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The Genesis of Loess: A Problem in Plant Ecology

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THE GENESIS OF LOESS A PROBLEM IN PLANT ECOLOGY.

BY B. SHIMEK.

The question of the origin of the loess of the Mississippi valley has attracted the attention of the geologists of the country for two-thirds of a century. The consideration of the question has been left almost entirely to geologists, who have offered various explanations of loess-formation, all based practically on physical grounds.

The biological phases of the subject have been thus far approached almost exclusively from the faunal side.

It is the purpose of this paper to briefly set forth a preliminary statement of the relation of plants to the formation of loess, and to call attention to the fact that the investigation of the problem of the genesis of loess lies within the province of the plant ecologist, for the study of plant relations throws light on several important phases of the subject, and incidentally strengthens the aeolian hypothesis.*

That plants play an important part in modifying the materials of the surface of the earth is well known. They assist in comminuting soil and rock both mechanically and chemically; they form an anchorage for fine materials brought both by wind and water, according to location; they prevent erosion of loose soils; by their decay they cause changes in the amount and distribution of the calcium carbonate and iron constituents of the soil; and finally, they return their own substance to the soil in finely subdivided condition.**

All this results in an increase in the amount of fine materials which may be removed by wind or water, or in the building up of deposits where the vegetation is sufficient to form an anchorage for the fine materials carried by these agencies.

The study of these influences of plants, and of plant-distribution as determined by environment, throws light on the following questions related to loess-formation by aeolian agencies:

I. *Distribution of loess.*

(a). It explains the greater thickness of loess on higher grounds near larger streams, where vegetation is more abundant because of the advantages offered by both the greater elevation and the more abundant plant-covering, thus forming an anchorage for the dust carried up from the adjacent bars on which the supply of dust is renewed by each succeeding flood. That vegetation was more abundant in this territory during the deposition of loess, as now, on elevations near the large streams is shown by the greater abundance of strictly terrestrial plant-feeding mollusks in the loess now occupying these elevations, the modern

* See writer's previous suggestions in Bull. Lab. Nat. Hist., St. Univ. of Iowa, vol. V, pp. 341, 359, 360, etc.; 1904

** See writer's paper, Proc. Ia. Scad. Sci., vol. X, pp. 41-48, 1903.

terrestrial molluscan fauna being similarly developed chiefly in the grosser vegetation of such situations.

(b). It explains the difference in thickness of loess on the east and west sides of the valleys of our larger streams like the Mississippi and Missouri. The prevailing southwesterly and westerly summer winds produce xerophytic conditions with less abundant vegetation on the east side, where the dust heaps up like snow in a drift, while the west side is mostly forest-covered, and receives a thinner blanket of finer dust which settles more uniformly in the more abundant vegetation. (See Plate III, figs. 1 and 2; Plate IV, figs. 1 and 2.)

(c). It throws light on the inequality and irregularity of loess distribution, the latter being determined largely by the irregularity of plant distribution, and it suggests that the more irregular and unequal loess was deposited on drier surfaces, while those which had a dense plant-covering, forest or otherwise, received a thinner and more nearly uniform deposit.

A suggestion of the cause of local irregularities in thickness is furnished by the morainic Wisconsin-drift hills in western Lyon county, Iowa. The southwestern windward slopes and the tops are covered with a tufted scattered vegetation, while that of the leeward slopes is much denser, being partly scrub forest. The bare portions of the former lose their finer materials and coarse drift appears at the surface, while the latter retains the finer materials and thus receives additional increments, and has already formed a distinct thin loess and soil.* (See Plate V, fig. 1.) If the vegetation on the windward slopes was gradually reinforced, as during more favorable seasons, and the deposition of these finer materials continued until both slopes were covered, the deposit of loess so formed would be unequal in thickness on the opposite slopes.

(d). It explains the presence of loess in high places, and its almost general absence from the intervening lowlands, for the elevations were earliest drained, and first presented conditions suitable for dust-deposition because of their greater elevation and their early plant-covering, while the lowlands were alternately flooded and exposed.

II. *Structure and composition of loess.*

(a). The greater coarseness of loess materials on the east side of the large rivers has already been noted, together with its probable cause.

(b). The presence or absence of lime nodules and iron tubules is of no value in determining the age or identity of loess, or loess-like deposits, for they may have been formed very recently in cavities formed by or around roots, by checking or slipping, or by water. The writer has found both lime nodules and iron tubules around fresh living roots. Moreover both sometimes occur in drift.

(c). The occasional alternation of sand and loess may be explained on the basis of changes in the plant-covering of the area during the formation of the deposit.

Such alternation and interlamination of sand and loess are not uncommon, and it is a significant fact that they may be observed, so far as the writer has seen, only in the vicinity of modern or manifest old sand-dunes. Fine illustrations occur in such locations in Iowa, Nebraska, Missouri, Illinois and Indiana.

In Iowa the finest examples may be found in close proximity to the Iowan drift border.

*See the writer's paper on "Additional Observations on Surface Deposits in Iowa," Proc. Ia. Acad. Sci., vol. IV, pp. 68-72, 1878.

