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General information on fine sand near the Iowan drift border in east-central Iowa is available in previous work (5) on soils and geologic deposits. Since little detailed work on engineering and geological properties has been done on these sands, the Iowa Engineering Experiment Station is now making such a study. The objectives of the first phase of the study are: (1) to determine the occurrence of sand deposits considered economically workable for engineering usage and, (2) to determine properties and property variations of the sands. This report covers the occurrence, method of sampling, field description, classification, and particle size analysis of the sands included in the east-central Iowa study.

Occurrence

The areal distribution of the fine sands mapped in the east-central Iowa area is shown in Figures 1 to 8. In the southern and southeastern part of the area studied, the sand is closely related to the major streams and to the Iowan drift border. In this region the sand is associated with the loess. The relationship of sand and loess has been pointed out in a previous study (5) of the loess in east-central Iowa. In that study, sampling traverses were made across the loess from the Iowan drift border southward. Particle-size analysis of traverse samples revealed a marked increase in the sand content of the loess directly south of the drift border and the river floodplains; however the sand content decreased rapidly with distance southward from the border and flood plains. Norton (7) reports similar findings in Scott County. He found that the loess grades vertically and laterally into sand, but that the sand is essentially absent a few miles south of the drift border.

The loess is thin or absent on the Iowan till plain in the northern and northeastern part of the area, and the mapped sand seems most closely associated with the till. In this part of the area, and especially in northeast Benton County, in northern Linn County, on the drift lobes of Johnson and Cedar Counties, and northeast of the Wapsipinicon River in Clinton County, the

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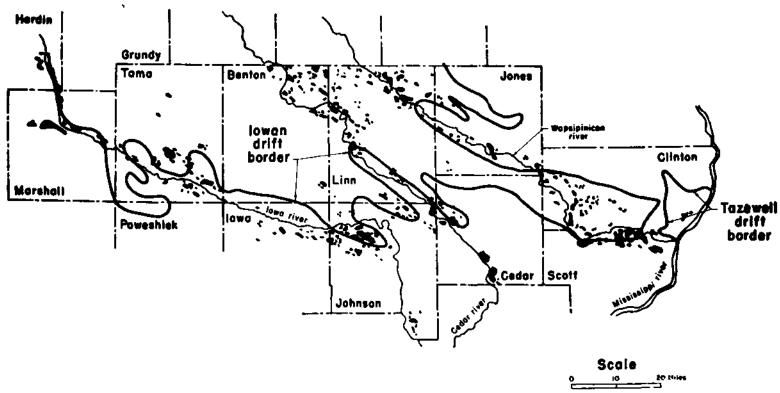

Figure 1. Map showing the areal distribution of fine sand in east-central Iowa.

sand occurs as hills and ridges on the till plain. Calvin (1) in discussing the ridges in northeastern Johnson County states that they contain a large amount of glacial drift but are essentially sand which is frequently overlain by loess.

Sand deposits are also found along some of the smaller streams in the area. In Minerva Township, Marshall County, the sand occurs on the high terrace and adjacent upland south of Minerva Creek. A similar relationship was also observed south of Clear Creek near Tiffin in Johnson County.

A few of the sand deposits are related to abandoned river channels. In Benton Township, Benton County, Savage (8) mentions such a channel that was once occupied by the Cedar River. This old channel is one-half to one mile wide, and extends in a southeasterly direction from the northwest corner of Benton Township into Linn County, where it meets the present channel. This old channel is known locally as "Sand Prairie."

Another old river channel is on the east side of Central City in Linn County. Norton's (6) report states that the old channel is separated from the present Wapsipinicon River by a ridge of bedrock that comes within a few feet of the surface. The lithology of a well sunk into this abandoned channel is reported as "4 feet black soil, and 96 feet fine, yellow sand" down to bedrock.

Mapping and Sampling

Mapping

The mapping of the sand deposits was done by field reconnaissance with the aid of agricultural soil survey maps and aerial

