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H. H. KIMBALL, Librarian.

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STUDIES OF FROST AND ICE CRYSTALS.

By WILSON A. BENTLEY. Dated Jericho, Vt., May 28, 1906. Revised July, 1907.

(Continued from October Review.)

VIII.—CLASSIFICATION OF ICE CRYSTALS.

(67) List of types.

There are at least five different and characteristic types among the nuclear or germ ice crystals, and two or three additional post-nuclear types. In general, if growth is allowed to proceed for a sufficient length of time, each of these various germ types passes thru certain typical and characteristic growth phases peculiar to it. All, or nearly all, when first organized, possess smooth edges and contours, but they subsequently pass thru the scalloped, the ray, and the branch-like stages of growth before completion. These various types, because of peculiarities of form and resemblance to the objects after which they are named, may be grouped and named as follows:

1. Lanceolate .... Lance-like, MLA.
2. Discoidal .... Disc-like, MDB.
3. Solid hexagonal ...... Solid hexagonal plate-like, MHC.
4. Flower-like .... Ice flower-form, MFD.
5. Spandrelliform .... Resembling a spandrel, MSE.
6. Coralline.............. Resembling coral, MCF.

Each of these respective types requires and will receive especial mention by itself in the text, in the order of relative frequency of occurrence of each in nature, so far as I have observed them at Jericho, Vt.

(68) Type MLA. Lanceolate ice crystals.

These lance-like or needle-like crystals are illustrated in photographs Nos. 233 and 234. Some of the crystals are very long and slender and lance-like, others shorter and broader at the center than at the extremities, while still others broaden out so greatly at a central point along one of their edges as to suggest the idea that segments of disks had attached themselves to them. Perhaps those first mentioned occur most frequently. They usually form upon and shoot outward from some object, as from the edges and sides of ponds, brooks, and artificial receptacles holding water in process of freezing. Photographs Nos. 233 and 235 will convey an idea of their general aspect.

The very first ice crystals to form when water begins to freeze are almost invariably of this description. As these latter grow upon the surface, scallops and branches form and grow outward from one or both edges, as shown in photographs Nos. 235, 236, 237, and 238; and eventually grow in parallel rows downward into the water from their under sides, in the manner shown in photographs Nos. 239 A and 239 B. They are perhaps the main fabrics of the ice, as they alone merge and form ice films by themselves in addition to frequently combining with other types of ice crystals to form such films. The needle-like ice crystals that broaden out upon one edge at the center (see photograph No. 234) always form independent of a support in the free water, and proceed to grow in many cases in the manner shown in photograph No. 240, thru the formation of scallops around their edges. These scallops soon develop into rays and branches, and they pass into the branch-like state and continue their growth in a branch-like manner.

(69) Type MDB. Discoidal ice crystals.

These strange and most interesting crystals of ice come into visible existence in the form of tiny, round, thin, disks of ice of various dimensions, as shown in the photograph No. 241. Some seem to be perfectly flat, and others slightly concave. All are exceedingly thin, and when first formed look like tiny films or specks of oil resting upon the surface of the water. They vary somewhat one from another in size and form, and in the degree of perfection, or spheroidicity, of the disks. Ofttimes two or more crystals merge together while yet in the germ state and form many-lobed disks of irregular, unsymmetrical shapes. At this first stage discoidal crystals seem not to possess secondary axes and grow in a round and seemingly most uncrystal-like manner. But as growth progresses they soon come to the "parting of the ways", and grow differently. At this, their critical stage of growth, tiny scallops begin to form at certain equidistant points (six in number) around their edges. Photograph No. 242 shows them at this stage of growth. This is a most strange and fascinating period in their life history. Under the influence of continued cold and a more rapid rate of growth and of certain mysterious crystallic laws, seemingly latent influences become active, and they pass from the germ, or nuclear, into the mature, from the simple into the complex state of being; they acquire secondary axes, and grow afterward in a more truly crystal-like manner, and are more in accord with the hexagonal system of crystallization to which they belong. Scallops soon form around their whole circumference and grow rapidly larger, but those that first appeared grow much faster than the others. Photograph No. 243 shows them at this period of their growth. Eventually certain of the scallops push outward so far beyond the others as to give a star-like or flower-like appearance to the crystals, and they pass into the beautiful "ice flower" stage shown in photographs Nos. 244 and 245.

