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Petrography and Engineering Properties Of Kansan Till in Southern Iowa

By A. R. Dahl, D. T. Davidson and C. J. Roy

Abstract. Kansan till outcrops over approximately 25 percent of the surface area in southern Iowa. Most natural outcrops occur along the flanks of loess-capped hills. The texture of the till may be roughly divided into thirds each of clay, silt, and sand and gravel. Quartz and feldspar are the dominant minerals along with montmorillonite and illite-group clay minerals. The majority of the calcareous till classifies as an A-6 engineering material.

This report summarizes several aspects of the Kansan till in southern Iowa. The subject matter of this report was obtained as part of the research being done under Project 283-S of the Engineering Experiment Station, 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 Suitability for Road Construction", is being carried on under contract with the Iowa Highway Research Board, and is supported by funds supplied by the Iowa State Highway Commission. In particular, this paper incorporates data procured to date on the Kansan till in southern Iowa by Riggs (1956), Dahl (1958), and Hansen (1958).

Distribution

Glacial till mapped as Kansan (Figure 1) outcrops in southern Iowa from the Missouri to the Mississippi Rivers. In the three lower tiers of counties across southern Iowa (excluding Des Moines, Louisa, and Muscatine counties), Kansan till outcrops over about 25 percent of the surface area. Percentages of other geologic mate-

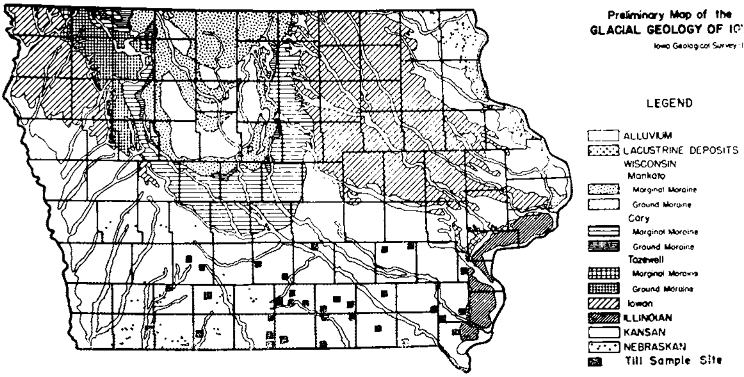


Figure 1. Map showing locations of till sample sites.

rials outcropping in the area are as follows: loess, 56 percent, alluvium, 18 percent; and bedrock, 1 percent (Simonson, *et al.*, 1952, pp. 16-17).

Thickness of the till, or tills, in southern Iowa is not known accurately, but in most cases is at least tens of feet, or greater.

Stratigraphic Relationships

Two major drift sheets are thought to be present in southern Iowa. The Nebraskan, the older, is overlain by the Kansan. A third, younger and less extensive drift sheet, the Illinoian, is present in extreme southeastern Iowa. Without evidence of an unconformity or weathering profile between two drift sheets, the glacial till outcropping west of the area mapped as Illinoian in southern Iowa is assumed to be Kansan.

Within the top of the Kansan till, a clay-rich interval, commonly known as gumbotil, is present locally.

In all road cuts and auger hole sections observed below the level of the higher, relatively flat interfluvial divides, a sandy silt occurs above the till, or gumbotil. This sandy silt grades up into an overlying clayey silt, which is called loess (Figure 2). In auger holes drilled into the higher interfluves, the amount of sand in this lower silt is less than that in the lower, more rolling terrain; but it also grades up into the overlying clayey silt, or loess.

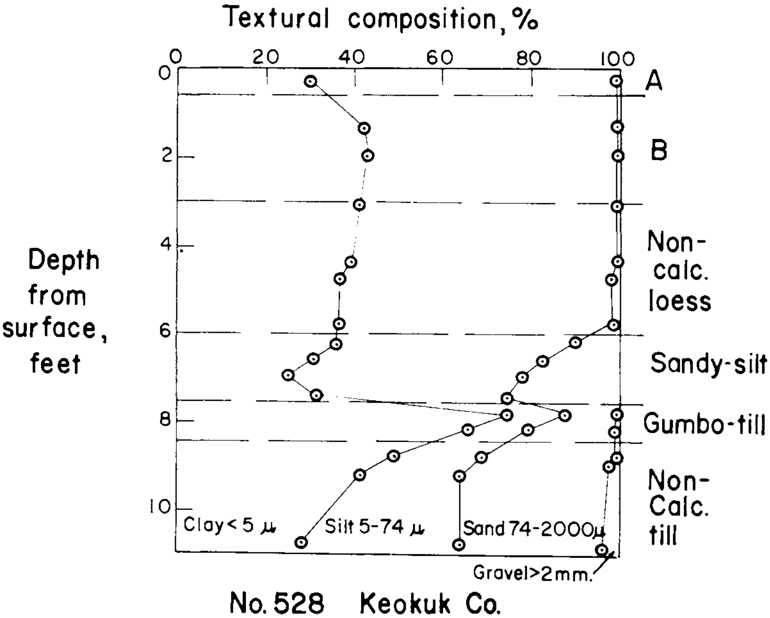


Figure 2. Texture with depth of sample site No. 528 in Keokuk County.

FIELD CHARACTERISTICS

Glacial Till

Occurrence. On the modern surface in southern Iowa, most natural outcrops of Kansan till are along the flanks of loess-capped hills in the more rolling terrain below the upland divides. Till exposures thus appear to be primarily a function of post-loess erosion, although post-loess creep and original loess thickness must also be considered.

The silt is thickest in the southwestern part of the state (Dahl, *et al.*, 1957; Hansen, 1958); a higher percentage of the surface area in the central and eastern part of southern Iowa shows till outcrops.

General features. The till mass is composed predominantly of blocky aggregates of sand, silt, and clay. It is typically a clay, or clay loam (BPR textural classification, Spangler, 1951).

The color of the calcareous and non-calcareous oxidized till can best be described as a yellowish-brown.