Those who have studied the Iowan drift in this state agree that the ice-sheet was comparatively thin. When the ice receded upon the great plain thus bared there were projecting points and ledges of rock as well as irregular drift elevations left by the ice. These elevations formed nuclei for the collection of minute dust particles from the broad plain in the same manner in which an obstacle on the surface of the earth may form the nucleus of a sand-dune or snow-drift. Such a dune or drift will itself form an obstacle which will intercept other material brought to it by winds, and will thus assist in its own upbuilding. In the same manner, the paha and the rocky ridge formed nuclei about which gathered the dust whose accumulations form the loess caps on these elevations. The comparative thinness of the ice-sheet also resulted in the early exposure of the surfaces of these elevations while the great intermediate plains still remained ice-covered. No doubt much fine material was washed out upon the surface of the ice and this probably furnished in some places the first material which was deposited on the exposed elevations. However, by far the greater part of the loess material was evidently deposited after the ice had receded and the climate had become sufficiently moderated to permit the development of an extensive vegetation, which supported a more or less abundant molluscan fauna. The fact has repeatedly been noted that along the border of the Iowan drift and on the paha within its borders there are great accumulations of sand lying immediately beneath the loess. This sand in some places shows no lamination and was probably deposited by the Iowan ice, though it may be of Kansan origin. Very much of it, however, is distinctly laminated in a manner which suggests the structure of an ordinary sand-dune. These laminations follow the vertical contours and in some places alternate with narrow belts and bands of fossiliferous loess, the sand being entirely free from fossils in all cases mentioned. The structure of these underlying sands suggests that soon after the recession of the Iowan ice there were extensive sand-dunes formed along the borders of the Iowan drift, and that there were isolated dune areas within the Iowan border. These shifting sands were probably bare for a time and the winds easily removed the finer particles of dust in great quantities.

The successive changes were probably such as take place in recent times in any sand-dune region. At first a scant vegetation consisting, perhaps, of tufted sedges and grasses and leguminose plants, is developed. Each plant forms a nucleus about which a small amount of finer soil material is gathered. While each plant thus serves as an anchorage for fine material, there are at first comparatively broad areas of loose shifting sands between these plant-tufts. As the scant vegetation gathers the finer soil, it prepares the way for a denser vegetation, which will accumulate more fine soil to the advantage of still other plants, until the whole area is covered with a carpet of plants which will check if it does not wholly prevent wind erosion. (See Plate V, fig. 2.) In the Iowan sand-dune area the fine material thus blown out of the sands was, after the recession of the Iowan ice, carried to the above noted elevations, and there lodged. It should be born in mind that these elevations presented the first suitable surfaces for terrestrial plants, for, no doubt, for a long period the flatter areas were at least swampy, resembling probably the corresponding areas upon the Wisconsin drift plain. Other portions were, evidently, for a time shifting sands upon which vegetation gained a foothold with much greater difficulty. Upon the elevations alone was there sufficient drainage to permit the development of an early terrestrial vegetation.

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During the summers many of these areas were exposed year after year by the evaporation of the waters and furnished new supplies of dust which accumulated upon the elevations in the well-developed flora which covered them. There are in some localities clear evidences of changes in surface conditions. The typical locality in the northern part of Madison township, Johnson county, will serve as an illustration. At the point in question there is a range of low hills on the south side of the Iowa river and parallel with it. These hills follow the river eastward to Curtis and thence to a point east of North Liberty. Exposures at various points indicate that the structure of this ridge is essentially that of the paha. At the intersection of this ridge and the C. R. & I. C. electric railway two cuts exhibit the structure here selected as an illustration. (See Plate VI, fig. 1.) The entire exposure in these cuts exhibits a succession of sand and loess bands following approximately the vertical surface contours. The loess bands, even where quite narrow, contain the characteristic fossil shells of terrestrial mollusks.

Upon the adjacent surfaces of the ridge there is now a forest covering and among the leaves and leaf-mould of the surface the same species of mollusks are found living.

Westward the ridges become lower and the river-valley expands into a sandy plain. During cycles of dry seasons the covering of vegetation becomes more scant and quantities of loose sand are shifted about by the winds forming small sand dunes or drifts in the fields and along the road sides and encroaching more or less upon the wooded tract. During wetter seasons the covering vegetation is more abundant and much less material is shifted about. The position and the structure of the ridge both suggest that in the past there were cycles of favorable seasons during which a dense vegetation, probably chiefly forest, was developed upon its surface and that this plant-covered area received only the finer dust blown from the adjacent surfaces. This dust formed the loess bands and entombed the mollusks living upon the surface. During dry seasons the exposed sandy areas were very much increased in extent and the sand being no longer retained by plants was carried by the winds into the forest, thus forming the sandy bands. Upon such sandy surfaces no land-snails grow today and no shells were imbedded in the sands in the past.

The structure herein discussed has been heretofore considered only in connection with the Iowan border, but may be observed in various localities remote from the Iowan border, and it is significant that in all these localities it is exhibited on ridges contiguous to manifest sand-dune areas.