The next step consists in a marvelously rapid development of the six longer scallops or rays, which push outward far beyond the others and assume the role of primary rays; then follows the formation and growth of numerous secondary rays upon and around such primary rays. The beautiful appearance of such flower-shaped crystals, or "ice flowers", is well shown in photographs Nos. 246 and 247.

The final and last step in their development consists in a continuation of the growth of the main rays and the formation, or multiplication and growth of secondary rays thereon. This stage is well shown in the beautiful branch-like crystals portrayed in photographs Nos. 248, 249. The crystals attain their greatest beauty and complexity at this point, and such as may have developed apart by themselves and in a symmetrical manner, often possess a beauty and complexity of form and outline rivaling that of many of the branch-like snow crystals which they so greatly resemble.

(70) Type MHC. Solid hexagonal ice crystals.

Ice crystals of this form differ little from those last mentioned, except that they possess hexagonal forms, having sharp or but slightly rounded corners instead of circular forms and outlines as is the case with discoidal crystals. Examples of this and other types of crystals may be seen in photographs Nos. 241 and 250. They pass successively thru the scallop, the ray, and the branch-like states of growth as do the latter, but unlike them, begin and conduct their whole growth from the very first upon the hexagonal plan, upon and around secondary axes, in a manner similar to that of the snow crystals. Owing to crowding and early merging together individual ice crystals of this, and indeed of other descriptions, are rarely permitted under natural conditions to continue development for any considerable length of time in a perfectly symmetrical manner or to attain a very considerable size. But under artificial conditions, such as may be brought about in the case of ice crystals that are allowed to form and to grow upon the calm surface of the water (as in a pail of water in process of freezing), individual crystals of this and of other types can be kept apart from each other and allowed to grow by themselves, by removing any crystals that form or float into their immediate vicinity. Under such favorable conditions, they can be made to grow and develop into crystals of large size, and of great beauty, complexity, and symmetry of form.

(71) Type MFD. Flower-like ice crystals.

This type of ice crystal seems to begin at once in the hexagonal star or flower form. These are quite tiny at first, and of simple form, the usual germ form consisting of a tiny hexagonal star with six leaf-like petals, like the smaller crystals shown in photographs Nos. 250 and 251. They rarely remain long in this form. Scallops and secondary branches soon form upon and around the edges of each of the six primary petals and they pass into the branch-like stage, as shown in photographs Nos. 252 and 253. This type of crystal also assumes elegant and symmetrical branching forms if allowed to develop under favorable artificial or natural conditions.

(72) Type MSE. Spandrelliform ice crystals.

These singular ice crystals vary somewhat in form one from another, even when first organized. Commonly one edge is straight in contour, and the opposite one curving. The two edges often conspire to outline a hat-shaped or spandrel-like figure. Photograph No. 254 pictures a typical example. These strange forms, like other types, successively pass thru the scallop and the branch-like stages of growth. Photograph No. 255 shows them while in the scallop stage, and No. 256 pictures one after entering upon the branch-like stage.

Singularly enough, quite a few of these and also some crystals of the needle-form type, shown in photograph No. 234, grow outward from the corners toward the straight edge, and assume a horseshoe or meniscus-like form. Photograph No. 257 shows a spandrelliform crystal that developed in this strange manner, while No. 258 shows a needle-form crystal, and also the spandrelliform crystal at a later stage of growth, after it had grown in the manner just described. Why certain isolated crystals of these respective types grow in the strange abnormal manner shown in the photographs is indeed most mysterious; and the mystery is heightened by the fact that it often happens that crystals of both of the respective types under consideration form and grow in a normal manner at the same time and upon the same body of water as those that develop abnormally.

(73) Type MCF. Coralline ice crystals.

This graceful and elegant type of ice crystal usually, if not invariably, forms upon and grows out from some preconstituted nucleus, as from some one or more of the other types, or from some irregular discoidal crystal germ. In general the coralline crystals seem rarely to grow from mature discoidal, hexagonal, or flower-shaped crystals; they seem to prefer the needle or lance-form ice crystals, or the spandrelliform crystals, as nuclei from which to develop. Coralline ice crystals consist of myriads of rounded, convoluted, disk-like outgrowths, clustered one outside another in such a manner as to form graceful curving branches, greatly resembling certain forms of coral. Their whole development occurs in a sinuous and meandering, rather than a straight and regular fashion, and in this regard they resemble the meandering type of window-ice crystals. Why these coral forms should grow in this seemingly uncrystal-like manner, upon the surface of water supporting growing needle-like, flower-like, and hexagonal ice crystals side by side with them, all of them growing in a crystal-like manner markedly unlike the coral forms, is indeed most strange and incomprehensible. Beautiful specimens of this type of ice crystal may be seen in photographs Nos. 259 and 260. No. 259 formed and grew from a tiny twin discoidal crystal similar to the one seen at one side of the coral-form ice crystal.