In general, the upper part of the till is non-calcareous but becomes calcareous with increasing depth. In some exposures, calcium carbonate concretions one inch or less in size are either within or at the top of the calcareous till.

Sand lenses and pockets are quite common within the main body of the till. These deposits are usually non-calcareous and fairly well sorted, although the till mass is usually calcareous and aways poorly sorted.

Where a deep roadcut or similar excavation has been made in the till, cracks assuming a crude polygonal pattern are observed. The segments outlined are typically from one to three feet in two-dimensional view. Ferric iron concretions are commonly concentrated along these joints and tend to outline blocks of till with a reddish-brown band about two inches wide. Occasionally calcium carbonate concretions are also present in the bands. The initial cracks are probably caused by mass movement, and the till outlined by bands occurs in three-dimensional blocks (Riggs, 1956).

Gumbotil

Occurrence. Gumbotil occurs at the top of the till. Its present distribution appears to be a function of erosion; it occurs persistently on the uplands, but not on the lower, more steeply rolling terrain. Because the sandy and clayey silt overlies relatively fresh till as well as more weathered till and gumbotil (Dahl, *et al.*, 1957, p. 51), pre-sandy silt and loess erosion must have determined the outcrop pattern prior to the time of formation or deposition of these younger sediments.

The gumbotil discussed in this paper is restricted primarily to buried deposits rather than those which outcrop infrequently on the modern landscape in southern Iowa.

General features. The gumbotil is mainly an aggregate mass of clay-size material with lesser amounts of silt, sand, and gravel. It typically occurs as blocky peds with waxy coatings sometimes called "clay skins". When exposed in a roadcut, the clay-rich interval is easily recognized because of shrinkage cracks caused by drying. The highest clay content is near the top of the till, and the amount of clay decreases with depth (Figure 2). The color is usually either a dark gray or reddish-brown, but there are variations between these. The gumbotil is non-calcareous, but grades down into calcareous till. When wet, it is plastic and tenacious; when dry, it is hard and blocky.

SAMPLING

The selected till sample sites are shown in Figure 1 and given in Table 1.

Table 1
Till Sample Sites

Sample Site	Section	Tier and Range	County
400	SE¼, NE¼, Sec. 20	T 68 N, R 24 W	Decatur
401	NW¼, SW¼, Sec. 5	T 67 N, R 24 W	Decatur
402	SW¼, Sec. 25	T 68 N, R 23 W	Wayne
403	SW¼, SW¼, Sec. 6	T 72 N, R 22 W	Lucas
404	SE¼, SW¼, Sec. 20	T 72 N, R 22 W	Lucas
405	SE¼, SE¼, Sec. 30	T 73 N, R 23 W	Lucas
406	NW¼, NW¼, Sec. 7	T 71 N, R 21 W	Lucas
407	NE¼, SE¼, Sec. 3	T 70 N, R 24 W	Decatur
408	NE¼, NE¼, Sec. 4	T 72 N, R 30 W	Union
409	SW¼, SE¼, Sec. 23	T 68 N, R 31 W	Ringgold
410	SW¼, SW¼, Sec. 4	T 73 N, R 34 W	Adams
411	SW¼, SW¼, Sec. 7	T 69 N, R 36 W	Page
413	NW¼, NW¼, Sec. 20	T 72 N, R 17 W	Monroe
414	NE¼, SE¼, Sec. 34	T 72 N, R 16 W	Monroe
415	NW¼, NW¼, Sec. 14	T 67 N, R 19 W	Appanoose
416	SW¼, SW¼, Sec. 6	T 76 N, R 25 W	Warren
417	SE¼, NE¼, Sec. 31	T 76 N, R 32 W	Adair
418	SW¼, SW¼, Sec. 24	T 76 N, R 31 W	Adair
419	NW¼, NW¼, Sec. 12	T 70 N, R 19 W	Appanoose
420	NW¼, NW¼, Sec. 33	T 75 N, R 22 W	Warren
421	NW¼, SE¼, Sec. 32	T 71 N, R 18 W	Monroe
422	NW¼, SW¼, Sec. 13	T 77 N, R 20 W	Marion
423	NW¼, NW¼, Sec. 21	T 70 N, R 16 W	Appanoose
425	SW¼, SW¼, Sec. 24	T 77 N, R 13 W	Keokuk
426	NW¼, NW¼, Sec. 4	T 77 N, R 10 W	Keokuk
427	NE¼, NE¼, Sec. 17	T 71 N, R 1 W	Des Moines
428	SE¼, SW¼, Sec. 32	T 69 N, R 4 W	Lee
429	SE¼	T 71 N, R 8 W	Jefferson
430	NE¼, NW¼, Sec. 33	T 75 N, R 5 W	Louisa
431	SW¼, SW¼, Sec. 32	T 70 N, R 7 W	Henry
432	SE¼, SW¼, Sec. 32	T 67 N, R 11 W	Van Buren
433	NW¼, NW¼, Sec. 31	T 69 N, R 13 W	Davis
434	SE¼, NW¼, Sec. 4	T 72 N, R 13 W	Wapello
435	Sec. 7	T 71 N, R 6 W	Henry

Riggs (1956), Dahl (1958), and Hansen (1958), all used the method set up by Riggs for determining the location of the glacial till sample sites. A general description of the method is given below; for details the interested reader is referred to Riggs, pages 14-17.

One of the principal objectives was to determine both the local and regional variations in the till. An important factor in the selection of sample sites was the attempt to prevent bias on the part of the investigator, so that a truly random selection of samples could be made. A knowledge of the nature of typical and representative glacial till was needed for this investigation and for a check on the observations of previous workers; yet, the selection of sites was to be made by workers without previous training or experience in Pleistocene geology.

In conjunction with the Statistics Department of Iowa State College, Riggs attempted to devise a system to fit these needs. Within the area of study, he computed the total outcrop area of soils developing from glacial till by using published soil maps. He then divided the area into equal parts, based on area of outcrop of glacial till. Thus, certain regions where outcroppings of glacial till were highest were given proper consideration.

