet occupied the position shown by its deposits as indicated on Plate VIII, Mississippi, Maquoketa, Wapsipinicon, Cedar and Iowa rivers with their tributaries were blocked on one side by an ice wall and on the other by uninterrupted Kansan bluffs 120 to 140 feet high. That the waters of these combined streams were ponded is evident. The question arises: would this ponding of the stream give rise to a lake or is it possible that in some way or other fluvial conditions were maintained? It is true that the ponded waters were able to spread over a considerable area, which may have resulted in shallow water conditions. However, it is hardly conceivable that deposition was so rapid as to have kept pace with the rising of the water, especially since the combined waters of several large streams were involved, not forgetting the water coming from

186 Udden, J. A., Geology of Louisa County: Iowa Geol. Survey, Vol. XI, p. 64, 1901.

187 Leverett, F., The Illinois Glacial Lobe: U. S. Geol. Survey Monograph XXXVIII, pp. 89-97, 1899.

the melting ice sheet. Furthermore, most of the aggradation must be attributed to the melting Illinoian ice itself and especially is this true towards the southern half of the lake basin where no large streams empty into the basin. Would this aggradation account for the relative thinness of the Illinoian deposit? It is a fact that the Illinoian drift is thin, but is it not more logical to explain this fact on the basis that the ice sheet had been greatly reduced in thickness, first because it was practically at its maximum distance from its source and secondly because in passing over from Illinois into Iowa, the ice had to fill up the wide valley of the Mississippi, thus permitting only its upper and less heavily laden portion to advance into Iowa? Such a diminution in thickness of the ice would necessarily mean a minimum amount of glacial erosion and hence a minimum amount of material for deposition. Hence, the terrace materials are not to be thought of as being the result of deposition of a stream the width of the terrace. That it does not take much to cause ponding of waters to form a lake is illustrated in the case of Lake Pepin, Wisconsin. Lake Pepin is an expansion of Mississippi river. It is from one mile to two and one-half miles wide and about twenty-two miles long, covering an area of approximately thirty-eight and one-half square miles. The lake is a result of the building up of a delta by Chippewa river. This river having a higher grade than that of the Mississippi is able to carry more and coarser material than the master stream is able to remove. If the incomplete obstruction of the Mississippi's course, as at the mouth of the Chippewa, is sufficient to cause the formation of a lake then it is certain that the complete blocking of the Iowa-Cedar river valley by the Illinoian ice sheet would give rise to Lake Calvin.

Thus it appears to the writer that ponding of the combined waters of Mississippi, Maquoketa, Wapsipinicon, Cedar and Iowa rivers must have resulted in the formation of a lake in which the sediments of the terraces were deposited.

THE MUD-ELKHORN CREEK VALLEY.

Discussion.—Of utmost importance in the consideration of the former existence of glacial lakes are the inlet and the outlet, especially the latter. If there really existed a lake with an inlet, some evidence of the latter might be manifested either in the form of the topography or in the nature of the sediments found in the inlet. The only possible inlet of Mississippi river to Lake Calvin was by way of Mud and Elkhorn creek valley as outlined under Theoretical Considerations. A careful study of this valley is therefore very important.

The valley occupied by Mud creek is well defined and ranges in width from one and one-half to a little over two miles. It unites with the large valley of Cedar river at Moscow and extends eastward for over seven miles past Durant. The valley walls, although more sharply defined at some places than at others, merge, in general, gradually into the conspicuous feature of the valley, the wide terrace described in chapter V as the Wilton Valley terrace. The surface of this terrace is flat and unobstructed by sand dunes and is continuous save for the course of Mud creek which has incised for itself a narrow flood plain thirty to forty-five feet below the terrace surface. At Durant an island-like ridge separates the valley into two branches, one trending in a northeasterly direction following what is known as Elkhorn creek and the other continuing eastward along Mud creek. Of the two branches, the northeast trending valley is the more conspicuous. For over two miles its course is direct and its width is scarcely over one-half of a mile. The valley walls are well developed and sharply outlined. The other branch continues eastward along Mud creek for about three miles and thence extends northward, meeting the Elkhorn valley in sections 19 and 20 of Cleona township in Scott county. All exposures of sediment in the valley are limited to the area between Moscow and Durant and consist chiefly of fine stratified sand and laminated silts or clays. Calvin in speaking of these sediments states "The fineness of the material, the regular stratification and absence of organic matter, indicated that at the time of the imbedding of the skeleton, the locality was covered with comparatively deep, clear and still water . . . . . The topography of the surrounding country and the nature of the drift itself, favored the idea that a lake at one time covered the territory of the West Liberty plain and reached up to Wilton, and that sediments from some inflowing river had aided in filling this lake.''[188]

The valley in which Elkhorn creek flows continues its course northeastward over the very gentle divide into the valley of Mud creek without either being constricted or losing its identity. The divide separating the headwaters of the north-flowing Mud and the south-flowing Elkhorn creeks lies at an elevation of about 720 to 725 feet above sea level and is so flat and poorly drained that several ponds and marshes cover its surface. The rise between the two creeks is so imperceptible that were it not for the fact that the creeks are seen to flow in opposite directions, a col would not be suspected. The divide is in sections 19 and 20 of Cleona township, Scott county, and is over one and one-half miles wide. The valley thence follows the course of Mud creek for over nine miles to Wapsipinicon river. Mud creek itself is an insignificant stream. Near its head, it is but a few feet across and from three to five feet deep, but it increases in size somewhat toward its mouth where it is four to five rods wide and six to seven feet below the valley floor. Because of its extreme youth there are no exposures along its course. Outcrops are lacking on the valley slopes also because of their gentleness. Another noticeable feature of Mud creek valley is that the wide valley floor extends up into the tributary valleys so that the latter near their mouths are exceptionally wide. ''It is believed that these broad flood plains (of the tributaries at their mouths) were filled from the main channel rather than aggraded by their own creeks.''[189]

If the Illinoian ice obstructed the lower course of the Wapsipinicon river valley then somewhere west of the present Mississippi river there must be evidence of a temporary Mississippi channel and such evidence is not lacking. A well defined valley follows the Wapsipinicon river valley east for about fifteen miles from the debouchure of Mud creek and in the other

188 Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, pp. 352-353, 1899.

189 Norton, W. H., Geology of Scott County: Iowa Geol. Survey, Vol. IX, p. 415, 1899.

direction it can be traced northward through Clinton and Jackson counties as far as Spragueville where it unites with the valley of the Maquoketa. In many respects this old valley, termed the Goose Lake channel and first described by McGee,[190] is similar to the one occupied by Mud and Elkhorn creeks. Both are occupied by two insignificant streams, one flowing to the north and the other to the south. In both cases, the streams occupy disproportionately large valleys. As the

FIG. 30.—View of Goose Lake Channel in Jackson county.

divide between Mud and Elkhorn creeks is imperceptible and ill drained, so too is the valley between the headwaters of the south-flowing Brophy creek and the north-flowing Deep creek. The divide between the two creeks is in sections 4 and 5 of Center township and 32 and 33 of Deep Creek township, Clinton county. Formerly a lake, Goose Lake, formed the head of Deep creek, but at the present time the site of the lake is represented by a large marsh. The streams that flow in the ancient valley occupy but mere trenches as they are very shallow and but a few feet wide. Goose Lake channel, figure 30, is far more pronounced than is Mud creek valley. Its valley walls,

190 McGee, W J, The Pleistocene History of Northeastern Iowa: U. S. Geol. Survey, Eleventh Ann. Rep't., Pt. I, p. 392, 1899; The Drainage Systems and Loess of Eastern Iowa, Private Publication, 1884.

especially in the northern half, are cut into bedrock and rise seventy to two hundred feet above the valley floor. Toward the south end of the valley the bluffs are only about twenty-five feet high. Exposures in the channel are extremely few. In section 34 of Center township, Clinton county, along the southeast bank of the creek several feet of horizontally stratified sand covered by two feet of loess is exposed. In the southeast corner of section 13, just north of Spragueville in Jackson county, a bed of laminated silts and sands several feet thick is exposed. Immediately north of Preston the south bank of the creek shows brown clay containing innumerable chert chips and pebbles. This clay, which is a foot to a foot and a half thick, overlies fine grained thinly bedded yellowish to brown

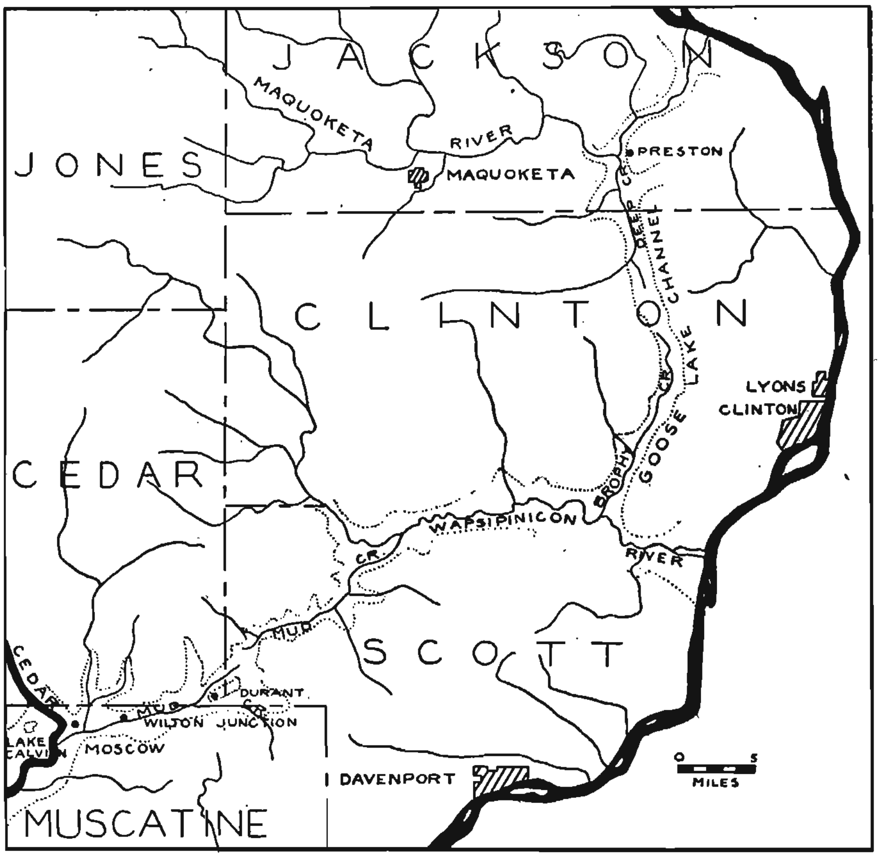

FIG. 31.—Map showing the course of Mississippi river north of the Lake Calvin basin during Illinoian times.

pebbleless sand. According to Carman "The surface material of Goose Lake valley passes downward into fine sand which is 60 to 100 feet thick on the divide south of Goose lake. Farther north in Secs. 17, 8 and 5 of Deep Creek township, Clinton county, several wells go to 110 to 120 feet in sand and fine gravel. In the south part of the channel south of Elvira wells 70 to 80 feet deep do not reach rock."[191]

The temporary Mississippi followed the rock bound gorge of Maquoketa river from the mouth of Deep creek to Mississippi river. The course of Mississippi river during the Illinoian times is shown on figure 31.

Interpretation.—The nature and structure of the silts and laminated clays exposed in Elkhorn valley in the vicinity of Wilton Junction practically preclude contemporaneous aggradation. As has been shown before, the terrace materials consist of fine horizontal laminated silts and clays without coarse sands, gravels or bowlders. It is practically impossible to assign such deposits to fluvial influence. The fine lamination of the deposits, which at places are over thirty feet thick, implies quiet water or lacustrine conditions. On the other hand, one might expect to find coarse sands and gravels, showing evidence of rapid deposition in the valley, if fluvial conditions existed, since the valley follows the edge of the Illinoian drift plain. Naturally here, nearest to the ice edge, we would expect the coarsest material to be laid down. Large bowlders are practically lacking from the terrace surface except those located by Udden[192] in sections 8 and 11 of Wilton township and in section 2 of Moscow township, Muscatine county. In speaking of these bowlders Udden states that they were "in all probability, transported by floating ice on the surface of the lake at an early stage, when the waters stood high, and were probably stranded on the shores."[193] To the investigator, the laminated silts and clays argue positively for lacustrine conditions.

