THE
SCIENTIFIC PROCEEDINGS

OF THE

ROYAL DUBLIN SOCIETY.

New Series.

VOLUME X.

DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.
LONDON: WILLIAMS & NORGATE.
1903–1905.

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Printed at THE UNIVERSITY PRESS, *Dublin.*

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ERRATUM.

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Vol. X. (N. S.) DECEMBER, 1903. Part 1.

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The Authors alone are responsible for all opinions expressed in their Communications.

DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.
WILLIAMS AND NORGATE,
14, HENRIETTA-STREET, COVENT GARDEN, LONDON;
20, SOUTH FREDERICK-STREET, EDINBURGH;
AND 7, BROAD-STREET, OXFORD.
1903.

Price Four Shillings and Sixpence.

Royal Dublin Society.

FOUNDED, A.D. 1731. INCORPORATED, 1749.

EVENING SCIENTIFIC MEETINGS.

The Evening Scientific Meetings of the Society and of the associated bodies (the Royal Geological Society of Ireland and the Dublin Scientific Club) are held on Wednesday Evenings, at 8 o'clock, during the Session.

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THE

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THE ROYAL DUBLIN SOCIETY.

I.

AN IMPROVED POLARIZING VERTICAL ILLUMINATOR.

By J. JOLY, M.A., D.Sc., F.R.S., Professor of Geology and Mineralogy, Trinity College, Dublin; Hon. Sec. Royal Dublin Society.

[Read December 16, 1902; Received for Publication January 1; Published March 9, 1903].

In the Scientific Proceedings of this Society, vol. i. (n. s.), p. 485, *et seq.*, I have described a method of observing on an ordinary rock-section the interference tints proper to double the thickness of the section, and thereby producing discriminative effects not possible to obtain in the ordinary mode of observation.

I may recall that the method consists in placing a plane reflecting surface (polished speculum metal, preferably) beneath the rock-section as it rests on the stage of the microscope, and transmitting, by means of any vertical illuminator (as used for examination of metals, &c.), a plane polarized ray vertically downwards through the rock-section. The ray reflected from the speculum metal is again returned through the object-glass, and, after passing through the analyser, shows to the eye the retardation proper to double the thickness of section. In this manner the range of colour-variation from one species to another is greatly increased: in fact, what *differences* exist for the single thickness are now doubled in amount.

In the different arrangements proposed to effect this, one objection, in some degree, applied in all cases: a want of verticality in the downward directed ray which involved necessarily that the section and its image in the reflector did not accurately overlie one another. In rocks of fairly coarse grain this did not signify; but, in those of finer grain, an unpleasant overlapping of the colours of adjacent crystals occurred in the plane of incidence and reflection. In all the forms of the apparatus described, there was also required a separate polarizer to polarize the beam entering the illuminator.

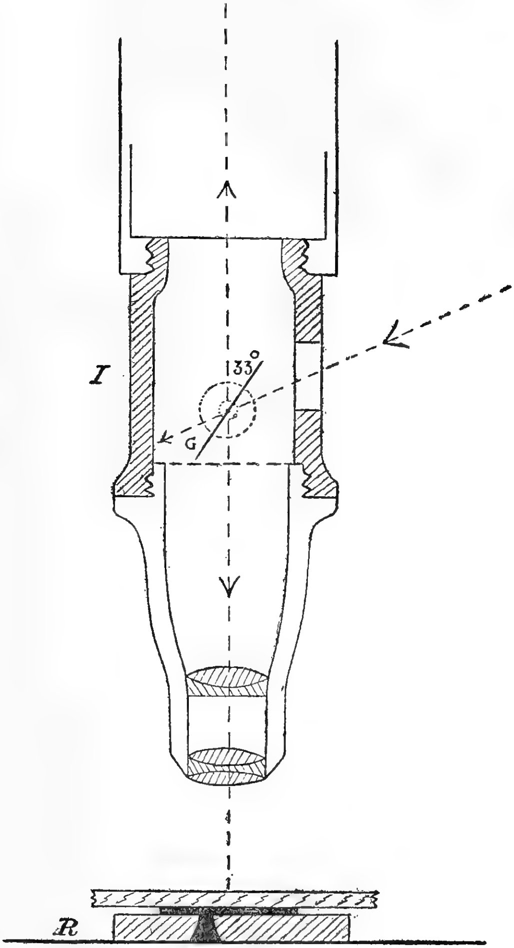
Recently it occurred to me to try the effect of a simple vertical illuminator which I saw described in Messrs. Watson's Catalogue, consisting of a single small cover-glass contained within a collar to be inserted just above the object-glass. The cover-glass is to be inclined so that rays entering an aperture in the front of the collar are, in part, reflected by the cover-glass (which can be rotated on a horizontal axis into the suitable inclination), and thence pass downward through the object-glass and illuminate the opaque object being examined. The rays finally reaching the eye (returning through the object-glass much the way they came) are for the most part transmitted through the transparent reflector.

In this arrangement the illumination is evidently vertical; and, the parallax in the plane of incidence and reflection involved with the use of prisms or opaque reflectors should be absent. I did indeed suggest such a mode of getting out of the difficulty in my former paper, but had not then given it trial.

On applying one of these very simple and inexpensive illuminators to the purpose described, I found that its use was in every way satisfactory. The quantity of light transmitted is sufficient even without the use of a lens to strengthen the beam. As an artificial source, a mantle-burner is excellent, and shows colour well. There is no appreciable parallax; and even small microlithic felspars in basalts may be seen, each glowing with its own colour and with sharp margins.

From the first I noted the added advantage that, with this mode of illumination, the use of a polarizer is unnecessary. Even using a horizontal beam and the glass at 45° to axis of microscope, the polarization of the ray reflected from the uncovered speculum metal is very complete, as may be seen by examination with a double-image prism, or more simply by rotating the analyser. But when the source of light is elevated above the horizontal level of the aperture in the illuminator, so that the ray more nearly reaches the glass at the polarizing angle, the polarization is still more complete.

As manufactured, the aperture is not placed so that the polarizing angle can be actually attained. It should be located a little above the axis of the reflector. The accompanying diagram shows the proper angles for mirror and ray when it is desired to obtain the ray as nearly unmixed with ordinary light as possible.



The cover-glass reflector should be inclined 33½ degrees with the optical axis of the microscope.

In the figure the illuminator is lettered *I*. The cover-glass, *C*, reflecting the light, is shown at 33° with the vertical axis of the microscope. This insures that the ray falling vertically through the object-glass is at the polarizing angle (57° nearly) with the glass reflector. It would be convenient if this angle was marked by the makers on the rotating head commanding the reflector. Or the correct position for the source of light (if artificial) may be found by arranging it to be 25 units of length above the plane of the aperture and 76 units distant. This gives a beam reaching the reflector at the proper angle; and it only remains to rotate the reflector till the eye, looking through the microscope, perceives the speculum reflector illuminated.

The larger part of the entering beam passes through the cover-glass, and is absorbed in the blackened walls of the illuminator. The reflected part is plane polarized, the vibration being executed parallel to the plane of the mirror. Descending, it passes first through the slip carrying the rock-section, it being advisable to invert the slip from its usual position, placing it face downwards, so as to bring the section nearer the speculum reflector. Then passing through the section, it meets the reflector of speculum metal (*R*); and is returned by it through the section, and so back to the cover-glass *C*. The greater part of the beam again passes through, reaching the eye, some part being returned to the source of light. What passes through is almost unmixed plane polarized light.

A lens placed in front of the aperture may be used to intensify the illumination. It has the effect of diluting with ordinary light the polarized beam somewhat, as rays from it are converging, and therefore do not all strike the glass at the polarizing angle. The loss of intensity of coloration is but trifling, and does not diminish the value of the arrangement as a means of diagnosis.

The usefulness of the reflector *R* is increased if it is perforated (I think preferably excentrically) with a conical hole, so that the upper edge is as sharp as possible. This hole should be blackened on the inside. The use of it is obvious. A small crystal can be examined simultaneously by the reflected ray and by light transmitted from the polarizer beneath the stage: the crystal being so placed that one part of it extends over the aperture. In making this comparison it is well to stop off sufficient of the transmitted substage light to make the twice transmitted and singly transmitted rays about equally bright. The result is a valuable discriminative test, as will be realized more especially by any one acquainted with the work of MM. Lévy and Lacroix, "Les Minéraux des Roches," to which I have more fully referred in my former paper.

It will be seen from the above that in order to use the method of examination by double transmission, the reflecting plate of speculum metal (a small disc about 3 cms. in diameter is a convenient size) and the vertical illuminator as described are alone required.

It is worthy of notice that this mode of obtaining the effects of a doubled thickness of the section by no means involves a doubled opacity; for inclusions, flaws, &c., lie above their own images, and fresh ones are not added, as would be the case in a section of actually double the thickness.

II.

HOW TO INTRODUCE ORDER INTO THE RELATIONS BETWEEN BRITISH WEIGHTS AND MEASURES.

By G. JOHNSTONE STONEY, M.A., Sc.D., F.R.S.

(Plate I.)

[Read February 17; Received for Publication, February 17;
Published May 2, 1903.]

The weights and measures that may lawfully be used in the United Kingdom are:—

1. The Imperial system of weights and measures, for all commodities.
2. Metric weights and measures, for all commodities.
3. Apothecaries' weights and measures, for drugs when sold by retail.
4. The ounce Troy and its decimal subdivisions, for bullion and precious stones.
5. Coin weights, for coins.

This is a complete list of British weights and measures, as the law at present stands.

In the time of Edward II., the British inch was defined as the length of three barley-corns, round and dry, taken from the middle of the ear, and placed end to end. The foot and yard were derived from the inch as determined in this way. In the time of Henry VII. a standard yard was made, and the foot and inch were derived from it. This was an immense improvement upon the earlier practice. Another yard, supposed to be a copy of Henry VII.'s standard, took its place as the English standard yard in the time of Queen Elizabeth. In 1742 a brass yard was constructed by Graham for the Royal Society, which was derived from the yard-measure of Queen Elizabeth; and a copy of Graham's yard was made by Bird, the optician, in 1760, which Parliament adopted as the British standard yard. It continued the standard until 1834. Our present standard was made in

1855, and represents the best attempt that it was found practicable to make, to recover the exact length of Bird's yard previous to the damage which it sustained in 1834.

Similar meritorious efforts were made from time to time to introduce the greatest accuracy which the state of knowledge at each period permitted[1] into our standards of weight and capacity, which, in earlier times, had been somewhat uncertain measures; until they have ultimately become those excellent standards which are now in the custody of the Board of Trade.

The imperial system of weights and measures was legally introduced into the United Kingdom by the Weights and Measures Act of 1824, from which date imperial standards were substituted for Winchester standards which had lasted from 1588 till 1824. The imperial system was subsequently modified and brought into its present form in 1856, by the substitution of the avoirdupois pound of 7000 grains, divided into 16 smaller ounces, for the troy pound of 5760 grains divided into its 12 larger ounces. The avoirdupois pound had, at various times, been divided into 15, or into 16, or into 20 ounces.

The standards legalised in 1824 were under the charge of the Clerk of the House of Commons, when the great conflagration took place on October 16, 1834, which destroyed the Houses of Parliament, and in which the British standards were either lost or so damaged that they were no longer available as standards. The present writer, when between eight and nine years of age, was an eye-witness of this great fire, and under circumstances which caused it to make a lasting impression on his memory. A few years later he reached an age when he could take notice of what was going on about him in the world; and he then followed with special interest the successive steps by which it was sought to restore our standards; and also the efforts that were being made by some of those who understood the subject, to obtain for Englishmen the lasting advantages of a system of weights and measures that had not grown up haphazard, but in which the measures of length, of surface, of capacity, and the weights, are

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[1] An interesting account of these successive advances will be found in "Our Weights and Measures," by H. J. Chaney, Esq., Superintendent of the Weights and Measures Department of the Board of Trade.

brought into the most convenient relations to one another, and all of them brought into relation with the system of numeration which all men employ.

This was sought in two ways—one party, including most of those who were competent to judge in the matter, endeavoured to introduce into England the metric system, not because the metre is approximately the ten-millionth part of the Earth's quadrant, but because the metric system presents in the greatest attainable degree the above-mentioned permanent advantages. The other party—a minority among those competent to judge—followed Sir John Herschel in his desire that Great Britain should set up a new system in competition with the metric system, in which the unit of length, which he proposed to call the module, should be the ten-millionth of the Earth's polar axis, and should be divided decimally. This module would be very nearly 50 British inches; and he proposed that the inch should be very slightly lengthened to make this relation exact. There would then be exactly 100 of the new half-inches in his module. He also proposed that the half-pint should be given a distinctive name, and that its capacity should be altered in the very slight degree which would suffice to make the new half-pint exactly the hundredth part of the new cubic foot. A similar slight change was to be made in the ounce: to make the new ounce exactly the weight of the tenth part of the new half-pint of water. He pointed out that to bring all this about would demand only excessively small deviations from our existing inch, pint, and ounce; and he thought that if England set up a decimal system based on these units, it would be at once adopted by the United States which employs English measures, and by Russia which at that time had a system of measures derived from the English; and that it would thus come into use in the greater part of the manufacturing industry and of the commerce of the world. A popular account of his proposal was given by Sir John Herschel in a lecture delivered in 1863: one of his "Familiar Lectures on Scientific Subjects," published in 1867. Herschel's advice was that his new decimal system should be sanctioned by Parliament; while at the same time permitting the continued use of the old multiples into feet, yards, pounds, gallons, etc., in their present relations to the inch, ounce, and pint, but with the slightly altered values consequent upon the small changes in the latter which he recommended, and which he made the foundation of the rational and decimal system which he suggested for adoption in England. If this option were allowed, he anticipated that the better system would gradually supersede the less perfect; and that thus a good, if not the best, system of weights and measures would become established in this country without demanding any appreciable sacrifice from the people, or enforcing upon them any sudden change of their habits.

This proposal was made forty years ago, and since then the world has not stood still. The use of metric measures, which up to forty years ago had advanced slowly, has made more and more rapid progress every decade since that time; and has now an assured footing among all the more civilized populations of the world, except those who speak English—not excepting the people of Russia, whose measures, forty years ago, were based upon those of England.

And, on the other hand, the considerations in favour of Sir John Herschel's proposal have become weaker. It is now perceived that far greater accuracy can be attained by comparing all other measures with the standards established by the International Committee on Weights and Measures, in which our Government has taken part, than by any attempted comparison with the length of the Earth's axis, to which Sir John Herschel attached so much importance, or with the length of the Earth's meridian as was laboriously attempted by the founders of the metric system; or by pendulum determinations, as had also been advocated. It must also be recognised that the measures of length, of surface, of capacity, and of weight, are brought into better relation to one another in the metric system than in Sir John Herschel's; and that this gives the metric system an advantage over its competitor of primary importance, and one the benefit of which will last for all future time within any nation that uses metric measures.

It is useless to speculate how Sir John Herschel, if he were writing in 1903 instead of in 1863, would deal with the question. For my part, I do not think that he, or any other man who is as competent to judge as he was, and who examines fully into the question as it presents itself in the twentieth century, could continue to advocate England's striving to set up the Herschel system of measures in competition with the metric system; or could entertain the least idea that it would ever become a universal system, employed by the whole civilized world, such as the metric system will become if it is adopted by the English-speaking populations of the world. Nor can we come to any other conclusion than that this is fortunate; since of the two systems, the metric system is distinctly the better for the whole future of the world, on account of the more useful relations established in it between measures of length on the one hand, and the weights and measures of surface and of capacity on the other.

There is another considerable practical advantage which attaches to metric measures of length, to which the attention of the present writer was called, nearly fifty years ago, by the late Dr. Humphrey Lloyd, Provost of Trinity College, Dublin. It depends on the magnitude of the millimetre, which is the smallest division placed on the metric rules used by artisans. The millimetre, though small, is so conspicuous to the eye on such rules that the workman measures, with extreme ease, to the nearest millimetre when making very rough measurements. This is a better measurement than is usually made in rough work with workmen's English rules. And the millimetre is also nearly the smallest interval that can be *correctly* subdivided into tenths by estimation. When one uses metric scales much, one insensibly acquires the power of dividing any length into tenths by estimation, with a remarkable approach to accuracy. This useful power, when once acquired, makes it possible for a workman, using a metric scale, to measure lengths *to the nearest tenth of a millimetre*, rapidly, with the naked eye, and without verniers. This is much greater precision than can be attained with the rules commonly employed by workmen in this country. The tenth of a millimetre is nearly the smallest interval that the unassisted eye can see. It is about the average thickness of sheets of paper.

What then is our present position in England in regard to weights and measures, and what are our prospects?

An Act was passed in 1864 which purported to make it lawful to use metric weights and measures in the United Kingdom; but it was held by our courts of law that it did not attain its object, because it did not recite and repeal a clause of a preceding Act which forbade the use of any other than imperial measures in buying and selling, and because it made no provision for the verification of metric measures by the Board of Trade.

The Weights and Measures Act of 1878 made a very halting advance. It provides for the verification of metric weights and measures and sanctions their use for other purposes, but forbids their being used in buying or selling commodities. This Act left matters in such a state that, though metric measures might lawfully be used by scientific chemists, and have been universally used by them, the pharmaceutical chemist who had to sell his medicines was compelled by the law to continue to use the old bad Apothecaries' weights and measures.

So matters remained until 1896, when the Government at length introduced a Bill permitting the use of metric measures for all purposes. To this Bill, as to the Acts of 1864 and 1878, were attached, unnecessarily complex tables of equivalents for the conversion of imperial into metric measures, and of metric into imperial; and when the attention of the Government was called to this, they omitted the tables from the Bill, and introduced a clause authorising the issue of tables by Order in Council. In 1897 the Bill passed in this amended form; and simpler tables have since been issued by an Order in Council, dated 19th May, 1898. These are now the tables of equivalents which have legal force.

After this legislation had passed, Mr. Balfour, the leader of the House, and Mr. Ritchie, who was then at the Board of Trade, expressed the opinion, in replying to deputations, that Parliament had now done its part, and that it was for the English people to make the next move. The deputations had asked the Government to introduce a Bill, forbidding the use of any other than metric measures after two years. I venture to submit that both the request and the reply need revision and amendment.

The contention that it is the nation who should make the next move is not tenable. Parliament has not as yet done anything to *facilitate* the use of metric measures. It has made it *barely possible* for an Englishman to do so. After forty years of legislation it has only gone so far as to relieve an Englishman who uses them from being punished for doing so; and it is plain to common sense that this is not enough. As matters now stand, with the intricate and troublesome relations which Parliament has allowed to subsist between the two systems of measurement, it is in vain to ask men engaged in the active employments of life, and trying to earn money, to use those measures which they judge to be best, merely because they will not henceforth be fined for doing so, but where *Parliament has left matters in such disorder that they will incur loss* in other ways. The disorder is at present such that work begun in shops using imperial measures cannot be finished in shops using metric measures, or *vice versa*, without involving both expense and trouble. Neither has Parliament, as yet, put it within the power of the English tradesman to make the change. How can a beginning be made? How can a prudent tradesman use other measures than those in which his customers are accustomed to think? He could indeed make the necessary beginning if a yard was only another name for nine decimetres, which is the proposal made in this paper, and if a pound was another name for 4½ hektograms; but he cannot start using metric measures so long as a yard is nine decimetres and a complicated fraction, and a pound 4½ hektograms and another troublesome fraction. It is the start that is impossible. He cannot begin using them as matters at present stand. It is therefore plain that Parliament has not done enough; and legislation, like other things, if it falls short of being sufficient, is a failure. If there is no further legislation, Englishmen may continue for another century compelled by the force of circumstances to put up with inferior weights and measures, and so far without the same advantages, both within this kingdom and in the competition of the world, as the Frenchman the German or the Belgian. Why should not we, as well as they, have every attainable advantage—every advantage that Parliament can procure for us and for our children—and which I venture to submit it is the duty of Parliament to place practically within our reach?

The deputations that waited on the Government proposed further legislation, but legislation so drastic that it is doubtful whether Englishmen would submit to it. For my part, I hope, on wider grounds, that Englishmen would resent any approach to being dragooned, and I think the proposal a very injudicious one.

Englishmen, as compared with the nations of the Continent, are fortunately more difficult to drive, while, also fortunately, they are easier to lead where the reason for a change can be made plain; and moreover it must be remembered that Englishmen are less prepared for a sudden change from one set of measures to another, than were the populations of continental countries, of whom a large proportion live sufficiently near frontiers that are mere imaginary lines, to grow up in familiarity both with their own way of measuring, and that employed by their neighbours over the border. On the other hand, our people know no other system than one, and at present cannot think in any other. This, I submit, ought to be fully recognised by Parliament in framing any legislation that is to be imposed upon the United Kingdom. The same want of preparedness for any abrupt change prevails throughout our British Colonies, and among the people of the United States, whose interests, in addition to those of our colonies, I think we are bound to try and promote, since they have hitherto used British measures. None of these nations —neither our daughter nations, nor the people of the United States, nor ourselves—are as prepared for acquiescing in change, as were the peoples of the continent of Europe. And to this may be added the fact, that, in many continental countries, it was found expedient to make such modifications of local measures as made it possible to allow them to continue in use along with the metric measures. All these considerations, and many others, point to that way of dealing with the task before Parliament, which I have endeavoured to work out in the proposed Draft Bill, which will be found in the appendix. The legislation which is there suggested is not any half-way house. It will accomplish the whole of what is required, and no further intervention by Parliament will be necessary.

The proposal aims at establishing sufficiently simple relations in place of the present needlessly complex relations between imperial and metric measures; and, at the same time, it leaves undisturbed the mutual relations between the different parts of the imperial system, to which the people of this country are accustomed. It thus seeks to make the change as little obtrusive as it can possibly be made, and as little likely to be felt as change by the bulk of the people; while at the same time it is *effectual*, inasmuch as it puts it within the power of any member of the community, without incurring loss, to use either metric or imperial measures whichever he finds most convenient: and under these circumstances the spread of metric measures is assured.

It will also make the teaching of weights and measures to children both easier and more instructive. A yard, to the children of the future, will simply be another name for nine-tenths of a metre; an imperial gallon will be nine-tenths of the metric gallon, or half dekalitre; a pound avoirdupois will be nine-tenths of the metric pound, or half kilogram; an acre will be presented to them by their teachers as a special name for the size of a strip of ground forty metres wide and 100 long; a mile, to them, will be another name for 1,600 metres; and so on. These relations to metric measures will then take the place of our present confusing tables of weights and measures. They will be easier remembered, convey more meaning, and dispense with a task which is at present one of the most irksome in school education. As to the metric tables, to which the imperial measures will be in the foregoing way annexed, they teach themselves: they need no elaborate learning.

Another further advantage is that, if these simple relations between imperial and metric measures are called into existence by Parliament, our posterity, reading books written now or heretofore, will find nothing in them that is unintelligible—descriptions of distances in miles, of heights in feet, of weights in pounds or tons, will be understood by them and will convey substantially the same meaning to them then as they do to us now.

It is perhaps the greatest merit of this proposal that the less educated part of our population will not be sensibly affected by it. To take the fifth of an inch off each foot, and half a quarter of an ounce off each pound, will leave those measures so like what they are at present, that the difference will scarcely be perceived, and will not be felt after the change has once been made. Even the price lists prepared under the present system need not be changed. They may continue in use: everything will be adjusted by allowing a discount of one penny in five shillings off the list price of goods sold by the foot or yard, and a discount of one penny off every half-guinea of the price of goods sold by the pound—or the adjustment can be made in another way, by adding an inch to every two yards in measuring lengths, and by adding an ounce to every eight pounds in weighing. These are not too serious burdens for Parliament to lay even upon our illiterate classes, in order to bestow upon Englishmen at large and upon all our posterity the great boon that is contemplated.