The available funds limited the number of samples which could be taken. Further subdividing the areas of equal glacial till outcrop by combining a group of four county sections into one supersection, Riggs then had numbered supersections which could be picked using a table of random numbers.

This method has been used for all the sampling of Kansan till, and it has proved to be both efficient and relatively rapid after the original conditions have been set up. Above all, it has resulted in an unbiased selection of sample sites.

PETROGRAPHY

Particle-Size Analysis

Mechanical analyses were performed on all samples by the hydrometer and sieving method (A.S.T.M. Designation: D422-54T, as modified by Chu and Davidson, 1953).

Except where indicated otherwise, the particle-size classification used in this report will be that of the American Society for Testing Materials (A.S.T.M. Designation: D422-54T) and the American Association of State Highway Officials (A.A.S.H. Designation: M146-49). These two classifications use the following size limits: gravel greater than 2.0 mm.; sand, 0.074 to 2.0 mm.; silt, 0.074 to 0.0005 mm.; and clay, less than 0.005 mm. in diameter. This classification closely approximates the Wentworth grade scale used by many geologists.

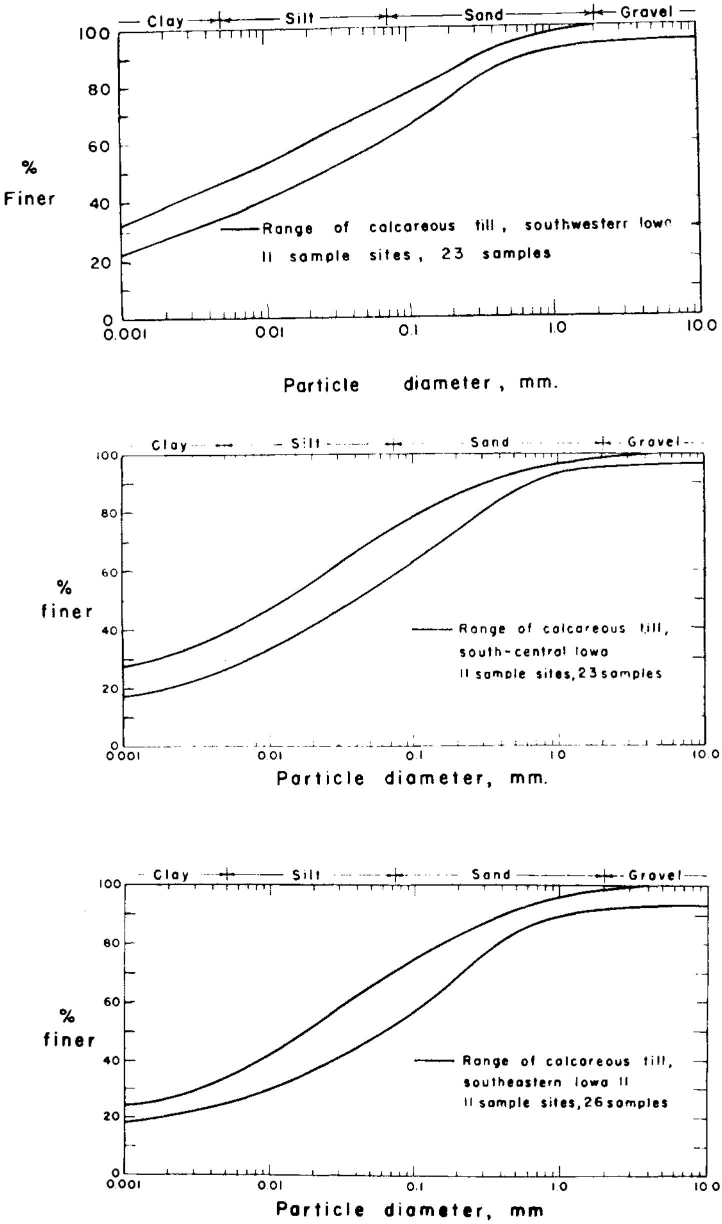
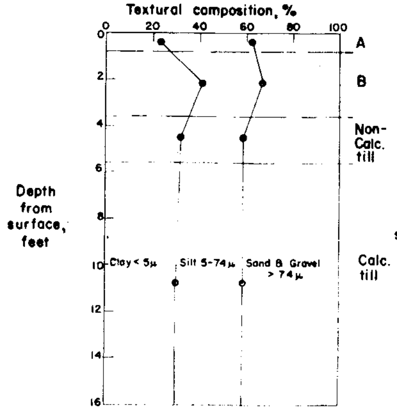


Figure 3. Range of particle-size distribution for calcareous till.

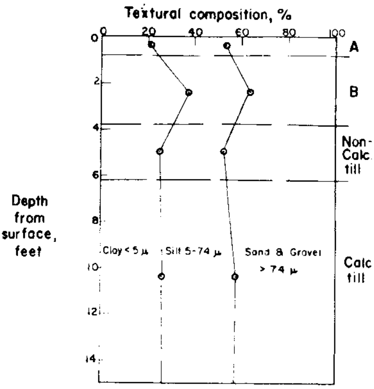
Glacial Till

The range of particle-size distribution for calcareous till outcropping across southern Iowa is shown in Figure 3. These data represent 71 samples taken from roadcuts and auger holes from 34 different sites. Sampling depth varied from 4 to 40 feet below the surface, but in most instances the maximum sampling depth was at least 16 feet. A composite sample of all the calcareous till outcropping or penetrated by the auger was taken at each site, along with numerous samples of 6 inch increments from each site.

