GLACIAL SCORINGS IN IOWA.

BY

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Although evidences of glaciation abound on every side throughout the 55,000 square miles of Iowa's territory, there have been recorded but few instances of ice scorings and striations. Until very recently less than half a dozen localities were known within the limits of the state where glacial markings had been noted. All of these were discovered more than a quarter of a century ago. Concerning them little more than the mere mention had been made, though in some cases the directions of the scratches were given. The locations where glacial markings on the indurated rocks were observed were at Burlington, near Council Bluffs and in the extreme northwestern corner of the state.

During the past year a number of new localities have been disclosed, at all of which good evidences of ice planing are shown. Some of these surfaces are in such an excellent state of preservation that they seem worthy of special mention at this time. The apparent rareness heretofore of glacial striations in Iowa is manifestly due not so much to an absence of ice action as it is to a lack of careful observation and examination.

In considering the rock scorings of the great ice invasions of North America Chamberlain* has called

*U. S. Geol. Sur., 7th Ann. Rep., p. 158. Washington, 1888.

attention to the very marked disparity in the geographical distribution of the glacial striæ. In attempting to record the known scratches on a map of the United States, some localities, as for instance New Hampshire, disclosed the striæ so abundantly that it was almost impossible to plat them properly, while other localities showed only an occasional mark often far removed from any others. In the map of the United States just alluded to, Iowa is credited with four places where glacial striation has been observed. As in other portions of the glaciated region the unequal distribution may be regarded as partly only apparent and partly real. Under the first are enumerated: (1) the illusory effects due to lack of observation on account of the deep drift covering, (2) post-glacial obliteration of markings, (3) unequal search for evidences of scorings and (4) unequal detection of ice planings. Under the second, or original irregularity of distribution are: (1) the greater abundance of markings in the northern than the southern portion of the glaciated tract, (2) greater prevalence of scoring north of the limiting moraines than south of them, (3) greater frequency of markings in hilly than plain regions, (4) greater prominence of striations as exposed sides of elevations than on the leeward, and (5) surfaces that sloped away from the onset of the ice were less universally scored than those inclined towards it.

Phenomena illustrating all of the peculiarities mentioned by Chamberlin in the distribution of the ice scorings are not wanting in Iowa. With one or possibly two exceptions they are all clearly defined.

As already stated the great paucity of glacial markings in Iowa is doubtless owing in a great measure to a want of proper search, while the great irregularity in distribution

QUARRY IN DEVONIAN LIMESTONE, SHOWING SALIENTS ICE POLISHED AND GROOVED IOWA CITY.

is probably to be accounted for partly by the same cause and partly by other causes. The lack of favorable observational facilities is most noticeable in the northwestern part of the area under consideration.

The earlier drift mantles all the district, except a small area in the extreme northeastern corner of the state. The later drift is represented by a broad, rounded lobe, which extends over one-third the way across the state, where it enters from the north and reaches down as far as Des Moines. The drift accumulations of the glacial materials over the northcentral part of the state prevent almost entirely a direct examination of the indurated rock surfaces. Within the area enclosed by the Des Moines lobe of the terminal moraine, there is as yet little or no evidence of ice planing. It is quite possible, however, that at Fort Dodge, some of the peculiarities shown on the upper surface of the gypsum deposits may be due to glacial action. The gypsum beds are from two to thirty or more feet in thickness and occupy the tops of the bluffs and hills. They are covered by drift clay to a thickness of ten to sixty feet, containing some sand and pebbles. Usually the gypsum is thickest where it is protected by the greatest bodies of drift materials. The upper surface of the gypsum deposit is often rounded into small hillocks, between which are sometimes deep pot-holes, while in many places the gypsum shows the effects of the solvent action of percolating waters. There are certain points where the overlying drift is undisturbed and is apparently just as it was originally laid down. If the gypsum was ever subjected to the gouging effects of the ice sheets it would be extremely doubtful whether glacial striæ would be preserved for any great length of time even under the most favorable circumstances since the material is so soft and so soluble.

The lithological characters of the rocks in many other parts of the state also preclude the retention of ice markings.

