Analysis of the giant particle component of the atmosphere over an interior desert basin

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ABSTRACT

An investigation of the mineral constituency of the dust component of the atmospheric aerosol over south-central New Mexico, U.S.A., was conducted from November 1964 to August 1965. The 81 atmospheric dust samples, taken near the surface during this period, were analyzed by dispersion staining microscopy to determine the concentrations of quartz, kaolinite, illite, gypsum, and the carbonate family within the "giant particle" range. These data reveal that high gypsum concentrations are rare despite proximity to one of the world's largest exposed surface deposits of gypsum, that kaolinite and illite concentrations rise with cold frontal passage from the east if the suspected source region is not snow-covered or water-soaked, and that there exist seasonal variations in concentrations. Geometric mean particle concentrations for the 81 samples were: quartz, eight per cent; kaolinite, eight per cent; illite, five per cent; gypsum, three per cent; and carbonates, ten per cent. Comments are made relative to the possible influence of oceanic and extraterrestrial particles on the observed concentrations.

Introduction

One of the factors necessary for defining the environment encountered by infrared energy propagating through the earth's atmosphere is knowledge of the mineral content of those airborne particles whose "diameter" is of the same order of magnitude as the wavelength of the incident radiation, i.e., 2.5 to 100 μ. Such particles constitute the giant particle fraction of the atmospheric aerosol. By virtue of low rainfall, scant vegetal cover, and abundant exposed fine soil particles, a number of areas in the south western United States contribute giant particles to the atmosphere.

Preliminary analyses of local dust samples by infrared absorption spectroscopy had confirmed the presence of the minerals quartz, kaolinite, illite, gypsum, microcline, calcite, dolomite, and aragonite and, at the same time, given an indication that the concentrations thereof varied markedly from sample to sample. By utilizing the microscopic technique of dispersion staining, it was possible to quantify these variations in concentration, at least for the giant particle fraction of the atmospheric aerosol.

The purpose of this paper is to describe briefly the major features of the dispersion staining technique, to present the results of the application of this technique to a nine-month series of atmospheric dust samples, and to discuss certain facets of the relationships which are felt to exist among the observed concentrations, the known or suspected source regions, and certain meteorological conditions.

Site, system, and program

The dust sampling site (Fig. 1) is located on the eastern alluvial slope of the Organ Mountains of south-central New Mexico (32°22′45″ N, 106°29′16″ W) at an altitude of 1311 m above Mean Sea Level (MSL). The adjacent mountains to the south through west of the site range up to 2600 m MSL; a 70 km-wide basin to the east averages about 1200 m MSL. The basin proper is one of sparse vegetation and abundant unconsolidated, porous soils which are subject to eolian translocation. The location of the site on

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Fig. 1. Dust sampling site, looking SW.

the grassy slope adjacent to the basin was planned to avoid the masking influence of the basin dust, dust which would tend to mask the presence of particles from without the area. Moreover, the site was remote from the contaminating effects of industrial activity.

Dust from the atmospheric aerosol was sampled by air filtration through membrane filters. The filters were of 0.8 μ pore size and had an effective filtering area of 278 mm^2. The filters were enclosed in a vaned mount (shown to the left of the ladder in Fig. 1), to permit directional sampling, and were located 3.5 m above the ground.

To provide sufficient dust for both the microscopic analysis and subsequent analysis by infrared absorption spectroscopy, a sampling period of 16 to 18 hours was necessary for the particular system employed in this study. The major portion of this period was confined to the sunset to sunrise hours so as to collect the giant particles as they were settling out of the atmosphere. Thus, the samples would be more apt to reflect long distance transport than would samples taken during the daytime when the turbulent exchange of dust from the surface is at a maximum.

Concomitant wind data are obtained from an aerovane located 3.9 m northeast and 0.8 m above the sampling orifice. Flow over the basin area was determined on the basis of surface and/or upper air wind data from nine locations within 160 km of the site.

Investigational procedure

Basically, the procedure to test for a given mineral was to transfer dust from the membrane filter to a glass microscope slide, immerse the dust in a selected fluid, and inspect the slide with a microscope. With the proper choice of fluid and microscope system, those particles of the given mineral which are in the field of view will take on characteristic colors. To determine the concentration of that mineral, the usual procedure was to randomly examine one thousand particles and note the number of particles exhibiting the characteristic colors. This value constitutes the mineral number concentration.[1] The procedure may be repeated for other minerals one desires to identify. Each subsequent mineral determination requires another selective

[1] It must be emphasized that the concentrations are in number of particles of a given mineral per one thousand total particles counted, as opposed to the generally determined number concentration (total number of particles per unit volume) or mass concentration (mass per unit volume).

Table 1. *Selected minerals, test liquids, and optical data*

Mineral or mineral group	Refractive index (NaD line)[a]	Dispersion ($\lambda_F - \lambda_C$)	Test fluid	Refractive index (NaD line)[b]	Dispersion ($\lambda_F - \lambda_C$)[b]
Gypsum	Nx = 1.521 Ny = 1.523 Nz = 1.530	0.0078 (Ny)	Ethylsalicylate	1.525 (14.4 C)	0.0206
Quartz	Ne = 1.553 No = 1.544	0.0081 (Ne) 0.0078 (No)	Ethynylbenzene	1.552 (12.5 C)	0.0338
Illite (A, B, C)	A = 1.588 B = 1.598 C = 1.588		33.3 % N-Ethyl-l-Naphthylamine 66.7 % Ethynylbenzene[c]	1.584	0.0360
Kaolinite	Nx = 1.560 (1.553–1.563) Ny = 1.565 (1.559–1.569) Nz = 1.566 (1.560–1.570)		Salicylaldehyde	1.574 (19.7 C)	0.0315
Carbonates	Calcite No = 1.658 Ne = 1.486 Aragonite Nx = 1.530 Ny = 1.681 Nz = 1.685 Dolomite No = 1.680 No = 1.501	0.0135 (No) 0.0060 (Ne) 0.0128 (Ny) 0.0139 (No) 0.0061 (Ne)	N-Ethyl-l Naphthylamine	1.648 (15.1 C)	0.0404

[a] Data from Winchell (1951) and Bradley & Grim (1961).
[b] Data from the International Critical Tables (1930).
[c] Per cent by volume.

fluid and the counting of an additional 1000 particles from the dust sample.

Dispersion staining is a term used to describe the color effects produced when a transparent object, immersed in a liquid having a refractive index near that of the object, is viewed under a microscope by transmitted white light. To effect the color identification of minerals, various microscope systems have been used. In this investigation, the positive phase contrast microscope system of Crossman (1949) and Schmidt (1955) was employed.

For the best color production, the immersion liquid should have the same refractive index at the sodium D wavelength as the mineral to be identified, but have a dispersion different from that of the mineral. For his phase contrast microscope system, Schmidt (1956) stated that for the appearance of rich colors, it was necessary to have a dispersion ratio of about 2.5 between liquid and mineral. Under these conditions and for positive phase contrast, the particles of the mineral being identified will appear a deep sky-blue with a red-orange halo.

The minerals, their corresponding test liquids, and the respective refractive index and dispersion data are summarized in Table 1. The concentration data, presented in Table 2, were obtained with a Bausch and Lomb phase contrast binocular microscope, Köhler illumination, a 21 × phase contrast objective, and a 10 × eyepiece. It is to be emphasized that the technique was applied to the determination of the mineral composition of only those particles whose diameter exceeded 4 μ.

An experienced microscopist "counted" all of the dust samples, and his repeated counts indicated no significant difference in counts from the same slide or in counts for a given mineral from different slide preparations of the same dust sample. These test counts disclosed that the error in either case was within ± 5 particles per thousand (ppt) for counts up to 50 ppt and ± 10 ppt for counts over 50 ppt. Microcline was counted, but the results are not presented because the random error was greater than the observed concentrations.

