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Extensive Gaging of Dust Deposition Rates

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Introduction

Several investigators have reported dust trapping studies for short intervals or restricted purposes, especially during periods of severe duststorms (Winchell and Miller, 1918; Miller, 1934; Choun, 1936; Martin, 1936; Robinson, 1936; Warn and Cox, 1951; Handy *et al.,* 1960). That the source of dust in some cases is obvious, reflecting disturbances by man, and that its deposition in the past has recorded climatic changes as well as other historical events, has been expounded by Sears (1964).

Cases are numerous of atmospheric sampling and study of impurities at different geographical locations, different heights, and especially in relation to suspected industrial or other sources of atmospheric contamination. Related literature is extensive and scattered through many types of publications.

Our study involves (1) continuous trapping of dust settling from the atmosphere over prolonged periods, (2) standard trapping simultaneously at several widely separated locations, and (3) quality, especially in terms of particle sizes and mineralogy.

Present sites are intended to provide some indication of the magnitude of dust influx from remote locations and to determine whether deposition rates indicate patterns related to geographic location, climate, superficial earth material, or land use. To test the influence of other variables such as local cultivation and exposed river bars, it will be necessary to locate stations at selected positions with respect to suspected sources. A likely influence considered in the initial site selections was the dust bowl region of southwestern Kansas, southeastern Colorado, northwestern Oklahoma, and northwestern Texas. It was reasoned that dust deposition might decrease with distance from this known center of severe wind action, especially during observable duststorms.

The Present Network

The first site was selected at Manhattan, Kansas, May 20, 1963, in the Flint Hills Region. It occupies a ridgetop position in rolling terrain. Grass cover is good for 1,200 feet or more in all directions.

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Other sites and their establishment dates are: Hays, Kansas, November 1963; McCredie, Missouri, December 1963; Marcellus, New York, March 1964; Riesel, Texas, March 1964; Tribune, Kansas, April 1964; Sidney, Montana, April 1964; Water Valley, Texas, April 1964; Marlboro, New Jersey, April 1964; North Platte, Nebraska, May 1964; Coshocton, Ohio (two stations), May 1964; Oxford Mississippi, June 1964; and Lethbridge, Alberta, Canada (in process).

All sites have been selected by cooperators in agricultural research at the locations indicated. They are exposed to normal climatic conditions, similar to standard rain gage locations, with the additional requirement that they are "nondusty" locations protected for a least several hundred feet by surrounding ground cover that effectively prevents surface soil from blowing. Locations are shown in Figure 1 with distances from an arbitrary point on the boundary between Kansas and Colorado where duststorms were active in the spring of 1964.

The Standard Station

Miller (1934) suggested that the standard Weather Bureau rain gage was appropriate for determining quantities of dust in rainfall. The outer cylinder of such a gage was chosen in the present case after considering other possible sizes, shapes, and designs.

To keep the trapped dust as free as possible from contamination by birds, insects, and plant fragments, and to prevent rainfall losses by

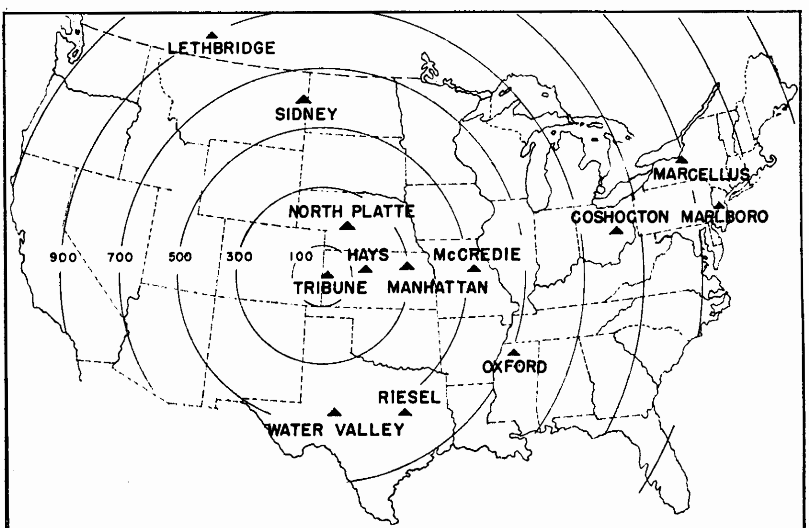

Figure 1. Site locations and distances in miles from an arbitrary point on the boundary between Kansas and Colorado where duststorms were active the spring of 1964.

splash, two standard 8-inch-diameter screens are nested in the top of the cylinder. The bottom screen has 1-mm.-square openings; the top, 6.35 mm.