For example, south of New Harmony, Indiana, along the east side of the Wabash valley there are sand ridges, evidently old dunes, which are covered with loess and exhibit essentially the same structure as that of the Iowan border as noted above. South and west of these areas there is a territory now covered with more or less shifting sand-dunes.

At Gladstone, Illinois, the bluffs near the town consist of drift, with superimposed sand which is often laminated, and this is capped with a layer of typical fossiliferous loess.* (See Plate VI, fig. 2.) Southward there extends a great sand plain which probably furnished the greater part of the loess dust. The northward continuation of the same bluffs east of New Boston shows again the same structure. There are now extensive sand-dune areas south of this point.

At St. Joseph, Mo., the same structure may be observed along the ridge north of the Francis street depot of the C., B. & Q. R. R. Opposite to this point to the south and west, there are extensive mud and sand bars, the latter during dry seasons developing to some extent a dune structure at the surface.

In the Indiana, Illinois and Missouri localities cited, this peculiar structure is shown only on the eastern side of the river.

Hooper and West Point, Neb., west of the Missouri, are located near the eastern extremity of an extensive sand dune area, a part of the famous sand-hill region of Nebraska. Exactly the same structure may be observed at both of these points and the relation of the loess to the sand is extremely suggestive of the aeolian origin of both deposits.

Sometimes the sand grades upward into loess without interlamination, and the transition may then be explained as in the following section.

(d). The gradual transition from loess to drift or sand, which may sometimes be observed, especially where loess overlies the Kansan drift or the sands of the Iowan border, is also best explained on ecological grounds, though it has usually been considered evidence that the loess and drift form a practically unbroken series, and that the loess was deposited by ice or by glacial waters.*

The fact should be emphasized that the extent of this intergradation has been greatly exaggerated. There is no general intermingling of drift and loess materials in irregular masses such as might be expected, at least locally, if water had promiscuously shifted these materials about in currents which varied in direction and force with the flood stage of the streams. On the contrary, when this transition does occur, and this is by no means the case in all places where loess and drift come in contact, it is quite consistently uniform and usually complete within a vertical distance of two to six inches. There is no interlamination of materials other than that of sand and loess already noted, no coarse materials appearing in this relation in any of the numerous sections exmined by the writer.

No cases are yet known in which drift materials appear in the loess, the one repeatedly cited in recent years by the advocates of the glacio-fluviatile hypothesis being an error in the determination of the lower member called loess. This is the supposed interloessial drift near Sioux City, Iowa, first reported by Todd and Bain** and later more fully described by the latter.*** It is a layer of boulder-bearing drift lying between what were reported to be two loesses. The writer has recently called attention† to the fact that the lower so-called loess in this and similar exposures near Sioux City is a drift clay and not loess. This drift clay is common in the Missouri river valley and in some places attains a thickness of many feet, as is shown, for example, in the great Union Pacific railway cut-off in South Omaha, Neb., where it meets the loess without the interposition of a boulder-bearing stratum.

While no interloessial drift, in the sense in which this expression was used, is known, interglacial loess-sheets are not uncommon, but they represent distinct

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* For example in the following and other papers:

N. H. Winchell—6th Ann. Rep. Geol. and Nat. Hist. Sur. of Minn., pp. 87-89, 1878; Bull. Geol. Soc. of Am., vol. 14, pp. 141-2, 1903; Am. Geol., vol. XXXI, pp. 279-282, 1903.

W. J. McGee—11th An. Rep. U. S. Geol. Sur., pt. 1, 1891, pp. 442-7, etc.

J. E. Todd—Proc. Ia. Acad. Sci., vol. XIII, p. 191, 1907.

** Proc. Ia. Acad. Sci., vol. II, pp. 20-23, 1895.

*** Rep. Iowa Geol. Sur., vol. VIII, pp. 283-4, 1896.

† Proc. Iowa Acad. Sci., vol. XIV, 1908.

interglacial periods, and do not connect the drift with loess. Such are the following examples which the writer has personally examined:

A post-Kansan loess between Kansan and Illinoian drifts in cut facing Hershey Ave., Muscatine, Iowa;* a similar loess between the Kansan and Iowan drifts in Jefferson twp., northwest of Iowa City;** a loess between the Kansan and Wisconsin drifts in Des Moines, Iowa;*** two loesses between the Kansan and Wisconsin drifts near Carroll, Iowa;† a loess between the Illinoian and Wisconsin drifts in the Farm creek exposure near Peoria, Ill.;‡ and other similar exposures. In all the examples mentioned the loesses are fossiliferous, and their relation to the drifts is clear.

These interglacial loesses present no evidence of close genetic relationship with the contiguous drift-sheets—on the contrary, their abundant terrestrial fossils indicate that the conditions which existed during the formation of these loesses were similar to those under which the same species exist today throughout the loess-covered area, and these species now exist abundantly on our upland surfaces in a temperate climate!

