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Earth Movements and Drainage Lines in Iowa

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EARTH MOVEMENTS AND DRAINAGE LINES IN IOWA.

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It is well known that several systems of drainage lines have been impressed upon the surface of the present state of Iowa, only to be successively wiped out by the hand of time. Not to mention possible earlier ones, a well marked drainage system was cut into the Saint Louis and older strata prior to Des Moines time. Upon the (relative) subsidence of the land during Des Moines time the valleys were filled and drainage lines obliterated to the farthest limits of deposition of Coal Measures rocks. Differences of nearly 400 feet in the altitude of the Saint Louis surface near Des Moines give evidence of the vigor of the erosive forces and the lapse of time during which degradation was active. At least some of the Coal Measures outliers of eastern Iowa may occupy depressions cut during this period, and, as Doctor Calvin[1] pointed out, the land surface of that time probably stood higher than at present, since the base of the Coal Measures sandstones of the Iowa City outlier is sixty feet below present river level. Beyond the eastern limits of the Des Moines strata the drainage systems doubtless continued for a long time, though at times sluggish and ineffective as erosive agents.

The Paleozoic era closed with extensive crustal movements, which initiated the formation of the Appalachian mountains in the east and excluded the sea from the continental interior. The sluggish streams of Carboniferous times must have been invigorated by these movements and new lines incised into the recently elevated Carboniferous rocks. This system of drainage persisted until, and, in eastern Iowa, through Upper Cretaceous times, but whether any of its elements survive to the present time is of necessity uncertain. An age somewhat greater than that of the Saint Louis limestone has been claimed for the prototype of the Mississippi[2] along the Iowa border and buried channels have been noted by numerous writers on Iowa geology.[3] These channels are usually referred to post-Cretaceous uplift and erosion, and, while it is possible that some of them may have been re-incised in Cretaceous and pre-Cretaceous valleys, the fact that pre-Tertiary drainage was toward

[1]Iowa Geol. Surv., Vol. VII, p. 94, 1897.
[2]Fultz, F. M; Iowa Acad. Sci., II, p. 39, 1895.
[3]Gordon, C. H.; Iowa Geol. Surv., III, 237-255, 1895; Bain, H. F.; Iowa Acad. Sci., II, pp. 23-26, 1895. Others might be cited.

the southwest renders it unlikely that any great proportion of this system should be perpetuated in the present southeastwardly trending lines. It is possible that such valleys as the lower part of Oneota or Upper Iowa river valley may represent remnants of this old pre-Tertiary drainage system.

The main purpose of this paper, however, is to attempt an explanation for certain incongruities in the topography and drainage of eastern Iowa. It was pointed out many years ago by McGee[4] and later emphasized by Calvin[5] that the streams of this region do not flow down the slope of the surface, but at practically a right angle. It may also be noted that in general these streams flow parallel to the strike of the underlying rocks and not with or against the dip. There is, however, probably no genetic relationship here. The anomalous courses of the Mississippi tributaries are probably due to the following course of events. During Upper Cretaceous time western, and perhaps a part of eastern, Iowa was under the sea, while the land area of the state was subject to prolonged erosion and so by the close of the period was reduced to base level. The slow-moving rivers wandered aimlessly across their broad, flat-bottomed, shallow valleys, miniature editions of the lower Mississippi of today. But the Mesozoic era was closed, as the Paleozoic had been, by marked crustal and mountain-making movements, which again elevated the upper Mississippi valley beyond the reach of the seas. However, at this time the locus of movement was in the west and the Rocky mountains began their growth, the Great Plains were tilted up and a new system of drainage was initiated. The direction assumed by the members of this system was the resultant of two factors: one, the eastward tilt given the plains between the young Rockies and the axis of the great trough whose eastern rim was, and still is, the Appalachian highlands; the other, the southward slope from the old continental nucleus—the pre-Cambrian shield of Canada. Hence, the Missouri and its tributaries from the west, also the westerly tributaries of the Mississippi, as they worked headward in their development, lengthened out to the northwest. Local factors have varied this scheme, but in general it holds good. The relatively small tributaries of Missouri river in Iowa are probably post-Kansan and owe their somewhat peculiar relations in part to a great southwardly-trending ridge of drift which lies immediately to the west of the present so-called divide and through which some of the larger streams have already carved their valleys. The courses of some, at least, of these streams may also

[4]U. S. Geol. Survey, 11th Ann. Rept., pp. 363-365, 1891.
[5]Iowa Geol. Surv., XIII, pp. 296-299, 1903.

be influenced by the great Sioux island centering about Sioux Falls and Pipestone, which has profoundly affected the history of the immediately surrounding regions.