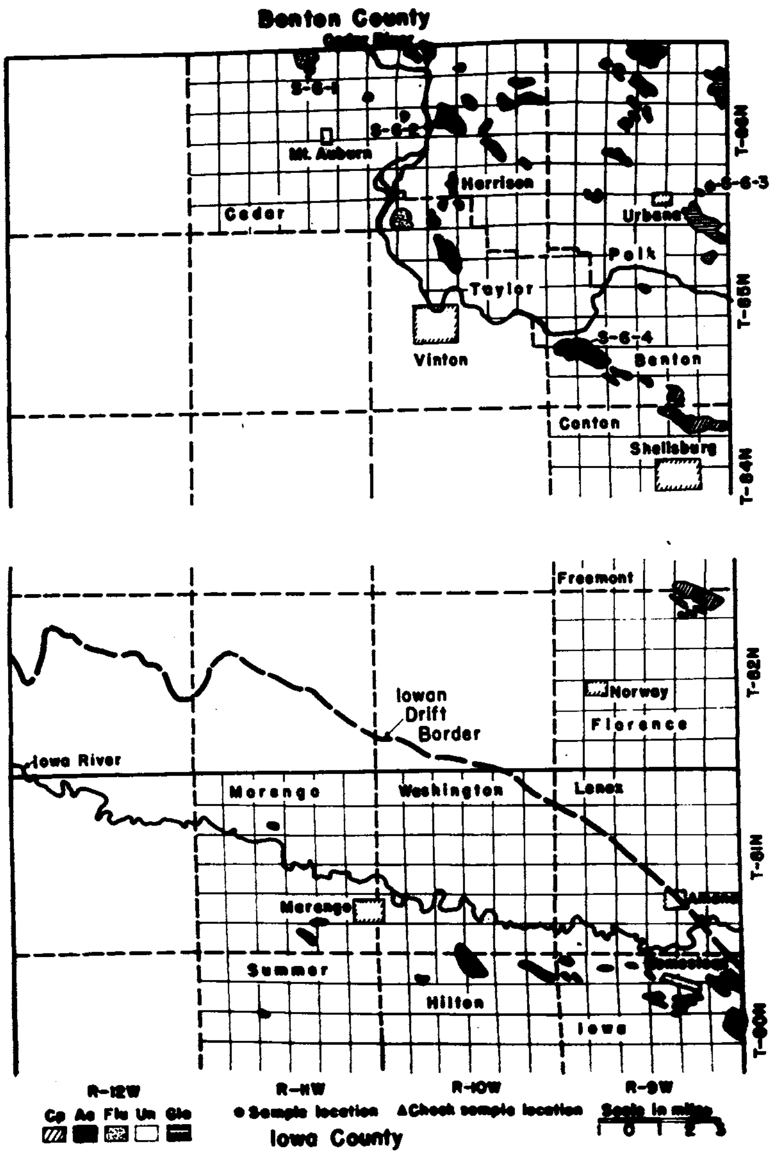

Figure 2. Sand deposits mapped in Benton and Iowa counties.

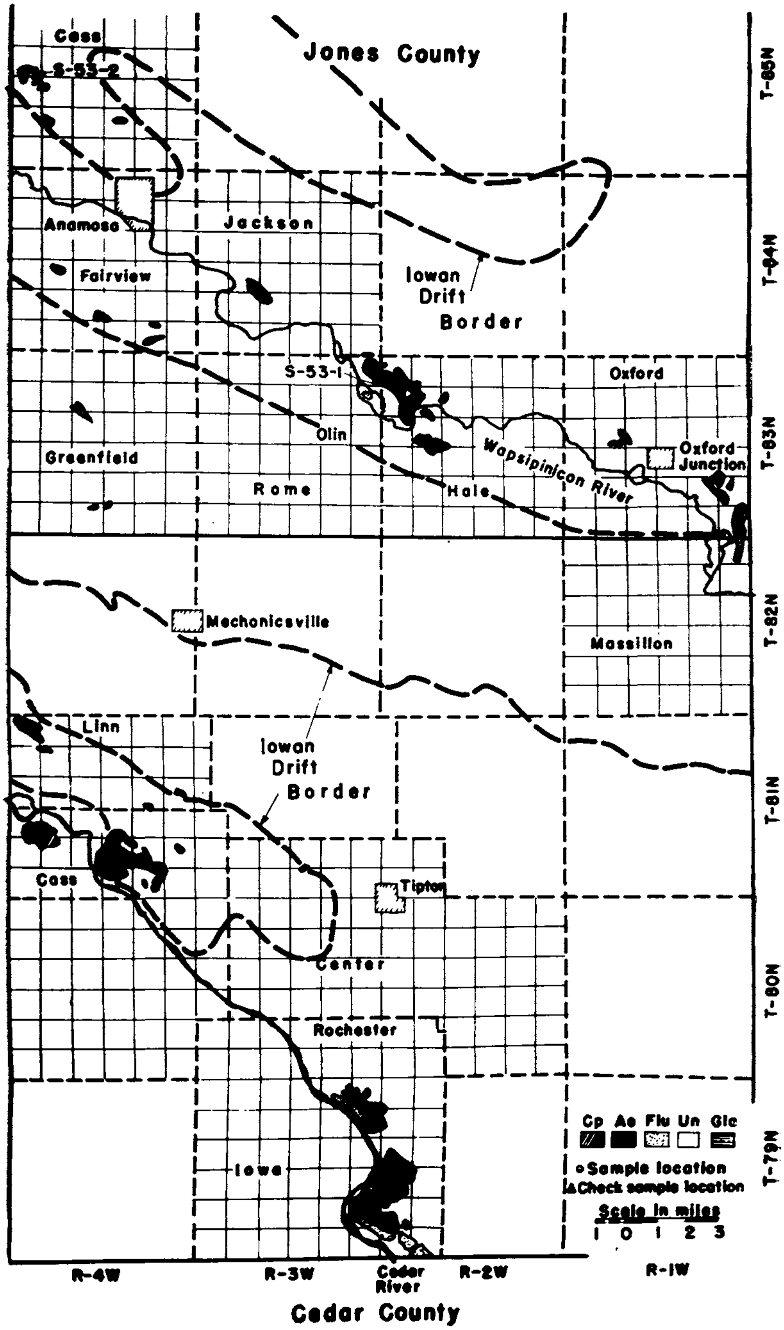

Figure 3. Sand deposits mapped in Cedar and Jones counties.

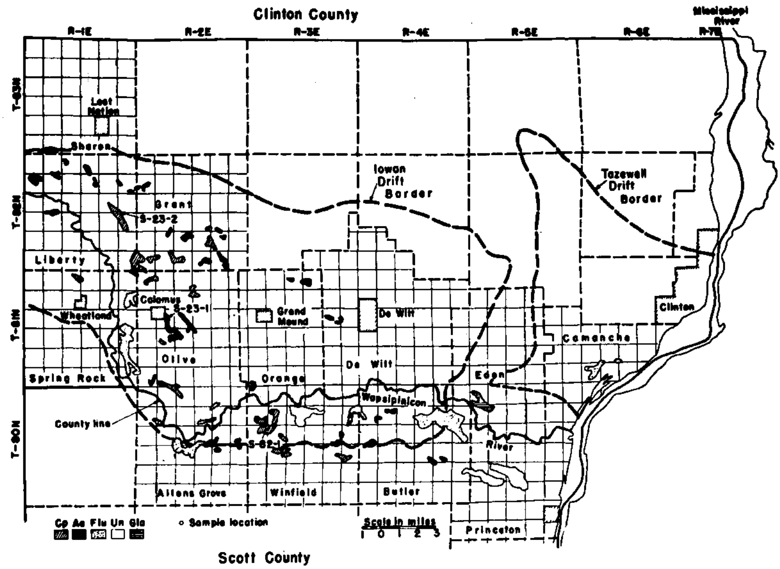

Figure 4. Sand deposits mapped in Clinton and Scott counties.

photos. Because of the widespread and scattered distribution of the sand, it is possible that all the deposits have not been mapped.

