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RELATIONS OF THE PROPERTIES OF WISCONSIN LOESS TO TOPOGRAPHY IN WESTERN IOWA*

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ABSTRACT. Previous studies have shown that thickness, particle-size distribution, and other characteristics of the Wisconsin loess in western Iowa vary exponentially with distance from an assumed major source. The intensity of development of soils derived from Wisconsin loess has been related to the decreasing thickness of the loess that has been recognized as a function of increasing distance from the source. Detailed studies of the characteristics of Wisconsin loess show that previous concepts apply only to sample sites on the summits of primary and secondary divides. Characteristics of the loess show greatest values on the crests of divides and progressively decrease down the flanks of interfluves both toward and away from the assumed source of loess. Detailed studies of weathering profiles in Wisconsin loess show maximum intensity of development on the crests of divides but progressively decrease in intensity of development down the flanks of interfluves both toward and away from the assumed major source.

INTRODUCTION

Several investigations have shown the regional curvilinear relationships of certain characteristics of loess deposits. Krumbein (1937) demonstrated that the thickness of loess relative to its source could be expressed by exponential curves. In a study of loess-derived soils in Illinois, Smith (1942) showed that thickness, particle-size distribution, and carbonate content of the Peorian, as well as the Late Sangamon (now recognized as Farmdale), loess varied exponentially with distance from the assumed source. Properties of soils developed on the Peorian loess were shown to be related to the loess thickness.

Hutton (1947, 1951), following Smith's approach in a study of loess-derived soils in southwestern Iowa, demonstrated similar characteristics of loess relative to distance from an assumed source, the Missouri River Valley. Soils were noted to be related to the thickness of the loess along Hutton's traverses (fig. 1). In Holt County, Missouri, Shrader et al. (1953) followed a similar approach and arrived at similar conclusions.

In the previous studies few measurements and samples were taken along traverses of considerable distances. In Illinois, Smith's traverses of approximately 70 and 100 miles are represented by 10 to 15 measurements of thickness with correlative samples. In southwestern Iowa, Hutton's northern traverse of 167 miles had 11 measurement and sample sites, and the southern traverse of 87 miles consisted of 10 measurements and sample sites. Simonson and Hutton (1954) recently extended the southern traverse through 257 miles on the basis of a total of 11 measurements of loess thickness.

The recent relocation of the Chicago, Rock Island, and Pacific Railroad in southwestern Iowa between Atlantic and Bentley has offered an excellent opportunity to study Pleistocene deposits in the area (Ruhe, 1954). Fifty major cuts, some 60 to 70 feet deep and half to three-quarters of a mile long, transect the north-south ridges generally at right angles along the traverse of 34 miles (fig. 1 and fig. 2, A). Each cut exposes not only the complete sec-

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tion of Wisconsin loess surmounted by a level or slightly rounded summit but also the buried summits and flanks of the Sangamon surface on which the Wisconsin loess was deposited. Thus excellent sections are available for accurate measurement of thickness of the Wisconsin loess as well as a study of its other characteristics relative to the basal surface of deposition, the