(74) Additional photographs of ice crystals.

The author's collection of photographs of ice crystals numbers over 200 and contains many beautiful and interesting forms, in addition to those already mentioned. It is thought best to select a few from among them to use for illustrative purposes. These added ones are Nos. 261, 262, 263, 264, and 265. No. 261 shows an interesting specimen of a twin discoidal ice crystal at a second stage; two circular discoidal crystals united together to produce it. No. 262 shows a very interesting group of ice crystals of various types. It shows how ice crystals of various types, sizes, etc., form and grow at the same time, side by side, upon a given body of calm, freezing water.

No. 263 is a photograph of a lenticular body of ice formed by the freezing of water in a shallow dish. In this case the water was frozen rapidly, and the ice crystals that accomplished the work formed around the edges of the dish and grew inward; hence the so-called air tubes within the ice, instead of forming with their longer radii normal to the surface of the water, formed for the most part parallel to the surface of the water. The forms and arrangement of the air tubes within this lens-shaped body of ice are well shown in the photograph.

Nos. 264 and 265 show how environment and crowding impair symmetrical growth, and how the segments of neighboring crystals lying farthest apart from such crystals as may be in their vicinity are stimulated in their growth by the proximity of relatively large areas of crystal-free spaces of chilled water surface, from which to draw material for new growth, while those segments that lie nearest adjoining crystals are retarded and hindered in their growth by such contiguity, and by a consequent lack of extensive areas of chilled surface water (water molecules) in their immediate vicinity from which to draw material for growth. They serve to establish the fact that growing ice crystals, resting upon the surface of the water, at first draw but little from beneath the surface of the water to aid in their growth; but that they draw material for their growth almost wholly from a thin film of chilled surface water.

IX.—HAIL.

(75) Probable manner of formation and classification.

It is well known that as a result of the action of certain meteorological forces and conditions, not yet well understood in all cases, a portion of the raindrops formed in summer during rain and thundershowers and tornadoes, and also in winter by the melting of snow crystals or snowflakes, is sometimes frozen in the air or in the clouds and converted into solid masses or accretions of ice called hail. In general, the forms, structures, sizes, degree of transparency or opacity, and presumable manner of origin of hailstones formed in winter vary in considerable degree from those produced in summer. Because of this, and also because in general winter hail is peculiarly the product of general snowstorms and of horizontal air currents, whereas summer hail is peculiarly the product of local rain and thundershowers and of violently ascending air currents, it is convenient and advisable to separate hailstones into two classes, winter hail and summer hail, according to the respective times of occurrence and manner of origin.

(76) Cause and occurrence of winter hail.

Because of its apparently greater relative frequency of occurrence, winter hail should perhaps receive mention first.

In general, winter hail is peculiarly the product of the eastern or southeastern segments of widespread general storms. Such storm segments seem to produce hail not always, but only in some cases. Whenever winter hail occurs the melting of the snow crystals, which presumably go to its upbuilding, is due to the presence of a warm but presumably relatively thin and somewhat elevated stratum of air lying between the earth and the clouds or between two low cloud strata. Such warm air currents almost certainly come from the south or east and flow spirally inward in a horizontal manner toward the centers of such storms between the colder air strata existing within such storms both above and below them. The melted snow that descends as liquid raindrops from the lower side of a warm air current freezes into hail while the drops are falling thru the cold substratum of air lying between the warm stratum and the earth.

Winter hail ofttimes occurs simultaneously over relatively large areas. In general, sleet or mixt sleet and rain precede and follow the occurrence of winter hail. Such hail usually occurs during southeast winds, when the temperature of the air at the earth's surface ranges from 23° to 35° F. The individual winter hailstones, tho occasionally of practically uniform size, in general vary somewhat in size and sphericity, both during a given storm and from one storm to another. Hailstones varying from one-thirtieth inch to one-eighth inch often fall together.

(77) Structure and forms of winter hailstones.

