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Recent project work in the Soil Research Laboratory of the Iowa Engineering Experiment Station has been focused on studies of loess in Iowa. Since most geologists believe that loess was carried and deposited by the wind, members of the Engineering Experiment Station have long been interested in seeing silt-laden winds in action. This means visiting dust storms, and opportunities for study have been infrequent during the past 15 years.

Recent devolopments in the southwest have changed this somewhat, and dust storms are once again plentiful. The combination of drought and strong winds has sent dust from Kansas and Colorado into many Mid-Western states, and recently an average depth of one-sixteenth inch was deposited in Iowa from one storm.

In addition to studying dust which settled in Ames, two of the authors visited the most severe dust areas of southwestern Kansas and the Oklahoma and Texas panhandles. The purpose of the trip was to obtain some sand samples for a separate stabilization study, and incidently to try to locate some dust storms. Both efforts were eminently successful.

The Dust-Bowl Area

Dust Storms

The major area of the March, 1954, dust storms is shown in Figure 1. Sources for the sand and silt were plowed fields which either were laid aside to prevent overproduction or had inadequate vegetative cover. Farther south in Texas the wheat crop was more advanced, and dusting was less. The dust sources were in many instances made up of many separate plowed fields. As in the 1930's the principal causes for the dust storms appear to be drought and overcultivation. Plowing or furrowing had both loosened the soil and contributed to air turbulence near the ground, causing the soil grains to be more easily picked up. Figure 2 shows dust from a single field; the dust was blowing across an adjacent highway, and headlights were required. On either side of the field the air was clear. Valleys sometimes were, in effect, funnels for the wind and dust, as shown in Figure 3.

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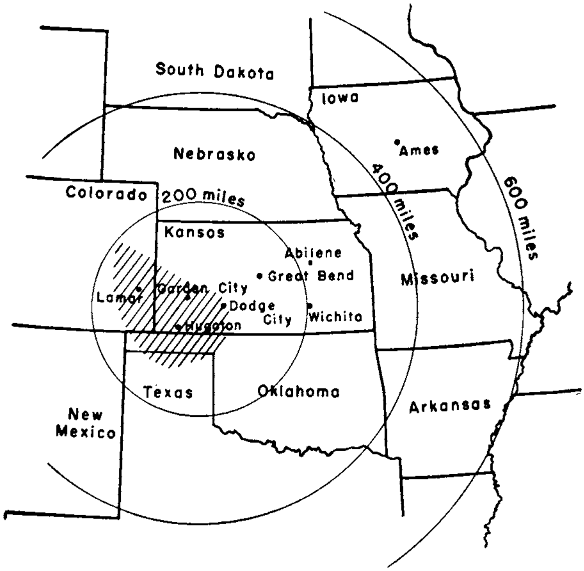

Fig. 1. Map of the major dust area observed during the March, 1954 storms. Dust area is shown by shading; the circles indicate radial distances.

Sand Drifts

In the dust area, fences clogged with tumbleweeds formed barriers to the wind, and fine sands were deposited in drifts on the lee side of the fences. The fences were in some cases almost buried, as shown in Figure 4. Fine sands also filled a few roadside ditches, and it was these sands which drifted across highways and railroad tracks to stop traffic. There were only a few publicized instances of actual traffic interruptions, and from this standpoint the sands were no more serious than a few inches of snow.

Visibility

A much greater traffic hazard was the reduced visibility near source areas of the dust during the most severe storms. Visibility was sometimes reduced to a few tens of feet or even less, and travel was virtually impossible due to the likelihood of getting lost. Some residents described the storms as the worst since the 1930's; others described the storms as even worse than the 1930's. According to the Soil Conservation Service, in number of acres blowing, conditions in 1954 were equal to the worst of the 1930's. However, the dust bowl conditions have not yet been prolonged through so many years, and the drought has not been associated with economic ruin as in the "dirty '30's."

Fig. 2. Dust blowing from a wheat field near Great Bend, Kansas. Sample No. 1 was obtained at this location.

Fig. 3. View of dust funneling through a stream valley near Junction City, Kansas.

Dust Clouds

Dust trails can often be traced away from source areas, much as smoke can be traced from a faulty incinerator. Going away from the source area, the trails tend to coalesce into clouds of dust, and the dust is often carried to elevations of one to four miles. Dust clouds may persist for hundreds of miles, and have been observed as far east as the Atlantic coast.