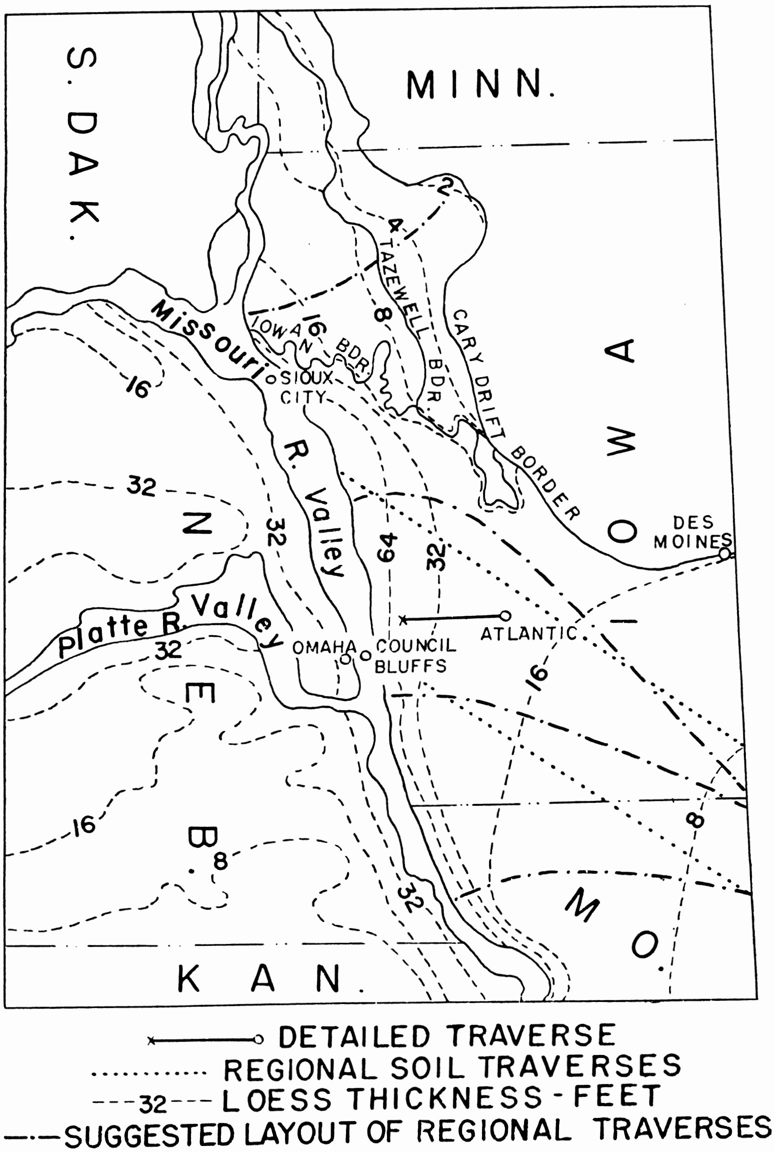

Fig. 1. Regional distribution of the thickness of Wisconsin loess and locations of traverses in western Iowa.