Maintaining water or antifreeze in the cylinder assures trapping all dust that settles. During heavy snow season, it is necessary to remove the screens to permit snow to enter freely.

The cylinder is mounted like a standard rain gage. The screens, when present, add 4 inches of height, placing the top of the trap about 34 inches above ground level. Surrounding tall weeds or grasses are clipped to keep their height below 34 inches.

Monthly intervals have been satisfactory for removal and study of dust deposits. Shorter intervals may be needed to evaluate efforts of specific weather conditions or other short-time influences.

Laboratory Processing

Since quantities of dust commonly are from 0.1 to 1.0 gram and sometimes less, it has been necessary to adjust details of technique accordingly. Guidance on principles of processing and preparation for mineralogical study has been provided by Kunze and Rich (1959) and Jackson (1956).

Acid treatments have been avoided to preserve carbonates and cemented aggregates for optical identification.

Colors of oven-dry dusts are determined by standard Munsel charts.

pH is being determined colorimetrically with Hellige-triplex indicator solution,[2] since quantities are too small for determination with standard glass electrode equipment.

Destruction of organic matter is accomplished with 30-percent hydrogen peroxide. Since carbonates are not removed, destruction of stable soil organic matter is not complete, but prolonged treatment with repeated increments of peroxide satisfactorily eleminates such crude organic materials as insect parts, seed coats, and plant fibers, which usually are present.

Dispersion is accomplished by overnight soaking after peroxide treatment and drying, followed by sodium metaphosphate (Calgon)[2] addition and high-speed stirring. Then, assuming a particle specific gravity of 2.65, the $< 2\mu$ clay is removed by repeated(four to six times) sedimentation and/or centrifugation. Clay is reflocculated with HCl and $MgCl_2$ at pH 3.0 to 4.5, then washed and adjusted to a 1 percent suspension before drying to form oriented slides for X-ray diffraction study.

A Norelco[2] diffractometer operating with nickel-filtered copper radiation at 40 kilovolts and 18 milliamperes with a 1-degree slit system is

[2] Use of this product does not imply endorsement by the USDA or that it is superior to other competing products.

used to examine the oriented slides. A scanning speed of 1 degree per minute, a time constant of 2 seconds, and a rate scale factor of either 200 or 500 are used. Each sample is monitored from 62 degrees to 1½ degrees 2Θ at room temperature; the sample is then treated with ethylene glycol and run from 15 degrees to 1½ degrees. An additional oriented slide is X-rayed from 15 degrees to 1½ degrees after heating for ½ hour at 450 degrees C. and 600 degrees C.

After the silt and sand are dried and weighed, appropriate subsamples are mounted permanently for optical study.

Deposition Rates

Some information about monthly deposits at Manhattan and Hays is presented in Tables 1 and 2. Weight loss by oxidation reflects such organic materials as insect and plant parts as well as soil organic matter, so weights after peroxide treatment may be more meaningful.

During the time represented, atmospheric dust was noticeable only a few days in April and May 1964, months with highest deposition rates.

The Soil Conservation Service noted considerable duststorm activity in western Greeley County, Kansas, and adjoining Colorado from November 1963 through May 1964.[3] During April 1964, U. S. Weather Bureau

Table 1. Monthly dust deposition into a standard trap at Manhattan.

Month	Weight		Loss by oxidation	pH	< 2μ diameter clay
	Gross	Oxidized			
	Lbs./acre	Lbs./acre	Percent		Percent
1963					
June	23	20	18.4		
July	62	50	19.6		
Aug.	64	40	38.2		33
Sept.	28	22	19.0		16
Oct.	35	32	7.8		46
Nov.	37	35	4.6		47
Dec.	29	22	22.1		43
1964					
Jan.	34	28	16.5	6.7	25
Feb.	37	33	11.7	7.0	51
Mar.	56	51	9.0	8.0	43
Apr.	124	101	17.5	7.5	29
May	108	99	8.2	8.2	37
June	42	37	12.7	8.2	43
Total	679	570			
Monthly average	52	44	15.8		37

[3] Information on duststorms was supplied by Kansas and Colorado State Conservationists, Soil Conservation Service, USDA.

rawinsonde data (1964) indicated that air movement from the ground surface to a dynamic height of over 19,000 meters in the region tended toward the east or northeast. Therefore, a point on the Kansas-Colorado border, 15 miles west of Tribune, where a standard trap was located, was chosen arbitrarily as a zero point to check whether dust deposition rate north and east was related to distance from this possible source.