As regards other classes of the community, the author has carefully gone into details in reference to each large class—merchants, tradesmen, manufacturers, mechanical engineers, civil engineers, artisans, country gentlemen, farmers, and others—and has ascertained that they will not be inconvenienced except to a slight extent and for a short time; while the proposal, if carried into effect, will secure permanent advantages to them and to their posterity out of all proportion to the inconvenience. It would too much lengthen this paper to attempt to go into these details. Instead of doing so, I may refer to the opinion recently expressed in public by Sir Andrew Noble, Bart., whose judgment in this matter should carry the greatest weight both with Parliament and the country, since it is based upon his prolonged and unrivalled experience as Head of the vast engineering works of Armstrong and Co., unsurpassed in England as regards both the variety and extent of their operations; and since it is the deliberate restatement of a judgment which he has now held for two and a half years. Speaking in the discussion upon weights and measures, which recently occupied two meetings of the Institution of Electrical Engineers, Sir Andrew Noble publicly recommended the proposal put forward in the present paper, and reiterated an opinion, which he had communicated to me two years and a half ago, when my proposal was first made. His judgment was at that time expressed in the following words, which he allows me to publish:—

"The Metric System is bound to become the system of the world; and it is difficult to conceive any scheme by which English measures can be brought into relation with the Metric System with less inconvenience to the public than that which you have arranged in your proposed Bill."

In Plate I. will be found a diagram of the present two-foot rule, and of the rule which will take its place if the proposal now made is carried out. The diagram shows that the foot and inch will look very much like what they have hitherto been; and it also shows into what very convenient relation with metric measures they will be brought.

Even less change than that exhibited in the diagram suffices in most other parts of the proposal.

APPENDIX.

DRAFT OF A BILL TO SIMPLIFY THE RELATIONS BETWEEN BRITISH WEIGHTS AND MEASURES.

Submitted by G. Johnstone Stoney, M.A., Sc.D., F.R.S.

Whereas it is lawful to use either imperial or metric weights and measures within the United Kingdom of Great Britain and Ireland for the purpose of determining the quantities of commodities to be bought and sold;

And whereas it is expedient to simplify the relations in which the weights and measures stand to one another, that may lawfully be so used;

Be it therefore enacted that on and after the first day of January, 190—, the imperial weights and measures shall cease to be derived from the standard yard and standard pound deposited with the Board of Trade, and shall on and after the aforesaid date be derived from the iridio-platinum linear standard metre and iridio-platinum standard kilogram deposited with the Board of Trade and numbered 16 and 18 respectively: in the manner set forth in Schedule A attached to this Bill, which shall be read as part of this Bill; in which are set forth the various weights and measures of the imperial system which, with their multiples and aliquot parts, may lawfully be used after the said first day of January, 190—; and in which are also set forth their equivalents in metric measure, and the ratios which may lawfully be used in comparing the imperial weights and measures at present in use, which are hereinafter called the old imperial weights and measures, with those that will take their place under the provisions of this Bill, which are hereinafter called the new imperial weights and measures.

In Schedule B attached to this Bill and which shall be read as part of this Bill, are set forth the metric weights and measures which with their multiples and aliquot parts may also lawfully be used in determining the quantities of commodities to be bought or sold, and their equivalents in the new imperial measures.

Schedule A.

NEW IMPERIAL WEIGHTS AND MEASURES,

WITH THEIR METRIC EQUIVALENTS.

I.—MEASURES OF LENGTH.

Section 1.

The mile shall continue to be divided into 8 furlongs, the furlong into 10 chains, and the chain into 4 poles or perches.

These measures shall have the following values:

New mile, ... = 1600 metres.
New furlong, ... = 200 metres.
New chain, ... = 20 metres.
New pole, or perch, . . . = 5 metres.

It shall be lawful to regard the ratio of each of the new measures in this section, to the old measure of the same name, as being the ratio of 100 to 100·58, or as being the ratio of 172 to 173.

Section 2.

The yard shall continue to be divided into 3 feet, and the foot into 12 inches.

These measures shall have the following values:—

New yard, ... = 9 decimetres.
New foot, ... = 3 decimetres.
New inch, ... = 25 millimetres.

It shall be lawful to regard the ratio of each of the new measures in this section, to the old measure of the same name, as being the ratio of 100 to 101·6, or as being the ratio of $62\frac{1}{2}$ to $63\frac{1}{2}$.

The new imperial yard is nine-tenths of the metric yard or metre.

II.—LAND MEASURES.

Section 3.

The acre shall continue to be divided into 4 roods, and the rood into 40 square perches.

These measures shall have the following values:—

New acre, ... = 4 dekares.
New rood, ... = 1 dekare.
New square perch, . . = $\frac{1}{4}$ of an are, or 25 square metres.

It shall be lawful to regard the ratio of each of the new measures in this section, to the old measures of the same name, as being the ratio of 100 to 101·17, or as being the ratio of 85·3 to 86·3.

III.—AVOIRDUPOIS WEIGHTS.

SECTION 4.

The ton shall continue to be divided into 20 hundredweights, the hundredweight into 4 quarters, and the quarters into 2 stones.

These weights shall have the following values :—

New ton, ... = 1000 kilograms.
New hundredweight, . = 50 kilograms.
New quarter, . . . = 12½ kilograms.
New stone, ... = 6¼ kilograms.

It shall be lawful to regard the ratio of each of the new weights in this section, to the old weight of the same name, as being the ratio of 100 to 101·6, or as being the ratio of 62½ to 63½.

SECTION 5.

The avoirdupois pound shall continue to be divided into 16 avoirdupois ounces, and the avoirdupois ounce into 16 avoirdupois drams. The pound may also be divided into 9 half-hektograms.

These weights shall have the following values :—

New avoirdupois pound, = 4½ hektograms.
New avoirdupois ounce, = 28⅛ grammes.

The new avoirdupois dram shall be one-sixteenth part of the new ounce.

It shall be lawful to regard the ratio of each of the new weights of this section, to the old weight of the same name, as being the ratio of 100 to 100·8, or as being the ratio of 125 to 126.

The new avoirdupois pound is nine-tenths of the metric pound or half-kilogram.

IV.—MEASURES OF CAPACITY.

SECTION 6.

The quarter shall continue to be divided into 8 bushels, the bushel into 4 pecks, the peck into 2 gallons, the gallon into 4 quarts, the quart into 2 pints, and the pint into 4 gills.

These measures shall have the following values :—

New quarter, ... = 288 litres.
New bushel, ... = 36 litres.
New peck, ... = 9 litres.
New gallon, ... = 4½ litres.
New quart, ... = 1⅛ litre.

The new pint shall be half the new quart.
The new gill shall be a quarter of the new pint.

It shall be lawful to regard the ratio of each of the new measures in this section, to the old measure of the same name, as being the ratio of 100 to 101·02, or as being the ratio of 98 to 99.

The new imperial gallon is nine-tenths of the metric-gallon or half-dekalitre.

V.—SPECIAL WEIGHTS AND MEASURES.

Section 7.—Troy Weights.

The Troy ounce shall continue to be divided into 20 pennyweights, and the pennyweight into 24 grains.

These weights shall have the following values:—

New Troy ounce, . . = 32 grammes.
New pennyweight, . = 1·6 gramme.
New grain, ... = one 15th of a gramme.

It shall be lawful to regard the ratio of each of the new weights of this section, to the old weight of the same name, as being a ratio of 100 to 97·2, or as being the ratio of 35·7 to 34·7.

Section 8.—Coin Weights.

It shall continue to be lawful to use coin weights of the same amounts as may lawfully be used at the time of the passing of this Bill.

Schedule B.

METRIC WEIGHTS AND MEASURES,*

WITH THEIR EQUIVALENTS IN NEW IMPERIAL MEASURE.

I.—MEASURES OF LENGTH.

Metric.				New Imperial.
Stage, or myriametre, . .	=	10 kilometres, . . .	=	$6\frac{1}{4}$ miles.
Kilem, or kilometre, . . .	=	1000 metres, ...	=	5 furlongs.
hektome, or hektometre, .	=	100 metres, ...	=	5 chains.
dekam, or dekametre, . .	=	10 metres, ...	=	2 perches or poles.
Metre, ...			=	40 inches.
decimetre, ...	=	$\frac{1}{10}$ of a metre,	=	4 inches.
centimetre, ...	=	$\frac{1}{100}$ of a metre,	=	$\frac{4}{10}$ of an inch.
Millimetre, ...	=	$\frac{1}{1000}$ of a metre,	=	$\frac{1}{25}$ of an inch.
Micron, ...	=	$\frac{1}{1,000,000}$ of a metre,	=	$\frac{1}{25,000}$ of an inch.

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* Everything that is possible should be done to get the names of metric measures to be henceforth so pronounced by English-speaking people, as to become good English names. To bring this about it is advisable to discourage the prevalent mistake of pronouncing kilo (which in English corresponds to Milo), as if spelled killo in such words as kilometre, kilogram, kilowatt; and of pronouncing litre (which should rhyme with mitre) as if it had been leetre. See note 2 on page 21.

II.—LAND MEASURE.

METRIC.				NEW IMPERIAL.
Hektare,	=	square of 100 metres,	=	$2\frac{1}{2}$ acres.
dekare,	=	10 ares,	=	1 rood.
Are,	=	square of 10 metres,	=	4 square perches.

III.—WEIGHTS.

METRIC.				NEW AVOIRDUPOIS.
Ton,	=	1000 kilos,	=	1 ton.
quintogram, or quintal,	=	100 kilos,	=	2 hundredweights.
quartogram, or myriagram,	=	10 kilos,	=	$\frac{1}{5}$ hundredweight.
Kilo, or kilogram,	=	1000 grammes,	=	$2\frac{2}{9}$ pounds.
metric pound, or half-kilogram,	=	500 grammes,	=	$1\frac{1}{9}$ avoirdupois pound.
hekto, or hektogram,	=	100 grammes,	=	$\frac{2}{9}$ pound.
dek, or dekagram,	=	10 grammes,	=	$\frac{1}{45}$ pound.
Gramme,	=	. . . . . .	=	15 grains.
decigram,	=	$\frac{1}{10}$ gramme,	=	$1\frac{1}{2}$ grain.
centigram,	=	$\frac{1}{100}$ gramme,	=	$\frac{3}{20}$ grain.
Milligram,	=	$\frac{1}{1000}$ gramme,	=	$\frac{3}{200}$ grain.

IV.—MEASURES OF CAPACITY.

METRIC.				NEW IMPERIAL,
Stere, kilolite, or kilolitre,	=	1000 litres,	=	$111\frac{1}{9}$ pecks.
hektolite, or hektolitre,	=	100 litres,	=	$11\frac{1}{9}$ pecks.
dekalite, or dekalitre,	=	10 litres,	=	$1\frac{1}{9}$ peck.
metric gallon or half-dekalitre,	=	5 litres,	=	$1\frac{1}{9}$ imperial gallon.
Litre,	=	. . . . . .	=	$\frac{2}{9}$ gallon, or $\frac{8}{9}$ quart.
decilitre,	=	$\frac{1}{10}$ litre,	=	$\frac{1}{45}$ gallon.
centilitre,	=	$\frac{1}{100}$ litre,	=	$\frac{1}{450}$ gallon.
Millite, or millilitre,	=	$\frac{1}{1000}$ litre.	=	$\frac{1}{4500}$ gallon.

In measuring commodities for purchase or sale, it shall be lawful to treat the following measures as equivalent:—

1 stere, and one cubic metre;
1 hektolitre, and 100 cubic decimetres;
1 dekalitre, and 10 cubic decimetres;
1 litre, and 1 cubic decimetre;
1 decilitre, and 100 cubic centimetres;
1 centilitre, and 10 cubic centimetres;
1 millilitre, and 1 cubic centimetre.

NOTE.—The stere differs very little from the cubic metre, the litre differs very little from the cubic decimetre, and the millilitre differs very little from the cubic centimetre; the ratio of the stere to the cubic metre, or of the litre to the cubic decimetre, or of the millilitre to the cubic centimetre, being approximately the ratio of 100·016 to 100, or of 6251 to 6250.

End of draft Bill.

NOTE 1.

On Graduating Scales, and Making Screws.

By a recent International arrangement, in which our Board of Trade took part, the following relation between the yard and the metre has been definitively agreed upon, viz.:—

Old yard = 0·9143992 metre.

This in practice is undistinguishable from 0·9144 metre, since the proportional increase which is here made is but a small fraction of the probable error in such determinations; as is manifest upon comparing with one another the values furnished by the best determinations that have been made in Europe and America.

Another consideration concurs in showing that the difference (which is less than the millionth part of the whole length) has no practical significance. It is the amount by which the length and subdivisions of a bronze rule are altered when the temperature deviates by less than $\frac{1}{20}$ of a degree Centigrade from that for which the rule was justified. Now the intended temperature of the original bronze standard, which was destroyed in the conflagration of the Houses of Parliament in 1834, and of which our present imperial standards are meant to be copies, is not known to this degree of accuracy; inasmuch as there exists no record of the kind of glass used in making the stems and bulbs of the mercury thermometers, by which the temperature prescribed by the Act of 1824, viz.: 62° F., was determined, when those copies were made from which our present standards are taken.

Adopting then the simpler value, we find that—

0·9 metre (the new yard) : 0·9144 metre (the old yard) : : 125 : 127, from which ratio we gain the following very valuable practical rule, that *Dividing Engines and Lathes which are furnished with Whitworth screws the pitch of which is known in old imperial measure, can be made to graduate scales and make screws of equal accuracy in the new imperial measure, or in metric measure, by the simple expedient of introducing two change-wheels, one with* 125 *the other with* 127 *teeth.*

NOTE 2.

On the Pronunciation of the Names of Metric Weights and Measures.

The word litre, like mitre and nitre, has come into English, through the French from the Greek; and in Greek the spelling and accentuation of the three words are alike. They should therefore be pronounced in the same way in English; both on this account, and still more in order not to infringe an almost universal rule that when the first syllable of an English dissyllable ends in i, the i is to be pronounced as it is in biped, cider, dial, final, giant, &c. To justify the pronunciation of the word litre which is now prevalent, it would need to be spelled lietre or leetre; and, as its etymology forbids this, it is the pronunciation which should be corrected.

Again, in χιλιάς and all its Greek derivatives, the ι of the first syllable is long. It is advisable therefore to pronounce the i long in its English derivatives, to avoid introducing a needless anomaly into our language. This concerns the words kilem or kilometre, kilo or kilogram, kilolite or kilolitre, and kilowatt; in all of which the i should be pronounced as it is in microscope, nitrogen, &c.

Euphony (which is really ease of pronunciation) in no degree requires us to keep up the practice of frenchifying the terms litre, kilometre, &c., especially in the objectionable form of pronouncing the first syllable as French and the other syllable or syllables as English. The practice has lost whatever semblance of appropriateness it may have had while Metric Weights and Measures were exclusively foreign. But in other cases euphony does justify a deviation from what would otherwise be required for etymological correctness, as when hekto is employed in the metric nomenclature as the prefix to signify a hundred. Hekato would be awkward in such words as hektogram, hektolitre, &c. So, again, kilo is excusable instead of kilio as the prefix for a thousand; and perhaps the spelling—k instead of ch—as being on the whole more convenient.

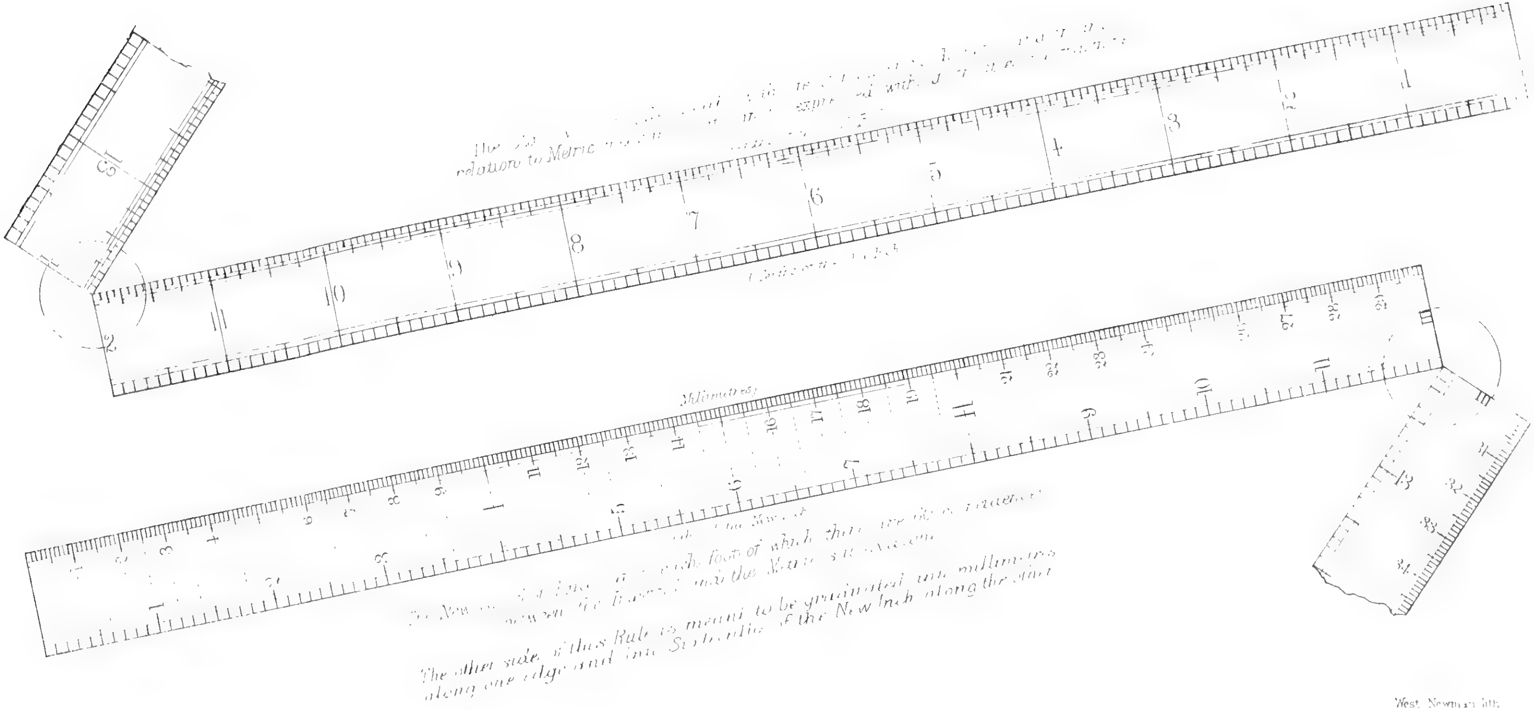
Are, the metric unit of land surface, and the group of letters *a-r-e* in the words hektare and dekare, should in English be pronounced as in the words declare, dare, &c.

NOTE 3.

On Alternative Names.

Shorter names for some of the metric measures will inevitably arise among English-speaking people who use those measures. It is therefore advisable that they be contrived with care, so as to secure:—

1. That they shall embody in briefer form the whole of the meaning conveyed by the longer names;



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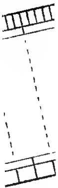

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2. That they shall be so unlike in sound, as not to be easily mistaken for one another. [One valid objection to the existing practice of mispronouncing the word *litre*, is that when mispronounced it sounds too much like metre. This liability to error does not occur in France, since in French mètre and litre have different vowel sounds: it was by frenchifying English that the confusion was introduced.]
3. That they shall be so related to the longer names as naturally to suggest them.

Keeping these ends in view the following alternative names are proposed, in which the letter i in the syllables ki and li is meant to be pronounced as in mile.

Kilem or kilometre.
Hektome or hektometre.
Dekam or dekametre.

Kilo or kilogram.
Hekto or hektogram.
Dek or dekagram.

Kilolite or kilolitre.
Hektolite or hektolitre.
Dekalite or dekalitre.

Millite *or* Millilitre.

These names are recommended; but if not approved, a pen may be drawn through them where they occur in the Draft Bill.

NOTE 4.

Convenient Identity of Relationship.

If metric measures are established in England under the proposed legislation, the following identity of relationship will in future years be found in an unusual degree convenient to persons reading books written before the change:—

The imperial yard = nine-tenths of the metre.
The imperial gallon, = nine-tenths of the metric-gallon, or half-dekalitre.
The avoirdupois pound, = nine-tenths of the metric-pound, or half-kilogram.
A bushel per acre, = nine-tenths of a litre per are, or of a hektolitre per hektare.

These are the yard, gallon, pound, bushel, and acre of the 'new' system, and differ by inconspicuous amounts from the yard gallon pound bushel and acre referred to by the books in question.

30, LEDBURY-ROAD, LONDON, W.
February, 1903.

III.

PHOTOGRAPHS OF SPARK-SPECTRA FROM THE LARGE ROWLAND SPECTROMETER IN THE ROYAL UNIVERSITY OF IRELAND. PART II.[1]: THE ULTRA-VIOLET SPARK-SPECTRUM OF RUTHENIUM.

By W. E. ADENEY, D. Sc., A. R. C. Sc. I., Curator and Examiner in Chemistry in the Royal University of Ireland.

[Read January 20; Received for Publication January 23; Published August 7, 1903.]

Reproductions of photographs of the spark-spectra of the platinum and other metals from the 21·5 ft. Rowland spectrometer in the Royal University, Dublin, have already been published in the Scientific Transactions of this Society, vol. 7, 1901.

Scales of approximate wave-lengths were ruled on the negatives from which the reproductions were prepared; and it was at first hoped that, with their aid, it would be possible to easily identify the spectral lines with those previously given in various tables of wave-lengths for the same metals, and that consequently it would not be necessary to exactly measure the lines.

More recent work, however—more especially that on the effect of pressure upon the wave-length of lines in the electric arc,[2] and on displacement of the spark-lines analogous to those in the arc[3]—has rendered it advisable to accurately measure all the lines on the photographs.

The measurements of the spectrum which forms the subject of this communication, have been made by means of a light microscope mounted on a stage which can be moved through a space of about one inch long by a short micrometer screw. Each line has been measured at least twice, and many of them three and four times.

Kayser's values[4] for the well-defined lines in the arc-spectrum

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[1] For Part I. see Trans. R.D.S., Vol. vii., 1901, p. 331.

[2] Humphreys and Mohler, Astrophysical Journal, 1896, 1897.

[3] E. Haschek, Spectroscopic Studies, Astrophysical Journal, 1901.

[4] Kayser, Konigl. Preuss. Akademie der Wissenchaften zu Berlin, 1897.

of the same metal have been employed as standards for calculating the wave-lengths from the micrometer measurements.

In the cases where the calculated wave-lengths have shown a close agreement with those by Kayser, the latter observer's values have been adopted. In those cases in which they have not agreed, they have been confirmed or corrected by remeasuring the lines with the same microscope and micrometer, but with the addition of a finely divided glass-scale in the eye-piece, and a photograph of a *réseau* belonging to the observatory of Cambridge University, for which the author is indebted to Mr. Arthur R. Hinks, M.A.[1]

With this arrangement, it has been possible to measure a number of neighbouring lines relatively to one another with considerable accuracy.

In the appended list of wave-lengths,[2] Kayser's have been given for convenience in indicating those lines which are common to both forms of the spectrum and those which only appear to belong to one or other form.

In the author's photograph of the ruthenium spectrum, 1461 lines have been measured between the two extreme limits of wave-length 2263 and 4560; and Kayser has given 1613 lines as occurring in the arc-spectrum between the same limits of wave-length.

About 800 lines are common to both forms of the spectrum. Besides these, about 800 lines occur in Kayser's list, but apparently not in the author's, and about 650 in the author's and not in Kayser's.

Displacements in some of the spark-lines, as indicated by Haschek in his interesting paper entitled "Spectroscopic Studies," may account for some of these differences; and such lines may therefore be similar, although slightly differing in wave-length.

Some of the wave-lengths in both lists may be affected by unusually large errors, owing to diffuseness in character of the lines, or to faintness or to some distortion in the films, or to some other source of error, and may in reality be coincident.

There can, however, be no doubt that a large number of the lines, which appear peculiar to each form of the spectrum, are due to the different modes of producing incandescence employed.

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[1] See Mr. Hinks' paper on "The Cambridge Machine for Measuring Celestial Photographs." Monthly Notices of R. A. S., May, 1900.

[2] Note the wave-lengths have been given to two places of decimals only.

Kayser states, in his paper, that the lines which Rowland gives near the cyanogen band 3883 could not be seen in his photographs owing to the band being very strong in them. Rowland[1] gives 15 lines in this part of the spectrum (3778 to 3876). All these occur in the author's spark-spectrum, with but one exception (3828·32).