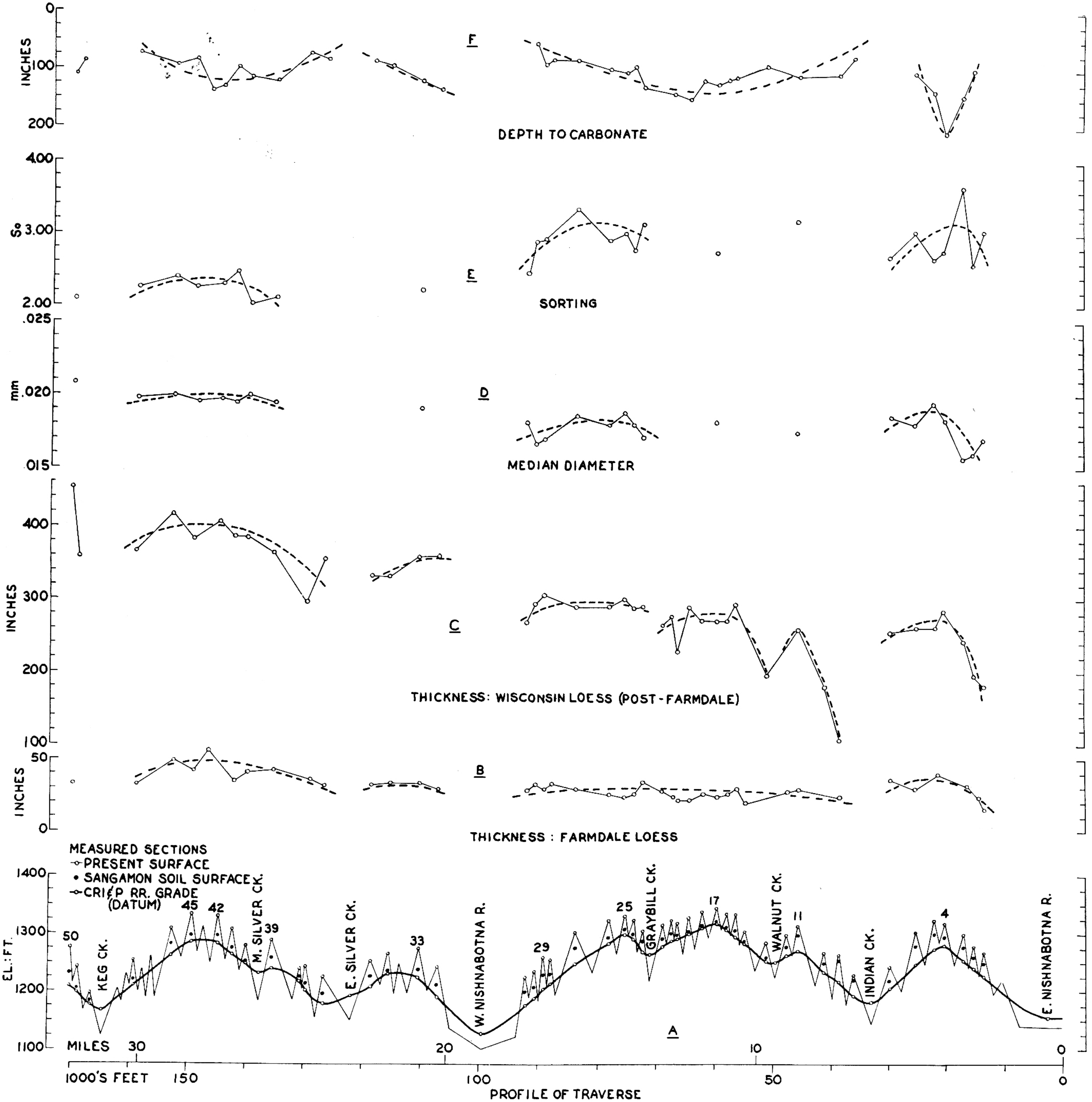

Fig. 2. Topographic profile and detailed curvilinear characteristics of Wisconsin loess along the Rock Island relocation in western Iowa. Note: topographic profile and curves of loess characteristics are lettered *A* to *F*; see text.

Sangamon surface. Selection of sites where post-loess erosion or other modification is at a minimum is facilitated by the cuts. The surveyed base grade of the Rock Island Railroad also serves as a controlled reference datum relative to distance and elevation. Thus, the exposure in the Rock Island cuts of 50 measurement and sample sites in a traverse of 34 miles affords an opportunity to compare the data of previous regional studies with the writer's detailed study.

REGIONAL CURVILINEAR RELATIONSHIPS

Figure 2. A shows that distribution of Wisconsin loess along the traverse is a curvilinear relationship of elevation to distance. The loess mantles the Sangamon landscape that stands highest at the primary divides. Primary divides are defined as the divides between the major drainages along the traverse. The major drainages are three: East Nishnabotna River. West Nishnabotna River. and Keg Creek. all tributary to the Missouri River. The primary divides are the heights of the Sangamon landscape at cut 17. and between cuts 42 and 45.

Secondary divides are those between main tributaries of the major drainages. Indian and Walnut Creek drain to the East Nishnabotna River. Cuts 4 and 11 are secondary divides within the East Nishnabotna system. Graybill. East Silver. and Middle Silver Creeks are affluent to the West Nishnabotna River. Cuts 25. 29. 33. and 39 are secondary divides within the West Nishnabotna system. Main tributaries to Keg Creek are not important within the reach of the stream transected by the loess traverse. All other divides are considered to be tertiary divides although some may be of a fourth or fifth order of magnitude. Because all drain to secondary drainages within short distances of the traverse. they are categorized in the same order of divide-magnitude.

The Sangamon surface slopes from the primary and secondary divides to the present primary and secondary drainages. A parallelism exists between the buried Sangamon surface and the modern surface (post-Wisconsin loess). The basic control of the expression of the modern loessial landscape is the buried Sangamon surface. Thus an analysis of the development of the modern landscape. that is essentially one of loess deposition but modified somewhat by post-loess erosion on slopes. should analyze also the surface on which the Wisconsin loess was deposited. the Sangamon surface.