The fact that a continuous valley, partly occupied by streams and partly abandoned, can be traced from the lake basin to

191 Carman, J. Ernest, The Mississippi Valley Between Savanna and Davenport: Illinois Geol. Survey, Bull. 13, p. 57, 1909.
192 Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, p. 354, 1899.
193 Idem, p. 354.

the Mississippi river by way of Maquoketa river strongly suggests the possibility of a lake. It has been shown that the Mud-Elkhorn valley is disproportionately wide and is not the product of the insignificant streams which occupy portions of it. Furthermore, the valley is distinctly traceable over two stream divides. A better inlet to the lake could not be desired.

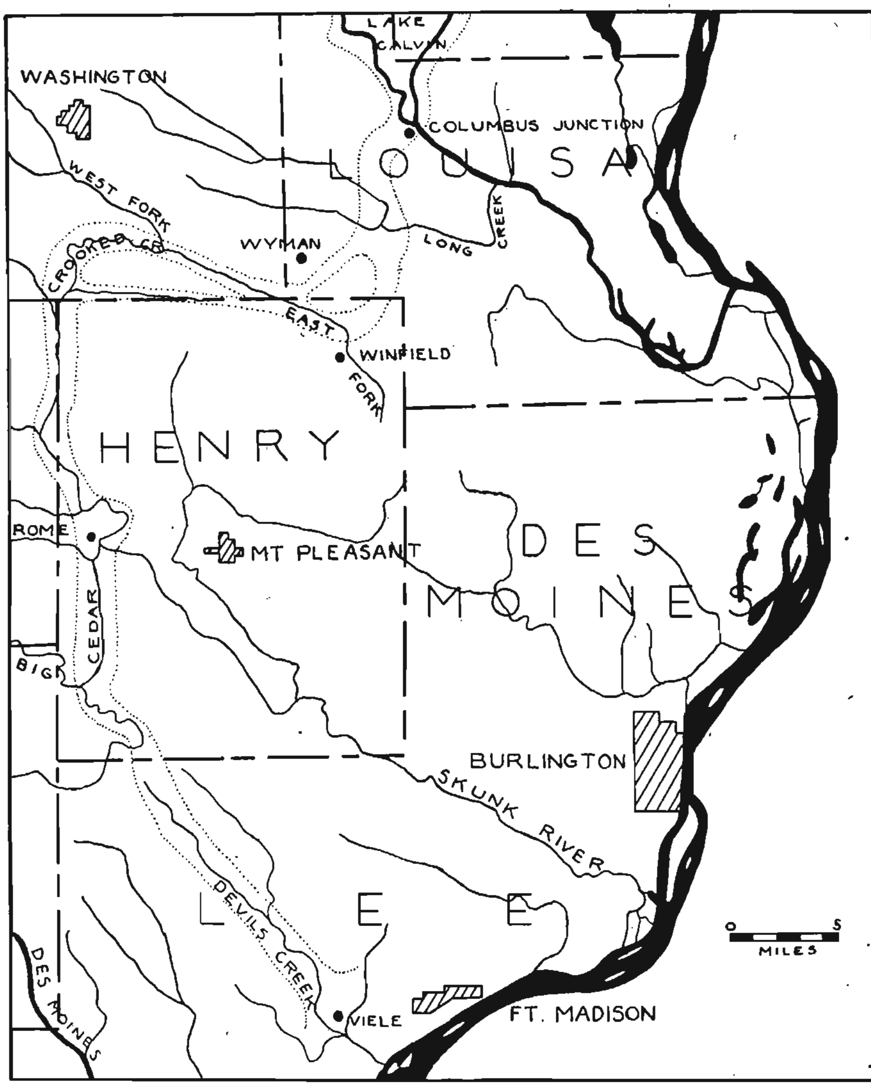

FIG. 32.—Map showing the course of Mississippi river south of the lake basin during Illinoian times.

THE TEMPORARY MISSISSIPPI CHANNEL OF LEVERETT.

Discussion.—The outlet is of still greater importance as a criterion of extinct glacial lakes. As early as 1896 Leverett discovered an abandoned channel between the Illinoian and Kansan uplands in Louisa county. This channel, which is outlined on figure 32, has been described in detail by Leverett in his monograph on the Illinois Glacial Lobe. The following description is taken from this report: "The course of the channel is southward from just above Columbus Junction to the vicinity of Winfield, a distance of 12 miles, crossing Long Creek, a small tributary of the Iowa, about six miles south of Columbus Junction . . . . . Before reaching Winfield a channel branches off to the west from the main channel and joins it again just south of Wyman. This channel has a breadth of but one-eighth mile or less. It is more direct than the main channel, and has about the same depth.

A short distance east of Winfield the main channel is entered from the east by the East Fork of Crooked Creek, and this stream meanders through the broad bottom of the main channel westward to its junction with the West Fork, and thence continues west and south to Skunk River Valley at Coppock. Another channel leads directly west from Winfield past Wayne to Coppock, a distance of 15 miles. The combined width of the two channels is but little greater than that of the portion of the channel north of Winfield, the channel along Crooked Creek being about three-fourths to one mile in width and the channel leading past Wayne one-fourth mile. The lower portion of Crooked Creek nearly occupies the full width of the north channel, but throughout the greater part of the course it is bordered by a broad terrace-like plain, several times the breadth of the valley which it has excavated . . . . .

The portion along Skunk river from Coppock to Rome, a distance of 10 miles, is so completely occupied by the valley of that river that only occasional narrow remnants of the abandoned channel appear as terraces on its borders, the average breadth of that part of Skunk River Valley being fully one mile. The most extensive remnant of the abandoned channel is found in the double ox-bow made by the river north and west of Rome, which stands, where not broken down by subsequent erosion, about 670 to 675 feet above tide.

From Rome the abandoned valley continues southward along the valley of Big Cedar Creek (reversed) and is preserved in terracelike remnants on each border of the valley which stands 30 feet or more below the level of the upland plain. The average breadth of the valley being not less than one-half mile the terrace remnants are narrow. From the bend of the Big Cedar, eight miles south of Rome, the old valley, as noted above, leads southeastward across Lee county to the Mississippi Valley at Viele, six miles below Fort Madison, gradually deepening from 30 feet to the north to 50 or 60 feet at the south. It is occupied for about 4 miles by Little Cedar Creek just south of the bend of Big Cedar. The remainder of its course is drained by Sugar Creek. The excavation along the channel from Columbus Junction to Viele is estimated to be one-half a cubic mile.''[194]

This ancient valley of the Mississippi is incised below the general upland surface of the Kansan drift plain thirty to sixty feet. The valley floor rises 120 feet above the level of Iowa river and in the vicinity of Columbus Junction it lies at an elevation of about 700 feet above sea level. Its general width ranges from one and one-quarter to one and one-half miles. The valley is well defined but is more conspicuous the farther southward it is traced. At the divide in sections 35 and 36 of Elm Grove township, Louisa county, seven miles south of Columbus Junction, the valley floor is one mile wide and thirty-five to forty feet below the general upland level. (See fig. 9, page 114.) Several miles south of Columbus Junction bedrock appears in the valley walls and that part along Skunk river is cut largely in solid rock. Unusual deposits of sand and gravel are lacking in the channel.

Interpretation.—The absence also of any notable deposits of sand or gravel in the temporary Mississippi river channel of Leverett seems to be in opposition to a fluvial hypothesis. If the filling up of the lake basin is due to stream deposition

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194 Leverett, F., The Illinois Glacial Lobe: U. S. Geol. Survey Monograph XXXVIII, pp. 91-93, 1899.

then there appears to be no logical reason why similar deposits as those found in the lake basin and in the Wilton Valley should not be seen in the abandoned Mississippi channel, the course pursued by the streams at the time of glaciation. The absence of such materials at once demands an explanation. There is no reason to believe that the streams were no longer overloaded by the time the waters used the channel nor that erosion has since removed the materials that may have been deposited. When it is remembered that a lake acts as a filtering plant for a river, it is easy to account for the absence of notable sand and gravel deposits in the abandoned valley if Lake Calvin existed and Leverett's channel served as its outlet. For comparison the streams emptying into and draining the Great Lakes may be cited. It is well known that the streams emptying into the Great Lakes are discolored and muddy because of the large amount of sediment which they carry. Also it is true that such streams as the Niagara and the St. Lawrence which drain away from the lakes are relatively clear and free from sediments and hence have little erosive power. Because of the filtration of sediments and perhaps also because "the ground in which this channel was excavated may have been frozen at the time of the Illinoian glaciation, its situation being on the immediate border of the ice sheet"[195] it is not to be expected that the outflowing stream would have much erosive power nor much material to deposit so that the absence of notable deposits of sand and gravel within the channel is quite the natural thing to be looked for. This too may explain why the abandoned channel of Leverett is not so well developed as the Mud-Elkhorn valley, especially that portion which is known as the Goose Lake channel. Leverett has traced the channel from the southern extremity of the lake basin at Columbus Junction across several counties to Mississippi river below Fort Madison. This channel furnishes an excellent outlet for Lake Calvin.

LAMINATED SILTS, CLAYS AND SANDS IN THE LAKE BASIN.

Discussion.—The finding of horizontally laminated clays or

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195 Leverett, F., The Illinois Glacial Lobe, U. S. Geol. Survey Monograph XXXVIII, p. 93, 1899.

silts is positive evidence of quiet water sedimentation and may be taken in most cases as indicating deep water deposits and lacustrine sediments. In general, it may be stated that the materials of the high and intermediate terraces are of low textural range and are finely stratified. Laminated silts or clays, however, are practically limited to the valley of Mud creek. Eight good outcrops of terrace materials are present in a distance of five miles, commencing one mile west of Wilton Junction and extending to a point four miles east of the town. As was mentioned in Chapter V under the discussion of the materials and structure of the Wilton Valley terrace, the eastern half of the valley shows a predominance of laminated silts and clays whereas in the west end fine stratified sands are more common. There can be no doubt that the deposits such as are represented by the typical section of terrace materials as given on page 159 (see fig. 25) were laid down under quiet water conditions. Practically thirty-four feet of laminated silt or clay is exposed in the type outcrop. Pebbles are entirely lacking and the stratification is horizontal and undisturbed except for a few minor wavy undulations. Other laminated deposits may be seen in the high terrace two and one-half miles east of Hills (see fig. 19, page 152), in sections 31, 32 and 36, Pleasant Valley township, Johnson county, and in sections 3 and 4 of Oakland township in Louisa county. Similar sediments are exposed in the intermediate terrace in section 8, Goshen township, Muscatine county. The exposed thicknesses of these deposits range from seven to twenty feet.

Interpretation.—The laminated silts and clays exposed in the terrace in the vicinity of Wilton Junction have been discussed. A study of the high and intermediate terrace materials shows that they consist principally of fine to medium-grained sands most of which are horizontally stratified. If these sediments are to be attributed to fluvial conditions, then the streams carried practically no coarse material, a condition hardly possible when one considers the enormous amount of material deposited and the vast area covered.

The structure of the sediments is even more detrimental to the theory of alluvial deposition than is their texture. It is difficult to account for the general horizontal stratification over such a wide extent as is found in the lake basin on the basis of stream deposition. In sharp contrast to the general horizontal stratification of the high terraces is the high cross-bedding of the sands and gravels of the low terrace. This terrace is without doubt of glacio-fluvial origin, as is evident from the nature of these deposits, from their texture and structure and from the fact that the low terrace can be traced to the Iowan drift plain. Is it possible that the Iowan ice sheet supplied coarser material than the Illinoian? Although it is possible, there appears to be no logical reason why it should have done so, especially since the Iowan ice sheet is believed to have been a thin glacier as is evidenced by the thin deposit of Iowan drift. Furthermore, the Iowan outwash materials were not laid down as directly in the lake basin as were the materials coming from the Illinoian ice sheet, which adjoined the lake basin.

It therefore appears that the nature of the sediments of the high, the intermediate and the Wilton Valley terraces demands another hypothesis than that of fluvial aggradation to account for their origin, especially since the known alluvial deposits as evidenced by their texture and structure are in striking contrast to those of the above mentioned terraces. On the other hand, the fineness of the deposits and the general horizontal stratification can well be accounted for by a lacustrine hypothesis.

TERRACES IN THE LAKE BASIN.