The possibility of some of the lines at least being due to impurities must be considered. Many of them are, as a matter of fact, coincident with those of other elements, particularly of iron. The author has carefully compared his spark-spectra of ruthenium with those of the rest of the platinum metals, and of iron, cobalt, nickel, chromium, manganese, copper, calcium, and silicon. As was anticipated from the very large number of lines in most of these spectra, several of them were found to have similar wave-lengths to many of the ruthenium lines; but on carefully comparing the character of these lines with those with which they coincided in the ruthenium spectrum, it was quite easy to see that they were not the same. The author has only been able to identify, in his ruthenium spark-spectrum, 19 lines due to iron, and 2 to calcium.

Exner and Haschek[2] have measured 2250 lines between the limits above given; some 1330 of these occur in the author's photographs. The larger number of lines occurring in the photographs of these authors is, no doubt, chiefly owing to the fact that different methods of producing the sparks were employed in the two cases.

The author desires, in conclusion, to acknowledge his indebtedness to Miss M. Hall for the very valuable assistance she has given him in the work of making the micrometer measurements and of calculating the wave-lengths from them.

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[1] Astrophysical Journal, 1896.

[2] Sitzungsberichte der Kais. Akad. der Wiss. in Wien., 1896.

RUTHENIUM.

KAYSER.	ADENEY.	KAYSER.	ADENEY.
	2263·73		2395·66
	68·26	2396·79	96·79
	82·00		97·70
	87·28		98·63
	98·80		99·28
	2303·06		2400·38
	04·97		01·18
	05·85		01·93
	13·51	2402·80	02·80
	20·82		05·00
	29·11		06·12
	31·23		06·67
	31·81		07·37
	32·26	08·00	08·00
	33·72		08·51
	34·05	08·74	
2335·05	35·05		10·24
	36·93		11·62
38·09	38·05		13·32
	40·00		13·60
40·77	40·77		14·00
	41·11		14·93
	42·66		15·30
42·92	42·92		15·82
	46·45		16·64
	50·51		17·05
	51·23		19·04
51·41			20·24
	52·92	20·91	
57·99	57·99		22·30
	58·90		22·91
	59·14		24·56
	62·47		26·66
	64·13		26·96
	67·31		27·26
70·25	70·25		27·82
	72·08		28·98
75·35		29·67	
	75·71		30·45
	76·30		31·00
	79·54		32·25
	79·94		33·81
	82·08	34·98	34·98
	83·53		35·53
	87·28	39·72	39·72
	91·73	41·05	41·05
92·50		41·42	41·42
	93·84		41·82
	94·70	43·04	

KAYSER.	ADENEY.	KAYSER.	ADENEY.
	2443·48	2490·56	
2444·13			2491·10
44·50		91·85	91·85
44·92		94·12	94·00
45·52	45·52		94·22
47·54		94·77	94·77
48·96	48·96	95·76	95·88
50·46	50·46		97·14
50·65	50·90	98·51	
	51·27	98·67	98·67
	53·85	99·87	99·60
54·27	54·27	2500·48	2500·36
55·01		00·94	
55·61	55·61	01·57	
56·52	56·59	01·99	02·12
56·67		02·48	02·48
57·31	57·31	02·97	
58·71			03·40
59·15	59·15		05·13
	60·17		05·73
	60·57		06·18
61·51			06·61
	62·20	07·09	07·13
63·03	63·03	08·38	
64·47		08·51	08·81
64·78	64·78	09·16	
67·67	67·67	09·71	
	69·78	10·24	
70·61	70·61	11·06	
70·81		11·65	11·41
71·58		12·90	12·79
72·22	72·22	13·42	13·42
	72·81		14·10
	73·55	15·37	
74·12			15·74
74·51	74·55		16·25
75·48		16·88	
76·40			17·00
76·96		17·40	17·40
	77·22	17·73	
	78·33	18·60	18·60
79·01	79·01		19·49
79·46		20·04	
79·61		20·93	20·89
	80·83		21·08
81·22	81·22	21·70	
	81·83	22·41	
82·63			22·83
	83·82	24·95	24·95
84·06	84·06		25·12
	84·66	25·26	
	86·31	25·73	25·68
	87·26	26·01	
	88·58	26·91	
	89·34		27·19
90·02		28·03	28·03

KAYSER.	ADENEY.	KAYSER.	ADENEY.
2528·81		2560·35	2560·35
29·81	2529·81	60·92	
	30·40	62·25	
	30·67		62·58
32·13			63·00
33·33	33·33		63·38
	33·66		63·78
	34·23		64·02
35·15	35·15	64·50	
	35·42	64.67	64·73
	35·80	65·28	
36·32			65·77
	36·51		66·30
	36·90	66·67	66·67
	37·18	67·98	
37·78	37·78	68·85	
38·57			68·93
39·82	39·82	69·84	69·84
40·41	40·41	70·18	
41·38		71·07	
	42·24		71·17
42·60		72·37	
43·24		72·51	
43·35	43·35		72·71
43·78			73·09
44·32	44·32	73·65	73·65
	45·10		74·20
45·87	46·01	75·34	
46·77	46·81		76·17
47·60	47·80	77·11	77·11
	48·86	78·65	78·65
49·26	49·26	79·07	79·10
49·58		79·31	
49·66		79·62	
	49·92	79·88	79·94
50·95			80·08
51·47		80·32	80·32
51·82	51·82	80·88	
52·08	52·08	81·23	81·23
52·38		81·99	
52·52			82·48
52·97		83·13	83·13
	53·58	84·21	
54·06		85·41	
54·79		85·82	
55·73		86·16	86·16
55·96	55·96		86·95
56·10	56·10	87·41	
56·99	56·84		88·08
	57·25	89·13	
57·78	57·78	89·65	89·65
	58·13	89·89	
58·36		91·09	
58·63	58·63	91·20	91·20
	58·91		91·44
59·50	59·60	91·71	

KAYSER.	ADENEY.	KAYSER.	ADENEY.
2592·09			2624·87
	2593·79	2625·17	
	94·65		25·59
94·93			25·95
95·73		26·29	
96·04	96·04	26·44	
97·42	97·42		26·60
	97·84	27·74	27·74
	98·07		27·90
98·68	98·68	28·38	28·38
	98·99 (Fe)	28·62	28·91
	99·53 (Fe)		29·49
	2600·00	30·01	
2600·84		30·31	30·19
01·39			31·22
01·55	01·55	31·66	
	02·49	32·21	
	03·00	32·58	
	03·43		32·85
04·41	04·41	33·54	
05·44			33·93
05·95		35·45	35·39
	06·40	35·93	35·93
	07·18 (Fe)	36·62	36·62
07·44		36·76	
08·02	08·02		36·95
09·14	09·14	38·60	38·60
09·57	09·57	39·21	
	10·18		39·67
11·13		40·41	40·41
	11·63	41·55	41·72
	11·99	42·06	42·06
12·17	12·17	42·61	
	12·63	43·04	43·04
12·99		43·60	43·60
13·14		44·71	44·71
	13·37	46·09	46·09
14·15	14·15	46·72	
14·67	14·93	47·39	
15·18	15·18	48·02	
	16·50	48·54	
	17·29	48·71	
17·88		48·87	48·87
	18·68	50·08	
19·11			50·21
	19·42	50·49	50·49
19·75		50·69	
20·15	20·15	50·97	50·97
20·71	20·71	51·37	51·37
21·17		51·60	
	21·46	51·94	51·94
	21·91	52·24	52·05
	23·51		53·05
	23·76	53·24	
23·91		53·78	
	24·35		54·01

KAYSER.	ADENEY.	KAYSER.	ADENEY.
2654·56			2685·57
54·90	2654·90		85·94
55·19		2686·38	86·38
55·29			86·94
56·33	56·33	87·21	87·21
56·64		87·58	87·58
56·78		88·22	88·22
57·25	57·25	88·67	
	58·28	88·97	88·97
58·48			89·51
58·86		90·49	90·49
	59·64	90·90	
60·67		91·20?92·20	
61·25	61·25		92·20
61·69	61·69	93·39	93·39
61·94		93·75	93·75
	62·36		94·25
	62·94		94·85
	63·85	96·65	
	64·65		97·18
64·83	64·83	97·60	
65·23		98·16	
65·54	65·54		98·23
65·80			98·80
67·48	67·48		99·42
	67·89	99·96	
68·04			2700·32
68·42		2700·58	
	68·71	00·77	00·77
	69·24		01·09
	70·60	01·43	
70·81		02·92	02·92
72·45	72·45	03·22	
73·09	73·09	03·40	
73·55		03·89	
73·69			04·31
73·93			04·65
74·27	74·27		04·99
	75·27	05·42	
	75·58		07·41
	76·27	08·05	
76·43		08·93	
	76·86	09·16	
77·06		09·29	09·29
77·41		09·85	
77·97		10·32	10·32
78·27	78·27	12·17	
78·84	78·84	12·49	12·49
	79·54	12·97	
79·84		13·27	13·14
	80·66	13·82	13·66
	82·84	15·33	
83·76		15·60	
84·17			16·15
84·54	84·69		16·23
85·24	85·24	17·10	

KAYSER.	ADENEY.	KAYSER.	ADENEY.
2717·51	2717·51		2752·14
	17·93	2752·55	52·55
18·92	18·92	52·87	52·87
19·61	19·61	53·54	53·54
19·84	19·84		55·30
21·65			55·80 (Fe)
21·94			56·46
22·49		57·18	
22·76	22·76	57·91	
22·90		58·10	58·10
	23·10		59·35
	24·95	60·27	60·27
25·55	25·55		60·88
27·06	27·06		61·60
	27·74		62·17
	29·04	62·40	
29·54	29·54	63·23	
30·12		63·51	63·51
30·42	30·42	64·01	
	30·79	64·82	
31·03			65·24
	31·48	65·53	65·53
32·01			66·00
	32·83	66·32	
33·17			66·66
	33·68		67·66
34·44	34·44	68·03	
35·81	35·81	69·02	69·02
36·41	36·54	69·99	
36·92	36·92	70·40	70·40
	37·66	70·81	
	37·87		71·15
38·98			71·59
39·31	39·40		71·99
	39·68 (Fe)		72·55
40·09		72·72	72·72
40·33		73·07	
	42·15		74·25
	43·57	74·59	
44·02	44·02	75·29	
44·54	44·54	75·72	75·72
44·82		76·01	
	45·22	77·63	77·63
45·34			78·54
	45·90	79·08	79·08
46·17	46·17		79·54
	46·62	80·86	80·86
	46·75	82·31	82·31
46·99	47·00		83·85
	47·62	84·62	84·62
	48·03	84·98	
	49·26		85·29
	49·66	85·75	
49·92			85·90
50·45			86·50
51·70			87·35

KAYSER.	ADENEY.	KAYSER.	ADENEY.
2787·93	2787·93		2826·36
	88·84		26·81
89·72	89·72		27·19
	90·28	2827·63	27·63
90·70		27·97	27·97
91·16	91·16	29·25	29·25
92·42	92·42	30·82	
92·75		31·28	
	94·42		32·00
95·46	95·46	32·76	
	96·10		33·64
96·65	96·65		33·97
	97·20	34·11	
	97·91		34·52
	98·91		35·77
	99·71	36·25	
	2800·03	36·68	36·68
2800·24		37·38	37·28
00·79	00·79	38·73	38·73
02·26	02·26		39·16
02·91	02·91		39·52
03·59		40·66	40·66
	03·76		41·23
	04·94	41·78	41·78
06·85	06·85	42·65	
	07·34	42·86	
	07·70	43·28	
08·34			44·86
10·13	10·13		45·30
10·65	10·65	46·43	
10·79	10·79	46·66	
11·36			47·25
	11·66		47·72
	12·06	49·40	49·40
12·93			49·73
	13·44		50·86
13·81	13·81	51·23	
	15·18		53·28
15·41		53·43	53·43
17·19		54·17	54·17
	17·74	54·47	
18·46	18·46		54·82
18·91			55·01
19·06		55·45	55·45
19·67		56·00	
21·28		56·15	
21·50	21·50		56·67
22·14		57·37	57·37
22·37		57·77	
22·66	22·66		57·88
22·91			58·69
	23·33		59·65
24·00		60·11	60·11
24·87		60·49	
	25·20		60·95
	25·62		61·17

KAYSER.	ADENEY.	KAYSER.	ADENEY.
2861·51	2861·54		2900·63
61·83		2901·89	01·74
62·96	62·96	02·22	02·22
63·11		02·97	
	63·33	03·18	
64·73		04·83	
	65·65	05·76	05·76
	66·19	05·95	
	66·41	06·42	06·42
66·74	66·74	08·59	
	67·20	09·35	09·35
68·29			10·10
68·43	68·43	10·54	
68·66		12·45	12·45
69·05	69·05	12·56	12·56
70·32		12·87	
	70·53	13·29	13·29
71·30			14·10
	71·57	14·43	
71·76		15·74	
	73·34	16·35	16·47
	73·83	17·25	
74·16		17·35	
75·10	75·10	17·88	17·88
77·20			18·76
77·93	78·04	19·28	
	79·20	19·73	19·73
79·47		20·37	
79·85		21·07	21·07
	80·24	21·28	
80·64	80·64		21·95
81·37	81·37		22·50
82·22	82·22		23·40
82·70			24·20
83·70	83·70	24·76	
84·60	84·60	25·19	
	85·60	25·69	
86·64	86·64	25·89	25·89
87·22	87·22		26·69
88·11	88·11	26·91	
88·74		27·23	
89·54	89·54	27·89	27·73
90·54			28·27
91·24	91·24	28·61	28·61
91·76		29·03	29·03
	92·00		29·87
92·65	92·65		31·35
93·84	93·84	33·37	33·37
95·55		34·30	
95·93		34·64	
96·64			35·67
97·82	97·82	36·13	
	98·40	36·38	
98·65		36·59	
98·85			37·20
99·82	99·70	37·45	

KAYSER.	ADENEY.	KAYSER.	ADENEY.
2937·68		2974·10	
39·25	2939·25	74·45	2974·45
39·80			74·79
40·06		75·25	
40·47		76·71	76·71
42·37	42·37	77·05	
42·82		77·35	77·35
43·59	43·59	77·60	77·60
44·04	44·04	78·76	78·76
44·29		79·85	79·85
	45·20	80·07	80·07
45·59		81·08	81·08
45·78	45·78	82·05	82·05
46·67			83·74
47·10	47·10		85·08
	47·72		85·78
	48·47	86·10	
49·61	49·61	86·45	86·45
50·08	50·08	88·05	
50·65		88·22	
51·52		89·08	89·06
	52·36	89·45	
52·60		89·77	
	52·78	90·41	
54·37	54·20		91·71
54·59	54·59	92·08	92·08
55·46			92·48
55·71		93·07	
55·96		93·39	
57·30			94·54
58·12		95·08	95·08
58·99			96·01
59·86	59·86		96·44
	60·35		96·89
61·10			97·34
	61·60	97·74	97·74
	62·08		98·09
62·44		98·45	98·45
62·71		99·01	99·01
63·52	63·52		3000·00
63·83		3000·34	
64·42			00·57
65·29	65·29	01·76	01·76
65·67	65·67	02·19	
65·82		02·60	02·60
66·67		04·71	
	66·98	06·09	
67·46		06·71	06·71
68·23	68·11		08·00
68·56	68·56	08·37	
69·07	69·07	08·70	
69·85	69·85	08·91	
	71·10	09·80	09·80
72·59	72·59	10·62	10·62
	73·08	12·00	
73·74	73·74	13·04	

KAYSER.	ADENEY.	KAYSER.	ADENEY.
3013·17		3050·31	
13·48		50·50	
14·31		51·70	
	3015·60	51·97	
	16·10	52·45	
16·82		53·45	
17·36	17·36	55·04	3055·04
18·16	18·16	56·88	
	18·32	56·97	56·97
19·47		57·47	
19·88	19·88	58·76	58·76
20·36		58·91	
20·99	20·99	59·28	59·28
	22·72	60·37	60·37
	23·05		60·67
	24·00	62·16	62·16
25·21		64·96	64·96
27·20	27·20		66·61
27·36			67·71
27·68		68·36	68·36
27·91	27·91	69·29	
28·79		71·59	
	29·04	71·72	
30·80		71·82	
30·89			72·42
32·03		73·44	73·50
32·77	32·77	75·41	75·41
	33·16	76·89	
33·56	33·56	77·18	77·18
34·17	34·17	77·66	
35·58		78·21	
	35·93		79·27
36·58	36·58	79·95	
37·85	37·85	80·29	
38·08		81·01	81·01
38·29		81·22	
38·85		81·49	81·49
39·59		81·95	81·95
40·07	40·07	83·25	
40·42	40·42	84·63	
42·03		84·73	
42·60	42·60	85·60	
42·95	42·95	86·18	86·18
43·16		86·63	86·63
44·08		87·04	
45·63		88·05	
45·83	45·83	88·18	88·18
46·11		88·36	
46·36	46·36	89·25	89·25
47·11		89·92	89·92
	47·88	90·34	90·34
48·44			90·54
48·61	48·61	91·00	
48·90	48·90	91·97	91·97
49·17		92·09	
	49·32	92·35	

KAYSER.	ADENEY.	KAYSER.	ADENEY.
	3093·01	3129·72	
3094·50	94·64	29·94	
95·64		30·71	
96·06		32·12	
96·67	96·67	32·99	3132·99
97·71	97·71		33·51
	98·05	33·80	
98·95		34·90	34·90
99·39	99·39	35·17	
	3100·05		35·48
3100·95	00·95	36·04	36·04
	01·59	36·45	
	02·50	36·66	36·66
	03·51	37·04	
04·07		38·88	
04·57		39·38	
05·38	05·38		39·65
05·52		41·08	41·08
05·91			41·66
06·94	06·94		43·46
07·37		43·76	43·76
07·70	07·70	44·37	44·37
07·83		44·82	
08·53		46·18	46·18
10·15			46·47
10·64	10·64	47·32	
	11·24	47·55	47·55
12·01	12·01	48·14	
12·41		48·59	48·59
12·78	12·78	50·28	
13·50		50·80	50·80
13·76	13·76		51·25
	14·53	51·78	
15·54			52·35
16·95		53·93	53·93
17·18		54·54	
17·56			55·90
18·17		56·73	
18·79		56·92	
20·65		57·74	
	20·90		58·70
22·11		59·00 (Ca)	59·00*
22·97		60·04	60·04
23·61			60·80
24·28	24·28	63·19	63·30
24·48	24·48	64·94	64·94
24·71		65·09	
	24·98	65·31	65·31
26·07			66·24
	26·15		66·68
26·73	26·73	67·51	67·51
27·39		68·36	
27·64		68·65	68·65
	28·07	70·20	
28·54		71·35	
29·57		72·78	72·78

* This line is not due to calcium in spark-spectrum.

KAYSER.	ADENEY.	KAYSER.	ADENEY.
3173·22			3213·33
73·50		3214·48	
74·24	3174·24	15·61	
	75·32	16·64	16·64
76·40			17·96
77·16	77·16	19·27	
78·84			19·49
79·38	79·38	20·20	20·20
		20·90	20·90
80·57		21·30	
81·13		21·49	21·49
81·31			22·07
	83·54	23·39	23·39
85·28	85·28	23·72	
85·55			24·18
86·16	86·16	24·77	
86·87			25·03
88·06		25·42	
88·46	88·46	26·50	26·50
88·71		27·02	27·02
89·42		28·02	
89·84		28·28	
90·09	90·09	28·65	28·65
91·30		28·85	
91·90		29·88	
92·17	92·17	30·74	
	92·52	31·87	31·87
93·62		32·18	
95·14	95·14	32·89	32·89
95·44		33·65	
	95·85		34·39
96·72	96·72	34·92	
97·60		35·23	
98·44		35·43	
	98·74		35·85
99·24		36·10	36·10
3201·37	3201·37	38·13	
01·60		38·67	38·67
02·70		38·90	
	03·62	39·75	39·75
	04·36	41·36	41·36
	05·08	41·64	41·64
05·43	05·43	41·88	
	06·82	42·28	42·28
	07·40	42·98	
07·75	07·75	43·64	43·64
08·41		44·48	
08·54		44·59	
08·87		44·72	
	09·43	45·75	45·75
09·76		46·38	46·38
10·29	10·29	47·50	47·50
	10·95		48·04
	11·38	48·98	
	12·30	50·07	50·07
13·10	13·10	50·15	

KAYSER.	ADENEY.	KAYSER.	ADENEY.
3250·61		3291·25	
	3251·10	91·79	
51·46		94·27	3294·27
52·03	52·03	94·93	
52·40		96·25	96·25
52·68		96·79	96·79
53·04		97·39	97·39
53·14		98·10	98·10
	53·36	98·56	98·56
54·67	54·67	99·48	99·48
54·86	54·86	99·93	
55·17			3301·35
55·36		3301·73	01·73
56·48	56·48		01·94
56·75		02·31	
	57·94	04·14	04·14
58·18	58·18	04·42	
59·11	59·11	04·63	
59·81	59·81	04·77	
60·30	60·30	04·95	
60·49	60·49		05·15
61·26		05·80	
63·74		06·31	06·31
63·99			06·81
64·69		07·68	
64·81	64·81	08·12	08·12
66·59	66·59		08·22
	67·07	08·75	
67·27			09·00
68·35	68·35		09·38
69·09	69·05	09·97	09·97
69·34		10·22	
	69·80	11·09	11·09
70·39		11·39	
71·75		12·07	
72·37		12·35	
73·22	73·22		12·99
73·77	73·77	14·20	
74·83	74·83		14·88
	75·87	15·18	
76·82		15·37	15·37
77·70	77·70	15·59	
79·52		16·52	16·52
	80·25	17·05	17·05
80·60			17·66
80·68		18·01	18·01
	81·26	18·99	18·99
81·74	81·74	19·66	
82·00		19·94	
82·74		21·39	
	83·11	21·63	
	84·46	22·37	
85·07	85·07	23·23	
85·51		24·08	
86·04		24·51	24·51
	86·55	25·14	25·14
89·39			

KAYSER.	ADENEY.	KAYSER.	ADENEY.
3325·37	3325·37		3370·19
27·83		3370·72	70·72
28·58		71·79	
32·19		71·99	71·99
32·48		72·92	72·92
32·77			73·45
34·76		74·12	74·12
35·82	35·82	74·79	74·79
36·30		75·04	
36·77		75·38	
37·96	37·96	76·19	
38·85		78·17	78·17
39·09		79·40	
39·69	39·69	79·75	79·75
39·93	39·93	80·30	80·30
41·23		81·04	
41·36		83·05	
41·81	41·81		83·75
42·85	42·85	85·30	85·30
43·00		85·61	85·61
	43·32	85·84	
44·67	44·67	86·39	
44·93		87·37	
45·45	45·45	87·97	87·97
46·36		88·85	88·85
47·75	47·75	89·25	89·25
48·15	48·15	89·64	89·64
48·83		91·04	
	49·25	92·03	92·03
49·82	49·82	92·65	92·65
50·24		95·47	
50·36	50·36	96·06	
50·68		96·97	
52·06		98·47	
53·12		99·04	99·04
53·44	53·44		99·15
53·78		3400·12	
54·00		00·74	
55·80		00·89	
56·33		01·30	
56·60		01·64	3401·64
58·11		01·88	01·88
59·23	59·23	03·92	
	60·20	05·43	
61·30	61·30	06·02	
62·14		06·74	
62·46	62·46	07·04	
64·23	64·23	09·42	09·42
64·93		09·70	
65·16			10·10
65·47			10·84
67·87		11·77	11·77
68·05		12·22	
68·59	68·59	12·95	12·95
69·43	69·43	13·87	
69·81		14·13	