Since the selected fluids serve to uniquely identify the given minerals only if no other minerals have similar refractive indices, these "other minerals" could be color identified as the minerals under test. However, such minerals are

Table 2. *Observed mineral concentrations, particles per thousand, for gypsum (G), quartz (Q), illite (I), kaolinite (K), and carbonates (C)*

Dates	Time (MST)	G	Q	I	K	C
November 1964						
4– 5	1530–1000	116	72	44	67	60
17–18	1530–0830	24	100	49	40	60
19–20	1430–0830	29	60	76	72	120
23–24	1530–0900	13	101	78	124	80
24–25	1530–0900	24	98	65	49	120
30– 1	1430–0900	28	118	157	121	200
December 1964						
1– 2	1530–0945	140	51	18	51	20
8– 9	1600–0900	38	95	76	66	200
10–11	1500–0930	24	37	53	44	200
14–15	1500–0900	45	68	81	84	220
15–16	1530–0830	27	71	105	128	140
17–18	1500–0800	44	90	160	291	100
21–22	1600–0800	28	81	40	80	140
23–24	1400–0800	34	105	66	75	180
28–29	1500–0800	46	37	32	40	40
29–30	1500–0800	24	68	47	67	100
30–31	1500–0800	24	88	71	114	80
January 1965						
5– 6	1400–0930	39	157	35	49	120
11–12	1530–1000	24	103	86	100	200
13–14	1500–0900	22	83	75	82	200
18–19	1600–1000	22	108	75	95	80
21–22	1500–0800	12	69	36	60	60
25–26	1500–0830	23	56	43	73	40
28–29	1530–0800	19	101	95	106	200
February 1965						
2– 3	1430–0800	20	56	73	80	120
3– 4	1500–0900	16	125	43	74	180
4– 5	1600–0800	20	67	59	107	80
11–12	1530–0830	9	35	12	20	20
15–16	1600–0830	11	96	106	92	40
16–17	1600–1200	9	75	97	157	140
24–25	1500–0900	29	77	39	65	60
25–26	1500–0730	24	85	75	106	100
March 1965						
4– 5	1530–0800	24	76	54	81	160
16–17	1530–0830	23	102	58	37	200
17–18	1530–0830	33	141	29	48	140
18–19	1530–0800	17	80	137	172	120
22–23	1330–0800	48	67	26	45	100
25–26	1530–0730	31	116	25	55	40
29–30	1530–0900	30	131	81	130	80
30–31	1600–0800	30	122	16	39	80
31– 1	1600–0730	41	90	51	62	80
April 1965						
1– 2	1600–0800	43	88	20	61	40
6– 7	1530–0830	22	82	25	56	60
8– 9	1600–0930	24	100	42	50	100
13–14	1500–0900	26	97	43	70	140
15–16	1530–0900	6	104	68	55	20
19–20	1530–0830	27	110	59	74	60
23–24	1600–0800	21	70	7	38	40
27–28	1500–0730	62	104	34	51	280
28–29	1600–0800	28	60	34	50	80
May 1965						
4– 5	1530–0900	45	90	66	80	240
6– 7	1500–0730	35	97	41	78	60
10–11	1600–0930	58	58	73	89	120
13–14	1430–0800	51	165	68	100	120
17–18	1500–0830	51	149	58	97	80
20–21	1530–0900	34	93	61	89	140
24–25	1500–0830	49	66	38	61	60
27–28	1530–0800	27	120	38	52	40
30–31	1900–0830	59	77	35	44	20
June 1965						
3– 4	1530–0800	11	33	22	52	40
7– 8	1530–0830	19	41	51	39	80
10–11	1600–0900	12	41	27	42	40
14–15	1530–0830	25	46	31	57	40
15–16	1530–0800	25	43	9	34	60
17–18	1530–0800	32	68	82	121	20
22–23	1600–0800	32	34	23	47	40
24–25	1530–1030	42	44	30	84	40
28–29	1500–0830	40	43	44	102	20
July 1965						
6– 7	1500–0800	30	23	23	49	40
8– 9	1600–0830	40	24	33	118	60
13–14	1600–0830	51	72	38	84	140
14–15	1500–0830	74	115	30	110	20
15–16	1600–0830	43	130	60	113	80
19–20	1500–0800	56	92	30	96	100
29–30	1500–0800	42	120	22	44	20
30–31	1600–0700	31	126	23	64	60
August 1965						
3– 4	1600–0900	34	101	15	46	40
5– 6	1600–0830	31	56	34	87	120
6– 7	1530–1200	17	83	32	89	120
9–10	1530–0830	123	28	16	34	80
11–12	1600–0900	22	75	31	41	240

apparently not common in the local atmospheric aerosol and so are neglected as being significant contributors to the observed concentrations.

Special mention needs to be made of the carbonate concentrations. As may be noted in Table 1, calcite, dolomite, and aragonite (members of the carbonate family) exhibit a wide range of indices of refraction. This would seem

to vitiate a refractive index fluid such that all particles of a given carbonate would exhibit the blue coloration with the red-orange halo regardless of orientation. N-ethyl-1-naphthylamine is a fluid whose refractive index is near the omega index of calcite (1.648). This fluid will exclude hornblende and biotite from the count, but it presents a problem because the omega index is not present in all possible orientations of the calcite particles on the microscope slide. By taking a sample of pure calcite particles, immersing them in the N-ethyl-1-naphthylamine, noting the number of particles out of one thousand total particles counted that yielded the characteristic colors, and repeating the process ten times, it was possible to arrive at a correction factor. Out of 10,000 total particles of pure calcite, 500 particles were color identified as calcite, thus giving a correction factor of 20. Hence, in the dust samples, the number of color identified calcite particles was multiplied by 20 to obtain an estimated total count. Although specifically designed for calcite, which is considered to be more common in the atmospheric aerosol over this area than either aragonite or dolomite, this test also suffices for dolomite and aragonite and thus the term carbonates has been used in lieu of calcite. By rotating the stage under polarized light, or vice versa, and by noting if the characteristic colors appear four times in 360 degrees of rotation, isotropic and weakly birefringent anisotropic minerals may be eliminated from the count.

Because of the generally arid conditions prevailing over the sampler, it generally suffices to scrape dust from the membrane filter onto a microscope slide with a sterile needle. If the amount of the sample is small and/or imbedded in the web of the filter, a procedure developed by Dennis (1961) may be used to dissolve the filter and let the dust settle on the slide.

Meteorological interpretations

By way of summary, the data of Table 1 are graphically illustrated in Figs. 2 and 3. Fig. 2 indicates some seasonal dependence of the mineral particle concentrations. Fig. 3, in addition to showing the frequency of occurrence of various mineral particle concentrations, shows the wide range in concentration which has been observed.

Certain aspects of the data of Table 1 are deserving of meteorological interpretation. Cases of high gypsum concentration, cases of high kaolinite concentration, and specific features of the composite concentration fall in this category.

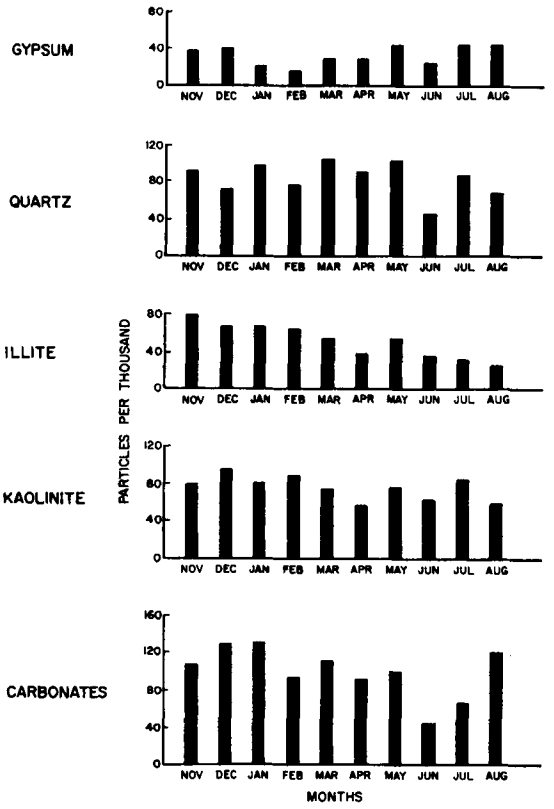

Fig. 2. Monthly mean mineral particle concentration, November 1964 to August 1965 (81 total samples).

Gypsum

Three cases of high gypsum concentration are discussed as examples of three diverse manners of atmospheric gypsum transport from a highly localized interior basin source to a sampler less than 50 km to southwest.

