

# The Dustfall of March, 1918\*

## Conclusions as to the Possibilities of the Wind as a Geologic Agent

By A. N. Winchell and E. R. Miller

SOME of the snow which fell at Madison, Wisconsin, on March 9, 1918, contained sufficient foreign material to change its color from white to a light brown or yellow. It was observed under conditions which permitted a close study and the collection of some evidence and data regarding the material. It is the object of this note to put these data on record, and to discuss the quantity, nature, and probable source of the coloring matter.

The colored snow came down at Madison in the form of moist snow mixed with sleet, during the passage of an unusually intense and fast moving cyclonic disturbance. It fell from 11:30 A. M. to 2:30 P. M., 90th meridian time, but the proportion of coloring matter is believed to have been greater toward the end than at the beginning. The moist snow and sleet were preceded by rain, from 9:30 A. M. to 11:30 A. M., which froze as it fell, and remained as a sheet of ice about 5/8 inch thick on trees, wires, etc. The moist snow and sleet were followed by dry snow from 2:30 P. M. to 9:30 P. M. Neither the ice nor the dry snow contained an appreciable amount of coloring matter.

At the time of the storm the snow and sleet were observed to have a light reddish brown color, not only by the Weather Bureau observers, but also by others, some of whom called upon the Weather Bureau office for an explanation of the "dirty snow" while it was yet falling. The discoloration was still more easily seen after the pure white dry snow had begun falling and drifting into the depressions in the darker layer. On the second day following, when the snow began melting the dust was left on top of the snow.

**Area of fall.**—The evidence obtained as to the area covered by the dusty snow fall is admittedly incomplete and inconclusive. Inquiries were sent immediately after the fall to a number of Weather Bureau officials in cities. The replies from most of these indicated that the contamination of the snow by city smoke, dust, and ashes had precluded any possibility of recognizing the colored snow. Inquiries were then sent to co-operative observers of the Weather Bureau in places remote from cities, from Wisconsin, eastward to Maine. The snow unfortunately had disappeared at many of these places by the time of the receipt of the inquiry, and only one-third of those to whom the inquiry was sent had noticed the phenomenon. All told, positive reports were received from Dubuque, Ia., Grand Haven, Mich., Portage, Wis., Hancock, Wis., Montello, Wis., Florence, Wis., Newberry, in upper Michigan, and Chelsea, Vt. The location of these points, where dust was observed, is indicated by dots on the outline map (Fig. 1).

**Nature of the coloring matter.**—A microscopic study of the coloring matter separated from the melted snow shows that it consists chiefly of inorganic substances, but contains also some plant tissue. All of the material forms a dust when dry and contains feldspar, quartz, opal, limonite, hematite, hornblende calcite, mica, magnetite, apatite, tourmaline, zircon. There is also some cloud-like material which may be kaolin. From Rosiwal measurements<sup>1</sup> the proportion of the chief constituents has been estimated to be: feldspar and quartz 65 to 75 per cent.; amorphous material, including limonite, hematite, kaolin, opal, etc. 20 to 30 per cent.

The feldspar fragments are remarkable on account of the fact that they show no alteration whatever; they are as glassy clear as is the quartz. Both the quartz and feldspar are stained by limonite and hematite, and this condition seems to pervade the fragments so thoroughly as to indicate that it is a condition of long standing. The feldspar shows no twinning and much

of it is probably orthoclase, but other feldspars are not excluded. Calcite, hornblende, mica, etc., are present in very small amount. Magnetite particles were discovered by using a magnet.

In addition to the minerals and organic material, this snow dust contains a considerable number of diatoms. There seems to be more than one kind of diatom present, and the sizes vary, but the usual size in this dust is 0.006 to 0.01 mm. in width, and 0.02 to 0.035 mm. in length. They are roughly cigar-shaped and so small that it would require 750 laid end to end to measure one inch, and more than three billions to fill one cubic inch. The portion of the diatom found in the dust is the test, which is composed of hydrous silica, or opal, and has various very regular markings over its surface.

Microscopic measurements of the size of the dust particles show that they range from about 0.003 mm. to about 0.1 mm., but a surprisingly large percentage falls within much narrower limits, namely 0.008 to 0.025 mm.

Professor Stewart reports also that the organic constituents were allowed to distribute themselves wherever they would among the separates, with the result that much, if not all of the four largest sizes consist of organic material, and the very fine sand includes both organic and inorganic matter.