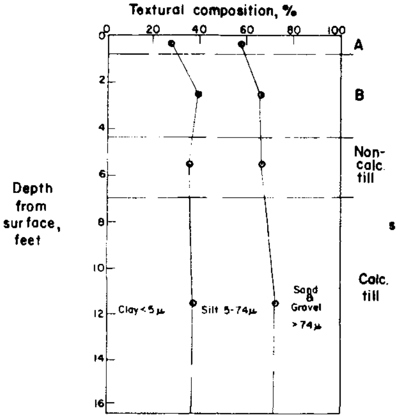
Considering the wide geographic spread of the area and the random sampling system, it appears significant that the calcareous till is relatively uniform in particle-size distribution. It is certainly poorly sorted and, as mentioned previously, it does contain conspicuous sand and gravel lenses and pockets. However, for general purposes, the Kansan till in southern Iowa may be roughly divided into thirds—one each of clay, silt, and sand and gravel. In this respect, the average particle-size distribution for the 71 samples shown in figure 3 is 34 percent clay (25-45 percent), 30 percent silt



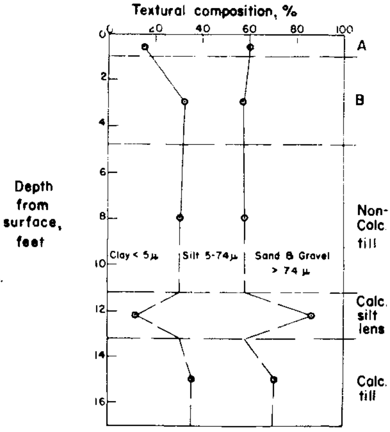
No. 421 Monroe Co.



No. 422 Marion Co.



No. 416 Warren Co.



No.423 Appanoose Co.

Figure 4. Texture with depth of several till sections.

(10-52 percent), 33 percent sand (15-48 percent), and 3 percent gravel (0.8 percent).

There does not appear to be any conspicuous regional trend in the distribution of the till texture. In fact, in southwestern Iowa, the maximum variation in texture was between two sites only a mile and a half apart (Riggs, 1956), and in south-central Iowa the maximum variation was between two adjacent counties (Dahl, 1958).

Excluding the more obvious silt, sand, and gravel lenses, the vertical variation in the till mass is slight. Figure 4 illustrates this fact in south-central Iowa, the sections showing particle-size with depth.

Gumbotil

The range of particle-size distribution for eight samples considered to be gumbotil is shown in Figure 5. These samples were taken

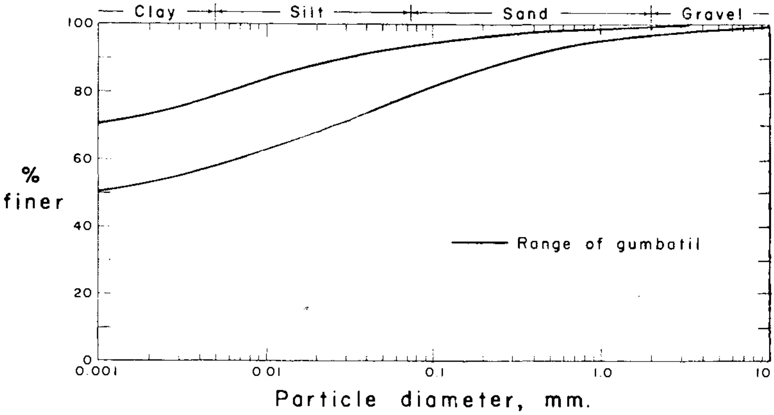


Figure 5. Range of particle-size distribution for heavy clay till (gumbotil).

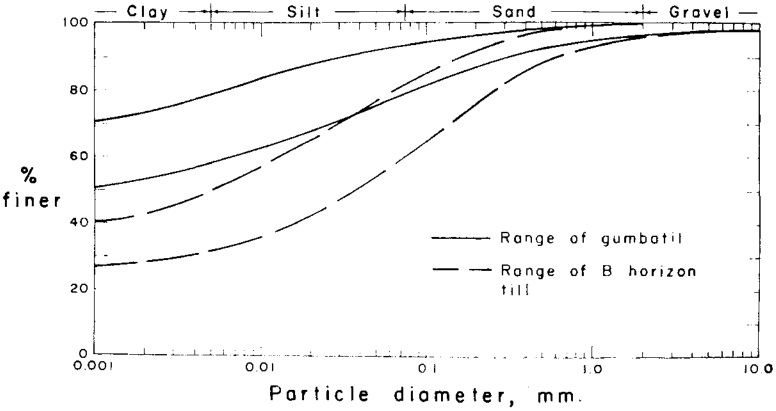


Figure 6. Comparison of ranges of particle-size distribution for gumbotil and B-horizon Kansan till.

Table 2

Mineral Composition of Kansan Till, Percentage by Weight and Percentage of Selected Size Fraction

Mineral	409-3 Calc. till Percent by weight	416-4 Calc. till Percent of two size fractions		425-5 Calc. till Percent of one size fraction	429-4 Non-calc. till Percent of one size fraction
	5—2000μ	20—44μ	105—149μ	20—44μ	20—40μ
Quartz	37	62	63	47	53
Total feldspar	13	20	16	25	24
Carbonates	2	5	6	17	7
Miscellaneous light	1	3	3	3	4
Miscellaneous heavy	3	4	5	4	5
Iron oxide concretions	3	2	4	2	4
Altered and not identifiable	6	4	3	2	4
Quartz/feldspar ratio	2.9/1	3.1/1	3.9/1	1.9/1	2.2/1
Clay, minus 5	37	—	—	—	—
Gravel, over 2000	2	—	—	—	—

from roadcuts or auger holes and the sites were located, in most instances, on spurs of upland divides extending out into more rolling topography. This gumbotil in all instances was buried by younger sediment and is immediately overlain by sandy silt.

True gumbotils are thought to be exteremely weathered till, and so should show the same general type of cumulative curve as the till except for a higher percentage of fine material. These samples show this relationship (Figure 6).

Mineralogical Analyses

Megascopic analysis. The coarse sand and gravel portion of the glacial till contains a variety of rock types and minerals, but the following are most commonly observed: granite, granodiorites, quartzite, slate, basalt, greenstone, gneiss, schist, quartz, and chert.