The primary surface deposit of gypsum in southern New Mexico is the 1250 km² which encompass the Lake Lucero–Alkali Flats–White Sands area located 35 to 75 km north-northeast of the sampler. Southwesterly winds have scoured the gypsum particles from Lake Lucero and the Alkali Flats and deposited

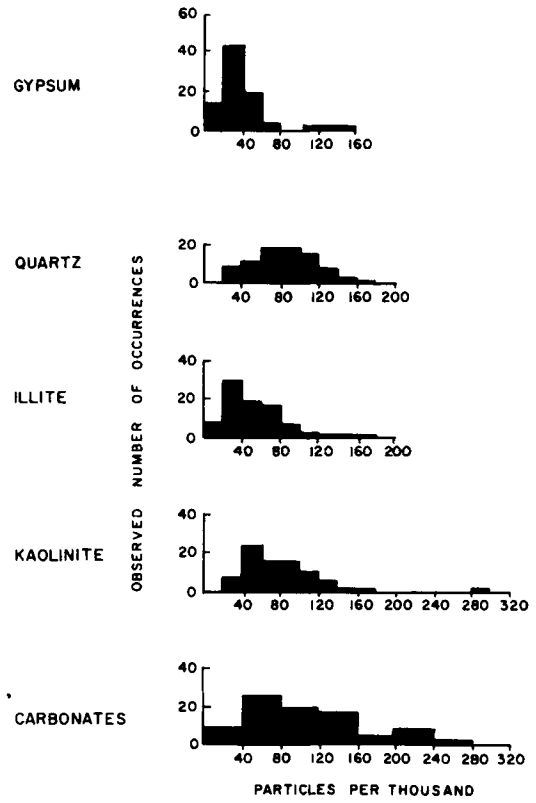

Fig. 3. Number occurrence of mineral particle concentrations, November 1964 to August 1965 (81 total samples).

them in the gypsum dunes of the White Sands National Monument to the northeast.

The primary source of airborne gypsum in this area is felt to be Lake Lucero, which is normally dry, and the southern portion of the Alkali Flats which lie adjacent to, but north of, Lake Lucero. Within this region the water table is generally within a meter of the ground surface. The saline water ascends to the surface by capillary action, evaporates, and leaves an alkali crust consisting of small crystals of gypsum, resultant anhydrous powders, and other soluble salts. Rains are infrequent, evaporation is high, and thus the area acts as a rather constant source of gypsum particles.

At the sampler, concentrations of gypsum are generally quite low (Fig. 3) because the atmospheric circulation is rarely such that gypsum would be transported from the source region southwest to the sampler. However, on occasion the gypsum concentration does reach a relatively high level, such as on November 4–5, 1964, December 1–2, 1964, and August 9–10, 1965.

November 4–5, 1964

Analysis of data on wind speed and direction at the sampler during the period of sampling afforded some indication that the gypsum count would be high. The surface winds were northeasterly from 1500 MST to 1700 MST on the 4th, but at 1700 MST, the wind veered to southwesterly and became light and variable after 2100 MST.

The general circulation is represented in Fig. 4 by the 500 mb height contour and surface charts at the start and midway through the sampling period, respectively. The dominant feature of the 500 mb flow over the area is an eastward-moving, closed low centered over the southeast corner of New Mexico. Over the basin, the northeast flow aloft extended downward from 500 mb to within 1 km of the surface. Thus, by virtue of the northeast winds aloft, the gypsum could be transported to the sampler if the dust could be entrained into the atmosphere from the source region. A mechanism for accomplishing this was available and is illustrated in Fig. 5. For at least 30 hours prior to 1900 MST, November 4, the basin winds near the surface were northerly at speeds up to 14 m/sec. This would allow obstacle lee deposition of fine particles which were then suddenly exposed by the abrupt shift of the surface wind across the basin to a southerly direction at speeds up to 11 m/sec. The basin surface flow remained southerly until midnight, after which time the surface winds at all basin sites became light and variable.

Thus, the picture is one of southerly winds across the source region of gypsum, after a prolonged period of northerly flow, picking up exposed gypsum particles which are then transported to the sampler by the northeast winds aloft.

December 1–2, 1964

The highest gypsum concentration of the 81 samples was observed in this sample. At the sampler, winds were westerly at mean hourly speeds ranging from 8 to 12 m/sec with gusts to 20 m/sec, a condition not, at first glance, likely to foster the record gypsum concentration.

The synoptic weather pattern associated with this sample is shown in Fig. 6. Aloft, an east-

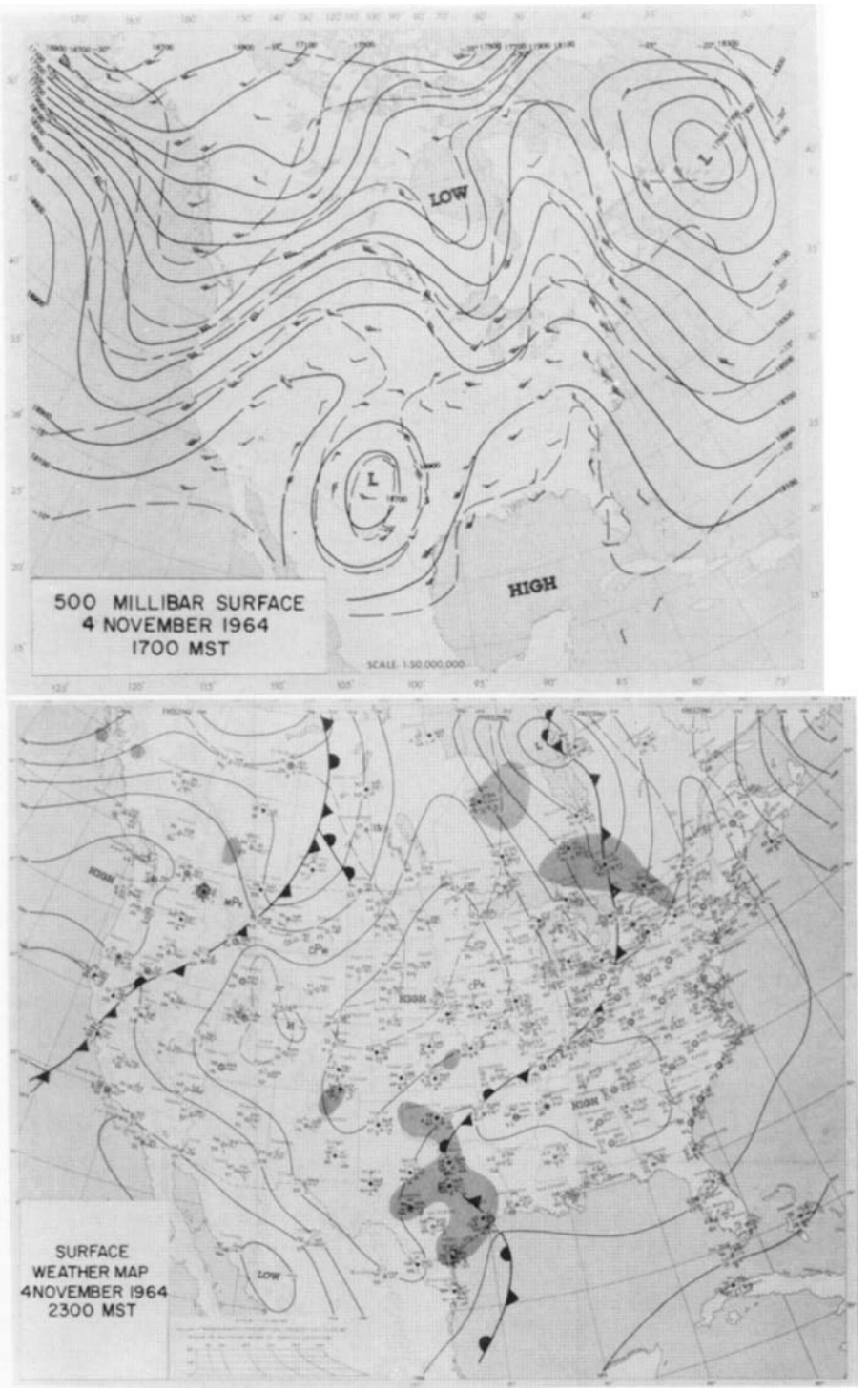

Fig. 4. Synoptic weather pattern associated with dust sample of November 4–5, 1964.