KAYSER.	ADENEY.	KAYSER.	ADENEY.
3414·42		3463·29	3463·29
14·79	3414·79	63·75	
16·33	16·33	65·44	65·44
	16·90	67·19	67·19
17·49	17·49		69·80
17·79			70·20
18·13	18·13		72·39
19·39	19·39	72·84	72·84
20·24	20·24		73·45
20·88		73·90	73·90
22·58			75·00
	24·39	77·35	
26·12	26·09		79·45
27·72	27·72	80·30	80·30
28·48	28·48	81·04	
28·79	28·79	81·47	81·47
29·70	29·70		81·66
30·57		82·50	
30·91	30·91	83·32	83·32
32·35	32·35	83·46	83·46
32·56			83·65
32·91	32·91	86·36	
33·41	33·41	86·95	
34·33	34·33		87·87
	34·93	89·90	
35·34	35·34		90·30
36·24		90·88	90·88
36·48		92·26	
36·89	36·89	93·38	93·38
38·52	38·52	94·41	
38·82		96·15	96·15
39·84		96·29	
40·36	40·36	98·10	98·10
41·94		99·10	99·10
43·31			3501·06
43·82			01·25
44·57		3501·51	
45·45		02·58	02·58
45·68			03·60
46·10	46·10		04·65
46·23			09·35
46·63		09·87	
	46·96		11·50
49·11	49·11		13·25
49·61		13·81	13·81
51·01		14·65	14·65
53·06	53·06	14·91	
53·37		16·05	16·05
55·55			18·00
55·89			19·10
56·77	56·77	19·80	19·80
	57·05	20·29	20·29
57·85			24·16
59·74			24·62
	61·55		27·39
62·21	62·21		28·05

KAYSER.	ADENEY.	KAYSER.	ADENEY.
3528·84	3528·84	3608·86	3608·86
	29·26	09·24	
31·55	31·55		12·30
32·97	32·97	14·49	
35·53	35·53		15·05
35·99	35·99	17·09	17·09
	36·78		18·90 (Fe)
38·10	38·10	19·33	19·33
39·42	39·42	20·43	20·43
39·52		23·80	23·80
41·79	41·79	24·00	
47·14	47·14	25·35	25·35
	48·70	26·90	26·90
	49·90	27·43	27·43
50·42	50·42		28·50
	50·73	29·35	
54·00	54·00		31·65 (Fe)
56·78	56·78	31·86	31·86
57·20	57·20	32·55	32·55
	60·00	34·06	34·06
	60·85	35·09	35·09
	61·83	35·66	35·66
62·04	62·04	37·61	37·61
	62·75	38·16	38·16
64·52	64·52	40·79	40·79
64·71	64·71	45·83	
	64·80	46·27	46·27
64·95	64·95		48·85
	66·59		49·75
67·31	67·31		50·47
	70·15	52·47	52·47
70·74	70·74	52·82	
	72·03		53·00
	72·13	53·86	53·86
	74·00	54·56	54·56
74·74	74·74	56·11	
	76·17		56·50
	77·10	57·32	57·32
	77·55	57·72	57·72
	78·90		59·55
79·92	79·92		60·25
	81·31 (Fe)	60·96	60·96
	84·21	61·49	61·49
	85·17	61·73	
87·34	87·34	63·53	63·53
89·37	89·37	68·89	
91·04	91·04	69·69	69·69
	91·58	71·36	
93·18	93·18	72·21	
96·32	96·32	72·53	
99·55		75·41	75·41
99·91	99·91		75·60
3601·63	3601·63	76·82	76·82
	04·45	77·10	77·10
05·79	05·79	78·14	
06·30		78·22	78·22

KAYSER.	ADENEY.
3678·47	3678·47
83·73	
85·20	85·20
86·11	86·11
86·74	86·74
90·18	90·18
	91·10
	92·60
	92·90
93·74	93·74
	94·30
96·74	96·74
97·92	97·92
98·02	
3700·49	
01·13	3701·13
01·46	
02·37	02·37
03·34	03·34
05·51	05·51
	07·05
	08·15
	09·35
12·44	12·44
14·79	
15·70	15·70
16·32	16·32
16·58	
17·15	17·15
17·82	17·82
	18·60
19·47	19·47
	20·10
22·46	
	22·80
24·11	24·11
24·63	
25·12	25·12
	25·59
	26·25
27·08	27·08
	27·33
28·17	28·17
30·59	30·59
30·75	
31·05	
32·17	32·17
33·19	
	33·90
	34·70
	35·00 (Fe)
37·55	37·55
37·90	37·90
38·77	38·77
39·06	39·06
39·62	39·62

KAYSER.	ADENEY.
3742·44	3742·44
42·94	42·94
	43·45
44·37	44·37
44·55	44·55
	45·75
	46·00
46·37	
	47·15
	48·15
	48·40
	49·60
	50·60
	52·00
	52·70
	53·00
53·70	53·70
55·24	55·24
55·87	
56·08	56·08
	57·40
	57·80
	58·50
59·98	59·98
60·18	60·18
61·64	61·64
	64·00
64·18	64·18
65·94	
67·50	67·50
	69·10
71·24	
73·31	73·31
	74·65
77·72	77·72
	78·00
78·85*	78·90
	80·20
81·31	81·31
	82·35
82 89	82·89
	84·30
86·19	86·19
90·65	90·65
95·05*	95·00
95·33	95·33
	95·80
98·21	98·21
99·04	99·04
99·49	99·49
3800·39*	3800·39
03·33*	03·40
	04·20
	04·70
05·57*	05·57
08·82*	08·82

* These lines are given in Rowland's list of wave-lengths, but not in Kayser's.

KAYSER.	ADENEY.	KAYSER.	ADENEY.
3812·87	3812·87	3906·14	
	13·20	08·91	3908·91
14·98*	15·00	09·23	09·23
	15·90 (Fe)	11·28	
	16·40	12·25	12·25
17·44	17·44	15·00	15·00
	18·00	19·71	
	18·30	21·06	21·06
19·18	19·18	22·48	
	20·00	23·64	23·64
	20·50 (Fe)	24·78	24·78
22·23	22·23	26·07	26·07
	24·50 (Fe)	26·58	
25·08	25·08	31·94	31·94
	26·10 (Fe)	32·44	
	26·30		33·06
	28·05 (Fe)		33·80 (Ca)
28·86	28·86	38·05	38·05
	29·40	39·27	39·27
	31·05	41·81	41·81
31·95	31·95	42·21	42·21
	32·50	44·34	44·34
35·19*	35·19	45·72	45·72
38·22	38·22	49·56	49·56
	38·82	50·19	
39·82	39·82	50·37	50·37
	41·10	50·55	
	42·90	51·35	51·35
	43·40	52·85	52·85
	46·80	57·38	
50·56*	50·56	57·60	57·60
52·26*	52·26		61·84
	54·90	65·06	65·06
	56·60		68·64 (Ca)
57·69	57·69	69·94	69·94
	60·05 (Fe)	72·57	
	60·80	74·65	74·65
62·82*	62·82	78·62	78·62
65·55*	65·55	79·59	79·59
67·97	67·97	82·04	
72·39		82·37	82·37
73·66*	73·65	84·84	
76·23*	76·23	85·01	85·01
	79·15	87·96	87·96
	80·95	89·34	
84·20	84·20	94·70	
84·85	84·85	96·14	96·14
87·96	87·96	96·65	96·65
90·35	90·35		4003·15
91·57	91·57	4005·79	05·79
92·37	92·37	06·75	06·75
92·92	92·92	07·68	07·68
94·39	94·39	08·42	08·42
97·39	97·39		09·91
98·50	98·50	11·88	
3901·39	3901·39	13·66	13·66

* These lines are given in Rowland's list of wave-lengths, but not in Kayser's.

KAYSER.	ADENEY.	KAYSER.	ADENEY.
4013·87	4013·87	4127·61	4127·61
14·30	14·30	28·02	28·02
18·89		37·41	37·41
19·70	19·70	38·92	
21·15	21·15		43·35
22·33	22·33	44·34	
22·84			45·80
24·00	24·00	45·91	
24·45		46·96	46·96
24·85		48·53	48·53
26·65		50·48	50·48
28·58		61·82	61·82
31·15	31·15	67·03	67·03
32·36	32·36	67·67	67·67
32·65		70·22	70·22
36·61			75·04
37·89		75·62	
39·37	39·37	82·62	82·62
40·62		82·81	
42·12		82·99	
	45·98 (Fe)	89·64	
	49·57	97·04	97·04
51·57	51·57	97·75	97·75
52·36	52·36	99·04	99·04
54·22	54·22	4200·07	4200·07
63·02		06·18	06·18
63·16	63·16	07·80	07·80
	63·76 (Fe)	12·24	12·24
64·26	64·26	14·61	14·61
64·61	64·61	17·44	17·44
67·78	67·78	20·84	20·84
68·53	68·53	25·26	25·26
71·56		26·83	26·83
73·15	73·15	29·47	29·47
73·26		30·47	30·20
76·90	76·90	32·48	32·48
79·44		36·84	36·84
80·78	80·78	40·19	
82·95		41·23	41·23
85·57	85·57	43·23	43·23
91·22	91·22	45·00	45·05
97·19		46·36	
97·97	97·97	46·52	46·52
4100·53	4100·53	46·90	46·90
01·91	01·91	48·30	
02·44		55·87	
06·07		56·05	
08·00	08·00	56·79	
08·22		59·15	59·15
09·80		60·17	60·17
12·91	12·90	63·55	
13·53	13·53	65·77	65·77
14·29		66·16	
18·68		73·12	
21·15	21·15	77·42	
23·23	23·23	78·84	

KAYSER.	ADENEY.	KAYSER.	ADENEY.
4282·09	4282·09	4362·87	
82·36	82·36	64·27	
84·50	84·49	70·58	
87·21	87·21	71·36	
90·69	90·69		4371·52
92·42		72·38	72·38
93·44	93·44	81·42	81·42
94·27		83·53	83·53
94·96	94·96	85·56	85·56
96·09	96·09	85·82	85·82
96·86	96·86	86·43	86·43
97·89	97·89	89·15	
4301·30		89·55	
02·15		90·61	90·61
	4306·20	91·19	91·19
07·75	07·75	95·13	95·13
08·57	08·57	96·87	
09·36		97·96	97·96
12·05		99·75	99·75
12·63			4404·93 (Fe)
13·07		4405·81	
14·47	14·47	10·21	10·21
15·22		12·05	
16·79		13·46	
	17·10	14·61	
18·60	18·60	20·63	20·63
20·05	20·04	21·01	21·01
20·74		21·63	21·63
20·97		23·14	
21·45		24·96	
23·12	23·15	26·18	26·18
23·63		28·62	
25·22	25·22	30·48	
	25·94 (Fe)	39·57	
26·99	26·99	39·94	39·94
27·49		40·25	
27·59	27·59	44·67	44·67
28·71		49·51	49·51
31·32	31·32	60·21	60·21
32·66	32·66	64·66	64·66
32·79		65·65	65·65
36·58	36·58	66·51	
37·43	37·43	67·43	
38·83			70·69
40·50		74·09	74·09
41·20		75·49	
42·24	42·24		79·80
43·18		80·60	80·60
46·64		82·19	82·19
49·87	49·86	88·55	88·55
50·63		90·40	90·40
54·30	54·30	91·85	91·85
54·96	54·96	98·32	98·32
57·03		4508·19	
61·37	61·37	08·72	4508·72
61·58		10·25	10·25

KAYSER.	ADENEY.	KAYSER.	ADENEY.
4511·35	4511·35	4547·11	
16·42	16·42	47·46	4547·46
17·06	17·06	48·03	48·03
17·98	17·98	50·11	50·11
21·11	21·11	52·28	52·28
25·62		54·70	54·70
31·04	31·04	59·22	
	40·05	60·16	60·16
42·85	42·85		

IV.

THE COHESION THEORY OF THE ASCENT OF SAP. A REPLY BY HENRY H. DIXON, Sc.D., Assistant to the Professor of Botany, Trinity College, Dublin.

[Read FEBRUARY 17; Received for Publication FEBRUARY 20;
Published JUNE 5, 1903.]

I.

IN a series of short papers in the Berichte der Deutschen Botanischen Gesellschaft for 1900, C. Steinbrinck has shown that cell-walls, lignified or not, imbibed with water or dry, are to a considerable extent permeable to air under a difference of pressure of less than one atmosphere.

This permeability to air of the walls of the conducting tracts he regards as rendering untenable the Cohesion Theory of the Ascent of Sap—a theory which Dr. Joly and I published in 1894.[1]

The fact observed by Steinbrinck is, however, by no means antagonistic to our views. In our paper, read before the Royal Society, we pointed out and showed by direct experiment that water containing large quantities of air is as capable of transmitting tension as air-free water.[2] Consequently air, diffusing through the moist lignified walls of the conducting capillaries, necessarily being in solution, would not break, or tend to break, the continuity of the water-columns within them.

The interesting fact which Steinbrinck has established—viz., the permeability of these membranes to air—only affects the problem of the Ascent of Sap so far as to show that we have, in the water of the transpiration current, to deal with water containing air, and not with an air-free liquid. At the outset, Dr. Joly and I had anticipated the probability, almost amounting to a certainty, that

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[1] Proc. Roy. Soc., Nov. 15, 1894; p. 3, vol. lvii. "Nature," Nov. 22, 1894, p. 93, vol. li.

[2] Proc. Roy. Soc., *loc. cit.* Trans. Roy. Soc., vol. cxxvii., p. 568.

the water in the capillaries contained appreciable quantities of air. This conclusion we arrived at from the observation that the fluid exuded during "bleeding" holds a considerable amount of air dissolved in it. It was for this very reason that we thought it necessary, and indeed essential, before publishing our Cohesion Theory of the Ascent of Sap, to investigate the possibility of tension existing in air-saturated water.[1]

The air which penetrates into the capillaries of the conducting tracts has first to diffuse through the water-imbibed walls. The passage through these wet walls, of course, secures that it can only enter the contained water in a state of solution. In this state, it has been experimentally shown that air does not lead to the rupture of tensile water. Only if free gas (*i.e.* undissolved gas) could, as such, pass through the imbibed walls would the water in the capillaries be rendered incapable of withstanding tension.

But even with regard to free gas, I venture to think that neither Askenasy nor Steinbrinck thoroughly realises how limitedly its presence, in moderate quantities, affects the transmission of tension in the water of the conducting tracts. One quotation from Steinbrinck will suffice:—

"Bekanntlich[2] hat Askenasy zugestanden, dass die Gegenwart von Luftblasen in den Leitungsbahnen seiner Theorie[3] Schwierigkeiten bereitet, da diese Blasen den Zusammenhang der Wasserfäden unterbrechen. . . . Stellen wir uns aber, um dieser thatsächlichen Schwierigkeit aus dem Wege zu gehen, die Leitungsbahnen eines etwa 20 m. hohen lebenden Baumes für den Moment einmal wirklich ganz blasenfrei und wassererfüllt vor, so würde . . . die Bejahung des erwähnten Satzes (viz., the permeability of the walls for air) sofort das Auftreten solcher Blasen am Gipfel der Leitungsbahnen und damit den Stillstand der Aufwärtsbewegung verlangen."

As a matter of fact, however, the permeability of the walls to air does not necessitate the liberation of free gas in the form of

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[1] Trans. Roy. Soc., *loc. cit.*

[2] Ber. d. deutsch. bot. Gesell., 1900, p. 392.

[3] It may be noticed that, although Steinbrinck in his earlier Papers attributes the authorship of the Cohesion Theory to Dr. Joly and myself in the first place, and to Askenasy in the second, in this latter Paper he patriotically assigns it to Askenasy alone. Cf. Ber. d. Deutsch. Bot. Gesell., 1897, p. 87, with quotation given here.

bubbles in the conducting tracts. And if by any chance a bubble does arise in one of the vessels or tracheids, it can only throw the lumen of that vessel or tracheid, in which it has arisen, out of function. For the *free* gas of this bubble cannot pass through the wet walls, but is confined within the compartment where it was formed. So the transpiration current is by no means brought to a standstill, but is merely deviated from that one element of the wood in which the rupture in the water (*i.e.* the bubble) has occurred.

So far, then, from the occurrence of bubbles being a difficulty to our Theory of the Ascent of Sap, it seems to be a happy confirmation of it. For it furnishes a reason why natural selection has favoured the development of conducting tracts provided with very numerous longitudinal and transverse partitions, which in themselves must act as obstacles to the free flow of water upwards. This fact we pointed out clearly in our original paper.

II.

Quite recently another criticism on the Cohesion Theory has appeared. It is published by Copeland in the Botanical Gazette.[1] His criticism is based on his own experimental work and on a discussion of the work of others.

The experiment on which Copeland lays most stress was one which he set up with the intention of illustrating the Cohesion Theory more strikingly than had been done before. The interpretation of his results, however, has led him to believe that this theory is inadequate. At the very outset, he admits that he is unable to explain the facts observed in his own experiment; and it would appear that his experimental methods are by no means free from error, nor is his way of interpreting them convincing.

In this discussion of his work, I shall first describe his experiment, as I understand it, and then try to show that his results are not inexplicable; and further, that the nature of the experiment does not allow it to be used as fairly illustrating the Cohesion Theory.

A tube, 12·4 m. high and 3 mm. in diameter, filled with plaster of Paris and water, and also containing some undissolved

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[1] Bot. Gaz., Sept., 1902.

air, was erected vertically. The tube was composed of short lengths, connected end to end by rubber-joints. These short lengths were filled with the plaster separately, and, as the plaster set, were boiled and cooled, and then kept immersed in boiling water for several hours. At the beginning of the experiment the whole tube terminated above in a funnel, also filled with plaster of Paris, which supported a chemically-produced semi-permeable membrane. The lower end terminated in a U-tube containing mercury and water. At a height of 8·4 m., by means of a T-joint, it was possible to connect a capillary tube, the lower end of which dipped under the surface of mercury.

At the beginning of the experiment, while evaporation was going on from the funnel, and before the lateral capillary was connected, mercury rose in the lower U-tube to the height of 150 mm. in four days, the rate of rise apparently slightly falling off. How much of this rise is due to evaporation above, and how much to other causes, is uncertain. There are no contemporary records of temperature and air-pressure given.

After four days the funnel was removed and the upper end of the tube closed. During the next few days the lateral capillary was put into connexion with the main tube; and later on the wide U-tube below was replaced by a tube of similar bore to the upper capillary. With these arrangements mercury rose in both capillaries. According to the final records, the mercury stood in the lower capillary at 428 mm., and in the upper one at 550 mm. above the external mercurial level.

Copeland seems to believe that his results indicate a continuous rise of water in the tube, due to the difference of pressure at the top and bottom of the tube indicated by the mercurial level in the two capillaries; and that this difference was established by evaporation from the funnel, and maintained by a kind of a lag. But, he says, "an analysis showing the elementary factors by which the water is raised has baffled me, even in my own apparatus." And he comes to the astonishing conclusion, "that a difference in pressure of less than one atmosphere between top and bottom will lift water much more than 10 m. under the peculiar conditions here present."[1] And again :—" The positive result of

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[1] *Loc. cit.*, p. 165.

our experiment is, that the water-column being continuous, but air being present, a suction of less than one atmosphere can still operate as a suction more than 12 m. lower down."[1]

In order to obtain a more definite idea from these general statements, we will apply the figures obtained by Copeland in his experiment. The rise in the upper manometer was 550 mm. This subtracted from the atmospheric pressure—say, 760 mm.—gives us the effective pressure exerted by the atmosphere at the level of 8·4 m. It is 210 mm. of mercury. In the same way the effective pressure below is 760 mm. – 428 mm., or 332 mm. According to Copeland, then, a column of water, 8·4 m. high, which is equivalent to 617 mm. of mercury, is lifted and supported by a pressure equal to the difference between 332 mm. and 210 mm., or 122 mm. of mercury. Such an overbalancing or equilibrating of a greater force by a lesser may, of course, readily be shown to lead to perpetual motion.

Suppose a glass-tube, having the same dimensions as Copeland's, and filled with water, were erected beside, and connected above and below with, the tube filled with plaster of Paris. The column of water in the clear tube being 12 m. high will exert a pressure on the water in the bottom of the plaster of Paris, at least amounting to one atmosphere. This pressure, according to Copeland's deduction, is more than sufficient to raise the water to the top of the plaster of Paris; and so it will flow over, across the upper connexion, and maintain the clear tube full of water. In this way a continuous circulation would be established.

The observations and deductions which have led to this untenable position are due principally to the neglect of two important factors, which may be, in the first instance, briefly summarized as follows:—

1. The readings of the manometers are not a true measure of the pressure-conditions of the water in the plaster of Paris, but rather of local differences of vapour and air-pressure.

2. Plaster of Paris continues to absorb water for a long time after it has set. This absorption, by reducing the volume of water

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[1] *Loc. cit.*, p. 166.

in the tube, will set up local differences of pressure, which the impermeability of the plaster will maintain for long periods.

1. Copeland states: "The tension of the water in the plaster and that of the air and water around it at the same height must be practically the same." So far as this statement refers to the practical equality of pressure in "air" and water, it is certainly mistaken. The pressure conditions in free gas contained in water involve, in all cases, as one factor the surface-tension of the meniscus enclosing the gas, and are necessarily positive from the nature of gases. These conditions are consequently not continuous with the pressure-conditions of the containing liquid, which may be either positive or negative. Thus, although we might infer the state of tension of a liquid by observing the maximum diameter of bubbles contained in it (and whose surface-tension is, therefore, necessarily in equilibrium with the stress in that region of the fluid), the gas within the bubbles is actually under positive pressure-conditions imposed upon it by this very surface-tension.

Manometers, then, which would register the pressure-conditions obtaining simultaneously in the bubbles and in the water of Copeland's tube, would give very different readings.

If the bubbles at any level are sufficiently restrained by the plaster, the gravitational pull acting against the surface-tension forces developed in the plaster will slowly put the water into a state of tension; while, of course, the gas in the bubbles would at the same time be in a state of positive pressure.

But we have no reason to believe that the manometers in the experiment were in a condition to indicate tension in the liquid, even if such existed. For Copeland does not state he took any special precautions to secure unbroken continuity between the water in the plaster of Paris and the mercury of his manometers.[1]

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[1] The neglect of securing proper continuity in the water experimented on is also probably responsible for the results quoted by Copeland to show that branches cannot take up water, unless the latter is supplied under pressure. In these cases, as soon as the pressure is much reduced, discontinuities appear in the water which has been raised into capillaries opening on the cut surface. As transpiration proceeds, these ruptures will enlarge till they become bubbles occupying the whole of the open capillaries. Nothing comparable to this, of course, occurs in the living tree, where, as a matter of fact, we know that water passes up in presence of gas-pressure amounting to less than one atmosphere.

Indeed, such continuity would have been well-nigh impossible to obtain. Hence, if the constraint, imposed by the surface-tension forces around the gas in the main tube, enabled the water there to get into a state of tension, discontinuities would have immediately appeared in the water above the mercury and at the point of contact of mercury and water. Thus, it would have been impossible for the manometers to register anything but a positive pressure, viz. the pressure of the bubbles in the main tube[1] about the connexion of the manometer, or of bubbles in the manometer itself. Other considerations, to be mentioned later, render it extremely probable that tension did exist in the water in the plaster; but the manometers, for reasons just given, could not record it.

2. The properties of plaster of Paris have often, rather unfortunately, been likened to those of wood. At any rate, the large resistance offered by plaster of Paris to the flow of water through it, makes it, in this particular, to differ markedly from wood. This resistance would prevent local differences of pressure being quickly equalized.

To give some idea of this resistance, I will quote one of several similar experiments.

A cylinder of plaster of Paris, 1·2 cms. in diameter and 5 cms. long, transmitted, under a head of 35 cms. of water, 1·54 ccs. of water in twenty-four hours. A piece of wood of *Taxus baccata*, containing about $\frac{1}{3}$ of its volume of heart-wood, and having the same dimensions and with the same head of water, transmitted during the first hour at the rate of 20·3 ccs. in twenty-four hours. The difference of permeability is, however, greater than this experiment would indicate; for, even in the first hour, there is a considerable falling off in the rate of transmission through wood. This falling off, due to clogging which takes place at the cut surface of wood, does not occur in the case of plaster of Paris.

The teaching of this experiment would appear to be, that the resistance offered by plaster of Paris to the passage of water

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[1] The actual pressure of the bubbles in the main tube will be very largely decided by the dilatation they have undergone in expanding from their original to their final volume. As this will be purely accidental—depending upon the fortuitous arrangement of plaster in the tube—we should expect that the pressure of these bubbles would be quite different at different points in the tube.

through it is at least thirteen times as great as that of wood. Taking into consideration the presence of heart-wood and the progressive clogging alluded to, we may, with greater probability, assume that the effective wood of *Taxus baccata* is at least 15–20 times more permeable than plaster of Paris.