The agricultural soil maps were used to locate potential sandy areas. The aerial photos were helpful in locating the sand not shown on the soil maps and in outlining the extent of the deposits. The areas located from the soilmaps and photos were drawn on base maps. These areas were then visited to determine whether or not the deposits were to be included in the study. Since there is no way to foresee future engineering specifications for sand, practically all sandy materials located were mapped regardless of quality. It is also possible that the character of the sand within an individual deposit varies considerably, and separation of what appeared to be sand of good quality from sand of poor quality would not be practicable from a limited field reconnaissance of this kind.

A deposit is shown on the county sand location maps if the sand is at least 5 feet thick without an appreciable amount of overburden and has an areal extent large enough to be workable with large excavating equipment. These deposits are shown on the county maps, Figures *2* to *8*.

Sampling

The number of samples taken from each county depended upon the areal distribution of the sand and the number of different

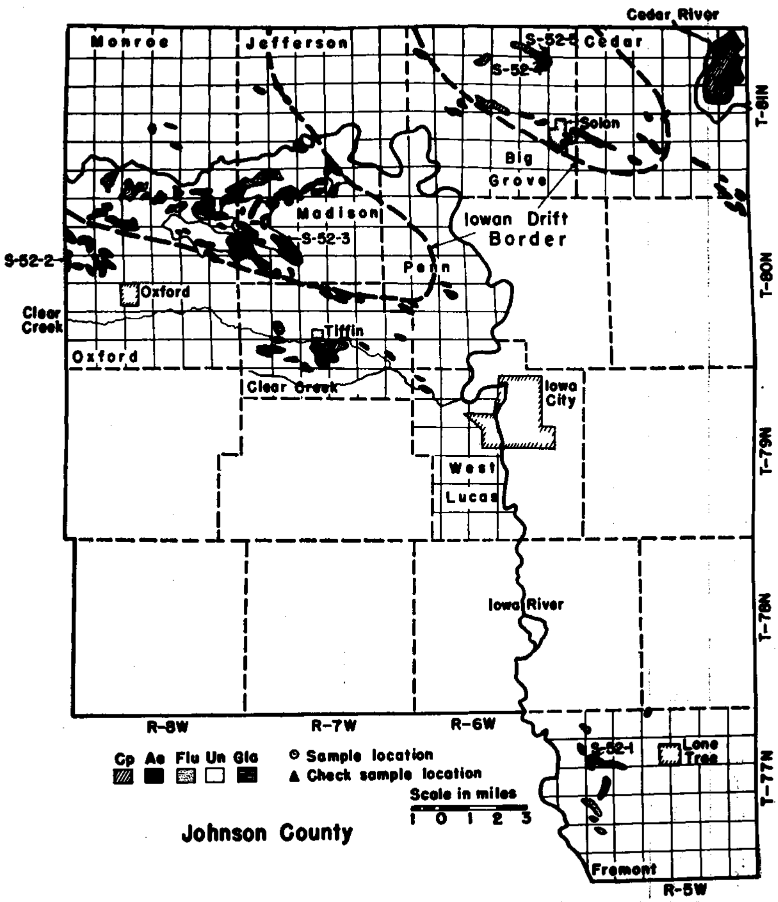

Figure 5. Sand deposits mapped in Johnson County.

soil series represented. The sampling locations of the sand are shown in Table I and in Figures 2 to 9. At least one profile was sampled for each of the major soil series. A few randomly selected C-horizon check samples were also taken from deposits over the whole area.

Sampling of A, B, and C horizons was done to show both the variation in particle size with depth and the amount of overburden above the C-horizon. Since the material from the A and B horizons probably would not be used for engineering purposes, it is considered as overburden. Exact differentiation of the A, B, and C horizons is sometimes difficult. In many instances identification is uncertain because of mixing and reworking of the upper part of the deposit by the wind. An added difficulty was that, since in some profiles

Table I

Sampling Locations of Sand in East-Central Iowa

Sample No.	County	Section	Township	Range	Horizon & Depth Sampled, Feet			Soil Series from Soil Survey Maps
					A	B	C	
S-6-1	Benton	NW¼, SW¼, S-2	86-N	11-W	....	....	9-10*	Carrington Sand (1925)
S-6-2	Benton	NE/C, SW¼, S-16	86-N	10-W	0-2/3	2/3-1 1/2	1 1/2-16-1/2	Carrington Sand (1925)
S-6-3	Benton	NW¼, SW¼, S-25	86-N	9-W	....	....	5 1/2-10*	Carrington Sandy Loam (1925)
S-6-4	Benton	NW/c, NW¼, S-29	85-N	9-W	0-1	1-2 1/2	2 1/2-6 1/2	Carrington Sand (1925)
S-23-1	Clinton	SW¼, NE¼, S-17	81-N	2-E	0-2	2-3	3-9 1/2	Carrington Fine Sand (1918)
S-23-2	Clinton	SW/c, SW¼, S-13	82-N	1-E	0-2 1/6	2-1/6-3 1/2	3 1/2-15 1/2	Carrington Fine Sandy Loam (1918)
S-42-1	Hardin	E½,-NE¼, S-30	87-N	19-W	....	....	6*	Carrington Fine Sandy Loam (1925)
S-52-1	Johnson	NW¼, SW¼, S-7	77-N	5-W	....	....	3 1/2-13 1/2	Knox Sand (1922)
S-52-2	Johnson	NW¼, NW¼, S-18	80-N	8-W	....	....	10-20	Knox Sand (1922)
S-52-3	Johnson	NE¼, SW¼, S-8	80-N	7-W	....	....	5-23	Knox Sand (1922)
S-52-4	Johnson	NE¼, NE¼, S-11	81-N	6-W	....	....	2-14 1/2	Knox Sand (1922)
S-52-5	Johnson	SE¼, SE¼, S-2	81-N	6-W	....	....	3-8 1/2*	Knox Sand (1922)
S-53-1	Jones	SW¼, SW¼, S-6	83-N	2-W	0-2	2-3 1/2	3 1/2-13 3/4	Lindley Fine Sand (1928)
S-53-2	Jones	SE¼, SE¼, S-18	85-N	4-W	....	....	5-8*	Lindley Fine Sand (1928)

*Check Samples.