This growing system of streams, then, to come back to our local province of eastern Iowa, carved out its valleys upon the Cretaceous peneplain until in many cases these had assumed great proportions and had reached late maturity or old age. A Tertiary base-level was being impressed upon the old Cretaceous plain. Whether the Tertiary peneplain extended merely as a narrow strip along the Mississippi, as urged by Hershey,[6] or was co-extensive with the great plain of the entire state, as indicated by Calvin,[7] may be a moot question, though the evidence seems to point to there being but one peneplain in northeastern Iowa. Hershey based his conclusions partially upon the work of McGee, and some rearrangement of McGee's geological section has been found necessary by later workers.

The valleys of the Driftless Area give a clear picture of the development of topographic features unmolested by glacial invasions and therefore show what might have been expected in all of northeastern Iowa had not the advance of the ice sheets terminated the Tertiary cycle. A study of the topographic maps of the Waukon and Decorah quadrangles, for example, will show Oneota or Upper Iowa river flowing in wide meanders across a dissected plain whose summit hills and ridges rise to a fairly common level. These summits represent the Tertiary peneplain and the intrenched meanders of the stream are faithful reproductions of the course of the river when it flowed up near the level of the uplands. It is clear that valley and plain alike must have been very mature by the beginning of the Ozarkian interval, that is, near the close of the Tertiary period.

Now, the Ozarkian was a time of elevation of the continent, of differential movements and warpings of the crust, and one of these warpings affected northeastern Iowa and adjacent portions of the adjoining states. The topographic maps of these states seem to indicate that this deformation assumed the shape of a long ridge trending west of south and culminating in central and southwestern Wisconsin, southeastern Minnesota and northeastern Iowa. Southward beyond Dubuque and westward toward Cedar river it declines rapidly. Unfortunately, the area covered by topographic maps is not sufficiently inclusive to render positive assurance to this supposition. The deformation may have been a dome rather than a ridge. In any case, the streams were obliged to

[6]American Geologist, XX, pp. 253-256, 1897.
[7]Op. Cit., XIII, pp. 298-299.

resume downward cutting in their valleys to prevent being ponded or reversed by the slowly rising land. They succeeded in the effort and now flow in deep canyon valleys whose floors in some cases lie 500, 600 or 700 feet below the hilltops. In fact, the valleys are over 100 feet deeper than this, for they have been filled to that depth with detrital material dropped by the streams, as will be explained later. But the result of the upwarp is that northern Iowa lies as a great trough, with Cedar river in its axis, rather than as a plain sloping uniformly to the Mississippi, as was seemingly the case during Tertiary time. The master streams, being so largely pre-Ozarkian, or reoccupying pre-Ozarkian valleys, have held the main lines of drainage to their old courses and also have been determining factors in establishing the courses of their affluents. These latter are not widely radiate, but are narrowly digitate, or dendritic, due, perhaps, to preglacial topography, coupled with the directions of glacial advance and consequent form of glacial deposition.

The partial filling of Ozarkian-cut valleys was mentioned above. The following cases may be cited. At the mouth of Oneota river wells sunk from an altitude of 650 feet penetrate 130 to 140 feet of alluvial filling before they reach rock. The level of the river here is 620 feet and the actual floor of the valley is 520 feet. Eight miles up Oneota river the floor lies at 560 feet and has been buried 100 feet. At Prairie du Chien the Mississippi bottoms are somewhat more than 600 feet above sea. A deep well sunk for 627 feet pierced 147 feet of valley filling, reaching the rock floor at 480 feet above sea. At Eagle Point, Dubuque, where the flood plain is 600 feet above sea, a well was sunk from this level through 160 feet of alluvium and from the Julien Hotel well, scarcely more than twenty feet higher, there is reported a thickness of 210 feet of loose material. This puts the valley floor at 440 to 410 feet. Most of the deep wells at Clinton strike rock within forty feet of the curb, which latter is about 588 feet above sea level, but one penetrates 205 feet of Quaternary material before bedrock is reached. This seems to indicate a very steep wall here, dropping to 380 feet above sea level. Again, the buried valley of the Mississippi west of Keokuk was cut at least as low as 374 feet above sea level, 103 feet below low water at Keokuk. The accompanying cut shows the relative sizes of the fossil and present channels.

The same situation holds for the tributaries of the Mississippi. For instance, the Wapsipinicon and Cedar-Iowa valleys were originally less than 400 feet above sea level, though nearly 300 feet of glacial and alluvial material has been dumped into them. In Scott county a buried channel, probably of Mississippi river, named by Norton, Cleona channel,

has likewise been cut lower than 400 feet above sea, though now entirely obliterated. Low water in the present Mississippi channel at Rock Island, only a few miles to the east, is 542 feet above sea, and the channel is very shallow and rock-cut.