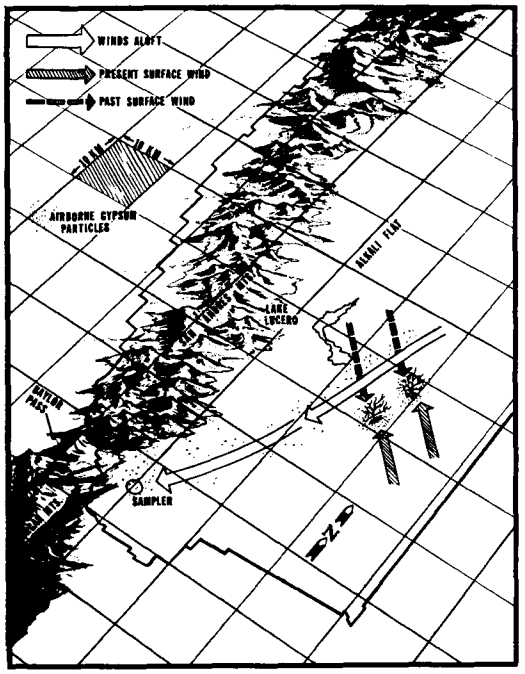

Fig. 5. Schematic illustration of gypsum transport, November 4–5, 1964.

ward-moving trough had passed over the basin by the start of the sampling period. At the surface, a low pressure system was centered over the Texas–Oklahoma Panhandle. This situation, coupled with the low gypsum concentration of the previous day, made it difficult to account for the transport of gypsum particles from the source region southwest to the sampler.

The flow over the basin was complex, but did resolve itself into a pattern which is illustrated in Fig. 7. The airborne dust generating mechanism is assumed to have been a mountain wave, which had been signatured by wave clouds earlier on the day of the 1st and which resulted from the moderate westerly flow normal to the ridge line. The gypsum source region has been observed by Lamberth, Reynolds & Wurtele (1965) to lie under the first wave trough east of the San Andres Mountains. Analysis of relevant meteorological data revealed a mountain wave blasting gypsum particles from the surface and thrusting a portion of them back toward the west into a channel bounded by the Organ–San Andres Mountains to the west and the mountain wave overhead. The gypsum particles were then transported toward the sampler in this duct as a result of the local surface low circulation generated by the mountain wave and perhaps supplemented by drainage winds. As the duct flow approached the sampler, the gypsum particles were entrained into the rapidly moving westerly flow through Baylor Pass (2000 m MSL, 8 km west of the sampler). The persistence of the mountain wave plus high gypsum concentration within the duct could account for the high concentration at the sampler despite the slow southerly transport within the duct.

August 9–10, 1965

The last example of high gypsum concentration is one engendered by thunderstorm activity. The associated synoptic pattern is revealed in Fig. 8, which shows that the western third of the United States was dominated by a slowly northeastwardly expanding ridge of high pressure. The surface weather map at 2300 MST revealed weak pressure gradients over the Southwest.

Analysis of the surface wind data for the basin showed that during the afternoon of the 9th the winds were easterly to southerly at speeds of 3 to 5 m/sec with gusts to 15 m/sec. By late afternoon, thunderstorm activity had developed over the White Sands National Monument area. In response, the surface wind switched to the north and northeast around sunset with mean hourly speeds of 10 to 13 m/sec at all basin wind sites. Gusts in excess of 20 m/sec were reported from sites along the southern fringes of the National Monument. The high wind speeds, coupled with the angle of attack of the thunderstorm downdrafts, provided efficient scourers of gypsum particles from the source region.

At the sampler, winds were out of the east until 1900 MST, at which time the winds shifted to north-northeasterly at speeds up to 15 m/sec. From 2100 MST until sunrise, winds were light westerly due to local drainage off of the Organ Mountains.

Over the basin, however, winds remained northerly to north-easterly all night following the initial surge of northeasterly flow. This, coupled with the light northeasterly to southeasterly winds aloft, could account for the observed high gypsum concentration. The mechanism is schematically represented in Fig. 9.

The foregoing three examples serve to illustrate that, because of the divers nature of local winds and because of the highly localized source of gypsum, high gypsum concentrations at the

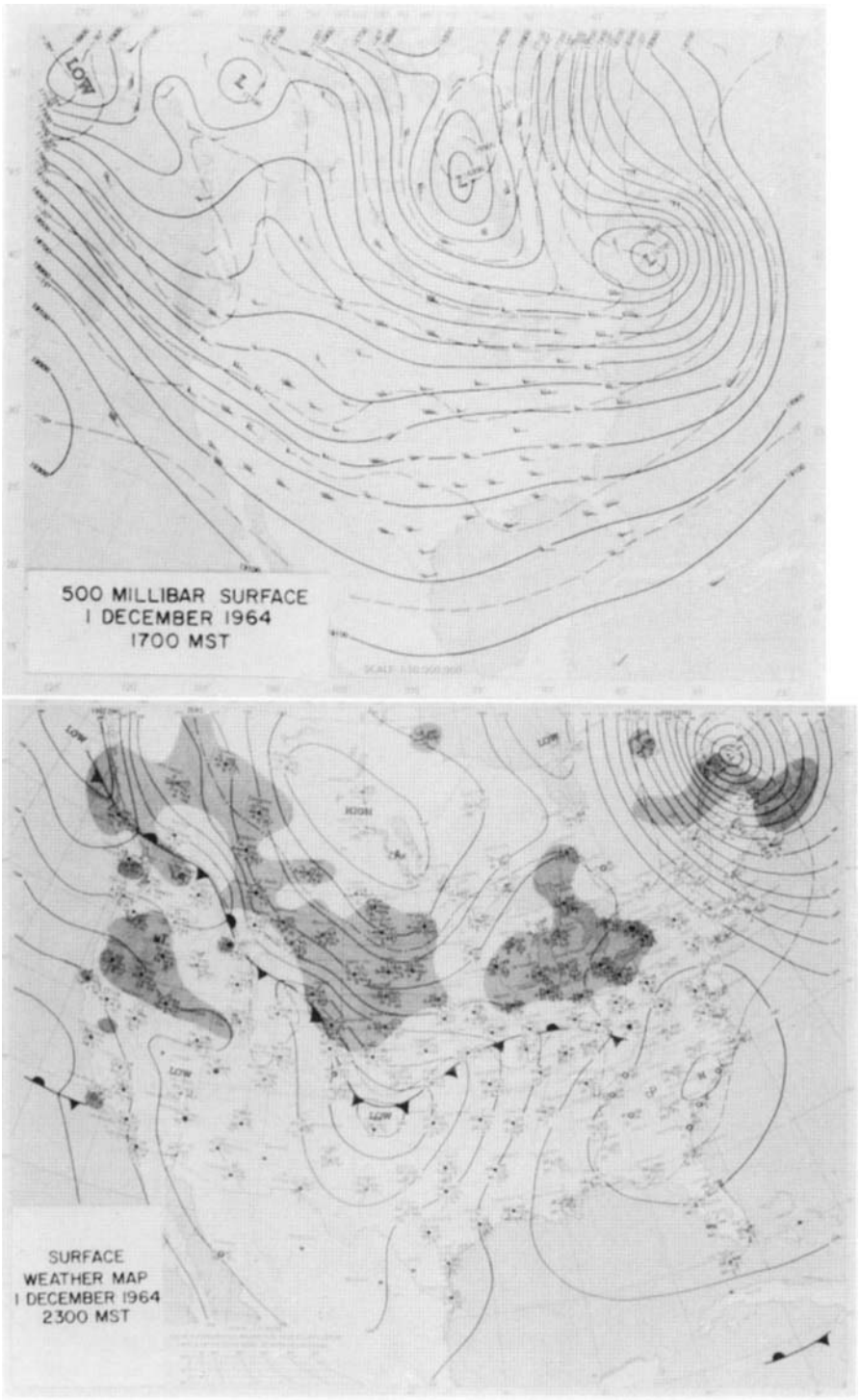

Fig. 6. Synoptic weather pattern associated with dust sample of December 1–2, 1964.