The interior structure of winter hailstones varies somewhat in different cases. All possess tiny air tubes and air bubbles, but some in greater quantity than others. Some contain but a few relatively large ones, others many small ones. Sometimes a tiny group of bubbles occurs clustered within their nuclear portions. In general, the larger air tubes radiate from the center outward. In most cases the majority of the air tubes are clustered at the center of each hailstone.

Winter hailstones assume various forms. The great majority are round, but some are egg-shaped, and pear-like shapes are not rare. These latter are of much interest. Pear-shaped hailstones are doubtless due to the fact that the larger spheroidal ones, because of their greater weight, fall downward faster than the smaller hailstones and the smaller undercooled raindrops, and hence overtake and merge with these. In some cases the tiny raindrops encountered are not too much undercooled to have time to spread around considerably upon the hailstones before solidification takes place; but in others they are undercooled to such an extent as to freeze instantly upon impact. The latter cases presumably produce the pear-shaped hailstones.

The writer secured many interesting photographs of winter hailstones, and of sections of such stones, during the winter of 1906–7, a few of which are reproduced herein as illustrations. Nos. 267 B, 268 A, 268 B, 270, and 271 show the typical arrangement of the air tubes within the stones. No. 266 B shows a more diffuse and less common arrangement. Nos. 267 A, 268 A, and 269 A show whole pear-shaped hailstones, while 267 B, 268 B, and 269 B show sections of pear-shaped and oval-shaped stones under larger magnifications.

(78) Occurrence and cause of summer hail.

Summer hail seems to be peculiarly a product of violent summer showers, and especially of thundershowers and tornadoes and of violently expanding volumes of cloud-laden air. Newly formed or forming showers, or newly forming annexes to old ones, and those terrible rotating storms called tornadoes seem to be the principal, if not the only summer storms that produce hail. Unlike winter hail, summer hail occurs over very small areas and is a purely local phenomenon. Yet it frequently happens that hail occurs simultaneously, or on the same date, at various and perhaps widely separated points. Hence it may be presumed that in general the same peculiar causes that operate to produce hail within some particular shower of a series will operate at other points, and cause the formation of hail there also. In general the portion or segment of a given shower that produces hail is of relatively small area, hence the path of a hailstorm is quite narrow. Such hailstorm paths vary from perhaps a few hundred feet to as much, in some cases, as a mile or so in breadth. It seems to be the case usually, if not invariably, that the clouds extend to a very great height above the particular segment of a shower that produces hail. Probably in most cases such hail-producing clouds far overtop the surrounding clouds that produce rain only.

(79) Usual structure of summer hailstones.

Tho the individual summer hailstones occurring in the same or in different individual storms often vary markedly one from another in size and exterior form, yet in general their internal structures and appearances are quite characteristic and similar. The nuclei of most summer hailstones consist of whitish, more or less opaque and seemingly amorphous ice. In nearly all cases a coat of clear normal ice extends around and incloses the opaque nucleus, and, in the case of most large hailstones, many alternate coats or accretions of both clear and partly opaque amorphous ice seem to have been superimposed in alternate concentric order upon and around such nuclei. Because of this a cross section of a large hailstone presents a circular banded appearance. A great majority of the smaller summer hailstones are round, ovoidal, or pyramidal in shape. The larger ones are remarkably less regular in form than the smaller ones, and a larger percentage of these possess ovoidal, oblate, or irregular jagged forms. Small summer hailstones rarely merge or freeze together, but when, as usually happens, small and large ones occur together, the small ones frequently merge with the large ones and freeze in most varied order upon them.

(80) Peculiar structures.

Certain peculiar large egg-shaped and facetted hailstones possess such a post-nuclear structure as would seem naturally to suggest that the outer or post-nuclear portion was formed subsequent to the nucleus, as a result of the merging of many small hailstones. The absence of cavities within them, however, makes this theory of their origin untenable. Under the microscope the whitish, snow-like, nuclear ice and the concentric coats of post-nuclear ice are seen to be thickly threaded by air tubes chaotically arranged, by icy nodules, and by granular fibers resembling those of which granular amorphous snow is composed, or such as would likely result were the fibers partially melted. The forms, locations, and arrangements of these interior air tubes and of the other features that resemble nodules and fibers of granular amorphous snow, correspond so closely to the jagged granules and fibers of which actual natural granular amorphous snow is composed, as to leave little doubt but that they have such a snow origin, and were inclosed and eventually frozen within a liquid coating of ice-cold water surrounding a pellet of granular snow, all of which may be said to constitute a raindrop of "melted snow".