These loesses clearly represent interglacial periods of long duration, and the foregoing cases cannot be considered in connection with the occasional gradual transition from drift to loess which seldom results in the formation of a stratum more than a few inches in thickness. But even this gradual transition, which as noted may sometimes be observed, does not prove the common origin of loess and drift, for it is entirely consistent with the aeolian hypothesis and gives substantial support to it. Such gradual transition from sand or drift to finer material, such as loess, would occur on surfaces on which the covering of vegetation increased gradually, particularly where the sand-dune or drift surface was adjacent to a broader territory over whose surface the same gradual increase in vegetation had taken place. While vegetation was still practically absent, the surface materials were freely shifted about, even coarse sand being thus moved. As vegetation gradually increased the coarser material was less frequently disturbed, or when shifted became mixed with finer materials, and finally only the finest dust, now forming the loess, was transported and lodged on the more densely covered surfaces.

Where the change in vegetation was very gradual there was a corresponding change upward from coarse to fine material. Where the changes were abrupt, because of changes in drainage, etc., the lines of demarkation became sharp, and where these conditions alternated, corresponding bands of loess and sand were formed, if the surface was quite sandy.

III. *Conditions existing during deposition of loess.*

The presence of numerous fossil mollusks in the loess proves that there was an abundant vegetation on the surface at the time (or successive times) of deposition. These mollusks are herbivorous, and they are terrestrial and air-breathing, chiefly upland species, and their distribution is determined by the character of the plant covering, which serves both for shelter and food. A comparison of the distribution of modern terrestrial mollusks and the plants

*Reported by the writer in Bull. Lab. Nat. Hist., St. Univ. of Iowa, vol. V, pp. 362-3.

**Reported by the writer, ibid., p. 366.

***Reported by McGee and Call, Am. Jour. Sci., vol. XXIV, pp. 202, et seq., 1882; and by the writer, Bull. Lab. Nat. Hist. St. Univ. of Iowa, vol. V, p. 367.

†Reported by the writer, ibid., p. 367.

‡Reported by Leverett—Monographs, U. S. Geol. Sur., vol. XXXVIII, p. 187, 1899.

among which they live, with that of the fossils in the loess, shows a striking similarity of habitats, and suggests, as the writer has repeatedly stated, that the conditions which prevailed when the loess was formed were not materially different from those now existing in the same region. The abundance of terrestrial mollusks and plants precludes the possibility of the presence of large bodies of water, or of glacial ice in a glacial climate. They render the glacio-fluviatile hypothesis wholly untenable.

IV. *Inter-loessial periods.*

In many cases where two distinct loesses are in contact, the lower is gray (post-Kansan) and contains numerous iron tubules which have been manifestly formed by roots, and these tubules often terminate abruptly in the oxidized band which so frequently separates these loesses. Less frequently they terminate similarly in the surface of contact of the loesses, the oxidized line or band being absent. (See Plate VII, fig. 1.)

This suggests that when the bluish-gray loess was at the surface it was covered with an abundant vegetation which has left evidence of its existence in these tubules. When the succeeding ice-sheet overwhelmed the territory this vegetation was destroyed, and the loess surface, just beyond the ice-border and on the elevations which had not been denuded by the thin ice-sheet, and from which the ice first disappeared, remained bare of plants for some time, and finally gradually developed a scant flora. During this partial or complete denudation the oxidization of the iron-stained surface probably took place, though it is possible that the iron was in part washed down to its present level after some of the superimposed newer loess was formed. (See Plate VII, fig. 2.)

The influence of the second ice-sheet would have been felt for some distance beyond its border, and the same sharp division of loesses would have resulted. It is probably for this reason that the sharp division of the post-Kansan and later loesses may be traced for a considerable distance beyond the borders of the later drifts, especially the Iowan.

A subsequent restoration of favorable conditions resulted in the development of another flora which built up the upper (newer) loess.

In addition to the foregoing important considerations there are other questions of interest which may be solved by due reference to the behavior of modern plants. The peculiar loose lobular structure of the upper three to five feet of much of the loess is evidently due in large part to the action of roots; the vertical cleavage of loess is probably due to the same cause; the fact that roots will decay in loess and completely disappear without leaving a trace of carbonaceous material is not without interest; this, together with the fact that exposed plant materials completely decay long before they could be covered by dust in the manner suggested by the aeolian hypothesis, accounts for the absence of plant remains in the loess; the effect which roots might have by dissolving shells of the fossil mollusks and thus making some of the loess apparently non-fossiliferous is also noteworthy; and perhaps other minor problems may be suggested.

It is also worthy of note that sometimes the study of the local flora makes it possible to determine the limits of loess and drift formations without making sections. Thus along the timbered portions of the Iowan drift border in Johnson and Iowa counties in Iowa it is possible in some cases to accurately limit the Iowan sands and the loess by the species of trees making up the forest covering, the dominant species on the sands being *Quercus velutina*, the yellow oak, and *Q. macrocarpa*, the bur oak, while on the loess of the Kansan *Q. alba*, the white oak, and *Q. rubra*, the red oak, take possession. This change is striking even in places where surface overwash, etc., have made the immediate surface deceptive.

The foregoing considerations suggest something of the importance of the study of plants in the field in connection with loess investigations and justify the title of this paper.

EXPLANATION OF PLATE III.