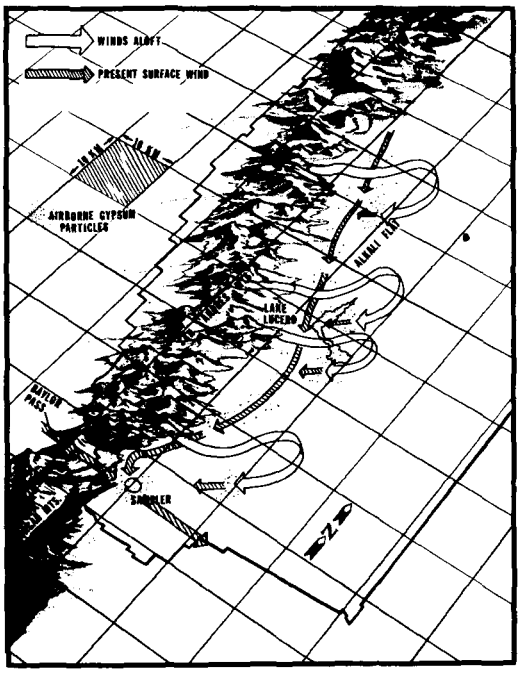

Fig. 7. Schematic illustration of gypsum transport, December 1–2, 1964.

sampler are not a function solely of the surface wind at the sampler. The circulation over the entire basin must be considered.

Kaolinite

Kaolinite, though not a major constituent of the area soils, is relatively common in the local atmospheric aerosol. At times the concentration rises to high levels such as in the samples of December 17–18, 1964 and February 16–17, 1965. In contrast to gypsum, however, the meteorological conditions under which they occurred were remarkable for their similarity.

December 17–18, 1964

The highest concentration of kaolinite in any of the 81 samples, 291 particles per thousand, was observed in this sample. The associated synoptic pattern, depicted in Fig. 10, shows a surface cold front associated with a mass of frigid air centered over eastern Kansas. Late in the afternoon of the 17th, this front passed over the basin accompanied by southerly to southeasterly surface winds. At the sampler, winds switched to the southeast shortly before midnight and remained light southeasterly to calm for the remainder of the sampling period. Winds aloft backed from northwesterly to southeasterly as the cold high moved in.

It is suggested that the high kaolinite concentration was due to the entrainment of kaolinite particles into the Arctic air mass as it swept across the exposed soils of the western Great Plains. It was then this kaolinite-laden sector of the anticyclone which was sampled.

February 16–17, 1965

Again a high concentration of kaolinite may be related to the passage of a cold front from the east, though this may not be evident from the synoptic maps of Fig. 11. However, analysis of available weather data from the several sites across the basin revealed that a cold front had passed across the basin from the east early on the morning of the 16th, too late to markedly raise the kaolinite concentration in that sample. The influx of kaolinite particles persisted as the air mass continued to advect across the basin on the heels of the northeasterly flow aloft. Once again, winds at the sampler did not help to clarify the picture; they were light and variable from 0200 MST on the 16th through 1000 MST on the 17th. During the sampling period, winds across the basin floor were light to moderate northerly through easterly in contrast to the southeasterly flow of December 17–18.

Thus, this case is similar to that of December 17 in that the kaolinite concentration rose with cold front passage from the east, the kaolinite probably once again originating from the exposed lands of the western Great Plains.

High concentrations of kaolinite also occurred in the samples of November 30–December 1, 1964, March 18–19, 1965, March 29–30, 1965 and June 17–18, 1965 and were likewise dependent on cold front passage from the east. In all six cases, the ground was relatively dry from the Panhandle of Oklahoma and Texas southwest across southeastern New Mexico, with only light amounts of precipitation reported during the two to three day period preceding the passage of the cold front at the sampler. Moreover, there was virtually no snow cover over the ground of these areas during this same period.

Evidence that this western Great Plains region may have been the source for the kaolinite is provided by the sample of April 27–28, 1965, when the kaolinite concentration following cold

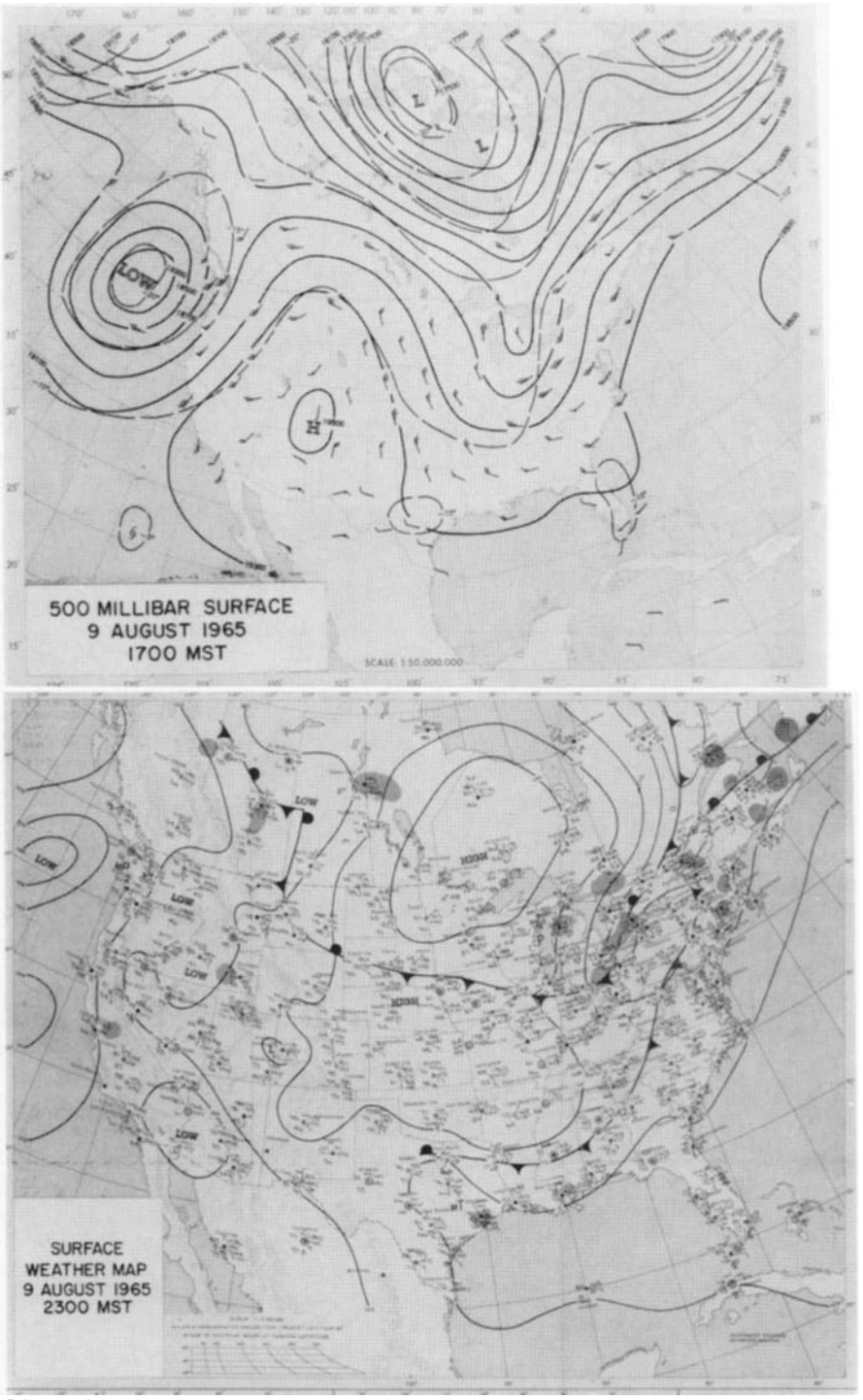

Fig. 8. Synoptic weather pattern associated with dust sample of August 9–10, 1965.