Previous investigators have utilized the modern surface as the basis of their landscape analyses. Smith (1942. p. 149). Hutton. (1947. p. 424). Simonson and Hutton (1954, p. 102) selected modern level to slightly rounded divides as sites for measurement of loess thickness and sampling. They assumed that any possibility of significant changes in thickness of loess through erosion or deposition of wash from adjacent higher land was precluded at these topographic positions.

Application of the regional research approach has been made by the present writer to the cuts along the Rock Island relocation. Sample sites were selected at the positions of primary and secondary divides, namely cuts 50. 45, 42. 39. 33. 29. 25. 17. 11. and 4 (fig. 2. A). The data are presented in figure 3.

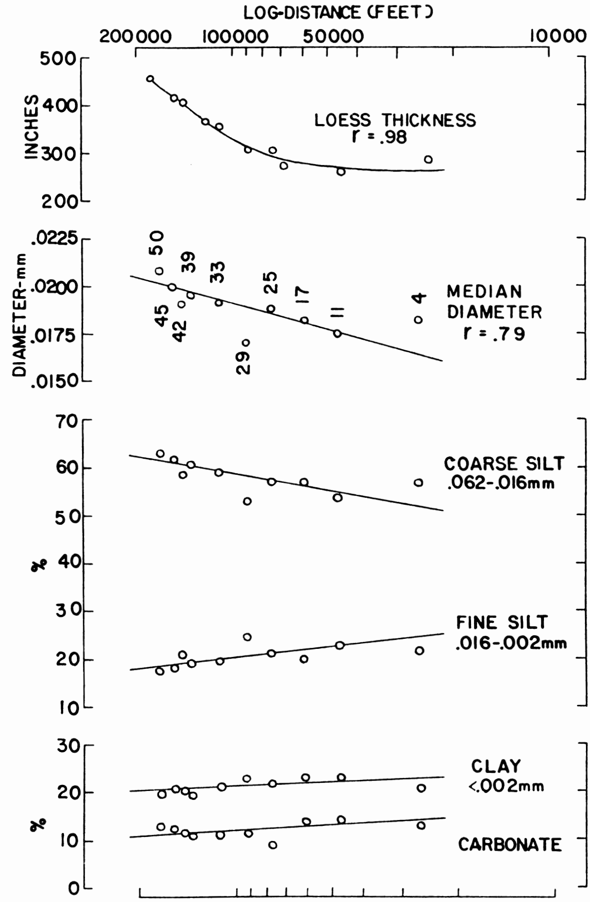

Fig. 3. Regional curvilinear characteristics of the Wisconsin loess along the Rock Island relocation in western Iowa.

The thickness of the loess systematically decreases with distance from an assumed source, the Missouri River Valley, from 453 inches at cut 50 to 285 inches at cut 4. This west-to-east traverse transects the regional loess-thickness lines at approximately a right angle in the west half of the traverse, but deviates from a normal to the loess thickness lines in the east half of the traverse (fig. 1). The latter deviation precludes an ideal traverse layout, but the deviation was unavoidable in order to take advantage of the railroad cuts. However, the traverse crosses all divides at approximately a right angle. The thickness data when tested statistically show a correlation coefficient of $r = 0.98$, indicating that the expected relationship, decrease of loess thickness with distance from the assumed source, is present.

Median diameters of oxidized and unleached, i.e., the least-weathered, loess from divide locations also systematically decrease from west to east along the traverse. The median-diameter data when tested statistically show a correlation coefficient of $r = 0.79$, also indicating that the expected relationship, decrease of median-particle diameter with distance from source, is present.

Other texture data are in accord with these relationships. The coarser silt fraction (.062-.016 mm) systematically decreases, and the finer silt fraction (.016-.002 mm) as well as the clay fraction ($<$ .002 mm) increase with distance along the traverse.