Fig. 1. The wooded bluffs above Florence, Neb. These rounded wooded bluffs are the prevailing type on the west side of the Missouri river. (See p. 58.)

Fig. 2. The abrupt treeless bluffs above Missouri Valley, Iowa. This represents the prevailing type on the east side of the river. (See p. 58.)

PLATE III.

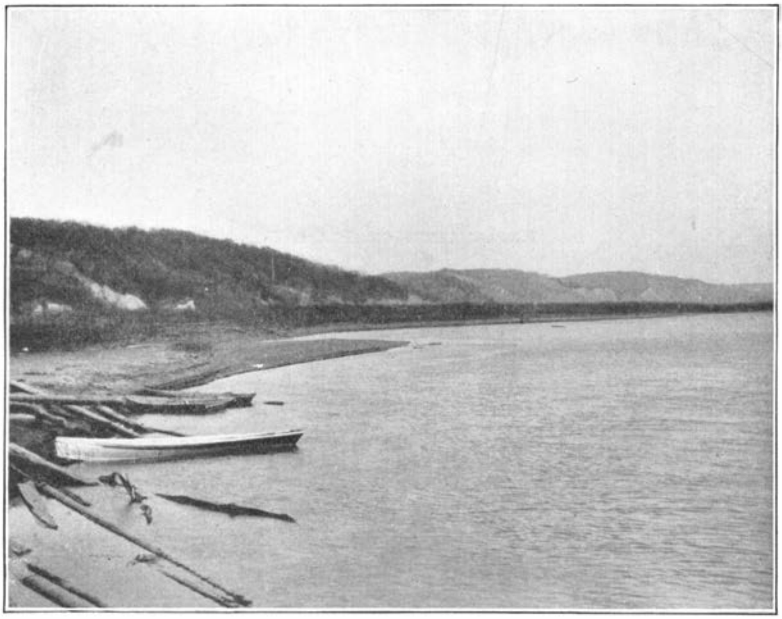

FIG. 1.

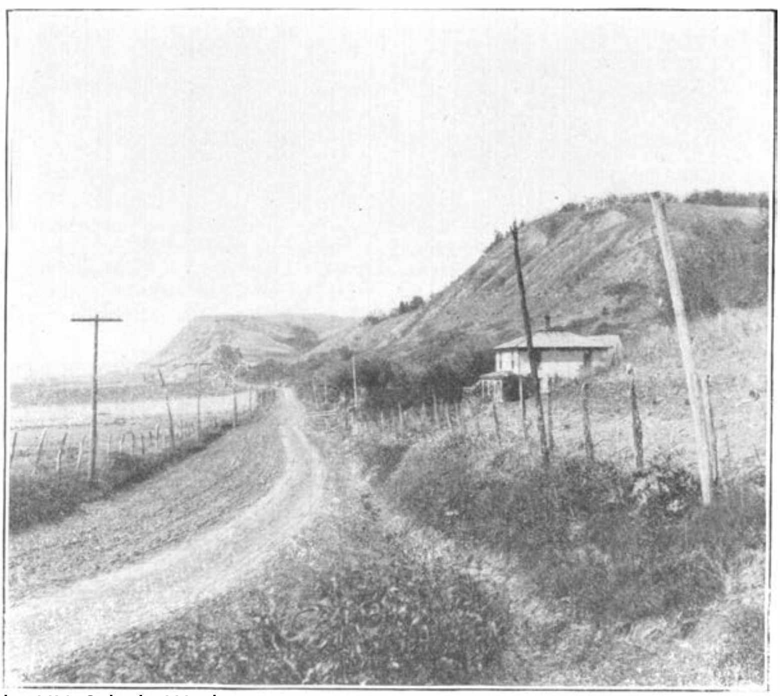

FIG. 2.

EXPLANATION OF PLATE IV.

Fig. 1. A portion of the face of the loess bluffs at Council Bluffs, Iowa, showing the tufted xerophytic vegetation with large bare spaces between the plants. Dust may therefore be whipped up these abrupt slopes much as snow is driven up the face of a snow-drift. (See p. 58.)

Fig. 2. A view of the top of the high ridge above Hamburg, Iowa, looking north. The slopes to the left face the river and are treeless. The eastern sheltered side is forest-covered and less abrupt. Where the eastern slopes of these ridges are treeless the return currents of air also whip the dust toward the crest of the ridge, and make these slopes almost as abrupt as those on the west side. (See p. 58.)

PLATE IV.

