Transactions of the Wisconsin Academy of Sciences, Arts and Letters. volume XVI, Part I, No. 3 1908

TRANSACTIONS

OF THE

WISCONSIN ACADEMY

OF

SCIENCES, ARTS AND LETTERS

VOL. XVI, PART I, NO. 3

EDITED BY THE SECRETARY.

Published by Authority of Law.

MADISON, WIS.:
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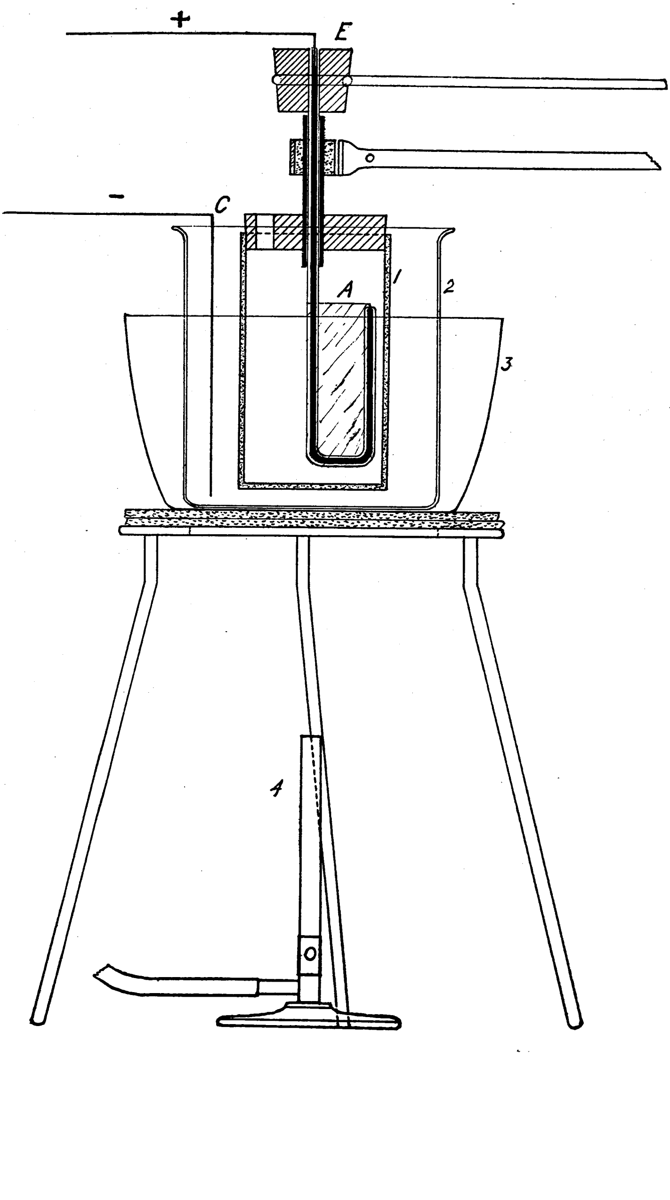
PRICE 50 CENTS.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ELECTROLYTIC PRODUCTION OF IODOFORM.

ARDEN R. JOHNSON.

An experiment very commonly assigned to students of electrochemistry is the electrolytic production of iodoform. The experiment is an especially good one for the beginner in the more difficult field of organic electrosynthesis, as the main reaction can be quite easily controlled and the product readily separated.

However, as most of the work has been done with acetone in place of ethyl alcohol as the ingredient to be oxidized, obviously on account of the better commercial possibilities for a process using the former substance, the use of alcohol, even in the laboratory, has been tried but little. Nevertheless, the use of alcohol in place of acetone has some distinct advantages over the latter in laboratory work at least.

The purpose of the experimental work herein described was to study the conditions most favorable to a maximum yield of iodoform from alcohol with the least consumption of materials and electrical energy. The matter of efficiencies particularly has been kept in sight at all times, for it is upon this very point that many conflicting data and confusion are found in the literature on the subject.

The apparatus used consisted of a porous cup (1), (Plate X), of 120 c. c. capacity, placed in a beaker (2), and this latter in a water bath (3). The whole could be heated to any desired temperature by means of the Bunsen burner (4). A, is a rotating anode of sheet platinum arranged in the loop of a piece of glass tubing bent into the shape of a J at one end. One corner of the platinum was sealed into the short leg of the tube and then the whole tube was filled with mercury. At the upper end of the longer leg was provided a pulley and bearing. The porous cup could be entirely closed, or provided with a reflux condenser. By means of a wire dipping into the top of the mercury column at (e) the current passed to the platinum anode, through the electrolyte and porous cup, to the iron cathode (c). A thermometer was always kept in the beaker.

Into the inner, or anode chamber of the apparatus, was introduced a solution of the following composition: H_2O, 60 cc.; alcohol, 50 cc.; KI, 20 g.; $M_2\ CO_3$, 6g.

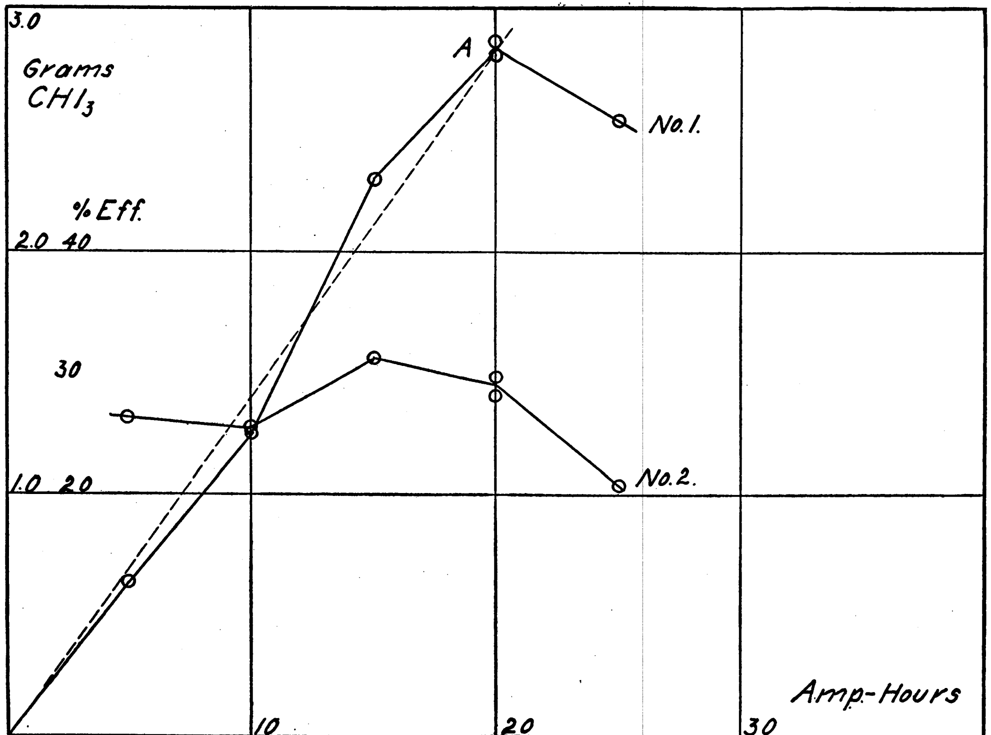
We regard the function of the electric current as that of primarily decomposing the KI, setting iodine free at the anode, and potassium at the cathode. The formation of iodoform is then the result of a series of secondary reactions which go on theoretically as shown by the following equations:

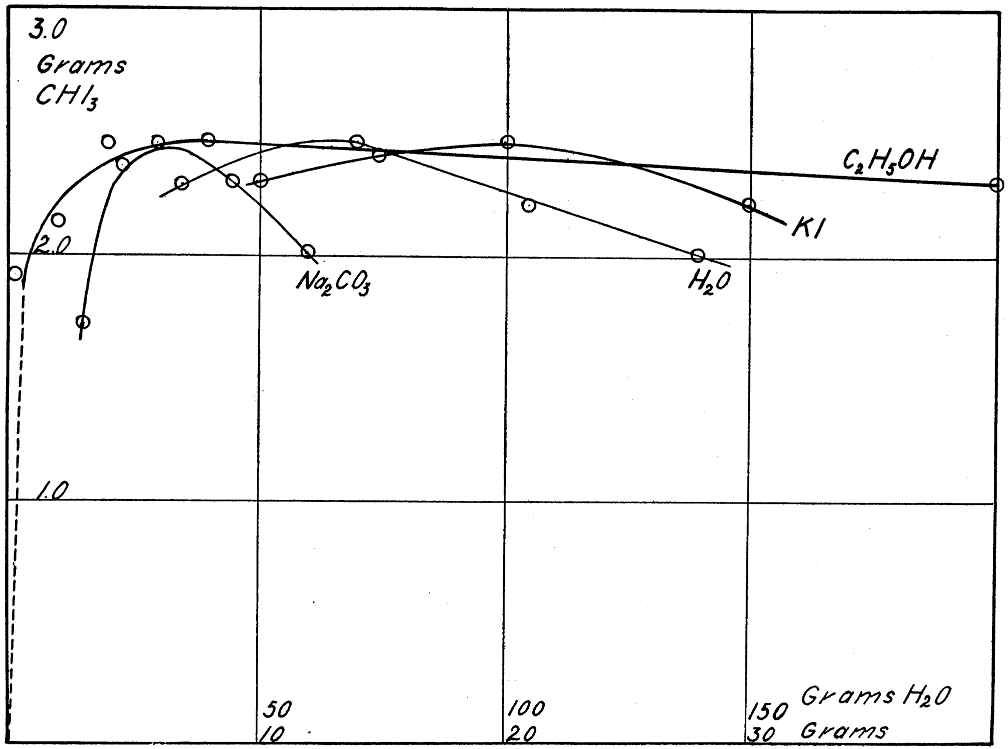
A. $CH_3\,CH_2O + 2I = CH_3\,CHO + 2HI$

$CH_3\,CHO + 6I = CI_3\,CHO + 3HI$

$CH_3\,CHO + HOH = CHI_3 + HCOOH$

The iodine first oxidizes the alcohol to aldehyde, then substitutes the three hydrogen atoms on one carbon atom forming the tri-iodo-aldehyde. This product in a weak alkaline, warm solution, breaks up into iodoform and formic acid. The purpose of the $Na_2\ CO_3$ is to neutralize the HI and HCOOH. The first trials with the above named electrolytes resulted as shown graphically by curve No. 1, Plate XI. Along the X axis were plotted ampere-hours and along the Y axis yields of iodoform in grams. Curve No. 2 is the corresponding current efficiency curve. Consideration of curve No. 1 shows us that to a certain point the yield of CHI_3 is approximately proportional to the number of ampere-hours. At point A, quite likely, the electrolyte had become depleted in one of the essential ingredients. The fact that the yield of iodoform is a linear function of the number of ampere-hours also suggests that there is a certain definite current efficiency. If a portion of the iodine liberated goes to form by-products, then this proportion of the whole amount of iodine liberated by the current is about constant under normal conditions. Curve No. 2 shows


3.0
Grams
CHI_3
% Eff.
2.0 40
30
1.0 20
A
No. 1.
No. 2.
10
20
30
Amp-Hours


3.0
Grams
CHI_3
C_2H_5OH
KI
2.0
Na_2CO_3
H_2O
1.0
50
10
100
20
150
30
Grams H_2O
Grams

that the current efficiency varied between 20 per cent and 31 per cent.

Another glance at equations, (A), representing the mechanism of the reaction, shows that it takes 2 iodine atoms to oxidize the molecule of alcohol to the corresponding aldehyde, and 6 more to bring about the substitution. Out of a total of 8, only 3 atoms of iodine appear in the product which we seek. Consequently, if the reaction went on ideally, just as depicted by equation A, only $\frac{3}{8}$, or 37.5 per cent of the iodine, could possibly be utilized, hence a maximum current efficiency of 37.5 per cent.

In order to find out the effect upon the yield of iodoform of the quantity of any particular compound necessary in the electrolyte, the concentrations of all the other ingredients were kept constant and that of the ingredient under test varied. A temperature of 70°–75° C. and a current density of 1.85 amperes per square decimeter, and 1.5 ampere-hours, were values maintained constant in all trials. The curves plotted with grams of ingredients as abscissae and of iodoform yield as ordinates show the results. (Plate XII.) The maximum point of the KI curve corresponds to 20g. of this salt; 65g., H^2O; 6g. $NA^2\ CO^3$; and about 6g. of alcohol.

Now, from equation (A), we can calculate about what the relative amounts of the different ingredients ought to be if everything went on as the equation indicates:

Ingredients.	CHI_3	Na_2CO_3	KI	C_2H_5OH	H_2O
Calculated am'ts per 1.5 ampere hrs...	2.45g	2.0g	8.3g	0.3g	....
Amounts actually required............	2.45g	6.0g	20.0g	4.0g	65g

The preceding table shows that to obtain the highest yield of iodoform we must use about 3 times the calculated amount of $Na_2\ CO_3$, more than twice the theoretical amount of KI, and at least 13 times the calculated amount of alcohol. It may be remarked that $Na_2\ CO_3$ and $K_2\ CO_3$ give exactly the same yield if added in amounts proportional to their molecular weights.

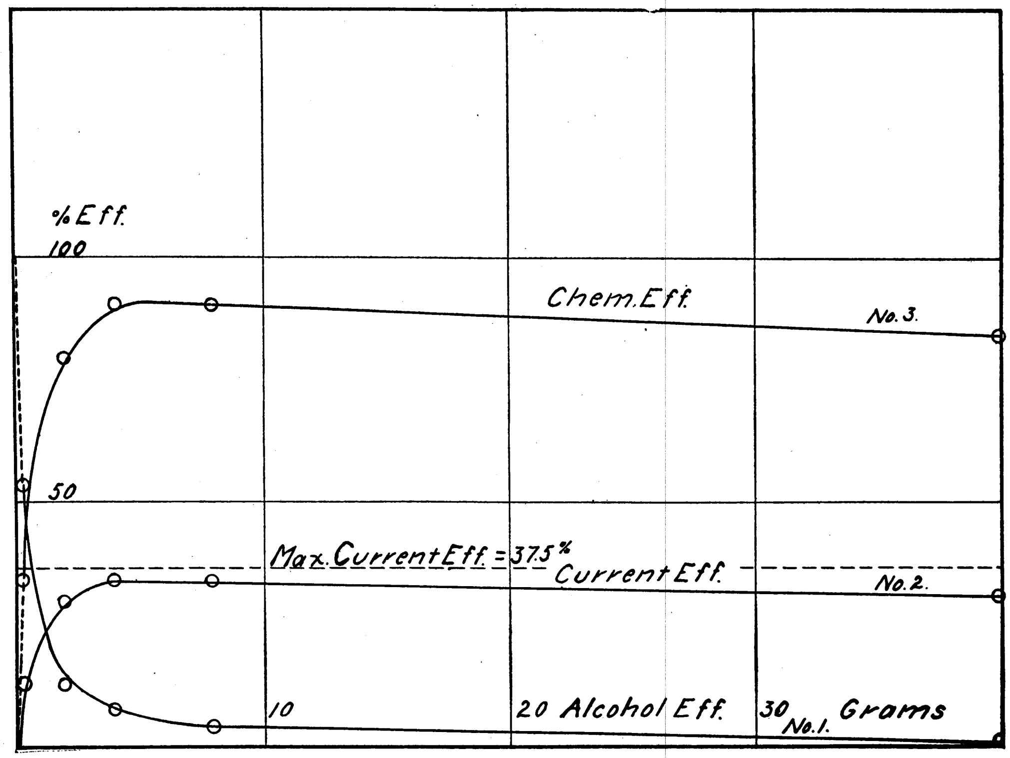
Experiments were also tried in which the theoretical amount of KI was taken, and in addition a certain amount of some foreign salt. It was found that if a comparatively large amount of Na Cl was added to the electrolyte, the yield of CHI_3 approached more nearly to the theoretical yield. Small amounts of Na Cl seemed to have but very little effect. The addition of an amount of $K\ Cl\ O_3$ equal to the calculated amount of KI also caused an increase in the yield.

Plate XIII shows some efficiency curves obtained by plotting grams of ingredients along the X axis, and per cent efficiency along the Y axis. Curve No. 1 is an alcohol efficiency curve, and by alcohol efficiency is meant the ratio of the total amount of alcohol actually converted into iodoform to the total amount added to the electrolyte. Curve No. 2 represents the current efficiency and lastly, curve No. 3 represents what may be termed a chemical efficiency curve, that is, the ratio of the amount of CHI_3 obtained to the amount our equations (A) tells us we ought to get if all went ideally. These curves show that a reasonably quantitative reaction for alcohol may be obtained only at the sacrifice of very low current and chemical efficiencies.

