1920

Origin and history of extinct Lake Calvin

Walter Henry Schoewe

State University of Iowa

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THE ORIGIN AND HISTORY OF EXTINCT LAKE CALVIN

By

WALTER HENRY SCHOEWE

A Dissertation Submitted to the Faculty of the Graduate College in Candidacy for the Degree of DOCTOR OF PHILOSOPHY

STATE UNIVERSITY OF IOWA

1920
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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 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,' 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 only, 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 and the development 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 presence 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,
4. to test the gumbotil hypothesis by seeing whether the presence of a Lake Calvin was in harmony 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 expanse of water, as can be seen from plate I, is confined primarily to an area lying roughly parallel to the 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
MAP SHOWING THE LOCATION AND EXTENT OF EXTINCT LAKE CALVIN
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 I. 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, the topography is more or less that of a monotonous plain with but little relief. With an elevation of about 680 feet above sea level in the northern extremity, this flat stretch of country gently slopes 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 1)

![Generalized cross-section of the Lake Calvin basin.](image-url)
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 bed-rock are lacking in the lake basin proper with the exception of the valley walls of the Iowa and Cedar rivers north of Iowa City and Moscow respectively, and in the arm-like extension of the lake along the English river in Washington county.

Drainage in the lake basin.—The Lake Calvin basin lies in the drainage systems of the Iowa and Cedar rivers which empty into the 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 the 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 the Cedar river, are marked by numerous 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. 

Because of the sandy soils 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 industry pertaining to 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 industry, 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 railroad forms the main means of communication between the numerous towns and villages. The main line of the Rock Island system traverses through 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 westerly branch to Riverside and Kalona and an easterly one to Lone Tree, Nichols and Muscatine. Still another spur connects Wilton with Muscatine.

The largest city on or at the border of the lake bas-
in 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 people and 1,000 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 to 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 the gumbotil deposits of Louisa county. A day was spent with Professor A. C. Trowbridge examining the out-
let of the lake in the vicinity of Columbus Junction. Dur­
ing the month of August 1917, the writer was accompanied in
the field by Mr. Bert G. Gose of Simpson Academy. In addition,
several local excursions and week-end trips were occasionally
made during the fall of 1917 and the month of June 1919,com­
pleting 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 practi­
cally the entire southern half of eastern Iowa, or the follow­
ing counties: Lee, Des Moines, Louisa, Jefferson, Henry,
Muscateine, Washington, Johnson, Cedar, Scott, Clinton and
Jackson.

Acknowledgments.— In connection with the field investi­
gation of this problem, the writer wishes to express his
appreciation to Dr. George F. Kay, Director of the Iowa Geo­
logical Survey, and to Professor A.C.Trowbridge, of the Geo­
logical department of the State University of Iowa for their
field conferences. To Professor Trowbridge, the writer also
acknowledges his indebtedness for the supervision of the
field work and for the examination and criticism of the manu­
script. Thanks are also due to the other members of the Geo­
logical staff of the State University of Iowa for encourage­
ment and for their keen interest in the problem. 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 IX

HISTORY OF PLEISTOCENE INVESTIGATION 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, as early as 1849, noticed erratic boulders scattered here and there over the surface. To explain their origin, he introduced 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, 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." In Hall's report, Worthen describes the geology of Washington County, including in his discussion loess and drift, the latter having been deposited by "Drift agencies."

C. A. White was the first state geologist of Iowa to give any detailed consideration to the Pleistocene. As early as 1858, glacial striae 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, however, without 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.

As early as 1887, Calvin attempted to account for

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*12. Calvin, S., Fragments of Geological History, Johnson County, Iowa Historical Record, 1-3, pp. 100-107, 1885 - 1887.
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." 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" 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 as early as 1888. McGee refers to these glacial scorings as being the only ones occurring in northeastern Iowa. In the same year, Shimek described some of the fossils found in the loess at Iowa City and Witter made some


It was for W. J. McGee 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 of Washington and Louisa counties, led him to believe that there were two distinct drift sheets in Iowa 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 the Iowa and Cedar rivers and discussed in rather detail the old Goose Lake channel which was occupied by the Mississippi river during the Illinoian stage of glaciation. McGee did not confine his work entirely to the Pleistocene deposits, but also included in his studies the indurated strata.

In 1892, Professor Witter of Muscatine published an account of the first gas wells in the drift in the northern part of Louisa county and in the following year, Keyes 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 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 that the great ice mass could have crossed the deep valley of the Mississippi river and have invaded southeastern Iowa seemed incredible at that time. 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 boulder 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 at this time that the Iowan and Illinoian ice invasions were believed to have been contemporaneous. In 1896, Fultz discovered further evidences of the Illinoian ice incursion by finding glacial striae in the southeastern part of the state. In the same year, Bain published his re-


port on the Geology of Washington county. In this report, Bain discussed the Kansan drift and loess and treated in some detail on the Washington and other preglacial channels found in that county. An attempt to explain the origin of the drainage system in the county was also undertaken.

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. In 1897, Calvin's report on the "Geology of Johnson County" appeared. 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."

He directed further 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." It was not until later that Calvin recognized this "rapidly widening alluvial plain" as the bed of an ancient extinct lake.


*27. Idem, p. 46.
Leverett first recognized and separated the Illinoian drift sheet from an older till 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 till 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 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 pre-glacial 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." This report deals at length with the pre-glacial surface of the county and discusses in detail the Cleona channel, a tributary of the pre-glacial 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 who was the first geologist to describe and map the old "fossil lake." In his account of the lake, Udden carefully described the old extinct lake bottom in Muscatine county as then known, accounted for its origin and named the lake "in conformity with precedents" 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 outside of Muscatine county, although an extension of this lake appears in Johnson county as far north as Iowa City on the "Preliminary Outline Map of the Drift Sheets of Iowa" for 1904, published by the state survey. In connection with Lake Calvin, Udden and Meyers 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, no other description of this ancient body of water has appeared since Udden's report with the exception of a short account by Calvin in the Iowa State Atlas for 1904, published for the St. Louis Exposition and in a short popular article prepared by the writer for the Iowa Alumnus.

In 1901, the last two county reports dealing with the geology of part of the Lake Calvin basin were published.


These reports are, "Geology of Louisa County" by Udden and the "Geology of Cedar County" by Norton. As in his other reports, Udden dealt with all the surface deposits, the Nebraskan, the Kansan, the Illinoian tills, the loess and the terraces of the Iowa and Cedar rivers and described the old temporary Mississippi river channel of Illinoian times. It is strange to note, however, that although Udden had previously mapped and described Lake Calvin and knew undoubtedly that the old lake had extended into Louisa county, that 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 failed to state the origin of the plain. The terraces of the "higher lowlands" along the Iowa and the Cedar rivers, the writer believed to have been built up, in part at least, at the time of the Iowan ice invasion. 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 being a

lake deposit. Furthermore, 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, the Mississippi river was forced out of its channel and occupied a broad and shallow valley which extends from the Iowa river border of the upland south past Columbus Junction to Winfield and then west to the Skunk river. And then after stating that "The significance of this valley was first made clear by Mr. Leverett," 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 pre-glacial surface and the pre-glacial Stanwood channel, probably a tributary of the pre-glacial Cleona channel. The terraces along the Cedar river Norton ascribed 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 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.

Of recent date, the only important new contributions 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 established the fact that the Iowa river north of Iowa City is post-Kansan in age and also that an old pre-glacial or at least a pre-Kansan valley extended in a northwest-southeast direction across the southern part of Johnson county south of Iowa City. Some of the terraces found along the Iowa river, Leighton attributed to the Iowan stage of glaciation. This same geologist in cooperation with Alden of the U.S. Geol. Survey discusses 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 the Cedar river, the writers did not consider it as being a super-Kansan upland gumbo. These same writers also suggested the possibility that the terraces along the Cedar river in the vicinity of Rochester, believed


*52. Idem, p. 196.
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.

As indicated under "Field work" on page 7, field work was not restricted to the Lake Calvin basin alone, 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 made at this time regarding the pre-glacial and glacial drainage of the streams, especially in reference to the Mississippi river. Probably no other problem in glacial geology is more complex and more difficult to solve than that of the history of the 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 the 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.

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

THE ROCK FORMATIONS.

General statement. - The bed-rock 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, sandstone and shale and ranges in age from Middle Silurian to Lower Pennsylvanian. The accompanying table (p. 24) is a summarized classification of the strata of this portion of the state. See also certain other references* and Plate II.

THE SILURIAN SYSTEM.
The Gower Limestone Formation.

The Le Claire dolomite member. - The oldest strata forming the bed-rock in the lake basin is the Gower limestone of Niagara 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,

Table 1. Classification of the indurated rock formations represented in the Lake Calvin basin.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>SYSTEM</th>
<th>SERIES</th>
<th>FORMATION</th>
<th>MEMBER</th>
<th>ROCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>PALEOZOIC</td>
<td>PENNSYLVANIAN</td>
<td>DES MOINES</td>
<td></td>
<td></td>
<td>SS. SH. COAL</td>
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<tr>
<td></td>
<td>MISSISSIPPIAN</td>
<td>OSAGE</td>
<td>BURLINGTON</td>
<td>L. BURLINGTON</td>
<td>L.S.</td>
</tr>
<tr>
<td></td>
<td>MISSISSIPPIAN</td>
<td>KINDERHOOK</td>
<td></td>
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<tr>
<td></td>
<td>DEVONIAN</td>
<td>U. DEVONIAN</td>
<td>STATE QUARRY</td>
<td>CEDAR VALLEY</td>
<td>L.S.</td>
</tr>
<tr>
<td></td>
<td>DEVONIAN</td>
<td>M. DEVONIAN</td>
<td>WAPSIPINICON</td>
<td>U. DAVENPORT</td>
<td>L.S.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>ANAMOSA</td>
<td>LE CLAIRE</td>
<td>L.S. + DOL.</td>
</tr>
<tr>
<td></td>
<td>SILURIAN</td>
<td>NIAGARAN</td>
<td>GOWER</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

is a hard, brittle, gray or bluish gray rock, sometimes oxidizing 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. Frequently assuming a brecciated or conglomeratic nature, it 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 becomes visible. Not only do the beds dip here in all directions and at high angles, the average higher angles varying 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. On weathering the surface of the Le Claire limestone, especially where heavy 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, granular rock with a dull luster in which fossils are rare. This soft laminated vesicular dolomite with even and parallel bedding-planes weathers into thin detached laminae.

Distribution.- The Gower limestone is limited in areal distribution to the northern and northeastern portion of the lake bed. As may be seen from the geologic map, Plate II, a tongue of this Silurian formation extends down into Muscatine county. Outcrops are found only along the 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 had at the Bealer's quarries, located along the Cedar river at Cedar Valley. Here about
116 feet of the Gower limestone formation are exposed.

**THE DEVONIAN SYSTEM.**

*Formations and classification.* - The Devonian system is represented in the lake area by the Wapsipinicon, Cedar Valley and the State Quarry limestones all of which belong either to the middle or upper part of the system. The Devonian rocks at the present time are classified as follows.

| Layer       | Missing
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>Lime Creek; 97-172 ft. State Quarry; 40 ft.</td>
</tr>
<tr>
<td></td>
<td>Cedar Valley; 60-150 ft.</td>
</tr>
<tr>
<td></td>
<td>U. Wapsipinicon---- U. Davenport; 20-40 ft.</td>
</tr>
<tr>
<td>Middle</td>
<td>L. Davenport; 20-35 ft.</td>
</tr>
<tr>
<td></td>
<td>L. Wapsipinicon Independence; 20 ft.</td>
</tr>
<tr>
<td></td>
<td>Otis; 10-30 ft.</td>
</tr>
<tr>
<td></td>
<td>Missing</td>
</tr>
<tr>
<td>Lower</td>
<td>Missing</td>
</tr>
</tbody>
</table>

Classification of the Devonian system in Iowa.

**The Wapsipinicon Formation.**

*Members.* - The Wapsipinicon limestone is of such a

---

variable character that it has been divided into the following four members:

<table>
<thead>
<tr>
<th>Wapsipinicon</th>
<th>Upper Davenport</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower Davenport</td>
</tr>
<tr>
<td></td>
<td>Independence</td>
</tr>
<tr>
<td></td>
<td>Otis</td>
</tr>
</tbody>
</table>

The Otis member.— Lithologically andstructurally, 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 colored rock breaking with a conchoidal or irregular fracture. The rock in places occurs heavily bedded, especially where 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 attaining a thickness of twenty feet. Frequently, the rock contains angular fragments of other limestones and of silica. At such places, it weathers into earthy-lustered, rough surfaces filled with angular cavities and protruding particles of sand 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 and fine grained whitish limestone in many places brecciated. The rock has a conchoidal fracture, is filled with siliceous nodules and frequently 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, hard, tough and of a gray color. In some parts of the member, brachiopod shells are so numerous 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 the Cedar river and occupies a large portion of the lake bed in Goshen, Pike, parts of Moscow and Wapsinonoc townships. The various members belonging to the Wapsipinicon formation outcrop in the high bluffs along the Cedar river from a point one mile north of the village of Moscow to 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 are exposed.

The Cedar Valley Formation.

The Cedar Valley limestone. - The Cedar Valley lime-
stone now considered to be of Upper Devonian age, consists of a series of limestones varying 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 or 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 the Iowa river near Iowa City, it is seen that the strata have a slight dip to the southward 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 are absent entirely, 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. But fifty feet of this formation can actually be seen in the quarry faces along the Iowa river. A typical section of the Cedar Valley limestone is to be had at the Hutchinson quarry located on the west bank of the Iowa river just opposite Iowa City. Here approximately thirty-two feet of rock
are exposed in which thirteen distinct beds can be identified. The section is as follows.

Hutchinson Quarry Section, Iowa City, Ia.

