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Stratigraphy, Sedimentology, and Moisture Contents in a Small Loess Watershed in Tama County, Iowa[1]

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Abstract. A traverse across a small first-order watershed in loess has been studied. The loess is Wisconsin in age and has a vertical tripartition that can be explained on a regional basis. Clear stratification is present in the middle loess increment. Moisture distribution patterns correlate highly with differences in particle-size distribution. The explanatory physical phenomena must be moisture-tension relationships.

As part of a larger integrated study of soils, geomorphology, hydrology, and stratigraphy in the Four-mile Creek area, Tama County, Iowa, some results of analysis of a traverse across a first-order watershed in loess are presented.

GEOMORPHIC SETTING

Four-mile Creek, a tributary of Wolf Creek, is located in the Iowan landscape of northeastern Iowa (Figure 1). Its northern divide consists of a Kansan inlier with a system of paha superimposed upon it.

Thom watershed is a first-order watershed on the southern flank of the paha system. The traverse studied extends from summit to summit, perpendicularly across the valley from N. 40° E. to S. 40° W. Because the traverse is not perpendicular across the contour lines, the slope gradients in the profiles are not maximum; the slope percentages for the linear backslope portions of the "northern" and "southern" slopes are 19 and 20, respectively.

SEDIMENTOLOGY AND STRATIGRAPHY

Samples to depth collected at 10 stations along the traverse by a hydraulic probe reveal that the subsurface materials consist of loess and loess-derived valley fill varying in thickness from 16 to 25 feet overlying till and till-derived valley fill.

The till has been identified as Kansan (2)[3]. In its upper part, a well-developed paleosol is present, is very dense, and has clay contents of more than 50 percent.

The loess is Wisconsin and has a weakly developed paleosol in its basal portion. In these areas, the maximum age for the basal loess is about 25,000 years, while loess deposition ceased 14,000 years ago (2).

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[1] Water Resources Institute Project No. A-0014-IA and Journal Paper No. J-5977 of the Iowa Agriculture and Home Economics Experiment Station, Ames. Project No. 1656.

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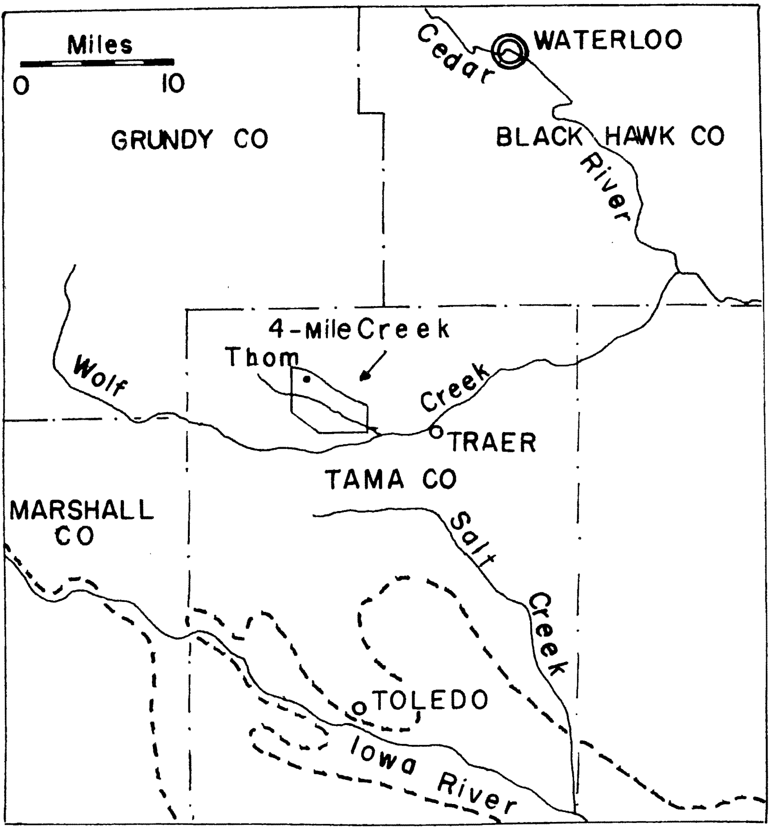
[3] Numbers in parentheses refer to references.