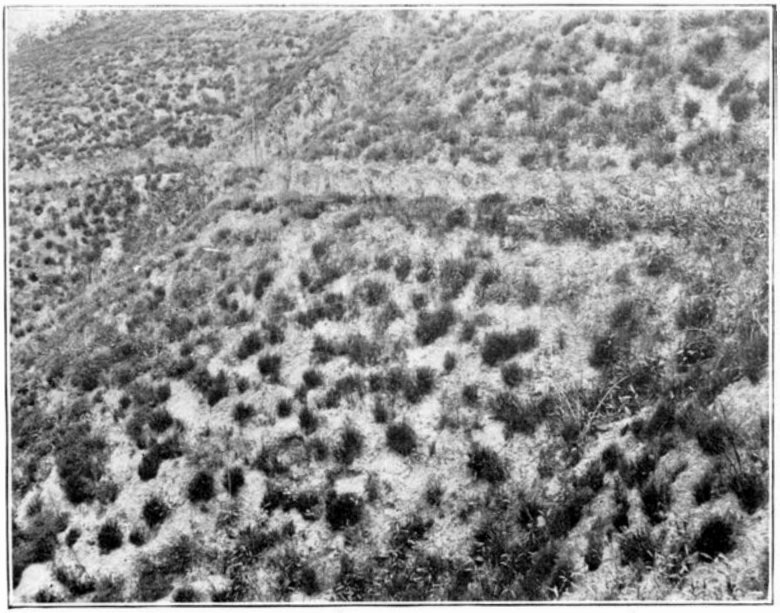

FIG. 1.

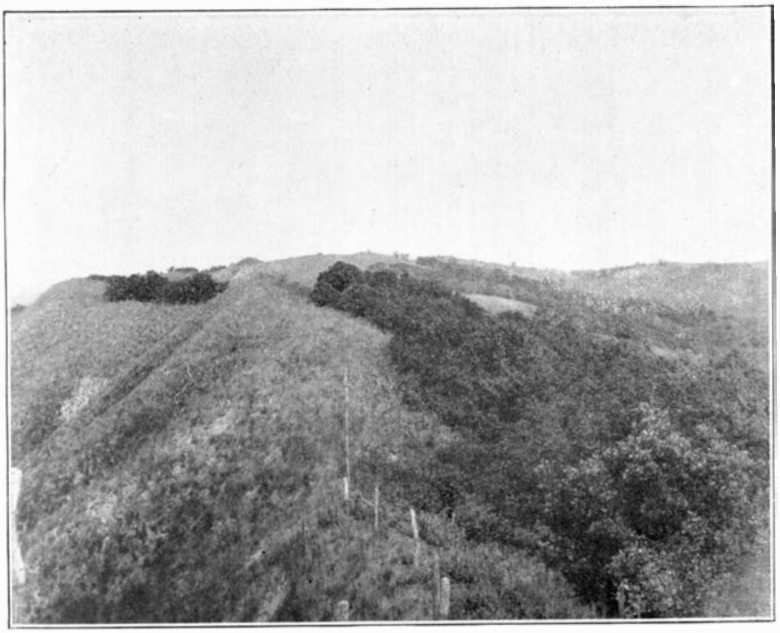

FIG. 2.

EXPLANATION OF PLATE V.

Fig. 1. The northerly slopes of a portion of the Wisconsin drift moraine in southwestern Lyon county, Iowa, showing more or less forest covering. On these slopes there is a distinct soil and a thin loess, while the exposed tops and windward slopes are treeless, and without surface soil. (See p. 58.)

Fig. 2. A sand dune on which plants (chiefly *Cassia chamaecrista*) have become established. The dune is now fixed and is beginning to form a finer soil. The trees are cottonwoods, and are responsible for the formation of the dune. Nearly all the plants on these dunes are leguminose, with abundant root-tubercles containing nitrifying bacteria. Harrison county, Iowa. (See p. 59.)

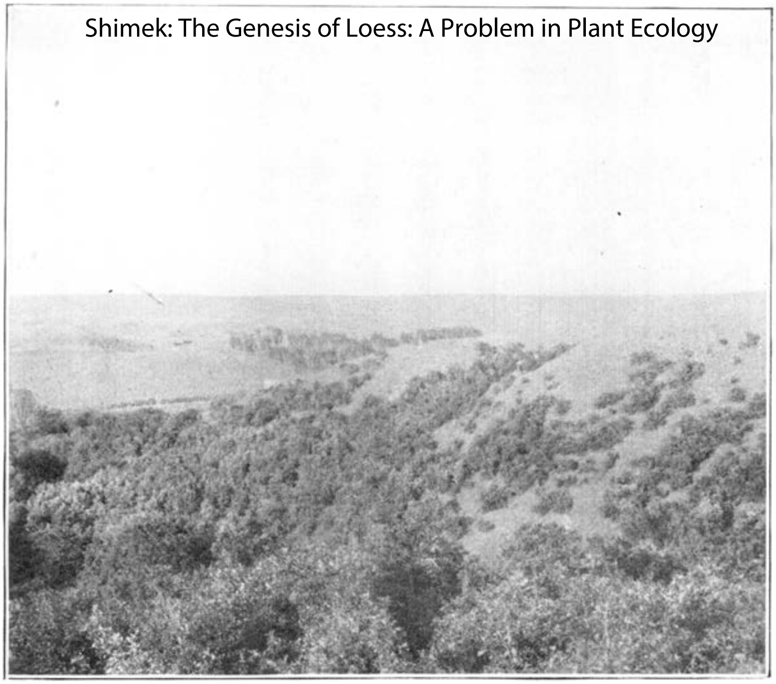

FIG. 1.