Perhaps one of the principal reasons why glacial scorings have not been reported more frequently is on account of the almost total lack of study in the field which has been given to the glacial deposits in all but one quarter of Iowa.

NORTHEASTERN IOWA.

In his elaborate study of the Pleistocene accumulations of the northeastern part of the state McGee* has stated that the entire history of the formations was deciphered "without a single glacial striæ or an inch of ice polish, save in one small spot, in the whole tract of 16,500 square miles." The isolated glaciated surface here alluded to is that which was found by Webster several years ago near Iowa City. The Iowa river at this point has cut a deep, narrow gorge into the hard Devonian limestone. The bluffs on either side of the stream are steep-sided, often perpendicular, and rise to a height of sixty to one hundred and twenty-five feet. On the west side of the water-course almost directly opposite the State University the stone has been quarried in a number of places. The top ledge is about fifty feet above low-water level in the river and is covered by ten to thirty feet of drift material. The latter is removed for a considerable distance each time the quarry face is carried forward. In stripping, the upper surface of the limestone is often well exposed. Several years ago when the top of the ledge was examined immediately after the removal of a large amount of the drift capping the hard limestone was found to be beautifully

* U. S. Geol. Sur., 11th Ann. Rep., p. 200. Washington, 1893.

GLACIAL PLANING ON DEVONIAN LIMESTONE. CLEAR CREEK, WEST OF IOWA CITY.

polished by ice and covered by glacial striations. (Plate ix, salient at extreme left is covered by striæ.) Numerous characteristic pot-holes (center of same plate) and ice furrows were also disclosed. These have been described in some detail by Webster* and figures of the more important ones given. The striæ varied slightly in direction. The principal markings were south 52 to 62 degrees east, the magnetic deviation being about $7\frac{1}{2}$ degrees east of north. Some of the best surfaces were disclosed at the south end of the quarry on one of the truncated salients (shown in the extreme left of the accompanying plate ix).

Still more recently, Professor Calvin has discovered additional surfaces showing glacial markings (plate x). The locality is a few miles west of Iowa City, on Clear creek, near the site of the old woolen mill. A short time ago the stream cut around the end of the mill dam, carrying away a portion of the bank, which was composed of loess to a depth of twenty or thirty feet, resting on a bed of sand, pebbles and small striated boulders. The material reclining directly on the planed surface of the limestone was a mixture of sand, clay, gravel and small boulders, having a maximum diameter of eight to ten inches. Many of the pebbles and boulders are smooth on one or two sides. The giving away of the dam exposed the Devonian rocks over considerable area. The planed surface at the old mill, like that of Iowa City, consists of very fine grained, compact, brittle limestone that resists the solvent action of percolating waters to an unusual degree. In general the indurated rocks of Iowa have the surface in contact with the superficial material eaten away or corroded to a depth of often several inches and thus the

*American Naturalist, XXII, pp. 408-409. Philadelphia, 1888.

effects of glacial action have been very generally obliterated. The striæ have a direction of south 62 degrees east, which is practically the same direction as the striations on the west bank of the Iowa river at Iowa City.

SOUTHEASTERN IOWA.

In Washington county, near Brighton, Mr. H. F. Bain has recently found glacial markings on the Saint Louis limestone. The location is at the Brighton quarries about a mile north of the town, on the southwestern branch of the Chicago, Rock Island and Pacific railroad. At the time of examination an area thirty by fifty feet had been stripped preparatory to quarrying. Some of the striations were fully half an inch deep and ten or more feet in length. The directions were south, south 4 degrees east, and south 6 degrees east (true meridian).

The first glacial markings which were reported to have been found in southeastern Iowa were those discovered by White in 1858 near Burlington. No account of them was published at the time, though afterwards, on several occasions, mention was made of the fact. The direction of these striations was approximately south 15 degrees east. Until very recently nothing additional has been recorded concerning the glacial striæ of this part of the state. On the west bank of the Mississippi river for the greater part of the distance between the mouths of the Iowa and Des Moines rivers a high escarpment capped by a massive limestone borders the stream. In many places the rocks stand out in bold cliff-like walls, one hundred to two hundred feet high, with a heavy talus at the base. Along much of this exposed scarp the conditions are exceptionally favorable to the recording of ice scorings.