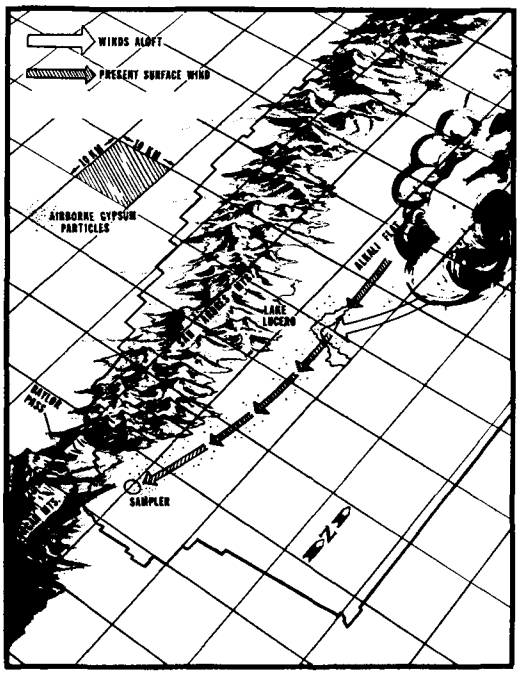

Fig. 9. Schematic illustration of gypsum transport, August 9–10, 1965.

front passage from the east reached only 51 particles per thousand. In this case, moderate rains had soaked the Panhandle area and southeastern New Mexico during the day of the 26th. Resultant particle agglomeration and soil saturation would have prevented wind erosion of the clay fraction of the soil.

Illite

The concentration trend for illite is similar to that of kaolinite. High illite concentrations are also associated with cold front passage from the east again dependent on the susceptibility of the source region soils to eolian translocation.

General features

The giant particle component of the atmospheric aerosol may consist of eolian dust from the land surface of the earth, oceanic salts, cosmic dust, volcanic dust, dusts of natural combustion, and industrial dust. With regard to the samples analyzed in this investigation, the atmospheric aerosol is composed of an identified fraction and an unidentified fraction. The former consists of quartz, gypsum, kaolinite, illite and carbonates, all of which are considered to be eolian dust from the land surface of the earth. These few minerals certainly do not comprise all of the eolian land dust minerals, but if they do comprise a significant fraction of this particular component, then by summing the individual concentrations one might be able to draw conclusions in regard to the unidentified portion of the giant particle component of the local atmospheric aerosol.

Seasonal variations in the concentration of the individual minerals are revealed in Fig. 12, where the data have been smoothed over 11 samples.[1] To analyze the unidentified fraction of the giant particles, these five curves have been added as shown in Fig. 13. In this mode of representation, the identified particles constitute the area under the curve, the unidentified particles the area above the curve. Thus, minima in the curve represent relative influxes of unidentified particles which could stem from any of the sources mentioned above, the two most likely being oceanic and extraterrestrial influences.

Oceanic influence

The two prime sources for oceanic particles over this area might be the Gulf of Mexico to the southeast and the Pacific Ocean to the southwest. Both sources are equidistant from the sampler, the Pacific Ocean being 1000 km to the southwest and the Gulf of Mexico 1000 km to the southeast. Incursions of sea-salt nuclei over inland areas have certainly not gone unnoticed, as evidenced by the work of Fournier d'Albe (1957) and Sekhon & Ramana Murty (1965) in India, Twomey (1955) in Australia, Bulinskaya & Zhavoronkina (1958) in the USSR, and Crozier, Seely & Wheeler (1952), Byers, Sievers & Tufts (1957), Junge & Gustafson (1957), and Reitan & Braham (1954) in the United States.

If the unidentified fraction were to be composed of particles having an oceanic origin, then high composite concentrations, i.e., December 1964 (Fig. 13), might imply a predominance of continental air over the sampler and a low composite concentration, i.e., June 1965, a predominance of maritime air.

Examination of the 700 mb and surface weather charts for the western United States, nor-

[1] Several types of smoothing, i.e., running-mean and binomial over various time and sample intervals, were used, but all revealed the same general features which will be discussed.

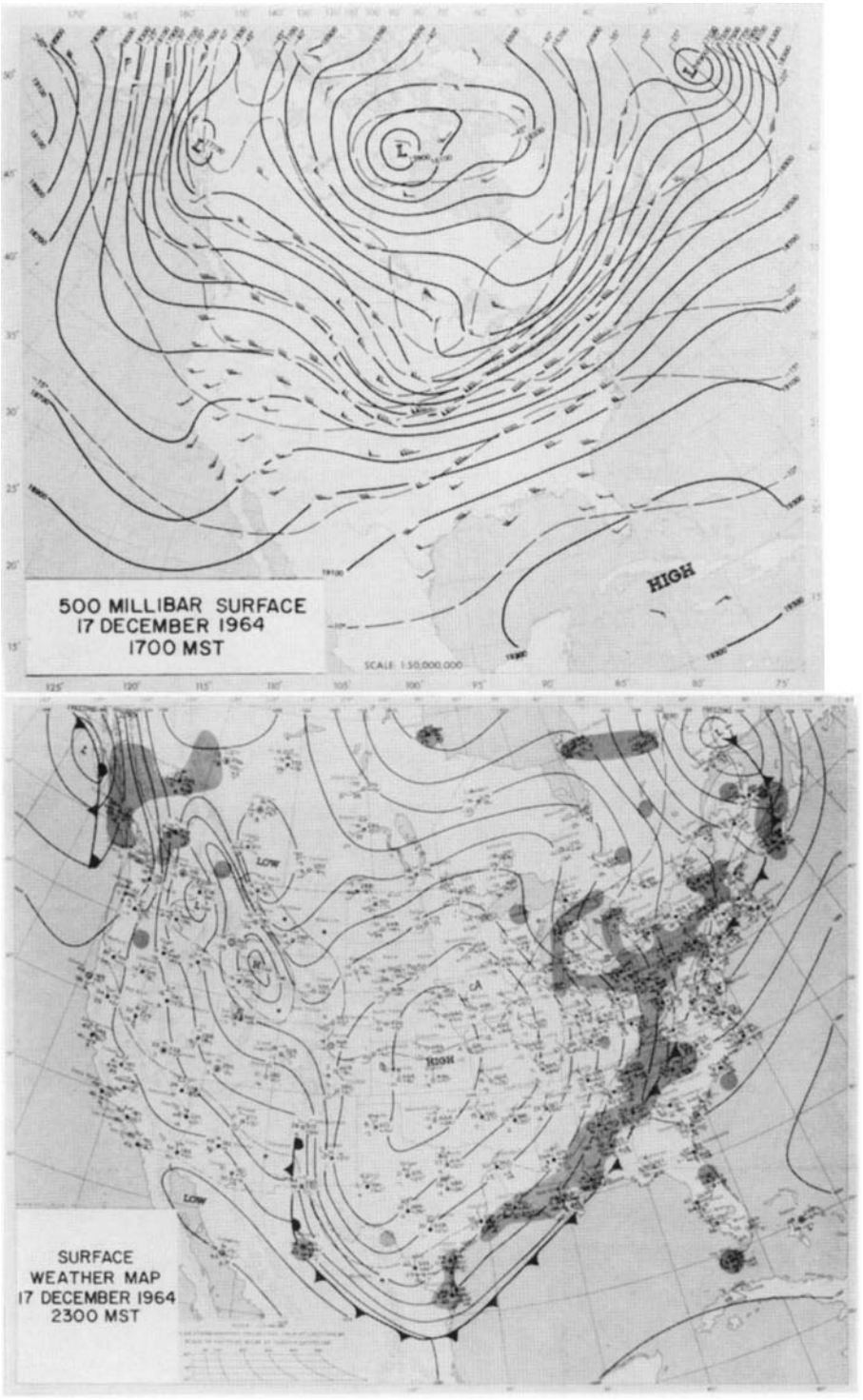

Fig. 10. Synoptic weather pattern associated with dust sample of December 17–18, 1964.