The highest chemical efficiency obtained was about 91 per cent; the greatest current efficiency 34 per cent, and the best alcohol efficiency 54 per cent. To obtain a current efficiency higher than 37.5 per cent would require a radical change in the chemistry of the process.

Data: Curves on sheet No. 1.

Trials.	Hours.	Current.	Ampere hours.	Grams CHI_3	Current efficiency.
					Per cent
1	1	0.5 amp.	0.5	0.6505	26.6
2	2	"	1.0	1.2505	25.63
3	3	"	1.5	2.309	31.50
4	4	"	2.0	2.8072	28.75
5	4	"	2.0	2.8583	29.6
6	5	"	2.5	2.5295	20.95


% Eff.
100
50
Chem. Eff.
No. 3.
Max. Current Eff. = 37.5%
Current Eff.
No. 2.
10
20 Alcohol Eff.
30
No. 1.
Grams

Data: Effect of foreign substances on yield.

H_2O.	Na_2CO_3	C_2H_5OH	10gKI Plus	Yield of CHI_3	Ampere hours.
70g.	6g.	4g	7.36g. KBr	2.193g	1.5
"	"	"	20g. NaCl	2.364	"
"	"	"	10g. $KClO_3$	2.393	"
"	"	"	10g. $KClO_4$	2.143	"

Data: (Curves, sheets 2 and 3).

H_2O.	Na_2CO_3.	C_2H_5OH.	KI.	CHI_3.	Amp. hours.	Alcohol eff.	Current eff.	Chem. eff.
						Per cent.	Per cent.	Per cent.
70g.	6g.	40g.	20g.	2.31g.	1.5	0.676	31.5	84.2
"	"	8.	"	2.46	"	3.61	34.+	91.
"	"	4.	"	2.45	"	7.2	34.	90.75
"	"	2.	"	2.14	"	12.52	29.8	79.5
"	"	0.2	"	0.923	"	54.1	12.78	34.03
"	3.	4.	"	1.71	"	....	....	....
"	4 75	"	"	2.352	"	....	....	....
"	6.	"	"	2.45	"	....	....	....
"	9.	"	"	2.285	"	....	....	....
"	12.	"	"	2.03	"	....	....	....
"	6.	"	10	2.294	"	....	....	....
"	"	"	15	2.411	"	....	....	....
"	"	"	20	2.450	"	....	....	....
"	"	"	30	2.214	"	....	....	....
35	"	"	20	2.288	"	....	....	....
70	"	"	"	2.45	"	....	....	....
105	"	"	"	2.191	"	....	....	....
140	"	"	"	2.005	"	....	....	....

Note: It was found that the current density could be varied within very wide limits without materially affecting the yield of iodoform.

The temperature of the bath varied from 70° to 75°C.

PECULIAR LOCAL DEPOSITS ON BLUFFS ADJACENT TO THE MISSISSIPPI.

GEORGE HULL SQUIRE.

The driftless area of Wisconsin includes three subdivisions differing quite markedly in topographic peculiarities. They are:

1. The lead region south of the Wisconsin.

2. The hilly area between the Wisconsin and the Mississippi —the central.

3. The region of low reliefs north of the northern escarpment of the Lower Magnesian Limestone—the northern.

The distinctive characteristics of the third area are sufficiently obvious.

The first two regions share in common a much stronger relief but their distinctive differences are quite marked and of much importance in their bearing on local glaciation.

I would refer more particularly to the somewhat greater altitude of the bluffs in the central region, the much greater depth and steepness of the valleys, and the greater depth of the fillings in the valleys.

If we compare like parts of the two areas, the bluffs of the central one will show approximately two hundred feet the greater altitude.[1]

Its valleys, however, do not share in this greater elevation. On the contrary if we compare valley sections equally remote from the main divide their altitudes are not only relatively, but often actually less. They are consequently very much deeper.

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[1] There are very few altitude readings for the bluffs of the central area. The figures given were obtained indirectly.

The topographic sheets of the lead region show that few of the valleys exceed 150 feet deep in a cross section, although the extreme range between the highest parts of the divide and the valley bottoms is somewhat greater.

In the central area the valleys show depths of 400′, 450′, perhaps in places even 500′ on a width between summits of 2,000′ to 3,000′.

This disparity in depth would be still further increased did the comparison extend to the ruck floors. The deposits on the valley bottom being rather shallow in the lead region.[2]

The average for the central area as a whole I have no means of estimating, but for the east—west belt which includes the La Crosse and Lemonweir valleys I think it will exceed 100′, and that in places it will nearly reach 300′.

The disproportionate depth of the valley floors in the two regions is somewhat suggestive of crustal warping.

Of the three areas, the lead region has received by far the most study; the central, I think, the least.

Nearly half a century ago J. D. Whitney[1] described a group of sandstone blocks which were about 125′ above their proper horizon.

A few years later Moses Strong[2] described two other occurrences of a similar character of which one was three, the other five miles from the nearest outcrop of the St. Peter sandstone.

More recently F. W. Sardeson[3] has described certain accumulations of clay, chert and sandstone blocks in the Pecatonica Valley having a somewhat morainic aspect.

Although I have never visited the lead region I should like to call attention to one aspect of the case which shows at the same time the extent of the glaciation problem as presented in the lead region and the great difference between the problem as there presented and as presented in the central region.

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2 Chamberlin and Salisbury give 18.17′ as the average of fifty-five measurements. Sixth Annual Report U. S. Geological Survey p. 250, 1885.

1 Geology of Wisconsin Vol. 1, P. 137, 1861.

2 Geology of Wisconsin, Vol. 2, P. 667, 1877.

3 American Geologist, Vol. 20, P. 392, Dec., 1897.

The bowlder groups noted by Strong were both of them altogether out of the path of true valley glaciers. One was "on the ridge between the Strickland and Myers branches" headwater streams of an eastern affluent of Fever River. No sandstone is shown on this affluent and but a small expanse on the main stream. If they were glacially transported we are virtually forced to the conclusion that they have crossed a divide from some other valley.

The other, a few miles west of south from Dodgeville, is on an upland where a glacier must have moved up the Pecatonica to have reached it. As a glacial deposit its probable source would be somewhere on the opposite, or Wisconsin slope of the main divide.

We are therefore forced to conclude that if there was glaciation it was of a thoroughly confluent type and on a scale so extensive that the Wisconsin Valley was filled to the point of overflow.

It would indeed be a physical impossibility that snow fields should form on the divide of sufficient volume to feed a southward flowing ice sheet twenty to twenty-five miles long without involving the Wisconsin Valley.[1]

The fact that the problem is thus extensive must needs inspire great caution in the interpretation of isolated features.

Contrasting strongly with the all-embracing ice cap as above outlined, the glaciation of the central area so far as the deposits give us an idea as to their extent, was by strictly valley glaciers of no great length, and not fed from common snow fields unless the vicinity of Tomah should be a partial exception.

The depth and steepness of the valleys would make them admirable receptacles for wind-drifted snow. The balance of probability is in favor of their having been filled by such deposits unless precipitation in the driftless region was practically nil. Not all of such deposits could have developed glacial motion, perhaps only a small part, but there are situations in

[1] In working out the above relationship the writer has made use of the excellent topographic sheets of the lead region.

which so far as we can judge, the conditions for motion were as favorable as in situations now occupied by small active glaciers.

The third, or northern area is too gentle in its reliefs to permit the formation of glaciers of the type here considered. It has been often studied and still receives much attention, with the purpose of locating the margins of the earlier drift sheets with greater precision.

My own labor has been bestowed on the central area or more accurately, on a few localities along its northern margin.

It was somewhat early in the eighties, I think in 1884, that the writer while spending a few days at Tomah (in Monroe county) was struck by the rather peculiar forms and the distribution of the hills of chert gravel and sand in that vicinity.

A year or two later, in making an excavation near Trempealeau, he discovered a bowldery ridge near the lower end, and transverse to the axis of a small valley.

For a few years thereafter, as opportunity offered, I sought for similar ridges in other valleys. Progress was slow, both on account of limited time and on account of the natural difficulties of a search where the deposits studied have been so thoroughly concealed by later deposits as is the case with these. The results of the search were given in The Journal of Geology.[1]

Soon after, in seeking for deposits corresponding to lateral moraines, I discovered the features which form the more especial topics of this article. They were described in the following year.[2]

In the meantime I had revisited Tomah and in 1894 submitted to Prof. Chamberlin an article descriptive of those features. He makes reference to it in a prefatory note attached to my first article giving his reasons for non-acceptance.

In the presentation of his reasons he displays his customary fairness and moderation.

In a third visit subsequent to this date I discovered features

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1 Vol. V, No. 8, P. 825, 1897.

2 Journal of Geology, Vol. VI, No. 2, P. 182, 1898.

much more strongly resembling kame moraine and outwash deltas and at the same time much more difficult to explain otherwise, than anything I had been able to note in the article to which he refers.

I think it but justice to myself to say that there are two considerations which weaken the force of the negative argument based on the absence of limestone from the deposits.

One is the abundance of chert in the limestone, which is very abnormal. Although the porportion of chert is not as great as in the cap of the west Blue Mound, a comparison with it would not be altogether inapt. So far as my very limited observation extended, limestone debris is rather scanty even on talus slopes where it would naturally be looked for.

The other is that chert fragents not preceptibly deangulated are quite abundant several miles from the present source of supply. They look as though freshly torn from the ledge.

Inasmuch as chert, when it forms solid, continuous strata of considerable thickness as it does here, is, in the process of weathering, left to form the out-jutting ledges, the limestone only showing in the re-entrants, it seems but natural that it should have been chert rather than limestone that a glacier should have taken as its tribute.

The vicinity of Tomah is very rich in interesting features. But their complexity to which much of the interest is due renders them difficult of description without much more of detailed study than I have thus far been able to give them.

In what has preceded I have confined my remarks to such features as are more or less closely related to the question of local glaciation, but I wish to add that both the possibly glacial and the admittedly non-glacial deposits of the region combine to furnish an interesting chapter in Pleistocene history.

My purpose in giving this somewhat lengthy introduction has been in part to present an outline of the present status of the question and at the same time to show the place which the features that I am about to describe hold in the general scheme.

I have selected these features for special description because on account of their proximity to my home and their openness to observation, the facts regarding them are more completely available than are those connected with any other class of phenomena.

The deposits in question may be concisely described by saying that they consist almost exclusively of material derived from the limestone capping of the higher bluffs (Lower Magnesian) occurring in positions to which no agency now operative could have carried it under existing topographic conditions.[1]

Thus far, only two hypotheses have been suggested in explanation.

1. That the deposits were formed as normal talus or hillside debris at a time when the topography was such as to permit it. That, in fact, they measure the topographic changes which have taken place since their deposition.

2. That they resulted from the operation of some agent not now acting. Virtually this limits us to some from among that class of activities which we recognize as glacial.

In describing the features as glacial phenomena one would wish to place them by the side of all other phenomena referable to the same cause. This, however, is not my present purpose, and I shall only speak incidentally of the glacial aspect giving my attention rather to such facts as bear on the first hypothesis.

Geographically the occurrences which I have thus far discovered are all quite near the Mississippi River to which vicinity my search has been largely limited. Taking into account only those which are well defined I may enumerate twelve of which eight are among the Trempealeau bluffs, which have been quite thoroughly explored, and four elsewhere, which include but an infinitesimal part of the possible localities.

Classified according to the topographic features with which they are associated, six are on the bounding buttresses of circs.

[1] The typical deposits among the Trempealeau Bluffs have been viewed at different times by Messrs. Salisbury, Leverett and Weidman. Not one of them so far as I am aware, has committed himself to any explanatory hypothesis, but I think all would recognize the correctness of this definitive statment.

One is on one side of a col. Three are on the outwardly projecting angles of bluffs abutting diagonally on the river (Fig. 1). One is connected with two ridges projecting from opposite sides, and nearly shutting in a small bluff alcove; and one is on the outer scarp of a foothill facing the river.

If we compare the deposits in question with the normal talus we find that whereas the latter follows the general law in composition, being a composite of material from all overlying formations, the former, although having an observed vertical range of nearly 300′, is everywhere practically identical in composition. The only included material not derived from the limestone being some of the harder sandstone immediately subjacent.

Wherever I have been able to examine the base, I have found the deposit overlying normal talus or rock waste with well defined unconformity, the two deposits being perfectly distinct up to the line of junction.

The hypothesis under consideration necessarily assumes a rather notable persistence for certain accumulations of hillside waste, exceeding, under certain conditions at least, that of the hill from which it was derived.

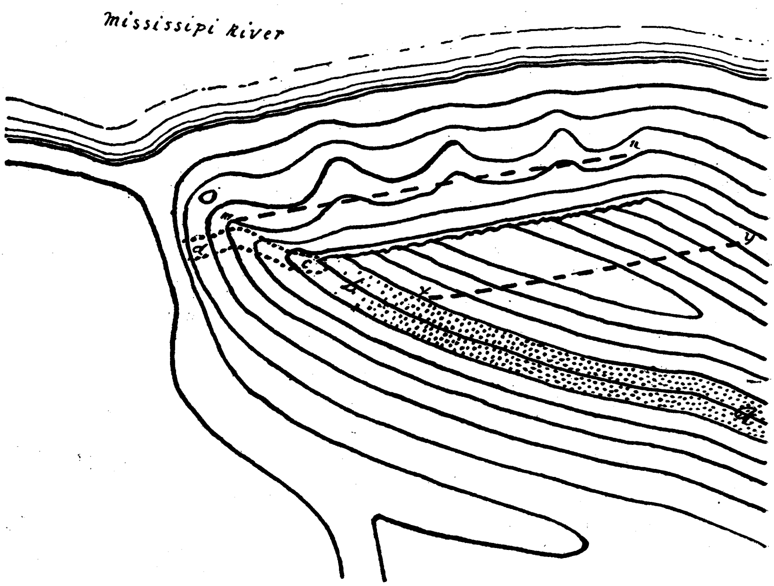
It will be recognized that this assumption is not in harmony with the general law that material detached from a ledge is subject to more rapid disintegration than the parent ledge, because in proportion to bulk a greater surface is exposed to weathering. In any given case it would require very clear evidence to overbalance this adverse presumption. I shall endeavor in what follows, to bring out such evidence as may be afforded by local and specific conditions.

It is not difficult to show for the region under consideration that unless it be in certain special cases, the relative endurance of fragmental deposits, and of the parent ledge harmonizes fully with the law above stated, for although the lower slopes of the hills up to an average height of three hundred feet are so thickly mantled with Loess that the true talus is rarely exposed, the horizon of the Madison sandstone is almost never so covered, and all fragmental deposits from the overlying limestone are conspicuously shown in contrast with its own sandy residuum.

We may see examples illustrating all stages from those in which the limestone capping of the hills displays nearly its full thickness, to those in which it is represented only by the last vanishing remnants.

Everywhere, unless the deposits in question are exceptions, we find the closest correspondence between the thickness of the limestone cap, and the abundance of its debris in the talus. An an appreciable quantity the debris disappears the sooner. As soon moreover as any particular horizon of the limestone disappears from the cap, it ceases to have representation in the talus, whereas the deposits in question represent at least a good share of its total thickness. Under ordinary conditions, therefore, the limestone debris as compared with the parent ledge is shown as relatively very ephemeral. If it ever shows the greater endurance it must be in certain special cases in which the ledge is removed with abnormal rapidity. Such conditions are presented by those bluffs which standing diagonally to the river, present mural fronts at the ends where basal erosion is active. The example which I have chosen for illustration, Fig 1, is known as Queen's Bluff. It is on the Minnesota side of the river, about eight miles below Trempealeau. It shows I think the highest vertical escarpment on the river.

The cliff faces about north, while on the south side the slopes are normal. The recession of the cliff gives rise to progressive shortening of the west end of the bluff. When in the future, the line of cliff shall come to occupy some position, *e. g.*, a section of the lower slopes now within range of limestone waste, will cease to be so just as some portions now out of range, would have been in range when the line of cliff stood at say *m n*. If, under the conditions the limestone waste on the south side of the bluff persists after the disappearance of its parent ledge it should not only extend from *a* to *b*, with little apparent diminution, but beyond *b* toward *o*, gradually diminishing with increasing distance. The actual conditions are substantially as follows: At *a* the limestone debris, as displayed along the Madison horizon is quite abundant, continuing so perhaps two-thirds of the distance to *b*. It then begins to diminish in abundance, quite rapidly toward the end,



Text Fig. 1. Diagramatic plan of Queen's Bluff.

The contour lines indicate intervals of about 50′

The dotted belt *a. b.*, is the horizon at the Madison beds and by the frequency of the dots I have endeavored to convey an idea of the relative abundance of limestone debris along that horizon. The portion above the dotted belt is the Lower Magnesian cap.