This assemblage of facts points, of course, to the conclusion that at some time in the past, probably during the Ozarkian interval, the lands stood high and that the valleys were being deepened rather rapidly, since the buried channels show very steep walls. Subsequently these valleys were depressed through a sinking of the land surface, or else their outlet was blocked, through a rise of land athwart its lower course or by a change in its course through the agency of an ice barrier. In any case, the result has been the same—the partial filling of the existing valleys with detritus and the entire filling of the abandoned ones.

It seems likely that two of these causes were active. We know that the Mississippi has been obliged to alter its course by invasions of

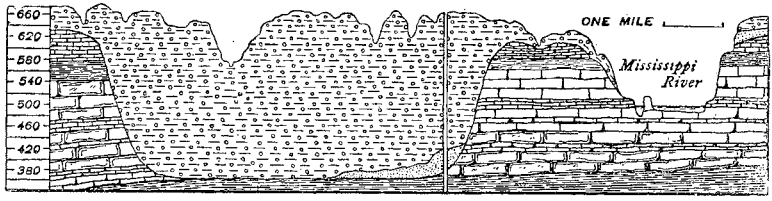

Fig. 6. Section across present and former channels of Mississippi river in Lee County. From Gordon.

glacial ice, and that parts of the course, once abandoned, have never been reoccupied, but that, instead, the river has cut new channels through the hills and is still rock-bound and shallow at these points. This is the cause of the rapids at Rock Island and Keokuk. It will be understood that this change would tend to cause a filling of the channel behind these rock barriers. Whether this cause alone would be sufficient to account for the observed phenomena is perhaps doubtful. But another agency which I believe may be looked upon as one of the causative factors is a depression of the land.

During the final withdrawal of the ice sheet at the close of the Wisconsin age a series of great lakes was formed in front of the ice wall. One of the lakes, Lake Agassiz, occupied the depression now drained by Red and Minnesota rivers, and a group with varying forms and areas filled the basins of the present Great Lakes and spread far beyond their borders. Now, these lakes formed beach ridges, shore lines, wave-cut terraces and other marks, which would naturally be horizontal. But at present these lines depart markedly from horizontality, and, further-

more, the lines which were made at various levels are not parallel one to the other. This means not only that there has been a tilting of the land, but that this tilting was going on while the ice was retreating and the glacial lakes were extant. It is not thought probable that the lessening burden of ice is primarily responsible for this,[8] and the fact that the ocean invaded the St. Lawrence and Hudson valleys at this time is evidence against such a cause. The significant fact is that while the land to the north of the Great Lakes was raised several hundred feet above present lake level the area south of Green bay and Saginaw bay, on Lakes Michigan and Huron, respectively, was being so depressed that certain of the shore lines are estimated to be 100 feet below lake level at Chicago.[9] So the shore lines of Lake Agassiz are 400 feet higher near its northern than at its southern terminus. Whether this change is due entirely to elevation, or to elevation combined with subsidence, cannot, of course, be determined, since there is no such reliable datum here as exists in the Great Lakes. Studies in the correlation of moraines and the deformation of shore lines show that the same class of movements was affecting the two regions,[10] hence the continuation of the tilting westward from the Great Lakes region to the Mississippi may be considered as somewhat certain. Lowering the valleys and hence the gradients of streams would at once result in lower velocities, diminished carrying powers and a gradual building up of the valley bottoms. This building up would continue until the movement ceased and the streams were aggraded to their base level.

Another factor which assisted in filling the valley bottoms was the immense quantities of silt, sand and gravel brought down by the floods from the Wisconsin ice front and carried down the Mississippi valley until decreasing carrying power forced their deposition. The tributary valleys were also aggraded by the backing up of the flood waters with their burden and the release of this burden in the slack waters of the estuaries. Terraces of detritus in the valleys of Mississippi and Oneota and other rivers fifty to sixty feet above present water level still bear witness to the size of the floods and of the loads carried by them and indicate the level at which the mighty stream once flowed. It is to this agent, at least as the artist which put on the last skillful touches, that the great valley owes its rugged headlands and bold, frowning scarps and precipices, while the side valleys still retain the smooth, flowing contours imposed by ages of weathering.

[8]Taylor, F. B.; An. Rept. Smithsonian Inst. for 1912, pp. 91-327.
[9]Chamberlin and Salisbury; Geology, Vol. III, p. 481, 1906.
[10]Leverett, Frank; Fourteenth Rept. Michigan Academy of Science, 1912, p. 15.