The carbonate content was found to increase with distance from the assumed source. In Illinois Smith (1942, p. 164-172) found that carbonate content systematically decreases with distance. Along the Rock Island traverse in Iowa, the increase is apparently the effect of secondary concentration of fine carbonate in the oxidized and unleached loess due to weathering processes. Carbonate determinations of particle-size fractions showed:

Cut	*Total*	*Coarser silt fraction*	*Finer silt fraction*	*Clay fraction*
50	12.6%	60.8%	42.2%	15,0%
33	11.2	60.5	22.3	17.2
11	14.0	42.8	29.8	27.4

The above data conform with and substantiate the regional studies of previous workers. Although Simonson and Hutton (1954, p. 100-101) suggest that traverses in western Iowa should be laid out in a southeasterly linear direction from the Missouri River Valley, consideration should be given to laying out loess traverses in regional studies in a curvilinear pattern so that the regional loess-thickness lines are crossed at right angles (fig. 1). Exponential equations of thinning of loess (Hutton, 1947) should vary considerably if linear and curvilinear traverses are compared. Secondly, if soils along loess traverses are to be compared, linear traverses may give a false association. Segments of different linear traverses may fall along one curvilinear traverse (fig. 1).

In northwestern Iowa, the loess thins in a curvilinear manner toward the northeast in contrast to the southeasterly curvilinear pattern in southwestern Iowa. The geographic distribution pattern could be accounted for by generally westerly winds removing sediment from a major source, the east-west trending Missouri River Valley between South Dakota and Nebraska, and distributing the sediment in a broad fan-shaped pattern to the east. Complexities in sedimentation are to be expected along the western margin of Iowa because of the near source of sediment in the south-trending Missouri River Valley. Complexities in sedimentation are to be expected also in northwestern Iowa because of loessial sedimentation contemporaneous with the recessions of the Iowan and Tazewell glaciers to the northeast.

LOCAL CURVILINEAR RELATIONSHIPS

Compilation of the data of the Wisconsin loess of each cut along the Rock Island relocation presents a picture of loess characteristics entirely different from that shown by only the regional samples of primary and secondary divides. Measurements and samples were taken at every cut, primary, secondary, and tertiary divides, where the loess is surmounted by a level or slightly rounded summit. Thus, the requirement is fulfilled of sample sites where significant post-loess erosion or post-loess deposition by wash essentially is precluded. Of 50 cuts, 8 were discarded as measurement sites because the cuts occur on north or south slopes along the trends of the ridges. Each sample site is similar, in a local sense, to all others, but they differ in that the secondary divide sites are located on the flanks of primary divides. The tertiary divide sites, in turn, are located on the flanks of secondary and primary divides (fig. 2, A). For example, 7 sample sites are located across the secondary divide between the East Nishnabotna River and Indian Creek. Each ridge, cuts 1 through 7, at the sample site is a level to slightly rounded summit. Cuts 5, 6, and 7 occur progressively lower on the west flank of the secondary divide surmounted by cut 4. Cuts 3, 2, and 1 occur progressively lower on the secondary divide. Similar divide units are located along the traverse:

Cuts	*Divide*	*Part of traverse*
8-12	Secondary	Indian Creek-Walnut Creek
13-22	Primary	Walnut Creek-Graybill Creek
23-31	Secondary	Graybill Creek-West Nishnabotna River
32-35	Secondary	W. Nishnabotna River-E. Silver Creek
36-46	Primary	East Silver Creek-Keg Creek

Occurring in each cut in the basal part of the Wisconsin loess and above the Sangamon soil is a thin leached zone characterized by a weakly developed buried soil (generally an A-C profile). This basal loess, incorporated entirely within the buried soil, is correlated by the writer with the Farmdale of Illinois (Leighton and Willman, 1950, p. 602-603). Above the Farmdale and progressively upward are weathering zones in the Wisconsin loess designated as deoxidized and leached zone, oxidized and unleached zone, deoxidized and unleached zone, and oxidized and leached zone (Ruhe, 1954, p. 640). In the upper part of the oxidized and leached zone, a soil classified as the Monona silt loam occurs generally west of cut 33, and to the east the soil is generally the Marshall silt loam.

Inspection of the data, thickness of Farmdale loess relative to distance along the traverse, shows that a mean curve of the values parallels the general topographic positions of the Farmdale sites upon the Sangamon surface (fig. 2, B). For example, across the primary divide between Keg and East Silver Creeks, the maximum thickness of Farmdale loess occurs at the crest of the divide. The Farmdale loess thins progressively down the flanks of the divide both to the west, *toward* the loess source, and to the east, *away* from the loess source. Similar relationships exist across the other divide units along the traverse.