As shown in Table 3, the Hays (150 miles) rate has been lower than for North Platte (190 miles) and Manhattan (300 miles). Even

Table 2. Monthly dust deposition into a standard trap at Hays.

Month	Weight		Loss by oxidation	pH	< 2μ diameter clay
	Gross	Oxidized			
	Lbs./acre	Lbs./acre	Percent		Percent
1963					
Nov.	33	28	16.7		59
Dec.	24	21	12.6		47
1964					
Jan.	25	20	19.2	6.7	16
Feb.	30	24	20.9	6.5	55
Mar.	55	45	18.0	7.5	32
Apr.	96	84	12.8	7.2	35
May	80	78	2.7	7.6	39
June	87	70	19.9	7.0	36
Total	435	370			
Monthly average	54	46	15.3		40

Table 3. Dust deposition rates, April, May, and June, 1964, with distances and directions from a point on the Kansas-Colorado boundary.

Station location	Relation to arbitrary zero		Monthly deposition		
	Miles	Direction	April	May	June
				Lbs./acre[1]	
Tribune	15	E	2,118	3,616	190
Hays	150	E	84	78	70
North Platte	190	NNE		146	109
Manhattan	300	E	101	99	37
McCredie	525	E	48	63	17
Coshocton (S)	1,025	E		21	8
Coshocton (N)	1,025	E		17	10
Marcellus	1,300	E	33	33	58
Marlboro	1,400	E	34	15	18
Sidney	600	NNW			36
Water Valley	460	S	42	24	16
Riesel	540	SSE	52	18	12
Oxford	700	SE			61

[1] Peroxide treated weight.

so, there is a suggestion that deposition rate was related to distance north and east from the arbitrary zero point for each of the 3 months represented except for the two most distant locations, Marcellus, New York, and Marlboro, New Jersey. At these stations the rates were higher than expected, probably reflecting other influences, especially the June rate at Marcellus (1,300 miles).

June rates, when duststorms were not active in the dust bowl, were lower than rates for April or May at all stations except Marcellus and Marlboro.

High deposition rates at Tribune during April and May, compared with more distant locations, indicate a rapid decline with distances. Probably the rate was greater west of this station because sediment at Tribune was dominantly finer than 200 microns in diameter which, according to Chepil (1957), would move in true suspension rather than by saltation. Moreover, the station was surrounded by grassland for 400 feet or more in every direction and neighboring cropland was not blowing.

At Water Valley and Riesel, Texas, deposition rates were highest in April (42 and 52 pounds, respectively), and lowest in June (16 and 12 pounds, respectively. Since blowing in April in western Kansas and eastern Colorado and at Amarillo, Texas (U. S. Weather Bureau, 1964), was dominantly from the west or southwest, no dust movement southward was expected. At Riesel, 6 dusty days were recorded locally in April, the month of maximum deposition.

Rates at Oxford were higher than in Texas (61 pounds for June and 49 pounds for July), possibly reflecting movement from local stream sandbars and cultivated land.

Mineralogical Notes

With the Manhattan samples, quartz in the silt and sand has varied from 99 percent in August 1963 to 20 percent in March 1964 (Table 4). Aggregates ranged from a trace to 78 percent in March 1964, in some cases stained and possibly cemented with iron oxides. Amorphous silica, generally tubular and believed to be of plant origin, was present consistently, up to 10 percent of the silt plus sand in January 1964.

Trace percentages (< 0.1 percent) have been found of feldspars, micas, lamprobolite (oxyhornblende), zircon, hornblende, tourmaline, epidote, magnetite, and ash shards. Some optically amorphous particles tentatively identified as ash shards later were identified as likely plant opal.

X-ray diffraction studies of the oriented slides of Manhattan clay fractions consistently have shown kaolinite (prominent) and illite (less

Table 4. Mineralogy of dust trapped at Manhattan.