The organic constituents were so obviously plant tissue that they were submitted to Professor R. H. Denniston of the Department of Botany, who reports that they include fragments of blades of grass, of leaves of clover or some similar legume, fibers of cotton, and fragments of coniferous wood, all more or less decayed, as shown by the presence of saprophytic fungi and their spores. The only inorganic material in the so-called "gravel" consists of white particles which effervesce with acetic acid; it is therefore a carbonate.

An attempt was made to separate the constituents of the dust by means of a heavy solution of potassium mercuric iodide. Most of the material sank in a liquid of specific gravity of 2.3, but the material still

floating contained the same materials as the part which sank. A portion of the dust separated by mechanical analysis to the size of 0.010 to 0.025 mm. was tested in the same way. Practically all of it floated at 2.7, less than one quarter of it sank at 2.6; again the two parts contained the same materials; the heavier seemed to contain less limonite stain than the other. It seems probable that sub-microscopic porosity modifies considerably the apparent specific gravity of much of the dust.

Comparison with similar analyses of soils, volcanic dust and atmospheric dust shows that the Madison dust has two peculiarities, namely, it is finer than the other dusts and it contains a large percentage within a small range of sizes. Some soils contain much larger amounts of clayey material (smaller than .005 mm.) than the Madison material, but a hasty search of the literature makes it clear that few, if any, soils contain as much silt; on the other hand shower and volcanic dust contains much less clay than the Madison dust. This may be explained as due to the fact that shower and volcanic dusts fall wholly through the action of gravity, while the Madison dust was brought down not by its own weight, but by the weight of the snow or rain condensed upon it.

No explanation is offered here for the small range of sizes within which such a large part of the Madison dust is included, other than the remarkable sorting power of the wind; perhaps this is a sufficient explanation even as compared with the shower and volcanic dust, if the size of the Madison dust is remembered.

**Quantity of the dust.**—Several samples of the dust were obtained at Madison. Professor W. H. Twenhofel collected the yellow snow from one sq. yd. of surface; A. N. Winchell obtained a sample amounting to 5 1/2 liters of snow water; smaller amounts were gathered by E. R. Miller and W. J. Mead. The residue after evaporating the colored snow obtained from

one square yard of surface weighed four grams, while the sample of 5 1/2 liters of snow water yielded 5.2 grams of residue which settled to the bottom as well as .15 grams of black material, which floated at the surface or in the liquid. These two determinations are mutually corroborative since the second sample was obtained from somewhat more than one square yard of surface. They indicate that the residue amounted to 4.8 grams per square meter, or 4,800 kilograms per square kilometer; in more familiar units, this amounts to more than 13.5 tons per square mile. Observers of the U. S. Weather Bureau, quoted above, report that this colored snow fell at least from Dubuque, Iowa, to Chelsea, Vermont, in an east-west direction, and from Madison, Wisconsin, to Newberry, Michigan, in a north-south direction. This is about 900 miles east and west, and 300 miles north and south as shown by the map. It covered an area of at least one hundred thousand