Discussion.—It is not evident whether a lake plain can be differentiated from a stream terrace on the basis of topography after dissection has progressed. The surface of the lake floor may be more level over a long distance or may have a lower gradient than that of an alluvial terrace, yet it does not follow that this need be the case. There are three distinct terraces in the lake basin, the high, the intermediate and the low, but what relationship exists between them is not apparent. The high and low terraces are in contact in numerous places in Johnson county and are separated by a well defined straight escarpment about thirty feet high. In Oakland township, Louisa county, and at West Liberty, the high and intermediate terraces join. The average vertical distance between the surfaces of these two terraces is thirty-five feet. As previously described the high and intermediate terraces are more or less gently sloping plains dotted with numerous sand dunes, an exception to this being the one in Wilton Valley. In contrast to these are the low terrace and the present flood plain of the rivers, which are practically free from sand dunes.

From a study of elevations as given on page 116, it is seen that the high terrace is closely related to the Wilton Valley terrace as well as to the one northwest of West Liberty. It is evident from a comparative study of their materials and structure, as well as of their elevations, that the low terrace in Johnson county is not represented by the intermediate terrace in Muscatine county. The low terrace is of fluvial origin as it is composed of Iowan outwash materials. From the descriptions of the materials given in the previous chapter, it is seen that the high and intermediate terrace deposits are much finer and the textural range is much lower than those of the low terrace. Furthermore, the stratification is, on the whole, more horizontal and less disturbed. An excellent comparison of terrace materials of the high and low terraces is to be had in two outcrops one mile and two and one-half miles east of Hills in Johnson county. The location of the two exposures is indicated in the following sketch map.

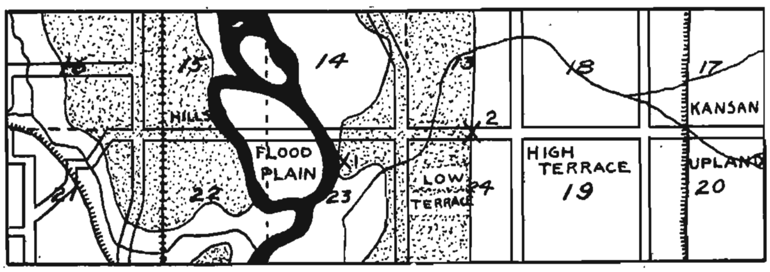

FIG. 33.—Sketch map showing location of two typical outcrops; 1, alluvial; 2, lacustrine.

Exposure 1 is in the low terrace and exposure 2 is in the high terrace. Whereas the material of the high terrace is extremely fine sand or silt, horizontally bedded, the material of the low terrace consists entirely of a fine to medium-grained, white to gray and brown heterogeneous sand containing numerous pebbles and having a medium textural range. Most of the sand is cross-bedded with cross dip at angles ranging from twenty to thirty degrees. Although in general the cross-bedding dips in a southerly direction, the direction of dip at any particular place is not necessarily consistent with the general dip. The gravel layers not only dip in all directions but they pinch out in short distances. In short, the structure of the deposit shows typical cross-bedding and pocket-and-lens type of structure. This deposit, twenty-one feet thick, is in sharp contrast with the other outcrop only one mile farther to the east where cross-bedding, pocket-and-lens type of structure and varying texture of materials are replaced by horizontal stratification and sediments of extremely low textural range and uniform composition. The conditions under which these two deposits were laid down are obviously not the same.

The slope of the high terrace appears to be gentler than that of the intermediate terrace. From the elevations obtained, the gradient of the former terrace is found to be one and four-tenths of a foot per mile, whereas the latter has a gradient of two and one-half feet per mile. However, the writer is inclined not to place much importance on the gradient of the high terrace, as barometric readings had to be used in its calculation. The gradient of the Wilton Valley terrace, one foot per mile, compares favorably with that of the high terrace. When a comparison is made of materials, texture and structure between either the high, the Wilton Valley or the intermediate terraces and the low terrace, it is apparent that the conditions under which they were formed were different.

Interpretation.—Many hypotheses may be advanced to account for the origin of three distinct terraces, depending upon whether they are all of different ages or whether some two or all three are contemporaneous. Before discussing any hypothesis, it will be well to see what relationship exists among them. The problem is somewhat complicated since the low and the high terraces are confined to the Iowa river arm of the lake basin and the intermediate terrace is limited to the Cedar river arm.

It has been shown previously that the high terrace, the terrace north and northwest of West Liberty and the Wilton Valley terraces had a common mode of origin. The questions now to be settled are

1. Are the high and intermediate terraces of the same age or do they represent two stages of terrace development?
2. Are the low and intermediate terraces contemporaneous in origin?

ARE THE HIGH AND INTERMEDIATE TERRACES OF THE SAME AGE OR DO THEY REPRESENT TWO STAGES OF TERRACE DEVELOPMENT?

A study of elevations, materials and structure of the high terrace and the Wilton Valley terrace shows that the two are closely related and undoubtedly are of the same age. The intermediate terrace lies at a lower elevation than the other two terraces, but is very similar to them in so far as materials and structure are concerned, although it differs in all three respects very strikingly from the low terrace. The question arises: Is the intermediate terrace contemporaneous in origin with the high terraces? If so, why the difference in elevation? All things being equal, the filling of a lake ought to be uniform and hence but one set of terraces should be expected to represent the ancient lake bed. However, in a case like that of ancient Lake Calvin where the lake if it existed consisted of two arms and where the supply of sediments coming into the lake was determined by the number and size of the inflowing streams, the lake floor need not necessarily have the same elevation in the two arms. To account for the difference in elevation between the high and intermediate terraces several hypotheses may be presented. The original slope of the valley walls and the depth of the valleys may have been an influencing factor in determining the height of the lake bed at various places. Under similar conditions of sedimentation, the bed of Lake Calvin ought to be uniform and have the same elevation in the two arms of the lake, provided that the depth of the valleys was the same. However, if the depth of the two arms differed or if the slope of the valley walls was different as is indicated in the following diagram, a difference in the elevation of the two lake floors might be possible. In a case such as is indicated by the diagram, figure 34, all things being equal, an equal amount of sediment would necessarily mean a higher lake bed in that portion of the lake occupying the shallower valley and having the gentler slope. The high terrace is confined practically to the eastern part of the western or Iowa river arm of the lake basin whereas the intermediate terrace occupies the eastern or Cedar river arm of the lake site. The bluffs adjacent to the intermediate terrace are very distinct, steep and sharply defined, whereas those forming the high terrace are less well outlined, due to the gradation between bluffs and terrace. Practically everywhere south of the latitude of Hills, the impression gained while standing on the terrace is that the Kansan upland slopes gradually toward the south and southwest and is covered by a veneer of finer sediments. The topography of the terrace is gently undulating, suggesting that the sediments composing the terrace materials were deposited in more or less shallow water, probably forming bars and beaches. The sand from these bars and beaches probably was formed into sand dunes which encroached upon the bluffs and thus caused them to be less well outlined.

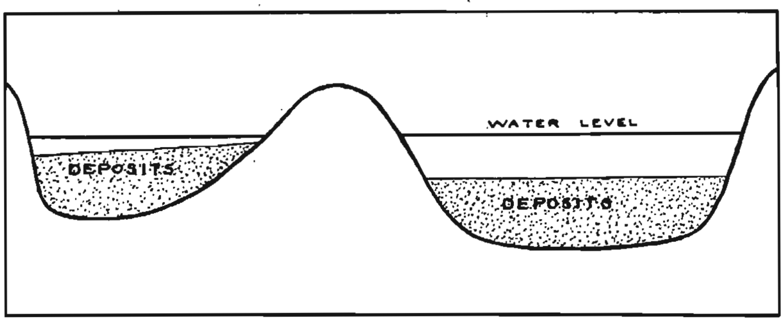

FIG. 34.—Diagram showing how the depth and the slope of the lake bed may result in different elevations of the lake floor, the amount of material being equal.

Another factor entering into the problem of the difference in elevation between the high and intermediate terraces is the number of streams emptying into the lake basin. A glance at Plate VIII shows at once that the Iowa river arm of the lake basin receives not only the greater number of affluents but also the larger ones. Since it receives larger and more tributaries, this portion of the lake naturally should receive the greater amount of sediment, a fact which seems to be borne out by the presence of the high terrace in this portion of the lake basin. The Cedar river arm of the lake basin receives practically no streams of any significance. The largest streams emptying into this portion of the lake basin are confined to the north end. In the northwest corner is Wapsinonoc creek with its two branches. Here also the terrace is higher than the intermediate terrace. In the Wilton Valley also, the terrace is higher than the intermediate terrace due undoubtedly to the fact that deposition took place there first as the valley formed the northeastern extension of the lake. The westward extension of this high terrace may have been hindered by Cedar river destroying it as quickly as the terrace was built up. On the other hand, an extension of the Wilton Valley terrace westward may have caused Cedar river to be dammed up more than the lake basin itself. Such a ponding of the river may have resulted in a lake being formed over the area to the east of the river, an area which has a topography quite unlike the ordinary Kansan. The region is essentially flat and is covered to a large extent by sand dunes. The age of this youthful-appearing supposedly Kansan area has been questioned by Leighton.[196] May it be Illinoian, or a former lake site, or is it a rock terrace covered with a veneer of Kansan drift? The problem still remains open.

A difference in the depth of the two arms of the lake basin and in the slopes of their floors, together with a greater supply of sediments to certain portions of the basin readily explains the different elevations of the lake bed. Thus, on the supposition that Lake Calvin existed, the high and intermediate terraces may be considered as having been formed contemporaneously. If the two terraces were formed at the same time should not the intermediate terrace be less cross-bedded than the high terrace and be made up of finer materials? Study of the terrace materials shows that the part of the high terrace south of River Junction is cross-bedded, due to the fact that the largest tributary, English river, emptied into the lake basin at that point. The terrace materials north of River Junction are finer and less cross-bedded because Old Mans creek

196 Personal communication.

and Clear creek are smaller and thus were not able to carry such coarse materials as English river carried. However, but few sections were seen in the upper part of the high terrace. New exposures may reveal cross-bedding and coarser materials.

DO THE HIGH AND INTERMEDIATE TERRACES REPRESENT TWO STAGES OF TERRACE DEVELOPMENT?

The question may be asked: On the supposition of a lake hypothesis, do the high and intermediate terraces represent two stages of terrace development? Is there any evidence indicating that Lake Calvin had two stages? Udden in discussing certain bowlders in the lake region, accounts for them as having been transported in all probability "by floating ice on the surface of the lake at an early stage, when its waters stood high."[197] Again, the same writer states "The high stage of the lake must, however, have been of short duration, for the bowlders are few and not associated with any indications of a shoreline. It may indeed have been of the nature of a periodic or an accidental overflow."[198] The above evidence does not prove the formation of any one of the terraces in the lake basin. Lake Calvin, if it existed, occupied the lake basin for a considerable time, probably until the coming on of the Iowan ice sheet. On the basis that the lake existed far into the Sangamon interglacial interval, the intermediate terrace may be explained as consisting of the first sediments laid down in the lake. This may account for the fact that the intermediate terrace contains the coarser materials of the two. Most of the deposits and those of the coarsest character naturally would be deposited in the early stages of the lake's history, especially while the ice sheet still occupied the region. As time elapsed and the glacier had retreated from the region, finer and finer as well as fewer materials were brought to the lake. These later deposits may constitute the sediments of the high terraces which are built out as deltas into the lake. It is a noteworthy fact that the high terraces are located wherever streams empty

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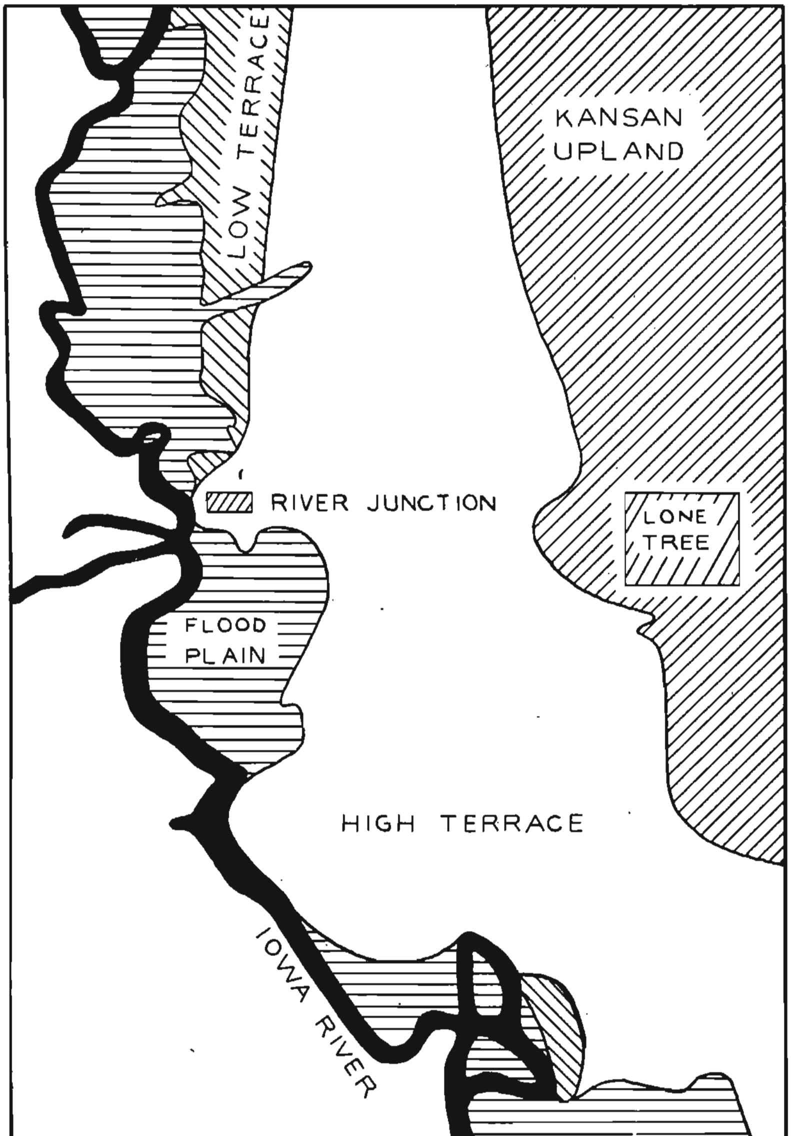
197 Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, p. 354, 1899.
198 Idem, p. 355.

into the lake basin at the present time. In that case the high and intermediate terraces will still have to be considered as having been formed contemporaneously.