(81) Probable manner of formation of summer hail.

Assuming this to be the case, hailstorms not only have a granular snow origin, but as growth progresses in cloudland they must repeatedly and alternately encounter clouds of warm mist and cold snow. If we may judge of the origin and formation of summer hailstones by what seems to be revealed or indicated by their forms, size, structure, etc., then it would seem that they are, in general, formed in the manner described in the following paragraphs:

(*a*) The nuclei, or rather what eventually go to form such nuclei, are first organized in the form of pyramidal or star-shaped granular snow, within the central and upper portions of very lofty, violently and vertically expanding, mushroom-shaped cumulus, or cumulo-cirrus clouds. The rapidly ascending air currents within the central portions of such clouds may expand upward in some cases as internal whirlwinds, and in others very strongly but without marked rotary motion; but their upward motion is assumed to be so rapid as to enable them to sustain and carry along upward with them all the raindrops and granular snow that come within their grasp.

The pellets of granular snow are blown upward and expelled or released from the grasp of the powerful updraft air currents only at or near the summit and spreading portion of a cloud. Once the pellets reach the spreading-out portion of a cloud, they are blown outward in a horizontal, rather than upward in a vertical manner; thus they lose their ascensional motion and begin to fall earthward. The larger pellets and the larger hailstones, caused by melting and refreezing necessarily fall first and nearest to the central vortex, while the smaller pellets are blown farther outward into the spreading portion of the clouds, and fall earthward farther away from the center. Many of the latter eventually fall as rain completely to earth at some point beneath the shower clouds.

(*b*) A portion of the granular pellets, however, and especially the large ones such as fall closest to the central vortex, as they fall earthward and become partly melted at lower levels, encounter strong horizontal indraft air currents, and are drawn by them again into the shower vortex, and are again carried far upward and converted into ice, and recoated with granular snow, and eventually expelled again, as in the first instance, from the summit and spreading portions of the shower clouds. In some cases, as when the uprushing and whirling winds of the shower's central vortex are very swift, the hailstones may even once again undergo a descent and an ascent, as in the first and second instances. Or again, in their fall earthward they may encounter a secondary, newly-forming vortex, as an annex to the main one; and after being partly melted within its milder air, they may be carried far upward by it, again reaching cold, freezing altitudes and be once again frozen, before they become so heavy as finally to fall to earth.

In short, this theory [9] assumes that, in general, summer hailstones begin as granular snow, and are melted or partly melted only by partial descent, and are congealed only thru

[9] The author assures us that he arrived at this theory quite independently of suggestions from the very limited authorities and literature to which he had access.—EDITOR.

ascent within the clouds. The writer believes that the process of hail formation as herein described, or some modification of it, is capable of completely explaining all the various phenomena of summer hail. Surely powerful air currents or winds must blow upward thru and within hail-producing clouds to sustain and buoy up the larger hailstones for the length of time necessary for them to grow to so considerable a size.

[*To be continued.*]

THE WINDS OF THE LAKE REGION.

By Prof. ALFRED J. HENRY, United States Weather Bureau. Dated December 10, 1907.

All motions of the air depend directly or indirectly upon differences in temperature. Differences in temperature arise in several ways, mostly, however, as a result of the varying amount of solar energy received at the earth's surface in the various latitudes and the unequal heating of land and water surfaces. The temperature of the equatorial regions, for reasons that need not here be stated, is high as compared with that of the polar regions; as a consequence the isobaric surfaces are inclined toward the poles, and there is, therefore, a flow of the upper air from the equatorial regions poleward in both hemispheres, with a countercurrent in the lower air from the poles toward the equator. This interchanging motion between the equatorial and the polar regions is modified by the deflecting force of the earth's rotation, by differences in barometric pressure on different parallels of latitude, and by other causes which conspire to interrupt and at times reverse the general motions here indicated.

In the Northern Hemisphere, with which we are most concerned, the principal winds are (1) the northeast trades whose polar limits do not extend much above 30° north latitude, and (2) the prevailing westerly winds of the middle latitudes. Each of these winds forms an elemental part of the general circulation of the atmosphere, and is therefore controlled and modified by general rather than local influences.