The narrow bore of the tube in Copeland's experiment would emphasize this property of plaster of Paris. For, if any local differences of pressure arose, the rate of equalization of pressure would be proportional to the square of the diameter of the tube. So that, with a tube only 3 mm. in diameter, and filled with plaster of Paris, local differences of pressure would be maintained for long periods.

In order to arrive at a more definite idea as to how great will be the flow of water through Copeland's tube under the difference of gas-pressure he observed—viz. 122 mm. of mercury—we will apply the results obtained in the experiment just quoted. The amount of water passing through the tube will be proportional to the pressure urging it, inversely proportional to the length, and directly proportional to the square of the diameter. In the experiment just quoted, the pressure was a head of 35 cm. of water; the length 5 cm.; the diameter 1·2 cm.; and the amount of water transmitted in twenty-four hours was 1·54 c.c. In Copeland's experiment the pressure was equal to a head of 122 mm. of mercury = 165·92 cm. of water; the length 840 cm.; and the diameter 0·3 cm. Therefore the amount transmitted in twenty-four hours

$$= \frac{165{\cdot}92 \times 5 \times ({\cdot}3)^2}{35 \times 840 \times (1{\cdot}2)^2} \times 1{\cdot}54 \text{ c.c.}$$
$$= {\cdot}0027 \text{ c.c.}$$

In other words, with the pressure observed, it would take over a year to transmit 1 c.c.

We now come to consider how differences of pressure may have arisen in Copeland's tube.

Evaporation at the beginning of the experiment may have been in part responsible for pressure-differences; but, owing to the impermeability of plaster of Paris, it seems improbable that its influence would have been appreciably felt at lower levels in the tube.

Another cause would have been the reduction of gas-pressure within the plaster on cooling, while the experiment was being prepared. Complete equalization of this by the flow of water would be almost indefinitely postponed, owing to the resistance offered by the plaster of Paris.

But the principal cause of these pressure-differences resides in a property of plaster of Paris, which seems, up to the present, to have been overlooked, and the possibility of which was suggested to me by Dr. Joly.

On setting, even when an excess of water is present, plaster of Paris does not take up the full amount of water it is capable of, but continues steadily to absorb water long after setting is complete. Boiling plaster of Paris immediately after setting (as in Copeland's experiment) does not appear to satisfy its avidity for water, but even seems to increase its powers of absorption. Whether this absorption is due to slow hydration of the calcium sulphate, or to the formation of interstices in it during crystallization, I have not determined. The former view is favoured by the fact that boiling the plaster seems to increase the effect; and it is known that plaster of Paris begins to lose water at comparatively low temperature, viz. 70° C.[1]

In order to show how easily this absorption of water might have produced the results which Copeland has observed, I shall quote a few of my own experiments:—

Exp. i.—100 grm. of plaster of Paris was well mixed with 80 c.c. of water in a wide-necked bottle of about 200 c.c. capacity. As the plaster set, a layer of free water lay over its surface. When set, the surface of plaster exposed to the water was 4·8 cm. diameter. The bottle was now transferred into a vessel of boiling water, which was kept in ebullition for two hours. The water was then allowed to cool; and the bottle lay in it for twenty-four hours. A rubber bung, with two perforations, was then fitted tightly into the neck of the bottle. Through the

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[1] Mendeléef: The Principles of Chemistry, vol. i., p. 611. "Gypsum loses $1\frac{1}{2}$ and 2 equivalents of water at a moderate temperature." (Note.) "According to le Chatelier (1888), $1\frac{1}{2}\,H_2O$ is lost at 120°; that is, $H_2O, 2CaSO_4$ is formed, but at 194° all the water is expelled. According to Shenstone and Cundall (1888), gypsum begins to lose water at 70° in dry air. The semi-hydrated compound $H_2O, 2CaSO_4$ is also formed when gypsum is heated with water in a closed vessel at 150° (Hoppe-Seyler)."

perforations, a thermometer and a capillary glass tube were introduced, care at the same time being taken that no free air should be enclosed in the bottle, and that the capillary should be full of water. The outer end of the capillary was then arranged so as to dip below the surface of mercury. The mean volume of the capillary, determined by weighing a mercurial index, was per 10 cm. = ·19 c.c.

On the next day, November 13th, the position of the mercury index was observed and marked zero.

DATE.	HOUR.	TEMPERATURE.	INDEX.
		°	mm.
November 13, .	iii. 30	15·0	1·0
,, 14, .	iii. 30	15·0	14·0
,, 15, .	ii. 30	14·5	47·0
,, 16, .	i. 45	13·3	89·5
,, 17, .	iii. 30	13·0	116·5
,, 18, .	iii. 30	13·0	134·0
,, 19, .	iii. 30	12·5	153·5
,, 20, .	iv. 15	13·0	165·0
,, 21, .	iii. 30	13·0	168·0
,, 22, .	iii. 30	14·0	158·0
,, 23, .	iii. 30	13·0	173·0
,, 26, .	iii. 00	16·0	164·0
,, 27, .	xii. 00	14·0	179·0
,, 27, .	iii. 00	15·3	175·0

This table shows a continuous absorption of water during fourteen days. The irregularities in the rise of the index are to be credited to the fluctuations of temperature, and also partly to the sticking of the mercury in the capillary.

As might be expected from the manner of treatment, the amount of absorption, as indicated by the movement of the index, will show considerable variations in different experiments. But all my experiments have shown a comparatively large amount of water absorbed. In the experiment just quoted, the smallest rise of the index for the weight of plaster was observed. In the following a good deal larger absorption is recorded.

Exp. ii.—For this experiment 50 grm. of plaster was mixed with 50 c.c. of water. When set, the whole was boiled for two hours, and after standing in boiled water was set up in a similar

DATE.		HOUR.	TEMPERATURE.	INDEX.
			°	mm.
December	13, .	i. 15	15·58	34·0
,,	15, .	i. 00	13·30	263·0
,,	16, .	i. 30	13·40	299·0
,,	16, .	iii. 00	15·40	290·0
,,	17, .	xi. 30	14·60	325·5
,,	17, .	iii. 30	16·50	317·0
,,	18, .	xii. 00	14·70	353·0
,,	19, .	xii. 30	15·00	378·0
,,	20, .	xii. 00	14·65	394·8
,,	21, .	ii. 30	13·80	422·0
,,	22, .	i. 15	13·80	439·5
,,	23, .	xi. 00	13·10	460·0
,,	23, .	xii. 00	15·58	444·0
,,	24, .	xi. 00	14·10	463·5
,,	25, .	xii. 00	12·10	482·5
,,	26, .	xi. 15	12·43	502·0
,,	27, .	xii. 30	13·80	501·5
,,	28, .	i. 00	11·50	523·5
,,	29, .	xii. 30	10·00	542·0
,,	29, .	iv. 30	11·60	532·0
,,	30, .	xii. 00	11·20	542·5
,,	31, .	i. 00	11·00	553·3
,,	31, .	iv. 00	12·10	547·0
January	1, .	iii. 00	13·40	545·0
,,	2, .	xii. 00	12·60	556·0
,,	3, .	i. 00	13·40	557·0
,,	5, .	i. 00	11·20	590·0
,,	6, .	i. 00	13·63	575·5
,,	7, .	ii. 30	14·60	575·5
,,	8, .	xi. 30	12·00	605·0

manner to the preceding. The same capillary carried the index. The surface of plaster exposed to the water was 19·62 sq. cm.

In this experiment, the volume occupied by the plaster of Paris was 62·1 c.c. The distance moved through by the index (allowing for temperature was 550 mm. in twenty-six days. This movement of the index is equivalent to 1·045 c.c. absorption.

Exp. iii.—In order to imitate the conditions of Copeland's experiment more closely, I set up another experiment in which the plaster was confined in four glass tubes, each 16 cm. long and 7·5 mm. in diameter. After filling, these tubes were treated as closely as possible according to Copeland's directions, and, having stood in boiled water, were enclosed in a large test-tube of boiled water, fitted with a bung carrying thermometer and capillary as before. The absorption, though slow, apparently on account of the small surface exposed to the water, was easily observable. The absorption continued without appreciable diminution over a very long time.

The experiment was started December 10th.

DATE.	HOUR.	TEMPERATURE.	INDEX.
		°	mm.
December 10, .	iii. 00	13·5	47·5
,, 15, .	i. 00	14·0	64·5
,, 22, .	i. 15	14·5	107·5
,, 31, .	iv. 00	13·0	163·3
January 1, .	iii. 00	14·0	151·0
,, 2, .	xii. 00	13·5	159·0
,, 6, .	i. 00	14·7	162·0
,, 8, .	ii. 45	14·3	168·0
,, 10, .	i. 00	14·0	176·0

Readings were taken every day; but it is only requisite to quote the readings taken when the temperatures were approximately the same.

These three experiments will serve as examples of many similar, in all of which plaster of Paris, after being boiled as in Copeland's experiment, shows itself ready to absorb water. I may also state that plaster treated in a similar manner, except that it had not been exposed to boiling, also shows itself unsatisfied with water, although an excess of water had been present while it was setting.

From the measurements given in Experiment ii., we may obtain an approximate estimate as to how far this absorption of water by the plaster will affect Copeland's experiment. In my experiment 62 c.c. of plaster of Paris absorbed 1·045 c.c. of water in twenty-six days. Each of the component tubes of Copeland's apparatus was 0·3 cm. in diameter and 40 cm. long. Consequently each contained 2·826 c.c. of plaster; and if they behaved similarly, would absorb 0·047 c.c. At the start of the experiment, the rate of absorption is more rapid, so that the amount absorbed *per diem* will be greater than $\frac{0\cdot047}{26}$ c.c., or 0·0018 c.c.

We have already seen that the volume of water, driven through by the difference of pressure observed, will not amount to more than 0·0027 c.c. *per diem*; while we now see that the absorption for only 60 cm. of the tube used in the apparatus will exceed this amount. And it is to be remembered that 840 cm. intervened between the upper and lower manometers in Copeland's experiments, rendering the equalization of pressure-conditions, by the passage of water, impossible.

Hence it follows that any flow of water due to pressure such as Copeland observed, would most certainly be completely masked by the absorption taking place in the plaster of Paris in the tube.

We may now summarize our discussion of Copeland's experiment as follows:—

The rise of mercury in the manometers was due for the most part to the reduction in volume of the water in the main tube by the absorption of the plaster of Paris. External atmospheric pressure lifted the mercury as space was given by this reduction in volume.

The readings of the manometers do not give any indication of the pressure-conditions of the water in the plaster, for the manometers were not so arranged as to be capable of indicating tension (*i.e.* negative pressure) in the liquid, even if such existed.

The differences of level in the manometers were due to differences of vapour- and gas-pressure. These differences were possibly quite local, not being able to equalise themselves, owing to the resistance offered by the plaster of Paris to the passage of water.

Criticisms, based on the behaviour of an apparatus involving the peculiar properties of plaster of Paris and on readings of manometers so arranged, cannot be valid against any theory of the elevation of water in the conducting tracts of plants. Nor can we for one moment admit that "the behavior of this apparatus was like that in trees as we know it," nor that "it is most probable that the same fundamental physical principles are operative in both cases."

Botanical Laboratory,
Trinity College, Dublin,
Jan. 14*th*, 1903.

V.

THE PETROLOGICAL EXAMINATION OF PAVING-SETS. PART I.

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(Plates II.–V.)

[Read March 17; Received for Publication, March 27; Published July 23, 1903.]

An ideally good paving-set should fulfil the following conditions:—

(1). It should be durable.

(2). Retain a rough surface in wet and dry weather.

(3). Wear down uniformly.[1]

The conditions of wear to which a set is exposed are of the severest. The stone has to resist endless hammering: not only the fast hoof-stroke of the lightly-laden horse, but the slow and sledge-hammer footfall of heavy draught-horses, as well as the shocks from the iron wheel-tires, the blows from which must often be of extreme violence. And this hammering, rubbing, and crushing is more often than not applied in presence of the impure surface-waters. Mechanical forces are here applied in the most destructive form; while the conditions of solution and alteration are those which Daubrée long ago showed to be the most effective: *i. e.* attrition in presence of a solvent.[2]

My object in these notes is to inquire if petrological examination of the rock may not suffice to determine beforehand how far a particular stone possesses the qualities necessary to satisfy the conditions indicated above.

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[1] Of course other practical economic considerations enter, such as ease of dressing and cost of carriage. In the last item the specific gravity of the rock enters as a factor.

[2] Géologie Expérimentale, I., p. 268.

(1) DURABILITY.

The durability, under such conditions of wear, depends both on the *hardness* and *coherence* of the rock, and on the *chemical stability* of its constituents; and it may be stated at once that these conditions necessitate the rejection of most of the sedimentary rocks. These rocks, in general, fail in the hardness of their constituents or in the strength and security with which these constituents are bonded together. A few which do not fail in these particulars—*e. g.* certain quartzites and conglomerates—possess too uniform a hardness, as will be gathered from what follows. It thus happens that paving-sets must, in most cases, be selected from rocks of igneous origin.

The *Hardness* of a rock involves the hardness of its constituent minerals. The hardness—as tested by scratching—of the more abundant rock-forming minerals is given in the following Table, according to the usual scale, in which diamond is assigned the numerical value 10. I further, for present purposes, classify them as hard, soft, and intermediate :—

HARD.		INTERMEDIATE.		SOFT.	
Quartz, . . .	7·0	Hornblende and other Amphiboles, . . .	5–6	The Zeolites, .	3·5–5·5
Opal, . . .	5·5–6·5			The Micas, .	2·5–5·0
Felspars, . .	5·5–6·5	Augite and other Pyroxenes, .	5–6	Chlorite, . .	1·0–2·5
Garnets, . .	6·5–7·5			Serpentine, .	2·5–4·0
Olivine, . .	6·5–7·0	Ilmenite, . . .	5–6	Kaolinite, . .	2·0–2·5
Epidote, . .	6·0–7·0			Talc (steatite), .	1·0–1·5
Tourmaline, .	7·0–7·5			Calcite, . . .	3·0
Magnetite, .	5·5–6·5			Dolomite, . .	3·5–4·0
Pyrites, . .	6·0–6·5			Aragonite, . .	3·5–4·0

A hard rock is necessarily made up mainly of the minerals whose hardness is about 6 or upwards. Of these minerals, some are better in the paving-set than others, as will later appear. Thus the frangibility of some minerals or their rapid yielding to solvent actions renders their hardness of little avail under the conditions of wear.

Coherence principally involves the bonding of the mineral grains or crystals[1]—in fact the *structure* of the rock.

The igneous rocks—crystallizing, as they do, progressively from a magma—in general, possess the requisite bonding. Some igneous-rock structures are better than others.

The *granitoid* structure, the typical structure of the deep-seated rocks—*e. g.*, of the granites, syenites, diorites, and gabbros—is perhaps the best generally available. Here the rock is completely crystallized into minerals which closely inter-fit on more or less irregular surfaces. That is, the true crystalline faces are but partially developed, the development of the one mineral substance having interfered with that of the other. The grains are typically of about equal dimensions.

In the granites, the quartz, in nearly all cases, plays the part of ground-mass, is the last solidified, and is hence moulded around the other grains. The compact inter-fit of the felspars, one with another, and with the quartz plays an important part both to the advantage and sometimes disadvantage of the granites as paving-set material. On the score of durability, at any rate, a compact, fresh granite is very certain to prove satisfactory.

The rock, however, requires careful examination for a too far-gone alteration of the felspars. Thus, if the felspar has been generally converted into kaolin, or replaced by chlorite, etc., it must be remembered that the hardness and cohesion of the rock now depends on the quartz alone. Such a rock is likely to break up rapidly. It may be remarked, in anticipation, here that a mere cloudiness of the felspars is not inconsistent with considerable durability. A small quantity of the alteration-products will give rise to considerable clouding, as observed in the microscope, and yet leave the crystal sufficiently resistant. The dangerously broken-down felspar becomes *quite* inactive towards polarized light, and, in the hand-specimen, is easily cut with the pocket-knife, and

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[1] The toughness of the mineral substance itself, its molecular bonding, of course also enters the question. It is difficult to define this. Thus, the amphiboles display a resistance to attrition which, under certain circumstances, is greater than the felspars, although the former are the softer minerals. To see this, observe the surface of a well-polished diabase or diorite, when the hornblende will be seen to stand out above the felspar. It does not follow, however, that under the conditions, affecting the set, the amphiboles will show the greatest resistance.

looks chalky. When so far gone, only the assurance of a practical test of the set should induce us to sanction its use.

The granitoid rocks of intermediate composition, the syenites and many diorites, are, in general, valuable rocks for street-pavement. The typical syenite is a rare rock. The diorites are fairly abundant. As in the case of the granites, mere cloudiness of the felspar of the intermediate and basic granitoid rocks is not sufficient evidence upon which to reject the rock. But these rocks possess no quartz ground-mass generally, and, relying mainly on the felspars for their hardness and durability, are more dependent on the freshness of this constituent. It may be stated that a greater degree of freshness is required in the felspars of the more basic granitoid rocks than in the acid granitoid series. The coloured constituents, more abundant in the former series than in the latter, do not in either case appear to play a leading part in sustaining the wear to which the set is exposed.

A familiar variety of rock-structure is the *porphyritic.* In this, the growth of the rock has not been continuous, but the conditions of development of the minerals have altered during their formation, so that a larger and older generation exists in a ground-mass of smaller and younger individuals; or, it may be, in a ground-mass not completely crystallized, and therefore partly in the form of glass. The availability of such rocks as paving-sets depends on the extent to which the porphyritic structure is developed and on the state of the ground-mass. If the large crystals are very large—say, one centimetre (one-half inch) and upwards in greatest dimensions—the risk of rapid disintegration by loosening of these, or by their break-up, must be borne in mind. Or, on the other hand, if resistant and hard, a slippery surface of polished and rounded prominences may render the set dangerous. The last will be the greatest risk in the case of porphyritic orthoclase, as in many granites; the former in the case of large crystals of mica, olivine, augite, etc. In the absence of experiment, such rocks are not to be recommended.

The presence of glass in the ground-mass should certainly be regarded as a danger. It is soft, brittle, and liable to devitrification. If composing any considerable part of the ground-mass, the rock should be rejected. Actual rough glassy lavas have indeed been used for paving where other stone was not procurable; but it is certain that in heavy traffic such sets would rapidly crumble away.

The *intersertal* structure of certain basalts and diabases is one in which a ground-mass of small felspars encloses the larger constituents. If glass enters as a considerable constituent of the ground-mass, the durability of the rock is very doubtful. A little residual glass in grains need not occasion the rejection of the stone. But, as a bonding material, it should not be trusted.

A type of structure not uncommon in basalts and dolerites, and very usual in diabases which are poor in felspar, is the *ophitic*. Here felspars are included in large plates of augite (or other coloured mineral); the felspar being idiomorphic (possessed of its own proper crystalline faces), while the containing mineral is usually allotriomorphic (without regular faces). Doubtless the combination of felspar and augite constitutes a fairly hard substance; but whether due to the cleavage of the augite, to its somewhat inferior hardness, or to its liability to undergo alteration, it is not resistant under the wear of the streets, and must be regarded as playing the part of a substance of intermediate hardness only.

In some granites, granite porphyries, quartz-diabases, etc., the intergrowth of quartz and felspar (pegmatite) affords, in the *granophyric* structure, a very durable and tenacious matrix to the grains of prior consolidation. If present in large masses, it is very certain to lead to the development under wear of polished slippery prominences.

The granites often show a structure designated *miarolitic*: that is, possess numerous cavities, in part in-filled with idiomorphic individual crystals. Such faults must, of course, be avoided. Basalts are often vesicular; and although the vesicles may often be filled up with various secondary minerals, these are, in general, soft and fragile (zeolites, calcites, chlorites); and even when hard (chalcedony), the existence of these secondary materials denotes generally far-gone changes in the rock of injurious nature. This *amygdaloidal* structure is to be condemned.

Any *cleavage* or *joint* structure is sure to result in the disintegration or fracture of the set under wear. Cleavage structure may be superinduced in fine-grained rocks, whether sedimentary or igneous, under the influence of certain dynamical agencies. Thus, while among the sedimentary rocks, the most perfect examples of cleavage structure are found, certain igneous rocks, *e.g.* some basalts, exhibit this structure, apparently brought about by dynamical action.[1] Joint planes are generally avoidable in the selection of the stone, being only locally distributed in the rock, and not affecting the minute rock-structure.

The Chemical Stability under the conditions of wear can, in the absence of direct experiment, only be approximately inferred from our knowledge of the weathering properties of the minerals under normal conditions. Daubrée has shown (*loc. cit.*) that attrition assists the activity of solvent and chemical actions, as indeed might have been anticipated, if only from its effects in removing the residual materials, and thereby eliminating their protective action.

In experiments in which I compared the solvent action of fresh water and sea water on some rocks and minerals, I found that orthoclase is decomposed at least fourteen times as fast in sea water as in fresh, and that various silicates of basic rocks also showed a feebler resistance in sea water. Daubrée, using only chloride of sodium in the solvent, found that there was actually a protective effect exerted by this solvent, when the behaviour of orthoclase was compared in the salt solution and in distilled water; attrition being applied in both cases. Neither experiments are quite applicable to the case of the paving-set, and, pending direct experiment, a certain conclusion as regards the weathering resistance cannot be arrived at.

The mechanical actions are, however, so intense, that our powers of prediction, as regards the qualities of a set, are in nearly all cases fortunately independent of the precise relative chemical stabilities of the constituent minerals. In the first place we do not expect that the stability of the softer minerals would enter the question; their removal, when in any considerable aggregates, is sure to take place from the immediate surface before any chemical instability can manifest itself. Thus the soft minerals kaolinite, serpentine, and talc, which are very resistant chemically; and calcite, the zeolites, and the chlorites, which are easily decom-

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[1] Some basalts occurring at West Loch Tarbert, Jura, show such a cleavage structure in wonderful perfection.

posed, alike disappear from the immediate surface of the set before wear has sensibly advanced on the harder minerals. Of those softer minerals which do not originate as decomposition products, the micas (which in the rock appear to vary in stability according to their mineral surroundings in a manner not easily explained) are again rapidly removed under wear. Nor does muscovite, the white mica, exhibit more resistance than biotite, although the latter is chemically rather unstable, while the former is a very stable substance.

The felspars are minerals which weather with some rapidity under the action of atmospheric waters, although generally durable when contrasted with the average life of a set. The potash felspars, orthoclase and microcline, are believed to be the most durable. Felspars under normal weathering sometimes disintegrate or break up along cleavage directions without appearing to suffer any sensible loss of constituents. All felspars alike yield the soft kaolinite as residual product.

There is conflicting evidence as to whether the felspars or hornblendes are the more resistant against the effects of normal weathering. The augites also take their place here in point of stability: in basalts augite appears, however, sometimes to be the last to yield. Among these minerals the felspars are the most durable in the set; the physical and not the chemical structures appearing to control the durability under the conditions of destruction. That the considerable degree of chemical stability possessed by the felspars, hornblendes, and augites is of first importance in the value of many sets is, however, evident.

Quartz, garnet, tourmaline, magnetite, and epidote, are, chemically, very durable minerals; the first-named practically unaffected by conditions of weathering and by most solvents. Pyrites is not a very stable mineral, being liable to oxidation.

Olivine is rapidly decomposed and softened by normal atmospheric influences. In basalts it is invariably the first to go. It becomes iridescent, and breaks up along irregular cracks. In the street the severe conditions of solvent denudation very probably act to hasten its destruction.

In the case of some igneous rocks, of somewhat open structure, *e.g.*, certain granites in which mineral alterations have taken place, the surface-waters of the street may visibly penetrate and discolour the set to a depth of one or two centimetres; and by their action on the more yielding minerals affect the alteration of the less stable substances: in fact, reversing the usual order, and anticipating the mechanical effects.

In brief, durability depends on the hardness, coherence, bonding, and chemical stability of the crystallized grains of which the rock is composed. The hardest common substances are quartz and felspar. The resistance to wear, in general, varies directly as the amounts of these minerals present. The sufficient bonding of the minerals is generally attained in the holocrystalline igneous rocks. But the rock must in all cases be fairly fresh. It follows that the granites, syenites, diorites, gabbros, dolerites, and some basalts may make good sets, the durability diminishing (in a general way) along with the silica percentage of the rock. Porphyritic and vesicular rocks are to be avoided, if these characters are at all marked.

(2) SURFACE ROUGHNESS UNDER WEAR.