The theory that the high terraces represent the lake's history during the time when the outlet of the lake was by way of the now abandoned Mississippi channel of Leverett and that the intermediate terrace represents the period when the waters of Lake Calvin escaped by way of the Iowa-Cedar river valley seems to have little weight. The intermediate terrace is by far the most widespread and, judging from several well records, undoubtedly has the greatest thickness of sediments. Hence, all things being equal, the formation of this terrace should involve a greater length of time than that of the other terraces. Furthermore, the greatest amount of deposition should have taken place during the earlier stages of the lake's existence. Indications, however, point in other directions. The straight line of contact between the high and low terraces suggests that the lake's outlet was by way of the now abandoned channel until the advent of the Iowan ice. This unusual line of contact seems to indicate that in the formation of the high terrace the stream did not meander and hence did not exist very long. It appears as if the terrace was eroded rapidly, or why the absence of the sinuous outline which it has where the flood plain of the present river abuts against it? (See Plate XIV.) To account for the remarkable line of contact between the two terraces, the following hypothesis is offered. Lake Calvin remained for an exceedingly long time after the ice sheet had retreated from the region. Its water level must have stood as high as the lowest point in the now abandoned channel which served as its outlet until the new outlet by way of the Iowa-Cedar river valley was formed. The formation of the new outlet must have taken place near the time of the advent of the Iowan ice and the lake must have been drained in a comparatively short time. This seems to be indicated by the fact that the river to which the formation of the high terrace may be attributed did not have time to reach maturity and meander and develop such a sinuous escarpment as the terraces bordering the present Iowa and Cedar rivers have. While the stream



Map showing the difference in the escarpment of the high terrace where it is in contact with the low terrace and with the flood plain.

was still in the early stages of forming the high terrace, the Iowan ice sheet invaded the region to the north. As a result of this ice incursion, the stream was changed from an eroding to an aggrading river due to the overloading of the stream with sediment coming from a new source of supply. Thus a new flood plain was developed. As soon as the ice had retreated and the supply of sediment was cut off the stream found itself above grade and immediately began to cut down its bed again, thus giving rise to the formation of the low terrace, part of which has been removed since. Sufficient time has not elapsed for the removal of all of the low terrace, hence the straight escarpment of the high terrace persists where the two are still present and are contiguous. The irregular escarpment of the high terrace is found only at those places where the river has removed the low terrace and has cut into the high terrace.

Another factor bearing upon the problem of the length of time that Lake Calvin was drained by way of Leverett's channel is that of the Illinoian gumbotil. If present contentions are correct, the formation of a gumbotil is an exceedingly slow process and implies little or no erosion. The Illinoian gumbotil is at least five feet thick and was formed before Lake Calvin could have been drained by any other outlet than the now abandoned channel south of Columbus Junction. Illinoian gumbotil outcrops along both sides of the Iowa-Cedar and Mississippi rivers. If our present ideas of the formation of the gumbotil are correct, then the lake could not have found its discharge by way of those valleys. The gumbotil then is in perfect harmony with the straight escarpment between the high and low terraces as vouching for a long life history of Lake Calvin.

Thus so far all indications point to the view that the intermediate terrace does not represent a stage in the existence of the lake when it was drained by way of the Iowa-Cedar river valley.

It can not be argued convincingly that the high terrace in the Cedar river arm of the lake basin was ever more widespread than it is now. As long as the outlet of Lake Calvin was south of Columbus Junction, a lake existed and erosion of the terrace was out of the question. The theory that erosion since the lake was drained has removed most of the high terrace does not seem sound. In the first place, why should not more of the high terrace in the Iowa river arm of the lake have been removed since that time? Then too, field relations do not warrant such a supposition.

It therefore appears to the writer that there is no way of escape from the conclusion that the high and intermediate terrace are contemporaneous in origin. Therefore they must be lacustrine, as exact contemporaniety is impossible on the basis of a fluvial hypothesis.

ARE THE LOW AND INTERMEDIATE TERRACES CONTEMPORANEOUS?

The establishing of the contemporaneity or of two distinct ages of the intermediate and low terraces can readily be done from a study of the terrace materials irrespective of either the lacustrine or the fluvial hypotheses. The low terrace is confined to the Iowa river section of the lake basin whereas the intermediate terrace lies practically all in Muscatine county. At no place are the two contiguous. A comparison of elevations of the two terraces at places having the same latitude shows that the intermediate terrace is ten to twenty-five feet higher than the low terrace as may be seen from the following table. However, a difference in elevation does not in itself disprove contemporaneity of origin. A study of terrace mater-

LATITUDE OF	LOW TERRACE ELEVATION	INTERMEDIATE TERRACE	DIFFERENCE IN ELEVATION
	Feet	*Feet*	*Feet*
Hills	640	665	25
Iowa Junction	628	638	10

ials, including their texture, stratification and structures, is the more important factor in determining whether the low and intermediate terraces had a common mode of origin. As shown in Chapter V, and on subsequent pages, the materials in the low terrace have a high textural range, are highly cross-bedded, show pocket-and-lens type of structure, in short show typical characteristics of fluvial deposits. On the other hand, the intermediate terrace is made up in the main of deposits having a low textural range, the stratification is, as a rule, fine and horizontal and the pocket-and-lens type of structure is inconspicuous if not entirely wanting. Considered on the basis of deposits alone, the terraces are undoubtedly not of the same origin. Furthermore, the fact that the terraces do not have the same elevation at places of the same latitude materially strengthens the foregoing conclusion.

Summing up what has been said so far regarding the three terraces, it is seen that on the basis of a lacustrine hypothesis the high and intermediate terraces are of the same age and the low terrace is not contemporaneous with the intermediate, thus reducing the set of terraces down to two. According to the fluvial hypothesis, there are three terraces of three distinct ages to be accounted for.

Since a study of terrace materials shows that the low terrace is positively fluvial or glacio-fluvial and is Iowan in age, since the other two terraces are quite unlike the former and can very readily be correlated in age under the lacustrine hypothesis, and since most of the other features of the lake basin can not be explained as well on the fluvial as on the lake hypothesis, there is no need for further discussion of the terraces.

A combination of the fluvio-lacustrine type of hypothesis has not been presented because of the readiness with which all features can be explained on the basis of a lacustrine interpretation.

ROUNDED BLUFF LINES OF THE LAKE BASIN.

Discussion.—Relative straightness and smoothly curving or rounded outline at places of indentations are the two striking features of the bluff line in the lake basin. A straighter line of bluffs than those marking the limits of the Illinoian upland can not be asked for. A comparison of the Illinoian bluffs in the lake basin and in the Iowa-Cedar river valley as shown on figure 35 brings out the fact that the former are far more regular than the latter. The valley along Iowa-Cedar river undoubtedly owes its origin to stream erosion. Does the straightness of the line of bluffs in the lake basin then argue for a different mode of origin? If not, why the difference in the

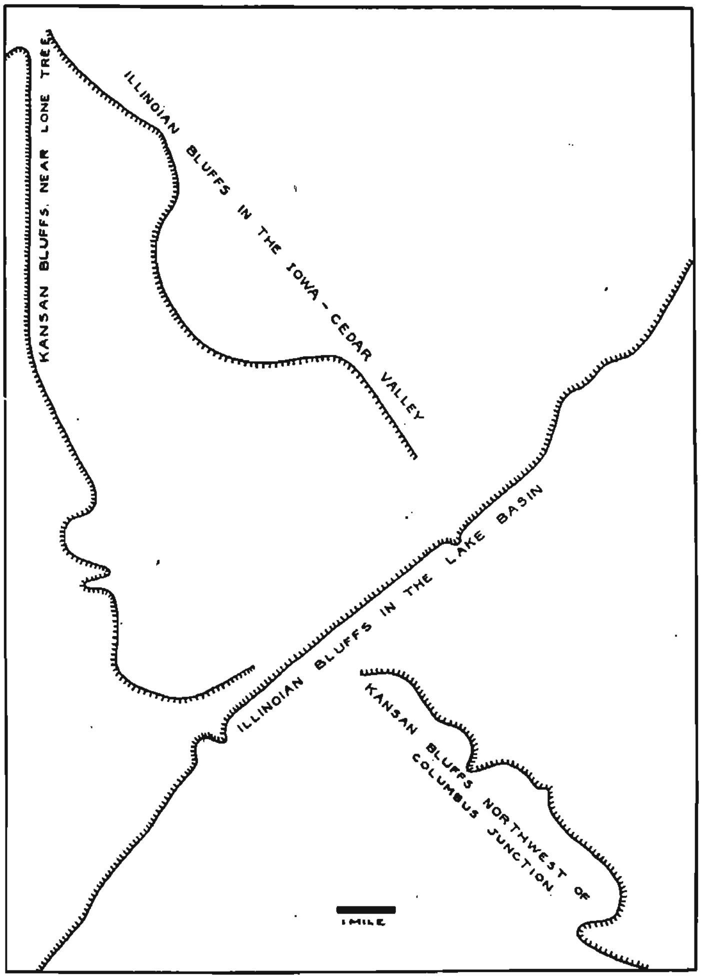
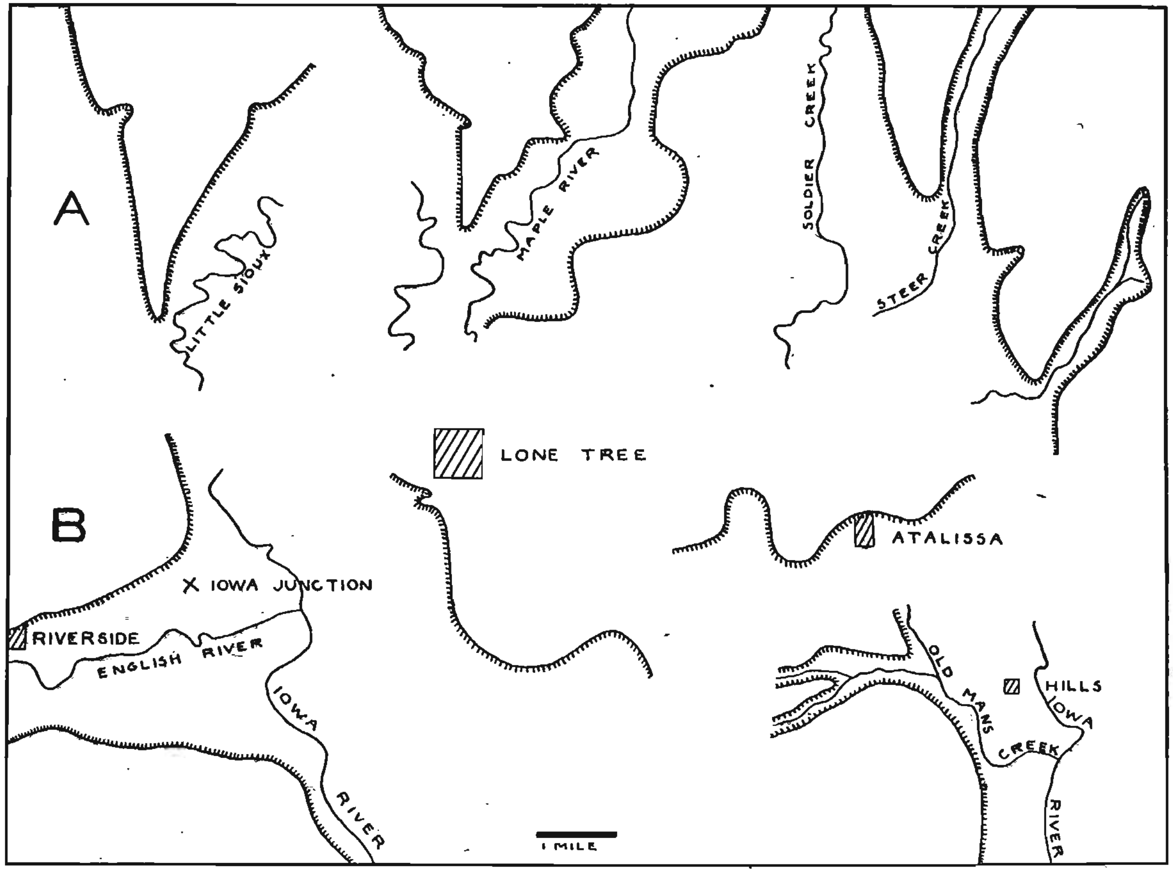


FIG. 35.—Comparison of bluff lines in the Lake Calvin region.

straightness of the bluff lines although both are cut into similar materials?