GLACIAL STRIATIONS ON DEVONIAN LIMESTONE AT IOWA CITY.

Burlington has been the only place known heretofore in southeastern Iowa which has disclosed glacial striæ. There is no record of White's original location, but it is thought to be two or three miles north of the city. On North hill, at the brow of the Mississippi bluff, striated surfaces have been reported from time to time but only on one occasion were they examined carefully. The bearing of the striæ was south 63 degrees east, the magnetic deviation being about 7 degrees. Mr. Frank Leverett has stated more recently that he also has measured the direction of some glacial grooves in the same vicinity. He reported the bearings to be 65 degrees east. Observations made a few years ago show that the sharp salient at the Cascade two miles south of the city was manifestly a center of much ice-planing. Mention of this place will be made later.

Everywhere in the neighborhood of Burlington the Pleistocene deposits consist chiefly of loess and the lower till. These incoherent materials cap the high hills and cover the uplands to a depth of ten to sixty feet or more. The preglacial surface relief of the region under consideration has not been completely obscured by the covering of glacial debris. The present topographical features are therefore to a greater or less extent dependent upon the indurated rocks which make up the greater portion of the altitude of the bluffs. Over the more elevated areas the later deposits are relatively thin, but over many of the lower places there are deep accumulations of drift materials. The city of Burlington itself is built upon several hills, all of which rise to a height of nearly two hundred feet above the low water level of the Mississippi river. The drift has formed nearly insulated plateaux the sides of which are scalloped by steep-sided ravines, very

deep toward the lower extremity but interiorly becoming rapidly shallow.

In protected places the surface deposits rest directly upon the Augusta limestone which is usually much decomposed and broken to a depth of two to six feet. The interstices and irregularities are filled with drift materials and red, residuary clays containing flint nodules in abundance. The drift itself is usually more or less modified superficially. It contains considerable gravel in places, but the boulders are for the most part small in size, being seldom more than four or five feet in diameter. There are, however, a few exceptions, one erratic being known which is more than fifteen feet across. Overlying the drift in most places is a mantle of loess carrying characteristic fossils. A road cutting upon the brow of North hill discloses the following section which may be taken as characteristic of a considerable area:

		FEET.
3.	Clay, brownish-yellow, free from gravel and for the most part homogeneous; graduating into 2.....	5
2.	Loess, typical, ashen, compact, containing numerous small, loess-kindchen and the following fossils: *Pupa muscorum* Linn., *Succinea obliqua* Say, *Patula striatella* Anth., *Limnophysa desidiosa* Say, *Patula perspectiva* Say, *Helicina occulata* Say.....	8
1.	Till, with an abundance of gravel, and pebbles up to three feet in diameter (exposed).....	20

Over much of this plateau the distribution of the Pleistocene deposits is essentially the same except that the lower member suffers considerable attenuation over the more elevated places, sometimes being reduced to only a few feet in thickness. Upon the removal of the drift materials in excavations it has been reported that polished and striated surfaces have been discovered at various

points, but as yet none have been brought to view at times when they could be properly investigated.

Incidentally, reference has been made to the evidence of glacial scorings two miles south of the city of Burlington. At the present time no ice markings are visible at this place. A few years ago, however, large limestone slabs four to five feet long and two to three feet wide were removed in quarrying from the top of the salient above the present works of the Granite Brick Company. Some of these flat blocks were beautifully glaciated, deep flutings