We now come to consider the more difficult question as to what features of the rock will enable us to pronounce on its probable fulfilment of the second condition: that of retaining a rough surface under wear.

In order that the set, exposed to friction, should remain rough, some of its constituents must yield before others: those that resist longest always standing above the general surface, and so giving a coarse file-like or granular formation upon which the horseshoe will bite. Durability further demands that the outstanding grains should be of hard and strong material. Thus, in granites, the mica goes first; and the felspars and quartz remain to act as the teeth of the file. Minute and careful examination of the worn surface of the set by aid of a strong lens generally shows clearly enough which mineral constituents have yielded, and which have held out. In this examination careful washing of the worn surface, using a stiff brush, is needful. It must be carried on in a good light: direct sunlight is the best.

From these remarks it will be inferred, in the first place, that a certain coarseness of grain is desirable. If the grain of the rock is too fine, the result under wear is a surface the roughness of which is on too minute a scale to afford bite, especially in presence of fine mud; and sanding, whereby hard quartz particles are supplied to act as temporary teeth, becomes necessary —a resort which, perhaps, ultimately intensifies the evil it is intended to remedy: the sand undoubtedly acting as a polishing and abraiding agent. It is on account of its fineness of grain that the well-known Penmaenmawr rock, or Welsh blue set, fails to preserve a sufficiently rough surface. Such sets possess a durability inversely as their surface-roughness. Obviously the set, once worn smooth, escapes to a considerable extent further wear. A fine-grained variety of the Welsh Penmaenmawr set just referred to was labelled by the engineer—to whose kindness I owe most of the other sets—" In a very slippery condition." Rocks so fine-grained as this, quite grainless to the unaided eye, should be avoided where a rough surface is desirable. For use on inclines, they should not be thought of.

While a certain coarseness of grain is desirable, on the other hand, a too coarse grain may defeat the end in view. Thus granites possessing large continuous developments of felspar may wear to a surface of considerable slipperiness. The hard areas here stand up, and becoming flat on top, refuse to allow the shoe to bite on the minor inequalities due to the destruction of the soft constituents. This is a common evil. Both in wet and dry weather, sets of this character will be more or less slippery, although, perhaps, never so dangerous as the set which owes its slippery quality to general polishing down of the whole surface: probably because a coarse sort of inequality continues. In the case of the fine-grained set, what bite there is after the smooth surface is attained must be due largely to the joints between the sets. More especially is this true in muddy streets.

What degree of coarseness of structure is desirable? Only examination of successful and unsuccessful paving-sets can enable us to answer this question. Such examination will be entered on presently, and the subject gradually developed. Many modifying circumstances, not easily specified in a few words, must enter any general rules laid down. It may be stated that the softer minerals, whether as single crystals or aggregates, should expose on the surface of the set areas above a certain dimension, in order that sufficient pitting may occur, and that, for uniformity of wear, these soft areas must be distributed with fair uniformity throughout the rock. Finally, the total percentage of the area occupied by soft minerals must not exceed a certain amount, if durability is to be secured. This limit may be about 25 or 30 per cent. In certain granites a less percentage is found consistent with the necessary surface-roughness. Other circumstances of rock structure in some cases enter the question as to whether the rock will make a completely satisfactory set or not.

EXAMINATION OF SOME TYPICAL SETS.

The Penmaenmawr Enstatite Diorite.

Before going further into the matter, it will conduce to clearness if some typical sets are more closely examined.

The first I take is the blue Penmaenmawr set already referred to. The rock is well known. Some varieties are coarser grained than others. The one I am now dealing with is from the finer-grained rock, and was used in Dublin. It is labelled by the engineer, "In a very slippery condition."

This rock breaks with a clean conchoidal fracture, sharp on the edge (always an indication of fine-grainedness). To the unaided eye, it shows no individual grains. Its colour is a dark greenish-blue. It is an enstatite diorite, or enstatite diabase, and has been described by Phillips (Q. J. G. S., vol. xxxiii. (1877), p. 423), and more recently by Teall ("British Petrography," pp. 272 *et seq.*). The rock is rather above the average weight: specific gravity, 2·827.

The section given in fig. 1, Plate II., is a photograph by ordinary light, magnified 12 diameters. The slice used is from a chip of one of the sets.

The coloured constituents are a very pale-brown augite in a fresh condition, showing little or no pleochroism; often twinned: and, considerably more abundant, and about the same in the size of the individual crystals—a fibrous rhombic pyroxene, extinguishing longitudinally. The colour of this mineral is very pale-brown, and the pleochroism faint: green in the direction of the principal axis: probably an enstatite rich in iron. Biotite is also present in irregular plates which are occasionally chloritized. This is much less abundant than either of the other coloured constituents.

An opaque black ore—probably magnetite—is present in scattered crystals. The rest of the field is occupied by felspars and quartz, the latter being quite subordinate to the former. These hard constituents compose some 70 per cent. of the rock. As it requires polarized light to differentiate these, they do not definitely appear in the figure. The felspars are columnar and lath-shaped, making up an almost continuous field of crystals orientated in every direction between the coloured constituents. In some cases, a felspar crystal may attain the length of as much as 4 or 5 millimetres; and in this case the rhombic pyroxene and augite will be included within it. More generally the felspars are of about the same dimensions as the coloured constituents. The smaller felspars are almost certainly plagioclase. Some of the larger may be orthoclase. The felspars are fresh, and unclouded in the sets examined. The quartz, which is fairly abundant, is interstitial, and also in part pegmatitic.[1]

The chief feature of the rock, from the present point of view, is the uniform distribution and fine state of subdivision of the various constituents.

When we examine the surface of the worn set, we see that the abundant felspars and intergrown quartz undoubtedly support the wear. It is difficult to determine how far the enstatite and augite assist; but it can be seen with certainty, in many cases, that the coloured constituents lie in the hollows. In fact, we may conclude, with little risk, that the cause at once of the durability and slipperiness of the set is apparent in its fine texture and the too uniform distribution of the soft minerals of the rock. The roughnesses in a set from such a rock can only be on the most minute scale. The surface is, in point of fact, *matt.* A

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[1] The quartz may be at once detected by its greater birefringence when the method of double transmission is used in examining the section. Examination of a slice of the usual thickness in the ordinary way (the polarized ray being transmitted from beneath the section, and so only traversing it once) differentiates between quartz and felspar only in so far that the quartz appears in a whiter grey. Using a reflector close beneath the slide, and a polarized ray directed vertically downwards, the retardation due to the doubled thickness is sufficient to raise the colour of the quartz to straw-yellow, and leave the felspar for the greater part still in the greys and grey-white. (See Proc. R. D. S., "On an Improved Method of Identifying Crystals in Rock Sections," vol. ix., p. 485, and vol. x., p. 1.) Mr. Teall, in his description of the rock, remarks upon the use of birefringence in distinguishing between the quartz and felspar.

more concentrated distribution of the soft minerals would have given a better set. As regards durability, the set will be, on the other hand, for these very reasons, exceptionally good. The smooth wear of this set leads to another evil on the score of slipperiness: the smooth rounding of the edges. In the case of the particular set here referred to, the upper surface is rounded off where it meets the vertical faces in the most hopeless fashion.

The White Caernarvon Granite.

A few sets have now to be examined labelled "White granite, Caernarvon." These are further described as "Slippery." They are in a better condition, however, than the enstatite diorite set already described.

This granite is compact and fine-grained; of a bluish-white or grey colour; sparsely mottled with specks of a dull greenish mineral which under the lens appears micaceous in structure. It is heavy for a granite: specific gravity, 2·702.

The rock composing these sets is possessed of many of the features common to the granites of Wales. It is almost without mica; this being apparently represented by a chloritic mineral having a very feeble dichroism, its pale greenish colour darkening a little to vibrations along the traces of cleavage. Between crossed nicols, the mineral remains so dark that only in thin specimens or with very strong light can the deep prussian-blue of its interference-colour be seen. It is probably one of the pennines. Certain radiated or fibrous and colourless constituents, often intimately associated with the chloritic mineral, assume, with crossed nicols, the bright colours of potash mica. The rest of the rock may be said to be composed of the hard minerals felspar and quartz. The quartz is abundant; interstitial most generally; but very exceptionally it appears with a true crystallographic face. (See Teall's "British Petrography," pp. 318 *et seq.*)

The felspars are mostly quite irregular in form, and very often crowded with an alteration product of elongated prismatic habit, polarizing in brilliant colours. Again, it is sometimes quite fresh and transparent. Its optical activity, when rotated between crossed nicols, is found to be always preserved. Rarely is the felspar idiomorphic, and still more rarely does it reveal twinning. A little apatite is present, associated with the decomposition-products of the mica.

The felspar and quartz are in grains of almost equal dimensions, interfitted most generally on irregular boundaries. The grain is fine for a granite. Quartz constitutes perhaps 20 to 25 per cent. of the rock : the softer minerals hardly 10 per cent. ; the remainder being felspar. The comparatively fine-grained relation of felspar and quartz is important, when considered along with the small percentage of soft minerals.

Examination of the photographed section (Plate II., fig. 2), and comparison with some given later (Plates III. and IV.) of the excellent Aberdeen granite, will best show how fine-grained is the Caernarvon rock : the Aberdeen being a granite of only average grain.

Surface-examination of the worn set shows that the fine-grained felspar and quartz are the outstanding part of the rock. The areas of felspar and quartz wear into flat-topped eminences, the chlorite and remaining mica come away. A little mica can be seen in the bottoms of the hollows. The slipperiness, such as it is, is mainly due to the fact that by far the greater part of the rock, certainly over 90 per cent., is composed of hard and resistant minerals which wear into smooth surfaces without sufficient intervening gaps to give an altogether satisfactory bite. The pits are indeed fairly coarse, but too few in number. That considerable bite exists is evidenced in the scraped-off iron adhering strongly to the felspar and quartz. Again, in this case, the large amounts of felspar, along with the considerable amount of quartz, might have enabled us to predict, from the microscopic examination of the rock, that the set would be durable under wear.

The minute intermixture of felspar and quartz, that is, the fine-grainedness of the hard constituents, taken in conjunction with the small percentage of soft minerals, might also have led to the inference that a smooth surface would develop, composed of the finely-intermixed, hard minerals, insufficiently broken up by the removal of the chloritic mineral.

It is remarkable that the impure surface-waters of the street have penetrated into the set, and discoloured it to a depth of over a centimetre from the surface and top sides. The rock becomes brownish in colour under this influence; and the soft green mineral is removed in these parts, leaving cavities up to 2 or 3 millimetres in diameter, containing a rusty and scaly-looking residue.

The Red and Grey Caernarvon Granite.

The next sets we have to consider are derived from a reddish and a grey granite from Caernarvon. They also are described as "Slippery." They are obviously in a much more slippery state than the foregoing granite.

Both these are fine-textured granites. In both a pink felspar occurs (orthoclase), but more abundantly in the red granite. A greenish black mineral mottles the surface of each, the nature of which is hardly determinable by the unaided eye. The specific gravity of the red granite is 2·612; of the grey granite, 2·642.

Under the microscope, the rock is seen to be in each case of coarser structure than any we have yet examined. A large felspar (orthoclase) exists in both rocks very abundantly, and in great part densely clouded, along with crystals of small size, also much clouded. The form is columnar, and the idiomorphism well-marked, the crystals being saved from mutual interference by a small quantity—perhaps 10 per cent.—of interstitial quartz. The felspar is mostly orthoclase: some plagioclase is present, no microcline. In spite of the dense clouding with alteration-products, the action on polarized light is in nearly all cases preserved. We thus regard the felspars, both large and small, as hard and resistant material. Adding the interstitial quartz, we find that the great bulk of the rock—not less than 95 per cent.—is composed of well-knit and very durable minerals. The quartz in parts is pegmatitic with felspar, and in parts again is ophitic in its relations with the felspar. A certain very small amount of the quartz is hypidiomorphic.

Coloured constituents make up only a small part of the rock, and consist for the most part of a chloritic mineral, probably an alteration-product of mica. This mineral is pale green, shows some cleavage, but often is quite irregular in form, and exhibits a plumose extinction in steely-blue colours. A very little hornblende is present. A black ore—probably magnetite—also occurs, but sparingly. In the grey granite set, remains of original biotite is found. A little apatite is present along with the alteration-products of the biotite.

The photographed section (fig. 1, Plate III.) of the red granite enables the grain of these granites to be compared with the rocks already described, the scale of magnification being the same, *i.e.* 12 diameters.

The cause—both of the durability and failure to preserve a rough surface—is evidently to be traced to the too overwhelming proportion of felspar. It is seen when the surface of the worn set is examined that the felspar and small amount of quartz compose the smooth part of the surface, and that this practically occupies the entire area under wear. The very subordinate depressions are shown to be due to the chloritic mineral by the fact that this substance generally remains far down. These pits are not numerous enough to offer a rough surface as wear progresses. It is instructive to note that coarse as the rock is in structure, this has not availed to preserve it from becoming polished. Although slippery, almost burnished on the prominences, the surface is not so generally smooth as the Penmaenmawr diorite. Iron clings to the felspar and quartz eminences, and its solution and oxidation has stained the surface.

Again we may be profitably wise after the event. There is little doubt that the uniform surface of felspar, unbroken by any large-grained constituent differing in physical characters, has led to the failure of the rock as regards retention of surface-roughness. It is quite possible that the abundant presence of the finely-divided and unctuous kaolinite throughout the felspar has furthermore exerted a lubricating effect as it becomes exposed under wear, much as if finely-divided black-lead was applied to the surface of the set. The point seems worthy of further investigation.

The Aberdeen White Granite.

I now come to a rock of much value for street pavement, and the praises of which I have heard from several experienced city engineers: the Aberdeen granite. Fig. 2, Plate III., and figs. 1 and 2, Plate IV., show photographs of this rock in thin section. Fig. 2 is magnified to the same scale as the previous photographs (twelve diameters), but figs. 1 and 2, Plate IV. only four and a half diameters, fig. 1, Plate IV. being taken with polarized light in order to display the large areas of almost limpid microcline felspar and clear quartz.

The granite is of a grey-white colour and of uniform and average coarse-grainedness. Its constituents are fresh and unaltered. The felspar is for a large part microcline; also partly orthoclase and partly plagioclase. The specific gravity is 2·661.

The felspar varies in development from idiomorphic to allotriomorphic. Most often it is allotriomorphic. It sometimes encloses what must be more or less spherical quartz inclusions. It is free from alteration-products, or almost so. The two micas are present fairly uniformly scattered over the field in large hypidiomorphic crystals. The quartz is allotriomorphic, and forms large areas, almost equal in size to the felspar. The variation of grain of each of these constituents will be gathered from the two photographs.

As the result of many measurements the dark mica constitutes about 14 or 15 per cent. of the rock. The white mica constitutes about 5 per cent. There is thus about 20 per cent. of soft mineral present. The quartz constitutes about one-half the remainder, and the felspar the other half.

The worn surface of the set shows abundant and large pits floored by mica and prominences of felspar and quartz, the felspar standing generally a *little* higher than the quartz. It is evident that this is due to the readier splintering and fracture of the quartz, the surface of this mineral exhibiting no sign of polish, but showing a broken surface or splintery roughness. The felspar shows generally a fine matt surface, and in no case is actually polished, as in the case of the kaolinised felspars in the Caernarvon granites already described. The difference may be due to the freshness and freedom from unctuous alteration-products of the Aberdeen felspar, or (less probably) to the microcline structure of many of these. We must notice, throughout these observations, how remarkably uninfluential the cleavage of the felspars appears to be. Quite the contrary would be anticipated under the conditions of wear.

In this set we find, then, quartz wearing with a distinctly rough surface, and rather more rapidly than felspars, the fresh felspar assuming a flat but still matt surface; and both minerals, associated as they are in distinct and easily descernible grains, presenting a surface of considerable roughness and inequality. The micas, constituting about 20 per cent. of the rock, and in grains comparable in dimensions with the grains of quartz and felspar, provide the coarser and deeper inequalities of the worn surface. The conditions here prevailing are, as experience shows, those affording a set at once sufficiently durable, maintaining its surface-roughness, and wearing uniformly.

The Arklow Dolerite.

The next set displays a very different surface to any of the foregoing. It is described as follows:—"Never wears smooth, but is rather soft." The rock is that of the Parnell quarries, south of Arklow. It is a dark, heavy rock, green in colour, and breaking with a rough fracture, and to the unaided eye reveals its grain; although the uniformity of colour renders this less conspicuous than would be the case in granitic or syenitic rocks of similar coarseness of structure. Specific gravity, 2·846.

The microscope (see fig. 1, Plate V., magnification, twelve diameters) shows that the rock, which is a dolerite or diabase, is fairly rich in alteration-products. These are of two kinds: sometimes evidently a chlorite, pale green, plumose, with steely-blue extinction. These areas extend into the augites present in such a way as to suggest that they represent materials derived from this mineral. The other decomposition-product is flaky and nondescript, only showing a partially active or spangly field between crossed nicols. This appears to be derived from the felspar, and is probably in part calcitic. Both these substances must be classed as soft material. The fresh and abundant augite present must also be classed as badly-resisting material. The relations of this augite with the felspars is variable. Generally the augite is allotriomorphic but is also found idiomorphic. In one or two places it is ophitic. Again, in places, the felspar is moulded on shapeless augite outlines. Magnetite is fairly abundant. The only important hard material present is the felspar. It constitutes about 77 per cent. of the rock. It is in crystals of elongated habit, which vary from very small to 3 or 5 millimetres in length, and is, for the greater part at least, plagioclase. It is occasionally clouded, but retains activity in polarized light The rock must be described as a dolerite or diabase. The amount of alteration is hardly enough to justify the latter term. Some specimens which I took from the quarries some years ago, have much the same petrographical characters as the set, but alteration has gone much further.[1]

The durable material is the sufficiently abundant felspar. The softer materials are the alteration-products and—considerably harder—the augite. It is the balance of these which confers upon the set its qualities. The worn surface, in fact, shows that the summits are the felspars; while the hollows are occupied by coloured substances and the iron ores. There are no extended and smooth table-lands. The surface is markedly rough to eye and to touch. The felspar-areas are not extensive enough to offer polished or smooth eminences of any injurious extent. They are well broken up by the aggregated grains of the softer minerals. These aggregates represent depressions on the surface of the set, and may measure up to 3 or 4 millimetres in diameter. The connexion between the worn surface-characters of the stone and its microscopic constitution is evident. That a rock with such a proportion of soft material would be fairly, not very, durable is to be expected; and that a hard material, intermixed in such proportions and with such distribution through a soft material, must afford a rough surface under attrition, might have been safely predicted.

The Ballintoy Olivine Dolerite.

The last set to be described here is one of typically soft character. The set is from the basic rock of Ballintoy, County Antrim. It never gets slippery, but wears rather rapidly and unevenly. This is, then, the first case we have met of a set failing to fulfil the condition of wearing uniformly. The rock is heavy and black, with rough fracture. It must be described as an ophitic olivine dolerite. Specific gravity 2·982.

The olivine occurs in large crystals (see the photographed section, magnification twelve diameters, fig. 2, Plate V.) of perfectly fresh character, as well as in small scattered grains. Some of the larger grains would not have fitted into the figure,

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[1] Mr. Watts (" Catalogue of Irish Minerals ") describes the Arklow rock as consisting of ophitic dolerites or diabases.

and attain 5 or 6 millimetres in length. The usual well-marked cleavage-cracks traverse the crystals. Around these grains, there is occasionally the appearance of flow-structure among the smaller lath-shaped felspars. The greater part of the space between the large olivine grains is occupied by large plates of augite, in which the majority of the felspars, both large and small, are ophitically included. The augite is of a pale pinkish-brown colour, and is very fresh. The felspars are also fresh and unaltered. Some few felspars attain a length of 4 or 5 millimetres. I have detected no glass in the sections.

A study of the worn surface of the set is instructive. The part to be ascribed to olivine as a set-mineral is at once determined. The large pits are lined with broken and splintered olivine débris, or often only a flooring of the mineral is left over. This mineral evidently breaks up readily under attrition and impact, and, although hard, must be classed with the yielding minerals. The cleavage is evidently one cause of this; probably also, in part, the liability to alteration.

We may also, from examination of this set, conclude that augite cannot be regarded as a durable mineral. If it were such—at least, in a degree comparable with the felspars—the set would not wear so rapidly as it does. In point of fact, while the felspar constitutes but a comparatively small part of the rock, felspar and augite together constitute at least two-thirds of the rock. The rapid wear and soft character of the set must therefore be ascribed in part to the failure of the ophitic augite. So small a proportion of felspar—actually only about some 25 per cent. of the rock—unless in a quartz setting, could not be expected to resist long; but as outlasting the olivine, it confers its roughness upon the set and whatever durability it can boast of.

The qualities of this set enable me to say a word here about the conditions generally influencing

(3) UNIFORMITY OF WEAR.

The failure to comply with the condition of uniform wear shown by this basalt, should not, I think, be ascribed to any inequalities in the gross texture of the rock but rather to its mineral composition. The conditions for uneven wear are present in every case; but only the soft and easily weathered set will show any yielding to them. It must be remembered that, like an ordinary road-surface, the conditions as regards wear are those of instability. That is, the areas which become depressed immediately become subject to an increased influence of solvent denudation and softening: for on to these parts there will be an increased gravitation of fluids, and the damp will be longer retained. If, now, minerals are present readily yielding to these influences, obviously the process will proceed acceleratively. To the readiness with which this rock (mainly the olivine) softens, I ascribe the uneven wear. The general lesson may be learnt that any rock which possesses a *large* amount of easily weathered or softened mineral—as the carbonates, zeolites, marcasite and other ores, olivine, &c.—will be liable to uneven wear.

It will be apparent, from the foregoing remarks, that the principal matter to attend to in the selection of the set-rock is the balance between the hard and soft materials. About 75 to 80 per cent. of the mineral matter present should be hard and resistant. Quartz and felspar will, in nearly all cases, be the effective minerals here. The felspar is not a hard mineral if alteration is *very* far gone. The test for optical activity between crossed nicols may be considered a sufficient one. The soft minerals will be mica, chlorite, and other decomposition-products, olivine, and, in a less degree, augite. Although I have hitherto examined no set containing plentiful hornblende, it may be accepted as very probable that this substance will not stand among the hard minerals. The pyroxenes and amphiboles may alike be classed as among the minerals not durable under the conditions of wear.

The grain of the rock must also enter into account. A sufficiently finely divided mixture of, say, 70 per cent. hard, and 30 per cent. soft, minerals might obviously afford, under wear, a surface possessing its roughness on so small a scale as to be useless. The soft minerals must be aggregated in grains, say, from 1 to 3 or 4 mm. in diameter, and the hard be in equally large grains. Doubtless, considerable margin is allowable here on the ascending scale, provided the proportions are about right. Felspars containing much alteration-products, but still preserving their hardness, should, so far as the evidence goes, be regarded as liable to wear to a polished surface.

It is hardly necessary to point out here that, in the same quarry, a rock may vary considerably in character, and for this the engineer must be on the look-out.

While experience in examining sets will always assist us in our power of making a correct forecast of the behaviour of the set, I trust that the remarks and photographs in this Paper will not be without use to engineers unacquainted with petrography. Many questions have arisen in the course of it which require further investigation. It is my hope that answers to them may be forthcoming.

APPENDIX.

ESTIMATING THE HARD AND SOFT CONSTITUENTS.

The problem of determining the proportions of hard and soft constituents in the rock under examination is very simply and readily solved in the following manner:—

The thin rock-section is placed in the microscope; and using a low power (1 inch or lower) and low eye-piece, the image of the field is projected on to a ground-glass screen above the eye-piece, any of the usual photographic apparatus being used. The ground-glass is turned rough side up. Upon this is placed a transparent divided scale prepared as follows:—A piece of logarithmic paper (divided to square millimetres or square tenths of inches) is placed in contact with a sensitive plate in a photographic printing-frame, and printed off by contact in the usual manner. The result is a negative, having the divisions appearing as clear lines on a dark background. This negative may be used if not too densely developed, or from this a positive is printed.