Table I (Continued)
Sampling Locations of Sand in East-Central Iowa

Sample No.	County	Section	Township	Range	Horizon & Depth Sampled, Feet A	B	C	Soil Series from Soil Survey Maps
S-57-2	Linn	E½, SW¼, S-12	84-N	8-W	0-1/2	1/2-1 1/2	1 1/2-14	Lindley Fine Sandy Loam (1920)
S-57-3	Linn	SW¼, SE¼, S-27	86-N	6-W	0-1 1/2	11/2-3	3-12	Lindley Fine Sand (1920)
S-57-4	Linn	NE¼, SW¼, S-10	82-N	6-W	....	....	1-25	Lindley Fine Sandy Loam (1920)
S-64-1	Marshall	NE/c, NE¼, S-2	84-N	19-W	....	....	6-8*	Knox Loamy Fine Sand (1921)
S-64-2	Marshall	SE¼, NE¼, S-10	84-N	19-W	....	....	2-15	Carrington Fine Sandy Loam (1921)
S-64-3	Marshall	SW¼, NE¼, S-17	84-N	18-W	....	....	3½-13	Knox Loamy Fine Sand (1921)
S-82-1	Scott	NW¼, NW¼, S-17	80-N	3-E	0-1½	1½-3½	3½-14	Shelby Loamy Fine Sand (1919)
S-86-1	Tama	SE¼, SW¼, S-9	82-N	13-W	....	....	8-20	Tama-Thurman Complex (1950)
S-86-2	Tama	S½, NE¼, S-30	83-N	15-W	....	....	8-13*	Fayette-Chelsea Complex (1950)
S-86-3	Tama	SE¼, SE¼, S-3	82-N	15-W	....	....	3½-20	Thurman Loamy Fine Sand (1950)
S-86-4	Tama	SW¼, NE¼, S-8	82-N	13-W	....	....	6-15	Chelsea Loamy Fine Sand (1950)

*Check Samples.

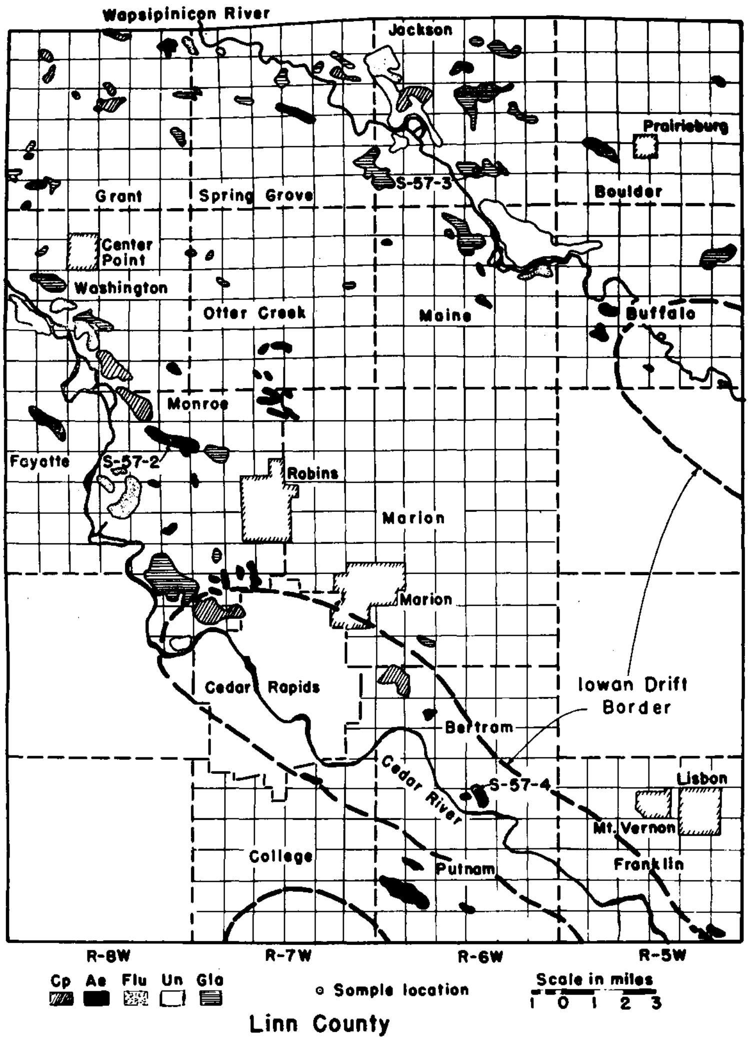

Figure 6. Sand deposits mapped in Linn County.

a zone of clay accumulation is not distinct, separation of the horizons was made partly on a difference in color.