The deposit *c. d.* is interrupted for a space above *d*, apparently covered by Loess. At *d.* the deposit forms a double ridge, with an interval of a rod or two between.

Below *d.* the deposit has been removed by the forming of a new rock gorge, the old valley axis to the westward being closed. The character of the filling is not well shown. Such newly cut channels are not uncommon, and are not necessarily due to the closing of an old channel by morainic deposits.

and is wanting for a considerable space near *b* (about 30′ in this case but much more in other cases). Outside of *b* toward *o* we reach the upper end of the deposit *c* resting on sandstone waste and rising abruptly, and steeply to a hight of six feet.

From this knob like end, the low ridge—the form the deposit assumes—follows down the crest of the bluff, which in the Mendota horizon still presents a partly mural front to the river. Then curving it follows a course more directly down the hillside nearly to the bottom. (In one of the three examples in this class it crosses the valley bottom and runs up an unascertained distance on the other side of the valley, and is partly cut through by the drainage channel.)

It is apparent therefore that even under the most favorable conditions the talus shows not the slightest tendency to superior endurance, while the deposits in question show characteristics, and extend to points for which the hypothesis offers no explanation. Occurrences to be described, will show both how great an antiquity the hypothesis would require that we assign the deposits, also that in fact they are quite recent.

The topographic features to which I have applied the term circs, are the joint product of the active erosion induced by the near vicinity of the river, and of the rather definite composition, and arrangement of the stratigraphic pile on which it acts.

They are therefore not only limited to the near vicinity of the river, but also to a rather short stretch of the river, about forty miles in length. The dip of the strata, both up and down the river bringing about an entire change in the character of the stratigraphic pile, and a corresponding change in the erosional forms. The circs show narrow outlets, floors of moderate slope which widen rapidly upward, ending in wide, but steep, sometimes precipitous, slopes next the bluffs. The buttresses naturally reverse the conditions, being narrow next the bluff, and widening rapidly outward. Plate XIV, Fig. 2, which is a view looking along the south front of the main mass of the Trempealeau Bluffs, shows a good example of this topographic type, two circs with their separating buttress, being seen in the foreground.

The deposits are found on the buttress in the foreground, on the further side of the second circ, and on the hither edge of a circ in the background, also on a buttress still further along, concealed by the rocky point. Plate XIV, Fig. 3, shows this last buttress, and the same rocky peak seen from the east. In this figure the buttress (shown as a slight convexity or shoulder at the left of the peak) is a considerable distance to the eastward of the peak, the nearest source of the material, and quite out of range of rolling material, even were the circ not present.

Of all the occurrences thus far discovered, those shown in Fig. 1 are most susceptible of explanation under the assumed hypothesis (survival of talus) since the bluff top above carries a thick capping of limestone. But since it is obviously impossible that talus should have formed aggregations of such form as are now presented, the hypothesis assumes that the deposit was once continuous along the bluff side, and that the circs have—in large part at least—been excavated in such deposits.

There are however two fatal objections to this assumption *a.* The composition of the deposits is radically different from that of normal talus of the same horizon; and *b,* it necessitates the assumption that here existed a continuous shelf some 300′ above the river, of such width and slope as to give support to talus deposits 15′ to 25′ in thickness. Such a shelf in such a position would however be a topographic anomaly, at least in this region.

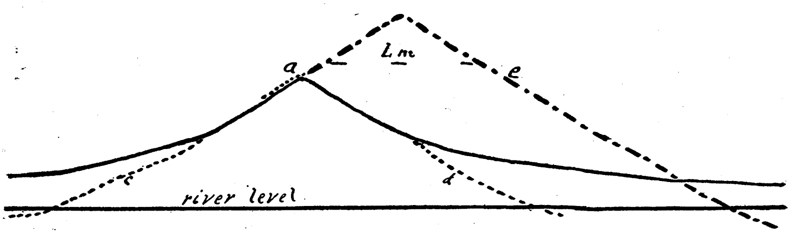
In classifying the occurrences according to topographic association, I noted one on ridges near the opening of a small valley. I have sometimes spoken of these ridges as buttresses, but they have no relation either in form or origin to those above referred to in connection with circs. They are offsets from the sides of the valley at its outer end, of about the same hight, and so placed that were the notch between them closed there would result an almost direct ridge from side to side. The valley itself shows the well rounded ampitheatre like contours characteristic of maturity both in the short, and in the digital ends of the longer valleys of the region, the ridges alone breaking into its normal symmetry of form. As topographic features they are a decided anomaly. They would be easily explained if we could assume the existence of a much harder ledge of rock crossing the valley, but in this region of undisturbed rocks, and in the upper part of the Potsdam, the explanation fails. No exposure of rock in place was observed anywhere about them. Whatever rock cores there may be in these ridges, they are deeply covered by rock waste from the lower Magnesian. The drainage passes through the ridge by a notch barely wide enough at bottom for the torrent course and very steep. Both in its bed, and in the ends of the ridges, there is nothing visible save the limestone debris of which the fragments are unusually large, and from the notch to the foot of the bluff the torrent course is a continuous cascade over similar material. One can hardly overlook the strong morainic aspect of these ridges in their entirety, yet they are so very massive, and prominent that I hesitate to claim them as such until further evidence is available.

I have shown that even where a bluff is being most rapidly removed by erosion, the talus shows no tendency to survive the disappearance of its parent ledge. The occurrence now to be described will show how extreme an endurance would under the hypothesis have to be assigned to it.

At the head of one of the small valleys in the Trempealeau bluffs is a col whose lowest point is somewhat above the base of the Madison sandstone. Along the south side of this col for a distance of 350 feet the deposits occur, partly reaching the summit and partly falling short of it, also showing lobate extensions down the hillside seventy-five feet or more below the main body. The col separates two opposing valleys, that on the north being much the shorter. While the river occupied its northern channel it would have had the advantage of the steeper gradient. Since that time there has been little advantage either way.

In Fig. 2, I show a section of the hill as it now exists, in solid lines, and on the north side, in broken lines, a section of the hill as it must have existed in order to have furnished the material, and indicating what must have been removed since the deposits were formed, the deposits and the south side of the hill meanwhile remaining intact. It amounted to a southward migration of the divide of about 150 feet.

In the occurrences thus far described there has been nothing tending to fix the age of the deposits save such limits as their capacity for endurance may suggest. There are two features however, which serve to fix their age within rather narrow limits. The inferior limits are fixed by the fact that in several places the deposits are seen to pass under Loess showing that they are older than at least a part of that formation. Its superior limit is fixed by the fact of its occurrence on the outer scarps of the foot hills facing the river. When the Mississippi forsook its old channel north of the bluffs and adopted the captured valley of a small tributary on the south there began a process of readjustment to adopt the small valley to its new service. This readjustment consisted in an energetic basal erosion which removed the lower slope of the bluffs giving rise to steep frontal scarps.



Text Fig. 2. The entire line gives a sectional outline of the hill as it now exists. The broken lines *c. d.* show the approximate position of the rock surface and will give some idea of the amount of filling on the lower slopes of the bluffs.

The outline in dots and dashes shows the outlines of the bluff as it must have been to have furnished material for the deposit a. I have indicated Lm. the position of the Lower Magnesian cap.

The distance from *a.* to *e.* was something like 300′.

Near Trempealeau Bay this scarp is particularly well developed, rising in one place almost precipitously from the waters edge. The circ opening out on this front is a hanging valley whose lip is about 100 feet above present river level. A few rods east of the outlet of this circ, on the steep slope, is one of the characteristic deposits, an isolated sub-circular patch perhaps 100 feet in diameter. It is evident that no appreciable recession of the scarp has occurred since the formation of the deposit, since it itself must have been among the first things to be removed.

This occurrence has in fact an important bearing on more than one point in local Pleistocene chronology. I alluded above to the fact that at one point the scarp rises directly from the water's edge. This is at the mouth of Trempealeau Bay. For a few hundred feet eastward from that the river is forced some two or three hundred feet outward by the massive depositional cone fronting the circ above mentioned. East of the cone the shore line is again conspicuous, at the foot of the scarp but the river bed is occupied by a lagoon. The historic sequence thus shown was: First, a long period of erosion (possibly more than once interrupted, but if so the evidence of the interruptions has been lost) during which the river was encroaching on the foot hills. During this period, whatever detrital output may have been furnished by the circ the river was able to keep it cleared away.[1]

There then followed a period during which the output of the circ was able to build up its cone apparently in the very face of the river (the base of the cone is at a considerable though unknown distance below present river level.) In doing so it furnished a protection to the scarp against further erosion. There is indicated therefore a very close time relation if not synchronism between the forming of the deposits and the building of the cones.

While as already stated it is not my purpose to discuss this question directly from the glacial standpoint it seems desirable to indicate the relations which these deposits are supposed to have held to glaciers. The fact that they are so universally composed of material from a certain horizon indicates that in some way the lower horizons were prevented from adding their contributions to them.

It is believed that with bodies of ice, or even semi-compacted snow resting against the sides of the bluffs with the upper edges somewhere near the base of the Lower Magnesian, the material from that horizon must have been largely superglacial, and that much of it would have moved across the steep upper surface by gravity aided by glacial drainage, and would have depended very little on the advance movement of the glacier itself.

The deposits themselves by their forms and positions, seem to confirm this belief. The one last described however—on the scarp—could only be explained as the result of superglacial drainage, being not only entirely removed from the direct action of a glacier occupying the circ, but on account of its peculiarly regular and sharp outlines impossible of formation by random rolling fragments, although there is no great interval between it and the marginal deposit of the circ.

RECAPITULATION.

Bearing in mind the hypothesis under consideration, that the deposits are survivals of normal talus, we note:

1. That they have a constant character at whatever horizon they occur, and differ from the normal talus of any horizon, and are sharply distinguished from it in section.

2. Normal talus, even under the most favorable conditions, shows no ability to survive the disappearance of the source of supply.

3. The topographic features with which some of the deposits are associated, are not only not especially favorable; they are notably unfavorable for the display of survival, because they assume an extreme and in every way improbable endurance.

4. The deposits are shown to be relatively recent.

G. H. Squier.

Trempealeau, Wis., March 30, 1907.

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[1] It is a somewhat surprising fact when we consider the great volume of water supposed to have passed down the Mississippi at its terrace stages, that by far the greatest share of the river's work in eroding the shore has been done at or near present river level, in this vicinity at least. There is indeed a rock terrace at 40′ to 60′ above present level, but its manner of forming rentrants at the openings of the valleys seems to show that it was an old gradation plain slightly modified by the river during its higher stages. Being lower than the upper terrace it is invisible away from the river but wells occasionally offer traces of it.

These are indications that a deep channel was maintained between the bluffs at Trempeleau, which did not become filled with deposits even during terrace stages.

PLATE XIV.

Fig. 2. Circs along south front of Trempealeau bluffs.

Fig. 3. Buttresses and peaks seen from the east. This figure also shows the outer scarp of the foot-hills to the left; but not at a favorable angle.

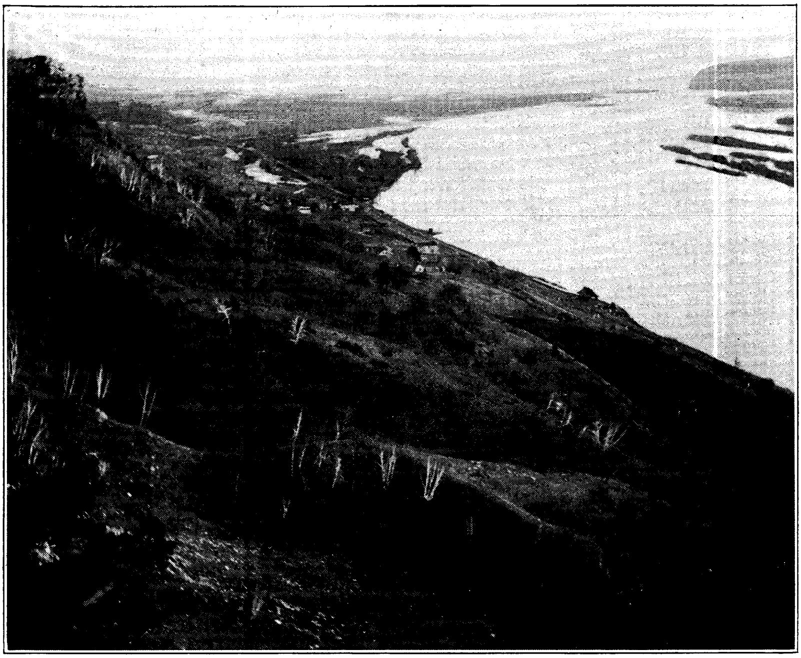

Fig .1.

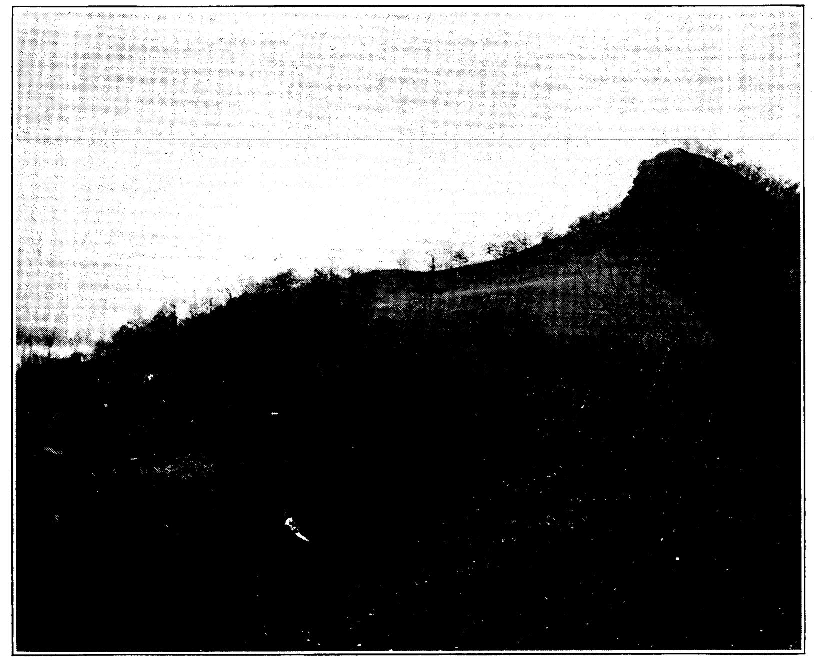

Fig. 2.

ON THE SUSPENSION OF SOLIDS IN FLUIDS AND THE NATURE OF COLLOIDS AND SOLUTIONS.

F. H. KING.

Sphere of Influence of Substances in Fluids.

When a glass marble, for example, with a thoroughly clean surface, is immersed in water it is impossible to withdraw it without bringing away a layer of adherent water. The removal of such a film proves that the marble possesses specific attraction for the water exceeding the internal molecular attraction of the water itself. Since the specific attraction of the marble for the water is great enough to withdraw a completely investing film in opposition to both gravity and the internal molecular attraction of the water, and since such a film may be borne about in the air, the simplest inference regarding this film of water is that while beneath the surface it likewise exists and travels with the marble whenever it is moved about in the water. In other words, through a mutual specific attraction between the marble and the water a portion of the water is differentiated from the balance of the mass, we have formed a new body, probably very nearly spherical in form, whose diameter exceeds that of the marble by twice the radius of specific attraction. This new body so formed will have a mean specific gravity determined by the relative volumes of the two substances, by their specific densities and by any compression which may result from the mutual specific attractions of the two members of the system.

So far as we are aware no one has determined the sphere of influence of any unit mass immersed in any fluid but, from various considerations, it appears that it must exceed the range of molecular attraction determined by Quincke, which he found to be 20 ten-thousandths of a millimeter.

When a long, wide glass tube, filled with water and held in a vertical position, is at once opened at both ends, permitting the water to fall bodily out, there remains behind, at the instant the mass has escaped, enough water to represent a film having a mean thickness of .1 m. m. Even immediately after draining has ceased, there may still be retained enough water to make a film of a mean thickness of .03 m. m. In such cases as this there appears to be no way in which surface tension can mechanically effect the retention of such water and yet the thickness of the film must exceed Quincke's range of molecular attraction 600 to 2,000-fold. Unless, therefore, there is some other cause for the retention of water in such cases we are justified in looking upon these as indicating something as to both the fact and the magnitude of a sphere of influence. Indeed, it appears clear that if such volumes of water as are here pointed out can remain stationary against the walls of a glass tube while it is being emptied, a similar volume would be likely to move through a fluid with a solid in motion.