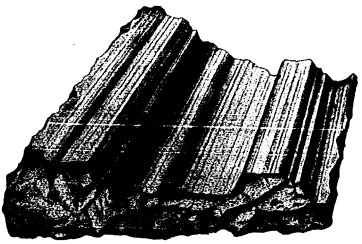
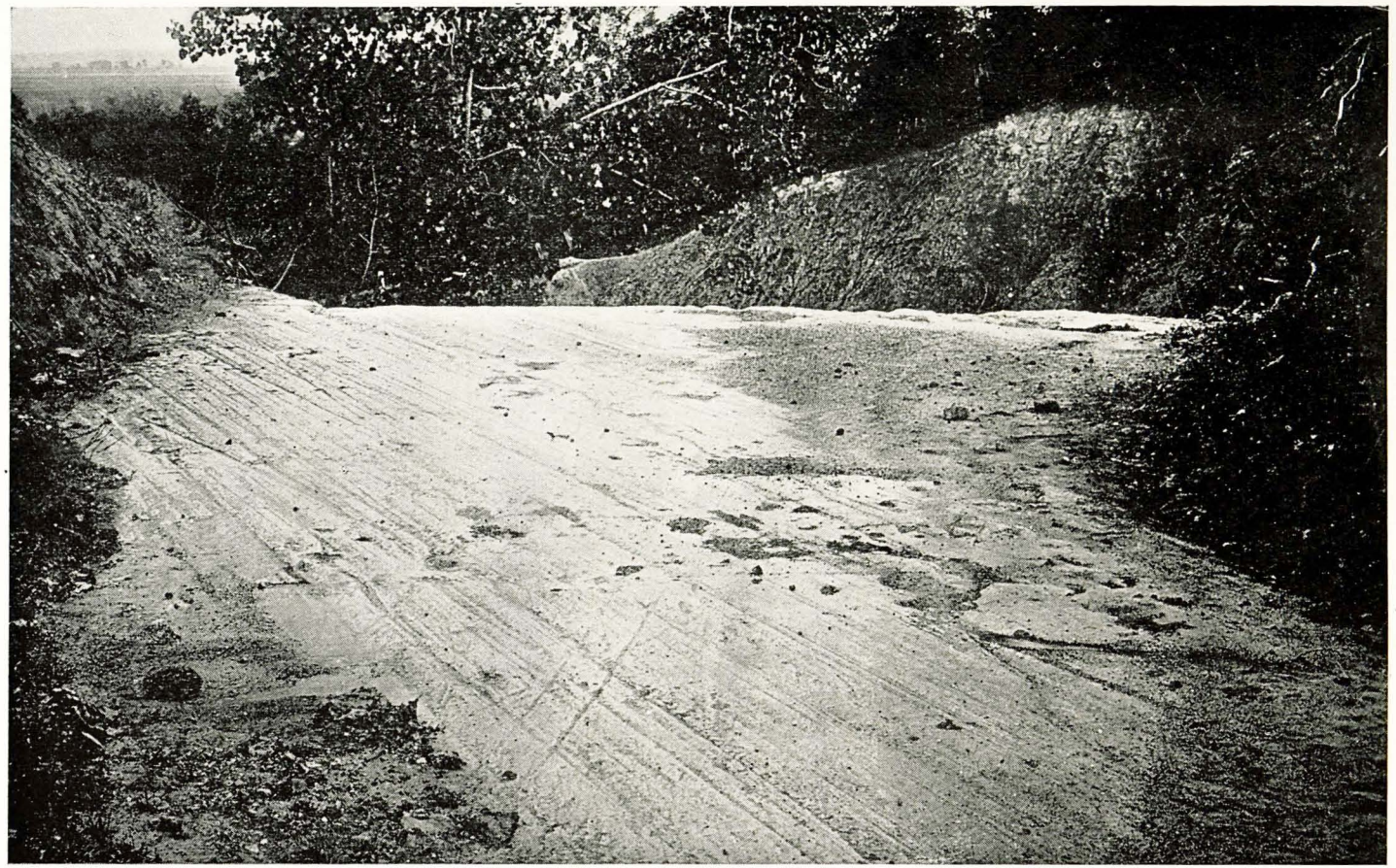


Figure 3. Ice Flutings. Burlington.

and moulding striated and polished to perfection. One of these surfaces is represented in the accompanying cut (figure 3). The broad median groove shown is about six inches deep and eighteen inches wide. The others, while not so deep, have sharper edges.