Fig. 1. Localities where the dustfall was observed

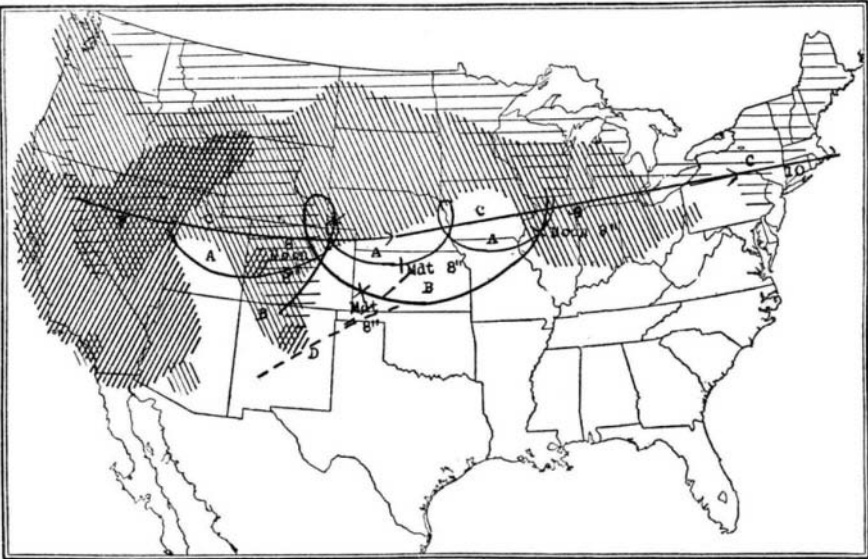


Fig. 2. Meteorological conditions March 7-10, 1918

Curve C shows path of center of storm of March 7-10. Curves B, A show trajectory of upper air current that arrived at Madison, Wis., at 11:30 A. M., 2:30 P. M., respectively, March 9. Curve D shows conjectured trajectory of dust-bearing lower current ascending to upper stratum. Horizontal hatchures show snow-cover 7 P. M., March 4, 1918. NE-SW hatchures show area of rainfall during 24 hours preceding 7 A. M., March 8, 1918. NE-SE hatchures show area of rainfall during 24 hours preceding 7 A. M., March 9, 1918.

At our request, a mechanical analysis of the material was made by Professor H. W. Stewart of the Soils Department of the University of Wisconsin. He reports that the water-free weight of the sample used was 1.8268 grams, and that it yielded the following:

Separates.	Size.	Per cent.
Clay.....	Less than .005 mm.	11.145
Fine silt.....	.005 to .010	22.005
Medium silt.....	.010 to .025	56.169
Coarse silt.....	.025 to .050	5.988
Very fine sand.....	.05 to .10	1.215
Fine sand.....	.10 to .25	1.035
Medium sand.....	.25 to .50	0.580
Coarse sand.....	.50 to 1.00	0.290
Fine gravel.....	1.00 to 2.00	1.078
Total.....		99.504

\*From American Journal of Science.  
<sup>1</sup>A. Rosiwal. Ueber geometrische Gesteinsanalysen, Verh. k. k. Reichsanstalt, Vienna, 1898, p. 143.

square miles and probably much more. Therefore the total quantity of dust may be estimated as at least a million tons, and probably considerably more. In fact, it seems likely that the material was brought down throughout the area covered by this snow storm, and in that case, the quantity deposited would run into the tens of hundreds of millions of tons.

*Origin of the dust.*—While the meteorological data do not afford evidence as to the exact locality from which the dust came that was deposited at Madison, yet the possible field may be limited very materially by appealing to them.

The winds near the ground can be eliminated at once, first, because the dust was brought down by sleet, which is known to be frozen rain, that is to say, rain formed in an upper, warmer, stratum, falls through a cold lower stratum and is frozen in it; and second, because the lower wind, traced back along its course, is found to have come from the northeast, blowing only over snow-covered ground, and the waters of Lake Michigan, during the time that it was under the influence of the storm, so that it could not have blown up soil or sand.

In dealing with upper air currents, say from 500 to 2,000 meters above the ground, it is usually assumed by meteorologists, that the velocity is determined by the distribution of pressure as observed with barometers at the surface, and that the direction is along the momentary direction of the isobar. The velocity of the wind has been shown by Shaw<sup>1</sup> to be a resultant of the gradient velocity and the storm movement in only certain types of storms, but for the sake of simplicity in obtaining a first approximation, these conditions have been assumed in this case. Various formulas, and tables for obtaining the gradient velocity have been given by Shaw, Gold, Patterson, and Humphreys. The revised monograph of Humphreys<sup>2</sup> has been used in obtaining the trajectories marked A and B in Fig. 3, for the dust-bearing upper currents that arrived at Madison at the beginning and end of the observed time of the dustfall.

The storm of March 7-10, 1918, was characterized by strong winds at the surface throughout its passage from Utah eastward, so that the mechanism for eroding the surface and carrying the dust up into the atmosphere was available over a wide area. The telegraphic report of the Weather Bureau at 7 A. M. of March 9, 1918, showed high winds prevailing throughout the southwest from the Mississippi valley to the Rocky Mountains. Among the higher velocities reached during the preceding night were 48 miles per hour at Oklahoma City, 44 at Denver, 44 at Wichita. On the preceding day the storm center was advancing through Utah and Colorado and a region of steep barometric gradients and strong winds passed over the arid regions of Nevada, Utah, Arizona, Colorado, and New Mexico, a maximum velocity of 48 miles an hour being attained at Modena, in southwestern Utah.

The velocities are sufficient to blow up into the air not only clouds of dust, but to whirl up from the ground gravel of considerable size. The limit of snow cover, from the Snow and Ice Bulletin of the Weather Bureau of March 5, 1918, and the areas covered by rainfall during the advance of the storm are shown in Fig. 2. Except in Colorado, and northern New Mexico, the territory subjected to high winds was not protected in any way, aside from the natural vegetal covering, against eroding winds. The reports from observers and from military camps in the region indicate that extraordinary duststorms prevailed and caused much discomfort.