The transparent divided scale is placed *face-downwards* upon the ground glass. We evidently now have an image of the field traversed by the lines upon the scale. On the back of this scale the outline of any particular constituent is traced by an ordinary writing-pen and ink. This done, the divided plate is lifted off; and, holding it up to the light, the number of square millimetres or square centimetres are estimated as contained within the ink outlines. The whole circular area of the field in square cms. is $\frac{\pi . D^2}{4}$; and hence the area occupied by the mineral can be estimated as a percentage of the area of the field. This is done for several fields, and an average taken; thus, in the case of the Arklow set described above, the approximate areas in square centimetres occupied by the coloured constituents and ores in successively taken fields were $14\frac{1}{2}$, 27, $17\frac{1}{2}$, 23, $17\frac{1}{2}$, $13\frac{1}{2}$, 16. The mean is $18\frac{1}{2}$. The field is just 10·1 cms. in diameter, or has an area of 60 square cms. Thus the constituents other than felspars amount to 23 per cent.; or we may assume that the felspar constitutes roughly between 75 and 80 per cent. of the rock. The underlying assumption is that the relative extents of areas taken all round are proportional to the relative abundance of the constituents; an assumption undoubtedly justified unless we are dealing with some special rock-structure. Thus it must be noticed that the mica in some granites may be present in fairly parallel plates. If these appear edge on in the field an allowance must be made or the quantity of this constituent would be under-estimated.

This method is very rapid; and a rough estimate of the chemical composition of the rock may be founded on it if the minerals are definite in kind.

EXPLANATION OF PLATE II.

PLATE II.

Fig. 1.

Penmaenmawr Enstatite Diorite. Magnification, 12 diameters. Ordinary light.

A, augite ; B, biotite ; C, chlorite ; M, magnetite ; E, enstatite.

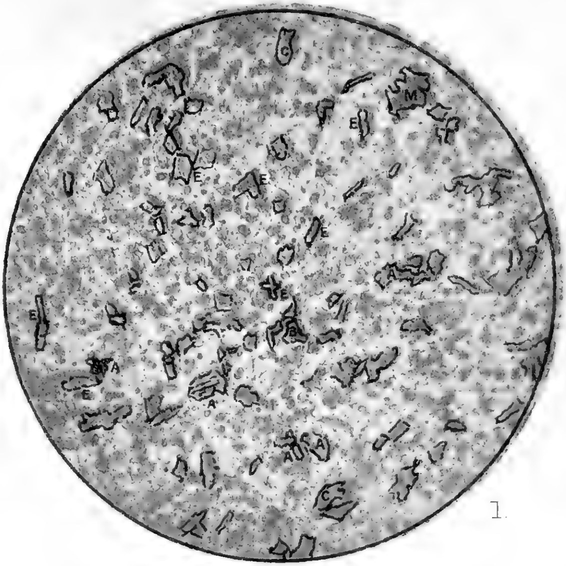
The white parts of the field are filled with interlaced felspar along with a little interstitial quartz.

Fig. 2.

White Caernarvon Granite. Magnification, 12 diameters. Ordinary light.

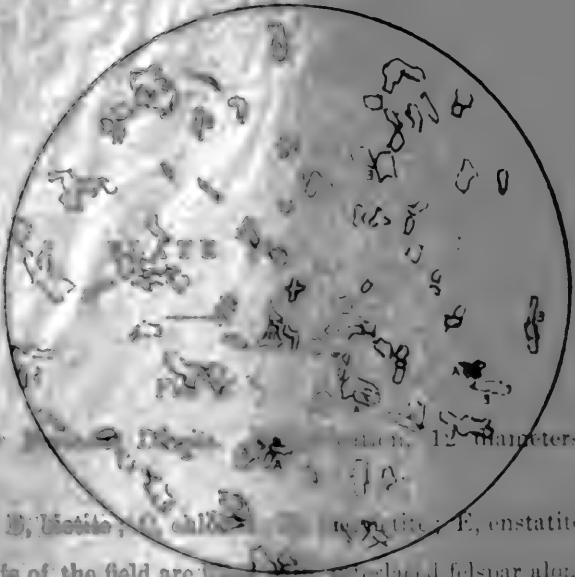
Q, quartz ; F, felspar ; C, chlorite (pennine) ; M, mica (muscovite) ; FM, intermixed felspar and minute flakes of muscovite.

The mica is a very subordinate constituent, only occurring in minute scattered flakes. Original mica is apparently represented by the chloritic mineral. The felspar always contains alteration-products.



1.

Bemrose Ltd, Derby.



[illegible] Magnified 12 diameters. [illegible] light.

A, augite; B, biotite; C, chlo[illegible] [illegible] magnetite; E, enstatite.

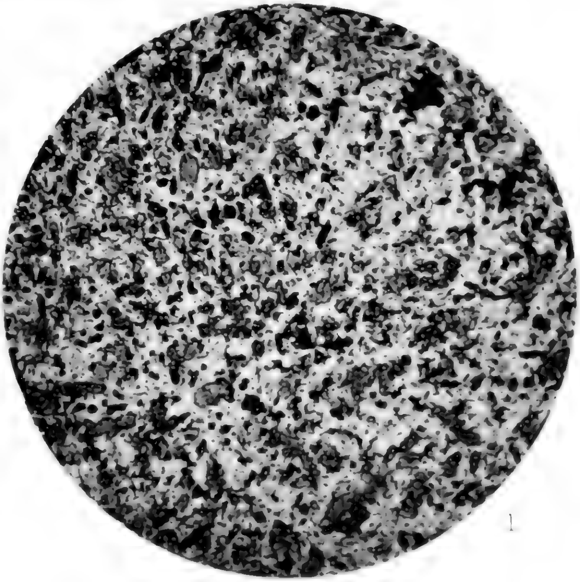
[illegible] parts of the field are [illegible] interlaced felspar along [illegible] interstitial quartz.

Fig. [illegible]

[illegible] Granite. Magnified [illegible] diameters. Ordinary light.

Q, quartz; F, felspar; C, chlor[illegible]; M, mica (muscovite); [illegible] intergrown [illegible] and minute flakes of muscovite.

The mica is very subordinate [illegible] occurring in minute scattered flakes. [illegible] represented by the chloritic mineral. The felspar [illegible] alteration-products.



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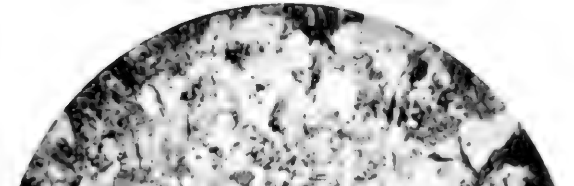

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EXPLANATION OF PLATE III.

PLATE III.

Fig. 1.

Red Caernarvon Granite. Magnification, 12 diameters. Ordinary light.

> O, orthoclase ; F, felspar (plagioclase or doubtful) ; P, pegmatitic intergrowth of quartz and felspar ; Q, quartz ; H, hornblende.

A very little biotite (unaltered) occurs in the rock. The felspar is clouded with alteration-products.

Fig. 2.

Aberdeen Granite. Magnification, 12 diameters. Ordinary light.

> A large crystal of microcline (M), containing included grains of quartz, fills the centre of the field ; B, biotite ; Q, quartz ; F, felspar.

The felspar contains but little alteration-products. The biotite is quite fresh.

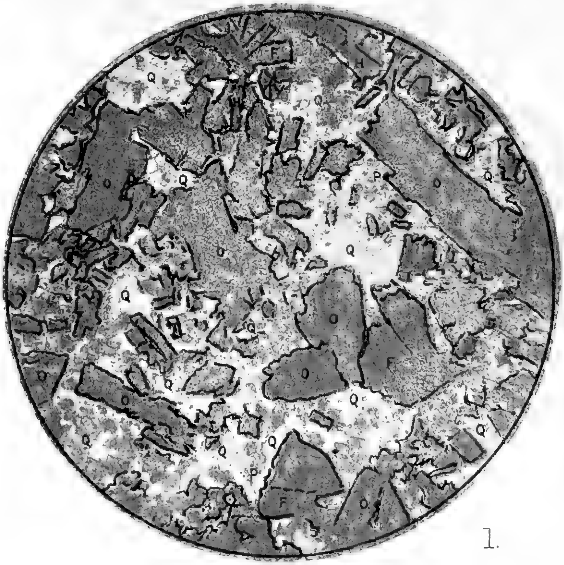

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PLATE II.

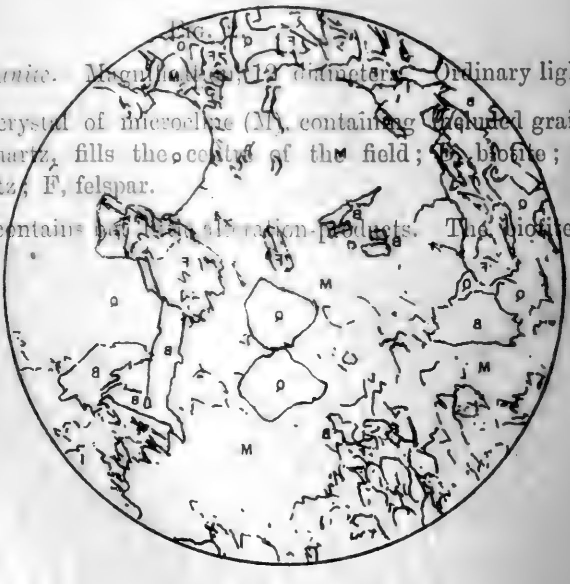
FIG. 1.

Red Caernarvon Granite. Magnification, 12 diameters. Ordinary light.

O, orthoclase; F, felspar (plagioclase or doubtful); P, pegmatitic intergrowth of quartz and felspar; Q, quartz; H, hornblende.

A very little biotite (unaltered) occurs in the rock. The felspar is clouded with alteration-products.

FIG. 2.



Aberdeen Granite. Magnification, 12 diameters. Ordinary light.

A large crystal of microcline (M), containing included grains of quartz, fills the centre of the field; B, biotite; Q, quartz; F, felspar.

The felspar contains but little alteration-products. The biotite is quite fresh.

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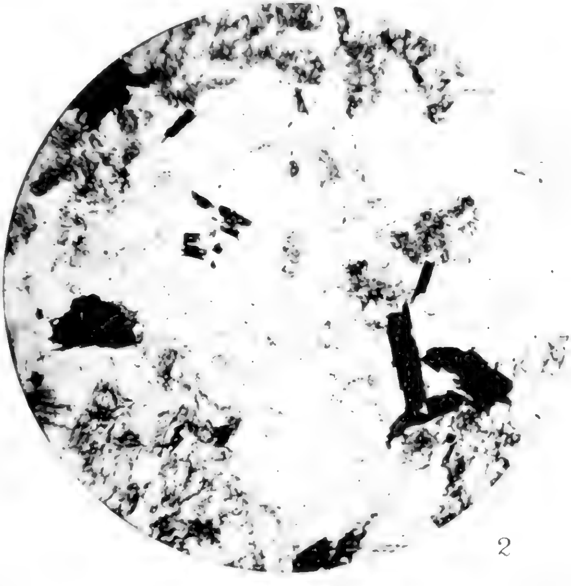

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EXPLANATION OF PLATE IV.

PLATE IV.

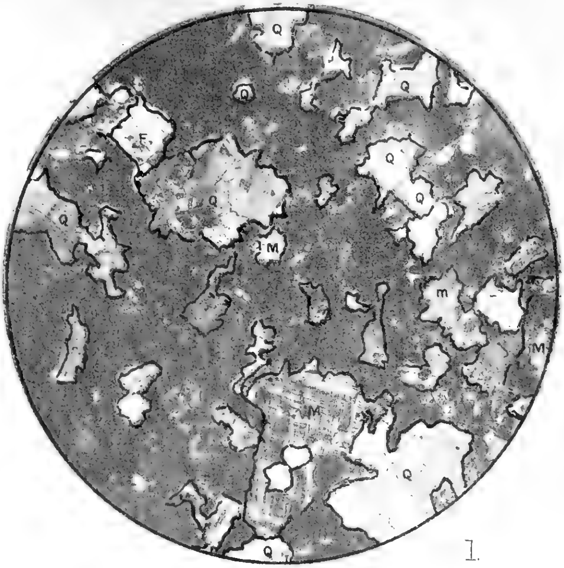
Figs. 1 and 2.

Aberdeen Granite. Magnification, 4·5 diameters. Fig. 1 taken with polarized light; fig. 2 with ordinary light. The large crystal of microcline of fig. 2, Plate III. is shown in lower part of field, centrally.

M, microcline; F, felspar; O, orthoclase; Q, quartz; B, biotite; M, muscovite.

Generally the darkest parts of fig. 2 represent biotite.

Plate IV.



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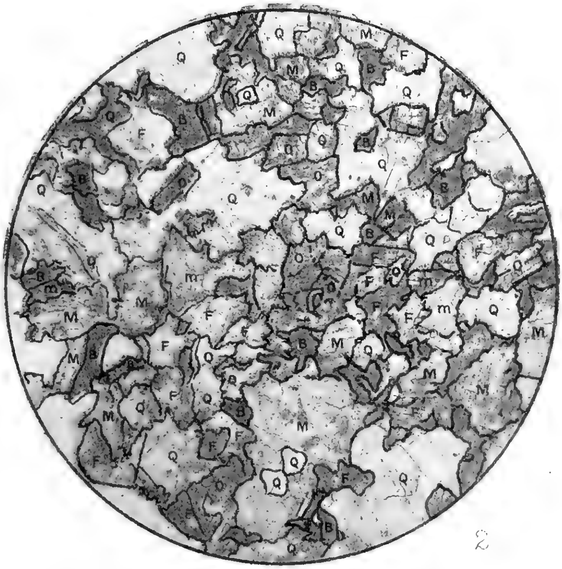

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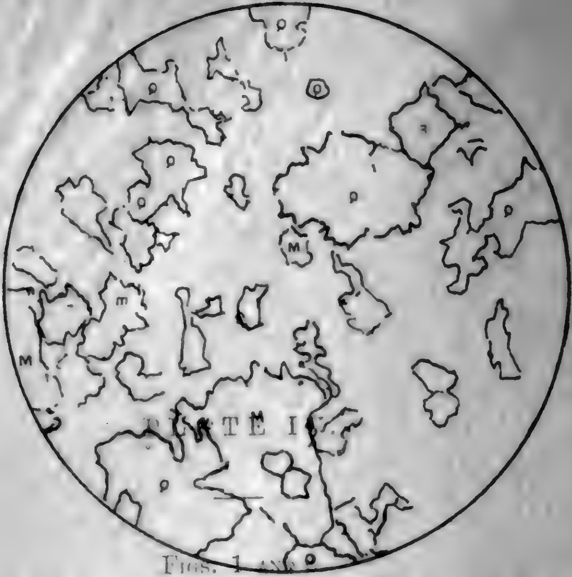
PLATE IV.



Figs. 1 and 2.

Aberdeen Granite. Magnification, 4·5 diameters. Fig. 1 taken with polarised light; fig. 2 with ordinary light. The large crystal of microcline of fig. 2, Plate [illegible] in lower part of field, centrally.

M, microcline; F, felspar; O, orthoclase; Q, quartz; B, biotite; M, muscovite.

Generally the darkest parts [illegible] represent biotite.

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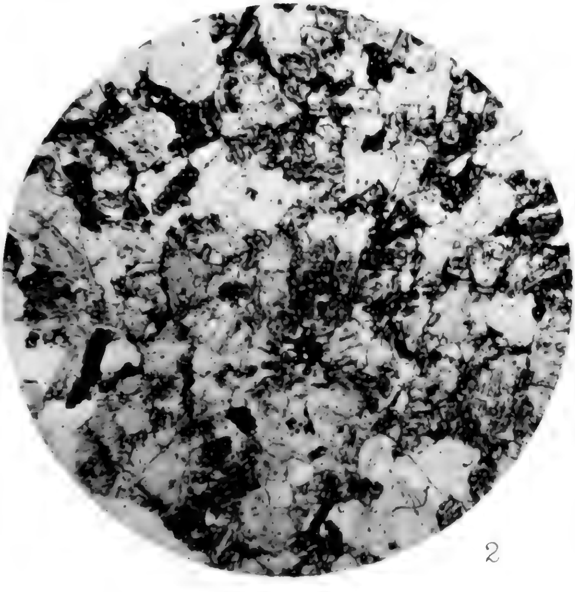

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EXPLANATION OF PLATE V.

PLATE V.

Fig. 1.

Arklow Dolerite. Magnification, 12 diameters. Ordinary light.

A, augite; F, felspar (plagioclase); C, chlorite; M, magnetite.

Fig. 2.

Ballintoy Olivine Dolerite. Magnification, 12 diameters. Ordinary light.

O, olivine; A, plates of ophitic augite; F, felspar, generally included in the ophitic augite; M, magnetite.

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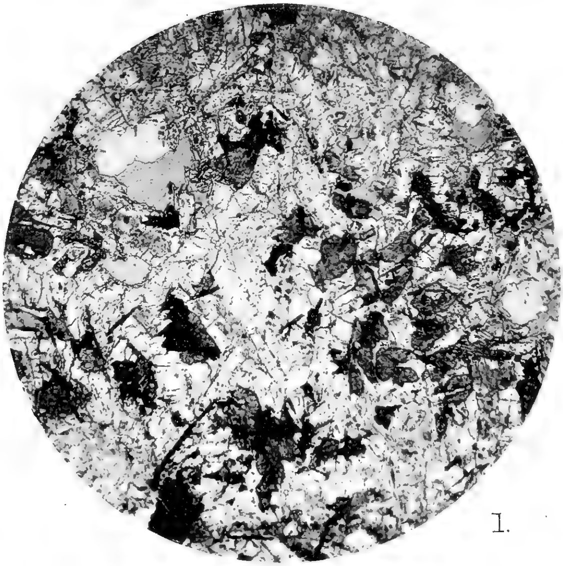

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VI.

ON AN IRISH SPECIMEN OF DOPPLERITE.

By RICHARD J. MOSS, F.I.C., F.C.S.

[Read May 18; Received for Publication May 26; Published July 18, 1903.]

In November, 1902, I received from Mr. R. Lloyd Praeger a specimen of a substance found in a peat bog in the County of Antrim; subsequently Mr. R. Welch, of Belfast, sent me a larger specimen from the same locality. On examination it proves to be dopplerite, and, so far as I can ascertain, this interesting substance has not previously been described as occurring in the United Kingdom. About twenty years ago I saw a specimen, which I suspect was dopplerite, occurring as a jet-like mass in dry peat, such as is used for fuel; at the time I was unaware of its nature. The specimen cannot now be traced; I only know that it was regarded as illustrating the transition of peat into coal, and that it was found in a bog in Ireland. The peat bogs and marshes of Ireland occupy an area of 1,553,000 acres, or about a thirteenth of the entire area of the country, and it seems strange that a substance not unfrequently found in the peat formations of Germany and Switzerland should have escaped notice, or at any rate have escaped recognition, in the great peat formations of Ireland. Mr. Bell deserves credit for recognising the substance he found as something out of the common, and worth inquiring about.

Early in the last century an elaborate report on the peat bogs of Ireland was issued by a Commission appointed by Government. These reports, which are mainly of an engineering character, and are accompanied by numerous large-scale maps of the various bogs surveyed, contain occasional scraps of information of scientific interest. In one of the reports,[1] Mr. (afterwards Sir Richard)

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[1] The second Report of the Commissioners appointed to inquire into the nature and extent of the Bogs in Ireland, and the practicability of draining and cultivating them. Printed by order of the House of Commons, April 1st, 1811, p. 48.

Griffith states, in referring to part of the Bog of Allen in the King's County, that there is a kind of compact or black bog which "has a strong resemblance to pitch or pitch coal, the fracture being conchoidal in every direction, and lustre glistening. This kind of bog contains very rarely any vegetable remains; where they do occur I have always found them to consist of some of the varieties of rushes which grow in stagnant waters; from hence we may be led to conclude that black bog was formed, or grew slowly, under water. . . . This supposition is strengthened by the fact that twigs and branches of trees are sometimes found irregularly scattered at the point of juncture of the red and black bogs." The pitch-like substance with conchoidal fracture and glistening lustre which Sir Richard Griffith observed nearly a century ago is probably of the same nature as the substance from Aussee in Styria, brought under notice by Doppler and Schrötter, Inspectors of Mines, and named dopplerite by Haidinger in 1849.[1] According to Dana[2] the same substance has also been found at Gonten in Appenzell, Switzerland, and at Obbürg, near Stansstad in Unterwalden, Switzerland. More recently other occurrences have been recorded, notably at Elizabethfehn on the Hunte-Ems Canal, Oldenburg, where T. Schacht[3] found the stem of a pine-tree changed into dopplerite. In this case the specimen was not found in peat, but in the sand underlying a peat bog, one-third to three-quarters of a metre under the surface of the sand. The overlying bog was formerly four metres in depth, but drainage has reduced its depth to about three metres. In describing this specimen Dr. C. Claessen[4] mentions, in addition to some of the localities above referred to, Dachlmoss and Aurich, as places where dopplerite has been found. Dr. H. Immendorff[5] mentions the extensive occurrences of dopplerite near Papenburg, Hanover. He also refers to a deposit found during the construction of the Ems-Jahde Canal between Aurich and Upschört (East Friesland), which occurred as a jelly or thick liquid in the sand under the bog, in a layer twenty to forty centimetres thick, and extending to about 100 metres. Dopplerite from Pilatus in Switzerland is also

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[1] Sitz. Ber. Wien, II., p. 287.

[2] Handbook of Mineralogy, 5th ed., 1874, p. 749.

[3] Mitteilungen des Vereins zur Förderung der Moorkultur, 1898, p. 149.

[4] *Ibid.*, p. 199.

[5] *Ibid.*, 1900, p. 227.

referred to by the same authority. Two interesting occurrences of dopplerite are mentioned by Dr. Immendorff as having been brought under his notice by Dr. C. Weber. In one case dopplerite of a tarry semi-fluid consistency was found filling small fissures in the boggy sand close to a stone tomb near Westerwanna in Hadeln. In the other case a funeral urn was found in a peat bog by Dr. J. Bohls; it was covered with a lid, and contained in addition to some bones an abundance of dopplerite, which in the fresh watery condition completely filled the urn.

The specimen I have now to describe was found in Sluggan bog, on E. M'Groggan's farm, at Drumsue, near Cookstown Junction, in the County of Antrim. The bog was formerly about 20 feet deep; it is now only 11 feet deep. About 7 feet from the surface, and 4 feet from the underlying boulder-clay, a gelatinous mass of dopplerite occurs, about 3 inches in thickness, thinning away irregularly into the adjoining peat. In its original moist condition the dopplerite presents the form of a stiff jelly, of a velvety-black colour. It is somewhat elastic to pressure, and less elastic to tension, breaking with a conchoidal fracture. It reddens blue litmus, is very slightly soluble in water, and apparently insoluble in acid or neutral solvents, but dissolves in alkaline solutions. In the water-oven it readily loses 85·9 per cent. of water. It shrinks greatly in drying, and becomes blacker in colour and very like jet, breaks with a conchoidal fracture, and exhibits a bright vitreous lustre. The edges of the splinters are translucent, and of a dark brown colour. It is perfectly homogeneous both in the moist and dry states, and under the microscope shows no trace of structure. When heated to ignition it burns without flame, glowing like tinder, and giving off very little combustible gas; it leaves an ash having the form of the original mass, and of a light reddish brown colour.

Two closely concordant analyses of the substance dried for twenty-four hours in the water-oven gave the following result:—

		Calculated free from Ash.	
Carbon,	55·50	Carbon,	58·49
Hydrogen,	5·11	Hydrogen,	5·38
Nitrogen,	1·34	Nitrogen,	1·41
Oxygen,	32·93	Oxygen,	34·72
Ash,	5·12		

In 15·3 milligrammes of the ash (the entire quantity at my disposal) I found 5·8 m.grms. of ferric oxide and alumina, including a trace of phosphoric acid, and 5·1 m.grms. of lime. An appreciable quantity of sulphate was present, but no silica except in the form of minute particles of quartz.