During the past summer, Mr. F. M. Fultz found two new localities in the neighborhood of Burlington showing exceptionally fine effects of glacial action. The one north of the city near Kingston was brought to light under very favorable circumstances and the general appearance of the



GLACIATED SURFACE ON BLUFF OVERLOOKING THE MISSISSIPPI. KINGSTON.

surface is well shown in the accompanying plate which is reproduced from a photograph taken by Mr. Fultz. (Plate xi.)

Mr. Fultz has made several special trips to this locality and also to the one west of Burlington, and his notes are so complete that they are given entire below.

Some Glaciated Surfaces near Burlington.

(*By F. M. Fultz.*)

Recently two new localities have been found near Burlington showing well preserved glacial scorings. One is near Kingston (Tp. 71 N., R. II W., Sec. 12, SW. qr.) in Des Moines county, about thirteen miles north of Burlington, on the top of the bluff which borders the Mississippi river. From Burlington northward this bluff takes a north-easterly course for several miles, thence changes to nearly due north and continues in this direction almost to the Louisa county line, where it assumes a westerly trend. In the county last mentioned it becomes for several miles the south border of the Iowa river valley. Throughout this whole extent the bluff is a prominent topographical feature. Although situated several miles from the river channel it rises abruptly, forming a high mural escarpment. At the top it is composed of the compact Upper and Lower Burlington limestones; at the base are the Kinderhook shales. The summit is capped with a very heavy covering of loess and drift. In places the limestones appear as bold salients; at others the rock front has broken down, and the whole face deeply covered by talus. While many of the smaller streams have cut through the limestone nearly to the base of the bluff, they offer no better exposures than the face of the bluff itself.

DIRECTIONS OF GLACIAL GROOVES AT KINGSTON.

The top platform of the indurated rocks remains hidden almost everywhere by glacial débris; and although it may, and undoubtedly does, exhibit abundant evidence of ancient glacier movements, it is so deeply buried that only by chance small surfaces are revealed. Occasionally a small block of limestone is found detached at the base of the bluff, or at a distance from the original ledge, which has one of its surfaces grooved and polished, showing unmistakably that it once was part of the rocky floor over which an ice stream moved.

The glaciated surface at the Kingston exposure is remarkably well preserved. It was originally covered with from ten to twenty-five feet of loess and drift, and was accidentally exposed to view in the following way. A water course coming down from the upland issues from the bluff at a very sharp angle. Although draining quite a large area the stream carries no water except during, and immediately after, heavy rains. Consequently the bed has been eroded only a few feet into the solid limestone. As the water issues from the bluff it breaks into a cascade about twenty feet in height, with rapids to the base. On account of the inconvenience caused by the great volume of water brought down during times of freshet the owner of the land decided to change the course of the rivulet. This was easily done by reason of its shallow bed and the sharp angle made with the general trend of the bluff. Going back from the crest of the escarpment a distance of about 150 yards, the old channel was dammed up and a trench excavated at right angles to the old course. This new channel is about forty yards long. Where it leaves the old bed the loess and drift are not more than three feet in depth but by the time the face of the bluff is reached the thickness has increased to fully

twenty feet, and two hundred yards further south the covering reaches a thickness of at least sixty feet.

The drift is quite typical and lies undisturbed upon the rock floor. This surface, as exposed in the new channel for a distance of more than one hundred feet, is perfectly level and is thickly covered with glacial markings. At least four distinct sets of scratches have been determined. Each one of the series consists of perfectly straight, parallel grooves, the larger ones of the latest being about an inch in depth while those of the oldest are nearly obliterated. Plate xii gives a good idea of the character of the glaciated surface.