<table>
<thead>
<tr>
<th>Bed</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.</td>
<td>Gray, thinly bedded limestone</td>
<td>3-4</td>
</tr>
<tr>
<td>12.</td>
<td>Light gray limestone, brecciated at places</td>
<td>6</td>
</tr>
<tr>
<td>11.</td>
<td>Upper idiostroma layer</td>
<td>1 ½</td>
</tr>
<tr>
<td>10.</td>
<td>Gray limestone</td>
<td>1</td>
</tr>
<tr>
<td>9.</td>
<td>Light colored limestone with numerous idiostroma</td>
<td>1 ⅔</td>
</tr>
<tr>
<td>8.</td>
<td>Base of the idiostroma bed, also birds eye coral</td>
<td>2 ⅔</td>
</tr>
<tr>
<td>7.</td>
<td>Hard ledge of gray limestone, with many acervularia and other fossils</td>
<td>2 ⅘</td>
</tr>
<tr>
<td>6.</td>
<td>Upper coral reef</td>
<td>2 ⅛</td>
</tr>
<tr>
<td>5.</td>
<td>Light colored limestone, few fossils</td>
<td>3</td>
</tr>
<tr>
<td>4.</td>
<td>Hard bluish gray limestone, separated from five by three inches of shale</td>
<td>1 ⅛</td>
</tr>
<tr>
<td>3.</td>
<td>Bluish limestone</td>
<td>1 ⅕</td>
</tr>
<tr>
<td>2.</td>
<td>Hard fine grained limestone</td>
<td>2 ⅝</td>
</tr>
<tr>
<td>1.</td>
<td>Coral reef</td>
<td>1</td>
</tr>
</tbody>
</table>

Total thickness 31 ⅝

Distribution.— The Cedar Valley formation is the bed rock for the southern portion of the Lake Calvin basin underlying parts of the following townships in Muscatine county: Wapsinonoc, Goshen, Pike, Lake and Cedar as well as the region bordering the Iowa river in Johnson county north of the village of Hills. Practically all of the ex-
posures are confined to the valley walls of the Iowa river in Johnson county from Iowa City northward. Two small outliers of the limestone 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 all hidden due to slump and overgrowth of vegetation.

The State Quarry Beds.

The State Quarry limestone.—The youngest Devonian strata in the lake basin belongs to the Upper Devonian and is known as the State Quarry limestone. This formation with a thickness of forty feet outcrops in an area three-quarters of a mile by one-half of a mile in extent along the west valley wall of the 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 thick-bedded, being as much as five feet thick, well jointed and are highly fossiliferous. Towards the base of the exposures the beds become thinner and vary from a
few inches to one foot in thickness. Distributed irregularly throughout the formation are masses of chert bands which at places are crowded with imbedded remains of fish teeth. This formation rests unconformably on the Cedar Valley limestone.

THE MISSISSIPPAN SYSTEM.

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

The Kinderhook Series.

The Kinderhook formation.—The Kinderhook formation may be divided into four members as follows:

| Wassonville limestone
| Kinderhook
| Oolitic limestone ledges
| English River Gritstone
| Maple Mill shale

The Maple Mill shale member.—This member is a non-fossiliferous, greenish gray, compact shale with a soapy or greasy luster. Throughout the shale are distributed small pale yellow cubes of iron pyrites. The rocks break

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 uniform angular quartz fragments. Intervening with the sandstone are thin seams of shaly material. The bluish gray rock weathers to a dull yellow color. Near the upper portion 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 of ten feet is a fine, compact, grayish, non-fossiliferous, lithographic limestone from three to four feet thick. This is followed by a non-fossiliferous 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 Oolitic limestone ledge member.—This rock is a white to yellowish limestone composed of small spherical oolites imbedded in a matrix of calcareous material. Where leached the two to three foot 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 becoming more or less arenaceous in places. Toward the base of the member, it occurs normally in thick ledges in which gray chert often showing an oolitic structure is found. The limestone is fossiliferous and
is approximately fifteen feet thick.

**Distribution.**—As indicated elsewhere, the rocks belonging to the basal Mississippian system underlie the major portion of the lake bed basin. From the geologic map, Plate II, it may be seen that except for a small outlier of Des Moines sandstone located along the 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 the 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.

*57

**THE PENNSYLVANIAN SYSTEM.**

**Des Moines Formation.**

**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 or so deep and having a trend S. 30° E. by N. 30° W. Two of these sandstone outliers outcrop in the lake bed region, one just north of Iowa City, the other north of Gladwin in Louisa county. The rocks belonging to the Des Moines formation consist of sandstones imbedded with layers of shale and coal. The sandstone is a light yellowish colored, thinly bedded, medium grained, iron cemented rock, rather porous and well jointed. At the Sanders quarry, located just north of Iowa City, where about twenty-six to thirty feet of the sandstone are exposed, the rock is filled with numerous spheroidal limey concretions and nodules of iron pyrites. The sandstone is interbedded with thin bedded layers of bluish black shales which vary in thickness from several inches to several feet. At places, the shale beds increase in number toward the top of the formation. Thin layers of coal, one-half to a few inches thick, are reported from both localities. In general the Des Moines sandstone and shale lie in horizontal beds, however, locally, 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 found crossing the region in more or less roughly parallel bands having a northwest to southeast trend as is shown on Plate II. 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.

The oldest rocks outcropping in the area under discussion are exposed along the 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 northward of the area are found still older rocks of Ordovician and of Cambrian times and deep well records 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 and which are considered to be Upper Huronian 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 was probably 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. From other localities it is known that the newly elevated land surface underwent a long period of erosion, but that finally submergence set in again. The best evidences from well records seem to show that this submergence resulted in a widespread epicontinental sea in which predominately sandstone and some limestone were deposited. The total thickness of these Cambrian deposits measure as much as 1000 feet, thus indicating 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 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 of the last formed group of strata at several places. The next formation to be laid down was the St. Peter sandstone believed by many as being of eolian origin, but which now appears to be of marine derivation as pelecypod 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 a total thickness of about 400 feet of the Platteville limestone, Decorah shale and Galena dolomite had been laid down. Sedimentation 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 shown by Savage, seas covered northeastern Iowa during Silurian times. By far, however, the greater part of the Silurian found in Iowa and in the region under dis-

*64. Savage, Thomas E., Geological Map of Iowa, 1905.
Cussion is of Niagaran or Middle Silurian age. As 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 the Cedar river north of the village of Rochester in Cedar county. In all about 120 feet of uninterrupted Silurian sediments were laid down in the region.

As may be inferred from the typical Silurian section of New York, the Upper Silurian is missing in Iowa and in this region. The fact that the Upper Silurian is miss-

Classification of the New York and Iowa Silurian.

<table>
<thead>
<tr>
<th>New York</th>
<th>Iowa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manlius limestone</td>
<td>Gower dol.</td>
</tr>
<tr>
<td>Cayugan (Upper Silurian)</td>
<td>Rondout waterlime</td>
</tr>
<tr>
<td>Cobleskill limestone</td>
<td>Guelph dolomite</td>
</tr>
<tr>
<td>Salina beds</td>
<td>Anamosa dol.</td>
</tr>
<tr>
<td>Niagaran (Middle Silurian)</td>
<td>Lockport limestone</td>
</tr>
<tr>
<td>Rochester shale</td>
<td>Hopkinton dol.</td>
</tr>
<tr>
<td>Clinton beds</td>
<td>Le Claire dol.</td>
</tr>
<tr>
<td>Oswegan (Lower Silurian)</td>
<td>Medina sandstone</td>
</tr>
<tr>
<td>Oneida conglomerate</td>
<td>Waucoma ls.</td>
</tr>
<tr>
<td>(and perhaps the Richmond beds)</td>
<td>Winston ls.</td>
</tr>
</tbody>
</table>

ing in Iowa presents two alternate views: namely, that this series never was deposited over the state or that if it was, it had all been removed before the deposition of the next sediment. In general there is an unconformity between the Silurian and the overlying Devonian rocks in northeastern Iowa, thus indicating that Iowa was land during Upper Silurian and Lower Devonian times or that if the Cayugan, Helderbergian and Oriskanian seas did extend over the region those sediments were all removed before the Middle Devonian seas spread out over Iowa. 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 Niagar an, thus indicat­
ing an erosional interval, lies the Wapsipinicon and Cedar Valley limestone 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 teaming with life as is now testified by the large number of marine fossils found in the limestone. After about 400 feet of these sediments had been deposited, the sea withdrew exposing 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 the corals and brachiopods of the previous seas, but also by thousands of fishes, which due to some unknown cause, suffered a sudden death as is now indicated by the cherty limestone beds which 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 which, judging from the thickness of the Mississippian series of rocks, about 500 feet thick, covered the region for a considerable length of time. Practically the entire sequence of Mississippian rocks is represented in Iowa; however, the oldest formation, the Kinderhook, is the only one which forms the bed rock of the Lake Calvin basin. That the Kinderhook sea extended farther north than is shown on the geologic map, Plate II, is shown by the small outliers of what were formerly known as the Sweetland Creek shales in Johnson county, a little north of North Liberty and 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, similar to those in the State Quarry beds. These fish, are now known to have lived in the Kinderhook seas and the strata are now correlated with the Kinderhook. Sedimentation continued for some time, as several of the younger Mississippian series are known to exist and 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 140 feet or so deep in the Cedar Valley limestone. 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 area. The evidence for this 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 submergence undoubtedly oscillated from time to time, as is shown by the interbedded coal seams of non-marine origin with the marine sandstone and shale above and below. 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 also practically all of the Pennsylvanian formations, excepting the few patches preserved in the valley north of Iowa City and the one in Louisa and in Muscatine counties. These patches of sandstone and shale were preserved, because they occupied low places or valleys and hence were thus protected.

The finding of undoubted Cretaceous fossils in the drift at various places as at Iowa City, Mt. Vernon, Cedar Rapids, Des Moines and at 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 deeply buried in a clay seems to have strengthened the idea that the fossil must have been near its original home, as it is believed that such a slender specimen could not have withstood far transportation without having been shattered.

Udden also describes two small deposits in Muscatine county, named the Pine Creek conglomerate which he states may either belong to the La Fayette formation or may be


of Cretaceous age. Trowbridge, however, is of the opinion that these deposits are Aftonian. Schuchert, 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.

SUB-GLACIAL TOPOGRAPHY.

It matters little whether or not the Mesozoic seas inundated the region here discussed. The fact remains that before the 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 now 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 sub-glacial topography has a relief of 300 feet or so, besides disclosing the presence of numerous large rock-cut channels which probably formed a drainage system of greater magnitude than exists now in the region.

*69. Personal communication.

As shown by Leighton, Calvin and Thomas, the bed rock 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 extreme southern border of the County, bed rock is high, but between these two areas there is a northwest-southeast belt in which the bed rock surface is low. The relief of the country was at least somewhat over 250 feet for the highland bed rock surface has an average elevation of about 700 feet above sea level and in the lowland district bed rock is as low as 460 feet A. T. This northwest-southeast trending lowland with a width of at least eleven miles crosses the Iowa river sector 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. This ancient valley undoubtedly extends diagonally across the northern portion of Louisa county and continues along


*75. Idem. p. 111.
the lowland underlying the Iowa-Cedar river valley of to­

day, until it joins the ancient valley of the Mississippi.

*76

Udden has shown that the subglacial surface under

the West Liberty Plain, (the lowland area bordering the

Cedar river in Muscatine county) was low and that the

valley now occupied by Mud creek lies in 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

*77

also that the Washington channel may have joined this

general lowland area somewhere in the vicinity of Colum­

bus Junction. The Washington channel to which Bain and

*78

Calvin have called attention extends diagonally across

Washington county in a northwest-southeast direction, pass­
ing beneath the city of Washington. This ancient buried

valley as well as the one in Poweshiek county at Deep


River may probably have some connection with the large buried valley underlying the famous Belle Plain Artesian basin which extends in a northwest-southeast direction through Tama, southwest Benton and northwest Iowa counties.

In the northeast, the West Liberty sub-glacial lowland was joined by an ancient valley thought by Carman, Norton, Udden and Leverett as probably the course of a pre-glacial Mississippi river. It is evident that the present course of the Mississippi river between Princeton on the north and Muscatine on the south is of much more recent date than those portions of the river to the north and


south of the two mentioned cities. It has been suggested that the preglacial valley of this mighty river extended up the Wapsipinicon river valley up to the mouth of Mud creek from which place it extended roughly parallel in a southwest direction to Mud creek as far as Durant. That portion of the channel from the Wapsipinicon river to Durant has been called the Cleona channel by Norton. 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. Bed rock 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. Well records show that the bluffs of the valley were rather steep, showing a declivity of as much as 250 feet within a mile. Several smaller tributaries to the Cleona channel have been mapped. From Durant the


*87. Idem, p. 58.


*89. Loc. cit. pp. 58 and 59.
preglacial valley extends in a general westward 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 now 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 the Iowa-Cedar river into the present Mississippi.

Another large channel undoubtedly a tributary to the Cleona river is the Stanwood channel 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 flowing finally along the east side of Sugar creek. About two and one-half miles north of Lime City it turned southeast and near Durant joined the Cleona channel. "Measured from crest to crest, its width is at least seven miles at Tipton."

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 deeply hid-
den under the drift covering a little west of Downey.
This channel probably connects with the one lying in the
upper northeast corner of Johnson county, between Solon
and the present Cedar river.

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 its own
making. Gordon and Leverett have shown that the sub-
glacial valley is much larger than the present one whose
average width is six miles and depth 150 feet as compared
to a width of six to fifteen miles and a depth of 250 feet

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

*94. Calvin, S., Geology of Johnson County, Iowa Geol.

*95. Gordon, C. H., Buried River Channels in Southeast-

*96. Leverett, F., The Lower Rapids of the Mississippi
Pre-glacial Valleys of the Mississippi and its Tributaries,
Journal of Geology, Vol. III, pp. 740-763, 1895. The Low-
VII, pp. 1-22, 1899. Old Channels of the Mississippi in
Southeastern Iowa, Annals of Iowa Historical Quarterly (3)
Monograph XXXVIII, pp. 460-477, 1899.
of the former. Between Keokuk and Montrose north to Muscatine the river is occupying the ancient course. 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.

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

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

THE PLEISTOCENE DEPOSITS OF THE LAKE CALVIN REGION.

GLACIAL AND INTERGLACIAL DEPOSITS.

Classification of Pleistocene deposits in Iowa.- Of the five great continental ice incursions now recognized for North America all are represented, directly or indirectly, in the Lake Calvin region.

Classification of the Pleistocene Deposits in Iowa.

9. Wisconsin drift (of the Des Moines lobe)

5. (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)

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)


*99. The Iowan stage of glaciation has now been fully established by Alden and Leighton, see the previous reference, pp. 49-212.
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 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 till 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 numerous records of wells scattered over the region.

Exposures of the pre-Kansan till occurring in the lake basin or the region surrounding it have been described by *100 Udden in his Louisa county report. However, when it is remembered that the earlier investigators did not know of or use the gumbotil to differentiate one drift from another but based their partition on color, texture, petrographic content of the deposits and intervening stratified sands and gravels, it remains an open question whether the described tills can be proven definitely to be Nebraskan. Some of Udden's exposures listed below were seen but only

in two (10 and 11) cases does the writer feel confident that the drift belongs to the oldest stage of glaciation. In the other outcrops, the drift may be either Nebraskan or Kansan.