The normal temperature gradient between the equator and the poles near the surface of the earth is the principal cause of the winds. It is subject to a rather large annual inequality—that is to say, it is strongest in winter and weakest in summer—consequently the winds, particularly of the middle latitudes, also show an annual inequality both in direction and velocity; and, moreover, they are interrupted by local and temporary disturbances in temperature which produce gradients strong enough to overcome the normal gradient for the time and place. These local and temporary disturbances occur most frequently in the warm season, when the equatorial-polar gradient is weakest; hence it follows that the winds are most variable in summer and steadiest in winter. Another cause for the general seasonal changes in the force and direction of the wind is the annual migration of the heat equator. The temperature differences which arise between the continents and the oceans, as a result of such migration, cause a corresponding movement of the lower portions of the atmosphere from the colder to the warmer region.

The meteorological stations in the Lake region from which the material for the following remarks was obtained are of two classes, viz, (1) the cooperative stations at which the prevailing direction of the wind by eye observations is recorded each day, and (2) the regular stations of the Weather Bureau where the direction and force of the wind is automatically recorded thruout each of the twenty-four hours. The Weather Bureau stations, with but one exception, are stationed along the Great Lakes. Since the direction of the wind is controlled at times by temperature differences that arise between contiguous surfaces of land and water, the local winds at lake stations may not always show the general movement of the air, but merely the direction and movement of the air within a narrow zone surrounding the lake. To meet this objection use has been made of a number of cooperative stations situated at some distance from the lakes.

Winds of the cold season.—In the cold season, viz, from November to March, the winds of the Great Lakes are controlled chiefly by the meteorological conditions which prevail in the interior of the continent. The general drift of the surface winds in the United States east of the Rocky Mountains and north of about the thirty-fifth parallel of latitude for this period is from a westerly quarter; more specifically, the winds of the upper Missouri Valley, the upper Mississippi Valley, and the northern portion of the upper Lake region are northwest; in the southern part of the upper Lake region, the lower Lake region, and the Ohio Valley, west or southwest, and in the Middle Atlantic States, northwest. The mean path of the prevailing winds[1] in these regions in winter is shown in fig. 1, No. 1.

As the meridional altitude of the sun increases, the thermal conditions which prevailed over the continent in winter become reversed; the interior becomes warmer than the oceans on the same parallels of latitude on both the east and west coasts and the Gulf of Mexico on the south. The consequence is, as pointed out by Ferrel,[2] the air over the interior of the continent becomes more rare than over the oceans, rises and flows out in all directions above; while the barometric pressure is diminished, and there is an inflow below from all sides to take its place. The effect of this general warming up is not sufficiently strong, however, completely to overcome and reverse the generally eastward drift of the atmosphere in these latitudes, but it is sufficiently powerful when the pressure gradients are weak to control the direction of the winds; hence, in the transitory months of spring and early summer the winds come alternately under the influence of (1) steep temperature and pressure gradients caused by the lingering cold of the continental interior, and (2) increasing solar radiation. The effect of the latter is seen mainly during intervals of clear weather and diminishing winds, which follow the passage of an area of high pressure and cold weather. As a consequence the winds of spring are more variable than those of winter, as may be seen from fig. 1, No. 2, where are charted the prevailing winds of spring.

An interesting fact in connection with the winds of spring is the beginning of what appears to be a slight monsoon influence on Lake Michigan, viz, onshore winds from April to September of each year, due in part, it is believed, to the difference of temperature which prevails between the lake surface and contiguous land surfaces, and in part to the prevailing pressure distribution in the late spring months.

The prevailing winds on the southwest shore of the lake, as may be seen from the data for Chicago, Table 1, are northeast from April to September; on the west shore, as at Milwaukee, northeast for April and May, and southeast from June to August, or from the lake to the land in both cases. At Escanaba, on Green Bay, the prevailing winds are northerly until May, then southerly from May to October, both inclusive. The prevailing winds at Grand Haven, the only available station on the east shore, are easterly in April and southwesterly from May to September, with, however, a large percentage of northwesterly winds in July and August. Thus it will be seen

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[1] The term "prevailing" unfortunately does not afford any indication of the relative frequency of the winds so designated. If the wind blew an equal number of times from each of the eight principal points of the compass, it would be said to have no prevailing direction, there being 12.5 per cent from each direction. If, on the other hand, it had blown as much as 13 per cent from any direction, that direction would be designated as the prevailing one. The term "prevailing" may, therefore, indicate winds of frequency ranging between 13 and 100 per cent. In Table 1 is given the percentage of wind from each of the eight principal points of the compass as determined hourly by automatically recording instruments.

[2] See "A Popular Treatise on the Winds".