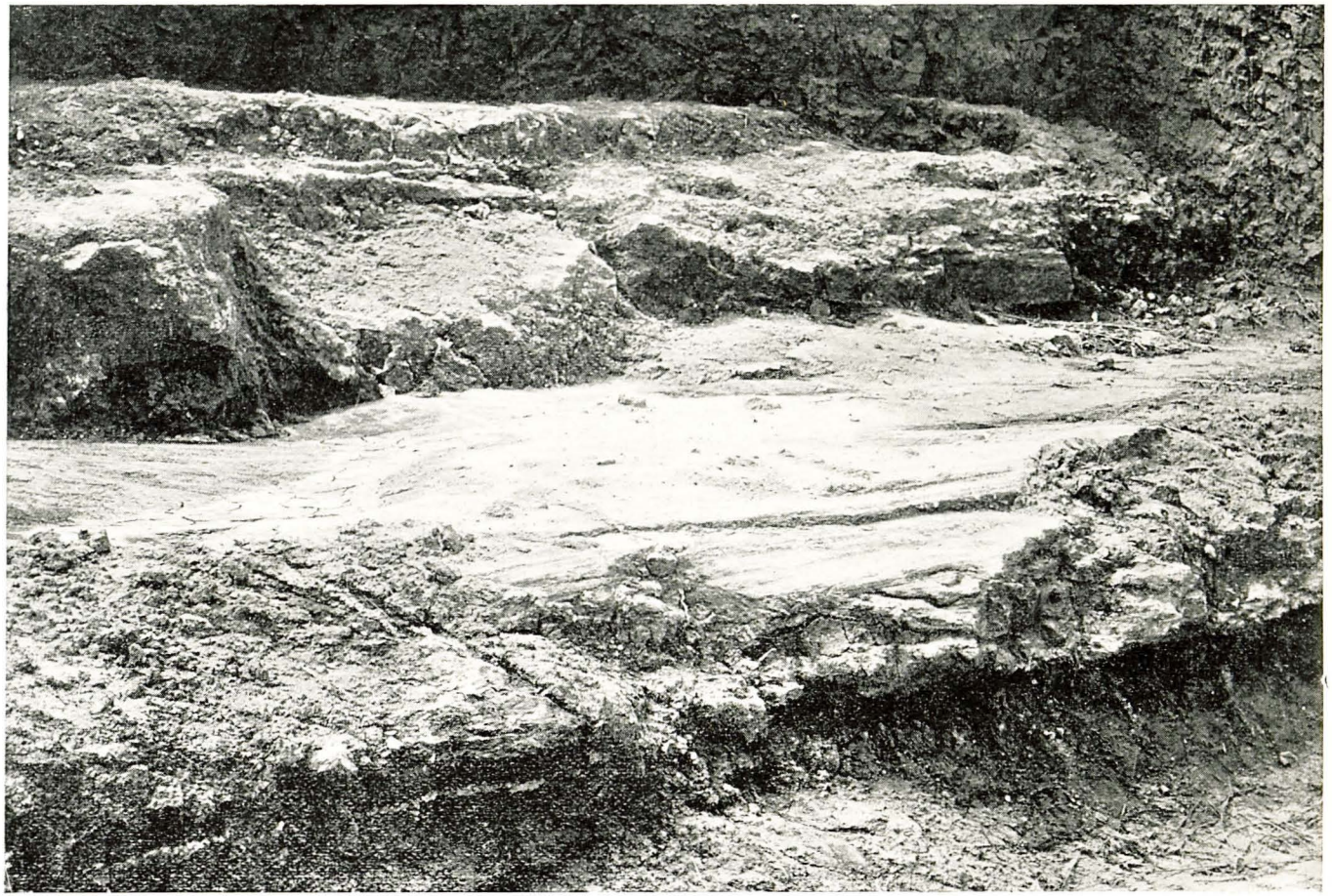
The direction of the different sets, as determined by the compass, making seven degrees allowance for the magnetic deviation, is as follows:

No. 1, south 30 degrees, 15 minutes east (line A-B, plate xii).
No. 2, south 64 degrees east (line C-D).
No. 3, south 60 degrees, 30 minutes east (E-E).
No. 4, south 72 degrees, 15 minutes east (G-H).

Set number 1 is nearly obliterated, but its traces are so numerous as to indicate that at one time it occupied the whole surface, and that it is the record of a long continued movement of the ice stream in one direction.

Number 2 is the most prominent, principally on account of the much greater number of the deeper grooves, on which the later cross movements have made but little impression.