A dust cloud blew over and through Dodge City, Kansas, on March 18, 1954, which was an especially good day for dust storms. The sun was blotted out and darkness fell, as did large amounts of dust. Silt was deposited wherever the wind velocity was diminished, as in window corners, doorways, etc. Silt was deposited to a depth of one-eighth inch on outside window ledges where screens served to lower the wind velocity. No rain or precipitation accompanied the dust fall. Many downtown sidewalks were hosed off with water, and the silt blocked storm sewer inlets and clogged gutters.

Sampling

At the Source

Source areas for the silt, as the field shown in Figure 2, are

Fig. 4. Fences clogged with tumbleweeds and drifted with sand and sand-size aggregates of topsoil. The photo was taken south of Garden City, Kansas, near the Oklahoma state line. Particle-size curves for this sand are labelled "B" in figures 9 and 10.

readily found and easily sampled. The sampling technique was to park the car downwind, spread out papers on the seats, and open a window approximately one inch. Near Great Bend, Kansas, about 15 gm. of dust was thus collected in a few minutes from the papers alone. For comparison, a sample of topsoil was taken from the adjacent source field.

As mentioned previously, sands in the source area were commonly drifted to the lee of fences, behind tufts of vegetation, in road ditches, etc. Several samples were obtained from such drifts and from their topsoil sources.

Near the Source

Two samples of silt were collected from window ledges, one in Garden City and the other in Dodge City, Kansas. Since the yield was about one-half pound at each sample location, risk of contamination was slight. Both samples were taken the day after deposition.

Far from the Source

Unusual conditions in Ames, Iowa, resulted in a sudden deposition of dust on March 12. The dust was brought down by snow and hail. The snow then melted slowly and evaporated, leaving dust-derived mud on windows, cars, etc. Dried dust was collected from two cars which had been washed just prior to the storm.

Sampling—Summary

The dust samples studied were collected in different manners and have different relationships to the storms. As illustrated in Figure 5, samples 1 and 4 represent dust captured from suspension in the air. Samples 2 and 3 represent coarse silts which dropped out of the air near the source.

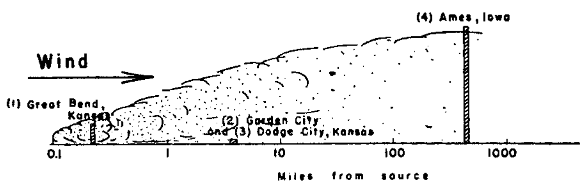

Fig. 5. Hypothetical dust storm showing materials represented by the various dust samples collected. Distances are shown to a logarithmic scale and are only approximate.

Particles Sizes

Methods of Analysis

Mechanical analyses of the dust and soil samples were performed by hydrometer and sieve methods used on the loess[5]. Where the usual 50 gm. sample was not available, the dispersing agent was reduced proportionally. The dispersion for mechanical analysis is designed to obtain as complete a separation of grains as possible without significant breaking up of particles[4]. This is desirable for engineering purposes since it gives a maximum indication of clay, the active soil fraction. Otherwise the clay remains as aggregates and coatings and is not distinguished from silt. However, analyses of this type performed on an eolian sediment probably do not give a true indication of particle-size during deposition. Even mixing an eolian sediment with water will result in some dispersion, and a reliable settlement analysis would be impossible unless done in a dry medium such as air. The wet method of measuring particle-size is therefore of value mainly for making comparisons.

Dust

Figure 6 shows particle-size curves for dust collected from the air near Great Bend, Kansas, and for the topsoil surce of the dust. The curves are very similar except for the sand content. They illustrate the selective action of the wind in removing silt and clay from the topsoil and leaving the sand.

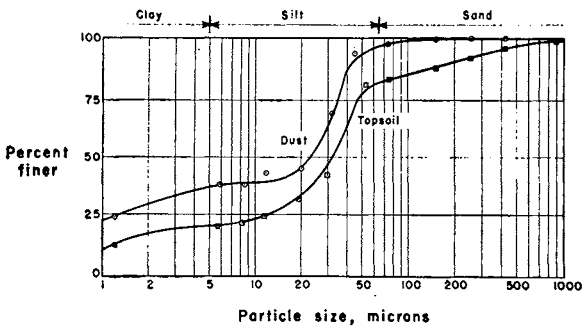

Fig. 6. Particle-size distribution curves for dust blowing from the field shown in figure 2, and for topsoil from the same field. The curves are similar except that the dust contains very little sand.