The microscopic study of the dust reveals several facts having an important bearing on its origin. First, it is well sorted and very fine. Both of these facts indicate that it has been carried a long distance in the air (according to the estimates of Udden a distance which may be a thousand miles or more). Next, the dust is charged with abundant limonite and hematite, although kaolin is not abundant and the feldspar is entirely unaltered. These facts indicate that the dust is a product of physical disintegration, and not of chemical decomposition, that is, it is derived from a region of very arid climate and not from any part of the Mississippi valley. Finally, the dust is dominantly composed of feldspar and quartz with very small amounts of other constituents. Therefore, it is derived from a region of siliceous feldspathic rocks, either granite or arkose, or a gneiss of similar composition. It is not derived from a region of limestone, sandstone, mica schist, or basic igneous rocks. It contains far too little kaolin and its feldspar is too fresh to be derived from any ordinary shale or argillite.

From all these lines of evidence it is believed that the dust came from an arid region of the southwestern part

of this country, where siliceous feldspathic rocks are abundant. Such areas are common in New Mexico and Arizona. It is conjectured that the material was whirled up from the surface on March 8 in the afternoon when the convectional currents are most effective both in causing rapid vertical movements, and in increasing the velocity of the surface air by mixture with the faster moving upper air. During vertical ascent the horizontal component of velocity gradually increased, and the direction gradually veered, as shown by the dotted curve D in Fig. 3, until it coincided with the line of gradient velocity indicated by the continuous lines A and B in Fig. 3. The dust-bearing current then whirled around the storm center, in contra-clockwise direction until it arrived at the flank of the colder current flowing in from the east over the Great Lakes and the St. Lawrence valley. The warmer and lighter air from the southwest then rose over the colder and denser air from the east, and the precipitation of the moisture upon the dust particles as nuclei came about through the mechanical cooling of the ascending air. The precipitated moisture was in the form of rain at first, but froze to sleet as it fell through the cold lower stratum. Higher ascent cooled the rising air below the freezing point, and then the snow formed that fell with the sleet formed lower down. The pure white snow fell in the northeast winds, following the storm, and these probably came from the snow-covered land to the north or east.

*Conclusion.*—The evidence here presented that a single storm may transport a million tons of rock material a thousand miles or more, emphasizes the importance of the wind as a geological agent. Water transports larger rock fragments, and its work is readily seen on every hand; air transports much finer material and its work is only rarely noticed at all; yet the air is constantly at work over a much larger surface than that covered by running water, and it is an open question whether the total work done by the air in transporting rock material is not of the same order of magnitude as the work of the same kind accomplished by water.

It is clear that arid regions will constantly lose rock material by wind action and that the dust will be held by moist areas which are covered by vegetation. This is a type of erosion which may carry material "up hill" from a dry region of little elevation to a moist region of greater elevation. In the case here presented however, the material probably came from a mountainous arid region to an area of lower elevation.

The soil of any region is probably derived in considerable part from material transported by the wind.

Diatoms and all sorts of plant and animal life of microscopic size as well as fragments of larger organisms may be transported long distances by the wind.

### The Perception of Sound

ALTHOUGH the pitch of a particular tone is, say, 640 d. v. per second, it is not necessary that, in order to recognise it, we should listen to that tone for a whole second of time. Prof. McKendrick many years ago demonstrated that we could recognise as distinct from its predecessor and successor a note in a musical composition if it were listened to for only 1/64th of a second. In such a case this would mean that only ten condensations would affect the organ of Corti, and presumably only ten nerve-impulses ascend the auditory nerve. Prof. McKendrick, with whom it was my privilege to be associated at that time, studied the surface of the wax-cylinder records of musical compositions recorded for reproduction by the phonograph.

Since the speed of rotation of the cylinder was known, the number of impressions in the wax corresponding with each of a series of tones could be ascertained; and it was found that, in order to recognise any given tone, it was only necessary to "hear" that tone for not longer than 1/64th of a second. If I remember correctly, a shorter period still was in some cases demonstrated to be sufficient.

Now if, say, 1/100th of a second is long enough, it is clear that the hearing of quite high tones could be effected by a comparatively small number of vibrations or disturbances in the internal ear and of subsequent impulses in the nerve.