Numbers 3 and 4 have comparatively few markings, but some of them are very deep and plainly show their later origin by cutting across those of number 2 and also reaching to a greater depth. The cutting of one groove directly across another is shown at x in plate xii. It will also be noticed that the later one shows the greater depth.



LATERAL ICE EROSION AND STRIATED SURFACES AT LOFTUS QUARRY. WEST BURLINGTON.

The second locality showing glacial markings is situated about four miles northwest of Burlington and about two miles from the nearest point of the Mississippi river bluff (Tp. 70 N., R. III W., Sec. 25, NW. qr., SW. $\frac{1}{4}$). The exposure was disclosed in stripping at the Loftus quarry. A section taken at this point gives:

		FEET.
6.	Loess.	4
5.	Drift.	10
4.	Limestone, thinly bedded, with flint bands	8
3.	Limestone, light colored, fine-grained, subcrystalline	6
2.	Limestone, heavily bedded, white	10
1.	Limestone, unevenly bedded, dark gray (exposed).	4

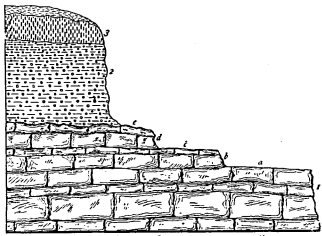


Figure 4. Cross-Section at Loftus Quarry. West Burlington.

The loess is very characteristic and compact. The drift is filled with striated stones which are smaller and much waterworn towards the top. Immediately beneath the loess it becomes quite gravelly.

The quarry has been opened along the face of the bluff which borders a small creek. The general trend of both the bluff and creek valley at this point is east and west. The bluff being on the south of the valley, faces the north. In working back into the hill the surface of the rock is

found to rise quite rapidly, showing that the brow and face have suffered considerable erosion. The rise is not uniform, but in a series of steps, as indicated in the accompanying cross-section. It is on these benches that the glacial markings occur. In the figure *a* is a ledge eight to ten feet in width; the whole surface is striated, scored and grooved, most of the markings being very well preserved; *b* is the edge of the next bench, and is finely striated and polished; *c* is the surface of the second bench, and like *a* is covered with parallel grooves; *d* and *e* are respectively the edge and top of the next higher bench. They show no markings, the rock being too badly disintegrated to preserve them. The markings on *a* and *c* resemble very much those already described in the exposure near Kingston, but only one set of striations can be made out. The direction of the markings has not been taken with a compass, but it is approximately south 68 degrees east. The general character of the lateral erosion is shown in plate xiii. The direction of the striæ and position of the benches would seem to indicate that the movement of the ice stream was in the same general direction as the trend of the bluffs.

The most striking feature of this whole exposure is the great differences shown between the scoring of the floor and the sides. The former is the same as is usually seen elsewhere. It consists largely of straight, parallel grooves, to the depth of an inch or more, situated on an almost perfectly flat surface. There is little or no gouging out where the rock is softer and no blocks have been wrenched loose or carried away. On the other hand the lateral planing shows no grooves, but a multitude of fine striæ which, while trending longitudinally, are not parallel, but cross one another at small angles. The softer parts of the rock

GLACIAL GROOVES AT KINGSTON.

exhibit gouging, and pieces of rock have been torn loose and carried away.

The character of the brow of the escarpment which borders the west side of the Mississippi river between the mouths of the Iowa and the Des Moines rivers is perhaps best shown at Keokuk. At several points within the city limits there are great accumulations of large boulders which rest partly upon the crest of the bluff in beds fifteen to twenty feet in depth and partly at the base of the cliff over which they have been tumbled. These boulders are composed chiefly of granites, porphyries, diabases, and other crystalline rocks, ranging in size from a few inches to two or three feet. In a recent street cutting just west of the Union station at Keokuk, one of these beds is well exposed. It is shown in the accompanying plate xv, which is reproduced from a photograph taken by Mr. Fultz.

SOUTHWESTERN IOWA.