According to the laws governing particles settling in a suspension, coarse material settles fastest. This is indicated by particle-size curves for dust which settled out of the air at Garden City and Dodge City, Kansas. These curves, in Figure 7, are for the samples collected 50 miles apart and deposited at different heights* by winds from different directions on different days. Yet the curves are practically identical, and indicate large amounts of coarse

*From window ledges on the first and third floor levels, respectively.

silt in these deposits. Fine materials, since they settle less rapidly, were presumably carried away in the wind. Unfortunately, no accurate data are available on distances from the sources of these two samples. However, the two dusts probably are approximate first materials deposited, which would explain the similarity and coarseness in particle-size. The storms were associated with strong, turbulent winds which normally would not permit extensive deposition. The winds therefore probably retained dust in suspension until obstacles such as trees and buildings in the two cities, lowered the wind velocity sufficiently to allow deposition of coarse material.

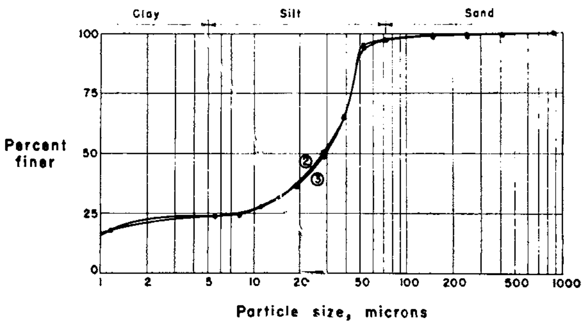

Fig. 7. Particle-size distribution curves for dust collected in Garden City (2) and Dodge City (3), Kansas.

Farther away from the source, one would expect the dust remaining in suspension to be progressively depleted of coarse material. While no settlement dust samples were obtained to illustrate this, the dust brought down in snow in Ames, Iowa, does give a satisfactory indication of air sorting. The sample of this dust (No. 4) is comparable to the Great Bend sample (No. 1) collected at the source, since both represent blowing dust. Figure 8 shows that the Ames dust is much finer than that from Great Bend. It should be pointed out that the Great Bend sample represents dust blowing from only one source; dust mixed in from other sources might change this curve somewhat. However, the changes to produce Curve 4 material from Curve 1 material involve a great decrease in coarseness of the silt, and such a decrease is improbable without wind sorting. Sorting by natural processes is further indicated by the straight-line logarithmic relationship in the silt size range of Curve 4.

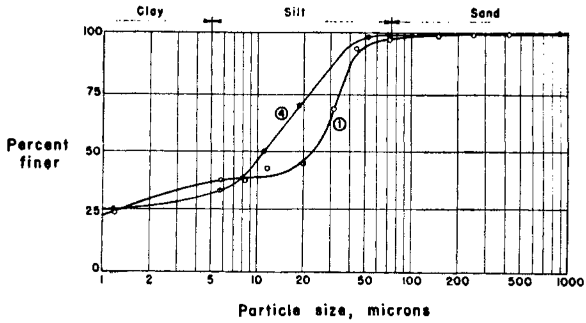

Fig. 8. Particle-size distribution curves for dust collected at Ames (4), Iowa and near Great Bend (1), Kansas.

Sand

In the Dust Bowl area, sand is too coarse to be suspended and blown into the next state but it is often bounced along into the next field or until it drifts behind a fence (Figure 4). Figure 9 shows particle-size curves determined by dry-sieving three such

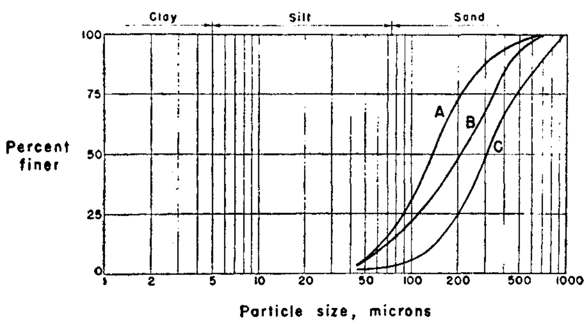

Fig. 9. Particle-size distribution curves obtained by dry-sieving three "sands" from fence-line drifts in the dust-bowl area.

drift sands. The analyses were then repeated by sieving and hydrometer tests after dispersion with sodium metaphosphate[5]. The particle-size curves are shown in Figure 10. The "sands", when the aggregates are broken and the grains dispersed, contain between 40 and 85 percent silt and clay; that is, the drift sands are comprised mainly of aggregates of topsoil. Previous experiences in the 1930's indicate that the sand-size aggregates become finer after repeated reworking by wind. It has been suggested that the sandy, poorly sorted Paha loess in eastern Iowa is similar in origin to these drift sands[8].