Exposures of Nebraskan Drift cited by Udden

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. 1/4 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 the Iowa river, in the Se. 1/4 of Sec. 9, Tp. 74 N., R. III W.
6. On the west bank of the Iowa river at Wapello.
7. On the west bank of the Iowa river one mile north of Columbus Junction and farther north.
8. In the west bank of the Cedar river two miles north of Columbus Junction.
9. In the railroad cuts in the bluffs of the Mississippi river in Sec. 2, Tp. 75 N., R. III W.
10. Foot of the west bluff of the 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.

For locality 10, Udden in describing the Nebraskan makes the following statement and presents the figure

(fig. 2) given below. "In one instance there seems to be a soil horizon on its upper surface." 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, d proving to be a typical gumbotil. Because of the 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 gum-

*102. Loc. cit. p. 104 and fig. 3.
botil is erroneous, no such big difference in elevation within such a short distance in the same gumbotil is permissible. The only outcrops of the Nebraskan drift in Muscatine county are found in the vicinity of Muscatine. No exposure of the oldest till is reported for Cedar county. In the Stanwood channel, *103 wells penetrate it, however. Exposures of the pre-Kansan till 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, its presence 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 descending from the upland to the lowland in the extreme southeast corner of the section. The other exposure is to the northwest of the first road leading down from the upland to the terrace lowland. 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 drift, 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. This exposure lies at 640 feet above sea level or approximately ten feet lower than the super-Nebraskan gumbotil in Johnson county. Because of their stratigraphic position and 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 referred to as probably being Nebraskan.

1. Johnson county, Liberty township, section 27, NE 1/4, west river bank.

2. Johnson county, Fremont township, section 24, S W 1/4, east river bank.


5. Washington county, Iowa township, section 23, N W 1/4, northeast part, west bank of river.


7. East bank of the Iowa river on both sides of the north line of section 16, Tp. 76 N., R. V W. (Udden's exposure 11, see page 54)

Character of the drift. - The Nebraskan till in its unweathered state consists of a hard, dark brownish to blue-black, calcareous, joint clay, compact, and containing at places many fragments of wood. The drift breaks into very small angular to rhomboidal blocks. Where seen, most of the pebbles scattered throughout the drift are small and the cobble or boulders are relatively few. At exposure 7 above, or 11 of Udden's outcrops, the clay appears to be without pebbles and finely laminated. Lying on the surface of the till, which in most cases forms a sort of bench, numerous cobble and boulders of all descriptions and sizes are found. Many of these are striated and a large number of the granitic type are thoroughly disintegrated breaking into thousands of pieces when stepped upon. It is also noticeable that wherever these cobbles and boulders 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 till sheets. According to Udden, the Nebraskan drift "contains about twice as many fragments of local rocks such as the Kinderhook and Burlington formations, as other drifts. Also

according 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 tills.

**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 the Iowa river, along the wagon road in the S E 1/4 of sec. 21, T. 76 N, R. V W. and at Indian Lookout in the S E 1/4 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 over conservative. It appears that on the whole the Nebraskan till is thin and is absent on the uplands except where the preglacial surface was low. Even in the low places it was found sparingly. According to Leighton, a study of well records in Johnson county gives the Nebraskan the following thicknesses: 15, 15, 25, 54, 86 and 122. For Louisa county, Udden reports from ten to twenty feet.


for the thickness of the drift and Norton reports a thickness of sixty-five feet in Cedar county.

THE SO-CALLED AFTONIAN GRAVELS.

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 southeastern one quarter of section 33 of West Lucas township. The third exposure is in Louisa county in the southeast one quarter of section 21 of Union township. This gumbotil believed to be the oxidized and leached product of the drift is drab or ash colored, thoroughly leached, hard and tough clay containing but few pebbles. The contained pebbles are small and consists of the more insoluble matter such as quartz, chert and quartzite; other constituents, however, as granites, basalts, etc. are not entirely wanting.


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


microscopic analysis shows that the gumbotil is made up of from sixty to seventy-five percent of minute, spherical, transparent grains of quartz and from twenty-five to forty percent of clay. When wet, the gumbotil breaks with a starch-like fracture and when dry its surface has a characteristic checkered appearance. Due to heavy slumping, a thickness of only about ten feet could be determined definitely at the exposures in Johnson county and only four feet at the third exposure. In Johnson county, a brownish till sheet lies on top and another beneath the gumbotil, whereas in Louisa county it is overlain by a loess and underlain by a brown to yellowish sandy drift. The gumbotil in Louisa county is believed to be Nebraskan rather than Kansan. Two miles to the north and at a similar distance from the outcrop is another gumbotil lying at an elevation of 705 to 710 feet above sea level. At these places, the gumbotil lies from 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 lies at 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, 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 the gumbotil.

A possible gumbotil has been reported by Leighton, outcropping along the west bluff of the 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 situ.

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 com-


*115. Personal communication to Dean G. F. Kay.
pact unaltered drift. The leaching and oxidation of these sands and gravels is believed to represent the time interval between the Nebraskan and Kansan stages of glaciation.

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

THE KANSAN DRIFT.

Distribution.- Except for the eastern border of the lake basin in Muscatine county, and several small isolated tongue-like areas in the northern portion of the lake region, practically the entire area consists of Kansan drift which is either exposed at the surface or which lies directly below a more or less heavy mantle of loess. As expo-


sures of this till may be seen almost everywhere along road cuts, along the valley walls of the Iowa and Cedar rivers, as well as along some of the smaller streams, no detailed location need to be cited.

**Character of the drift.**—Several phases of the Kansan drift sheet were noted: namely, the fresh or unaltered drift, the oxidized but unleached till and the oxidized and leached boulder clay. The unchanged drift consists of a very compact dense material of a bluish color in which the pebbles are predominately small and which at places is impregnated with 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 boulders 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 are also numerous throughout this phase of the drift. Practically everywhere, large boulders of granite, dolerite and basalt are in evidence. Some of these are highly weathered, crumbling 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 boulders lying on the surface of the Kansan drift within the lake basin near to the bluff line, a fair pro-
portion are more or less slab-like instead of the characteristic subangular form. In Johnson county the Kansan drift is relatively free from large boulders except locally as in the tributary gullies of the Iowa river north of Iowa City where numerous large fresh boulders of various kinds have been concentrated. According to Udden, a larger proportion of diabase, granite and other Keweenawan pebbles are found in the Kansan of Louisa county than in the Nebraskan, whereas the number of limestone and dolomite pebbles are 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, setting it off from the other portions of the drift. This thin zone is known as the "ferreto" zone.

**Thickness of the drift.** The Kansan drift varies in thickness from place to place being least thick where resting on bed rock. Practically everywhere in Morning Sun township, Louisa county, where the till was seen ly-

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ing directly on the country rock, its thickness rarely exceeds fifteen to twenty feet and at the Interurban cut on the west side of the Iowa river at Iowa City, its thickness is not quite eight feet. The maximum thickness of this till seen in the field is at least sixty feet although well records in Johnson county, as shown by Leighton, indicate a thickness of over 200 feet. Udden reports a maximum of 100 feet for Muscatine county. In general the leaching of the Kansan drift has not penetrated farther down than from five to thirteen feet, whereas the oxidation as observed in the field has in many cases extended to a depth of sixty or more feet.

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 oxidized Illinoian till above the gumbotil. Its thickness where seen varies from six to

*-120 Loc. cit. p. 118.
eleven feet. This small range of thickness, however, does not in all probability represent the entire development of the interglacial deposit, 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 twelve to fifteen feet would probably not be far from correct, especially as that is the average thickness of the Kansan gumbotil in near by counties. In altitude the Kansan gumbotil plain ranges from 670 to 730 feet above sea level, being higher towards the western portion of the lake region.

The Buchanan gravels.-- Most of the Buchanan gravels seen in the lake region are those described by Leighton. 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 gulley immediately south of the railroad tracks of the branch line of the Chicago, Rock Island and Pacific railroad where it crosses the Iowa river.

The Buchanan deposits consist of highly oxidized and decayed, stratified sand and gravel whose textural


range is from fine sand to boulders one foot or so in diameter. Many of the sands and gravels are of a highly reddish color and at places show cross-bedding and con
tortion. Calvin has divided the Buchanan gravels into two phases: the upland phase and the valley phase, the former consisting of the coarser and bouldery mate-
rial, 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 sheet. Leighton, however, has come to the conclu-
sion that Calvin's valley phase or terrace gravels rep-
resent Iowan outwash deposits.

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

*125. Idem. pp. 142-146. An Exposure showing post-Kan-


*127. Leighton, Morris M., The Buchanan Gravels of Cal-

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.


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 a highly ferruginous or brownish red coarse sand and fine pebbles. The pebbles are mostly all well rounded and some are striated. The material is leached as well as 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 an eight-inch, 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 gumботил, 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 690 feet above sea level. If these deposits 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 and which are according to Leighton 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 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, suggests 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 for Louisa, Cedar and Johnson counties. Udden describes a sand somewhat gravelly as well as soil bands for Louisa county. Norton reports one exposure of a dark red sand con-


taining disseminated pebbles in Cedar county and Leighton refers to the Buchanan gravels being encountered in numerous wells in Johnson county.

THE ILLINOIAN DRIFT.

Distribution and character.- The Illinoian drift forms the surface material in the region lying east and south of the lake basin in Muscatine and Louisa counties. 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 till sheets. Not only is the thickness of this drift less than that of the other two, but leaching and oxidation have not progressed nearly so far. Where examined, leaching does not penetrate more than two or three feet and oxidation at one place 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 even lacking entirely. An average thickness for this drift where 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 re-

pects, 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 also numerous 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 section line between sections 33 and 34, and in the north bluff of the 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. At these places, the gumbotil is usually highly carbonaceous. In section 10, the peat bed is five feet thick, the upper two feet of which are 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 has also been described by Alden and has been referred to by Udden. 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 73)


<table>
<thead>
<tr>
<th>LOCATION</th>
<th>TOPOGRAPHIC POSITION</th>
<th>ELEV.</th>
<th>DIFFERENCE IN ELAVATION</th>
<th>DISTANCE MILES</th>
<th>SLOPE FEET PER MILE RECONSTRUCTED GUMBOTIL PLAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Section road between sections 25 and 30, 1 mile S. of Columbus Junction.</td>
<td>Upland</td>
<td>710</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>NE. corner of NW 1/4, section 15, 2 1/2 miles E. of Cairo.</td>
<td>Upland</td>
<td>700</td>
<td>10</td>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
<td>C. of NW 1/4, section 14, 1 mile NW of Oakville.</td>
<td>Upland</td>
<td>680</td>
<td>50</td>
<td>12.5</td>
</tr>
<tr>
<td>4</td>
<td>Intersection of road and Ill. bluffs in section 22, 2 miles E. of Fredonia.</td>
<td>Valley walls</td>
<td>640</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>E. central part of section 5, Port Louisa township.</td>
<td>Valley walls</td>
<td>620</td>
<td>20</td>
<td>5.5</td>
</tr>
<tr>
<td>6</td>
<td>N. central part of NW 1/4, section 9, Port Louisa township.</td>
<td>Valley walls</td>
<td>615</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>NW. corner, section 19, 2 1/2 miles N. of Wapello.</td>
<td>Valley walls</td>
<td>610</td>
<td>5</td>
<td>1.25</td>
</tr>
<tr>
<td>8</td>
<td>W. central part section 23, 1 1/2 miles NE. of Wapello.</td>
<td>Valley walls</td>
<td>610</td>
<td>0</td>
<td>2.25</td>
</tr>
<tr>
<td>9</td>
<td>S. central part of section 31, 3 1/4 miles SE. of Wapello.</td>
<td>Valley walls</td>
<td>600</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>NE. corner along section road between sections 9 and 10, 2 1/2 miles NE. of Elsies</td>
<td>Valley walls</td>
<td>610</td>
<td>10</td>
<td>3.25</td>
</tr>
<tr>
<td>11</td>
<td>NE. corner along section road between sections 15 and 22, 1 3/4 miles NW. of Oakville.</td>
<td>Valley walls</td>
<td>620</td>
<td>10</td>
<td>1.5</td>
</tr>
</tbody>
</table>

| 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 | 680 - 620 | 30 | 1 | 3.0 |

**Table 2. Table of Gumbotil Elevations and Slopes of Reconstructed Gumbotil Plains in the Region of the Iowa - Cedar River Valley.**
seems to indicate that a large sag existed over the present valley of the Iowa-Cedar river after the retreat 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 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 is 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 elevation between 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 from 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 considered independently are in perfect agreement but not in harmony with the gumbotil hypothesis or with the existence of
Lake Calvin when treated collectively, 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 are described by Udden for Louisa and Muscatine counties and gumbotils by Leighton and Alden in Louisa county.

THE IOWAN DRIFT.

Distribution and Character.- Unlike the Kansan and Illinoian drift sheets in the lake region, the Iowan does not constitute a continuous surface formation, but occurs in five separated areas in the northern portion of the region. Although possessing some characteristics of the typical Iowan drift plain, all but the westernmost tracts have recently been questioned as to their ever having been covered by the Iowan ice sheet. Exposures of drift in this younger drift plain are rare, because little dis-

section has taken place since the deposition of the till. The Iowan area is characterized by its youthful topography, its absence of a loess covering and the presence of huge coarse grained granitic boulders. The drift itself is not distinctive. In contrast with the Kansan till, the Iowan drift is more sandy and porous and has a yellowish color. Oxidation has penetrated to but eight or ten feet and leaching on an average between three and five and one-half feet. This boulder clay is characterized by a low content of calcium carbonate. The unleached portion of the till is of a darker color and varies from a bluish or drab gray to a slate color. On the whole, the fresh drift is somewhat harder and denser than the oxidized portion. Many of the contained pebbles and boulders exhibit a marked degree of freshness. The Iowan drift is thin, probably averaging no more than ten feet.

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, silt-like material, composed of very fine angular particles of quartz, feldspar, mica, ferromagnesian and other minerals. The deposit is some-


what sandy, but pebbles are lacking in the typical loess. It can be easily detected by its remarkable ability to stand in vertical faces for a long time after being exposed. The loess where 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 frequently 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 varies from place to place from a probable maximum thickness of thirty feet to nothing more than a thin veneer. The loess is not only found on both the Kansan and Illinoian uplands, but is also present in the lake basin itself, however, not to a great extent.

THE WISCONSIN AND POST-WISCONSIN DEPOSITS.

Wisconsin terraces and valley train deposits.—The only known deposits representing the Wisconsin stage of glaciation in the lake region are the sands and gravels of a few scattered terraces in some of the tributary valleys of the Mississippi and the Wisconsin valley 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 the
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 rocks show, 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 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 stage of glaciation in

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

The advent of the next ice sheet, the Kansan, was preceded by a very long erosional interval. During this stage, known in literature as the Aftonian interglacial stage, atmospheric weathering attacked the newly formed drift plain, oxidized and leached the drift into a tough, sticky, drab colored gumbotil from ten to fifteen feet in thickness. Presumably, contemporaneous with the formation of the gumbotil, the sands and gravels described in Washington and Louisa counties 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." From 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.