Broken line is border of IOWan Landscape

Figure 1. Location of traverse in northeastern Iowa.

Four buried surfaces can be distinguished in the loess-derived valley fill in this traverse. The lower two of these have been radiocarbon dated and are respectively 7,710 ± 130 (I-3057) and 6,200 ± 125 (I-3056) years old[4]. The fourth buried surface is overlain by a shallow layer of what is recognized as "postsettlement deposit" and is therefore approximately 100 to 150 years old.

To characterize the textural composition of the loess deposit for about 450 samples, the particle-size has been determined by the pipette method and according to modified Wentworth's particle-size fractions.

Below the solum, the clay content is mostly 15 and 16 percent, with a range of 13 to 18 percent for the slope and summit stations. For the loess-derived fill in the valley bottom, the clay content varies between 24 and 30 percent.

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[4] Radiocarbon samples: I—Isotopes, Inc.

The size fractions that show significant changes downward and laterally are the various silt fractions between 8 and 62 microns as well as the sand fraction from 62 to 125 microns. Appreciable amounts of sand occur only in the southern slope of the traverse where it is concentrated in three major lenses, varying in thickness from ¼ to 1 inch, which can be traced laterally. Aside from the major sand lenses, many very thin lenses, often only a few grains thick, can be distinguished. Seventeen of these minor lenses were counted at station 10 over a depth range of 80 to 140 inches. These, of course, cannot be traced laterally.

For each sample, the median particle diameter has been determined graphically. The medians have been combined into a profile (Figure 2). From this lithologic profile, a vertical tripartition can be observed in the loess deposit. In the basal increment, the weakly developed loess-derived paleosol is present. The clay content is at a minimum just above the till-derived paleosol. Sand is virtually absent. The median increases in upward direction from 11 to 23 microns. The isomedians tend to parallel the buried till-derived paleosol.

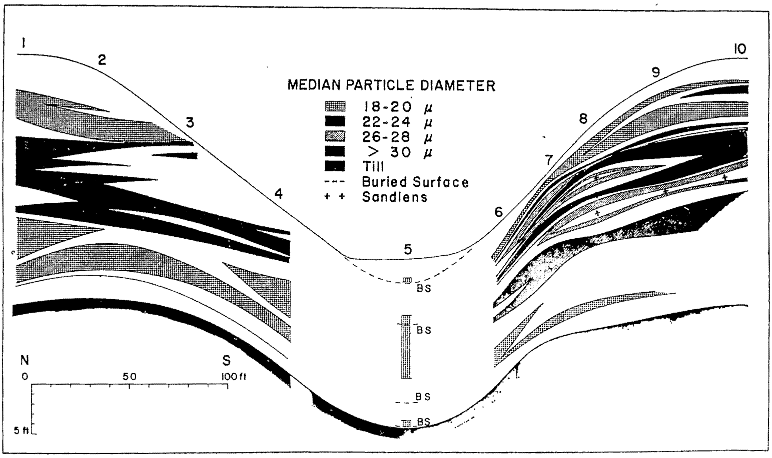

Figure 2. Lithologic profile with distributions of median particle diameters.

In the middle increment, the sand lenses occur in the southern slope where the median varies between 23 and 40 microns, passing through several maxima and minima. No appreciable amounts of sand are found in the northern slope. There the median varies between 23 and 26 microns. Because of vertical and lateral differences in the coarse silt and sand fractions, the pattern of the isomedians in both slopes is irregular.

The upper increment is characterized by medians that generally decrease in an upward direction from 25 to 18 microns. Sand is virtually absent. The pattern of the isomedians resembles that in the basal loess increment.

A vertical tripartition in the Wisconsin loess of the Iowan area has been reported earlier and is characteristic of it (2). An extensive study by Ruhe and associates led to the following conclusions:

> "The basal zone represents the loess increment that fell on the landscape during the early period of loess deposition in Iowa. This increment in part predates and in part relates to the cutting of the Iowan erosion-surface complex. The sandy (intermediate) zone represents the period of active cutting of the Iowan erosion-surface complex. The source of the sand is the sand in the loam till into which the erosion surface was cut. . . . The agent of distribution of sand must have been wind. The upper relatively sand-free zone of the loess represents the latest increment of loess deposition in Iowa that culminated 14,000 years ago" (2).