Normally at the junctions of stream valleys projecting spurs are found, such as are illustrated in A of Plate XV. A study, however, of the bluff line in the lake basin at places where two valleys meet brings out the fact that the normal type of projecting spur is missing but is replaced by very broad curves or rounded bluff lines. Granting that in exceptional cases such a bluff line may be developed by stream erosion, nevertheless



Diagrams showing the type of spur developed at the junctio n of two normal stream valleys in Harrison and Monona counties, A, and in the Lake Calvin basin, B.

it will also have to be admitted that when in the majority of cases the normal type of spur is replaced by the rounded form of bluffs, some other explanation than ordinary stream erosion will have to be sought to account for the abnormal conditions.

Interpretation.—A line of bluffs such as those of the Illinoian upland does not appear to be in harmony with the work of streams. Even on the supposition that the river was overloaded and therefore was aggrading its valley, the meandering of the stream must have caused it to cut into the bluffs somewhat and to erode them by lateral planation, thus giving rise

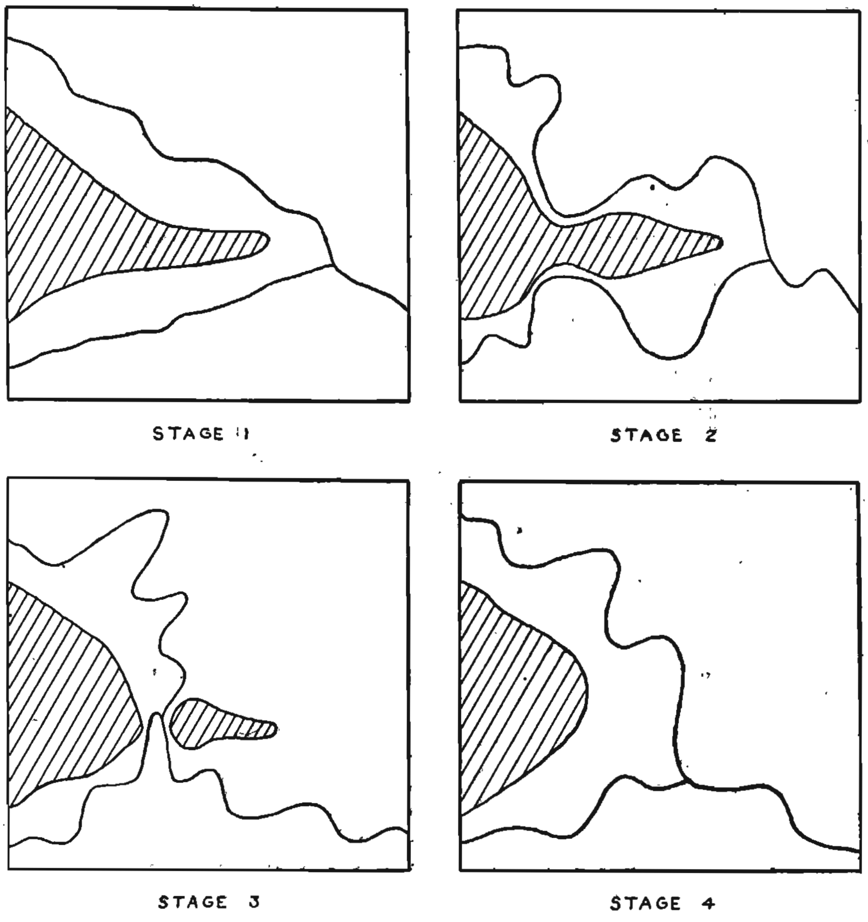


FIG. 36.—Diagrams showing the development of a rounded bluff line at the junction of two streams by the meandering of the rivers and the involving of stream piracy.

to a river-scarred type of valley wall. However, all traces of such a valley wall are lacking.

Perhaps the most difficult feature to account for is the characteristic and striking rounded bluff line found at the junction of two valleys, (See PlateXV.) The absence of the normal type of projecting spur in the lake basin very strongly indicates that other agencies than running water carved out the bluffs. A single case of a rounded bluff line at the junction of two valleys may be conceived of as having been formed by the action of running water due either to the meandering of the streams followed by piracy or to the development of tributaries and piracy. A case illustrating the latter method in the process of development is shown at Capitol Hill at Des Moines, Iowa, (See figs. 44-46, Iowa Geol. Survey, Vol. XXV, pp. 539-541, 1914.) A rounded bluff due to the former method is shown by the diagrams on figure 36. But when the majority of bluffs at the junctions of streams show broad curves, the hypothesis of

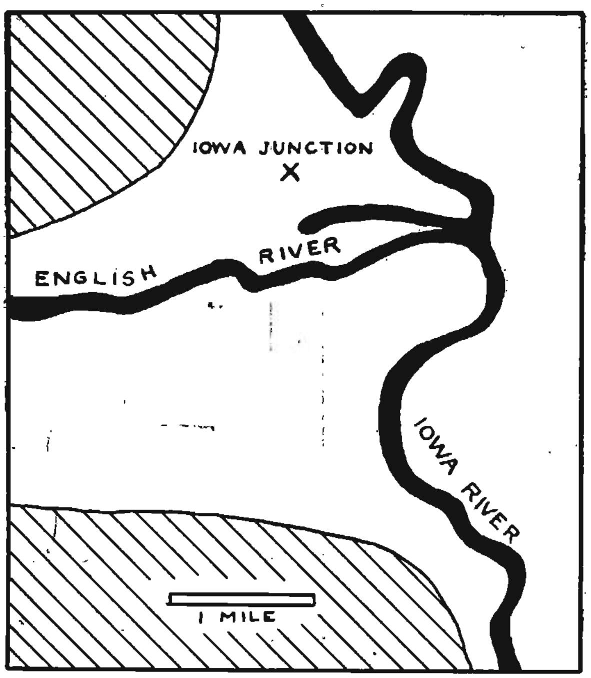


FIG. 37.—Sketch map showing the rounded bluff lines on both sides of English river.

stream work has to be abandoned. Furthermore, when the bluffs on either side of the river, as illustrated in the preceding diagram, figure 37, are of the rounded type, the idea of stream work as the agent loses much of its significance.

A more likely explanation for the abnormal type of bluffs in the lake basin is in the action of waves. There is no better force than the constant beating of the waves on the bluffs from all sides to explain their rounded character. Lakes never show characteristic sharp erosional headlands but rather features of well rounded outline. To the writer, the broad curving type of bluff line amounts to practically positive proof of the former existence of a lake in the lake basin.

BOWLDERS IN THE LAKE BASIN.

Discussion.—Bowlders are extremely few anywhere within the borders of the lake basin. The following is a list of locations where bowlders are found.

Louisa county

1. Oakland township, Sw.¼ Sw.¼ sec. 11, base of terrace.
2. Oakland township, Sw.¼ Nw.¼ sec. 15, top of terrace.
3. Oakland township south central edge of sec. 9, base and top of terrace.
4. Concord township, Ne. corner sec. 7, base and slope of terrace.

Muscatine county

5. Pike township, Ne. corner of sec. 7, top of terrace.
6. Goshen township, central part Sw.¼ sec. 34, top of terrace.
7. Pike township, Ne.¼ sec. 3, slope of terrace.
8. Pike township, Nw. corner Ne.¼ sec. 3, slope and base of terrace.

Except for localities 1, 2 and 3 the bowlders are within four and one-half miles of the Illinoian bluff line and the greatest number and the largest are found but half a mile distant from these bluffs. Bowlders at 1, 2 and 3 are from seven to eight and one-half miles from the same bluff line. The bowlders are mainly of the granitic type, although two are limestone and one is greenstone. They range in size from those having dimensions of 1.5x1.5x.5 feet to those having dimensions of 3.5x3x2 feet. In every case, the bowlders are associated with the intermediate terrace and lie either on its surface, as do those at 3, 5, 6 and 7; or on its escarpment slope, as is the case at 2, 4, 7 and 8, or else at its base, as in the case of those at 1, 3, 4 and 8.

Several possibilties present themselves as to the way by which these bowlders may have been brought to their position and location. These are summarized as follows:

1. Alluvial material.
2. Outwash from the Illinoian ice.
3. Ice-rafted bowlders floating down a stream.
4. Ice-rafted bowlders floating on a lake.
5. These bowlders may be from the original till underlying the lake basin; they mark places where the till outcrops now.
6. Some may have been carried in by man.

Interpretation.—Of the six methods summarized to account for the position and location of the bowlders in the lake basin, the first, fifth and sixth may be set aside after brief consideration. That the bowlders do not owe their position and location to ordinary fluvial conditions seems to be apparent when one considers the juxtaposition of the few large and scattered bowlders to the fine materials of the terraces. If the streams were able to transport a few bowlders from those a foot in diameter to those three feet in diameter then gravel could also have been transported easily and should therefore be in evidence among the terrace materials. However, gravel is not to be found and thus the finding of scattered bowlders on fine sands demands another hypothesis than that of ordinary alluvial conditions. That the bowlders are not the outcropping of an underlying till is clearly proved in most cases by the fact that many of them lie on the surface or slope of the terrace which is known to consist of stratified materials. In cases where the bowlders lie at the base of the terrace, it is not so apparent whether they are or are not to be considered as outcrops of till. At several places, as where the shingle-like gravels are found, the till lies but thirty feet or so beneath the terrace surface. On the other hand, records of wells at other places show a depth of over 250 feet of sands and gravels before the till is reached. Unfortunately well records in the lake basin are few and scattered.

With the exceptions of those at localities 5 and 6, there seems to be no logical reason why the bowlders should have been brought by man. A limestone bowlder was found at each of localities 5 and 6. In each case, the bowlder was found near a fence on the terrace surface. These two bowlders may have been brought in by man. However, at other places, the bowlders lie in such locations that artificial transportation is extremely unlikely.

The fact that the largest bowlders are found nearest to the bluff line and the smaller ones farther away suggests Illinoian outwash deposits. Yet the absence of other coarse material as well as the lack of structure typical of rapid deposition is not in harmony with an outwash hypothesis. The bowlders are best explained as being ice-rafted bowlders floating either down a river or on a lake, and as reaching their present position by the melting and the stranding of the icebergs. From what has been said before regarding the terrace materials and from the fact that many of the bowlders lie on the surface or slope of the terrace, which consists of fine to medium-textured, and for the most part horizontally stratified sand, it is easier to account for the bowlders as being brought to their final resting place by debris-laden icebergs floating on a lake than by any other method.

CERTAIN GRAVEL DEPOSITS IN THE LAKE BASIN.