After a prolonged period of weathering, diastrophic movements elevated the region and erosion became the dominant process dissecting the original gumbotil plain.

The period of erosion was gradually followed by climatic changes, the climate became colder and colder until finally the lake region was invaded from the north by a


second 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 were 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 the Iowa river and undoubtedly that of the Cedar was established. That this, the Yarmouth interglacial stage, was of longer duration than the Aftonian seems to be indicated by the thicker deposit of gumbotil formed during that time. Whether more pronounced erosion took place, is difficult to state as records of post-Nebraskan pre-Kansan erosion are not available, however, evidence 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."

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 radially 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 the Mississippi river into Iowa. It was the displacing of the Mississippi river by the ice invasion which gave rise to the ponding back of the combined water of the 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. Either due to diastrophic movements or because of its proximity to the unaffected parts of the Mississippi river valley, erosion set in and began to remove 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 inaugurated. This stage of non-glaciation 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 and in the lake basin. During the ensuing interglacial stage, the Peorian, loess was deposited over most of the region and dissection of the Iowan terraces began. The dissection may temporarily have been halted during the Wisconsin stage of glaciation.
by the ponding back of the Iowa and Cedar rivers due to the building up of the Mississippi valley by deposits of Wisconsin outwash materials. Erosion, however, soon became active again resulting in further removal of the Iowan terraces and the building up of the present flood plains of the rivers which process 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 found especially in the northern portion of the lake site. The arms of the "V" extend in a direction parallel to the Iowa and Cedar rivers forming its apex near the junction of the two streams at Columbus Junction, Louisa county. (See plate III, Map of Lake Calvin.)

Extent.— Not considering 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 sectors 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 considered as belonging to the main basin of the lake site, the English river extension branching off of the Iowa river arm in Washington county is the largest. Its length and average width are fifteen and one-half miles respectively as compared to a length of ten miles and a breadth of somewhat over a mile of the Old Mans creek ramification, the
northern branch of the Iowa river sector 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 that portion 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. In width the valley
averages two miles. At the time of its greatest expansion,
the waters of the lake covered an area approximately 325
square miles or 208,000 acres, an area, as may be seen from
figure 3, about three-fourths of Muscatine county. To have

Fig. 3. Diagram showing comparative areas of
Muscatine county and the Lake Calvin basin.
Cross-hatched portion represents the area of
Lake Calvin.

followed the shore line of Lake Calvin during this stage
of maximum development would have been equivalent to 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 up-
lands consisting of the Kansan, Illinoian and Iowan drift
plains. Of these highlands which rise from eighty to one hundred feet above 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 IV.) The Iowan drift plain which forms the two exceptions to the Kansan upland area just referred to, borders the lake basin at its two northern extremities along the Iowa and Cedar rivers respectively. The more widespread Illinoian plain comprises the entire remaining area of the region south and east of the lake lowlands.

THE KANSAN UPLAND

Topography.—The Kansan drift plain comprising by far the greater portion of the highland bordering the lake basin, consists of a maturely dissected upland (Plate V) whose general elevation lies from about 840 feet above sea level in the northern and western parts of the lake region to 740 feet near the borders of the lake basin. Originally a somewhat gently sloping flat plain, its surface to-day is deeply incised by an intricate dendritic system of valleys. Topographically, the region presents many diversities. Approaching the larger stream valleys from the inter-

*146. The drift plain bordering on the eastern side of the Cedar river, known as the Tipton Lobe of the Iowan drift sheet has recently been questioned as being of Iowan age. See *The Iowan Drift* by Wm. C. Alden and Morris M. Leighton, Iowa Geol. Survey, Vol. XXVI, p. 179, 1916.
View in northeastern Washington County, Iowa, showing mature erosion of the Kansan drift plain. Relief 100 to 150 feet.
stream 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 cut into its surface are characterized by broad bottomed, open and 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 resorted to. At various other places, 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 with while traveling over the lower Muscatine road between Iowa City and Downey, in the region lying east and north-east of Iowa City extending up to the Cedar river and on the west side of the Iowa river between Iowa City and Old Mans creek. Leaving the uneroded remnants of the original plain and progressing closer and closer towards the master streams, the surface of the upland becomes 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 increased until finally at the borders of the upland, the
streams have thoroughly dissected the region and excavated their valleys to their greatest depth. Here maximum ruggedness and relief prevail. Thus is the border country of the river-like extensions of the lake basin, north of Iowa City and the village of Rochester along the 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, separated from the sharply cut steep-sided ravines and valleys having a relief of sixty to one hundred and sixty feet, by long winding even-crested ridges. Where the drift has been only slightly modified by loess, this ruggedness becomes less pronounced. Although 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 seen between the valleys of Old Mans creek and the English river and in that portion of the drift plain lying to the east of the 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
from ninety to one hundred and twenty feet above the level of the Iowa river and which lies at an elevation of about 700 feet above sea level in the vicinity of Columbus Junction, becomes 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. 4) taken in section 36 of Elm Grove township, shows the incised valley cut from thirty-five to forty feet below the general upland and one mile wide. This place practically marks the divide between the north and south flowing streams developed in the sag.

Attention was at first called to this abandoned channel by Mr. Frank Leverett of the United States Geological Survey.
THE ILLINOIAN UPLAND

Topography.—The Illinoian upland comprises that portion of the lake region lying east and south of the lake basin or lowlands between the 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 710 to 730 feet above sea level. In contrast to the Kansan highland whose general surface slopes gently to the south or southwestward, 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 the city of Muscatine, the divide between the drainage lines lies closer to the eastern portion of the upland than to the western border. Because of this, the north and westward flowing streams are the larger and occupy the shallower and more open type of valley. South from the latitude of the city of Muscatine, the watershed has shifted entirely to the east following the bluffs of the Mississippi river and forming 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 the city of Muscatine, the height of the land between the 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 the Mississ-
ippa river in section 18 Fulton township, two and one-half miles south-east of Durant. At this place an elevation of 800 to 820 feet above sea level is attained.

Due to the varying width and proximity to master drainage lines, the Illinoian upland presents many diversities in its topographic position. 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 sudden termination as soon as the southernmost extremity of the lake basin at Columbus Junction is reached. South of the Junction, no trace of a sand dune marking the limit of the Illinoian plain is to be had. The dune-covered surface is, as a rule, confined to an area less than one-half of 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 to two miles. The average height of the sand knolls and ridges is from ten to thirty feet, but reaching heights of forty to fifty feet at those places where the sand covers larger area. Numerous ponds, as the one seen on the right hand side of the following photograph, are hemmed in between the dunes.

In contrast to the Illinoian drift plain of Lee and Scott counties which is characterized by extensive areas of
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 the Iowa-Cedar river and in the country forming the watershed between Mud creek, Cedar and Mississippi rivers north of the city of Muscatine. Proceeding outward in all directions from these flattish remnants or interstream areas towards the master streams, the Mississippi and Cedar rivers, the country becomes more and more cut up, at first by wide open swales or sags which closer to the master streams, however, develop into deeper valleys until finally within a few miles from the main drainage lines, the whole topography is etched out
into a system of hills and valleys by the numerous ramifica-
cations of the dendritic stream courses. Thus everywhere
along the eastern and southern border of the upland, the
bluffs of the Mississippi river are cut into by young streams
the heads of which are from 100 to 150 feet below the up-
lands. South from the latitude of the city of Muscatine,
in townships Seventy Six of Muscatine county and Grand View
and Port Louisa township, 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. Be-
cause of the position of the divide to the master streams,
the north and westward flowing streams, as a rule, flow in
more open and wider valleys than those pursuing the south
and easterly courses. Such are the valleys, especially in
the northern tier of township 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 or more feet in depth, and,
together with the numerous sand dunes dotting the surface,
present an unusual type of topography, one which is both con-
structive and destructive and which is particularly charac-
teristic 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 Colum-
bus Junction, the northwest-southeast trending valley of the
Iowa-Cedar rivers divides the drift plain into two uplands
which are separated by a distance varying from three to five and one-half miles. The northfacing termination of the upland south of the gap, consists of steep undissected bluffs which rise one hundred or more feet 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 are often fringed by a line of low sand dunes. Four and one-half miles south of Columbus Junction, the southern portion of the upland is redivided into a north and south section by the valley of Long creek which is from one-quarter to one-half of a mile wide and from seventy to eighty feet deep. South of Long creek, the western edge of the upland is characterized by two parallel ridges considered by Udden as 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 of a mile wide.

THE IOWAN DRIFT PLAIN

Topography.- North Liberty Lobe.- The Iowan drift sheet forms a lobate upland area in the northern portion of the lake region. The largest of the five tongue-like extensions of this drift sheet, named the North Liberty Lobe by Calvin, enters


*148. The lobate character of the Iowan drift plain has recently been questioned with the exception of the North Liberty Lobe. See " The Iowan Drift " by Wm. C. Alden and Morris M. Leighton, Iowa Geol. Survey, Vol. XXVI. pp. 177, 179, 180, 1917.
the lake region in the northwestern part of Monroe township, Johnson county and extends southeastward across the Iowa 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 by McGee "paha". Compare plates VI and VII. 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, having a relief of not more than twenty feet nor slopes greater than twelve degrees. One depression is occupied by a small pond of water whereas the others are of a slough character. Many undrained depressions exist in the northeastern quarter of the plain, notable among which is Swan lake. That portion of the Iowa plain lying south of the Iowa river is practically unaffected by drainage except near its borders. The "somewhat higher and more billowy" north lying portion is more highly cut up by young valleys and ravines whose depth at the border of the Iowa river varies from eighty to more than 120 feet.

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View showing the flat surface of the North Liberty Plain
Plate VII

View showing the erosional topography of the Kansan taken near the border of the North Liberty Plain.

(See plate IX. Vol.25, La. G.S.)
Shueyville Lobe.—A very much smaller extension of the Iowan plain, with similar surface characteristics, lies to the east of the North Liberty Lobe to which it is connected. This plain is known as the Shueyville Lobe.

The remaining tracts of Iowan drift in the lake region known respectively from west to east as the Solon, Tipton and the Clinton Lobes have recently been questioned by Alden and Leighton as belonging to the Iowa drift plain. *151

Solon Lobe.—The Solon Lobe as described by Calvin occupies a low plain when compared with adjacent loess-covered 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 pahas. 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 the Cedar river which it parallels southward to within one to one and one-half miles of Cedar Valley. The surface of this plain is divided by Baldwin creek into two topographically unlike parts. That portion of the plain to the north and west of the creek presents an exception to the usual

undissected character of the Iowan surface and is in all respects similar to any of the Kansan upland topography bordering the Cedar river. The remaining parts of the Tipton Lobe compare with sufficient closeness to the normal Iowan drift plain. Alden and Leighton after considering everything, and especially the erosional character of the topography surrounding this area doubt if the Iowan ice ever covered the tract known as the Tipton Lobe.

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

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, 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. The island-like high-


land is separated from the main upland to the northwest by a distance of one-half of a mile and rises on the average seventy-five feet above the level surface of the surrounding plain, the intermediate terrace. Its summit which reaches an elevation of 760 feet above sea level at the schoolhouse in section 7 and which is 110 feet higher than the road at the base of the upland in section 8 about three-fourths of a mile directly east, 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 not quarried, the slopes have an average slope of about seventeen degrees. Towards the south and especially towards the southwest, the remnant border due to the numerous sand dunes is less conspicuous and merges more gradually into the surrounding lowland. Sand dunes crown the upland summit.

**Iowa City Remnant.** The Iowa City remnant of the Kansan upland is less well outlined than the one in the vicinity of Moscow. Extending southward from what is now Iowa Avenue as far as Kirkwood Avenue in Iowa City, the top of this isolated ridge is followed by the well-named Summit street. From Kirkwood Avenue, the island spreads out in a general east-west direction, giving it the appearance of a large, inverted railroad spike. Approximately one square mile is occupied by the remnant whose maximum length and width are one and one-half miles respectively and which is
separated from the main upland by the one-half mile wide valley of Ralston creek. Its surface is loess-covered and in Iowa City modified by the works of man. The borders of the highland rise from 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 extensions 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 indentation. Even in the narrower arms of the basin, there is indication of these characteristic features of the main lake border, rather than the sharper sinuosities of meander scars. The bluffs are mainly cut in the unconsolidated drift materials of the various till sheets bordering the lake basin. Bed rock forms part of the bluffs in the western and southwestern end of the English river branch of the basin, along the 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 primarily 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 cut into the country-rock, the bluffs are exceptionally steep and even precipitous. See plate VIII.

Illinoian Bluffs.- In spite of the meandering of the 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 line, composed primarily of Illinoian till, sand and loess, trends in a northeasterly direction with a striking directness to the northcentral part of section 6 of Bloomington and Lake townships. From here the bluffs swing in a smooth gentle curve northeast to the south-central 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. Practically along its entire northeast-southwest course of twenty-three miles, its top is covered by the rolling sand dunes previously described. The slopes are steep and vary in height from one hundred or more feet in the south to seventy and seventy-five feet in the north. The base of the bluff line is sharply defined from either the terrace or flood plain which abuts against it. Following the margin of the lake basin eastward along the valley
view showing the steep and rocky bluffs of the lake calvin basin along the cedar river extension north of moscow.
of Mud creek, the line of demarcation between upland and lowland is less pronounced than in the lake basin proper. 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 smaller 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.—In the larger finger-like extensions of the lake basin as along the Cedar river north of Moscow, in the Wapsinonoc valley north of West Liberty, up the valley of the English river and Old Mans creek and along the Iowa river north of Iowa City, the bluffs are very pronounced and steep, especially where cut into solid rock. At many places the bluffs reach a height of seventy to eighty feet, although a general average rise between thirty and fifty feet 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 less abrupt and lower than the bluffs to the east or west is, nevertheless, at most places very distinct and sharply set off from the lowland to the south.

called by Udden the West Liberty Plain. (See fig. 6)
The heights of these bluffs range from forty to fifty-five feet. As the map (Plate IV) 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 from 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 ex-
trending southwestward from West Liberty in a relatively straight or gently rounded outline, has, especially in the vicinity of Nichols, an almost even skyline. The bluffs rise abruptly from the lowland and vary in height from less than sixty-five feet, two miles south of Nichols to ninety feet in section 26, Wapsinonoc township, 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 pass over into Johnson county for a little over half of a mile to the southeast part of section 25, Fremont township, maintaining their sharp outline, but decreasing in height above the lowland. Broken by a gap extending to the corner of sections 23, 24, 25 and 26, the bluff line trends in a smoothly rounded curve to the southwest corner of section 27, losing much of its conspicuousness and definiteness. From the southwest corner of section 27, the bluffs again assume their characteristic features, rise sharply forty feet above the lowland to the west and continue in a northerly direction to practically the southern limits of the village of Lone Tree. North of the village to section 31, Scott township, the bluff line loses much of its identity as to definiteness of outline and height, maintaining, however, its relative straightness. The inconspicuousness of the border between lowland and upland is due in large measure to the numerous rolling
sandy tracts of dunes which mask the sharpness of the contact line. These dunes often cause a blending of the upland into the lowland and only from some distance on the lowland, can the line of demarcation be recognized. From section 31, Scott township, the line of bluffs assumes its prominent features again, being easily tracable 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 the lowland, 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 IX. 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 portion 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. - Southward from 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 skyline is uniform. At Indian Lookout, in section 34, West Lucas township, the bluffs rise 120 feet a-
MAP SHOWING LAKE CALVIN AT IOWA CITY
bove the terrace, becoming 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 the 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 also found in the southern angle between the 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 having a northwest-southeast trend to Columbus Junction in Louisa county. Between these two points, the bluffs are unusually steep because of the lateral planation of the Iowa river at their base 140 feet lower.