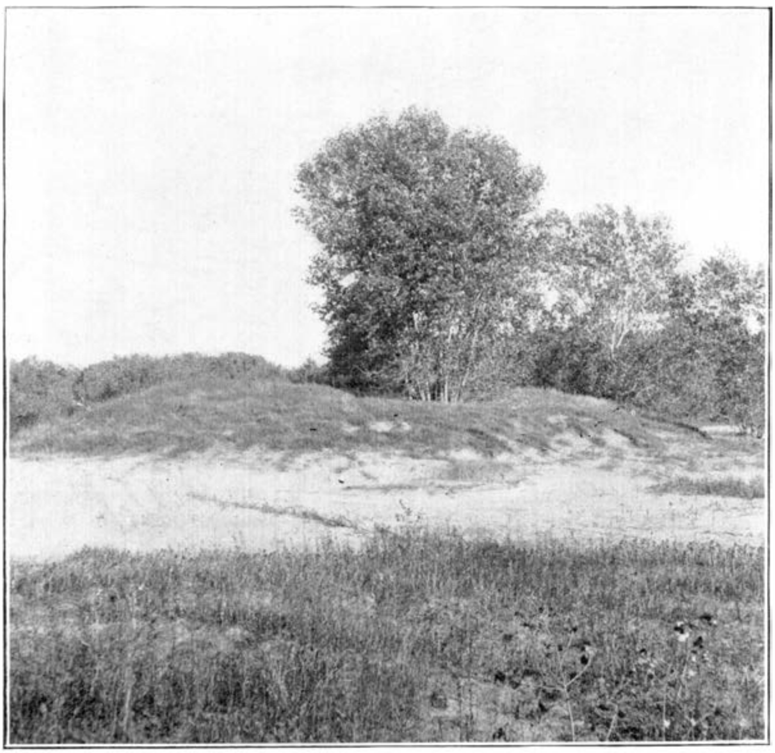

FIG. 2.

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EXPLANATION OF PLATE VI.

Fig. 1. Section along the Interurban railway in Madison township, Johnson county, Iowa, south of the Iowa river. It shows alternating bands of sand and fossiliferous loess, especially in the upper part. The lower portion shows a thicker stratum of loess. These bands vary in thickness from a fraction of an inch to several feet. (See p. 60.)

Fig 2. A part of a section at Gladstone, Ill., showing laminated loess resting on stratified sand, the two blending more or less, and showing some interlamination. The loess is fossiliferous. (See p. 60.)

PLATE VI.

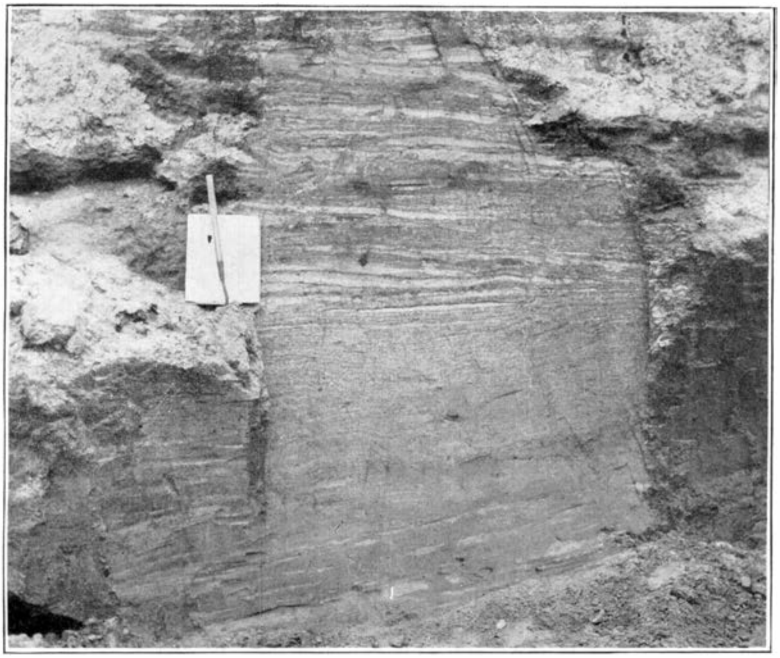

FIG. 1.

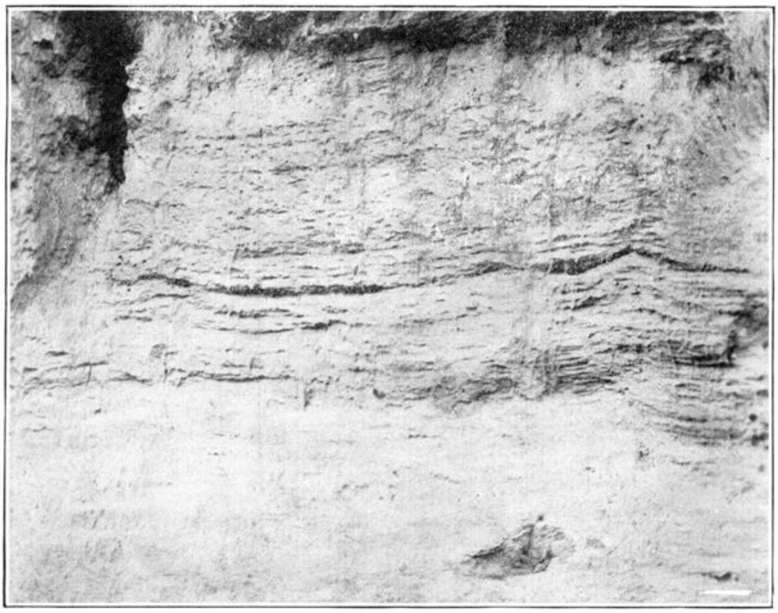

FIG. 2.