Microscopic analysis. Table 2 is a summary of accumulated petrographic data (Riggs, 1956; Dahl, 1958; Hansen, 1958). These mineral determinations were made with a Leitz petrographic microscope by determining grains along traverses. At least 300

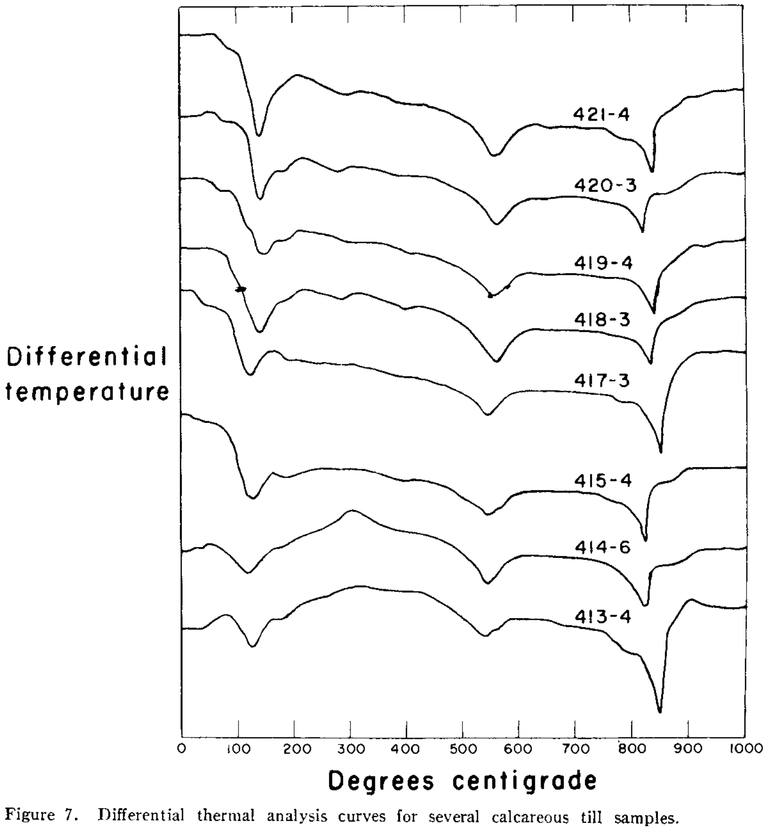


Figure 7. Differential thermal analysis curves for several calcareous till samples.

grains were determined in each particular size fraction. The data identifying numerous size fractions between 5 microns and 2.0 mm. may be the most pertinent, for this gives the mineral composition by weight of the whole sample (Riggs, 1956).

The dominant miscellaneous light minerals are mica and chert; the dominant miscellaneous heavy minerals are amphibole, pyroxene, zircon, tourmaline, and chlorite. In all samples, quartz is the dominant mineral and feldspar is second in abundance.

A seemingly poor correlation between field observation and laboratory analyses is illustrated by the various carbonate percentages, which vary from 2 percent by weight of whole till to 17 percent of selected size fraction for till described in the field as calcareous.

Clay Mineral Studies

Differential thermal analysis. Differential thermal curves for several calcareous tills are shown in Figure 7. These curves are for the minus 44 micron fraction, dry sieved, and placed in an atmosphere of 50-55 percent relative humidity for at least two weeks prior to the analysis.

The curves suggest that illite and montmorillonite are the dominant clay minerals in the samples. The presence of a montmorillonite-group mineral is indicated by the relatively large absorbed water reactions at 100° to 200° C. Montmorillonite and possibly an illite-group-montmorillonite-group mixture are indicated by the pronounced endothermic reaction at 550° C., which indicates the loss of OH structural water. Calcite and minor amounts of dolomite are strongly indicated by the endothermic peak at 850° C.

X-ray analysis. Although the X-ray study was intended primarily to cover only the clay minerals and those minerals occurring in the finer fractions, information is presented on the mineral composition of some fractions occurring in the silt and sand range. All curves except the bottom one in each figure (undispersed whole sample less than 44 microns) came from material which was dispersed with sodium metaphosphate and then elutriated prior to analysis.

In figures 8, 9, and 10, the first prominent reflections in the finer fractions (and in the undispersed whole sample, less than 44 microns) occur between 16.7 and 17.3 Angstroms, and are interpreted as first order basal spacings for glycolated montmorillonite. Unglycolated samples had first reflections that varied between 10-18 Angstroms in a broad band, or were prominent at 14.7 Angstroms—again suggesting montmorillonite.

The 10.0 to 10.16 Angstrom spacing is the first order reflection of an illite-group clay mineral, or muscovite. This is prominent in all but the minus 2 micron fraction and the very coarse fractions. The