**TERRACES**

**General description.** At least three sets of terraces, a high, an intermediate 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 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 the Iowa and

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The upermost or higest terrace is confined primarily to the Iowa river sector of the lake basin. It forms the higher of the two terraces following the Iowa 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 limited to the east side of the stream. Terraces presumably corresponding to this upper one are in Mud creek valley passing by Wilton Junction and 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" north of Iowa City and possibly north of Moscow along the Cedar river.

THE INTERMEDIATE TERRACE

Topography

Area.- The intermediate terrace forms the major por-


*162. In view of the fact that Udden's West Liberty Plain forms the major portion 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 feasible to consider this terrace first.
tation of the lowland in Muscatine and Louisa counties 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 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 form the two terrace remnants corresponding to the high terrace in the Iowa river sector of the basin. Furthermore, the western portion of the northernmost expansion of the Iowa river lowlands in Louisa county, lying west of Prairie creek in Oakland township and which constitutes the south end of the West Liberty Plain really forms the southern extremity of the upper or high terrace along the 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 the Cedar river which has incised its valley from 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 out of the twenty-two and one-half miles of its length, the terrace maintains an average width between four and three-fourths miles. On the west side of the 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 at least nine remnants. Of these remnants the largest 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 in few places exceeding one mile.

Although without slope apparent to the eye, the terrace has a very gentle dip to the south. Lying at an elevation of approximately 660 feet above sea level in the northern extremity, the surface of the plain slopes gently southward to the southern end of the terrace in Louisa county. Here, the terrace, eighteen miles from its northern end at West Liberty, 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 exception of the valley of Wapsinonoc creek, the few water courses developed on the terrace surface are more in the form of shallow ditches five to eighteen feet deep and from a few feet to a rod or two wide rather than well developed young valleys. The larger streams such
as the Wapsinonoc, Honey and Prairie creeks have developed wider sags, having on the average a width of one-fourth of a mile and a depth of twenty feet. To insure proper run-off on the plain, numerous irrigation ditches have been dug and tiling had to be resorted to. Although 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 by the symbol, Ks, Knox fine sand, as mapped by the United States Bureau of Soils on their map of Muscatine county.

In sections 12 and 13 of Goschen township and in section 7 of Moscow township, Muscatine county, are a series of sand dunes which not only occur on the terrace but which also cover the southeastern flank and a large part of the top of the island-like upland found at that place and previously described under the Kansan upland. The dunes here average about twenty feet in height.

**Boulders on the terrace.** At several places, large boulders lie scattered over the surface, as well as along the base of the escarpment of the terrace. At the base of the terrace escarpment in the northeast corner of section 7, Concord township, Louisa county, fifty or more large granite

boulders weighing perhaps on the average a ton each were noted. At this locality, the Cedar river flows at the edge of the terrace. It is also noteworthy to remark in this connection, that these boulders are but one-half of a mile west of the Illinoian bluffs. In the central part of section 34, Pike township, Muscatine county, a limestone boulder lies on the surface of the terrace and in section 3 of the same township many boulders 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, several granite and greenstone boulders have dimensions of one by one by one foot. These boulders are two miles east of the Illinoian upland. Udden also mentions the finding of boulders * near the south line of section 8, in Wilton township ------- and one near the center of the west line of section 2, in Moscow * 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 terrace 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 half

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of sections 3 and 10, is covered with dunes. Among the
dune ridges, as in the northwest one-quarter of the south­
east one-quarter of section 3, there are undrained depres­
sions 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 terrace is forty feet
above the intermediate terrace. The line of separation
between the high and lower terrace 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 to thirty-five feet. Everywhere else, the
terrace is separated from the bottomlands of the 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 escarp­
ment of the terrace in section 13, Goshen township, Musca­
tine 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
gravel, 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 primarily of sand, although gravel and clay were at times mentioned. The deepest well in the area of the intermediate terrace is at Nichols which is recorded to have penetrated at least 250 feet of unconsolidated material. The surface materials consist of fine yellowish to brownish or drab colored loess-like silt and sands the latter forming the sandy and dune areas previously described. Occasionally, a few scattered boulders are found dotting the terrace surface.

**Materials and structure.** Practically the only clue as to the nature of the materials composing the intermediate terrace is to be found in the terrace escarpments facing the Cedar river. Although the east facing escarpment of the modern valley of the 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

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could be ascertained from the few exposures seen, it appears that the terrace materials in the northern portion of the plain are finer and less disturbed than those farther south. The following section in the western escarpment wall near Terrace Materials, Section 8, Goshen Township, Muscatine County.

Feet In.

A. Loess-like 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 ............ 1
E. Fine laminated pebbleless clay or silt .......................... 1
F. White stratified fine-grained sand, containing some clay ............. 2
G. Fine laminated fine-grained sand, laminae one-fourth of an inch thick and of various colors as chocolate, brown, yellowish and white, exposed. 2
H. Slump .................................. 25

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. 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 thinly bedded. Some
cross-bedding and contortion of the beds occur as indicated by the lower bed No. H shown in the following diagram and section.

*Fig. 7. Diagram of exposure in the west terrace escarpment, southwest corner of section 13, Goshen township, Muscatine county. See the following section.

**Feet In.**

A. Brown sandy soil ................. 1 6

B. Brown medium grained sand, poorly stratified ......................... 3 10

C. Yellow light colored medium grained sand, stratified ............... 1

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 .................. 1/2-2
H. Thinly bedded layers of brown and light yellow sand. Contorted layers of an inch thick, exposed.... 2-3

I. Slump............................ 30

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.

Fig.8. View of terrace material showing the fineness of the deposit.

In all of the exposures so far indicated, the material described forms the upper portion of the cuts, the lower half or so being hidden because of the heavy slump. However, on the opposite bank of the river east of the outcrops in section 13, in a gulley four to five feet deep, in section 16, Moscow township, the sand is brownish in color and fairly coarse. Besides the sand, a gravel bed, four feet thick, consisting of 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 described exposures which portion 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 the 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 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 but four feet in elevation. The terrace at Moscow lies 654 feet above sea level and at Atalissa five miles farther to the west, the elevation is at 658 feet. This closeness of elevation suggests to the writer but one terrace. Furthermore, Udden mentions in connection with his discussion on Lake Calvin "riffles of boulders" in the bed of the river "at the old ford in section 36 in Goshen Township." Also "On section 32, in Orono township, the river cuts into the gravel on the plain bed." Thus it appears that the base of the intermediate terrace is composed of coarser and more gravelly deposits than that of the upper portion.

Following the terrace on the western side of the river southward from the cuts in section 13, the next exposure of terrace material is in section 26 of the same township. Here, as in the other sections, the sand is of a prevailing white color 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 a prevailing high angle of twenty-three degrees. See the following photograph. In this highly cross-bedded sand

![Fig. 9. View of the highly cross-bedded sands in the terrace in section 26, Goshen township, Muscatine county.](image)

there are numerous thin layers of pebbles, the largest of which have a diameter under one inch. In the exposure, a section of which follows, the uppermost cross-bedded sand No.D shows more irregularity in its structure than the
Terrace Material, Section 26, Goshen Township, Muscatine County.

Feet  In.

A. Very fine silty soil, at times peaty, appearance of hazy 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 ash 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 one-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.................................
lower bed No.G. Compare figures 9 and 10. 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 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 grained silt or sand 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 river 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 of a foot thick, overlying roughly stratified brownish-to red-colored, fine-grained sand. Several other exposures visited reveal similar sands and structures as described.

On page 361 of the Muscatine county report, 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. Considering elevation, it is found that the ter-

race at Moscow is at 654 feet above sea level and the intermediate plain at Atalissa but five miles to the west at 658 feet. The material described by Udden does not differ essentially from that of the intermediate terrace. Tracing the terrace 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 covered by a deposit of loess five to eight feet thick. Evidence of quiet water conditions is also seen 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.

<table>
<thead>
<tr>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Brownish pebbleless loess-like clay........... 5</td>
</tr>
<tr>
<td>B. Brownish ash colored silt or loess, extremely hard to hit into. Iron mottled and pipe stems................................. 5</td>
</tr>
<tr>
<td>C. Finely laminated ash colored silt, iron stained layers................................. 1-2</td>
</tr>
<tr>
<td>D. Fine almost fatty laminated brown silt, interbedded with an ashy silt.................... 1-2</td>
</tr>
<tr>
<td>E. Ash colored silt or clay, exposed to water level................................. 3</td>
</tr>
</tbody>
</table>

*Alden and Leighton in their report "The Iowan Drift"

indicate that some of the deposits of the terrace along the Cedar river south of Rochester "may have resulted from slack-water during the Illinoian stage."

THE HIGH TERRACE

The high terrace.- The presence of at least two terraces in the Iowa river sector of the lake basin had been noted as early as 1891 by McGee. However, from the map showing the surficial formations of northeastern Iowa accompanying McGee's classic monograph on the Pleistocene 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." Of the two terraces, the former description applies well to the high terrace of this report, for it lies about sixty feet above the river and also takes in 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 'ter-


race ' rather freely, for but two terraces, the high and the low, occur along the 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." that Calvin did not recognize two systems of terraces. No description of the upper one is found in his report and by comparing his superficial map with one showing the two sets of terraces as mapped by the writer, it is evident that at that time when 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 the 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 widens out until a maximum width of almost six miles is attained, three miles south of the two mentioned villages. Still farther to the south, due to the encroaching of the Iowa river, the terrace restricts to a narrow neck less than one-half of 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 forming the flood plain of a small tributary of the 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 one-half of a mile wide. In the vicinity of Iowa City the terrace has a width of three miles.

On the west side of the Iowa river, the high terrace is not continuous, but occurs as small isolated remnants, the largest one of which is in the valley of Old Mans creek, occupying portions of sections 4, 5, 9, 15 and 16 of Liberty township and sections 31 and 32 of West Lucas township. Its average width is between one-fourth and one-half of a mile and its length 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 the Iowa river to the city park at Iowa City; (2) on both sides of the 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, on the average thirty feet high. Near Iowa
City it lies sixty feet above the Iowa river, fifty feet in the vicinity of Hills and thirty-two feet in section 16. Oakland township, Louisa county. With an elevation of 680 feet in the vicinity of Iowa City the terrace gradually becomes lower reaching a height of 670 feet near Hills six to seven miles farther to the south, 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, it is apparent that the surface of the terrace has a much gentler slope, one and four-tenths of a foot 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 peninsular-like extension of the main terrace in sections 1, 2, 11 and 12, Pleasant Valley township. Sand dunes bordering the terrace margin south of River Junction are of common occurrence.

Topography. - The most remarkable feature of the high terrace is its exceedingly straight border or escarpment where in contact with the low terrace. Where the flood plain of the Iowa river abuts against it, as south of River Junction, the border is marked by numerous large irreg-
ularities common to regions bordering courses of meandering streams. This straightness of the terrace margin where not in contact with the lower terrace is 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 sections, a northern and a southern one, the former including the area lying between Iowa City and about the latitude of Hills, the latter comprising all of the plain to the 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. 11. View showing the flat surface of the high terrace in section 25, East Lucas township, Johnson county.](image)
The topography of the southern section is gently undulating. Compare fig. 11 and fig. 12. Its surface is marked by low linear and short elevations which in sections 13, 18, 19, 24, 25 and 36 of Pleasant Valley township rise from twelve to fifteen feet above the general surface. The elevations wherever cut by roads reveal a fine grained sand without pebbles and undoubtedly are dunes. Numerous undrained depressions, many of which are marshy and some of which contain ponds, were noted to dot 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 northwest-southeast projection of Kansan upland. Closer examination, however, revealed the

Fig. 12. View showing the gently undulating topography of the high terrace, section 19, Pleasant Valley township, Johnson county. Compare with fig. 11.
fact that the surface really consists of a series of broad and low, linear, mound-like elevations between which are undrained depressions. The material, as seen in the road and in the farmyard of the farm 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 Pleasant Valley township, the undulations are more pronounced, the dunes having a height from thirty to forty feet. Ponds between the undulations are in evidence. Most of the dunes are not migrating but are under cultivation and at places covered by groves of trees whose diameter measure as much as one and one-half feet. In general the undulations trend east to west.

South of the Rock Island and Pacific Railway tracks between River Junction and Lone Tree, a similar topography prevails. The impression gained on viewing the topography is that the plain is the Kansan upland sloping gently west and southwest. This impression is strengthened by the fact that the barometric elevations show that the region slopes gently in these directions. Due to some agent, the gentle upland slope was modified, giving it the undrained-depression type of topography. This same impression is gained where the high and intermediate terrace come in conjunction 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. 13. Toward the top of the ridge, the road crossing it is very sandy. To the south, the region lies from forty to fifty feet lower, rising however, to the same height again at the edge of the terrace one mile distant. This knoll appears to be the terminus of a high fringe 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 the Iowa river, with one exception. 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 portion 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 varies 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 to forty feet between the two surfaces.

On the west side of the Iowa river, the larger terrace remnant in the valley of Old Mans creek is separated from the river's flood plain by a steep bluff of forty-eight feet or 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 lowe terrace.

MATERIALS AND STRUCTURE OF 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 loess-like clay, averaging four feet in thickness. Sections are extremely few in number in the northern part of the plain. In the southwest one-quarter of section 24, East Lucas township, a few feet of horizontally bedded silts are exposed. Along Snyder creek, ten to fifteen feet of fine, horizontally stratified sands appear in the north bank of the creek at the crossing of the road between sections 36 and 31 of East Lucas and 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. 14. The section follows.