The following discussion pertains to the Wisconsin loess that is post-Farmdale in age, and the term Wisconsin loess, for the sake of brevity, will be restricted to the post-Farmdale increments. Inspection of the data (fig. 2, C), thickness of Wisconsin loess relative to distance along the traverse, shows more distinctly the correlation of thickness of Wisconsin loess to topographic position on the Sangamon surface. Any modification by the thin Farmdale increment is slight. The relationships, thickness of loess to distance along the traverse, are:

Divide unit	*Part of traverse*	*Characteristics*
Primary	Keg Creek-E. Silver Creek	Maximum thickness at crest of divide; progressive thinning on divide flanks to west and east.
Secondary	East Silver Creek-West Nisnabotna River	Maximum thickness at crest of divide; progressive thinning on divide flanks to west and east.
Secondary	West Nishnabotna River-Graybill Creek	Maximum thickness at crest of divide; progressive thinning on divide flanks to west and east.
Primary	Graybill Creek-Walnut Creek	Maximum thickness at crest of divide; progressive thinning on divide flanks to west and east.
Secondary	Walnut Creek-Indian Creek	Maximum thickness at crest of divide; progressive thinning on divide flanks to west and east.
Secondary	Indian Creek to East Nishnabotna River	Maximum thickness at crest of divide; progressive thinning on divide flanks to west and east.

The relationship, maximum thickness of loess at crests of divides with progressive thinning on divide flanks both in a westerly direction, *toward* the loess source, and an easterly direction, *away* from the loess source, differs radically from the generally accepted concept developed in regional studies that loess thickness decreases exponentially with distance from the source.

It seems apparent that another factor other than a simple distance relationship may control the thickness distribution of loess. The general parallelism of the thickness curves to the topographic curves (fig. 2, A, C) suggests that configuration of the surface upon which the loess was deposited may influence the thickness distribution of the loess. The surface of deposition is the Sangamon surface, and in a macrosense is a rough surface. The thickness of loess relative to a rough surface of deposition may be evaluated by comparing the thickness of the loess at any point on that surface with the elevation of the surface of deposition at that point (fig. 4). The data may be tested statistically. Correlation coefficients determined for divide units are r values of 0.68, 0.77, 0.77, 0.86, 0.87, indicating that the thickness of loess deposited upon a surface is influenced by the elevation of the surface at the point of deposition. This cause and effect is restricted to individual units of the rough surface, i.e., individual divide units along the traverse. The correlation does not hold across several adjacent divide units. For example, the correlation coefficient of data across the multiple divide unit, West Nishnabotna River to Indian Creek is $r = 0.42$.

Thinning of loess on the flanks of divides is generally uniform both west and east. There is not a greater accumulation on one side of the divide than on the other, but the mantle is generally symmetrical to axes of the crests of the Sangamon surface. Individual cuts in general show the same symmetry of Wisconsin loess mantle on the Sangamon surface. Greatest accumulations of loess occur above the crests of the buried Sangamon surface. General statements in the literature report that in western Iowa greater thicknesses of loess occur on the east sides of hills or ridges (Kay and Graham, *1943*,