Discussion.—Gravels are exposed at numerous places along the course of Iowa river. These gravels rest on a bluish to black till in practically every case and consist of rocks of all descriptions and sizes. There is no doubt that the gravels are closely related to the till and remain as distinct deposits because the finer mud or silt has been carried away. The noteworthy fact regarding these deposits is that an unusual number of the gravels and bowlders are flat or slablike rather than subangular as is characteristic of ordinary glacial material, or rounded, as are typical fluvial deposits. This shingle-like form is not limited to the softer sandstone and limestone but is common also to the more resistant varieties of rocks as cherts, granites, basalts, etc., and to rocks of all sizes from those an inch to two in diameter to bowlders measuring over a foot. It is important to remark in this connection that wherever these shingle-like gravels appear, the bluff line of the drift uplands is very close at hand. In no case is the bluff line more than one mile distant from the gravels. Gravels having the typical shingle-like character are found at the following places:

1. Washington county, Iowa township, sec. 23; half a mile from bluffs.
2. Johnson county, Fremont township, sec. 24; half a mile from bluffs.
3. Johnson county, Fremont township, sec. 25; half a mile from bluffs.
4. Johnson county, West Lucas township, sec. 34; a quarter of a mile from bluffs.
5. Johnson county, East Lucas township, sec. 27; one mile from bluffs.
6. Johnson county, Liberty township, sec. 27; one mile from bluffs.

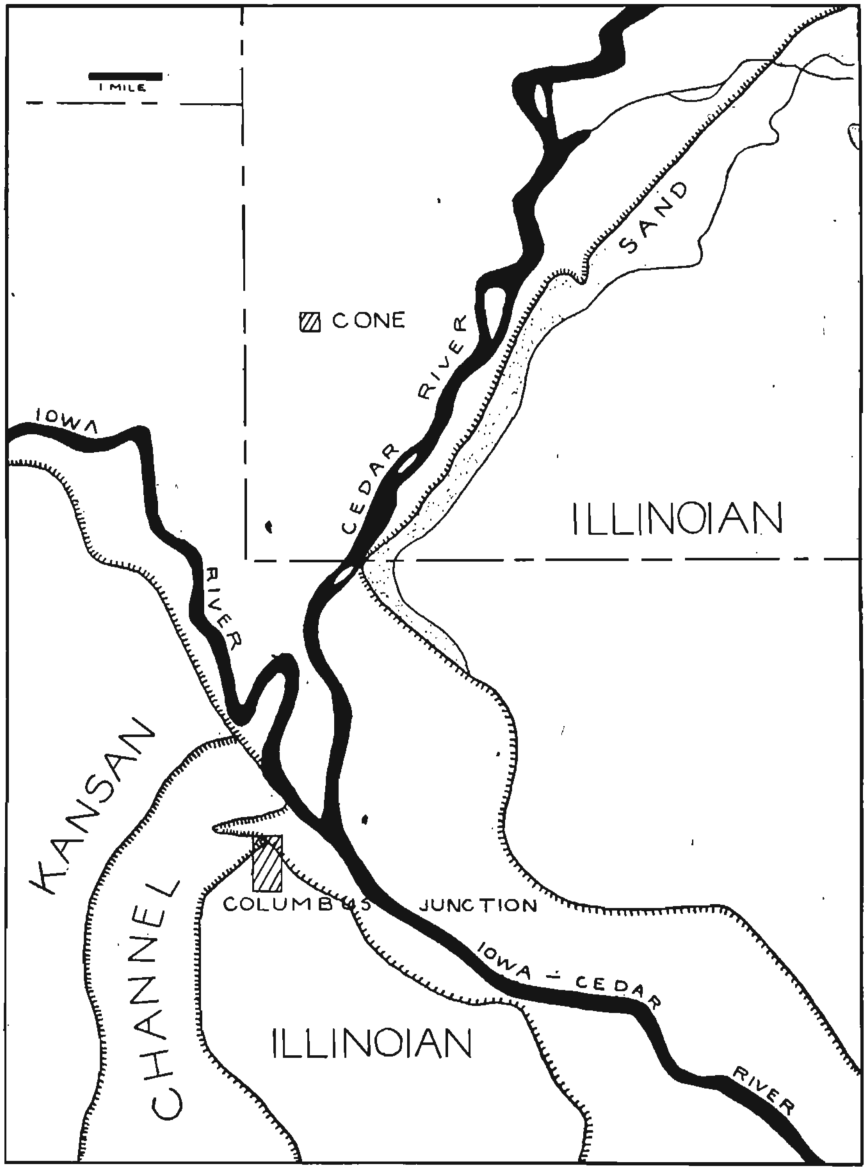
The shingle which is exposed in the abandoned railroad gravel pit in the southwest quarter of section 34, West Lucas township, Johnson county, does not rest on till but is interstratified between two sands of the low or Iowan terrace. The gravel bed is twelve to twenty-four inches thick and consists principally of limestone. The pieces range texturally from small sand grains to bowlderets nine by six by four inches. The slablike form, however, is not confined to the limestones, but is found also on the cherts and basalts. The Kansan bluffs are but a quarter of a mile to the west. According to the owner of the land in which the pit is located, the gravels underlie a large part of the low terrace. Evidently in this case the gravels attained their characteristic form before reaching their present position.

Interpretation.—It is a well known fact that in many cases gravels found along lake beaches or sea coasts possess a slablike form and show an arrangement similar to that of shingles on a roof, from which fact the deposits have received the term 'shingle'. From the fact that the gravels under discussion are of this type, and that the shingle character is not confined to any one kind of rock, but is common to all, whether they are resistant or nonresistant, igneous or sedimentary, and from the fact that the deposits appear to be related to the underlying till or the nearby bluffs, the writer feels inclined to explain the characteristic form of the gravels by the continued washing upon them of the waves. The shingle-like gravels interstratified between the sands in the low terrace in section 34, West Lucas township, Johnson county, undoubtedly were rehandled and brought to their present position by the action of glacial streams at the time of the Iowan stage of glaciation.

THE ILLINOIAN UPLAND WITHIN AND WITHOUT THE LAKE BASIN.

Discussion.—One of the noticeable features of the Illinoian upland is its sandy and dune covered border in the lake basin and the absence of such sandy deposits south of Columbus Junction and in the Mud-Elkhorn valley. This feature is the more striking because of the abrupt termination of the sandy tract south and east of the lake basin. (See Plate XVI.) A fringe of undulating sand dunes extends all along the bluffs from Mosquito creek in Moscow township, Muscatine county, almost to Columbus Junction in Louisa county. These sandy tracts are on the average less than half a mile wide, but reach a width of a mile or two miles at places, as two to three miles north of Bayfield. The dunes range in height from ten to fifty feet. The question at once arises: Why should there be a difference in the character of the bluff line east and south of the lake basin if conditions were the same? If no lake existed, but a river, why should there be a restricted area of sand? On the other hand, if Mud creek valley was the inlet to the lake and the outlet was south of Columbus Junction bordering the Illinoian upland, might there not be a difference in the character of the bluff line at these places as compared with the intervening Illinoian border which formed the shore line of the lake?

Interpretation.—On the basis of the theory that the filling of the lake basin is alluvium, there appears to be no good reason why the sandy tract should be restricted to the Illinoian bor-



Map showing the abrupt disappearance of sand dunes along the Illinoian upland border south of the lake basin.

der adjacent to the lake basin and abruptly terminate at Columbus Junction and be absent in the Wilton Valley. If a stream occupied the Wilton Valley, the lake basin and the temporary Mississippi channel of Leverett, then the entire Illinoian border adjacent to these places ought to be similar. Yet this is not the case as Plate XVI shows. On the other hand, if a lake occupied the area to the west of the Illinoian sand covered margin and the Wilton Valley and a stream flowed in the now abandoned channel, then it becomes a relatively easy matter to account for the difference in the bluff border. It is but natural that along the shores of a lake sandy beaches are thrown up. The sand on becoming dry becomes the prey of the wind which soon drives the sand into dunes. Sand dunes are not common along the courses of streams especially where these streams occupy the entire valley. If a lake existed in the region then the stream draining the lake would naturally be relatively free from sediment and also would have minimum erosive power to collect material for the formation of sand dunes. The absence of the dunes in the Wilton Valley, which probably was the site of a lake rather than of a river, may be accounted for by the facts that its longer axis is in the same direction as that of the prevailing winds, that the lake at this place was narrow and thus not well adapted for the formation of large waves and that the valley is not exposed as much as the lake basin proper. Thus all things considered, the writer prefers to explain the difference in the character of the Illinoian bluff line on a lacustrine basis.

A COMPARISON OF THE WIDTH OF THE VALLEYS IN AND OUTSIDE OF THE LAKE BASIN.

Discussion.—A study of the width of either the Iowa or the Cedar river valleys within and without the lake basin reveals the fact that the width of the valleys within the lake basin greatly exceeds that without. At various places the valleys outside of the lake basin are wide, not so wide, however, that they can not be accounted for by stream work. With the exception of one locality the width of the valleys outside the lake basin is nowhere one-half as great as that within the basin.

The Iowa-Cedar river valley in the vicinity of Wapello, where the valley is known as the Wapello prairie, has an unusual width. At Wapello it is six miles wide and for a distance of about five miles on either side of the town the valley is unusually well developed. The cause for this abnormal width has not been investigated.

Interpretation.—Why such a vast difference in the width of the valleys within and without the lake basin should exist if they are due to stream work is not easy to see. This is especially true since the valleys are cut into similar materials. The valley of Iowa river west of Curtiss, Johnson county, is unusually wide, although it in no way compares with the valley south of Iowa City and yet in both places the valley is cut into drift. It is easier for the writer to think of the valleys of Iowa and Cedar rivers within the lake basin as being of lacustrine origin rather than of fluvial origin.

CONCLUSIONS.

In order to sum up the various interpretations presented and before making any conclusions, the following table is introduced to show what hypothesis is favored by the interpretation of the various features found in the lake basin.

TABLE 3. TABLE SUMMARIZING THE HYPOTHESIS FAVORED BY THE INTERPRETATION OF THE VARIOUS FEATURES IN THE LAKE CALVIN REGION.

Feature	Hypothesis Favored	
	Lacustrine	Fluvial
Theoretical considerations	X	
The Mud-Elkhorn creek valley — the Inlet	X+	X—
The temporary Mississippi river channel of Leverett — the Outlet	X	
Laminated silts, clays and sands in the lake basin	X	
Terraces in the lake basin		
Three terraces of different ages		X
High and intermediate terraces same age, low terrace Iowan	X	
Texture and structure of high and intermediate terraces	X	
Rounded bluff lines of the lake basin	X	
Bowlders in the lake basin	X+	X—
Certain gravel deposits in the lake basin	X	
The Illinoian upland within and without the lake basin	X	
A comparison of the width of the valley in and outside of the lake basin	X	
Illinoian gumbotil	X	

The table shows at once that every feature can be explained very readily by the lacustrine hypothesis, whereas but two out of twelve features can be explained as well by the fluvial hypothesis and only one better. In view of the fact that the weight of evidence is in favor of the lake hypothesis and that this hypothesis is in complete harmony with the gumbotil idea the writer is convinced that Lake Calvin was a reality.

ORIGIN OF LAKE CALVIN.

Since the existence of Lake Calvin has now been established its origin might next be outlined briefly. The Illinoian ice sheet in its advance into Iowa occupied and filled the valley of Mississippi river thereby displacing the stream toward the west. Finding an outlet by way of Maquoketa river, the waters flowed westward to a low col in the vicinity of Preston in Jackson county. From here the combined waters of the two streams flowed southward as far as Wapsipinicon river and thence westward to the mouth of Mud creek from whence a southerly course was pursued over the Mud-Elkhorn divide to Cedar river at Moscow. As the valley of Iowa-Cedar river also was blocked by the same ice sheet on one side and by high Kansan bluffs on the other, the waters of Mississippi, Maquoketa, Wapsipinicon, Cedar and Iowa rivers and those flowing from the ice edge rose until the entire lake basin was covered by a wide expanse of water, to which Udden has applied the term 'Lake Calvin.' The lake rose until the level of the now abandoned valley south and southwest of Columbus Junction was reached and afforded an outlet.

CHAPTER VII.

THE DRAINAGE AND HISTORY OF EXTINCT LAKE CALVIN.

Earlier Views Regarding the Duration of Lake Calvin.