In our studies of soil solutions and of the influence of soils and sands upon solutions of extremely soluble salts, phenomena have been observed which are difficult to explain except on the basis that solids immersed in a fluid may retain about or upon their surfaces a layer of the fluid which is restrained by them, from moving, or is compelled to move with them, in such a manner as to become an integral part of a compound system of solid and fluid. It has been found, for example, very difficult if not quite impossible to completely wash from a clean quartz sand so soluble a salt as potassium nitrate. In one case 50 grams of the dry sand was repeatedly treated with disulphonic acid to free it from all traces of nitric acid and of organic coloring matter, after which it was charged with a potassium nitrate solution which after a time, was drained away and the sand dried. Over 50 grams of the sand, so treated and placed in a porcelain evaporating dish, was poured 100 c. c. of distilled water in which, with continuous stirring it remained during three minutes, when the solution was drained away and the content of nitric acid determined. To the same sample of sand was added a second 100 cubic centimeter of distilled water in which it was washed by continuous stirring during three minutes and the solution drained away. This operation was repeated 10 times, after which the sand was dried and treated directly with disulphonic acid for the recovery of any nitrates which might have been retained. The first washing recovered, stating the results in round numbers, 3 milligrams, the second .3 milligram and the last four, when the rate of removal had become constant, carried away with each washing only .01 milligram. But on drying the sand, after the 10th washing, and treating it with disulphonic acid in the same manner that the nitric acid would be taken up from the evaporating dish itself in an ordinary determination, there was recovered nearly .8 of a milligram of nitrates, or nearly 3 times the amount which was recovered from the sand in the second washing and more than one quarter of that recovered with the first 100 cubic centimeters of solution.

It appears clear that, in this case, each individual sand grain must have appropriated to itself a certain amount of the first 100 cubic centimeters of distilled water added; that this amount of water took into solution the nitrates carried by the respective grains; that the identical molecules of water first appropriated by the individual sand grains remained with them throughout all of the agitation incident to the stirring associated with the 10 washings; that it was only by slow diffusion into rather than by a mechanical mixture of the retained water with the successive 100 cubic centimeters of distilled water added during the 10 washings that nitrate recovered from the sand found its way into the water drained away; and, hence, that through a mutual specific attraction of the sand grains and the water, a portion of the first 100 cubic centimeters was differentiated from the mass but a small portion, if any, of which was drained away in the succeeding washings, this water thus shielding from removal the nitrates retained about the sand grains except as influenced by diffusion.

Had there been no appreciable retention of water about the sand grains the concentration of nitrate in the successive washings would have followed the simple law of dilution, changing, as in the table, from 43.45 to .0000002 instead of from 35.75 parts per million in the first 100 cubic centimeters to .11 parts in the last washing, as was observed.

Observed and Computed Concentration of Nitrate in Successive Washings of Sand in Distilled Water.

No.	Water retained in sand.	Observed Concentration.	Computed Concentration.
	Grams.	Parts per million of Solution.	
1	12.7	35.75	43.4551000
2	13.2	3.30	4.8969000
3	13.1	.451	.5710100
4	13.4	.174	.0661390
5	13.05	.138	.0078153
6	13.3	.128	.0009023
7	13.5	.110	.0001059
8	13.5	.110	.0000126
9	13.5	.110	.0000015
10	13.4	.110	.0000002

Were the exact effective diameter of the sand grains experimented with known it would be possible to compute from the amount of water which did not drain away the minimum thickness of the water film which each controlled. It is certain that this diameter lay somewhere between .08 and .15 millimeters. The mean amount of solution retained after each of the 10 washings by the 50 grams of sand was 13.265 grams, the smallest amount retained in any one case being 12.7 and the largest 13.5 grams. Using this amount of water, which is 26.53 per cent of the dry weight of the sand, and a specific gravity of 2.65 for the sand grains, the minimum thickness of the water film would lie somewhere between .008 millimeter and .015 millimeters, where the diameter of the sand grain is taken at .08 and .15 millimeters. But since 13.265 grams is the amount of water which the sand was able to retain against gravity it is to be presumed that the thickness of the water film which would be controlled by the individual sand grains, when in suspension in water, would exceed the 8 to 15 thousandths of a millimeter computed.

There is another quite different set of phenomena which, likewise, appears to be most simply explained by a retained film of fluid about the surfaces of immersed solids. The law of flow of fluids through capillary tubes affirms that the volume per unit time is directly proportional to the effective pressure; but our own observations on the flow of water and of air through porous media recorded in the 19th Annual Report of the U. S. Geol. Survey, showed that of 44 capillary tubes experimented with 16 gave flows, throughout the entire range of pressure, increasing faster than the pressure while most of the others gave flows increasing faster than the pressure through a portion of the series. Of 55 comparisons of flow through wire gauze, under a water presure of 1 centimeter to 30 centimeters, in all but 5, the flow increased faster than the pressure. Of 147 comparisons of the flow of water through sandstone under a pressure of 21 centimeters to 1,055 centimeters of water, in all but three cases the flow increased more rapidly than the pressure. Of 132 comparisons of the flow of water through sands under pressures from 1 centimeter to 1,150 centimeters of water, in 100 of these the flow increased faster than the pressure. The flow of water has increased faster than the pressure by amounts, with sands, ranging from 0 to 45.79 per cent; with rock from 0 to 85.9 per cent and with capillary tubes from 0 to 20.9 per cent.

Of 59 comparisons of the flow of air through sand, dust shot, bundles of knitting needles and capillary tubes, under pressures ranging from 1 millimeter to 50 millimeters of water, in all but 10 cases the flow increased faster than the pressure. Of 121 comparisons of the flow of air through capillary tubes Meyer found 64 cases where the flow increased faster than the pressure; 52 cases where it increased slower than the pressure and but 5 cases of strict agreement with the law.

Finally, with all the observations of all observers, whether using sands, rock or capillary tubes; whether with high or low pressures and whether with long or short tubes or columns, the departures from the law of capillary flow have been systematically in series either plus or minus instead of in single observations, first one side and then the other, as should be expected if the observed departures were due to errors of observation or of manipulation.

It has, from the first, been recognized that under certain relations of length and diameter of tube to velocity of flow the law of capillary flow did not hold and that the discharge fell below the amount computed. This falling away in the amount of visible work done has been explained by the absorption of energy at the ends and within the body of the tube through the setting up of vortex or other movements of the fluid more or less transverse to the axis of the main stream, which necessarily absorb more or less energy, tending to produce flow and thus to diminish the amount of discharge in unit time. But the fact that the flow may increase faster than the pressure does not appear to have been generally recognized or considered significant and we have nowhere seen it explicitly stated in any discussion of the law of capillary flow.

It is true that a flow increasing more rapidly than the pressure could occur only under conditions where the resistance to flow became less as the pressure became greater, and as the earlier theoretical investigations of Maxwell lead to the deduction that the viscosity of gases must be independent of pressure there was no apparent means of explaining a flow which increased more rapidly than the pressure.

The later experimental investigations of Rőngten,[1] Warburg and Kundt,[2] Warburg and Sachs,[1] and Cohen,[3] appear to have established the fact that the viscosity of both water and air does change with pressure, that of water appearing to decrease in some amount or ratio with an increase of pressure. At any rate their observations indicate that for water the flow through capillary tubes increases faster than the pressure, even when

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1 Annalen der Physik und Chemie, Vol. XXII, 1884, pp. 510, 518.
2 Annalen der Physik, Vol. CLV, 1875 p. 337.
3 Annalen der Physik und Chemie, Vol. XLV, 1892 p. 666.

that pressure is very great, and this has been interpreted as meaning that the viscosity has decreased with increased pressure.

It is a significant fact in this connection that all determinations of the viscosity of water and of air by the capillary or transpiration method have given results which are lower than those derived from observations of oscillating disks or spheres or swinging pendulums. But this relation of determined values is what should be expected did the flow of fluids through capillary tubes and porous media increase faster than the pressure. The extremely careful work, therefore, which has been done to determine the viscosity of fluids it appears, may be legitimately placed in evidence in support of the view that the flow of air and water through capillary tubes and through sands, soils and rock may increase more rapidly than the pressure.

Were it admissible to suppose that there is a stationary or comparatively stationary film of fluid adhering to the walls of capillary tubes through which water or air is flowing and that this layer could become thinner as the pressure is increased, then this change would have the effect of increasing the effective diameter of the tube or pore, and thus of allowing the flow to increase faster than the pressure, while at the same time the viscosity might remain unchanged and yet appear to decrease with the pressure.

We are inclined, therefore, to accept the fact of the flow through capillary tubes and pores increasing faster than the pressure as further proof that solids immersed in fluids retain about and upon them a layer of appreciable thickness which is restained by, or compelled to move with them, according as one or the other medium is in motion. Since a tube having a diameter not exceeding .05 millimeter permits a flow of water which increases more rapidly than the pressure, it appears that narrower tubes possess the power to prevent the formation of vortex or cross currents which impede flow, and it appears reasonable to ascribe this prevention to the specific mutual attraction of the solid and fluid whose restraining influence maintains nearly or quite parallel currents throughout the flowing stream. If this is correct then the thickness of the film under restraint by the walls should be expected to be equal to about the radius of the capillary tube or, for water, about .025 millimeter. We have therefore presented three lines of evidence which appear to indicate a sphere of influence not less than .008 millimeter and perhaps not greater than .1 millimeter or an average of say .05 millimeter for water.

Suspension of Solids in Fluids.

In taking up the study of soil solutions and the composition and amount of salt carried in them, one of the greatest obstacles encountered was the difficulty in obtaining a solution free from turbidity. Many of the soil particles are so minute as to readily pass the closest textured filter-paper in multiple layers after repeated filtration. No length of standing would render them clear and it was not permissible to clear them by the use of flocculating agents. The use of clay filters, of the Pasteur-Chamberlin type, was our final resort and proved to be thoroughly effective and so effective, indeed, as I shall explain directly, as to retain entirely outside the filter walls such soluble salts as potassium nitrate, as shown by the fact that the last portions of a solution being passed through the filter acquired a greater concentration than the original.

There are no soils which do not contain grains smaller in diameter than .001 millimeter, and not a small per cent of the finest soils consist of grains which are almost beyond the limits of the strongest microscope to resolve, which means that their diameters are close to, and probably even below .0003 millimeters. But notwithstanding this extreme division it is an astonishing fact that, being 2½ times heavier than water, some of these particles will remain suspended indefinitely in a room approaching absolute quiet and where the diurnal range of temperature is less than a degree C., as we found to be the case in the subcellar constant-temperature room of the agricultural laboratory of the University of Wisconsin.

But more strange than this is the fact that the Mississippi, after winding back and forth some 1,100 miles upon a flood plain which falls but one inch in 40 rods, delivers in suspension into the Gulf more than 11 tons of sediment per second, 2.65 times heavier than the water and yet drops this load almost at once on commingling with the denser water of the sea. Almost equally strange is the movement along the bottom of more than one additional ton per second of coarser sediment, making an aggregate per annum of 392 million tons or more than 224,000 acre-feet. By what process or mechanism is this enormous load of rock particles sustained so long and borne so far across a plain so nearly level and then dropped at once in the stiller, heavier salt water? And when the question is solved for silt in suspension in water, the solution must also include the suspension of dust particles in the atmosphere whose specific gravity must exceed that of the air itself some 2,049-fold.

If it is true that solid particles, when immersed in water, air or other fluid, become invested with a layer of the suspension medium and that this is compelled to traved with them, such a layer must increase the effective diameter of the particles by twice the thickness of the retained layer. It must increase the effective volume of the particles in the ratio of the cubes of the actual and effective diameters, and it must augment the head resistance to motion very nearly in the ratio of the squares of the actual and effective diameters. At the same time it must materially reduce the effective specific gravity to a value approaching that of the medium of suspension. These being true it is clear that when the retained fluid layer has sufficient thickness to reduce the specific gravity nearly to that of the fluid of suspension its power to float the particles becomes relatively very great.

The diameter of the finest clay particles ranges all the way from .001 millimeter down to and below .0003 millimeter, and observations indicate that particles of gold just beginning to precipitate possess diameters as small as .0002 to .00005 milimeter; while it is claimed that the diameters of collodial particles are as small as .000011 millimeter to .000004 millimeter. In the data we have presented indicating the thickness of the retained water layer on solids the mean value is .05 millimeter. Taking the thickness of the investing film at one-fifth of this, or .01 millimeter, for a clay particle having a diameter of .001 millimeter, its effective diameter would become

$$.01 + .001 + .01 = .021 \text{ millimeter.}$$

The effective volume, therefore, in consequence of the investing layer of water, would be increased 9,261-fold. Its head resistance to motion would be increased by the square of the effective diameter, or 441 times, while the specific gravity would be reduced to 1.0002, computed from the formula:

$$\text{Sp. Gr.} = \frac{\frac{\pi d^3 \,.\, \text{sp. gr.}}{6} + \left(\frac{\pi D^3}{6} - \frac{\pi d^3}{6}\right)}{\frac{\pi D^3}{6}}$$

d = diameter of solid nucleus taken as unity.
D = diameter of solid-fluid system.
sp. gr. = specific gravity of the nucleus.
Sp. Gr. = specific gravity of the solid-fluid system.

We have just stated that the Mississippi delivers to the Gulf 11 tons of sediment per second. Since the effective specific gravity, according to the computation, is only .0002 greater than that of the water itself, the vertical component of the force of suspension need not exceed 4.4 lbs. in the aggregate for the whole section of the stream bearing the 11 tons of sediment. And since the increased diameter of the grain, due to the adhering film, augments the effective cross-section of the grain 441-fold it is clear that a much small vertical motion of the water of the stream would be required to maintain suspension than if this force were to be exerted upon the surface of the grain itself.

If the same principle is applied to the suspension of dust particles in the air and a similar computation made results like the following appear: taking the diameter of a dust particle at .001 millimeter and with a specific gravity of 2.65. Taking the ratio of water to air at 62° F. at 1 to 816.8. Taking the thickness of the retained air film at .01 millimeter, the same as that for water, and making no allowance for compression of air in the retained film, the effective specific gravity becomes 1.2336, or about one-fourth greater than that of an equal volume of air. According to this view the dust particle is wrapped in a sphere of air which increases its effective volume, in this specific case, 9,261-fold; which increaes the surface upon which an upward current may act to maintain suspension 441-fold. The power of suspension which is developed by the surrounding film of the suspending fluid is very much greater than would result from simply reducing the specific gravity of the solid particle to the extent computed without at the same time altering its effective diameter. This is so because the resistance to falling through the suspending fluid and the lifting power of the fluid itself, as the result of ascending currents, increases with the square of the diameter of the body held in suspension. Suppose a body having a specific gravity of 2 to be immersed in water. The water will buoy it up with a force of 1 and the residual power of gravity to produce the displacement of water necessary to permit sinking is 1, while the cross-section of the column of water displaced by the body in sinking or rising must also be 1. Now suppose a second body similar in every way except that it possesses the power of fixing about itself a layer of water sufficient to increase its diameter 5-fold is also immersed in the same water. Its ability to displace water, when moving, will be increased 25-fold while its power of displacement remains as in the other case. Hence, with 25 times the work to be done in displacing water while moving a given distance, there is only the same amount of unneutralized effective gravity with which to do it. It cannot, therefore, fall as rapidly, and a much less strong upward current would be required to sustain it.

Influence of Filters on the Concentration of Solutions.

It is a matter of common observation that when a colored solution, like some of the fluid inks, is dropped upon filter or blotting paper, the action of capillarity causes the ink to spread radially and in doing so the solvent of the ink travels faster and farther than the color ingredients held in solution or in suspension, so that often there is an outer colorless, or nearly colorless, zone. Goppelsroeder has written a volume on this and related subjects, pointing out how the principle may be used in separating the ingredients of many complex organic compounds for analysis. I have here a blotter upon which has been dropped at one point mono-chroic writing ink and at another ordinary carmine ink, which serve to illustrate the phenomena in question. It is clear that we have here a differential capillary movement in which the solvent travels more rapidly than the other ingredients. The simplest explanation of the phenomena is to regard the several colored components of the ink disseminated throughout the solvent, but with each color particle surrounded by a layer of the solvent which it controls in the manner supposed with the silt in turbid water and dust particles in the air. As the solvent spreads by capillarity and invests each paper fiber in an envelope of fluid to the extent of entirely filling the pore space of the paper, through this entangled fluid the several color ingredients, loaded with their film of solvent, and thereby being relatively large, are floated and dragged forward in the currents set up. They are never able, however, to outrun the solvent and the smallest color particles are likely to travel faster and farther than the larger ones, thus bringing about the colored zones which appear, as the result of the separation.