Sampling was usually done at hilltop positions where the sand was assumed to be the thickest. Whenever roadcuts were found, the cut was cleared of slump and the samples taken. In locations where roadcuts were not found, a pit was dug for sampling the profile. A 4 inch auger was used to obtain samples deeper than the roadcuts or pits. Composite samples were taken of the A, the

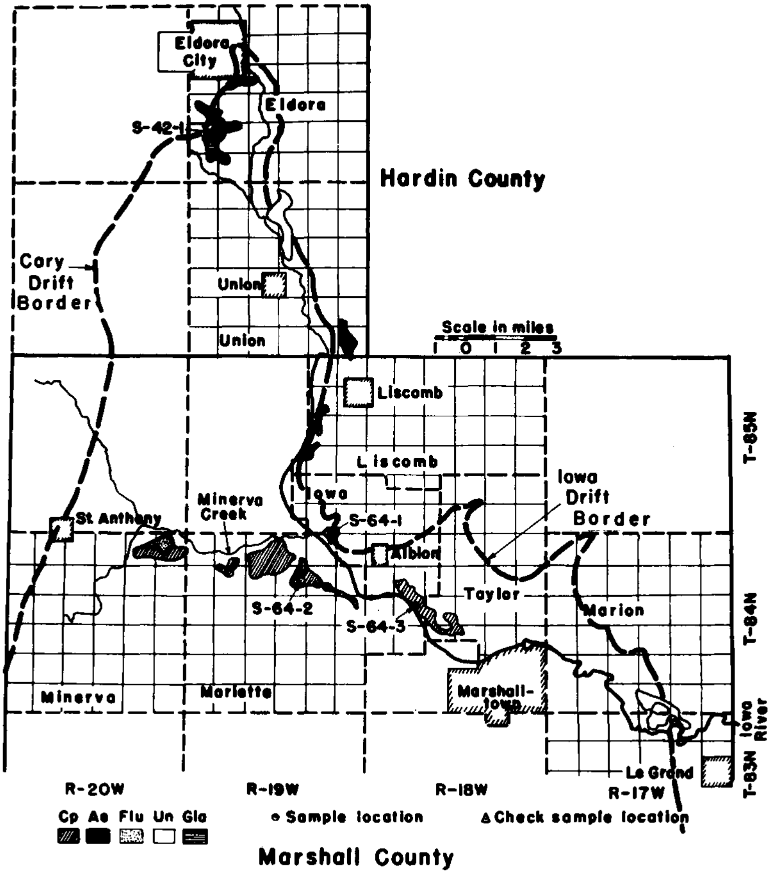

Figure 7. Sand deposits mapped in Hardin and Marshall counties.

B, and part of the C horizon for the depths shown in Table I and figure 9. Total thickness of most of the deposits was not found because of the difficulty in sampling at great depths with an auger. In many instances also water entered the sample hole and interfered with sampling.

Field Description and Classification

Field Description

The sands appear very similar in the field. They are fine-grained and are often covered with varying thicknesses of silt. The character of the sands changes with depth, depending upon the origin and the amount of reworking.

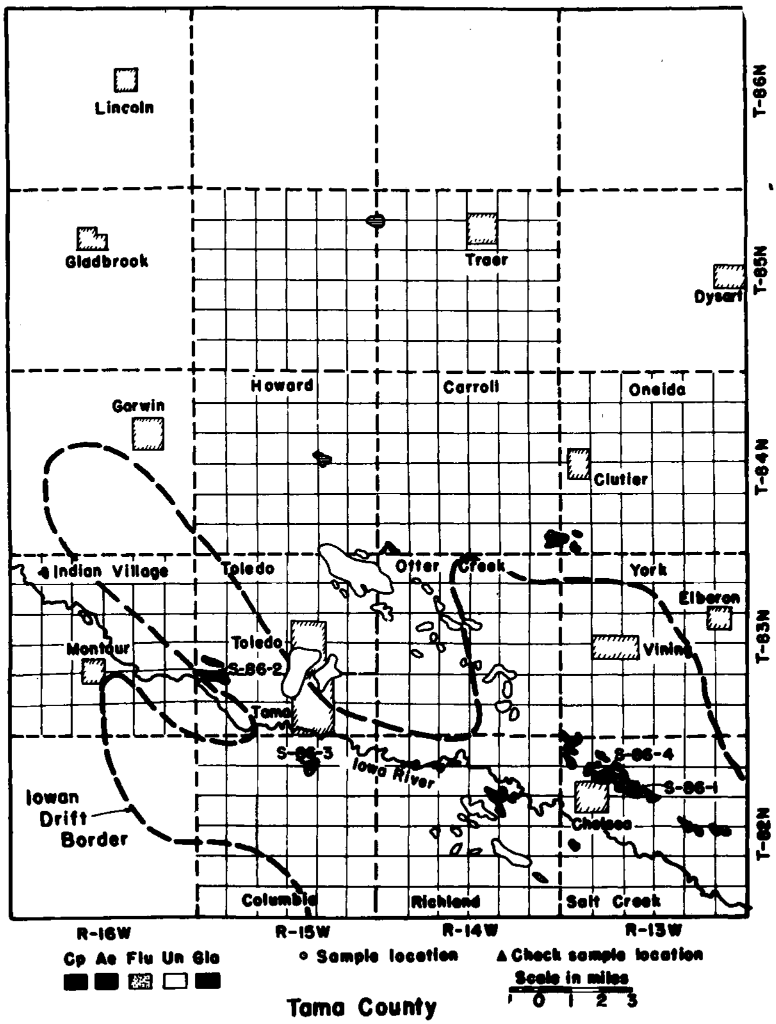

Figure 8. Sand deposits mapped in Tama County.

As previously stated, the sands that are associated with the loess sometimes grade both vertically and laterally into the loess. Contacts with other geologic materials may be sharp. The deposits that contain large quantities of silt are mapped as sand-silt complexes on the more recent agricultural soil maps.