Although Udden does not discuss the drainage of Lake Calvin, he undoubtedly was of the opinion that the lake was drained for only a short time by way of the abandoned channel. This is shown by the following sentence quoted from his report. "For most of the time of its subsequent existence it (the lake) must have been a wide expansion of the Cedar river, somewhat like Lake Pepin in the Mississippi of today, with its water level but slightly higher than the present surface of the West Liberty plain."[199] The southern end of the West Liberty plain of Udden or the intermediate terrace of this report has an elevation about 610 feet above sea level or approximately 120 feet below the floor of the now abandoned channel. Our present knowledge of the Pleistocene, especially that concerning the origin of the gumbotils, will not warrant a view such as is suggested by the quoted sentence. Leverett also favors the view that "The abandonment of the lower end of the channel from Columbus Junction southward probably occurred as soon as the ice sheet had withdrawn sufficiently to uncover the present line of the stream, for the altitude along the present Mississippi bluffs is a few feet lower than the bed of the abandoned channel. This lower altitude along the Mississippi is due to the incomplete filling of the preglacial channel by drift."[200] However, Leverett at the time of writing did not see the significance of the gumbotil, although he had seen the gumbotil and had described it. Furthermore, the fact that the Mississippi bluffs are a few feet lower than the bed of the abandoned channel does not preclude the drainage of the lake by way of the abandoned channel south of Columbus Junction. The Illinoian-Mississippian sag if it existed was at least twenty

199 Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, p. 355, 1899.

200 Leverett, F., The Illinois Glacial Lobe: U. S. Geol. Survey Monograph XXXVIII, pp. 96-97, 1899.

miles distant from Lake Calvin by way of the present Iowa-Cedar river valley. What the elevation of the intervening topography was is not known. The Illinoian upland at Columbus Junction is about 730 feet above sea level; at Morning Sun, but two and three-fourths miles from the south valley wall of Iowa-Cedar river, it is 752 feet and at Newport, only two miles south of the river bluffs, it is at least 720 feet above sea level. The Mississippi bluffs north of Wapello are at many places over 700 feet above sea level. Leverett also does not appear to have had much faith in the existence of Lake Calvin for he barely mentions the lake in his classic monograph on the Illinois Glacial Lobe.[201] Then too, the absence of notable sand and gravel deposits in the channel should have been the natural clew to suggest to him the presence of the lake. As has been shown in the previous chapter, the absence of such deposits in the channel is in perfect harmony with the lake hypothesis. The lake acted as a filtering plant and so the outflowing stream was free from sediment, hence there should be no deposition. Furthermore, as a stream without a load has minimum erosive power, such material would not be collected, especially if the ground were frozen as suggested by Chamberlin.[202] Thus it is easier to explain the absence of notable deposits of sand and gravel in the channel on the basis of a lake than on that of a frozen stream bed.

The Duration of Lake Calvin.

The writer agrees with the conclusion of Udden[203] that Lake Calvin persisted almost to the time of the Iowan ice incursion, although the means by which he arrived at that view are no longer tenable. It is obvious, if the present view concerning the origin of the gumbotil is correct, that Lake Calvin could not have been drained by way of the Iowa-Cedar river valley shortly after the ice had retreated, since outcrops of Illinoian gumbotil appear on both valley walls of the Iowa-Cedar and the Mississippi river valleys. Hence, to say the least, drain-

201 Idem, p. 96.
202 Idem, p. 93.
203 Udden, J. A., Geology of Muscatine County: Iowa Geol. Survey, Vol. IX, p. 355, 1899.

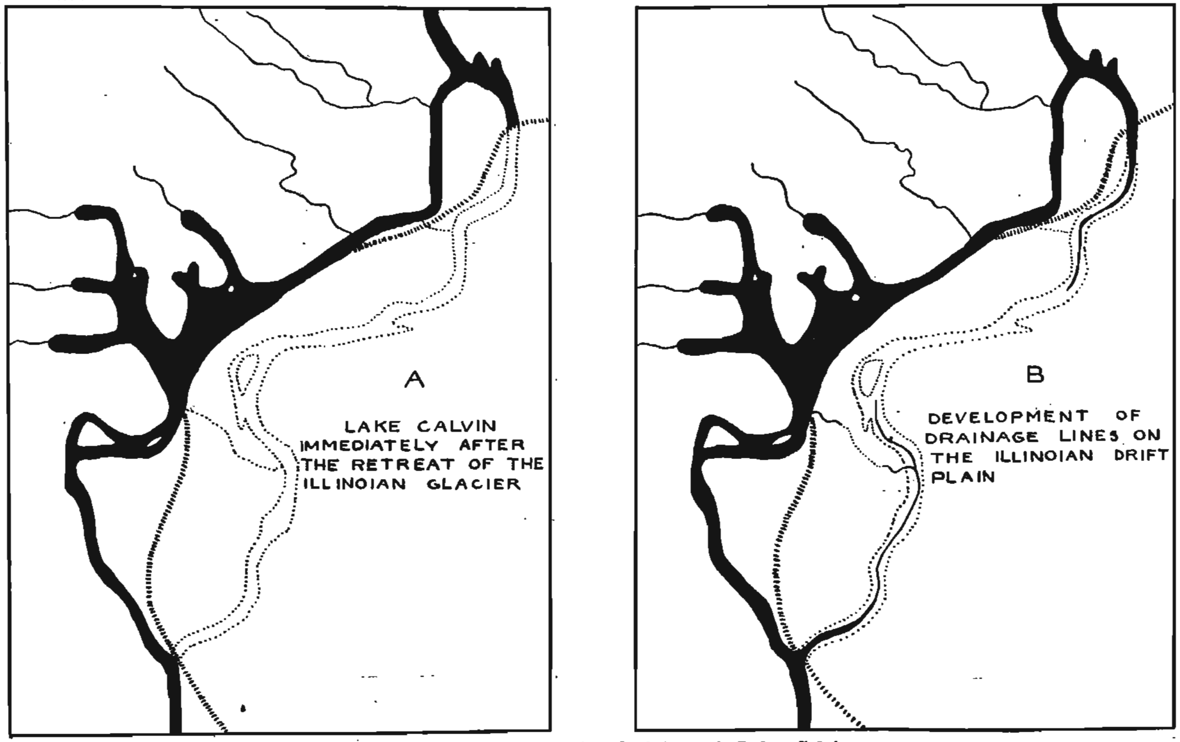
age of the lake by this route is post-Illinoian-gumbotil in age. A long-lived Lake Calvin is in accord with the theory of the formation of the Illinoian gumbotil as the levels of the lake and of the gumbotil as they are shown at Columbus Junction were not separated by more than ten to twenty feet, a difference in height which would not give rise to pronounced erosion. Another factor supporting a long existence for Lake Calvin with an outlet south of Columbus Junction and a sudden draining of the lake by way of the Iowa-Cedar valley is the straight line of contact between the high and low terraces in the Iowa river arm of the lake basin. At places where the low terrace is missing, the escarpment of the high terrace is sinuous due to the meandering of Iowa river. At other places, however, where the low terrace lies between the high terrace and the flood plain of the river, the line of contact between the two terraces is unusually straight. This suggests to the writer that the stream which eroded into the high terrace was not meandering and that the formation of the terrace was suddenly halted by the building up of another flood plain which was subsequently cut away to form the low terrace. Therefore, the writer believes that Lake Calvin existed almost to the time of the coming of the Iowan glacier, that the lake was drained in a comparatively short time and that the down-cutting of the lake bed to form the high terrace was shortly interrupted by the aggrading of the valley. The change from an eroding to an aggrading stream was the result of overloading of the stream with sediment received from the melting Iowan ice sheet to the north. As soon as the glacier had retreated from the region, the stream, no longer receiving an unusual amount of sediment, found itself above grade and consequently began to remove the deposited material, producing thus the low terrace, the destruction of which is still in progress.

Thus on the basis of the Illinoian gumbotil, the straight line of contact between the high and the low terraces along Iowa river and the great amount of sediment in the lake basin, the writer is convinced that Lake Calvin was not short-lived but existed almost to the time of the Iowan ice invasion.

The Draining of Lake Calvin.

No hypothesis regarding the draining of Lake Calvin has ever been advanced. It is obvious that the main factors in the draining of the ancient lake were the development of streams on the recently formed Illinoian gumbotil plain and stream piracy. Just where and how the piracy took place must remain hypothetical as field evidence is lacking. To begin with, after the Illinoian ice sheet had withdrawn from the region, a long time elapsed before erosion became active. During this period of quiescence, the drift was subjected to the effects of atmospheric weathering and a gumbotil at least five feet thick was formed. That the formation of gumbotil is an exceedingly slow process has been demonstrated by Kay.[204] Then erosion became active due either to diastrophic movements or to the fact that the region lies in close proximity to the master drainage lines. New streams tributary to Mississippi river north and south of the Illinoian area soon developed and worked their way headward into the Illinoian upland. Finally, some stream was able to work its way backward until Lake Calvin was tapped and drained. A possible method by which Lake Calvin was drained is illustrated in Plates XVII and XVIII. Sketch map A of Plate XVII shows Lake Calvin immediately after the retreat of the Illinoian ice sheet. According to the gumbotil idea, the Illinoian drift plain after the disappearance of the glacier consisted essentially of a flat ground moraine very much like that left by the Wisconsin glacier in northcentral Iowa. A prolonged period of weathering followed during which at least five feet of gumbotil was formed. Young streams soon developed on the Illinoian drift plain. It is fairly safe to assume that a stream developed at each end of the buried Mississippi channel as well as at the western edge of the Iowa-Cedar river valley at Columbus Junction, as sags might be expected to exist over buried channels. Sketch B of Plate XVII shows the development of the newly formed drainage lines on the Illinoian drift plain. In the life history of rivers, some streams due to various causes gain advantages over others and finally absorb

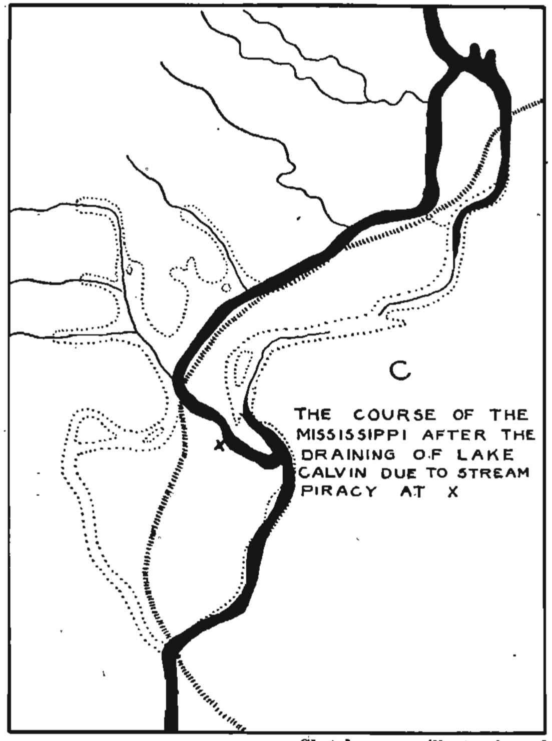
204 Kay, G. F., Jour. Geology, Vol. XXVIII, pp. 89-125, 1920.

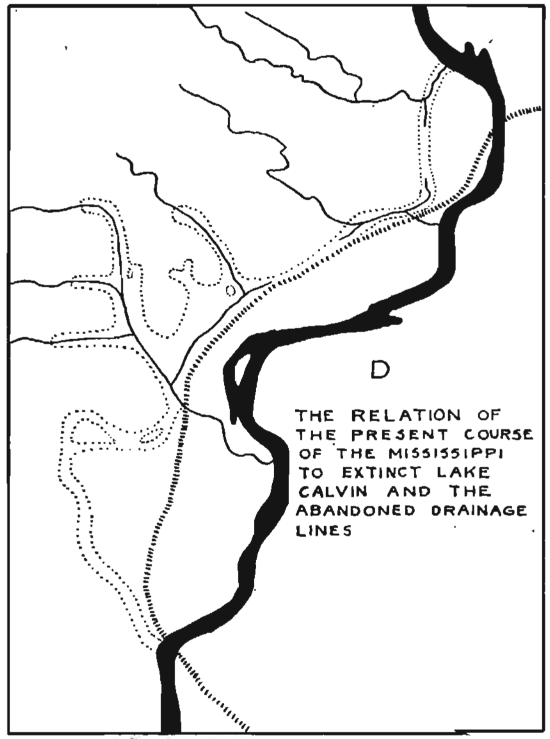


Sketch maps illustrating the draining of Lake Calvin.