Ordinary water solutions, such as nitrates, sulphates and phosphates, appear to behave similarly in passing through porous media to the extent that the first portion escaping from the filter may be very much less concentrated than the original. Nor is this all. The residual portion of the solution not passing through the filter may become more concentrated than the original solution, apparently on account of the retention of some of the salts entirely on the outside of the filter. Taking a specific case in which 500 cubic centimeters of a composite solution containing K_2SO_4, $MgSO_4$, $Ca\ (NO_3)_2$ and $CaHPO_4$ was slowly passed through a Pasteur-Chamberlin filter under a constant but gentle pressure. The solution as it escaped was collected in 50 cubic centimeter separates, except the first two which were 25 cubic centimeters each and there was left behind, not passing the filter 80 cubic centimeters. Each of these separates was analyzed and it was found that while the original solution contained in 500 cubic centimeters 176.5 mgs. of K, the first 25 cubic centimeters coming through contained only 77.4 mgs. per. 500 c. c., 100 mgs. less, and the 80 cubic centimeters not passing the filter had increased in strength to 179.5 mgs., or a gain of 1.7 per cent. In the case of calcium the results stood: original, 137 mgs.; first 25 cubic centimeters, 55 mgs.; not passing filter, 146 mgs.; or a gain of 6.5 per cent. For the magnesium the results stood: original, 164.6 mgs.; first 25 cubic centimeters 79.6 mgs.; not passing filter, 168.2 mgs., or a gain of 2.1 per cent. In the case of nitric acid the results stood: original, 530 mgs.; first 25 cubic centimeters, 259.6 mgs.; not passing filter 540 mgs., or a gain of 1.9 per cent. For sulphuric acid the results found were: original, 806 mgs.; first 25 cubic centimeters, 340 mgs.. not passing the filter, 862.5 mgs, or a gain of 7 per cent.

Results similar to these have been repeatedly secured with potassium nitrate alone, with potassium sulphate and with sodium bicarbonate and with sodium chloride alone, although in the last case the concentration of sodium chloride outside of the filter was invariably very small.

The simplest explanation of such differential movements of salts through porous media as these, and the retention of them outside the filter, appears to be to suppose that either the whole of the water, or some portion of it, is apportioned to the salts held in solution in such a manner as to place a molecule or group of molecules of each salt at the center of a sphere of water capable of moving as a unit and not fundamentally different from what we have supposed in regard to the suspension of silt, unless difference in magnitude be regarded as such. With such a compounding of water and salt there would be less freedom to movement of the salt through the filter and a separation of the salt and water, more or less complete, would necessarily result. Such a compounding, too, would be qualitatively, at least, in harmony with the elevation of the boiling point and the lowering of the freezing point of water, which are associated with the addition of salts in solution, as well as with changes in viscosity and with the nature of colloid solutions. So, too, such a structural control of the water would seem to necessitate a change in optical properties and electrical ones as well.

If particles immersed in a fluid become the nuclei of spheres of that fluid, surface tension also would result. This surface tension would be greatest when the diamater of the spheres is smallest and would become negligible when the diameter, in terms of the nucleus, is very great. According to this view, in a saturated solution the number of nuclei is so great and the spheres of fluid so small that any further increase in the surface tension, caused by a fall of temperature or the addition of more nuclei, would force a number of the spheres to coalesce, thus throwing the nuclei together until the aggregate is great enough to cause precipitation and to restore sufficient free fluid to again reduce surface tension below the intensity which causes coalescence. With this conception, when alum or other salt is added to a turbid solution these molecules appropriate water to themselves, thereby reducing the diameter of the silt-water spheres and increasing their effective specific gravity and at the same time their surface tension until a coalscence of both salt and alum spheres is forced, producing sufficiently large aggregates to cause them to subside. It is a well established fact that strong solutions precipitate particles in suspension more quickly and more completely than do those more dilute. It is also well established that the salt which causes the precipitation is itself, to a considerable extent, thrown out of solution, even though that salt is one extremely soluble and chemically inert under the conditions, like potassium nitrate. This too is what would be expected if a coalescence of spheres took place and hence, when the turbid water of a stream commingles with the salt water of the sea there begins at once a reduction of the thickness of water films about the suspended sediment, which increases their effective specific gravity and at the same time increases the surface tension, causing flocculation, which carries to the bottom both the silt and a portion of the salts which initiated the flocculation and final precipitation.

THE COLD-WAVES OF SOUTH-CENTRAL WISCONSIN.

JAMES L. BARTLETT.

Of all the atmospheric phenomena attending winter storms the cold-wave is the most noteworthy. The term was originated many years ago by the United States Signal Corps to signify a marked fall in temperature rather than the occurrence of extreme cold. As used at present by the Weather Bureau it is understood to mean a decrease in temperature of 20° * in 24 hours, independent of the regular diurnal change, to or below a certain fixed minimum which varies from zero during the winter months in western Wisconsin to 24° in the eastern portion of the state during the remainder of the year. The reason for this variation of the minimum is to limit the official cold-wave to a phenomenon of economic importance. In this paper the subject will be discussed from a meteorological point of view.

The meteorological cold-wave consists of an abnormal temperature fall, occurring usually in the western quadrants of a cyclonic storm area, during the colder months, and generally attended by high north to west winds, increasing barometric pressure and clearing weather. The foregoing atmospheric conditions of course occur during all seasons of the year, their frequency depending almost wholly upon the frequency of the passage of cyclonic storms. For example, in Table 1 the second curve shows the sharp temperature fall attending the thunder-squall between 2 p. m. and 4 p. m. of June 1, 1905. This fall in temperature corresponds, for the summer months,

1 Temperatures in this paper are in the English or Fahrenheit scale.

to the winter cold-wave, and might be dignified by the name "cool-wave," the minimum temperature reached not being sufficiently low to be considered cold by anyone except a denizen of the tropics.

It is interesting to note that cold-waves occur, under various names, in all regions of the world except the tropics. In our Northwest, when attended by high winds and snow at low temperatures, they are called "blizzards." In Texas and over the Gulf of Mexico they are known as "northers." In Europe the cold-wave is less severe than in the United States, usually coming from the northeast, and is called "mistral" in France) "bora" at the head of the Adriatic Sea, and "bura" or "purga" in Russia. In South America the "pampero" and in Australia the "burster" are identical with our cold-wave, though in those countries they accompany southerly winds.

WINTER TEMPERATURE CONDITIONS IN THE NORTHWEST.

During the winter, temperature conditions are much more variable from day to day than at other seasons. The rapid and frequent movement of cyclonic areas across the country causes many decided changes in temperature. The mean variability of temperature, by which is meant the average change from the temperature mean of one day to that of the next, at Madison in January is over 6°, while during July it is less than 3°. February's mean variability is even greater than January's, while that of December is but little less.

A consideration of the average monthly temperatures over the United States during January (see Plate XV) reveals decided differences in temperature within comparatively short distances. The coldest region in the country is the Red River Valley, with an average January temperature of zero or lower. During this month the mean temperature at Madison is 16°. Under average temperature conditions then, any cause, such as the northwest wind, which will transfer the cold air of the Red River Valley to Madison, a distance of 400 miles, would produce a fall of 16° in temperature, almost enough to verify

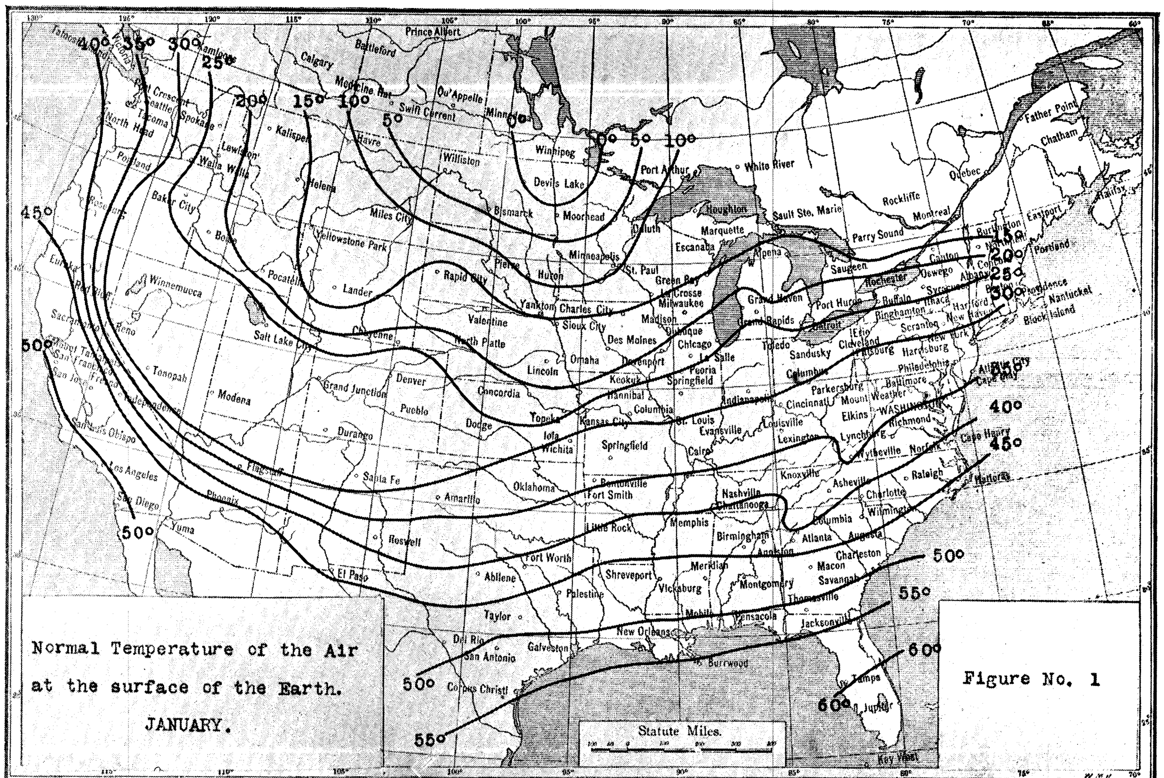
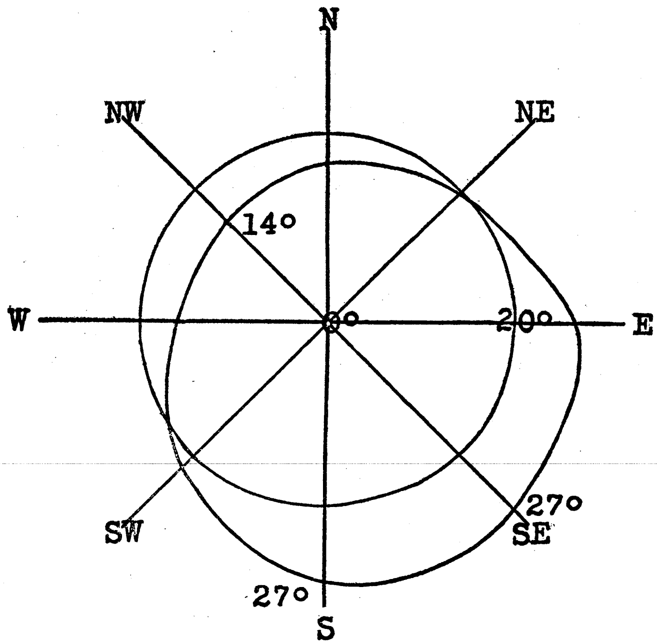

Normal Temperature of the Air
at the surface of the Earth.
JANUARY.
Figure No. 1
Statute Miles.
Prince Albert
Battleford
Calgary
Medicine Hat
Swift Current
Qu'Appelle
Minnedosa
Winnipeg
Port Arthur
White River
Kalispell
Havre
Williston
Devils Lake
Helena
Miles City
Bismarck
Moorhead
Duluth
Houghton
Marquette
Sault Ste. Marie
Rockliffe
Quebec
Montreal
Father Point
Chatham
Halifax
Eastport
Burlington
Portland
Parry Sound
Saugeen
Rochester
Oswego
Albany
Boston
Providence
Nantucket
Block Island
Yellowstone Park
Rapid City
Minneapolis
St. Paul
Escanaba
Alpena
Green Bay
Milwaukee
La Crosse
Grand Haven
Port Huron
Buffalo
Ithaca
Binghamton
Hartford
New Haven
Scranton
New York
Pocatello
Lander
Huron
Pierre
Yankton
Charles City
Sioux City
Madison
Dubuque
Grand Rapids
Detroit
Toledo
Sandusky
Cleveland
Erie
Pittsburg
Harrisburg
Philadelphia
Atlantic City
Cape May
Winnemucca
Salt Lake City
Cheyenne
Valentine
North Platte
Des Moines
Chicago
Davenport
Omaha
Lincoln
Peoria
La Salle
Springfield
Keokuk
Hannibal
Columbus
Parkersburg
Baltimore
Mount Weather
Washington
Cincinnati
Indianapolis
Eureka
Red Bluff
Sacramento
Reno
Tonopah
Modena
Grand Junction
Denver
Pueblo
Concordia
Topeka
Kansas City
Columbia
St. Louis
Evansville
Louisville
Lexington
Elkins
Lynchburg
Richmond
Norfolk
Wytheville
Cape Henry
Hatteras
Mount Tamalpais
San Francisco
San Jose
Fresno
Independence
San Luis Obispo
Durango
Dodge
Iola
Wichita
Cairo
Knoxville
Asheville
Raleigh
Charlotte
Wilmington
Los Angeles
San Diego
Flagstaff
Santa Fe
Amarillo
Oklahoma
Bentonville
Fort Smith
Nashville
Chattanooga
Yuma
Phoenix
Roswell
Little Rock
Memphis
Birmingham
Atlanta
Augusta
Columbia
Anniston
Charleston
Macon
Savannah
El Paso
Abilene
Fort Worth
Shreveport
Meridian
Vicksburg
Montgomery
Thomasville
Palestine
Taylor
Mobile
Pensacola
Jacksonville
New Orleans
Del Rio
San Antonio
Galveston
Burrwood
Corpus Christi
Tampa
Jupiter
Key West

Fig. 1.

a cold-wave prediction. This transfer would require, with the average wind velocity at Madison during January of 10 miles per hour (for all directions; northwest winds average greater velocity), and provided no heat was taken up by the air from the earth during its southeastward movement, a period of 40 hours, nearly twice the time limit of the official cold-wave. It frequently happens that a temperature difference much greater than the average exists between Madison and the eastern boundary of the Dakotas, so that a northwest wind could produce the necessary temperature fall within the required time.



Text Fig. 1. Wind rose showing average temperature of winds from the different points of the compass during the winter months at Madison, Wis. The circle represents the average monthly temperature during the period considered.

In considering the general winter temperature conditions it is also of interest to note the average warmth of winds from the different points of the compass. This is shown, for Madison, by the accompanying wind-rose, Text Fig. 1, from which it may be seen that northwest winds have an average temperature some 6° below the monthly mean, while south and southeast winds are 7° warmer than the mean. If, then, thru any cause, such as the passage of a cyclonic center nearby, the southerly wind of average winter temperature is, within a short time replaced by an average northwest wind the thermograph registers a fall of 13°. However, it is not necessary to look to the Red River Valley for air of low temperature. Directly above us is air of extreme coldness. At a height of two miles, or even less, during the winter we may find air 20° colder than at the earth's surface. Any effort to force this air vertically downward, however, results in warming it so much by compression that at the ground it would be warmer than the air already there. The extreme dryness of this upper air, increasing when forced downward, is of importance in cooling the lower atmosphere, as in the case of the anti-cyclonic center. This dryness of the air is very favorable for cloudless skies, permitting rapid radiation of heat from the earth's surface, and in the winter, when the days are short and the nights long, is often attended by extreme cold. The intense winter cold of the Red River Valley and of the Canadian provinces of Manitoba and Saskatchewan is produced in this manner. Cloudiness in winter is favorable for the retention of heat at or near the surface of the earth, Dr. Fassig has found that at Baltimore the average temperature of cloudy winter days is some 5° higher than that of clear days at that season. A cloudy day, preventing the sun's rays from reaching the ground, followed by a cloudless night, permitting the escape of terrestrial radiation, would naturally be favorable for lowering the average lower air temperature in winter.

A cyclonic storm, central over or to the northward of southern Wisconsin, unites the above mentioned conditions favorable for a rapid fall in temperature at Madison. As the storm center moves eastward, warm, cloudy winds from the south are soon replaced by cold west to northwest winds with clearing weather. If the central pressure of the storm is sufficiently low, and if there is, as often occurs, a high pressure area accompanied by cold weather in the Dakotas, Montana or western Canada, these conditions are sufficient to cause strong northwest winds. The cold air of the Dakotas is thus drawn rapidly southeastward over Wisconsin where a cold-wave results. Let us consider an actual case of this kind.