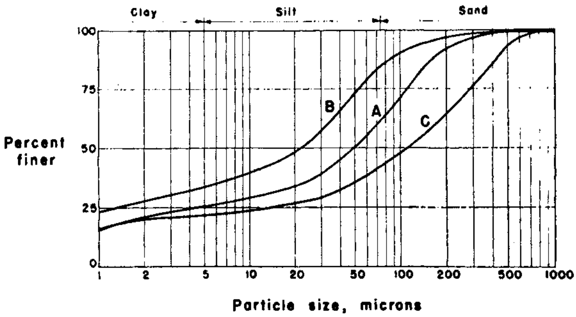

Fig. 10. Particle-size distribution curves for the same materials as in Fig. 9. These curves were obtained by conventional mechanical analysis with dispersion, and show that some of the drift "sands" are composed mainly of aggregates of silt and clay.

Figure 11 shows particle-size curves for one of the sands and for the topsoil source of the sand. The drift sand is coarser than the topsoil, indicating removal of fine materials as dust.

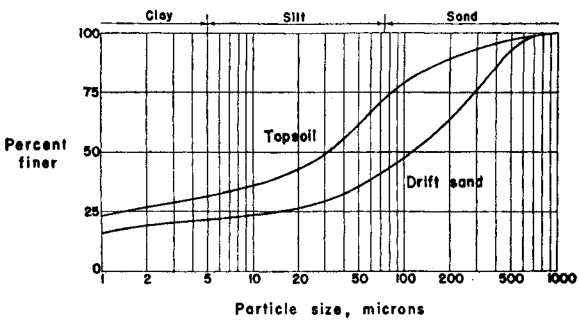

Fig. 11. Particle-size distribution curves for a drift sand and its topsoil source. Note the loss of fine materials when topsoil is eroded and drifted by the wind.

Mineralogical Composition

Differential Thermal Analysis

Differential thermal curves for dust samples 2, 3, and 4 are presented in Figure 12. The reactions are labelled on the bottom curves. All samples contain considerable amounts of organic matter, as is indicated by the broad exothermic humps between 225°C and 600° C. Since this oxidation reaction masks others in that range, particularly the clay, the tests were repeated in a nitrogen atmosphere to inhibit oxidation. Curves for samples 2 and 3 from Garden City and Dodge City, Kansas show the presence of organic matter and quartz and probably montmorillonite.

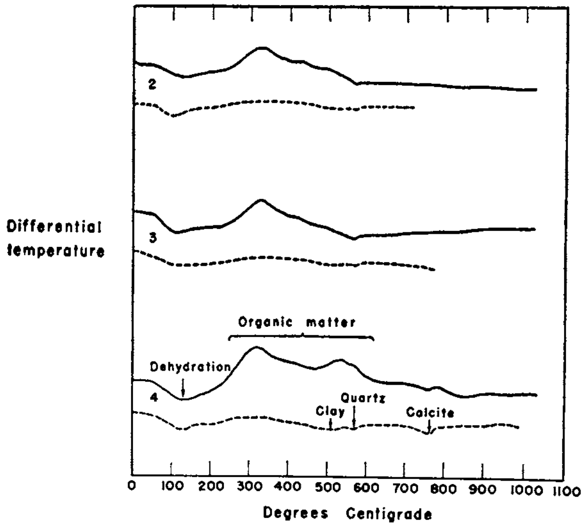

Fig. 12. Differential thermal curves for three dust samples from Garden City and Dodge City, Kansas, and from Ames, Iowa. Dashed lines are from analysis of the same samples in a nitrogen atmosphere to inhibit the masking reactions of organic matter.

The curve for sample 4, from Ames, Iowa, shows similar but larger organic matter and clay mineral reactions. Quartz and calcite are also indicated.