The sands associated with the streams and found on the till plain are more variable than the sands associated with the loess. The surface material is usually reworked to some extent, and the deeper sands are more likely to be coarser and more poorly sorted

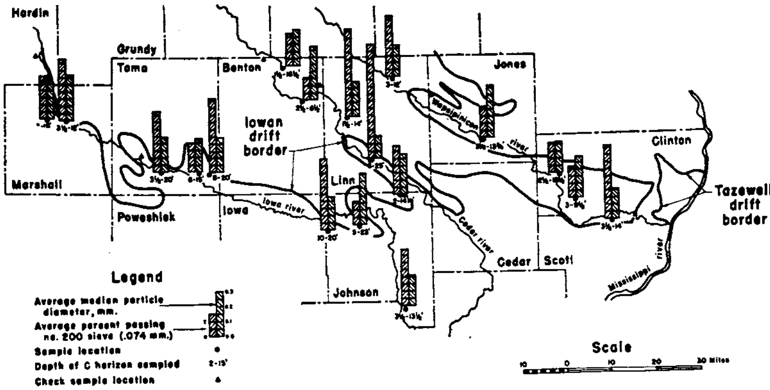

Figure 9. Sampling locations in east-central Iowa. Blocks represent weighed average values of median particle diameter and per cent passing the no. 200 sieve for the C-horizon depth ranges shown.

than the surface material. In some sections, stratification and weakly developed graded bedding were observed. The sand on the till plain grades into the till, which is often quite gravelly.

The color of the sands is generally yellow to buff, although darker colored sands do occur. The darker colors are due mainly to a higher percent of silt and clay and organic matter and are most common in flood plain, terrace, and outwash deposits.

All except two of the sand sections are leached of carbonates to the depths studied. The two sections that are not completely leached are S-57-4, unleached below a depth of 14 feet and S-86-1, unleached below 16 feet.

In many of the sand deposits, reddish-brown bands were observed. Although the bands were not observed in all deposits, Folks (3) reports that for all the sandy parent materials he studied in Iowa, the number of deposits containing the bands were more common than the deposits in which the bands did not occur.

Three samples were taken from the bands. Mechanical analyses of these show that they are higher in clay than the adjacent material in the section, but their composition was such that they are classified as sand in the textural classification chart in Figure 11. Chemical tests have also shown that the bands are high in iron, and it is generally thought that the clay and iron form separately (3).

The banding usually occurs in a series of bands found at a depth of several feet down to 14 feet and occasionally deeper.

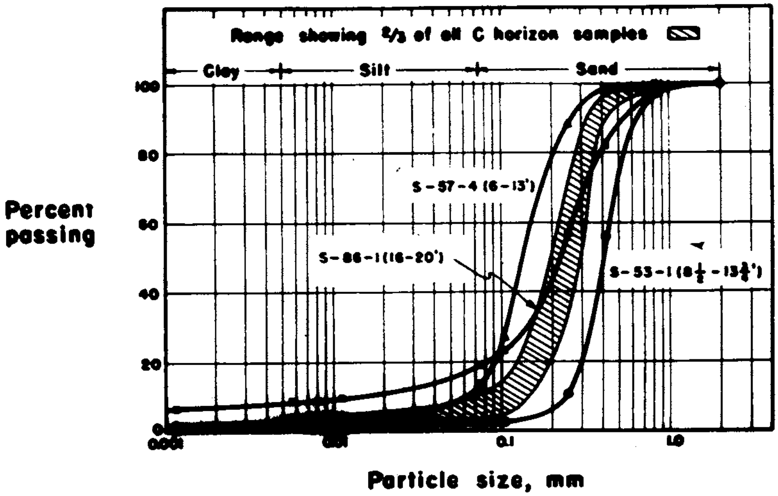

Figure 10. Particle-size distribution curves of three sand samples in east-central Iowa showing the range in particle-size distribution.

They range in thickness from a fraction of an inch up to 8 inches. Sometimes the bands are closely spaced and intermingled. Examples of the banding are shown in Plate I.

No attempt has been made to determine the origin of these bands, but several theories on their information are worthy of mention. Perhaps the most favored hypothesis is that the bands were formed by some kind of periodic precipitation. Hedges (5) found that this phenomenon is a general one, and that periodic structures can result from any two substances that form a precipitate under favorable conditions.

Another theory is that the bands are levels in which a relatively permanent water table stood at various heights for extended periods of time. The reduced iron became oxidized at the contact between the water table and the aerated sand and was deposited on the sand grains to form the band (3).

Structures in the sand other than banding were uncommon. In a few deposits, stratification with silts and weekly developed graded bedding, was observed.

Classification

To simplify sampling for future property studies, a tentative classification of the sands in east-central Iowa is proposed. Topographic position, associations in the field, and character of the ma-

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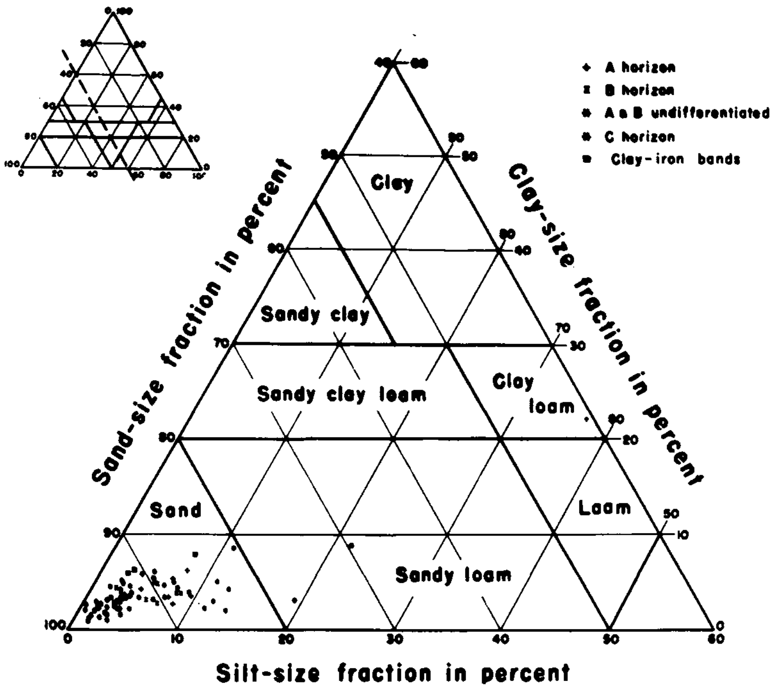

Figure 11. Textural classification chart of all sand samples in east-central Iowa. (From textural classification chart, U. S. Bureau of Public Roads.)

terial are the main basis for classification. The sand deposits with their designated classification are shown in Figure 2 to 7. The classifications are as follows:

Alluvial	
Fluvial	(FLU)
Glacial outwash	(GLA)
Aeolian	(AE)
Compound	(CP)
Unstudied possibilities	(UN)

Alluvial refers to material that has been deposited by running water. Since it is a general term that can be applied to several types, the alluvial category has been separated into two parts, fluvial (FLU) and glacial outwash (GLA). The term *fluvial* designates a stream as the agent of deposition. The fluvial sands in this classification include the deposits found on flood plains and terraces in which there has been little or no reworking by the wind.