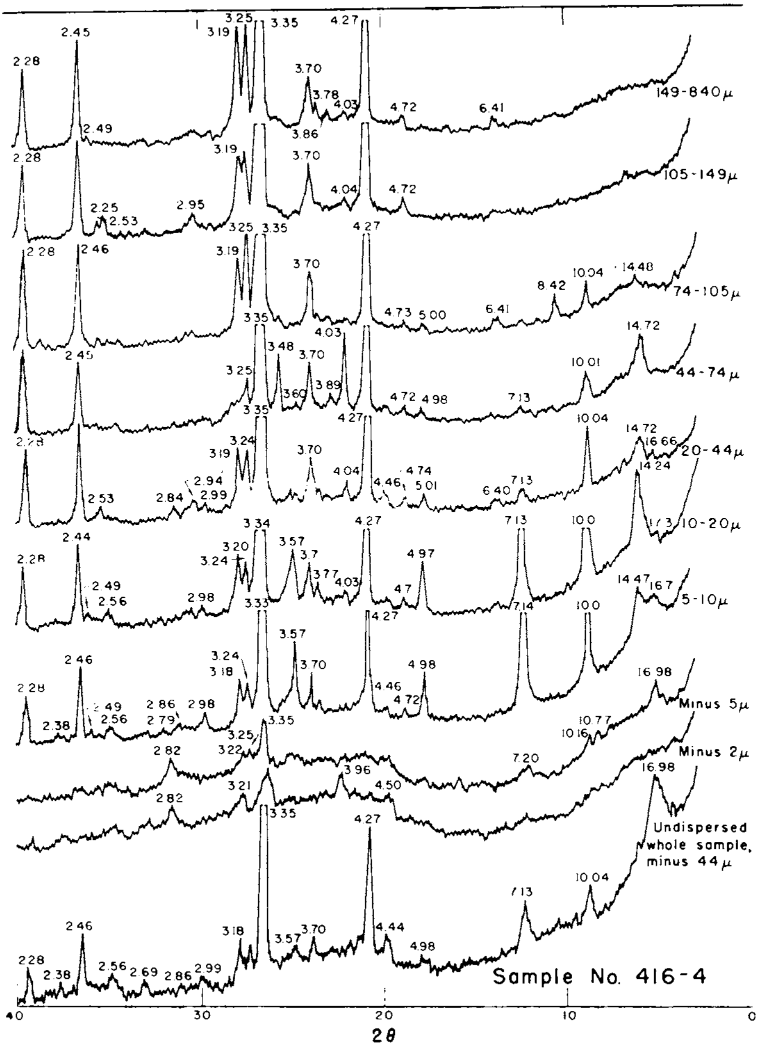


Figure 8. X-ray diffraction curves for several size fractions of sample No. 416-4.

presence of mica and mica-like clay minerals is thus established in the fractions from 5-105 microns.

The 7.13 and 3.57 Angstrom spacings are diagnostic of kaolinite. Since these spacings are also diagnostic of chlorite, some differentiation is necessary. On being heated to 600° C., kaolinite tends to lose its crystalline character, but chlorite is little affected (Grim, 1953). After several fractions were heated, the elimination or extreme decrease of the 7.13 Angstrom reflection indicated the presence of kaolinite.

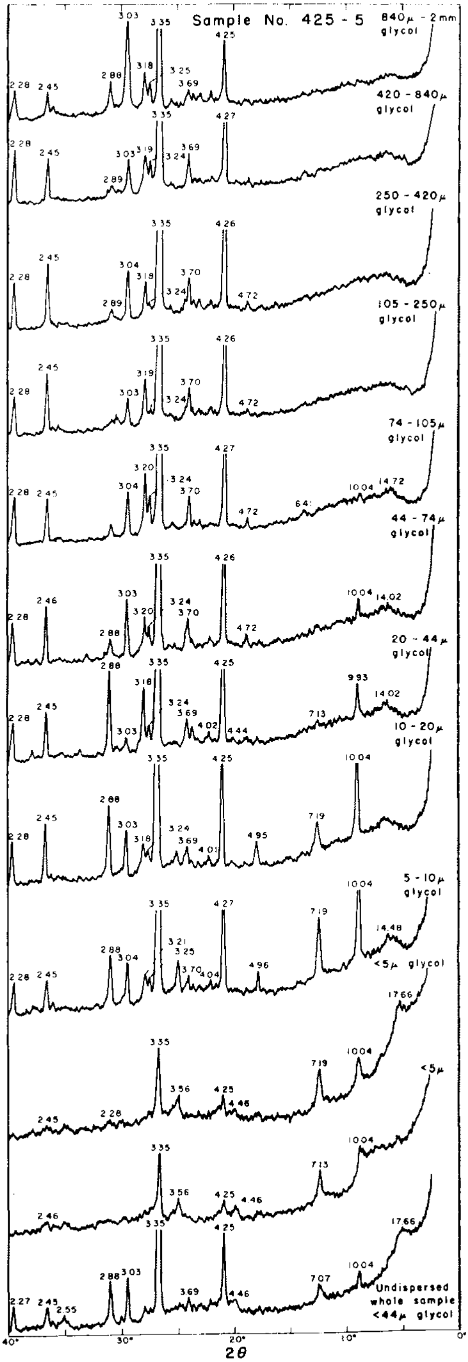


Figure 9. X-ray diffraction curves for several size fractions of sample No. 425-5.