	1963					1964					
< 2μ diameter[1]	August	September	October	November	December	January	February	March	April	May	June
Kaolinite	2	1	4	4	4	4	4	3	2	2	4
Illite	3	4	1	2	2	2	2	1	2	1	2
Montmorillonite	0	0	0	0	0	0	0	0	0	0	0
Quartz	1	1	1	0	0	0	1	0	0	1	1
> 2μ diameter[2]											
Quartz, percent	99	98	95	40	40	55	69	20	92	90	92
Plant opal, percent	1			1		10	1	2	4	2	7
Aggregates, percent	T	T	T	57	T	35	30	78	3	5	T
Carbonates, percent	T	2	2	2					T	3	1
Orthoclase		T	T		T	T	T	T	1	T	T
Microcline									T		
Plagioclase		T	T		T	T	T		T		
Hornblende	T	T	T			T			T		T
Lamprobolite	T							T	T		T
Tourmaline				T	T	T					T
Muscovite							T				
Zircon					T		T	T	T		
Biotite					T			T	T	T	T
Epidote		T			T				T	T	T
Magnetite			T								
Glass	T	T		T		T					

[1] Relative abundance of clay minerals by X-ray diffraction is indicated on an increasing scale from 0 to 5.
[2] Particles > 2μ were determined petrographically. T = trace (< 0.1 percent).

prominent) but essentially no 14 Å minerals. Quartz has been indicated in several cases but not as a major constituent of the clay fraction.

Hays samples of silt and sand have ranged from 96 percent quartz in March 1964 to 5 percent in January 1964 (Table 5). Unidentified aggregates have ranged from 95 percent in January to a trace in February to a trace in February and March 1964. Amorphous, generally tubular silica, apparently of plant origin, has ranged from a trace in November to 12 percent in February. Also, this amorphous material appeared to constitute a considerable part of the aggregates dominating January samples. Carbonates amounted to 2 percent in April.

Other minerals and ash shards have been present as traces, including feldspars, lamprobolite (oxyhornblende), hornblende, epidote, zircon, biotite, apatite, and magnetite.

The clay fraction from Hays has been partially amorphous optically and to X-ray, with X-ray indications of illite and kaolinite possibly diluted with X-amorphous materials.

Table 5. Mineralogy of dust trapped at Hays.

	1963		1964					
$< 2\mu$ diameter[1]	November	December	January	February	March	April	May	June
Kaolinite	0	0	2	2	2	1	1	2
Illite	0	0	2	3	1	2	2	2
Montmorillonite	0	0	0	0	1	0	0	1
Quartz	0	0	0	0		0	1	1
$> 2\mu$ diameter[2]								
Quartz, percent	88	85	5	88	96	41	92	89
Plant opal, percent	7	5	T	12	4	46	8	8
Aggregates, percent	5	10	95	T	T	10	1	3
Carbonates, percent				T		2		
Orthoclase		T	T		T			
Microcline				T	T			
Plagioclase	T	T	T		T			
Hornblende	T	T	T	T	T	T	T	T
Lamprobolite	T	T			T	T		
Tourmaline								
Muscovite								
Zircon	T			T	T			
Biotite				T	T	T	T	
Epidote						T		T
Magnetite							T	
Glass	T	T	T	T				
Apatite				T		T		T

[1] Relative abundance of clay minerals by X-ray diffraction is indicated on an increasing scale from 0 to 5.
[2] Particles $> 2\mu$ were determined petrographically. T = trace (< 0.1 percent).

A sample of dust for comparative study was available from the major duststorm, March 18, 1954.[4] The silt and sand fraction (80 percent of the total) contained 87 percent quartz; 3 percent tubular amorphous silica; 10 percent clay aggregates; and traces of oligoclase, muscovite, hornblende, lamprobolite (oryhornblende), epidote, biotite, and calcite. The clay (20 percent) was dominantly illite with a trace of kaolinite; no 14 Å clay was present.

Mineralogical studies indicate that the dust trapped in standard gages at Manhattan and Hays, Kansas, during the first year of this study differs from mineralogy of Kansas loess (Swineford and Frye, 1951) or dust trapped previously during selected duststorm periods (Winchell and Miller, 1918; Alexander, 1934; Warn and Cox, 1951).