EXPLANATION OF PLATE VII.

Fig. 1. Section along wagon-road southwest of Farley, Iowa. in Sec. 23. T. 88 N., R. I. W. This shows two loesses separated by an oxidized line. The lower (post-Kansan) gray loess contains large iron-stained root-tubes, which terminate abruptly at the upper limit of this loess. The upper yellow loess is stratified and contains no root-tubes. (See p. 63.)

Fig. 2. Section in Gaulocher's brickyard in Iowa City, Iowa, showing two loesses very sharply separated but with scarcely a trace of an oxidized line between them. The lower is a gray post-Kansan loess with iron tubules. The upper yellow loess has gray vertical lines or streaks which resemble the lower loess, and which were evidently formed by the roots. In some cases the gray upper streak is continuous with the iron tube in the lower loess; both having evidently been formed by the same root long after both loesses were formed. (See p. 63.)

PLATE VII.

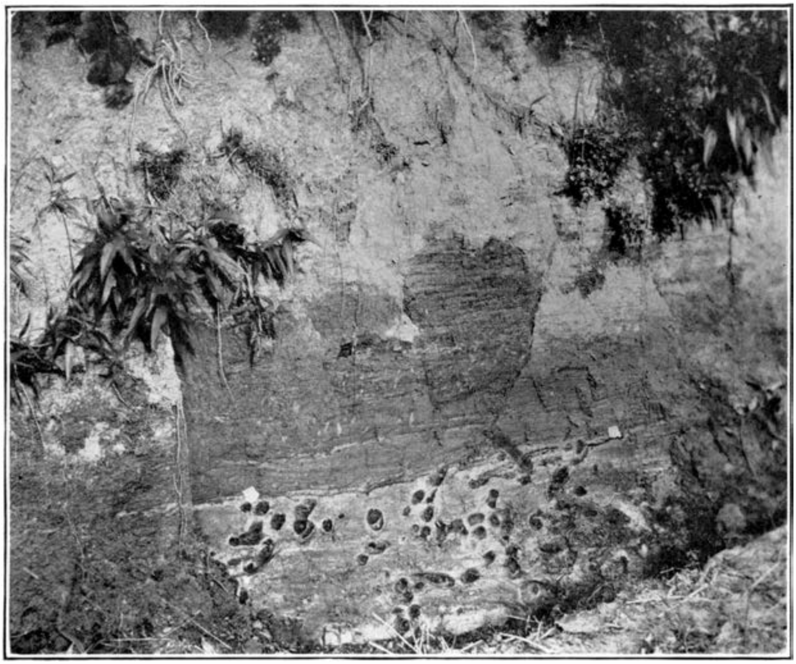

FIG. 1

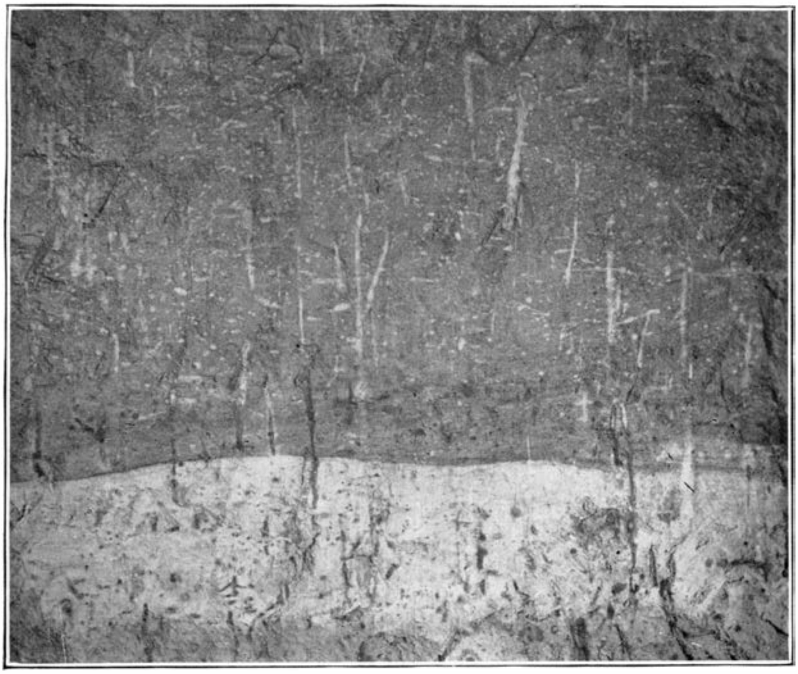

FIG. 2.