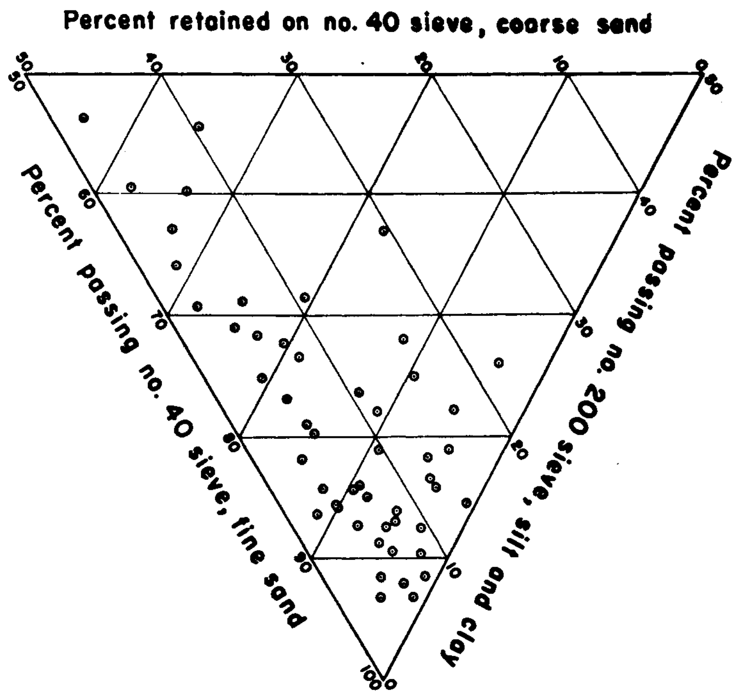

Figure 12. Separation of the C-horizon samples into fine sand, coarse sand, and silt and clay.

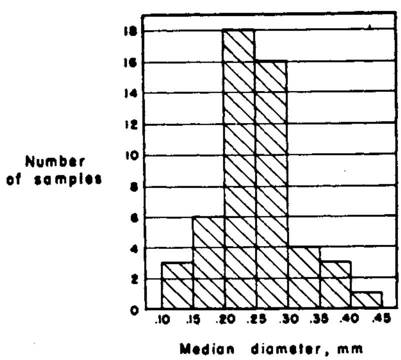

Figure 13a. Histogram showing range in particle size of all the C-horizon samples.

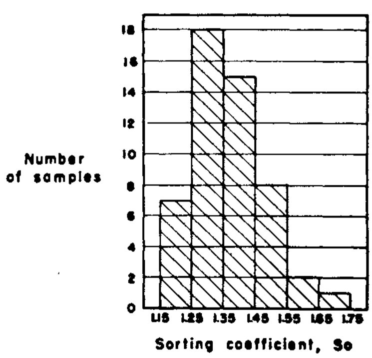

Figure 13b. Histogram showing the range in sorting coefficients of all the C-horizon samples.

Glacial outwash sands are those found on the till plain and along the margins of the drift border. These sands have not been reworked appreciably by wind action.

The *aeolian* (AE) category includes the deposits found in dunes and other deposits which appear to have been extensively reworked by the wind. These sands are often associated with silts.

The *compound* (CP) category includes the sands in which no single geologic agent has been dominant. These sands may have been alluvial or aeolian but have modified by drifting, blowouts, erosion and cultivation; so their origin is not identifiable without more detailed study. They differ from dune sands in that the dune characteristics are not present; however the sand near the surface suggests some aeolian reworking.

The *unstudied* (UN) possibilities include the sands that did not appear in the field to be of very good engineering quality. Some of these are alluvial sands found on flood plains and in some terraces and outwash deposits. Others consist of the very silty sands and interbedded sands and silts, mapped on soil survey maps as sand-silt complexes. Because of the time limitations these were not studied, but a more detailed study may prove some of them to be usable.

Particle Size

Particle-size determinations were made on the sands by the method outlined by Davidson and Chu (2). The particle-size distribution curves shown in Figure 10 represent the total range in particle size for all the C-horizon samples. The two outside curves represent the maximum and minimum median diameter particle sizes. As shown in Figure 11, all of the C-horizon samples except one are classified as sand. Most of the A and B horizon samples are also sand, though several classify as sandy loam and clay loam. The clay-iron bands all also classified as sand. A further separation of the C-horizon samples into fine and course sand is shown in Figure 12. In each of the samples more than 50 percent of the material passed the no. 40 sieve.

The range of the median diameters of all the C-horizon samples is shown in the histogram in Figure 13a. Two-thirds (34 of 52) of all the samples have a median diameter between 0.20 and 0.30 mm. The shaded area in Figure 10 represents the range into which that two-thirds of all the C-horizon samples fall.

The sorting coefficients of the C-horizon samples are in the histogram in Figure 13b, which shows that nearly two-thirds (33 or 52) of the samples have a sorting coefficient between 1.25 and 1.45. However, these do not necessarily correspond to the same two-thirds range of median diameters, as illustrated by the intermediate curve in Figure 10. The sample represented by this curve has a median diameter within the two-thirds median diameter range, but its sorting coefficient does not fall in the 1.25 to 1.45 range of sorting coefficients.