Microscopic Examination

Three of the dust samples were analyzed under a petrographic microscope and percentage determinations made. The dust samples were mounted in balsam without any pretreatment or size separation of the samples. Results of the studies are presented in Table 1. High feldspar contents of samples 2 and 3 probably indicate rather localized source areas, particularly in the case of sample 3, with over 70% feldspar. The authors do not have sufficient informationn at the present time to evaluate possible specific source areas. Several materials such as opal and volcanic glass in the Iowa sample point to a distinctly western origin.

Clay in the three dust samples occurs mainly as coatings on the silt grains, although aggregations of clay and organic matter are also common. Isolated grains of clay were quite rare. The occurrence of heavy minerals in eolian dusts is contrary to some opinion[11], but has also been reported by other investigators[1,7].

Comparison of Dust and Loess

Similarities in particle-size composition of loess and of eolian dusts have been demonstrated many times, but few investigators

Table 1.
Mineralogical Composition of Three Wind-Blown Silts.
(Percent by volume of untreated, whole sample).

Mineral	Dust Samples and Locations		
	No. 2 Garden City	No. 3 Dodge City	No. 4 Ames, Iowa
Quartz	63.9	14.5	64.0
Feldspar, undifferentiated	23.8	71.1	9.0
Mica (Biotite and muscovite)	0.8	1.3	3.2
Heavy minerals*	4.3	3.4	5.8
Clay aggregates	5.2	8.5	12.0
Others			
Calcite	0.4	—	2.8
Opal	1.3	0.5	2.1
Volcanic glass	—	0.6	0.9

Remarks: Clay coatings on grains are common. Feldspars are predominantly of the potash type. Organic material is abundant in all samples.

*Separated by visual examination only.

have pointed out differences. Dusts resulting from contemporary dust-bowl conditions are rather unique for two reasons: The dusts are derived mainly from topsoils, and the dusts are usually picked up by abnormally strong winds, since strong winds are necessary to erode the topsoil. The dusts therefore contain significant amounts of organic matter and silt-size aggregates of clay, and because of the high winds, the dusts probably blow higher and farther than they would under ordinary conditions.

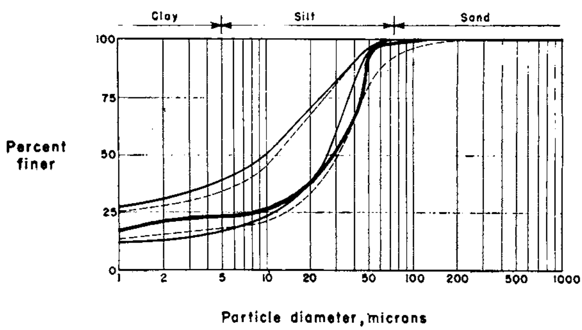

Fig. 13. The heavy line indicates particle sizes of dust which settled in Garden City, Kansas. Other particle size curves are for Wisconsin-age loess in Iowa. The solid lines are for typical samples from southwestern Iowa, the dashed lines for typical samples from east-central Iowa.

Figure 13 shows particle-size curves for a variety of C horizon Wisconsin loess samples in Iowa and for the dust which settled in Dodge City, Kansas. There is general agreement in that all curves show a break at about 50 microns. For the dust sample, this break in the curve indicates the maximum-size particle easily carried in suspension, and many of the dust particles are close to this size. Furthermore, the remarkably good sorting in the silt-size range is not in accordance with the large amount of clay present in the dust. Considering that the clay was deposited partly as aggregates, as suggested above and confirmed under the microscope, the effect of topsoil aggregates is to increase the clay and decrease the silt contents measured after dispersion. Corrected for this effect, the particle-size curve of the dust would be closer to those for loess. Clay also occurs as coatings, which would further modify the curves, but this is equally true for both the dust and the loess.

Conclusion

A number of relationships are demonstrated by this study:

1. Dust blowing from a source is approximately equal in particle-size to the source material minus the sand.
2. A decrease in wind velocity results in settling out of the dust, particularly the coarser sizes.
3. Dust blown hundreds of miles becomes progressively finer because of settling out of the coarser materials.
4. Sand drifts in the Dust Bowl Area are made up of sand and sand-size aggregates of topsoil. A comparison of a drift sand with the topsoil sources shows a considerable loss of silt and clay, presumably as dust.
5. Particle-size curves for dust near the source differ from those for loess near the alleged source of the loess. The difference is in the silt and clay ranges, and may be due to clay aggregates in the dust.

Acknowledement

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