The absence of sand accumulation in the northern slope requires additional clarification. As evidenced by the presence of the till-derived paleosol at all stations, except number 5, and the configuration of this buried surface, the drainageway predates the period of loess deposition. As shown by the descending trend in the major sand lenses, the drainageway must have been present also during loess deposition. Downvalley in Four-mile Creek alluvium, wood is buried at a depth of 14 to 15 feet and is 18,400 ± 310 years old (I-2329). Thus the valleys were present during the time of loess deposition. This suggests that the valley served as a relatively still-wind depression in which sand-size particles were trapped and prevented from being blown over to the northern slope.

This implies that the local source area for the sand was situated to the south of Thom watershed, which is confirmed by the presence of an area of the Iowan erosion-surface complex within a 1,000 feet to the south of Thom watershed (Ruhe, personal communication).

The coarse and medium silt-size fractions, however, were affected much less by this still-wind depression so that there is still evidence in the middle increment of the activity of the Iowan erosive period in the northern slope. The relatively coarse constituents here may also have been derived from other areas of the Iowan erosion surface complex.

Before 7,700 years ago and perhaps also earlier during loess deposition, the valley bottom must have been cut down by erosion so that all materials older than 7,700 years were removed. The 18 feet of fill now present at station 5 was deposited since that date and has been derived from the slopes descending to it and from the upstream portion of the watershed. Therefore, these slopes are less than 7,700 years old.

Since the strata in the northern slope are severely beveled by the present land surface and the strata in the southern slope tend more to parallel it, it may be inferred that the northern slope has been eroded at a higher rate than the southern slope, although the slope gradients are virtually the same; i.e., 20 and 19 percent.

MOISTURE CONTENTS AND HYDROLOGY

Within a one-year period, the traverse was sampled several times for gravimetric moisture-content determination. Samples were collected each time at depths of 2.5, 5.0, 7.5, 10.0, and 12.5 feet by the hydraulic probe. The samples were canned at the spot and analyzed in the laboratory. The moisture content is expressed as percentage of the oven-dry sample weight (Table 1).

The data for August 16, 1966, May 31, 1967, and July 17, 1967, have been combined into moisture-content profiles (Figures 3, 4, and 5). Comparison of the three moisture profiles as well as the rest of the data shows that the moisture content follows the same distribution pattern throughout the year of observation, although absolute values at different dates are not the same. Moisture contents for the summit and slope stations, as well as for the upper 7.5 to 10.0 feet of station 5, are for unsaturated samples. The deeper part of station 5 was saturated. At the other stations, the portions of the basal loess just above the till-derived paleosol were often wet upon visual inspection and approaching saturated condition. No samples of that depth have been analyzed, however, and no factual information on depth of saturation is available.

The till-derived paleosol is relatively dry within a few inches below its upper boundary. Thus, qualitative information points out that the till-derived paleosol causes perching of a zone of ground water. The zone of minimum moisture content remains most often at the same depth for each station.

Comparison of the moisture profiles with the lithologic profile reveals a striking similarity as to distribution patterns. In the northern (i.e., south-facing) slope, the zone of minimum moisture content coincides with the transition from the middle to the upper loess increment. In the southern (i.e., north-facing) slope, the dry zone extends somewhat into the middle loess increment and is slightly more subjected to variations in depth.

There is roughly an inverse relationship between moisture content and median particle-size within each station. From soil-physical studies, it is known that moisture content is related to particle-size distribution by moisture tension. Finer materials contain more water than coarser materials at the same tension (1). The same behavior will hold true for a not-too-large range of tensions. For each station and for stations within the same slope, this qualitative relationship seems to work out satisfactorily.