Essential absence of montmorillonite, low percentages of feldspars, micas, and other primary minerals, low percentages of carbonates, prominence of amorphous material (at least part of which is plant silica) and consistent presence of kaolinite (especially at Manhattan) are characteristics not anticipated from known mineralogy of loess or from studies of dust deposited during observable duststorms. The presence of green hornblende, lamprobolite (oxyhornblende), and epidote agrees with previous reports regarding loess (Swineford and Frye, 1951; Metz, 1954; Frye, Glass, and Wilman, 1962).

Preliminary work with sediment at Tribune, near the dust bowl, indicates more montmorillonite in the clay fraction and more primary minerals other than quartz in the silt and fine sand than in Manhattan or Hays deposits.

Discussion and Conclusions

The relatively similar rates of deposition for a number of months when the atmosphere appeared free of dust suggests that specific sites, or perhaps regions, may be characterized by a basal rate of influx somewhat comparable to the base flow of streams, providing a lower bound from which increased rates caused by "special" or "unusual" influences may be measured. If some "normal" variation is allowed, the records at Manhattan and Hays might thus be interpreted. The greatest departure from base rates could be considered as "dust floods," occurring in the spring of 1964 when the dust bowl was quite active, with a smaller flood evident during July and August 1963 at Manhattan but not at Hays.

If the basal influx idea is valid, it would be important to establish characteristic measures of quantity and quality by locations to serve as

[4] Provided by Dr. C. P. Walters, Professor of Geology, Kansas State University. Obtained from a carefully cleaned concrete porch floor.

bounds to gage the influence of unusual variables causing important departures or "floods" of dust into the region.[5]

Quantities of influx over long periods are great enough to be of agricultural, historical, and scientific interest. Monthly averages of earth material have been 44 pounds per acre at Manhattan for 13 months and 46 pounds at Hays for 8 months at sites where the soil surface is well covered with grass and local soil blowing is not evident.

Minimum deposition of dust was 20 pounds per acre in June at Manhattan and in January at Hays, both months with no noticeable dust in the air. Maximum monthly deposition occurred during April and May when duststorms were active in western Kansas and eastern Colorado and dust was noticeable in the air throughout eastern Kansas.

Deposition rates at Tribune, a short distance east of the actively blowing region, were much higher than at any other station.

Quality of dust has varied from month to month and among locations. Absence or low percentages of feldspars and micas in the silt and sand, and of 14 Å clays in the $< 2\mu$ fraction have been consistent characteristics of the catch at Manhattan and Hays. Kaolinite has been consistently present in the clay fraction at Manhattan. Considerable amorphous silica has been identified as plant opal in the silt fraction, especially at Hays.

The absence of definite shades of red appears to eliminate the "red beds" region of south-central Kansas and north-central Oklahoma as likely sources of the dust influx.

The pH of rawdust generally has been between 7.0 and 8.5, suggesting essential base saturation of colloids and some free alkaline earth carbonates.

Aggregation, as noted by Handy *et al.* (1960) makes particle sizes difficult to interpret. Dispersion with Calgon has resulted in percentages of clay ($< 2\mu$ diameter) ranging from 16 to 65. Median silt plus sand diameters have been in the silt or fine range between 7 and 30 microns with some particles 100 microns or greater in diameter.

Continuation of the present study over longer intervals, and similar but more intensive gaging to measure selected local influences, may contribute to our understanding of soil genesis, soil renewal, and the origin of loess.

Acknowledgments

Cooperators in the dust trapping network are: Manhattan, R. K. Krauss, K. L. Anderson and C. R. Unruh, Jr.; Hays, W. W. Duitsman

[5] The idea that dust influx may be characterized by a base rate somewhat comparable to the base flow of streams was first suggested to the authors by Dr. V. C. Jamison, Research Soil Scientist, Agricultural Research Service, Columbia, Mo.

and R. G. Handley; McCredie, V. C. Jamison; Marcellus, G. R. Free and C. E. Bay; Riesel, R. W. Baird, A. G. Woltman, and H. D. Berndt; Tribune, T. B. Stinson; Sidney, F. H. Siddoway; Water Valley, J. E. Box, Jr. and George Skeete; Marlboro, G. D. Brill; North Platte, D. E. Smika; Coshocton, L. L. Harrold and R. E. Youker; Oxford, D. A. Parsons and B. R. Carroll; Lethbridge, D. T. Anderson.

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