A tone of 2,000 d. v. per second could be recognised by 20 impulses, and one of 10,000 pitch by 100, and so on. Apparently the auditory nerve is competent to transmit individual impulses of that order of frequency.

It seems to me that attention to this point will make the problem of hearing rather simpler than at first it appears by removing the necessity for believing that, in order to appreciate a note of a given pitch, we require to have the auditory nerve transmitting the large number of impulses corresponding with the large number of vibrations which, according to physicists,

is the pitch or number *per second* of that note. In other words, the different tones in a musical composition follow one another with such rapidity that no particular note is produced for a whole second, and, therefore, not perceived for a whole second.

But, on the other hand, it is clear that we can listen to a high-pitched note for a second or for a minute or for any length of time. When we are hearing a note of 20,000 d. v. per second pitch, we are almost certainly *not* receiving 20,000 impulses per second into the central nervous system. To take an analogy from vision: when we perceive red light, we are certainly not receiving anything like  $(395 \times 10^{12})$  impulses per second, which is the "pitch" of red light. If, in seeing colored light, such an enormous number of vibrations in the æther affect the retina, there must be something of a very different character as regards frequency, which, ascending the optic nerve, so stimulates the visual centre that we see colored light.

We have in perceptual consciousness qualitative differences corresponding with objective quantitative differences, an ever-present problem of psycho-physics; and no one has ever suggested that our optic nerves and visual centres are dealing with impulses at many millions a second. Why, then, may we not apply the same reasoning to the ear?

When we are listening to all possible tones from, say, 1,000 d. v. per second pitch to 40,000, may we not somehow have in consciousness qualitative differences corresponding with objective quantitative (arithmetical) differences? We cannot, apparently, be more definite than this.

In the case of the eye there is no conceivable possibility of an identity between the rhythm of optic-nerve impulses and that of the vibrations of the æther; is it not by analogy probable that neither is there any direct correspondence between the auditory nerve-impulses and the periodicity of sonorous vibrations?—*D. Fraser Harris, in Nature.*

### Long-Range Guns

IN a recent number of the Field Artillery Journal extracts are given from a lecture delivered at the British Royal Artillery Institute by Major J. Maitland-Addison, R.A., on "The Long-range Guns," in which, he discusses the gun used by the Germans to throw shells into Paris. Speaking of the "ultimate limit" of velocity of projectiles, he explains that he uses the expression "ultimate velocity limit" for want of a better term; that the "ultimate limit" is to throw projectiles off the earth into space, such a feat as Jules Verne had in his mind when he wrote his book, "De la Terre à la Lune." "The requisite velocity is not so immeasurably higher than has already been achieved today," he said. "A velocity of a mile per second has been attained. Assuming that some day we may be able to increase this to five miles per second (a velocity only five times greater), the projectile would then travel around the earth as a grazing satellite, completing its orbit between seventeen to eighteen times daily, and with a still higher velocity of about seven miles per second, it would move off into space never to return. But it must not be pre-supposed that the dimensions of a gun are merely in simple proportion to the velocity it is required to produce. On the contrary, they increase as some power of the velocity. Nevertheless, it is a remarkable fact that such a velocity as one mile per second has been reached."

### Gases in Alloy Steel

THE gases dissolved in steel consist chiefly of carbon monoxide and hydrogen. Hydrogen predominates at low temperatures, but as the temperature is raised, decreases to a minimum value, after which it again rises with further heating. Carbon monoxide is present only in small quantities at low temperature, but rises on heating to a maximum and then commences to decrease. At high temperatures carbon monoxide and hydrogen are present in more or less equal amounts. Carbon dioxide, methane, and nitrogen do not as a rule constitute more than 5% of the total gases present. The evolution of gases on boring is related to the critical points, the greatest development occurring at these temperatures. In special steels the gases present decrease as the nickel, silicon, chromium, manganese, or other special constituent is present in increasing amounts. The gases dissolved are similar to those present in carbon steels with the exception that silicon and manganese lower the content of carbon monoxide and increase that of hydrogen. Chromium appears to increase the amount of nitrogen present. As in the case of ordinary steels the largest volumes of gas are set free in the region of the critical points.—*Note in Jour. Soc. Chem. Ind. on an article by A. Stadeler, in Stahl u. Eisen.*

<sup>1</sup>Revolving fluid in the atmosphere, Proc. Roy. Soc., Lond., ser. A, 94, p. 34-52.

<sup>2</sup>Journal Franklin Inst., November, 1917, p. 673, revised.