At 7 a. m. on January 19, 1907, a storm of considerable strength was central in southern Minnesota (see Plate XVI). It had been attended at Madison, during the preceding night, by southerly winds and warm, cloudy weather, with rain, the temperature rising above 40°. During the 19th this storm moved eastward to Lake Michigan, and by 7 p. m. at Madison the wind had shifted to northwest and the temperature had fallen decidedly. Simultaneously with the easterly storm movement the High in Alberta developed in intensity and also moved eastward. Plate XVII shows the march of the meteorological elements at Madison during the passage of the storm and the approach of the anti-cyclone, and also shows the movement of the cold-wave across southern Wisconsin as indicated by the thermograph traces at several Weather Bureau stations. From the Madison data it is to be noted that the wind during the cold wave was from the west or northwest, with an hourly movement of 20 miles or more (a maximum 5 minute velocity of 38 miles per hour was recorded) and that the barometric pressure was increasing rapidly. The similarity of the temperature falls at the various points is also noteworthy. This cold-wave was one of the most marked on record at Madison, the temperature falling 48° in 17 hours, from 47° at 4 p. m. of the 19th to —1° at 9 a. m. of the 20th.

The passage of another cold-wave which was of considerable interest on account of the damaging sleet storm which it attended is illustrated in Plate XVIII. This storm passed from Illinois northeastward across Wisconsin on December 27, 1904, and was remarkable for its low central pressure and the large amount of rain, sleet and snow which it caused. Its destructive effects were chiefly due to breaking down trees and wires which had become overloaded with ice. The cold-wave accompanying the storm as may be seen from the diagram, consisted in a fairly steady, rapid temperature fall, rather than a sharp drop, and was attended by much wind, clearing weather and a rapid increase of barometric pressure.

In Plate XIX are shown the normal daily variation of Madison's January temperature and the temperature changes during several other decided cold-waves of recent years. The weather map conditions preceding these may be noted in the table on page 296. Probably the most severe of the cold-waves illustrated is shown by trace (G), February 12–13, 1905, on account of the low temperature at which it occurred, the thermometer reading —24° at 7 a. m. of the 13th. Trace (E) for January 30–31, 1906, is of interest from the fact that the cold-wave occurred far to the west of the storm center which was in eastern Ontario at 7 a. m. of the 30th. Trace (D) followed a storm central in Oklahoma with decidedly cold weather in Manitoba; few of our cold-waves occur under these weather map conditions.

A tabulation of all the cold waves at Madison during the past 20 years shows that approximately 206 have occurred in that period, distributed among the calendar months as follows:

January,	69
February,	56
March,	26
April,	4
November,	24
December,	27

While the average annual number is thus about 10, during 1887 no less than 23 occurred. During this 20 year period some remarkable falls in temperature have occurred, as may be noted from the following table.

January 29–30, 1887, —50° in 24 hours; 36° in 10 hours.
March 12, 1887, —32° in 17 hours.
April 3, 1887, —33° in 17 hours.
January 12, 1888, —43° in 24 hours.
February 4, 1889, —42° in 17 hours.
Febrauary 21–22, 1889, —44° in 24 hours.
March 24, 1891, —43° in 17 hours.
January 21–22, 1895, —39° in 24 hours.

November 18–19, 1896, —40° in 24 hours.
November 26, 1896, —34° in 10 hours.
January 24, 1900, —32° in 10 hours.
April 29, 1903, —42° in 17 hours.
March 2, 1904, —32° in 10 hours.
January 19, 1907, —44° in 12 hours.

The rapidity of the temperature fall in a few hours is also often remarkable, though not equaling in abruptness the falls during thunderstorms.

Some instances of such marked falls are noted in the table.

During the winter months many cyclonic storms pass across the country without causing cold waves in Wisconsin. It becomes of interest, therefore, to study the 7 a. m. weather map preceding a number of cold-waves in this section. For this purpose the accompanying table has been prepared, showing in condensed form, the principal weather map features for all Madison cold-waves since December, 1904, 18 in all. This table presents the location, and strength of central isobar, of the cyclonic (Low) and anticyclonic (High) areas influencing Wisconsin weather, the 7 a. m. temperatures in the Dakotas

Cold-Waves at Madison, Wis., December, 1904, to March, 1907, Inclusive.

Date.	Weather Map Features at 7 A. M.				Temperatures in the Dakotas.	Temperatures at Madison.			Wind direction attending cold wave.	Maximum wind velocity and direction
	High.		Low.							
	Location.	Strength.	Location.	Strength.		7 A. M.	Next 24 hours' change.	Other marked changes.		
1904 Dec. 27	Idado	30.7	Illinois	29.25	—10° to —30°	30°	—27°		N. W.	37 N. W.
1905 Jan. 2	N. Dakota	30.5	Indiana	29.7	Near zero	25°	—22°		N.	40 N,
Jan. 9	Dakotas	30.5	L. Superior	29.9	0° to —20°	21°	—34°	—10°, 1 hour	W.	25 W.
Feb. 1	Montana	30.9	Ontario	30.15	Below —20°	—2°	—20°		N. W.	24 N. W.
Feb. 9	Alberta	30.5	L. Superior	29.45	Near or below zero	13°	—24°	—32°, 16 hours	W.	20 W.
Feb. 12	Wyoming	30.6	Ohio	29.9	—30°	1°	—25°	—25°, 15 hours	N. W.	26 N. W.
Nov. 13	Manitoba	30.3	Wisconsin	29.75	+40°	38°	—21°	—14°, 2 hours	N. E.	46 N. E.
Nov. 28	Saskatchewan	30.4	Minnesota	29.15	10° to 30°	45°	—24°	—32°. 17 hours	W. S. W.	37 S. W.
1906 Jan. 21	Saskatchewan	30.5	Wisconsin	29.7	Near zero	34°	—27°		N. W.	29 N. W.
Jan. 30	N. Dakota	30.4	E. Ontario	29.7	Zero to 28°	32°	—28°	—19°, 4 hours	N. W.	38 N. W.
Feb. 1	Manitoba	30.7	Ontario	29.8	Near zero	24°	—25°		N. W	31 N. W.
Feb. 4	Dakotas	30.8	Ontario	29.7	Zero to —20	12°	—20°		N. W.	29 N. W.
Feb. 13	Manitoba	30.8	Oklahoma	29.9	Near zero	36°	—33°		N.	54 N. E.
Dec. 6	Saskatchewan	30.5	L. Ontario	29.25	—10°	25°	—24°		N. W.	29 N. W.
1907 Jan. 8	Montana	30.8	E. Ontario	30.05	Zero to —10°	28°	—26°		N. W.	28 W.
Jan. 19	Alberta	30.2	S. Minnesota	29.3	Zero to 20°	42°	—42°	—44°, 12 hours	W.	38 W.
Jan. 24	Alberta	30.7	S. Minnesota	30.05	Zero to 15°	20°	—21°		N. W.	22 N. W.
Feb. 2	Saskatchewan	30.9	N. Michigan	29.4	—10° to —20°	8°	—20°	—39°, 20 hours	W.	34 W.

whence the cold air to form the cold-wave is usually drawn, the resulting temperature drop at Madison, the wind direction prevailing during the cold wave; and the highest wind velocity for 5 minutes. An examination of this table reveals that, preceding a cold wave at Madison, a storm center usually overlies the Great Lakes, or the adjacent states, while an area of high barometric pressure is as a rule central in the Dakotas, Montana or western Canada (see Plate XX). The strength of the storm, as shown by the central isobar, may vary from 29.15 to 30.05 inches, with an average strength of 29.65 inches. The central pressure of the High usually ranges from 30.2 to 30.9 inches, with an average of 30.6. The average difference in pressure between the High and Low centers thus amounts to 0.95 inches. The greatest difference was 1.5 inches on February 2, 1907, while the least was 0.55 inch on November 13, 1905.

Preceding a cold-wave at Madison the temperature is generally near or below zero in the Dakotas, though in all except the winter months it may be higher. During the past two years most of the cold-waves have been attended by northwest winds; although occasionally west or north winds prevail and on one date, November 13, 1905, the temperature fall was accompanied by a northeast wind. This last wind direction is quite unusual during a cold wave as usually it brings a rise rather than a fall in temperature, or signifies a breaking up of any threatening cold-wave. It is to be noted, however, that this was in late fall rather than in winter and that the temperature did not need to fall extremely low to verify a cold-wave forecast. The table also shows that high to gale winds often accompany the cold-wave.

It occasionally happens that, with the 7 a. m. weather map conditions favorable for a cold wave, no decided drop in temperature occurs. Such a case, with the resulting thermograph trace at Madison, is shown in Plate XXI. One would naturally expect much colder weather in southern Wisconsin following such a map. Some disturbing influence, possibly the storm in Utah, appeared to force the Saskatchewan High north of Lake Superior on the following day so that the wind at Madison became northeast with a slight rise in temperature instead of northwest with a cold-wave.

The chief damage caused by cold-waves in this section is thru their overtaking and freezing perishable merchandise which has been shipped during the preceding warm weather. Fruit, vegetables, canned goods and liquids of all kinds may be seriously damaged by very cold weather. For this reason shippers of such products in the large cities watch weather conditions very closely during the winter months and often hold back their shipments until the temperature is more favorable.

Anyone whose business or work is liable to injury from extreme cold can with advantage watch, during periods of unseasonably warm winter weather, for the conditions which precede the cold-wave. A storm, as shown on the weather map, over the Great Lakes or Northwest, will usually be followed by cold weather. One who does not have access to the weather map may often obtain advance knowledge of a cold-wave by closely observing local atmospheric conditions and watching for those which indicate the passage of a storm area. Thus, with southerly winds of any strength, rain or snow and unusually warm weather for the season, colder weather may be expected in 24 hours. Also low barometric pressure, equivalent to a sea-level value of 29.8 inches or less, indicates the presence of a storm which will be followed by colder weather. When the pressure falls much lower (29.5 inches or less, sea level) a cold-wave almost invariably follows, of severity in proportion to the depression of the barometric reading below normal.

The Chief of the Weather Bureau, Willis L. Moore, attributes much of the physical and intellectual excellence of our nation to the invigorating effect of the cold-wave. To a person in good health the rapid temperature change is not necessarily disagreeable, and the human system receives a certain stimulation, both mental and physical, from the coldness and dryness of the air. With its approach foreseen and provided for, the cold-wave may well be considered beneficial rather than detrimental to the welfare of mankind.

PLATE XVI.

Fig. 2. Weather map showing storm conditions on Jan. 19th, 1907.

FORM E.

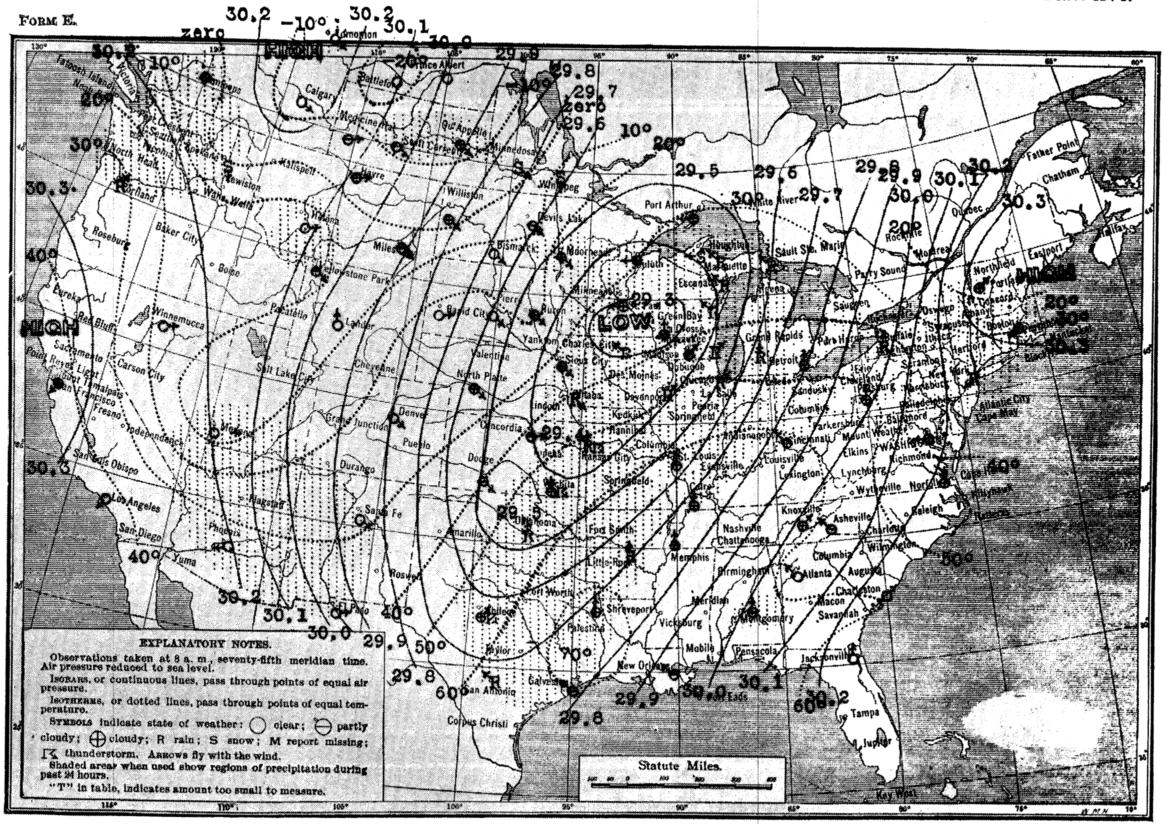
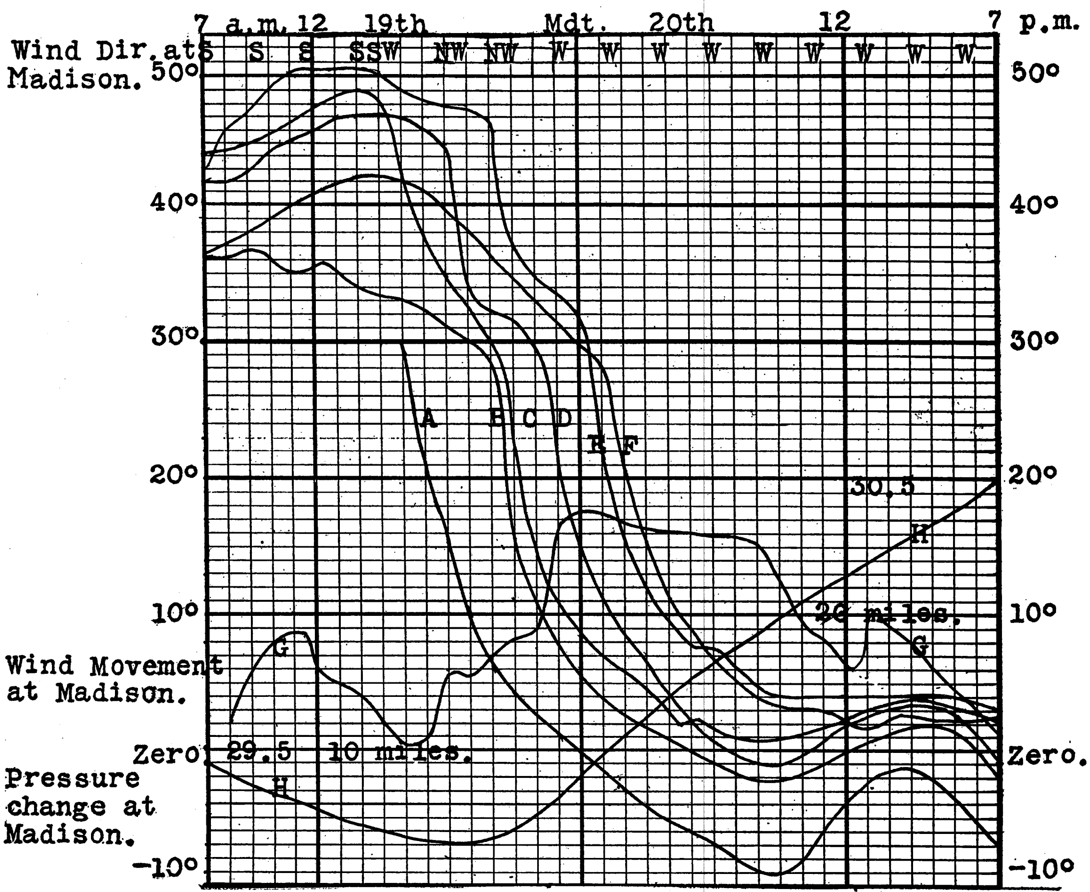

HIGH
LOW
HIGH
HIGH
EXPLANATORY NOTES.
Observations taken at 8 a. m., seventy-fifth meridian time. Air pressure reduced to sea level.
ISOBARS, or continuous lines, pass through points of equal air pressure.
ISOTHERMS, or dotted lines, pass through points of equal temperature.
SYMBOLS indicate state of weather: clear; partly cloudy; cloudy; R rain; S snow; M report missing; thunderstorm. ARROWS fly with the wind.
Shaded areas when used show regions of precipitation during past 24 hours.
"T" in table, indicates amount too small to measure.
Statute Miles.