Table 1

Moisture Content Determinations*

Station No.	Depth (feet)	Moisture Content at Specific Dates				
		8-16-66	5-31-67	6-7-67	6-22-67	7-17-67
1	2.5	22.2	19.4	21.5	24.3	21.6
	5.0	20.0	14.7	18.5	19.8	19.9
	7.5	13.8	14.9	14.1	17.5	15.0
	10.0	12.6	13.8	14.0	15.0	13.7
	12.5	16.7	16.4	16.2	16.5	15.2
2	2.5	22.2	17.0	14.8	16.6	18.6
	5.0	17.6	14.4	13.6	15.2	17.3
	7.5	12.1	13.3	13.7	14.0	13.4
	10.0	14.2	14.7	14.7	14.7	15.4
	12.5	15.3	16.2	16.2	14.7	16.1
3	2.5	14.5	17.0	15.0	18.3	—
	5.0	17.3	18.1	17.2	18.5	—
	7.5	20.0	19.4	20.2	18.5	—
	10.0	23.0	22.7	21.5	22.8	—
	12.5	25.4	24.9	24.9	25.3	—
4	2.5	18.6	19.0	18.2	22.2	17.5
	5.0	22.3	22.9	14.1	22.4	22.6
	7.5	26.9	25.3	25.1	25.7	25.4
	10.0	27.8	27.7	27.6	27.2	27.1
	12.5	26.0	24.9	24.4	25.5	25.2
5	2.5	24.8	23.1	—	25.0	20.1
	5.0	23.9	22.2	—	23.0	24.2
	7.5	28.4	29.8	—	27.0	27.3
	10.0	31.4	30.7	—	31.3	32.2
	12.5	34.5	33.7	—	31.7	30.8
6	2.5	23.0	23.6	—	24.9	22.7
	5.0	17.1	23.2	—	23.0	19.6
	7.5	25.8	26.6	—	26.0	26.3
	10.0	27.1	26.3	—	26.0	27.9
	12.5	26.1	26.7	—	27.0	26.3
7	2.5	21.2	19.4	—	15.6	18.3
	5.0	16.4	18.9	—	19.4	18.1
	7.5	23.1	22.0	—	21.8	20.8
	10.0	26.0	27.5	—	26.4	26.8
	12.5	27.0	27.1	—	27.2	26.4
8	2.5	22.9	22.8	22.2	19.4	—
	5.0	18.8	16.6	15.9	14.6	—
	7.5	18.5	20.2	20.4	17.8	—
	10.0	21.1	22.1	20.9	21.1	—
	12.5	26.1	25.2	25.0	25.4	—
9	2.5	22.7	22.1	20.4	20.6	—
	5.0	23.0	22.2	16.8	18.2	19.4
	7.5	19.2	19.3	19.8	17.4	16.8
	10.0	16.6	17.7	15.6	13.7	14.5
	12.5	22.4	20.3	20.8	19.8	21.4
10	2.5	22.4	21.3	20.9	21.4	19.4
	5.0	19.4	16.7	17.2	23.0	16.2
	7.5	19.5	14.3	14.0	14.5	15.5
	10.0	14.8	12.5	18.6	13.9	16.3
	12.5	16.6	16.7	16.5	17.9	16.6

***Determined gravimetrically on oven-dry basis.**

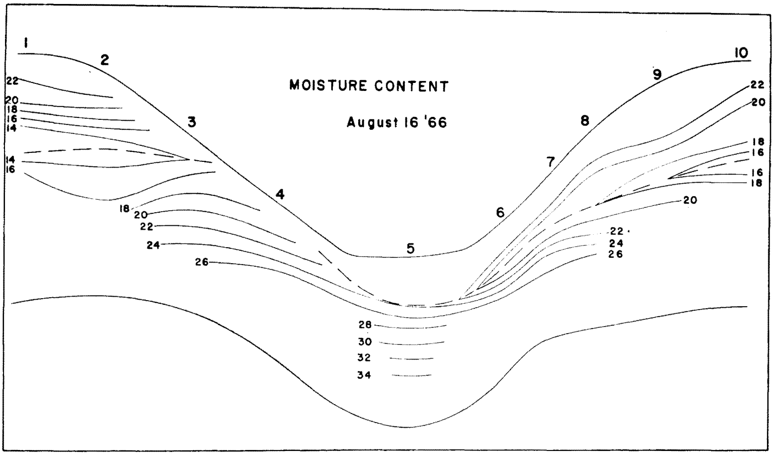

Figure 3. Moisture distribution at August 16, 1966, with moisture content expressed as percentage of oven-dry weight.