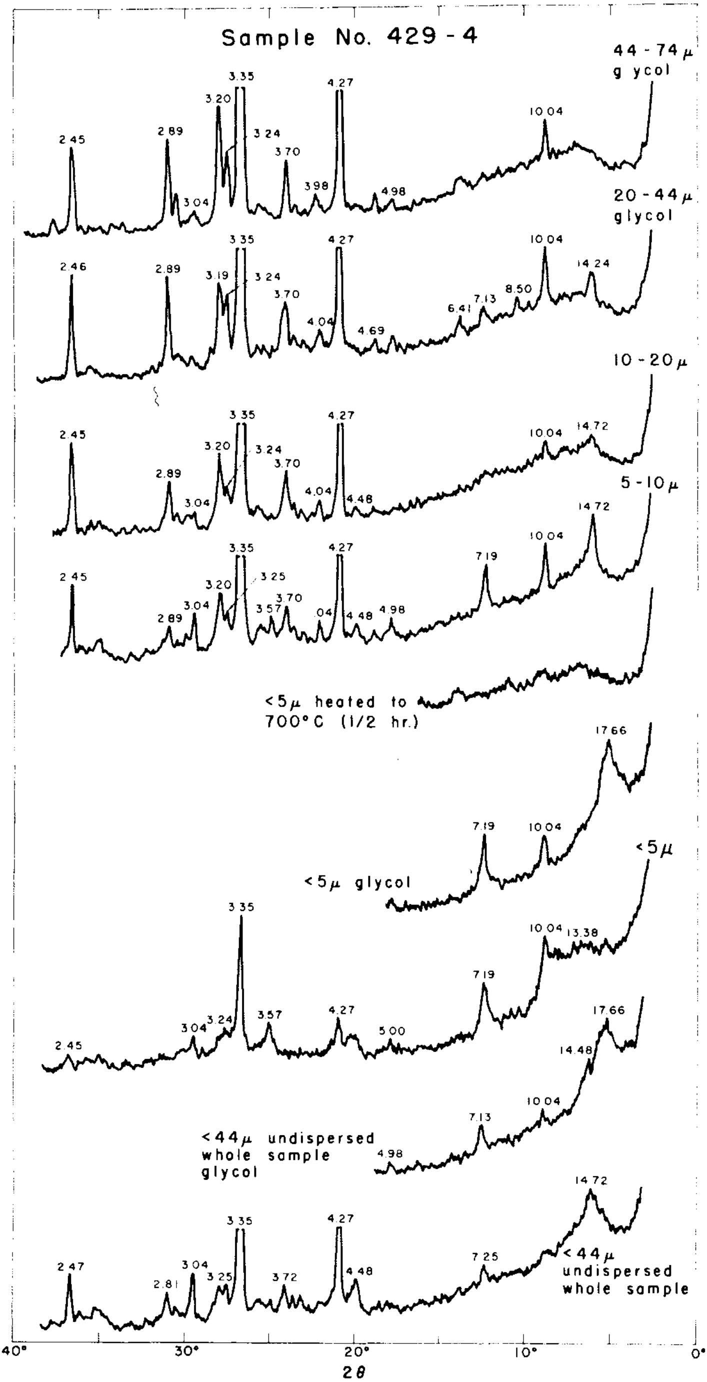


Figure 10. X-ray diffraction curves for several size fractions of sample No. 429-4.

In the coarser fractions (mainly 5-74 microns) the first prominent reflections occur between 14.24 and 14.72 Angstroms and are interpreted as first order basal spacings for chlorite or vermiculite. A distinction may be made between these two minerals by heating the sample at 700° C., at which temperature the 14 kx line of vermiculite is replaced by a line at 9.3 kx, representing the basic talc-like layers (Brindley, 1951). Several fractions were heated to this temperature and, upon X-raying, it was observed that the 14 Angstrom line was either reduced, or completely eliminated, and that weak or no reflections were observed at spacings from 8.6 to 9.3 Angstroms. Thus, vermiculite, minor chlorite, and the possibility of mixed-layer clays and hydrous micas were found in these samples.

Reflections in the coarser fractions are mainly for quartz, feldspar, and mica.

A peculiarity is noted in the diffraction curves for the finer fractions analyzed. In particular reference to the minus 2 micron curve for No. 416-4 (Figure 8), note that the majority of material in this fraction appears amorphous, although there are some weak reflections for quartz and feldspar. Since clay mineral reflections are prominent in the undispersed whole sample, less than 44 microns, it was thought that the clay peaks would be very prominent in this fraction. It may be that the method of preparation is responsible for this lack of clay peaks in the finer fraction, but consideration must also be given to the possibility that there may be only a small percentage of actual crystalline clay minerals in the clay-size fraction.

Table 3

Atterberg Limits and Engineering Classification of Calcareous Glacial Till

Sample No.	Liquid Limit	Plastic Limit	Plasticity Index	Engineering Classification
404-4	38.3	15.9	22.4	A-6(12)
406-3	36.0	15.9	20.1	A-6(5)
407-3	43.2	14.6	28.6	A-7-6(16)
409-12C	42.4	20.5	21.9	A-7-6(11)
411-4C	41.8	14.9	26.9	A-7-6(14)
413-4	35.2	15.0	20.2	A-6(11)
414-6	35.0	16.0	19.0	A-6(10)
415-4	39.6	14.6	25.0	A-6(14)
416-4	38.2	15.1	23.1	A-6(12)
417-3	33.8	14.0	19.8	A-6(10)
418-3	44.8	15.4	29.4	A-7-6(16)
419-4	31.0	13.3	17.7	A-6(8)
420-3	38.8	17.6	21.2	A-6(11)
421-4	30.9	12.6	18.3	A-6(8)
422-4	28.9	14.1	14.8	A-6(7)
423-5	40.9	17.3	23.6	A-6(12)
425-5	29.0	17.0	12.0	A-6(7)
426-6	36.4	16.4	20.0	A-6(11)
427-5	29.9	15.1	14.8	A-6(9)
429-4	27.6	14.7	12.9	A-6(6)
430-6	29.9	14.3	15.6	A-6(7)
432-4	28.1	14.1	14.0	A-6(7)
433-7	29.3	12.3	17.0	A-6(8)

ENGINEERING PROPERTIES

The Atterberg limits and an engineering classification (Spangler, 1951) of numerous calcareous glacial till samples are given in Table 3.

The general rating of the glacial till as a subgrade material is fair to poor. In particular, the group A-6 (in which the majority of these samples fall) has the following general description (Spangler, 1951):

> "The typical material of this group is a plastic clay soil 75 percent or more of which usually passes the No. 200 sieve. The group includes also mixtures of fine clayey soil and up to 64 percent of sand and gravel retained on the No. 200 sieve. Materials of this group usually have high volume change between wet and dry states. The group-index values range from 1 to 16, with increasing values indicating the combined effect of increasing plasticity indexes and decreasing percentages of coarse material."

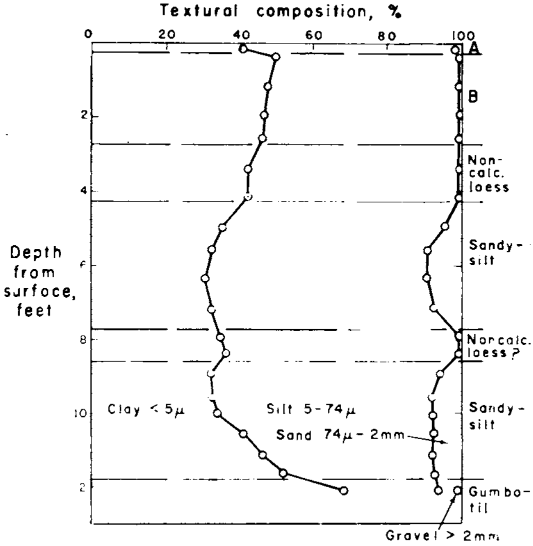
PROBLEMS

The studies of glacial till and other Pleistocene deposits have raised several problems, some of which are as follows:

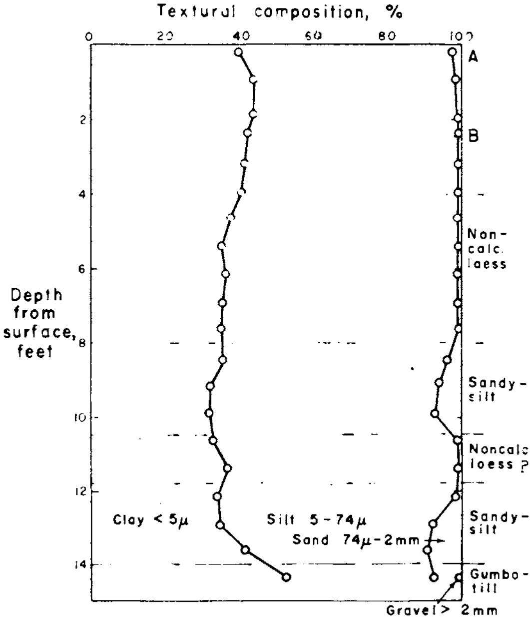
1. If it is correct to assume that the texture of at least the upper few tens of feet of glacial till is consistent with the texture presented in this paper, then the mechanisms of till deposition must be considered. Would material with so little areal or vertical variation in particle-size distribution be deposited by lodgement under an ice cap?
2. The origin of sandy silt is yet to be explained on the higher interfluves and where it overlies gumbotil. This sediment has been observed between the till (or gumbotil) and the clayey silt (loess) in both the more rolling terrain and on the flatter uplands.

   One investigator who has worked on the sandy silt (which he terms pedi-sediment or translocated sediment) in Adair County in southern Iowa, has related its origin to a process of landscape evolution (Ruhe, 1956). According to this investigator, the pedi-sediment is derived from till and is formed during the multi-cyclic erosion (pedimentation) of the pre-loess glacial till landscape. No pedi-sediment was observed on the highest surface in that area, the Yarmouth-Sangamon, which is described as a highly weathered, but little eroded, relict of the Kansan drift plain now covered by loess. Thus no pedi-sediment was over the now-buried heavy clay soil or gumbotil found on this Yarmouth-Sangamon surface.

   However, borings in the NW¼ of NW¼ of NE¼, Section



No. U_5 Adair Co.



No. U_6 Adair Co.

Figure 11. Texture with depth of sections No. U_6 and No. U_5 in Adair County.

13, T76N, R32W, Prussia Township, Adair County, Iowa, revealed sandy-silt above gumbotil (Dahl, 1958). (See Figure 11.) Based on map locations, it is believed this sediment was located on and above the Yarmouth-Sangamon surface (Ruhe, 1956, p. 443).

Auger holes were also bored into upland topography in Mahaska, Marion, and Warren conuties, and in all the borings a sandy silt was found above the gumbotil and below the loess. Several borings down the crest of an interfluve in Monroe County (Dahl, 1958), also revealed a sandy silt above gumbotil (Figure 12).

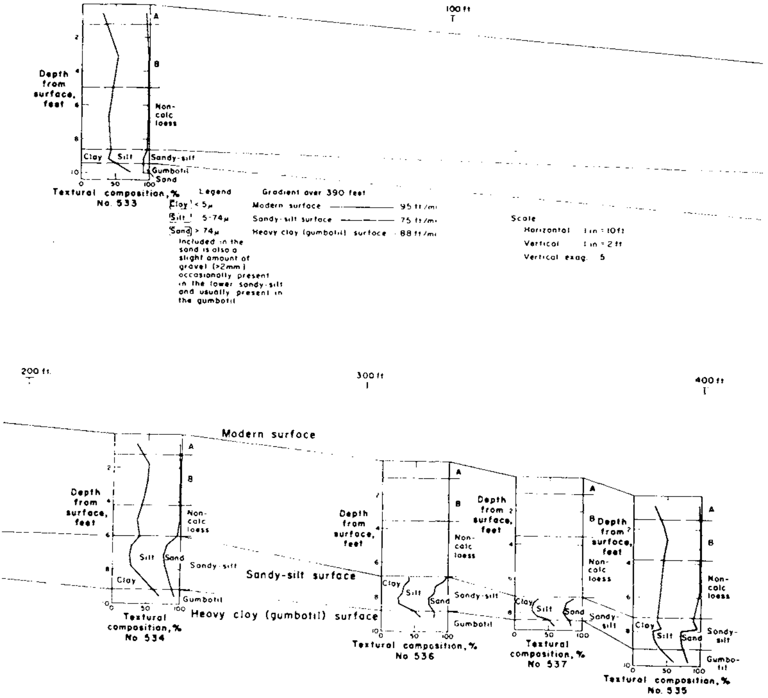


Figure 12. Texture with depth of section down crest of interfluve in Monroe County.

Note in Figure 11 that in section U_5 only the upper four feet might be called loess, but in U_6 (two feet higher on the modern landscape and forty feet horizontally from U_5) eight feet might be called loess. However, without careful field observation and detailed sampling, the material in U_5 down to a depth of about 12 feet, and in U_6 down to a depth of 14 feet, might be called loess. The use of the word "loess" thus raises a problem also. The texture of this deposit does change with depth and, in fact, there is a thin increment of clayey silt lying between two sandy silts which may have been identified by others (Ruhe, 1956, p. 445) as Farmdale loess. Not only does the texture of the section vary, but so does the mineral composition of the sand-size material. The clayey silt (loess) does contain some sand-sized sediment, but it is made up principally of authigenic iron concretions. In the sandy silt, the sand-sized particles increase; and these sand grains are mainly quartz and feldspar, as well as some iron concretions. Obviously, the sand in the upper sandy silt of Figure 11 could not have been derived from the underlying clayey silt or Farmdale loess. Thus, the origin of the sandy-silt, as well as the use of the word "loess" to mean wind-deposited silt, both raise problems.

3. The third problem to be raised concerns the clay mineralogy of the glacial till. What percentage of the clay-size fraction is made up of recognized crystalline clay minerals?

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