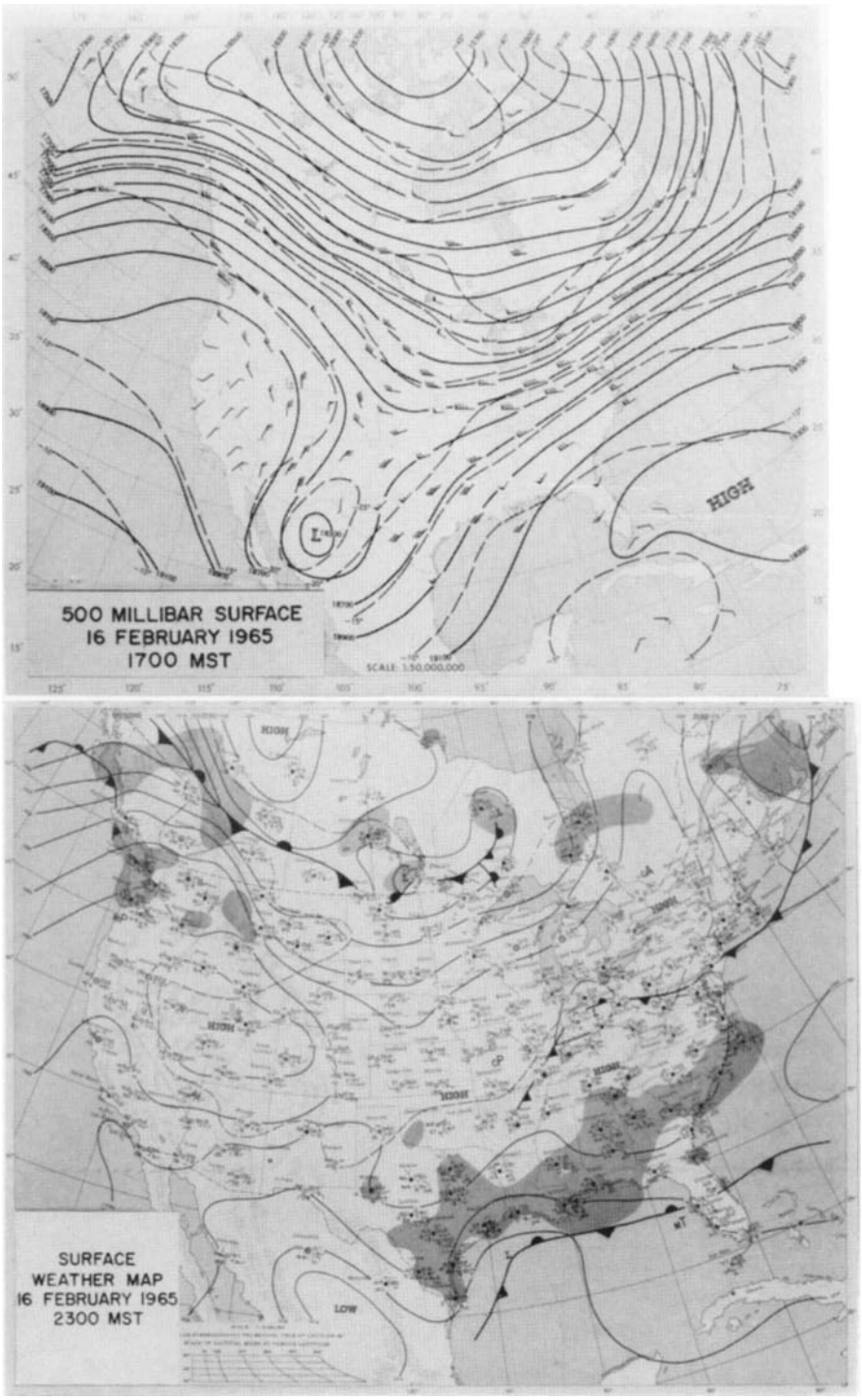

Fig. 11. Synoptic weather pattern associated with dust sample of February 16–17, 1965.

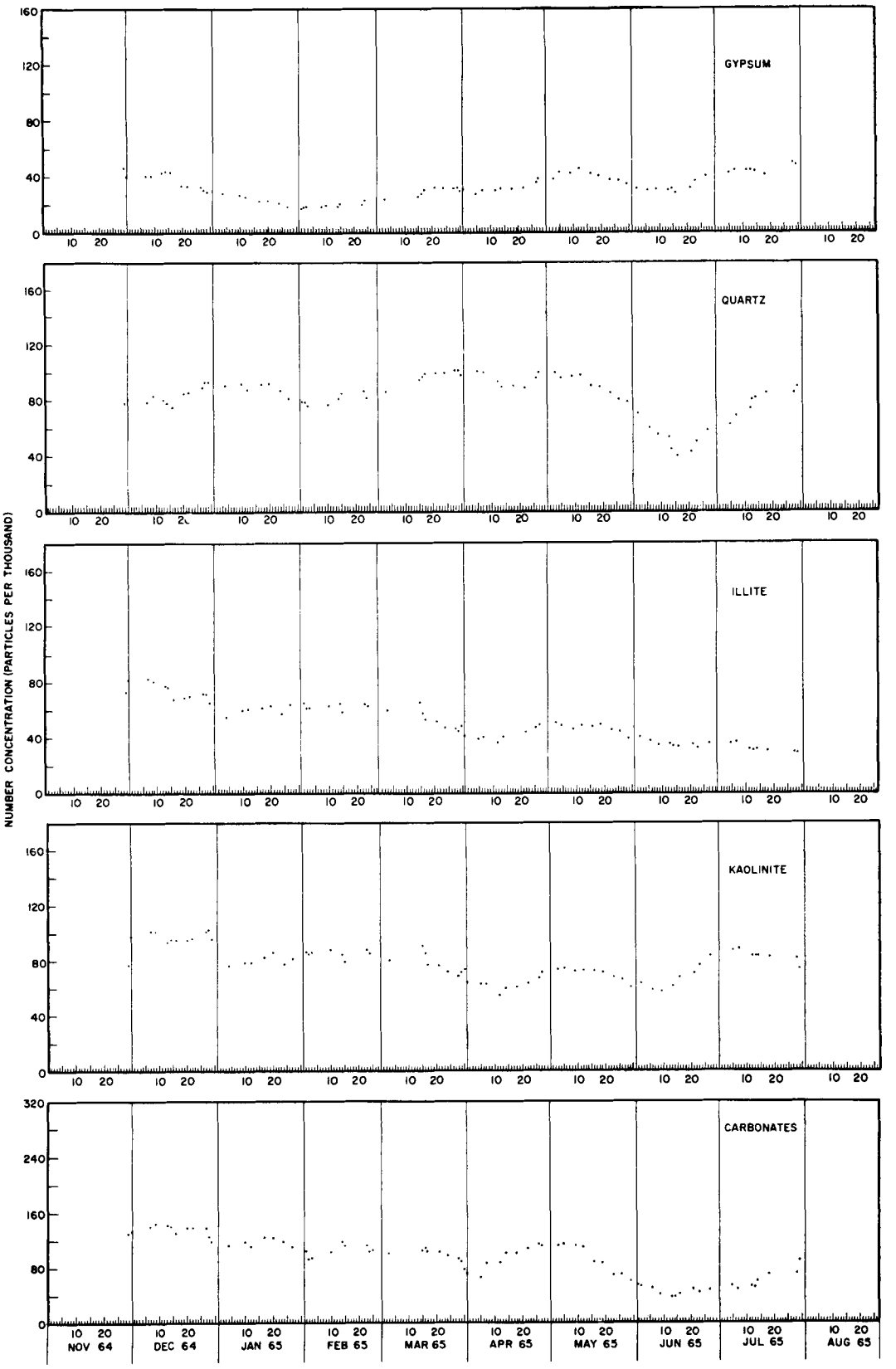

Fig. 12. Eleven-sample running-mean mineral particle concentrations, November 1964 to August 1965.