Terrace Material, High Terrace, 2½ miles East of Hills.

A. Loess-like clay.............................. 2-3

B. Extremely fine-grained, yellow to brown colored sand or silt. Stratification essentially horizontal, somewhat wavy. Lamination fine, lithological constituents uniform. Exposed.................. 3-7
Fig. 14. 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.

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 exposure east of Hills. From the outcrop in the south bank of the creek in the northeast quarter of section 31, it appears that the terrace is composed entirely of this fine-grained, laminated material. Here, the twenty feet of sand is exposed to within two to three feet of the top 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.
But 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 gulley 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.

<table>
<thead>
<tr>
<th>Feet</th>
<th>In.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Brown to reddish colored fairly coarse grained sand, grading into a whitish to grayish clay or silt, leached and structureless.</td>
<td>17</td>
</tr>
<tr>
<td>B. Reddish to brownish black gumbo-like material, sticky when wet, practically free from grit. Material thoroughly leached. Surface uneven.</td>
<td>0-13</td>
</tr>
<tr>
<td>C. Buff to ash colored clay, gritty, pebbleless leached, exposed.</td>
<td>2</td>
</tr>
</tbody>
</table>

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

![Diagram showing the relation of the gumbo-like material, B, to the material A and C.](image)
the terrace at this locality is thirty-two feet above the
flat to the east and the black sticky material, B, fifteen
feet. A similar gumbo-like clay outcrops one hundred yards
to the southeast at practically the same level. Also the
well log at the house 200 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 one-half
of 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. Here similar leached sands and clays
as those seen at the first locality are exposed. The lay­
ers 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 con­
structed. A deposit of four to five feet of loess-like
clay lies over the sands of which four feet are exposed.
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 is also more in evidence in the coarser material. It was noted that the cross-bedding is fine and variable in direction. It is worthy of remark, that the material is of low textural range, large pebbles being absent entirely. These cross-bedded layers are interstratified with the finer horizontally bedded material which predominates. A typical section follows:

Terrace Material, High Terrace, Southwest Corner,
Section 24, Fremont Township, Johnson County.

Feet

A. Loess-like 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 highly cross-bedded, cross-bedding fine; 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 boulders 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, fig. 16. In connection with the gravels, cobbles and boulders seen at the various exposures along the bank of the Iowa river lying between the stratified materials and the till, it was noticed that a fair proportion are flat
or slab-like. Not only is this true of the softer local limestone, but also of the harder igneous material. See fig. 17.

Fig. 17. View of the slab-like igneous boulders lying on the surface of the till and beneath stratified terrace deposits in section 23, Iowa township, Washington county.
THE WILTON VALLEY TERRACE

Area and topography.—According to Udden, the terrace along the course of Mud creek passing by Wilton Junction to Durant is a northeast extension 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 connected, as illustrated below, 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 past Durant. The terrace is well defined. Its

Fig. 18. Diagram showing the interrupted profile of the surfaces of the Wilton Valley and Intermediate terraces when connected.

---

surface is flat (see fig. 19) and not obscured by sand dunes. In width, the northern portion averages one-half of a mile, whereas to the south of the creek the terrace is from three-fourths to one mile wide. Its surface which lies from thirty to forty-five feet above Mud creek meets the valley walls in a gentle slope.

**Materials and Structure.**

**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:

A. Loess-like clay

B. Stratified sand, usually fine grained
C. Finely laminated silts or clays

D. Stratified sand, becoming more gravelly as traced westward

The deposits seen in the various outcrops are of such a uniform character that they may be represented by the following two 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 one-quarter of the northwest one-quarter of section 3, Wilton township, three miles east of Wilton Junction. At this place, Mud creek makes a sharp 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's level. Figures 20, 21 and 22 illustrate the materials at this place.

Fig. 20. View showing the finely laminated silts exposed in the Wilton Valley terrace, in the SW_1/4, NW_1/4, section 3, Wilton township, Muscatine county.
Fig. 21. Detail of laminated silts shown in Fig. 20.

Fig. 22. View showing the laminated silts of Fig. 20 exposed to within a few feet of the terrace surface.
The section is as follows:

**Terrace Material, Wilton Valley Terrace, SW. 1/4 NW. 1/4 sec. 3, Wilton Township, Muscatine County.**

**A. Loess-like clay................................. 1-5 Feet**

**B. Fine grained thinly-bedded yellow sand above the finely laminated silts or clays, laminae 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 fig. 22 shows, are in evidence.

The section typical of the terrace material in the western half of the valley is shown in the following photograph, fig. 23. 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 above the creek and the outcrop twenty.

Terrace Material, Wilton Terrace, Western half, sec. 11, Moscow Township, Muscatine County.

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

Terrace remnant in Cedar county.— A remnant of what appears to be a high terrace is in sections 13, 14, 23 and 24 of Iowa township, Cedar county on the west bank of the 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 the Cedar river. No exposure in it was seen and the only clew as to the nature of its material and structure is inferred from its sandy surface and an exposure of bedrock in the creek bed in section 14 where the bluffs of the upland and high terrace meet. This suggests a rock terrace partly covered over with loose sandy deposits. The upland is but one-half of a mile to the west of the
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 traced up the two mentioned creeks very readily. The creeks 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 in contact with the lower terrace. This terrace is Udden's*177 other extension of the West Liberty Plain.

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. In sections 29 and 30 of Scott township, Johnson county, the terrace

elevation 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 the 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 the English river lie at approximately 640 feet, which is also the approximate elevation of the terrace east of the Iowa river at River Junction. Thus, it seems that in so far as elevations are concerned, there appears to be 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 the Iowa river or somewhat less above the bottom-lands and from twenty to forty feet below the high terrace. Where 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 the Iowa river. Along the stream courses of Old Mans creek and the English river north of Iowa City,
the terrace is represented by "mere remnants at the bends
"178
of" the Iowa river. These ' mere remnants ' have been
*179
described by Leighton 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 Coop Falls.

3. On the north side of the bend of the Iowa riv­
er 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
one-quarter of section 32, township 81 north,
range 6 west.

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

South of Iowa City, the terraces are better developed
and of greater dimensions. One-half of a mile south of
the Iowa City limits in West Lucas township, the terrace
has a width of one and one-fourth miles and on the east
side of the river in East Lucas township, sections 34, 35
and 36, a width approximating two miles is reached. How­
ever, the average width of the low terrace in the Iowa river
valley is less than two miles, varying between one-fourth to

*178. Alden, Wm., and Leighton, Morris M., The Iowan

1914.
three-fourths of a mile. In the valley of Old Mans creek, the terrace maintains an average width of about one-half of a mile and along the course of the English river about one mile. In these two valleys, the terrace attains its maximum length of ten and seventeen miles respectively. Two insignificant remnants, one on each side of the river, are at the intersection of Johnson, Louisa and Washington counties. It is possible that the low terrace is represented along the Cedar river north of Cedar Valley, Gower township, Cedar county.

Topography, Materials and Structure

Topography.— The surface of the low terrace is flat except where interrupted by occasional and shallow gulleys 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 textural range and consist predominately of sands with extremely little silt or clay. In structure there is also a difference. Whereas the high and intermediate terraces are thin 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 one-quarter of section 33. The outcrop is in the east bank of a slough of the 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 at approximately 640 feet above sea level.

2. Johnson county, Liberty township, central part of the northeast one-quarter of section 27, one and one-fourth mile south of Hills. The materials are in the west bank of the Iowa river.

3. Washington county, Iowa township, northeast corner of the northwest one-quarter of section 23. The exposure is in the southwest bank of the Iowa river.

A composite description of the three outcrops follows. The upper three to six feet consist of a loess or a brownish loess-like clay which overlies a fine to medium grained sand highly cross-bedded, having a predominant dip to the south. Numerous small granite, chert and limestone pebbles one inch in diameter are scattered through the sand whose thickness ranges from two to four feet. 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 is also cross-bedded and peppered with little pebbles. Its thickness is three feet. Beneath the white sand is a coarse, brown-colored sand containing numerous pebbles measuring 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 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 soon pinch out. Some horizontal as well as irregular or wavy bedded layers occur throughout the deposit. Beneath the stratified material which is exposed to 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 boulders a large proportion of which are slab-like. See fig. 17, page 140. 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 one-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 surface of the terrace is fifteen feet above the flood plain of the Iowa river and is about one-eighth of a mile wide. A diagram and section follow:

Fig. 24. Diagram of the terrace materials seen in the low terrace in the SW\text{\small{4}} of section 34, West Lucas township, Johnson county.
Terrace Material, Low Terrace, Southwest One-Quarter, Section 34, West Lucas Township, Johnson County.

In.

A. Darkish colored sand peppered with pebbles or small gravel, some well rounded. Occasionally, large pebbles are found. Lower surface somewhat irregular................. 6-15

B. Coarse lighter sand 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 one-half of which is blackish and contains occasional pebbles, lower half is 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 about fifty per cent of limestone; textural range high, varying from small sand grains to coarse boulders nine by six by four inches. Many of the gravels are in the form of slabs or shingle. Some of the limestone slabs are from one-eighth to one-fourth of an inch thick and six to seven inches in length and four inches wide. This slab-like form is not confined to the limestone alone, but 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 reveals 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
when 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 varying distances below the terrace surface, generally, not very far beneath it, however.

THE FLOOD PLAINS OF THE LAKE BASIN

The flood plain of the Cedar river.- The flood plains of the two master streams are of varying width and height below the level 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 the 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 constricts to one and one-half miles. This width is maintained to two miles north of the Muscatine county line from which point to the junction of the Iowa and Cedar rivers, the flood plain is no wider than one-half of a mile. In the northern portion of Muscatine county in Goshen township, the bottom lands lie from thirty-seven to forty-three feet below the intermediate plain. As the flood plain is traced southward, its surface lies correspondingly higher in relation to the terrace as is shown by a vertical difference, ranging from thirty-two to forty feet. Traced still farther to the south, the difference between the surface of the intermediate terrace and the flood plain is lessened still further, being twenty-seven feet in Orono township and finally in Louisa
county but twenty feet. The flood plain in turn lies on the average five to seven 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 plains of the Iowa river and its tributaries.- The flood plains of the Iowa river and its tributaries are in all respects similar to that of the Cedar river. The bottom lands of the Iowa river are on the average twenty feet below the surface of the low terrace and from thirty-two to forty-eight feet lower than the high terrace in the valley of Old Man's creek and from forty to forty-five feet near River Junction. At other places, in sections 24, 25, 31 and 32, Fremont township, Johnson county, heights varying 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 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. Of these, 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 surrounded by the high terrace and on the north and east by the intermediate plain, whose surface lies on the average thirty to thirty-five feet higher. 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 crescentric ponds or lakes dot its surface, one in the northwest corner of section 13 and adjoining parts of sections 12 and 14, the other occupying the southeast corner of section 15, the southwest corner of section 14 and the northwest 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. Then the bottom lands become narrower, maintaining at first a width of one and one-half miles, then one mile and finally at Iowa City scarcely one-eight of a mile. South of River Junction, the flood plain is two and one-half miles across, becoming suddenly constricted to one-half of a mile in sections 25 and 26 of Iowa township, Washington county. Farther to the south of these two sections the flood plain widens again 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 to the junction of the Iowa with the Cedar river, the bottom lands vary from one-third to one mile. The flood plains of the tributaries of the Iowa river are insignificant and need no further comment.
CHAPTER VI

EVIDENCES 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, 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

To these may be added several others as for instance, ice-rafted boulders, boulder 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 has never been presented. Udden's work was confined only to Muscatine county and the evidences cited by him in his report on

Lake Calvin do not establish the certainty 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 strips in the channels of an aggrading stream perhaps no larger than the Cedar of today." 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."

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

sheet (fig. 25) the waters of the Mississippi were dammed back as far as the Maquoketa river from whence

Fig. 25. Sketch map showing the blocking up of the Mississippi and lower portion of the Wapsipinicon river valleys. (Modified after Carman)

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 leads southward for over nineteen miles to the valley of the Wapsipinicon river. Due to the ice barrier closing the mouth of that river, the

combined waters of the 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 and finally into the Cedar river at Moscow. From here the four streams pursued a southerly course to Columbus Junction, Louisa County where the Iowa river added its that of waters to the others. Obstructed on the east by the ice wall of the Illinoian glacier and on the other sides by high Kansan bluffs the waters again being dammed back must have risen until the abandoned channel dis-

covered and mapped by Leverett was reached. As shown by Leverett 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 the Mississippi river during the Illinoian stage of glaciation followed the course just outlined is not disputed. That the ponding back of the combined waters of the Mississippi, Maquoketa, Wapsipinicon, Cedar and Iowa rivers together with that of the melting ice sheet necessarily gave birth to a quiet


body of water in the lake basin area or that aggradation kept pace with the increasing influx of water so that the 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 as shown by its deposits indicated on Plate III, the Mississippi, Maquoketa, Wapsipinicon, Cedar and Iowa rivers with their tributaries were blocked on the 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 back is evident. The question arises would this ponding back of the streams 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 the melting ice sheet. Furthermore, most of the aggradation must be attributed to the melting Illinoian ice itself, 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 deposits? It is a fact that the Ill-
inoian 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 diminishing in thickness of the ice would necessarily mean a minimum amount of glacial erosion and hence 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 the ponding back of the waters to form a lake is illustrated in the case of Lake Pepin, Wisconsin. Lake Pepin is an expansion of the Mississippi river. It is from one 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 caused by the ponding back of the Mississippi river as a result of the building up of a delta at the southeast end of the lake by the Chippewa river. This river having a higher grade than the Mississippi is able to carry more and coarser material than the master stream is able to remove. If the partial 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 up of the Iowa-Cedar river valley by the Illinoian ice sheet would necessarily give rise to Lake Calvin.

Thus it appears to the writer that the mere ponding back of the combined waters of the Mississippi, Maquoketa, Wapsipinicon, Cedar and Iowa rivers would 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 topography or in the nature of the sediments found in the inlet. The only possible inlet of the Mississippi river to Lake Calvin could have been 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 varies in width from one and one-half to a little over two miles. It unites with the large valley of the 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 from 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 primarily 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

Neither constricting nor losing its identity, the valley in which Elkhorn creek flows continues its course northeastward over the very gentle divide into the valley of Mud creek. 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 then follows the course of Mud creek for over nine miles to the 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, increasing somewhat in size toward its mouth where it is from four to five rods wide and from six to seven feet below the valley floor. Because of its extreme youth, exposures are not to be had along its course. Outcrops are also lacking on the valley slopes 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."