The glacial scratches of southwestern Iowa require but passing mention in this place in order to make complete the known records in Iowa. The first mention of the markings in this part of the state is by White, who found them in Mills county, at the Stout quarry, about five miles south of Pacific Junction (Tp. 71 N., R. XLIII W., Sec. 16, SE. qr). The location is on the abrupt eastern bluff of the Missouri river, about three miles from the stream. The marks are upon the Upper Coal Measure limestone which crops out a few feet above the broad flood plain.

According to White the scratches are of two sets, one a rather coarse, the other much finer and much more numerous than the former. The rock surface is beautifully planed. The direction of the striations of the first series

was south 10 degrees east and of the second set south 1 degree east (magnetic deviation here about 10 degrees). Professor J. E. Todd has visited the same locality lately and found several series of striæ. The coarsest and best developed were found to be south 2 degrees west and 0 degrees, 3 degrees and 6 degrees east. Two finer series had bearings south 25 degrees east and south 31 to 34 degrees east, and still more delicate striæ were detected south 50 degrees east. About a rod to the eastward and on the same level, striæ equally distinct were noted with directions south 6 degrees west and south 12 degrees west. About a mile north of the Stout quarry, Todd also reports another place in which the striæ run south 3 to 5 degrees west. A quarter of a mile farther north and twenty or thirty feet above the flood plain he has observed a limestone surface on which the striations are mostly south 5 degrees west; a few, however, are south 30 degrees west.

NORTHWESTERN IOWA.

The glacial scratches observed in northwestern Iowa are all in the extreme corner of the state where the Sioux quartzite crops out. In many places the hard quartzite has been bared over considerable tracts. These surfaces frequently exhibit glacial scratches and grooves. Some of the latter observed a mile south of Rowena, just over the Iowa line in Minnesota, were thirty feet or more in length and several inches wide. The direction was south 53 degrees east. Fine scratches were also noticeable. Glacial striæ have been noticed in a number of places in the vicinity of the northwestern corner of Iowa. At Lawrence, a short distance to the northeast in Minnesota, the striæ have a direction south 15 to 25 degrees east.

BOWLDER BED ON CREST OF MISSISSIPPI BLUFF. KEOKUK.

At Sioux Falls, a few miles to the northwest, variable directions are shown, but some of the most pronounced scratches are south 40 degrees east.

Table of Observed Directions of Glacial Striæ in Iowa.

LOCALITY.	DIRECTION. (Corrected.)	AUTHORITY.
NORTHEASTERN IOWA—		
Iowa City	S. 52 E.	Webster.
Iowa City	62 E.	Webster.
Iowa City	54 E.	Keyes.
Iowa City (Clear creek)	62 E.	Calvin.
SOUTHEASTERN—		
Brighton	4 E.	Bain.
Brighton	6 E.	Bain.
Burlington, 2 miles north	15 E.	White.
Burlington, North Hill	63 E.	Keyes.
Burlington, North Hill	65 E.	Leverett.
Kingston	30 E.	Fultz.
Kingston	60 E.	Fultz.
Kingston	64 E.	Fultz.
Kingston	64 E.	Fultz.
Kingston	72 E.	Fultz.
West Burlington	68 E.	Fultz.
SOUTHWESTERN—		
Pacific Junction, 5 m. South	10 E.	White.
Pacific Junction, " "	41 E.	White.
Pacific Junction, " "	2 W.	Todd.
Pacific Junction, " "	due S.	Todd.
Pacific Junction, " "	3 E.	Todd.
Pacific Junction, " "	6 E.	Todd.
Pacific Junction, " "	25 E.	Todd.
Pacific Junction, " "	31 E.	Todd.
Pacific Junction, " "	34 E.	Todd.
Pacific Junction, " "	80 E.	Todd.
Pacific Junction, 4 " "	6 W.	Todd.
Pacific Junction, " "	12 W.	Todd.
Pacific Junction, " "	3 W.	Todd.
Pacific Junction, " "	5 W.	Todd.
Pacific Junction, 3¾ " "	5 W.	Todd.
Pacific Junction, " "	30 W.	Todd.
NORTHWESTERN—		
Granite, 3 m. North	53 E.	Keyes.