Fig. 2.

PLATE XVII.

Cold-wave of January 19–20, 1907. Copies of Thermograph Traces at

A St. Paul.
B La Crosse.
C Dubuque.
D Madison.
E Milwaukee.
F Green Bay.
G Wind movement at Madison.
H Pressure change at Madison.



7 a.m. 12 19th Mdt. 20th 12 7 p.m.
Wind Dir. at Madison.
S S S SSW NW NW W W W W W W W W W
50°
40°
30°
20°
10°
Zero.
-10°
A B C D E F
30.5
H
20 miles.
G
Wind Movement at Madison.
Zero 29.5 10 miles.
H
Pressure change at Madison.

FIG. 3.

PLATE XVIII.

March of the Meteorological Elements at Madison, Wis., during the Coldwave of December 27–28, 1904.

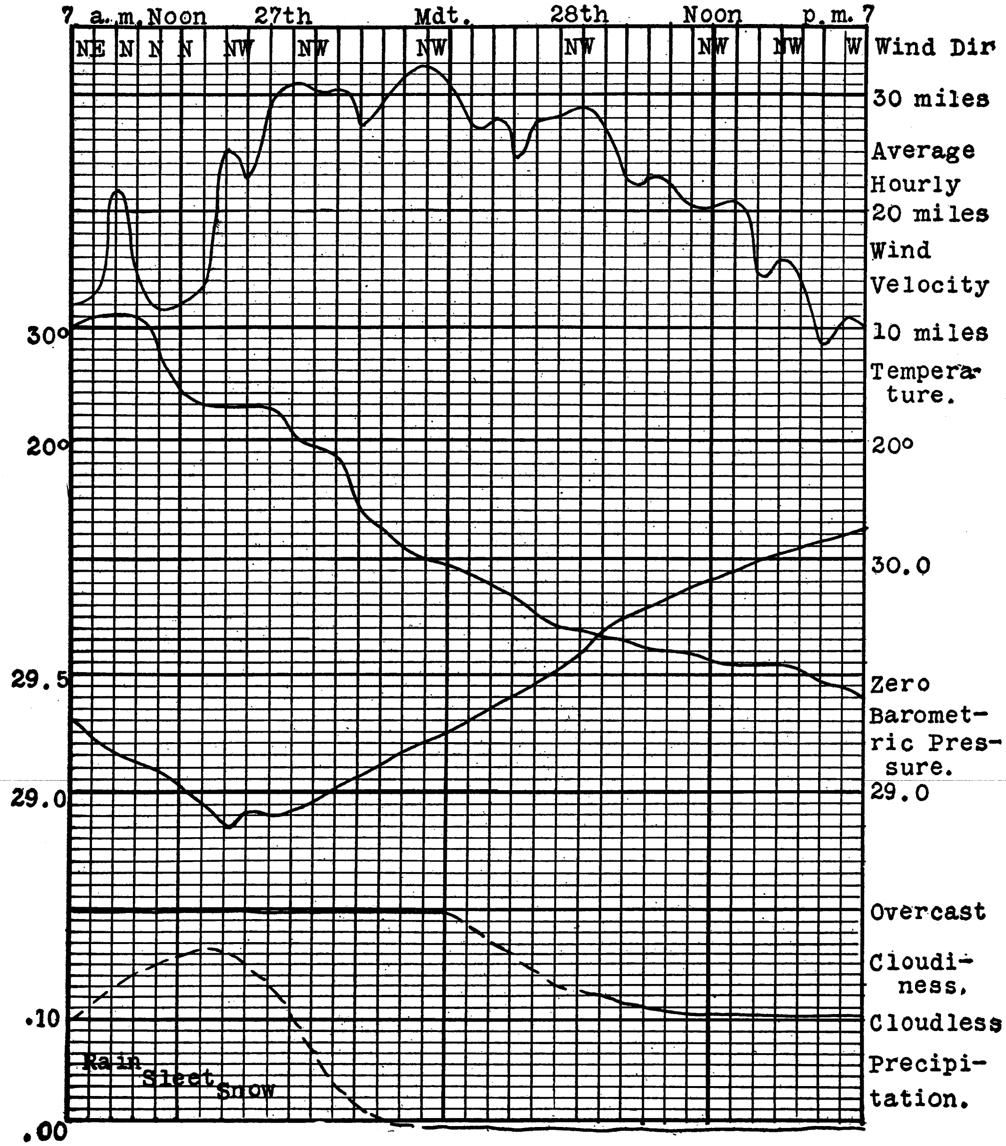

7 a. m. Noon 27th Mdt. 28th Noon p. m. 7
NE N N N NW NW NW NW NW NW W
Wind Dir
30 miles
Average Hourly
20 miles
Wind Velocity
10 miles
30°
Temperature.
20°
20°
30.0
29.5
Zero Barometric Pressure.
29.0
29.0
Overcast
Cloudiness,
.10
Cloudless
Rain Sleet Snow
Precipitation.
.00

FIG. 4.

PLATE XIX.

Fig. 6. Temperature Changes at Madison, Wis.

(A) Normal Daily Variation during January.

(B) Sharp Fall during Thunderstorms, June 1–2, 1905.

(C) (D) (E) (F) (G) Falls during Cold-waves as dated.

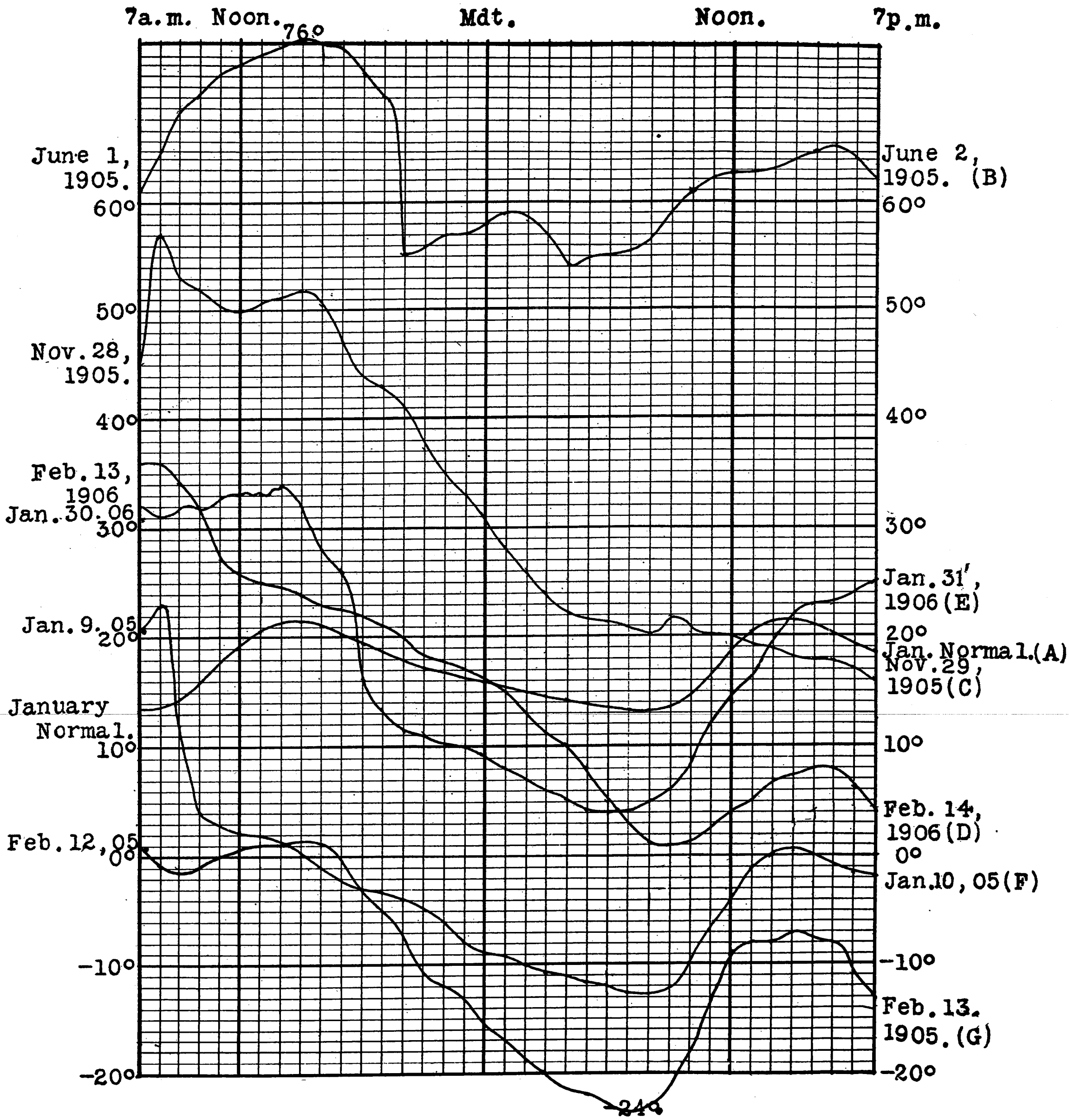

7a.m.
Noon.
76°
Mdt.
Noon.
7p.m.
June 1, 1905.
60°
50°
Nov. 28, 1905.
40°
Feb. 13, 1906
Jan. 30. 06
30°
Jan. 9. 05
20°
January Normal.
10°
Feb. 12, 05
0°
-10°
-20°
-24°
June 2, 1905. (B)
60°
50°
40°
30°
Jan. 31, 1906 (E)
20°
Jan. Normal. (A)
Nov. 29, 1905 (C)
10°
Feb. 14, 1906 (D)
0°
Jan. 10, 05 (F)
-10°
Feb. 13. 1905. (G)
-20°

Fig. 5.

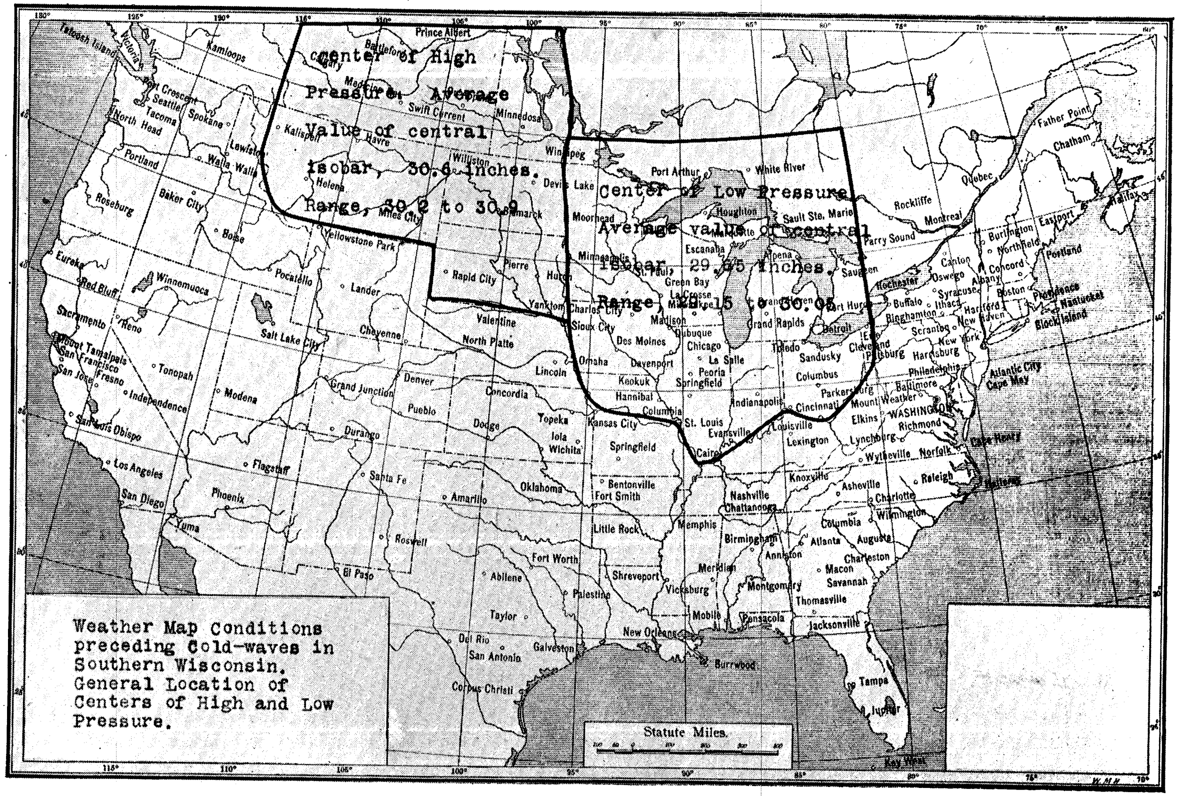

Center of High Pressure. Average Value of central isobar, 30.6 inches. Range, 30.2 to 30.9
Center of Low Pressure Average value of central isobar, 29.65 inches. Range, 29.15 to 30.05
Weather Map Conditions preceding Cold-waves in Southern Wisconsin. General Location of Centers of High and Low Pressure.
Statute Miles

Fig. 6.

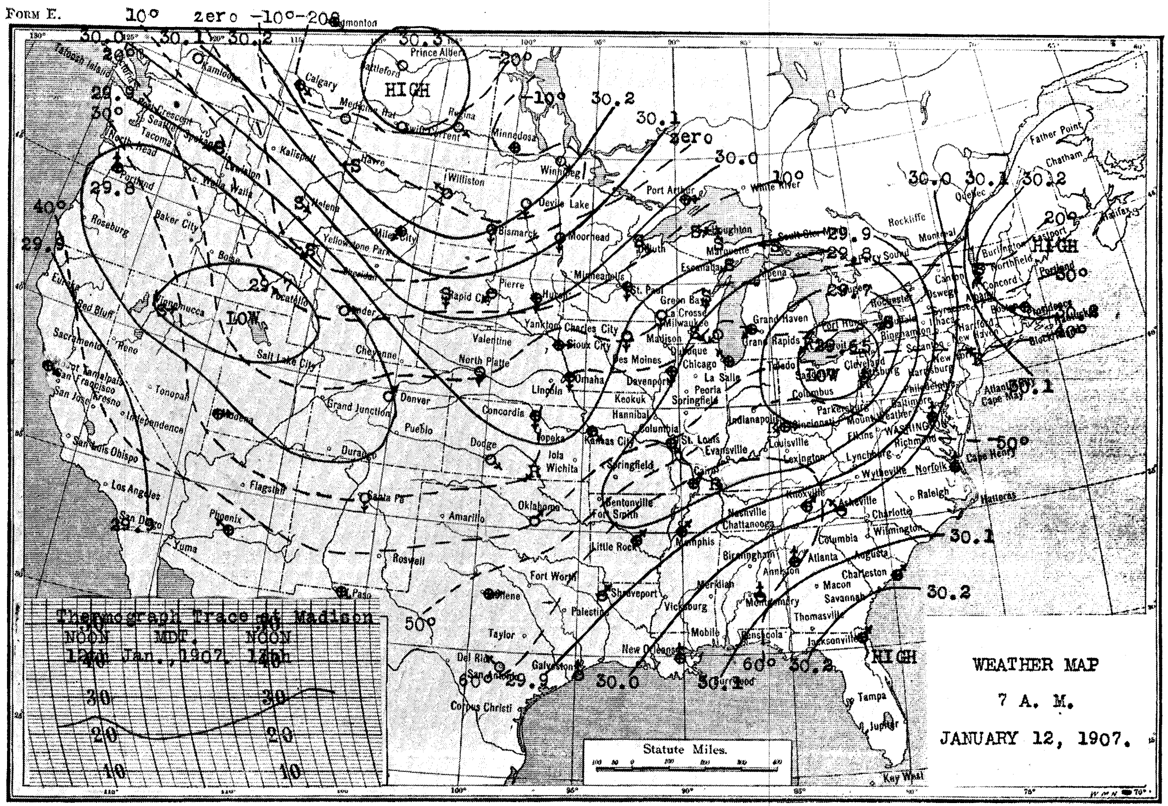

Form E.
WEATHER MAP
7 A. M.
JANUARY 12, 1907.
Thermograph Trace at Madison
NOON MDT. NOON
12th Jan., 1907. 13th
Statute Miles.
HIGH
LOW
HIGH
LOW
HIGH
HIGH

Fig. 7.