Then, how comes the river to be flowing at its present intermediate level? After the ice melted beyond the margins of the valley, the stream, though much diminished, still was freed from its great burden and was, therefore, able to degrade its channel instead of aggrading it. Further, during the early part of its existence Lake Agassiz was drained into Minnesota and thence into Mississippi river. This volume of water had left its load of detritus in the lake, hence was able to assist in carrying away the material which is found choking the valley of the Mississippi. It is possible, of course, that there has been a slight uplift of the entire valley following the disappearance of the ice, but of this we have no positive knowledge. We do know that there have been postglacial uplifts in eastern and northeastern America.

In this connection there is another fact of some interest. Some years ago, during our work in Winneshiek county, Doctor Calvin called my attention to the fact that the smaller streams of the region were all cutting into their valley filling. The accompanying cut, taken from the report on Winneshiek county,[11] gives a good illustration of the situation. It will be readily seen that, whatever the cause of this re-erosion, it is of recent occurrence and its effects are just now being felt in this region. It may be noted that this photograph here reproduced was taken less than two miles from Oneota river, and, therefore, in a location where any quickening of erosive activity in the master streams would be easily felt in their tributaries.

The most reasonable explanation of this phenomenon seems to be its correlation with the formation of the great terraces along the major drainage courses through the degradation of the detrital accumulations within them, as discussed above. The lowering of the water levels in the larger streams would necessitate a readjustment of gradients throughout their basins and a consequent increase in velocities and erosive powers. It may be remarked parenthetically that this increased activity is not confined to northeastern Iowa, but may be observed in other drainage areas. Gullies twenty feet deep and scarcely as wide at the top are being cut into the loess plains of the western slope of the state. Similar instances are occurring elsewhere. The incursion of human civilization and agriculture has been held responsible for this phenomenon, but whether the coincidence is causal, or merely fortuitous, or both, is, as yet, undetermined. Certain it is that there has been, within recent years, a notable depression of the ground water table, and these various changes may be intimately related one to the other.

[11]Iowa Geol. Surv., XVI, pp. 55, 56, 1906.

Resumé.—The streams of northeastern Iowa are strike streams, rather than dip streams. Their southeasterly direction was determined originally by the eastward tilt of the Great Plains and the southerly slope from the old Canadian land nucleus. Later the slope of the area considered was changed by an upwarp extending across southwestern Wisconsin, southeastern Minnesota and into northeastern Iowa. The streams were quickened, cut deep valleys into this ridge and so have held to their courses instead of being changed to other directions of flow. The land was formerly higher than now, as attested by the partially filled valleys of Mississippi and tributary rivers. This filling was aided by floods from the Wisconsin ice, which dropped great quantities of silt, sand and gravel along the bottom lands. Much of this material has since been cut away, leaving the remnants as terraces along the valley walls.

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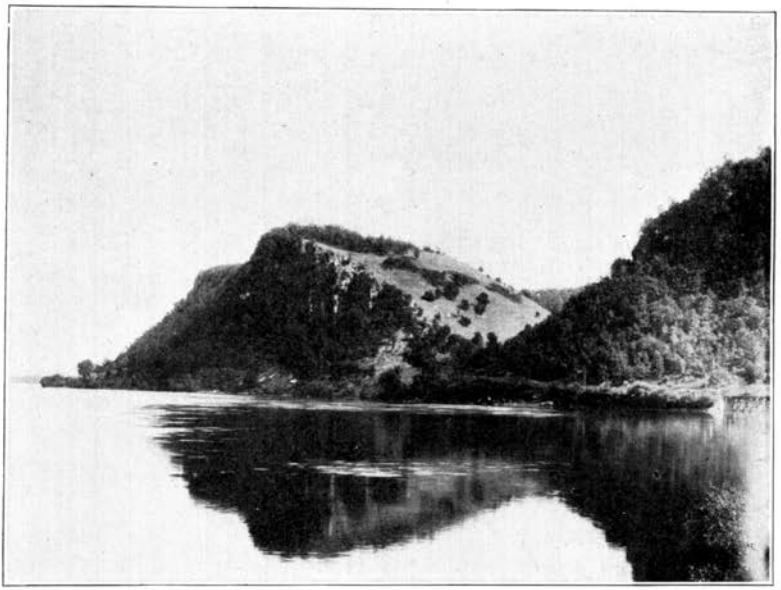

FIG. 1.—Mississippi bluffs below Lansing, Allamakee county, showing vertical walls fronting the river, but mature side and back slopes. From Calvin.

FIG. 2.—Reërosion of an aggraded valley, in the northeast quarter of section 21, Glenwood township, in Winneshiek county. From Calvin.