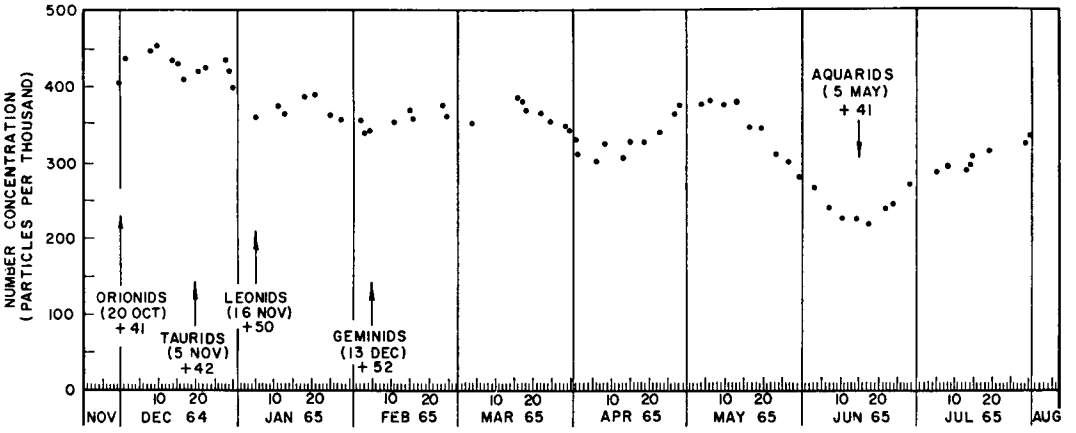

Fig. 13. Eleven-sample running-mean of the summed mineral particle concentrations, November 1964 to August 1965.

thern Mexico and the adjacent Gulf of Mexico and Pacific Ocean areas revealed that many of the features of Fig. 13 could be related to incursions of maritime or continental air over the sampler. For example, during the high concentrations of December a ridge over the southwestern United States blocked the inland penetration of maritime air from the west until the last week of the month when a trough moved over the West Coast and adjacent Pacific Ocean. During mid-January the blocking ridge was reestablished and the composite concentration was observed to increase. Similar relations were observed through February, March, and April.

During May a 700 mb trough developed over the Southwest, a trough which was to persist through June although its intensity was gradually diminishing as the Bermuda high began to encroach over the basin from the east. Thus the persistent albeit diminishing southwesterly winds over the area through mid-June could have resulted in oceanic particles from the Pacific Ocean gradually reducing the concentration from early May to the mid-June nadir. However, instead of the concentration continuing to decrease as air from the Gulf of Mexico first penetrated the basin along the western edge of the Bermuda high about mid-June, the concentration began to increase and continued to rise as the summer progressed. This may be attributable to the contemporaneous onset of the thunderstorm season in mid-June over the basin. As shown by Elser (1959) and Warn (1952) the thunderstorm provides a mechanism for thrusting land surface dust into the atmosphere. This dust could increase the identified fraction even though maritime air dominated the area. Moreover, rains between the Gulf of Mexico and the sampler would leach out a portion of the hygroscopic salts.

Extraterrestrial influence

Extraterrestrial dust, not consisting of quartz, gypsum, kaolinite, illite, or carbonates, could contribute to the unidentified fraction. If a sufficient amount of this dust were to penetrate the earth's atmosphere to the sampler, then the observed concentrations would be reduced.

Fig. 13 also illustrates the possible effect of meteor showers on the observed concentrations. Meteor showers which could have influenced the observed data were: Orionids, October 20, 1964; Taurids, November 5, 1964; Leonids, November 16, 1964; Geminids, December 13, 1964; and Aquarids, May 5, 1965. The positive numbers beneath the dates of the showers are the approximate number of days after the dates of the showers that minima were observed. This is in excellent agreement with the data of Link (cited by Junge (1957)) on the fall time of meteoritic dust for spherical particles, 4 to 5 μ in diameter, of both the metal and stone types.

The extraterrestrial dust which reaches the surface of the earth consists of spherule and angular particles. According to Öpik (cited by Junge (1957)) the dominant fraction of these

particles with diameters less than 20 μ is angular. These angular particles are difficult to distinguish from the terrestrial component and so cannot be ruled out as a contributing factor to the observed concentrations. However, spherule particles were probably negligible because out of 450,000 particles examined, only one could possibly have been properly classed as a spherule.

Meteor showers impinge on the earth's atmosphere at much higher geocentric velocities than do the interplanetary dust particles, thereby lowering substantially the upper limit of the diameter of particles surviving the fall through the atmosphere. Also, only for the more dense showers will the number concentrations of meteoritic material exceed that in the dust envelope.

According to Mason (1962), kaolinite, aragonite, and illite have yet to be observed in meteorites. Calcite has been recorded only once in meteorites; dolomite has been reported as an accessory mineral in certain carbonaceous chondrites; gypsum was found in a carbonaceous chondrite, but may have been contamination; and quartz has been identified in small amounts in calcium-rich achondrites. Therefore, it seems likely that no extraterrestrial particles were identified as gypsum, quartz, kaolinite, illite or carbonates. As noted, however, they may have been present in the sample and thus served to reduce the individual concentrations.

As reported by Mason (1962), the maximum incidence of meteorite falls occurs during May and June. This might imply that during May and June the earth crosses a region in space that contains a higher density of meteoroids. This, in turn, might enhance the probability of extraterrestrial dust reaching the surface of the earth, which would lower the observed composite concentration. It is interesting to note that the lowest composite concentrations did occur during June.

Is this extraterrestrial dust in sufficient mass concentration to affect our observed mineral concentrations? Pettersson (1960), on the basis of data from Mauna Loa, Hawaii, estimates that the cosmic dust content of 100 m^3 of air is 0.6 mg, or 0.6 $\mu g/m^3$, which would be of sufficient magnitude to affect the observed concentrations, especially if this mass concentration were to be enhanced during times of meteor showers or meteorite falls.

Conclusion

The technique of dispersion staining microscopy as applied to the quantitative analysis of the mineral constituency of the giant particle fraction of the atmospheric aerosol is quick and reliable. Only small samples, which can be collected in minutes if necessary, are required.

Dispersion staining microscopy is not applicable to the identification of Aitken and large particles because of the limit of resolution of the light microscope and because of the state-of-the-art limitation of dispersion staining to particles of a diameter greater than 0.8 μ, but it is well suited to a quantitative analysis of local giant particles.

From the analysis of dust samples taken under a wide range of meteorological conditions, but not solely duststorms, it has been possible to draw the following conclusions in regard to the giant particle component of the local atmospheric aerosol. Wide sample-to-sample variations exist in the concentrations of quartz, gypsum, kaolinite, illite, and carbonates. In certain cases it has been possible to relate high concentrations to specific meteorological conditions. Gypsum, because of the highly localized source, and the location of the source with respect to mountain waves over the San Andres Mountains is a potential natural tracer for mountain waves and their resultant local circulations. The primary source of the kaolinite in the samples appears to lie to the east of this area as inferred from the fact that kaolinite is not a common constituent in the basin soils and that the kaolinite concentration increases with frontal passage from the east when the suspected source region is not water-soaked or snow-covered. The frontal system may not have been carried on the surface weather maps, so complete reliance on the surface weather map for forecasting high kaolinite concentrations for this area is not advised. Quartz is a ubiquitously common constituent of soils in the Southwest, but the observed concentrations are not as high as one might expect.

Analysis of the composite concentration affords an insight into the source regions for the unidentified fraction of the samples. The evidence supporting an oceanic or extraterrestrial source for the dust comprising the unidentified fraction, while not conclusive, is noteworthy.

In explaining the observed concentrations of the various minerals from samples taken at the

particular site selected for this investigation, it was necessary to consider not only the wind speed and direction at the sampler, but also the flow within a radius of at least 1000 km of the sampler. Knowledge of the mineral content of area soils, the mechanisms by which nature can thrust particles into the atmosphere, and cognizance of possible influxes of unidentified particles help to clarify certain problems.

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АНАЛИЗ ФРАКЦИИ ГИГАНТСКИХ ЧАСТИЦ В АТМОСФЕРЕ НАД ПУСТЫНЕЙ

В период с ноября 1964 г. по август 1965 г. над центрально-южной частью Нью-Мексико, США, было проведено исследование минерального состава пылевой компоненты атмосферного аэрозоля. Под микроскопом была проанализирована 81 проба атмосферной пыли, взятой вблизи поверхности в течение названного периода для определения концентраций кварца, каолинита, иллита и группы карбонатов. Результаты анализа показывают, что высокие концентрации гипса встречаются редко несмотря на близость одной из самых больших в мире открытых залежей гипса, что концентрации каолинита и иллита возрастают с прохождением с востока холодного фронта, если только подозреваемая в качестве источника область не покрыта снегом или не размокла от дождей, и что существуют сезонные вариации в значениях концентраций. Средние (по размерам) значения концентраций частиц для 81 пробы были следующими: кварц — 8%, каолинит — 8%, иллит — 5%, гипс — 3%, карбонаты — 10%. Обсуждается возможное влияние частиц океанического и внеземного происхождения на наблюдаемые значения концентраций.