SLEET STORM IN THE OZARK REGION OF MISSOURI.

E. R. BUCKLEY.

When in Wisconsin a number of years ago I had the good fortune to observe and record a most interesting case of the formation of ice ramparts as a result of the expansion of the ice sheets covering the lakes in the vicinity of Madison. The results of the simple expansion of the ice sheets, as illustrated by photographs taken at that time, were most surprising, to one who had never seen these forces at work.*

Many times prior to and during the period of my connection with the Wisconsin Geological Survey, my attention was directed to the so-called "wind falls" in the tamarack swamps of the northern part of the state. In some instances, these trees were probably felled by wind storms, but where they lay piled like jack straws, with their tops pointing in every direction, the cause must have been other than wind, probably snow and ice.

On the 19th and 20th of November, 1906, a belt of about 100 miles southeast and northwest across the Ozark plateau was visited with a sleet storm of remarkable severity. I had occasion to see the results of this storm in the pinery region of St. Francis county, Missouri, and in the more settled area of Phelps county in the neighborhood of Rolla. As in the case of the ice ramparts, one could scarcely believe, unless he had been an eye witness, that a sleet storm could prove such an active geological agent of destruction.

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* See, "Ice Ramparts" by E. R. Buckley, Wisconsin Academy of Sciences, Arts and Letters, Vol. XIII, pp. 141 to 162.

In St. Francis county the storm was not as severe as in Phelps county. Nevertheless the accumulation of ice on the branches and needles of the pine trees was so great that trees six inches and more in diameter were uprooted while others four inches in diameter were broken off like pipe stems as a result simply of the weight of the coating of ice. The uprooting of the trees was so universal in the pinery that teamsters going out with loads were obliged to carry axes to cut their way through the forest roads. Figures 1 and 2 show some of the uprooted pine trees.

It was noticeable that in this vicinity the chief damage was to the pine trees, the others escaping with here and there a broken limb. The deeper, more firmly rooted trees withstood the weight of the coat of ice better than the shallow rooted pines.

In the vicinity of Rolla the storm did the greatest damage. This appeared to be near the middle of the sleet covered belt which is known to have extended from Dixon to St. Clair stations along the St. Louis and San Francisco railroad. Over this area everything was covered with a thick coating of ice.

The storm which began on the 19th lasted into the night of the 20th. In the evening the weight of the ice became so great that limbs began to crack and break falling to the ground. All night long the stillness was broken by the continual snap of limbs followed by crashes as they fell to the ground. Telephone and telegraph poles were broken and wires crossed the streets in tangled masses.

The morning of the 20th found the ground covered with a wreckage of branches, limbs, trees, poles and wires, such as had never been witnessed before in this region. The branches and ice fell during the day and people moving back and forth to town kept the open highways. Finally the weather moderated and the ice fell from the overhanging branches, leaving behind a most wonderful exhibition of the damage that may be accomplished by a simple sleet storm of a day and a half duration.

There were two other sleet storms during the winter, following the one here described and illustrated. One of them was not of sufficient duration to do any damage, but the other, which occurred in another part of the Ozark region farther north, wrecked the trees very much as did the one here referred to. This storm reached the Missouri river bottoms, breaking and bending to the ground the slender willows of the "bottoms." A year following the storm these willows still remain bent like bows. They are bent in every conceivable direction, which would not be the case were it the result of a wind storm.

Referring to the sleet storm of November 19th–20th, 1906, the destruction occasioned thereby is well illustrated by the accompanying figures. Figure 3 is a view of a portion of the campus of the Missouri School of Mines as it appeared during the summer prior to the sleet storm. Figure 4 is a view of about the same portion of the campus just after the storm. These illustrate very clearly the havoc wrought the shade trees by the sleet. Figures 5, 6, 7, 8, 9, 10, 11 and 12 were taken in various parts of the city of Rolla and further illustrate the destruction accomplished by the storm.

It may be interesting to note that the temperature during the storm was almost constantly at one degree below freezing. Measurements were made, in the offices of the Bureau of Geology and Mines, by Mr. H. A. Buehler, showing the weight of ice carried by some of the branches, wires, etc. A twig 12 inches long with ice attached weighed 8 ounces. The twig after removing the ice, weighed ½ ounce. A branching twig 15 inches long carried 18 ounces of ice.

The coating of ice which formed on twigs, branches and wires was from 1 to 1½ inches in diameter. It was estimated that each wire strung between telegraph poles 200 feet apart carried 100 pounds of ice and that 12 wires, carried a half a ton. These estimates are probably under rather than over the actual weight.

Bureau of Geology and Mines, Rolla, Missouri.

PLATE XXII.

Fig. 1. Pine trees 8″ in diameter uprooted by sleet storm in pineries near Flat River, St. Francis Co., Mo.

Fig. 2. Pineries in same locality and at same time as shown in Fig. 1. Triangulation station broken down by fall of a pine tree.

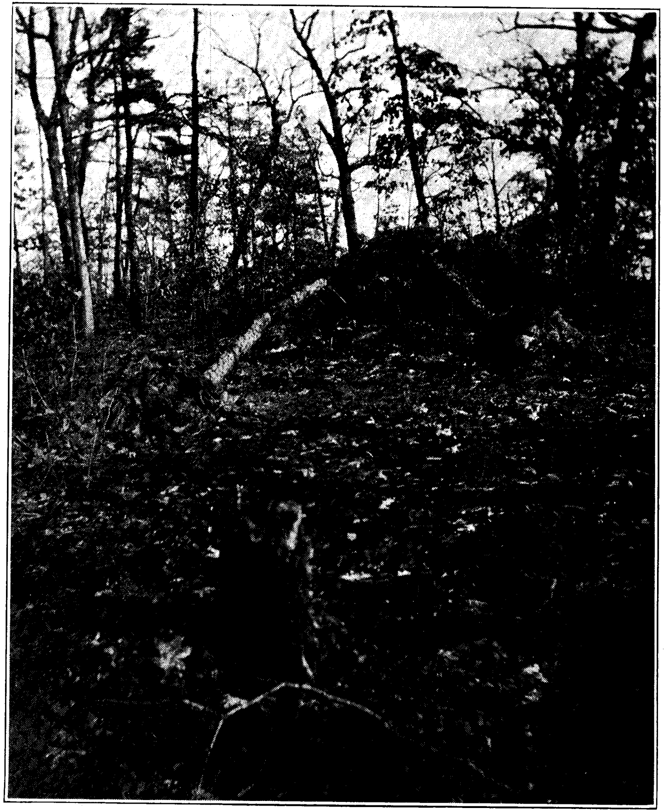

Fig. 1.

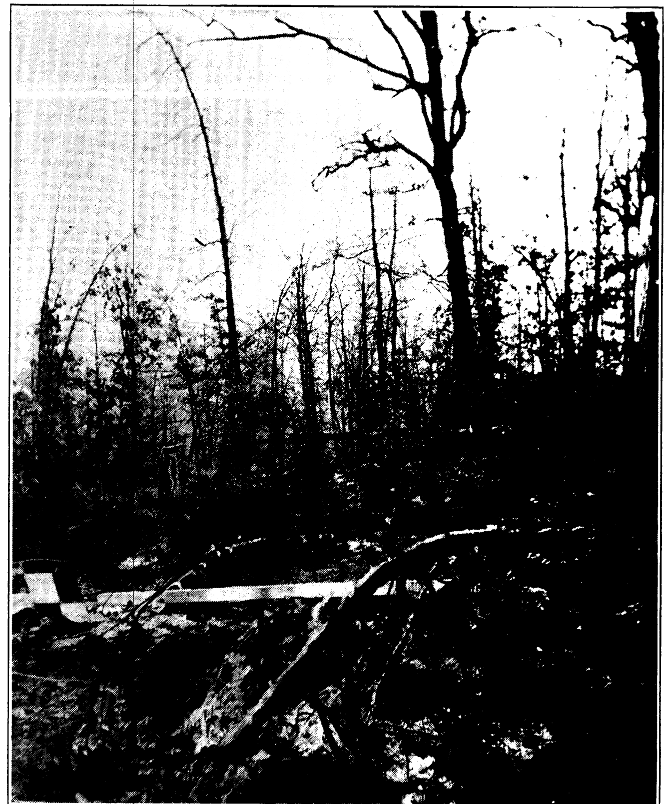

Fig. 2.

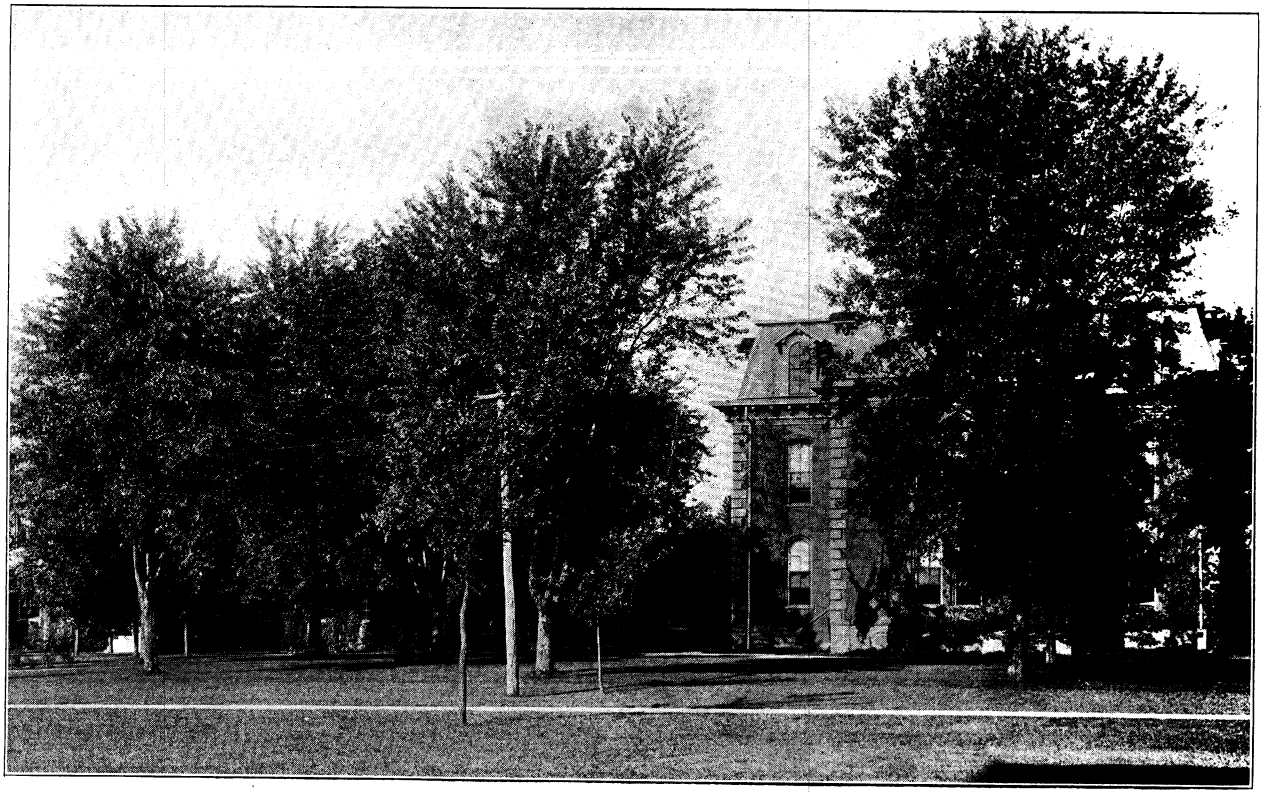

Fig. 3.

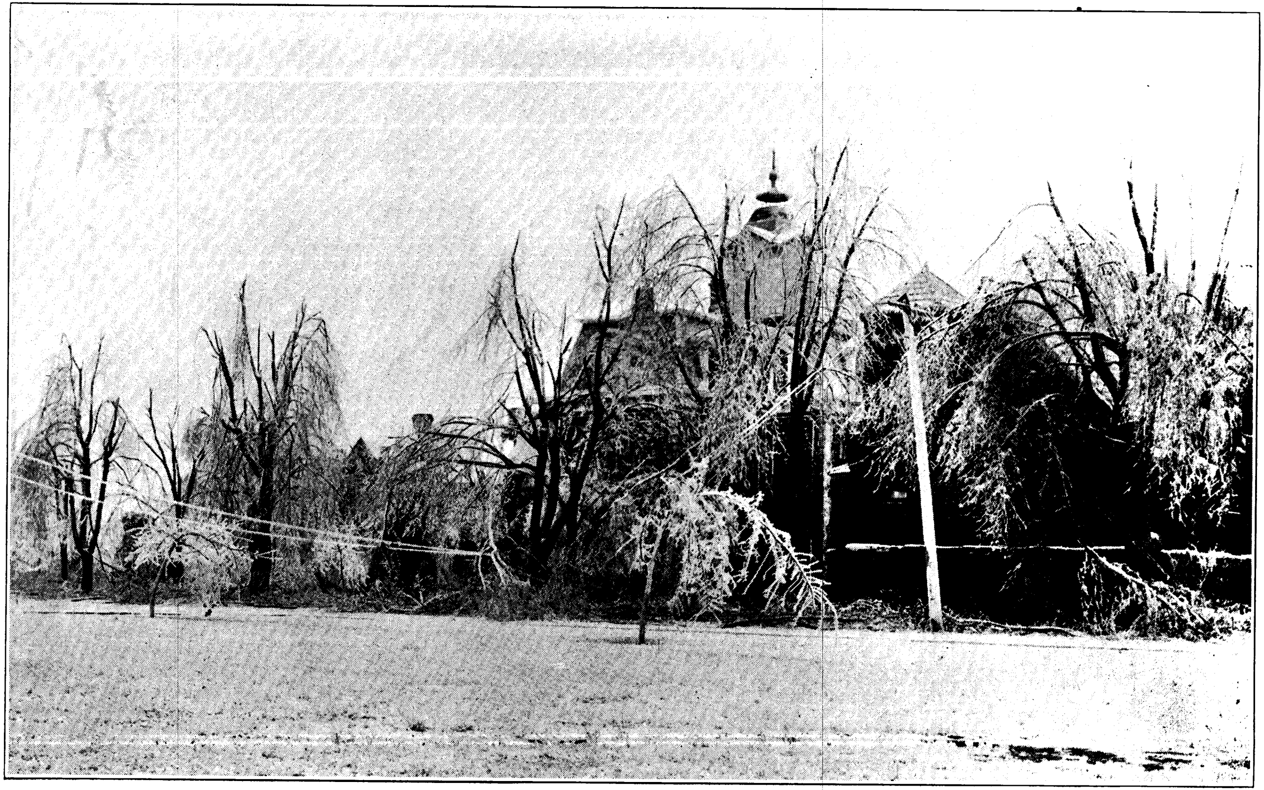

Fig. 4.

Fig. 5.

Fig. 6.

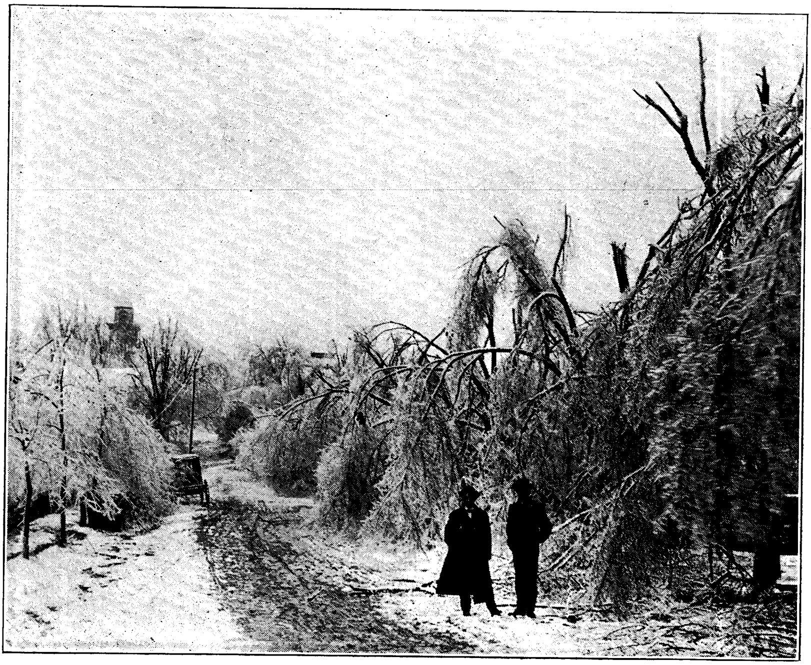

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.