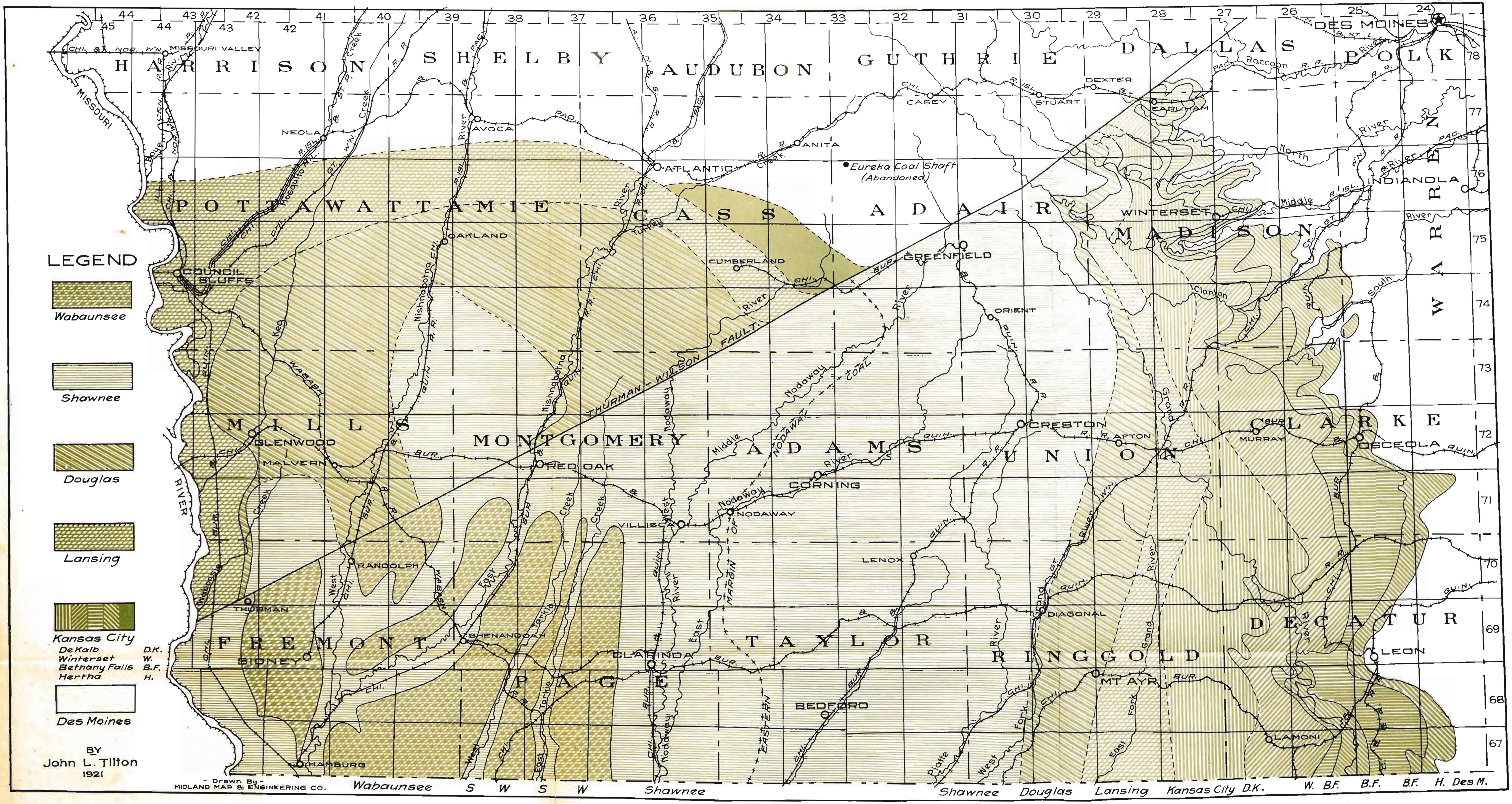
them, thus gaining larger volume and hence more erosive power. For convenience, it may be supposed that the southern tributary of the Mississippi, sketch map C, Plate XVIII, had the advantage over the other youthful streams. Working backward by head erosion, the stream after a time extended its valley as far north as the present mouth of Iowa-Cedar river, where it sent out a branch westward over the course of the buried Iowa-Cedar valley. This tributary, which because of its relation to the master stream had the advantage over the other small streams which occupied the same valley but drained into the lake, soon shifted its divide westward and captured the west flowing stream, thus draining Lake Calvin and directing the course of the Mississippi through its channel. (See sketch map C of Plate XVIII.) Finally, after continued head erosion by the north and south flowing streams in the partly filled Mississippi valley, the north-flowing stream was captured by the south-flowing river and the entire drainage was directed southward as is shown on sketch map D, Plate XVIII.

It is possible that Lake Calvin never was drained by way of the Iowa-Cedar river valley. Stream piracy may have taken place between the north and south flowing streams developed over the buried Mississippi valley rather than in the Iowa-Cedar valley. In that case, the drainage of the lake would have been diverted northward instead of southward. (See sketch maps E and F, Plate XIX.) To have established the drainage as it is now, sketch map D, Plate XVIII, at least one other case of piracy would have been necessary either in the Iowa-Cedar river valley or in the lake basin itself. To the writer, the first view regarding the drainage of Lake Calvin is just as logical as the latter. It may be asked: Why should the tributary developed in the Iowa-Cedar river valley at the mouth of the present Iowa-Cedar river have had the advantage over the main stream? On the assumption that the north and south flowing tributaries of the Mississippi extended their valleys headward at the same rate, the head of the northflowing river would have been a few miles below Davenport at the time that the south flowing stream had extended its valley as far north as the mouth of the present Iowa-Cedar river. If they continued





Sketch maps illustrating the draining of Lake Calvin.



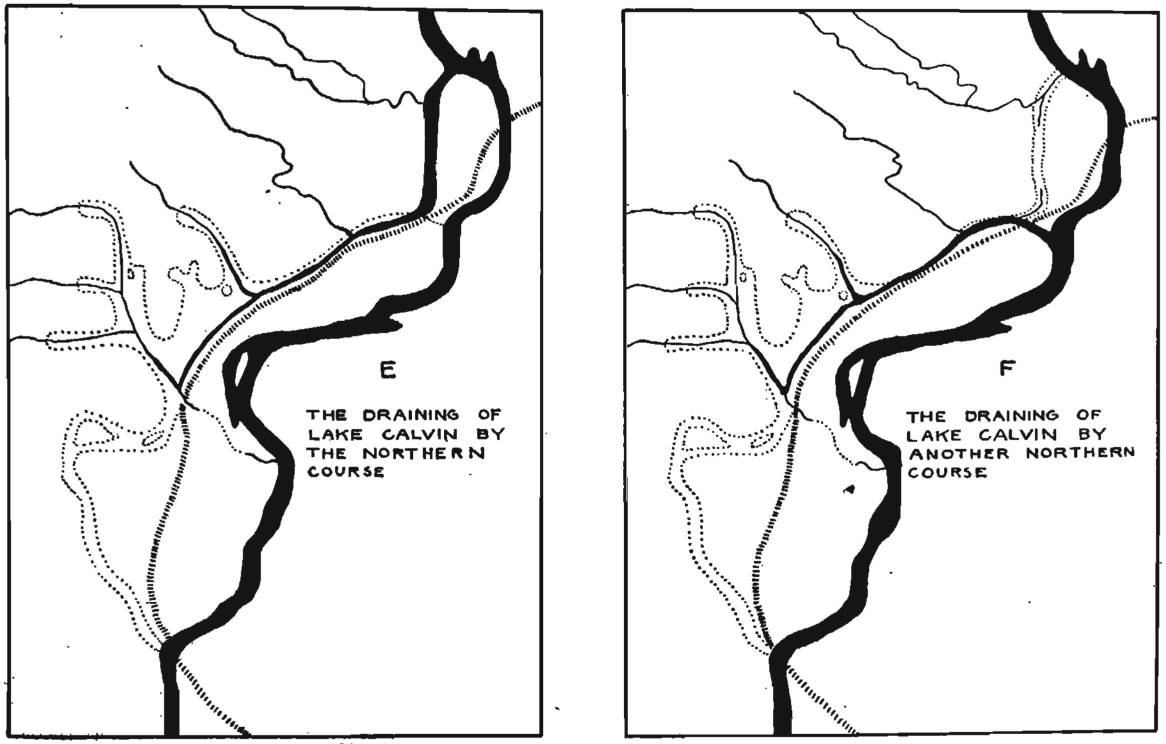
DISTRIBUTION OF THE STAGES OF THE MISSOURI SERIES IN SOUTHWESTERN IOWA.

at equal rates the two streams should have met near Muscatine. The distance between the lake basin and the present Mississippi river is equivalent to the distance between the mouth of Iowa-Cedar river and Muscatine. The question arises: "Is it possible that the two tributaries developed over the buried Iowa-Cedar river valley united before the two main streams were able to do so? It seems plausible, especially when it is remembered that in the case of the Iowa-Cedar valley two streams were involved in the same distance that one of the main streams had to work headward before stream piracy could have taken place. Furthermore, the east flowing tributary may have developed as rapidly as the south flowing stream since the former must have been accordant with the latter. Then too, it must be remembered that the two main tributaries did not extend their valleys headward at the same rate for in that case a permanent divide instead of stream capture would have resulted. Also, the south flowing stream had the advantage over the one flowing to the north as the Mississippi is now pursuing a course to the south. Moreover, the greater portion of the valley through which the north tributary flowed is cut into solid rock whereas the valley south of Muscatine is in drift. To the writer, the drainage of Lake Calvin by way of the Iowa-Cedar river valley is more probable than by the more northerly course.

The History of Lake Calvin, a Resume.

After the retreat of the last seas, probably the Cretaceous, the Lake Calvin region underwent a prolonged period of erosion. It is not certain whether the Nebraskan ice sheet advanced over a peneplain as suggested by Trowbridge[205] or whether the region presented a maturely dissected topography similar to that of the famous Driftless Area of southwestern Wisconsin and the adjoining states of Iowa, Illinois and Minnesota. Nevertheless, it is certain that at least before the advent of the Kansan ice, stream valleys two hundred to three hundred feet deep traversed the region in various directions, forming a network of drainage systems comparing very favorably with those of the present time. Of these, at least two occupied the

205 Personal communication.



Sketch maps illustrating the draining of Lake Calvin.

site of the lake basin, one in the region of the present Cedar river, the other in the Iowa river sector of the lake basin. The Nebraskan glacier undoubtedly changed the aspect of the topography, whether it was a peneplain or a highly dissected region, by destroying all valleys which may have existed and leaving on its retreat a glacial topography of low relief. The drift was subjected to weathering and erosion during the ensuing long Aftonian interglacial period so that portions were changed into gumbotil, and the region was deeply dissected[206] before the oncoming of the second glacier, the Kansan. Again the old topography was obliterated and a newly formed ground moraine was left in its place. After the retreat of the ice, more gumbotil was formed and the Iowa and Cedar river valleys were called into existence.

Unlike the other two ice sheets, which entered the lake region from the north, the third or Illinoian ice sheet found its way into the lake region by advancing from the east. The advancing glacier, in crossing into Iowa, blocked the valley of Mississippi river and filled it with ice. This caused the waters of the great river to be dammed back and necessitated the finding of a new course to the west. The stream found an opening by way of the Maquoketa river valley and flowed first westward then southward through the Goose Lake channel to the valley of Wapsipinicon river and finally over the low divide between Mud and Elkhorn creeks to the valley of the Cedar at Moscow. Thence continuing southward to the junction of Iowa and Cedar rivers at Columbus Junction, the combined waters of Mississippi, Maquoketa, Wapsipinicon, Cedar and Iowa rivers found their pathway obstructed on the one side by the great ice wall of the Illinoian ice sheet and on the other by the Kansan bluffs which stand 120 to 140 feet high. As the waters could find no outlet, they rose until the entire area of the lake basin was covered by a vast and deep expanse of water to which Udden gave the name 'Lake Calvin.' During the long existence of the lake, the surplus water found its way to the unfilled valley of the Mississippi by a devious course

206 Professor Trowbridge believes that during Aftonian times most of the rough subglacial topography was carved out.

through the now abandoned channel discovered by Leverett and traced by him across several counties to the present valley of the Mississippi below Fort Madison. In the meantime, at least five feet of gumbotil were formed and new streams were developed on the Illinoian drift plain. Finally, shortly before the time of the next or Iowan ice incursion, Lake Calvin was tapped and drained, due to stream piracy. The high and intermediate terraces were soon formed but because of the overloading of the streams by the vast amount of sediment derived from the melting glacier to the north, the terrace formation was halted and a new flood plain was developed. Since the retreat of the glacier, however, Iowa river has been cutting down its new flood plain, producing thereby the low terrace, the destruction of which is still continuing. Thus ends the history of the Lake Calvin basin to the present time.

APPENDIX A

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