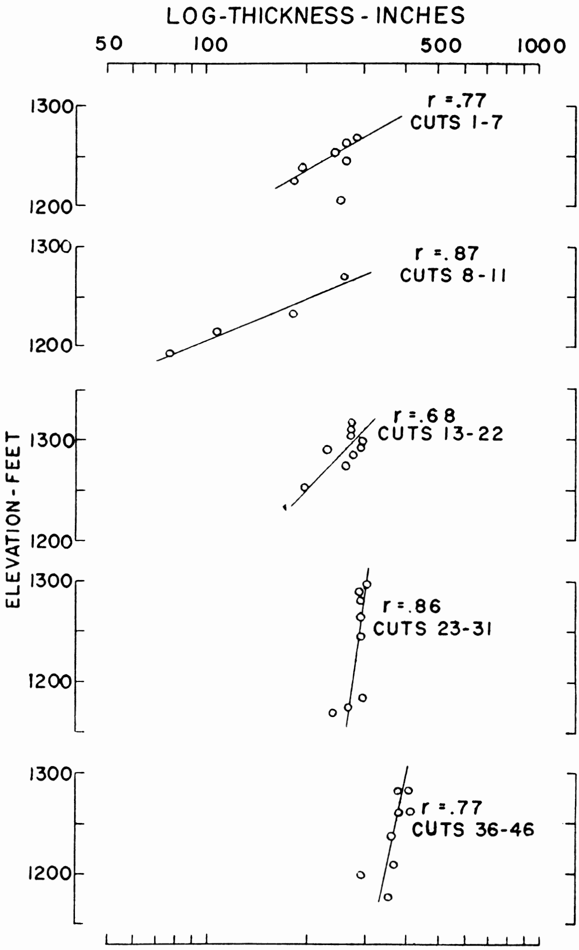

Fig. 4. Correlation of the thickness of Wisconsin loess and the elevation of points on the Sangamon surface at which loess was deposited.

p. 161) or the southeast sides of ridges (Simonson and Hutton, 1954, p. 100). Such asymmetrical loess accumulations have been used as evidence of lee-slope deposition to support interpretations of prevailing winds during loess deposition. The following data are presented as a contradiction to the assumed asymmetry of hills:

Number of cuts	*Wisconsin loess-mantle configuration on Sangamon surface*
45	Symmetrical
4	Asymmetrical (to east)
1	Asymmetrical (to west)
50	

Scale drawings of all cuts have been constructed. Earthmoving operations in cut construction completely penetrated the Wisconsin loess and went deeply into pre-Wisconsin hill and ridge cores. In the writer's experience asymmetry of loess mantle is restricted to the narrow belt of bluff hills immediately east of the Missouri River Valley.

Inspection of the data presented in median diameter and sorting curves (fig. 2, D, E) shows a correlation with each other and the thickness distribution across the divide units. Median diameters are greater at the crests of divides and progressively decrease on divide flanks in both a westerly and easterly direction, i.e., both *toward* and *away* from the loess source. Previous regional concepts held that mean particle-size decreases with distance from the source. The sorting curves indicate that poorer sorting (greater *So* values) occurs at the crests of the divides. Sorting becomes progressively better (lesser *So* values) down the flanks of divides both west and east, i.e., both toward and away from the assumed source of loess.

These data, thickness distribution and variability in texture and sorting across local divides, when evaluated in regard to regional curvilinear relationships, show that loess sedimentation is complex and not just a simple function of distance from source.

LOCAL CURVILINEAR RELATIONSHIPS AND WEATHERING

Considerable work has been done on the physical and chemical properties of loess-derived soils relative to thickness of parent material along regional traverses. Bray (1934, 1937) and Smith (1942) pioneered this type of study in Illinois. Following the work of Hutton (1947, 1951) in western Iowa, other investigators (Ulrich, 1950, 1951; Godfrey and Riecken, 1954) have shown the progressive increase in the intensity of weathering of the sola. These changes in physical and chemical characteristics have been correlated with decreasing thickness of the loess as a function of distance from the assumed major source, the Missouri River Valley. No previous detailed studies have been made of local variability of soils across primary and secondary divides.

The data presented in figure 2, F indicate that such a detailed soil study may be desirable. The weathering profiles (Scholtes et al., 1951, p. 296-297) were examined and measured at each cut along the Rock Island traverse. Each measurement site was selected so that a level or slightly rounded summit surmounted the section. The mean curves representing depths to carbonates across the interfluves show an inverse relationship to the loess thickness, median diameter, and sorting curves. Greatest depths of leaching occur on the crests of divide units. Progressively lesser depths of leaching occur down both the west and east flanks of interfluves, i.e., both toward and away from the assumed source of loess.

Because a regional correlation exists between the physical and chemical properties of soils derived from Wisconsin loess relative to loess thickness, particle-size distribution, and degree of sorting, the question may be raised whether the local inverse relationship across interfluves of weathering to loess thickness, particle-size distribution, and degree of sorting may not be reflected in different properties of soils on the flanks of divides relative to crests.

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