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. Neither is such evidence lacking. Following the Wapsipinicon river valley east for about fifteen miles from the debouchure of Mud creek is a well defined valley which can be traced northward through Clinton and Jackson counties as far as Spragueville where it unites with that of the Maquoketa. In many respects this old valley, termed the Goose Lake channel and first described by McGee, 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 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 pursuing Deep creek. The divide between the two creeks is in sections 4, 5 and 32 and 33 of Center and Deep Creek townships respectively, 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 being very shallow and but a few feet wide. Goose Lake channel, fig. 26, is by far more pronounced than Mud.

Fig. 26. View of Goose Lake channel in Jackson county.
creek valley. Its valley walls especially in the northern half are cut into bed rock and rise from seventy to two hundred feet above the valley floor. Towards the southern end of the valley, the bluff is lower to twenty-five feet or so. 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 the horizontally stratified sand covered by two feet of loess are exposed. In the southeast corner of section 13 just north of Spragueville in Jackson county several feet of laminated silts and sands are exposed. Immediately north of Preston, the south bank of the creek shows brown clay containing innumerable chert chips and pebbles. This clay, one to one and one-half feet thick, overlies fine grained, thinly bedded, yellowish to brown, 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 *191 to 80 feet deep do not reach rock.*

From the mouth of Deep creek to the Mississippi river, the temporary Mississippi followed the rock

bound gorge of the Maquoketa river. The course of the Mississippi river during the Illinoian times is shown on Plate X.

**Interpretation.**—The nature and structure of the silts and laminated clays exposed in Elkhorn valley in the vicinity of Wilton Junction practically also precludes contemporaneous aggradation. As shown before, the terrace materials consist of fine horizontal laminated silts and clays without the presence of coarse sands, gravels or boulders. It is practically impossible to assign such deposits to fluvial influence. The fine lamination of the deposits at places 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, the coarsest material would be expected to be laid down. Large boulders lying on the terrace surface are practically lacking, except those located by Udden in sections 8 and 11 of Wilton township and in section 2 of Moscow township, Muscatine county. In speaking of these boulders Udden states that they were "in all probability, transported by floating ice on the surface of the lake at an early

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Plate X

Map showing the course of the Mississippi river during Illinoian times.
stage, when the waters stood high, and were probably stranded on the shore." To the investigator, the laminated silts and clays positively argue for lacustrine conditions.

The fact that a continuous valley, partly occupied by streams and partly abandoned, can be traced from the lake basin to the Mississippi river by way of the 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 distinctively traceable over two stream divides. A better inlet to the lake could not be asked for.

THE TEMPORARY MISSISSIPPI CHANNEL OF LEVERETT.

Discussion.- Of greater importance as a criterion of extinct glacial lakes is the outlet. As early as 1896 Leverett discovered an abandoned channel between the Illinoian and Kansan uplands in Louisa county. This channel outlined on Plate XI 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

Map showing the course of the Mississippi river south of the lake basin during Illinoian times.
Iowa, about 6 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 from Winfield, the channel along Crooked Creek being about three-fourths to 1 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 1 mile. The most extensive remnant of the abandoned channel is found in the double oxbow 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, 8 miles south of Rome, the old valley, as noted above, leads southeastward across Lee County to the Mississippi Valley at Viele, 6 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 **194 to be one-half a cubic mile.**

This ancient valley of the Mississippi is incised below the general upland surface of the Kansan drift plain from thirty to sixty feet. The valley floor rises

120 feet above the level of the Iowa river and lies at an elevation of about 700 feet above sea level in the vicinity of Columbus Junction. Its general width varies and from one to one-quarter to one and one-half miles.

The valley is well defined but becomes 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 from thirty-five to forty feet below the general upland level, see fig. 4, page 89.

Several miles south of Columbus Junction bed rock appears in the valley walls and that portion along the Skunk river is largely cut into solid rock. Unusual deposits of sand and gravel are lacking in the channel.

**Interpretation.**—The absence of any notable deposits of sand or gravel in the temporary Mississippi river channel of Leverett also seems to be in opposition to a fluval hypothesis. If the filling up of the lake basin is due to stream deposition 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 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 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 sediment 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 it is not 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 the 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 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 fineness of stratification. Laminated silts or clays, however, are practically limited to the valley of Mud creek passing by Wilton Junction. In a distance of five miles, commencing one mile west of Wilton Junction to a point four miles east of the town, eight good outcrops of terrace materials are to be had. As 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 or clays whereas in the western 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 140, see fig. 20, were laid down under quiet water conditions. In the type outcrop, practically thirty-four feet of laminated silt or clay is exposed. Pebbles are lacking entirely and
the stratification is horizontal and undisturbed except for a few minor wavy undulations. Other laminated deposits are seen in the high terrace two and one-half miles east of Hills, see fig. 14, page 136 and 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 thicknesses of these deposits exposed 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 primarily 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.

More detrimental to alluvial deposition than the texture of the sediments is the structure. It is difficult to account for the general horizontal stratification over such a wide extent as found in the lake basin on the basis of stream deposition. In sharp contrast to the general horizontal stratification of the high terraces
are highly cross-bedded sands and gravels of the low terrace. From the nature of these deposits, their texture and structure and from the fact that the low terrace can be traced to the Iowan drift plain, the low terrace is without doubt of glacio-fluvial origin. 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, 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 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, intermediate and 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 other. On the other hand, the fineness of the deposits and the general horizontal stratification can well be accounted for on the basis of a lacustrine hypothesis.

TERRACES IN THE LAKE BASIN.

Discussion.—Whether a lake plain can be differentiated from a stream terrace on the basis of topography
after dissection has progressed is not evident. Over a long distance, the surface of the lake floor may be more level or have a lower gradient than that of an alluvial terrace, yet it does not follow that this need to 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. At numerous places in Johnson county, the high and low terraces are in contact, being 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 from thirty to forty 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 the 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 pages 147 and 148, 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. That the low terrace in Johnson county is not represented by the intermediate terrace in Muscatine county is evident from a comparative study of their materials, structure, as well as of
elevations. Without doubt, the low terrace is of fluvial origin probably being 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 much lower than that 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 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. 27. Sketch map showing location of two typical outcrops; 1, alluvial; 2, lacustrine.

Exposure 1 is in the low terrace and outcrop 2 in the high terrace. Whereas the material of the high terrace is extremely fine sand or silt, horizontally bedded, the deposit of the low terrace consists entirely of a fine to medium, white to gray and brown, heterogeneous sand containing numerous pebbles, having a medium textural range. Most of the sand is cross-bedded with cross dip at an angle varying 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. The gravel layers do not only dip in all directions but 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 extreme 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 plain. From the elevations obtained, the gradient of the former plain is 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 too 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 of materials, texture and structure between either the high, the Wilton Valley or the intermediate terraces and the low terrace is made, it is apparent that the conditions under which they were formed were different.

Interpretation.- On the basis of three distinct ter-
faces, many hypotheses may be advanced to account for their origin, depending upon whether the terraces 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 to the Cedar river sector.

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 and Wilton Valley terraces 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 compares very favorably with them in so far as materials and structure are concerned, differing, however, 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
in of a lake ought to be uniform and hence but one set of terraces is all that 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 is determined by the number and size of the inflowing streams, the lake floor need not necessarily have the same elevation. 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 varied 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, 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 sector of the lake basin whereas the intermediate terrace occupies the eastern or
Fig. 28. Diagram showing how the depth and the slope of the lake bed may influence differential elevation of the deposited lake floor, the amount of material being equal.

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 gradual gradation between bluffs and the 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 fine 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 was probably formed into sand dunes which encroached upon the bluffs and thus causing the less well outlined bluffs
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 III shows at once that the Iowa river arm of the lake basin receives not only the greatest number of affluents but also the largest. Receiving the largest and the most tributaries, this portion of the lake naturally should receive the greatest 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 northern 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, the terrace is also 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 the 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 the Cedar river to be dammed up more than the lake basin itself. Such a ponding up
of the river may have resulted in a lake having been 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 covered to a large extent by sand dunes. The age of this youthful appearing supposedly Kansan area has been questioned by Leighton. 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 and in the valley slopes of the two arms of the lake basin together with a greater supply of sediments being brought to certain portions of the basin readily explains the differential elevation of the lake bed. Thus the high and intermediate terraces may be considered as having been formed contemporaneously on the supposition that Lake Calvin existed. If the two terraces were formed at the same time shouldn't the intermediate terrace be less cross-bedded and be made up of finer materials than the high terrace? Study of terrace materials shows that portion of the high terrace south of River Junction is crossbedded, 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 and Clear creeks are smaller and

*196. Personal communication.
and thus not able to carry such coarse materials as English river. Furthermore, 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 boulders 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. Again, the same writer states: “The high stage of the lake must, however, have been of short duration, for the boulders 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.” 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 inter-
mediate terrace contains the coarser materials of the two.
In the early stages of the lake's history, especially when
the ice sheet still occupied the region, the most and coars-
est deposits would naturally be deposited. As time elapsed
and the glacier had retreated from the region, finer and
finer as well as less materials were brought to the lake. These
latter deposits may constitute the sediments of the high ter-
races which were built out as deltas into the lake. It is
a noteworthy fact that the high terraces are located wherever
streams empty into the lake basin at the present time. In
that case, the formation of the high and intermediate ter-
races will still have to be considered as having been formed
contemporaneously.

That the high terraces represent the lake's history
during the time that the outlet of the lake was by way of
the abandoned Mississippi channel of Leverett and the inter-
mediate terrace, 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 wide-
spread and 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. Indi-
cations, 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 abandoned channel until the advent of the Iowan ice incursion. 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 remain 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 XII. 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 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 advent of the Iowan ice invasion 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 a sinuous escarpment as the terraces bordering the present Iowa and Cedar rivers have. While the stream was still in its 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
Map showing the difference in the escarpment of the high terrace where in contact with the low terrace and the flood plain.
river due to the overloading of the stream with sediment coming from a new source of supply of sediments. Thus a new flood plain was developed. As soon as the ice had retreated, the stream finding its supply of sediment cut off, 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 where the two are contiguous. The irregular escarpment of the high terrace is found only at those places where the river has removed the low terrace and 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. There are at least five feet of a gumbotil which were formed before Lake Calvin could have been drained by any other outlet than by that of the abandoned channel south of Columbus Junction. Along both sides of the Iowa-Cedar and Mississippi rivers, Illinoian gumbotil outcrop. 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 is out of the question. That erosion since the lake was drained has removed most of the high terrace does not seem plausible. In the first place, why shouldn't more of the high terrace in the Iowa river arm of the lake have been removed then? Then too, field relations do not warrant such a supposition.

It therefore appears to the writer that there is no way of escape the conclusion that the high and intermediate terraces are contemporaneous in origin. Therefore they must be lacustrine, as exact contemporaneity 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 made from a study of the terrace materials irrespective to either the lacustrine or alluvial hypothesis. The low terrace is confined to the Iowa river sect-
or of the lake basin whereas the intermediate terrace
lies practically only 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 from ten to
twenty-five feet higher than the low terrace as may be
seen from the following table. However, a difference

<table>
<thead>
<tr>
<th>Latitude</th>
<th>Low Terrace</th>
<th>Intermediate Terrace</th>
<th>Diff, Elev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hills</td>
<td>640</td>
<td>665</td>
<td>25</td>
</tr>
<tr>
<td>Iowa Jc.</td>
<td>628</td>
<td>638</td>
<td>10</td>
</tr>
</tbody>
</table>

Table showing the elevation of the low and inter-
mediate terraces at places of the same latitude.
in elevation does not in itself disprove contemporaneity
of origin. A study of terrace materials, their texture,
stratification and structure, is the more important fact-
or in determining whether the low and intermediate ter-
races have had a common mode of origin. As shown in
chapter V, and 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 strati-
fication is, as a rule, fine and horizontal and the
pocket and lens type of structure is inconspicuous if
not wanting entirely. On the basis alone of deposits,
the terraces are undoubtedly not of the same origin and
together with the fact that the terraces do not have the same elevation at places of the same latitude, the foregoing conclusion is materially strengthened.

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 sets 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 alluvial as on the lake hypothesis, there is no need for a further discussion of the terraces.

A combination of a 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 outstanding 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 Plate XIII brings out the fact that the former is by far more regular than the latter. The valley along the 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 straightness of the bluff lines both being cut into similar materials?

Normally at the junction of two stream valleys a projecting spur is found, such as are illustrated in A of Plate XIV. 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 almost invisible curves or rounded bluff lines. Granting that in exceptional cases such a bluff line may be developed by stream erosion, nevertheless, 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. On the supposition that the
Comparison of bluff lines in the Lake Calvin region.
Diagrams showing the type of spur developed at the junction of two normal stream valleys in Harrison and Monona counties, A, and in the Lake Calvin Basin, B.
river was overloaded and therefore was aggrading its valley, the meandering of the stream must have been cutting somewhat into the bluffs and eroding them by lateral planation thus giving rise 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 Plate XIV. The absence of the normal type of projecting spur in the lake basin very strongly indicates other agencies than running water to have effected the bluffs. A single case of a rounded bluff line at the junction of two valleys may be conceived to have been formed by the action of running water either due to the meandering of the streams followed by piracy or by the development of tributaries and piracy. A case in the process of development illustrating the latter method is at Capitol Hill at Des Moines, Iowa, see fig. 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 Plate XV. But when the majority of bluffs at the junction of streams show almost invisible curves, the hypothesis of stream work has to be abandoned. Furthermore, when the bluffs on either side of the river, as illustrated in the following diagram, are of the rounded type, stream work as
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.
Fig. 29. Sketch map showing the rounded bluff lines on both sides of the English river.

the agent loses much of its plausibility.

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 invisible curving type of bluff line practically amounts to positive proof of the existence of a former lake in the lake basin.

BOULDERS IN THE LAKE BASIN.

Discussion.— Boulders anywhere within the borders of the lake basin are extremely few. The following is a list of locations where boulders were found.
Louisa county

1. Oakland township, SW\(\frac{1}{4}\), SW\(\frac{1}{4}\), sect. 11, base of terrace.

2. Oakland township, SW\(\frac{1}{2}\), NW\(\frac{1}{2}\), sect. 14, top of terrace.

3. Oakland township, S central edge of sect. 9, base and top of terrace.

4. Concord township, NE corner, sect. 7, base and slope of terrace.

Muscatine county

5. Pike township, NE corner, of sect. 7, top of terrace.

6. Goshen township, SW\(\frac{1}{4}\), central part, sect. 34, top of terrace.

7. Pike township, NE\(\frac{1}{4}\), sect. 3, slope of terrace.

8. Pike township, NW corner, NE\(\frac{1}{4}\), sect. 3, slope and base of terrace.

Except for localities 1, 2 and 3, the boulders are within four and one-half miles from the Illinoian bluff line and the greatest number and largest are found but one-half of a mile distant. Boulders at 1, 2 and 3 are from seven to eight and one-half miles from the same bluff line. The boulders are mainly of the granitic type, although two are of limestone and one is greenstone. They vary in size from those having a dimension of 1.5 x 1.5 x .5 feet to those weighing a ton or more. In every case, the boulders are associated with the intermediate terrace, either lying on its surface as those at 3, 5, 6 and 7; or on its escarpment slope as at 2, 4, 7 and 8, or else at its base as at 1, 3, 4 and 8.