Textural variations with depth are shown in Figure 14 for four sections representing the four types of sands of the tentative classification. The fluvial section (S-86-3) is on a high terrace south of the city of Tama and just south of the Iowa River. The upper 3½ feet of the section is silt and was not sampled. The percent of silt and clay is rather uniform throughout the upper part of the section and increases with depth. The sand also becomes more poorly sorted with depth.

The glacial outwash section (S-57-3) is located on the Iowan till plain in northern Linn County. This section contains more silt and clay and is more variable throughout than section (S-86-3). The sand becomes slightly coarser and more poorly sorted with depth.

The aeolian section (S-6-2) is taken from a hill, which is interpreted as a dune 35 to 40 feet in relief. This section contains silt in the upper portion. The silt gradually decreases with depth, while the percent of clay increases slightly. The sand is rather uniform throughout the section, except for clay-iron bands observed at a depth of 5½ to 10 feet.

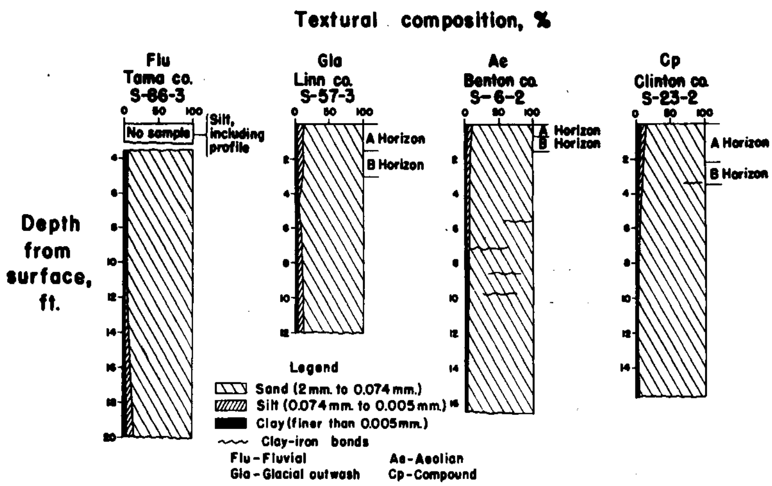

Figure 14. Variation of textural composition with depth for representative sections of the four types of sand in east-central Iowa.

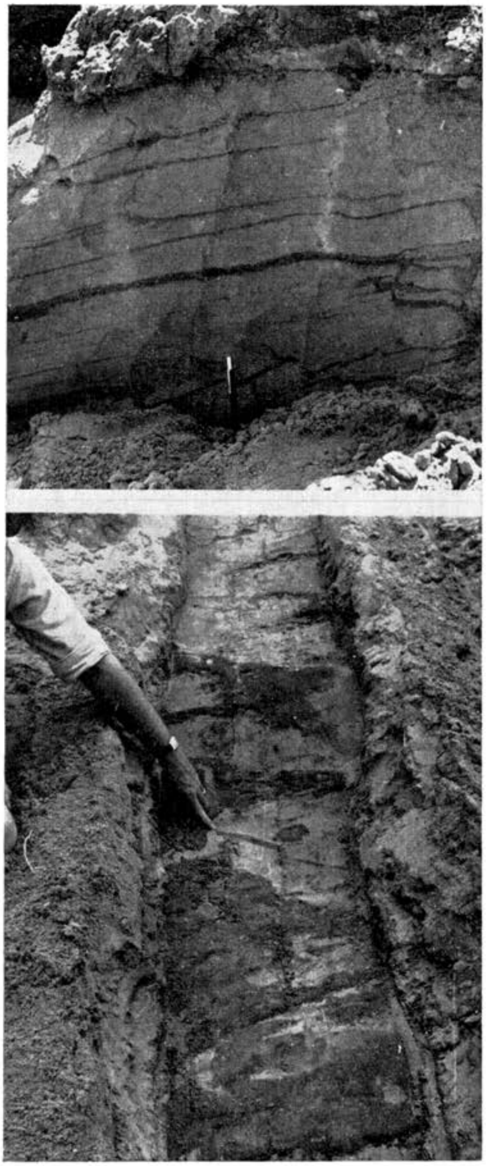

Plate 1. Examples of clay-iron bands that occur in the sand deposits in east-central Iowa. Scale in upper picture is a pencil.

The compound section (S-23-2) is taken from a dune-like hill on the Iowan till plain, and is interpreted as glacial outwash which has been reworked to some extent by the wind. The percent of silt and clay is fairly high in the upper part of the section but gradually decreases with depth. A few clay-iron bands were observed at 3½ to 4 feet.

The percent of material passing the no. 200 sieve (silt and clay) and the average median diameter size for each composite C-horizon sample are shown in Figure 9. The data show no specific trend. The values (shown in the figure) were obtained by calculating both the weighted averages of the combined silt and clay and the median diameter for the depth range of each sample section.

Summary

The sands of east-central Iowa which were studied are related to the main streams, the Iowan drift border, and the Iowan till plain.

Field observations and aerial photograph interpretations suggest that the sands are derived locally. The lack of any trend in textural composition confirms this.

Although further studies may result in modifications, the sand deposits have tentatively been divided into several classes. All of the sands studied are texturally classified as fine sands.

Acknowledgement

The subject matter of this paper was obtained as part of the research being done under Project 283-S of the Iowa Engineering Experiment Station of Iowa State College. This project, entitled "The Loess and Glacial Till Materials of Iowa; An Investigation of Their Physical and Chemical Properties and Techniques for Processing Them to Increase Their All-Weather Stability for Road Construction," is being carried on under contract with the State Highway Commission and under the sponsorship of the Iowa Highway Research Board. The project is supported by funds supplied by the Commission and the United States Bureau of Public Roads.

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