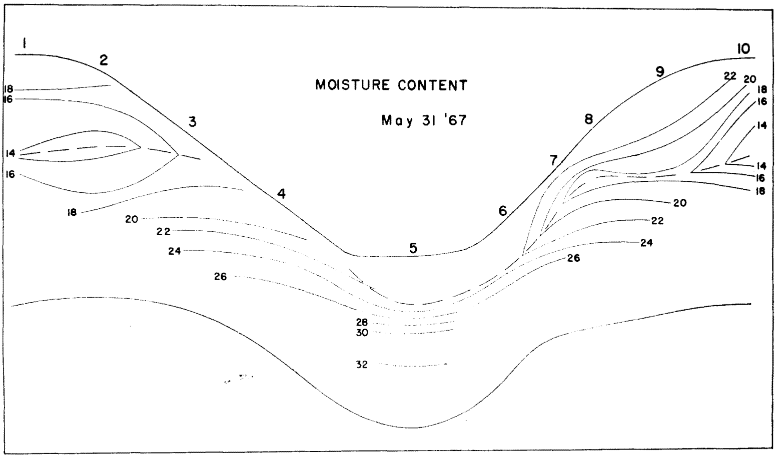

Figure 4. Moisture distributions at May 31, 1967, with moisture content expressed as percentage of oven-dry weight.

In comparing the two opposing slopes, notice that this simple principle cannot be directly aplied. The minimum moisture contents in the south-facing slope are lower than those of the north-facing slope, but they occur in materials that are finer textured. This indicates that the moisture in the minimum moisture zone of the south-facing slope must be at a higher tension than that in the north-facing slope.

Most of the samples studied have clay percentages around 15 and 16. Their organic-colloid content is virtually zero below 2.5 feet. Therefore, their wilting point will be approximately the same. For

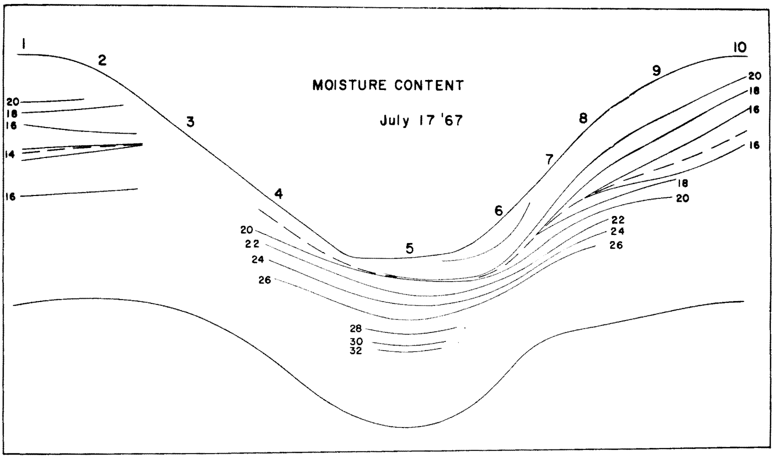

Figure 5. Moisture distributions at July 17, 1967, with moisture content expressed as percentage of oven-dry weight.

this reason, assuming that most of the moisture-content values obtained are for the tension range between field capacity and wilting point, the amount of plant-available moisture in the south-facing slope will be less than the north-facing slope. The difference in exposure of the slopes may cause this difference in moisture tension. Moisture withdrawal by evapo-transpiration is greater on the south-facing slope because of longer and more intensive isolation. Because there are indications that the rate of erosion, and thus the rate of surface runoff, on the south-facing slope is greater, however, there must be a difference in infiltration capacity between the two slopes. This may cause a lesser replenishment of subsurface moisture in the south-facing slope and maintenance of relatively greater moisture tensions.

CONCLUSIONS

Particle-size analyses performed on many samples along a traverse across a first-order watershed in loess and integrated into a lithological profile show a clear vertical tripartition in the loess. Distinct stratification in the middle loess increment is shown by sand lenses and differences in silt fractions.

Strong beveling of the strata in the south-facing slope indicates that this slope has experienced a higher rate of erosion than did the north-facing slope.

Comparison of the lithological analysis with moisture distributions at different times within a one-year period brings out that there is a close relationship between particle-size distribution and moisture content.

The explanatory physical phenomena must be moisture-tension relationships.

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