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

1. Alluvial material
2. Outwash from the Illinoian ice
3. Ice-rafted boulders floating down a stream
4. Ice-rafted boulders floating on a lake
5. These boulders 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 boulders in the lake basin, the first, fifth and sixth may be set aside after brief considerations. That the boulders do not owe their position and location to ordinary alluvial conditions seems to be apparent when one considers the juxtaposition of the few large and scattered boulders on the fine materials of the terraces. If the streams were able to transport a few boulders a foot in diameter to those weighing about a ton 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 boulders on fine sand demands another hypothesis than that of ordinary alluvial conditions. That the boulders are not the outcropping of an underlying till is clearly proven in most cases by the fact that many of them lie on the terrace surface or slope which is known to consist of stratified materials. In cases where the boulders 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, at other places well records show a depth of over 250 feet of sands and gravels before reaching the till. Unfortunately well records in the lake basin are few and scattered.

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

The fact that the largest boulders 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 boulders are best explained as ice-rafted boulders either floating down a river or on a lake, reaching their present position by the melting and the stranding of the ice bergs. From what has been said before regarding the terrace materials and from the fact that many of the boulders 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 boulders as being brought to their final resting place by debris laden ice bergs floating on a lake than by any other method.

CERTAIN GRAVEL DEPOSITS IN THE LAKE BASIN

Discussion. - At numerous places along the course of the Iowa river, gravels are exposed. In practically every case, the gravels rest on a bluish to black till 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 boulders are flat or slab-like rather than possessing the characteristic subangular form of ordinary glacial material or the rounded shapes of fluvial deposits. This shingle-like form is not limited to the softer sandstone and limestone but also to the more resistant varieties of rocks as cherts, granites, basalts, etc. and to rocks of all sizes from an inch or two in diameter to boulders measuring over a foot or so. In this connection it is important to remark 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. At the following places gravels having the typical shingle-like character are found:
1. Washington county, Iowa township, sec. 23; ½ mile from bluffs

2. Johnson county, Freemont township, sec. 24; ½ mile from bluffs

3. Johnson county, Freemont township, sec. 25; ½ mile from bluffs

4. Johnson county, West Lucas township, sec. 34; ½ mile from bluffs

5. Johnson county, East Lucas township, sec. 27; 1 mile from bluffs

6. Johnson county, Liberty township, sec. 27; 1 mile from bluffs

In the abandoned railroad gravel pit in the southwest one-quarter of section 34, West Lucas township, Johnson county, the shingle does not rest on till but is interstratified between two sands of the low or Iowan terrace. The gravel bed is from twelve to twenty-four inches thick, consists primarily of limestone and the pieces vary in textural range from small sand grains to boulders nine by six by four inches. The slab-like form, however, is not confined only to the limestone, but is found also on the cherts and basalts. The Kansan bluffs are but one-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 have attained their characteristic form before having reached their present position.

Interpretation.—It is a well known fact that gravels found along the beaches of lakes or sea coasts often possess a slab-like form and show an arrangement similar to that of
shingles on a roof, from which the deposits have received the term 'shingle.' From the fact that the gravels are of this type, and that the shingle character is not confined to any one kind of rock, but to all whether resistant or non-resistant, to igneous or to sedimentary, and 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 to the continued washing upon them by 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 the sandy and dune covered border in the lake basin and the absence of such deposits along the Illinoian margin south of Columbus Junction and in the Mud-Elkhorn valley. This feature is the more striking because of the sudden termination of the sandy tract south and east of the lake basin. See Plate XVI. All along the bluffs from Mosquito creek in Moscow township, Muscatine county almost to Columbus Junction in Louisa county is a fringe of undulating sand dunes. These sandy tracts are on the average less than one-half of a mile
Map showing the sudden disappearance of sand dunes along the Illinoian upland border south of the lake basin.
wide, reaching, however, at places, as two to three miles north of Bayfield, a width of one to two miles. The dunes vary 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 to the intervening Illinoian border which formed the shore line of the lake?

**Interpretation.**—On the basis that the filling in of the lake basin is alluvium, there appears to be no good reason why the sandy tract should be restricted to the Illinoian border adjacent to the lake basin and suddenly 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 abandoned channel, then it becomes a rela-
tively 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 along the courses of streams especially where occupying the entire valley are not common. If a lake existed in the region then the stream draining the lake would naturally be relatively free from sediment and also have minimum erosive power to collect material for the formation of sand dunes. The absence of the dunes in the Wilton Valley which was probably more of a lake than a river may be accounted for by the fact that its longer axis is in the same direction as that of the prevailing winds, the lake at this place was narrow and thus not well adapted for the formation of large waves and 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 VALLEY 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 width of the valleys outside of the lake basin is well developed, however, not in such a measure that it can not be accounted for by stream work. With but one exception the width of the valleys is in no case one-half as great as within the lake 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 of the valley at this place 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 when the valleys are cut into similar materials. The valley of the Iowa river west of Curtis, Johnson county, is unusually wide, although it in no way compares to the valley south of Iowa City and yet in both places the valley is cut into drift. To the writer, it is easier to think of the valleys of the Iowa and Cedar rivers within the lake basin as being due to lacustrine influence rather than that of running water.

CONCLUSIONS.

In order to sum up the various interpretations presented and before making any conclusion, the following
Table 3. Table summarizing the hypothesis favored by the interpretation of the various features found in the Lake Clavin region.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Hypothesis Favored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical considerations</td>
<td></td>
</tr>
<tr>
<td>The Mud-Elkhorn creek valley-the Inlet</td>
<td>x + x-</td>
</tr>
<tr>
<td>The temporary Mississippi river channel of Leverett-the Outlet</td>
<td></td>
</tr>
<tr>
<td>Laminated silts, clays and sands in the lake basin</td>
<td>x</td>
</tr>
<tr>
<td>Terraces in the lake basin</td>
<td></td>
</tr>
<tr>
<td>3 terraces of different ages</td>
<td></td>
</tr>
<tr>
<td>High and intermediate terraces same age, low terrace, Iowan</td>
<td>x</td>
</tr>
<tr>
<td>Texture, structure of high and intermediate terraces</td>
<td>x</td>
</tr>
<tr>
<td>Rounded bluff lines of the lake basin</td>
<td>x</td>
</tr>
<tr>
<td>Boulders in the lake basin</td>
<td>x + x-</td>
</tr>
<tr>
<td>Certain gravel deposits in the lake basin</td>
<td>x</td>
</tr>
<tr>
<td>The Illinoian upland within and without the lake basin</td>
<td>x</td>
</tr>
<tr>
<td>A comparison of the width of the valley in and outside of the lake basin</td>
<td></td>
</tr>
<tr>
<td>Illinoian gumbotil</td>
<td>x</td>
</tr>
</tbody>
</table>
The table shows at once that every feature can be explained very readily on the basis of a lake, whereas but two out of twelve features can be explained probably as well on 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 the lake 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 up the valley of the Mississippi river thereby displacing the stream towards the west. Finding an outlet by way of the Maquoketa river, the waters drained to the westward until a low col in the vicinity of Preston in Jackson county was found. From here the combined waters of the two streams flowed southward as far as the Wapsipinicon river and hence westward to the mouth of Mud creek from whence a southerly course was pursued over the Mud-Elkhorn divide to the Cedar river at Moscow. As the valley of the Iowa-Cedar river was also blocked by the same ice sheet on the one side and the valleys of the streams by high Kansan bluffs on the other, the waters of the 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 applied the term of 'Lake Calvin.' The lake rose until the level of the abandoned valley south and southwest of Columbus Junction was reached, affording thus an outlet to the lake.
CHAPTER VII
THE DRAINAGE AND HISTORY OF EXTINCT LAKE CALVIN.

Earlier Views Regarding the Duration of Lake Calvin

Although Udden does not discuss the draining of Lake Calvin, he undoubtedly was of the opinion that the lake was not drained by way of the abandoned channel for a very long time. 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 to-day, with its water level but slightly higher than the present surface of the West Liberty plain." The lowest extremity of the West Liberty plain of Udden or the intermediate terrace of this report has an elevation of about 610 feet above sea level or approximately 120 feet below the floor of the 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.\textsuperscript{*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 draining of the lake by way of the abandoned channel south of Columbus junction. The Illinoian-Mississippian sag if it existed was at least twenty 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 at about 730 feet above sea level, at Morning Sun but two and three-fourths of a mile from the south valley wall of the Iowa-Cedar river at 752 and at Newport, only two miles south of the river bluffs, at least at 720 feet. 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.\textsuperscript{*201} Then too, the absence of notable sand and gravel deposits in the bed of 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


\textsuperscript{*201} Idem, p. 96.
lake hypothesis. The lake acting as a filtering plant left
the outflowing stream free from sediment, hence there should
be no deposition. Furthermore, as a stream without a load
has minimum erosive power much material would not be collected,
especially if the ground were frozen as suggested by Chamber-
Lin. 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 merely on a frozen stream bed.

THE DURATION OF LAKE CALVIN

The writer agrees with the conclusion of Udden that
Lake Calvin persisted almost to the time of the advent of
the Iowa ice incursion, although the means by which he arrived
at that view are no longer tenable. It is obvious if the pres­
ent 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 as long
as outcrops of Illinoian gumbotil appear on both valley walls
of the Iowa-Cedar and the Mississippi river valleys. Hence, to
say the least, drainage of the lake by this route is post-
Illinoian gumbotil. A long lived Lake Calvin is in accord
with the formation of the Illinoian gumbotil as the level of
the lake and the gumbotil as 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 the Iowa river. At other places, however, where the low terrace lies between the high 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 into forming the low terrace. Therefore, the writer believes that Lake Calvin existed almost up to the time of the coming of the Iowa glacier, that the lake was drained in a comparatively short time and that the down cutting of the lake bed forming the high terrace was shortly interrupted by the aggrading of the valley. The changing from an eroding to an aggrading stream was the result of overloading of the stream with sediment received from the melting Iowa 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 the 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 up 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. That the development of streams on the newly formed Illinoian drift plain after the formation of the gumbotil and stream piracy are the main factors in the draining of the ancient lake is obvious. 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. Due either to diastrophic movements or to the fact that the region lies in close proximity to the master drainage lines, erosion became active. New streams tributary to the Mississippi river north and south of the Illinoian area soon developed and worked their way headward into the Illinoian upland. Finally, due to stream piracy,

*204. Kay, G.F.,
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 of the Wisconsin stage of glaciation in north central Iowa. A prolonged period of weathering during which at least five feet of gumbotil were formed followed. 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 may be expected to have existed over places of buried channels. Sketch map 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 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 the Iowa-Cedar river where it sent out a branch westward
SKETCH MAPS ILLUSTRATING THE DRAINING OF LAKE CALVIN.
SKETCH MAPS ILLUSTRATING THE DRAINING OF LAKE CALVIN

PLATE XVI

C
The course of the Mississippi after the draining of Lake Calvin due to stream piracy at X.

D
The relation of the present course of the Mississippi to extinct Lake Calvin and the abandoned drainage lines.
over the course of the buried Iowa-Cedar valley. This tributary because of its relation to the master stream having the advantage over the other small stream occupying the same valley, but draining 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 XVII. Finally, after continued head erosion by the north and south flowing tributaries of the unfilled Mississippi river, 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 draining 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
SKETCH MAPS ILLUSTRATING THE DRAINING OF LAKE CALVIN

E
The draining of Lake Calvin by the northern course

F
The draining of Lake Calvin by another northern course.
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 north flowing 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. Continuing at equal rates, the two streams should have met at about Muscatine. The distance between the lake basin and the present Mississippi river is equivalent to the distance between the mouth of the 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 are involved in the same distance that one of the main streams has to work headward before stream piracy is able to 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 draining of Lake Calvin by way of the Iowa-Cedar river valley is more plausible 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 witnessed a prolonged period of erosion. It is not certain whether the Nebraskan ice sheet advanced over a peneplain as suggested by Trowbridge 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 stage of glaciation stream valleys from two 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 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 a peneplain or a highly dissected region by destroying all such valleys which may have existed and leaving on its retreat a glacial topography of low relief. Subjected to renewed processes of weathering and erosion during the long ensuing Aftonian interglacial period, portions of the drift were changed

*205, Personal communication.
into gumbotil and the region was deeply dissected before the coming on 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 incursions 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. In crossing into Iowa, the valley of the Mississippi river was blocked and filled with ice by the advancing glacier. This caused the waters of the great river to be dammed back, necessitating thus the finding of a new course to the westward. Finding an opening by way of the Maquoketa river valley, the Mississippi at first flowed westward then to the south through the Goose Lake channel to the valley of the 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 the Iowa and Cedar rivers at Columbus Junction, the combined waters of the 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 high Kansan bluffs from 120 to 140 feet high. Finding no outlet, the waters rose until the entire area of the lake basin was covered by a vast and

*206. Professor Trowbridge believes that during Aftonian times most of the rough subglacial topography was carved out.
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 through the 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 the work of 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, the Iowa river cut down its new flood plain producing thereby the low terrace, the destruction of which has continued up to the present time. Thus ends the history of the Lake Calvin basin up to the present time.
APPENDIX A

BIBLIOGRAPHY ON THE DRAINAGE PROBLEM OF THE 
MISSISSIPPI RIVER.

Work of Frank Leverett:


Work of W J McGee:


Work of Samuel Calvin:


Work of Francis M. Fultz:


Work of G. K. Warren:


Work of O. H. Hershey:


Work of J. A. Udden:


Work of W. H. Norton:


Work of H. Foster Bain:


Work of C. R. Keyes:


Work of N. H. Winchell:

1. (A History of the buried river channels of Minneapolis and vicinity is found in) Geol. Survey of Minnesota, Fifth Annual Report, p. 175, (1877); also Final Report, II, p. 313, (1888).


Work of James H. Lees:


Work of Frederick W. Sardeson:


Work of A. C. Trowbridge:


Work of:

L. G. Westgate.

U. S. Grant.

E. W. Claypole.

C. H. Gordon.

J. E. Carman.

E. K. Soper.