In previously published analyses there is no record of the composition of the peat immediately accompanying the dopplerite, when the substance was found in peat. I had an opportunity for making such an analysis in this case, and the result obtained was as follows:—

		Calculated free from Ash.	
Carbon, . .	57·80	Carbon, . .	60·54
Hydrogen, . .	5·66	Hydrogen, . .	5·93
Nitrogen, . .	1·47	Nitrogen, . .	1·54
Oxygen, . .	30·54	Oxygen, . .	31·99
Ash, . . .	4·53		

Peat is certainly a mixture of compounds of a highly complex nature, and dopplerite may be quite as complex in character. One cannot venture to deduce formulæ from the ultimate composition of either substances; but, for the purpose of more clearly perceiving the difference between the two substances, the following formulæ may be taken as roughly representing the atomic relations of the constituents, omitting the ash:—

Peat, . . $C_{50}H_{59}NO_{20}$
Dopplerite, . $C_{49}H_{54}NO_{22}$

A legitimate deduction from these figures is, that the transition from peat to dopplerite is an oxidation process such as takes place in the conversion of an alcohol into its corresponding acid.

It has been suggested that dopplerite is a calcium salt of one or more humus acids; but Dr. C. Claessen[1] has shown that this view is not tenable, because the ash varies in different specimens within wide limits. The minimum recorded is 2·23 per cent., and the maximum 14·32 per cent. The organic constituents, on the other hand, show no such marked variation, except in the case of nitrogen. If we exclude one specimen from Aussee, which differs

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[1] Mitteil. d. Ver. z. Förd. d. Moorkultur, 1898, p. 198.

rather widely from all the rest, the quantities per cent. of the dry substance free from ash, in the case of nine specimens mentioned by Dr. Claessen and two by Professor Immendorff, are carbon, 55·55 to 60·12; hydrogen, 4·77 to 6·29; nitrogen, 0·57 to 2·27; oxygen, 32.75 to 38·23.

When the dopplerite from Sluggan bog is sliced into sections about two millimetres in thickness, soaked in strong hydrochloric acid for a day, and then washed in a Soxhlet extractor, until the washings show no trace of chlorine with silver nitrate, the substance remains perfectly unaltered in appearance, and when dried it is quite undistinguishable from a dried specimen of the original substance. The final washings to which silver nitrate had been added slowly acquired a reddish colour, and after some time deposited metallic silver. An analysis of dopplerite treated in this way gave the following result:—

Carbon, ...	57·90
Hydrogen, ...	4·98
Oxygen and Nitrogen, ...	36·69
Ash, ...	·43

Owing to the small quantity of material available it was not possible to determine the nitrogen; the experiment, however, shows that almost the entire ash may be removed without producing any perceptible change in the appearance of the substance. The constituents of the dopplerite capable of forming crystalloids with hydrochloric acid evidently diffuse out of the colloidal mass, and are thus almost completely removed. Whether the action of hydrochloric acid, and the subsequent long-continued washing, have any effect in addition to the removal of mineral matter, cannot be decided by a single experiment. The quantity of hydrogen in the washed substance is, according to this single analysis, less than in the original, while oxygen shows a slight increase, if it be assumed that there is no change in the quantity of nitrogen present. If I can obtain a sufficient supply of material, I hope to investigate this point further. An important question to be answered is—In what condition is the nitrogen present? It is certainly present almost entirely in organic combination. M. Berthelot[1] points out that the action of ammonia on artificial

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[1] Chimie Végétale et Agricole, IV., p. 159.

humic acid results in an insoluble compound to which he assigns the formula $C_{54}H_{47}NO_{19}$, which he states may be regarded as derived from humic acid, thus:—$3C_{18}H_{16}O_7 + NH_3 - H_2O$. He regards this compound as comparable to aspartic acid.

When I first became aware of the nature of the Sluggan specimen I decided to determine its acidity by the method devised by Dr. Tacke for determining the acidity of peat and soil. I subsequently ascertained that this method had already been applied to dopplerite by Professor Immendorff, who obtained the following results:—

	Dopplerite from		
	Elizabethfehn.	Papenburg.	Pilatus.
Carbon-dioxide liberated in three hours at ordinary temperature in an atmosphere of hydrogen,	2·79	1.07	1·52
Carbon-dioxide liberated at the boiling point, otherwise as above, ...	4·43	2·29	2·61

Assuming that Mayer's formula for humic acid $C_{17}H_{18}O_8$ is correct, that it contains one carboxyl group, and that the liberation of carbonic acid in Tacke's method is due simply to displacement by humic acid, the above results correspond to the following quantities of free humic acid in 100 parts of the dry substance from the places mentioned:—

Elizabethfehn, ...	70·48
Pilatus, ...	41·52
Papenburg, ...	36·43[1]

I have determined the acidity both of Sluggan dopplerite, and of the peat immediately associated with it, employing the following

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[1] These figures I quote from a private communication from Prof. Immendorff, who informs me that an error crept into his former calculations, and that the figures originally published in Mitteil. d. Ver. z. Förd. d. Moorkultur, 1900, p. 232, are wrong.

modification of Tacke's method:—An accurately weighed quantity of the original moist substance, about 10 grammes in each case, was reduced to a fine pulp in a mortar, with the addition of water, and washed into a 200 c.c. flask; the total quantity of water employed was about 50 c.c. The flask was then closed with a cork through which two tubes pass, one tube reaches to the bottom of the flask, and is connected with a hydrogen generating apparatus. The other tube extends only a little below the cork, and communicates with the lower orifice of a double surface condenser; the upper orifice of the condenser is connected with a $CaCl_2$ tube, and a weighed soda-lime tube. With this arrangement, and a supply of cold condensing water, it is possible to pass a current of hydrogen through the boiling contents of the flask for several hours without carrying over more water vapour than a short $CaCl_2$ tube is capable of removing. The tube through which the hydrogen enters the flask is made in two pieces; the lower piece is a thistle-tube, to which the upper piece acts as a stopper. This arrangement enables one to add water, in which calcium carbonate is suspended, to the contents of the flask without admitting air or allowing hydrogen to escape. The hydrogen, before it entered the flask, was passed through a solution of potassium hydroxide in a Pettenkofer absorption tube at the rate of about two litres per hour.

The application of this method to the Sluggan dopplerite and peat gave the following results:—Dopplerite, 10·05 grammes of the moist substance containing 1·413 gramme of dry matter liberated in three hours at the ordinary temperature 0·0237 gramme CO_2. On boiling for three hours a further quantity of CO_2 weighing 0·0411 gramme was evolved, making a total of 0·0648 gramme CO_2. This corresponds to 4·58 parts of CO_2 for every 100 parts of dry matter. Peat, 10·19 grammes containing 1·134 gramme of dry matter, liberated 0·0168 gramme CO_2 in three hours at the ordinary temperature, and ·0260 gramme on boiling, making a total of 0·0428 gramme, corresponding to 3·77 parts CO_2 for every 100 parts of dry matter. On the assumptions already referred to these figures show that the Sluggan dopplerite in the dry state contains 72·87 per cent. of humic acid, while the peat with which it is immediately associated contains 59·98 per cent. of humic acid. If instead of Mayer's formula for humic acid we adopt the more recent formula of M. Berthelot[1] for the hydrate of humic acid $C_{18}H_{16}0_7$, giving a molecular weight of 344 for a monobasic acid, it will make very little difference in the quantities of humic acid as calculated above.

I find that dopplerite decolourises a solution of phenol-phthalein made pink by the addition of a minute quantity of alkali; the reaction may possibly be utilized in titrating the acidity of this and other humus substances.

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[1] Chimie Végétale et Agricole, IV., p. 125.

VII.

TYLOSES IN THE BRACKEN FERN (*PTERIS AQUILINA*, Linn.).

By T. JOHNSON, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, and Keeper of the Botanical Collections, National Museum, Dublin.

(Plate VI.)

[Read, May 19; Received for Publication, May 26; Published, August 17, 1903.]

A general feature in the stem of some woody plants is, that as the water-conducting sap-wood becomes converted into the hard, durable, non-conducting heart-wood, the cavities of the wood-tubes or xylem vessels become more or less blocked up by masses of large, bladder-like, thin-walled cells which have entered the cavity of the vessel by the bulging in, through the pits of the vessels, of the surrounding xylem parenchyma, at one or more points. Each intrusion is called a tylose. Tyloses are well seen in the stem of the False Acacia tree, and of the Vine. Recently Delacroix noted that the stem of the common potato plant, which is ordinarily free from tyloses, shows them invariably when the potato plant is suffering from the microbe form of the disease commonly called "yellow blight"—an observation I have myself been able to confirm.

This pathological appearance of tyloses is in keeping with their production in the stems of trees suffering from wounds, artificial or otherwise. Here the interference with the flow of sap, or other disturbance in the plant economy, may be accompanied by the more or less complete plugging up of the cavities of the xylem vessels, in part by wound gum, and in part by tyloses.

Recently, in the usual course of inspection of the microscopic preparations made by the students in the botanical class in the Royal College of Science, I was struck by the appearance of the xylem in one of the preparations. One of the trachëides, as the xylem elements are called in the Bracken Fern (though in old rhizomes or underground stems vessels occasionally occur), was filled by well-marked tyloses. It was unfortunately impossible to say what was the cause of their formation, as the section was made from a small, detached piece of the rhizome.

It would be of interest to see if, in the usual process of cutting bracken, the consequent interference with transpiration in the fern fronds causes a formation of tyloses in the underground stem.

Tyloses cannot be common in the Bracken Fern, or they would have been observed already, seeing that in the course of class-teaching one sees hundreds of sections without any indication of their presence.

Though tyloses are, as Molisch and others have shown, found in most of the groups of the flowering plants, according to Küster,[1] the only case on record of tyloses in *Pteridophyta*, or *Vascular Cryptogams*, is that of *Cyathea insignis*, in the old leaf-stalks of which Conwentz found them.

There are several points in Küster's chapter on tyloses which it may not be out of place to mention here.

Whether found in the cavities of xylem vessels or trachëides, in resin-passages, in secretory sacs, or in the respiratory cavity or air-chamber of stomata, they are the result of *Hypertrophy*. This term, meaning an abnormal enlargement of a cell, without cell-division, is used in contrast to the term *Hyperplasy*, in which the abnormality is accompanied by cell-division. Küster states, contrary to views now generally held, that a tylose very rarely shows cell-division, and that the diverticulum into the "free space" is not, as usually supposed, cut off by a cell-wall from the parenchymatous cell giving rise to it. The tyloses which may arise at many points, by the ingrowth, in the case of the xylem, of the surrounding xylem or conjunctive parenchyma, are due to the local hypertrophy of that part of the xylem parenchyma opposite the thin part of the wall of the vessel or trachëide, which, through some cause or other needing further investigation, bulges into the cavity of the vessel, and forms a cellular swelling. This, with or without the parent nucleus or a daughter nucleus, combines with similar swellings to fill up more or less completely the cavity of the xylem vessel,

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[1] "Pathologische Pflanzen-Anatomie," 1903.

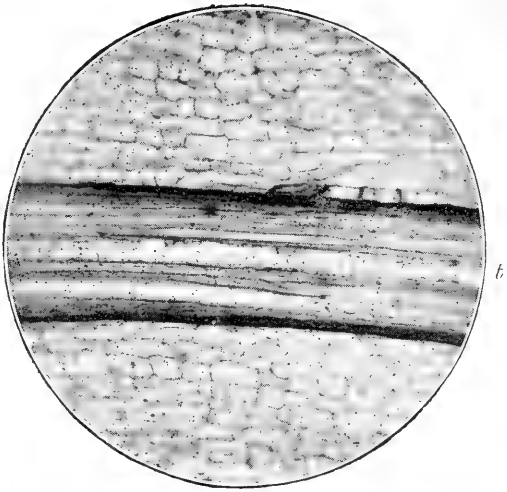

Fig. 1.

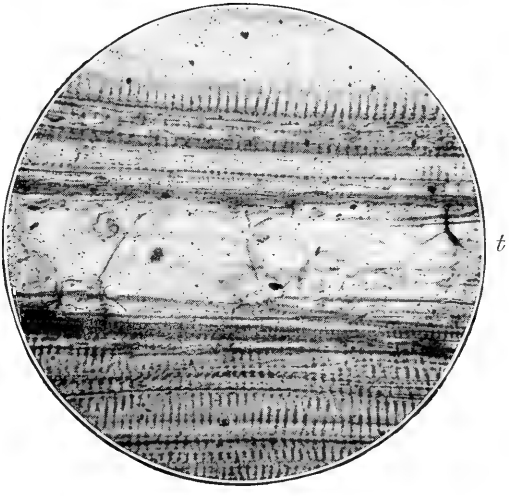

Fig. 2.

Tyloses in the Bracken Fern.

producing in some cases a pseudo-parenchyma in it. Tyloses may in some cases be purely pathological, due to injury or the age of the tissue in which they occur. In some instances, as, *e.g.*, in some cases of leaf-fall, they may arise in connexion with the healing of the wound, may block up the vessel, and stop the transpiration current through it; or in some cases they may, only partly filling the cavity of the vessel, withdraw food-materials from it for the living parenchyma in the xylem.

EXPLANATION OF PLATE VI.

FIG. 1.—Low-power micro-photograph, showing one of the xylem trachëides, *t*, filled by tyloses.

FIG. 2.—A small portion of fig. 1, more highly magnified, showing, in fair outline, a nucleated tylose cell at *t*.

VIII.

A NEW METHOD OF PRODUCING TENSION IN LIQUIDS.

By J. T. JACKSON, M.A.

[Read, June 16; Received for Publication, June 26; Published, September 30, 1903.]

That liquids are capable of sustaining a considerable pull, tension, or negative pressure without rupture can be proved in various ways. The mercury may stick in the top of a barometer-tube and stand at a height of 33 or 34 inches. A siphon will work under the exhausted receiver of an air-pump. A column of water will remain in the longer limb of a J tube, even when the only pressure on the free surface in the shorter limb is the vapour-pressure of the water itself, and is quite incapable of supporting the column. A glass bulb completely filled with water may be gradually cooled; and the vapour-filled space left, as the water contracts, will make its appearance, not gradually, but suddenly, and with a sharp metallic click.

To produce tension in liquids by any of these methods, the liquid must have been boiled, and the glass with which it comes in contact chemically cleaned. Very high tensions have been obtained in these and other ways by Berthelot, O. Reynolds, Worthington, and others.

It was shown by Joly and Dixon (Proc. Roy. Soc., 1894) that the necessity for boiling the liquid arose, not because the presence of dissolved air would render the liquid incapable of sustaining tension, as had been previously assumed, but because the presence of unwetted, or only partially wetted, dust-particles in suspension would afford points of weakness at which rupture could readily occur, and that the air expelled by boiling might be redissolved without rendering the liquid incapable of sustaining tension.

The question then arises as to whether this boiling of the liquid and chemical cleansing of the containing vessel is absolutely necessary in order to render tension either possible or demonstrable. Now it may be that evolution of gas from organic or other particles suspended in the liquid or attached to the sides of the vessel will render a *static* method of producing tension unworkable, while, if the particular portion of the liquid subject to a tensile stress be rapidly changing, and the particles not given time to evolve gas, and so induce rupture, quite a considerable tension may be produced. To take a specific case, is it possible to subject ordinary water as drawn from a city supply main to any considerable tension without rupture? Such water will not stand tension for any considerable time. Will it stand it for even a very short time?

A convenient and simple means of producing low and possibly negative pressures is afforded by the well-known variation of pressure in a liquid flowing through a tube of varying diameter, the pressure being low where the cross-section is small, and high where the cross-section is large. If the liquid were perfectly mobile and the flow steady, the pressure at any point might be deduced from the measured pressure at any other point, the density of the liquid, the rate of flow, and the areas of cross-section of the tube at the two points, the relation between these quantities being

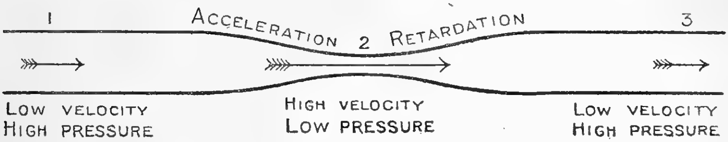

FIG. 1.

$$p_1 - p_2 = \frac{\rho C^2}{2}\left(\frac{1}{A_2^2} - \frac{1}{A_1^2}\right).$$

But actual liquids are far from being perfectly mobile; and the motion of a liquid in a tube is not steady if the velocity exceed a fixed small value, so that the effects of viscosity and turbulent motion would render the above formula inapplicable. If, however, we assume that the current depends only on the pressure-gradient and the form and size of the tube, and does not (at least in the case of an almost incompressible liquid like water) depend on the absolute magnitude of the pressure, we see that the pressure-difference between any two points can depend only on the strength of the current and on the form and size of the portion of the tube between these points, or

$$p_1 - p_2 = F_{12}(C),$$

where the form of the function F_{12} depends on the linear dimensions of the tube only; the density and viscosity of the liquid and the character of the motion between the points considered being assumed to be independent of the absolute pressure.

If now the pressure-difference $p_1 - p_2$ corresponding to a certain value of the current C be determined from an observation in which the absolute values of both pressures are determinable, then, when C has the same value again, and the absolute value of p_1 can be measured, that of p_2 may be at once deduced.

Now in the case of liquid flowing through a tube of varying section (as shown in fig. 1) the pressures in the large-bore portions of the tube as at the point marked (1) or (3) are easily measurable by manometers connected to the tube; but in the small-bore portion as at the point (2) the difficulty of inserting a manometer connection would be great: the readings of the manometer might not give a true indication of the pressure in the flowing liquid (as, owing to the high velocity of flow, the effect of the eddies formed at the junction of the manometer tube with the tube in which the liquid was flowing would be large and uncertain), and finally, as soon as the pressure became negative, rupture would occur in the stationary liquid within the manometer tube. So that negative pressures, if produced, cannot be measured directly, but must be deduced from observations on measurable positive pressures.

But in order that negative pressures at the narrow portion of the tube may be deduced from observed values of the current, and of the pressure in the large-bore portion of the tube by the use of the relation

$$p_1 - p_2 = F_{12}(C),$$

it is necessary that some special determination of values of p_1 and p_2 be made for each value of C. For p_1 the determination is easily made by a manometer, and for p_2 advantage is taken of the fact that a special value of p_2, viz. a value very nearly equal to the the vapour pressure of the liquid is produced and maintained when the flow of liquid just below the point (2) is discontinuous, for then the pressure in the space not occupied by liquid can only be that due to vapour of the liquid, with, perhaps, a small additional pressure due to evolved air.

The apparatus employed was simple; it consisted of a glass tube about $\frac{5}{16}$ in. internal diameter, constricted at the middle to about $\frac{1}{20}$ in. internal diameter. On both sides of the constricted portion smaller tubes were joined in. These tubes, turned upwards and closed at their upper ends, served as compressed air manometers, readings being taken on a scale fixed behind them. The glass tube was firmly fixed in a wooden base, and at one end it was connected by a short rubber tube capable of standing considerable pressure to a brass union which afforded easy means of connection with the water pipes in the laboratory. Another short rubber tube connected the other end of the glass tube to a simple form of current meter, the construction of which will be at once evident from the figure (see fig. 2). This form of current meter proved very satisfactory: it adjusted itself very quickly to variations in the current—a point which was of considerable importance, as will be seen later on.

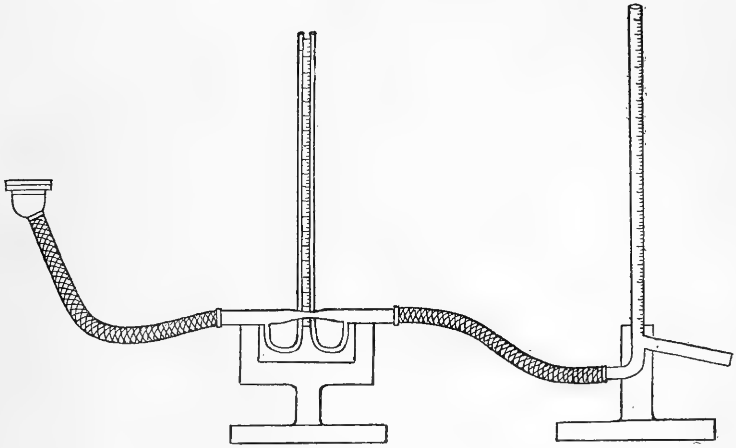

FIG. 2.

On connecting the union to a water-tap, and gradually opening the tap, the following observations were made :—

1st. Pressure-difference, as shown by manometers, and rate of flow as shown by height of water in current gauge, both increased steadily till—

2nd. The column of water in the tube ruptured at the constriction, a roaring or hissing sound was produced, and the water just below the point of minimum cross-section appeared milky with small bubbles.

3rd. At the moment of rupture or commencement of discontinuous motion the pressure-difference, as shown by the manometers, sharply increased, while the current diminished.

4th. The pressure-difference at which rupture occurred was not definite. Rupture was liable to occur if the pressure-difference was above a certain fixed minimum, and the higher the pressure-difference rose above this minimum the greater the liability to rupture.

5th. On closing the tap gradually current and pressure-difference diminished, till at a certain definite pressure-difference the water column united at the constriction and the hissing sound ceased.

6th. Rupture occurred more readily (*i.e.* at lower pressure-differences) shortly after the apparatus had been connected to the tap than after the water had been running for some time.

7th. In an experiment in which the apparatus was connected to the tap through a length of new grey rubber tubing, rupture of the column occurred at a definite pressure, which did not noticeably exceed the pressure at which the column would mend.

The following is one series of observations :—

Temperature of Air, . .	14·0° C.
Temperature of Water, . .	10·8° C.
Barometric height, . . .	29·74 in.

FIRST SET.—*Flow of Water continuous.*

MANOMETER READINGS.		Current-gauge readings.	PRESSURE IN INCHES OF MERCURY.	
Above constriction.	Below constriction.		Above constriction.	Below constriction.
77·6	79·2	No current.	29·74	29·74
46·0	78·0	15	50·2	30·0
42·0	78·0	23	54·8	30·0
40·0	78·0	28	57·6	30·0
38·0	77·5	34	60·5	30·3
37·0	77·5	38	62·2	30·3
35·0	77·5	44	65·7	30·3
33·0	77·0	52	69·8	30·5
32·0	77·0	57	71·8	30·5
31·0	76·5	60	74·2	30·7
30·0	76·5	68	76·7	30·7
29·0	76·5	75	79·3	30·7
28·6	76·5	78	80·3	30·7
27·6	76·5	85	83·2	30·7
27·0	76·2	90	85·2	30·8
26·3	76·2	95	87·3	30·8
26·0	76·2	100	88·3	30·8
25·5	76·0	100	90·1	30·8
25·0	76·0	103	91·8	30·8
24·0	76·0	110	95·7	30·8
24·0	76·0	111	95·7	30·8
23·0	76·0	120	99·8	30·8
24·5	76·0	107	93·7	30·8
23·8	76·0	120	96·5	30·8
23·0	76·0	125	99·8	30·8

SECOND SET.—*Flow of Water discontinuous*.

Manometer Readings.		Current-gauge readings.	Pressure in Inches of Mercury.	
Above constriction.	Below constriction.		Above constriction.	Below constriction.
15·5	76	100	147·5	30·8
15·4	76	102	148·5	30·8
17·0	76	95	134·5	30·8
17·0	76	90	134·6	30·8
18·0	76	87	122·3	30·8
19·0	76	80	120·5	30·8
20·2	76	76	112·5	30·8
22·0	76	70	104·2	30·8
23·6	76	65	97·2	30·8
25·5	77	60	90·0	30·6
28·0	77	55	82·0	30·6
30·0	77	50	76·6	30·6
32·0	77	48	71·8	30·6
33·0	77	45	69·8	30·6
35·0	77	40	65·8	30·6
37·0	77	35	62·2	30·6
37·5	77	34	61·4	30·6
77·0	78	No current.	29·74	29·74

Plotting these results, using as ordinates the calculated pressures, and as abscissæ the observed current-gauge readings (which were heights in tenths of an inch at which the water in the vertical tube stood above the centre of the efflux tube), the curves shown in fig. 3 were obtained.

It is remarkable how closely the curves approximated to straight lines. This, of course, is an indication that the pressure-gradient and the current-gauge reading both vary in the same way as the current changes, and it is a fortunate circumstance, as it affords a ready means of exterpolation. In this way, assuming that the curve so long a straight line would continue as one, the dotted portion of the curve of discontinuous flow in fig. 3 was obtained.

In this diagram the difference of the ordinates of the curves of discontinuous and of continuous flow must represent the tension produced in the water, *plus* the vapour-pressure of the water, or as

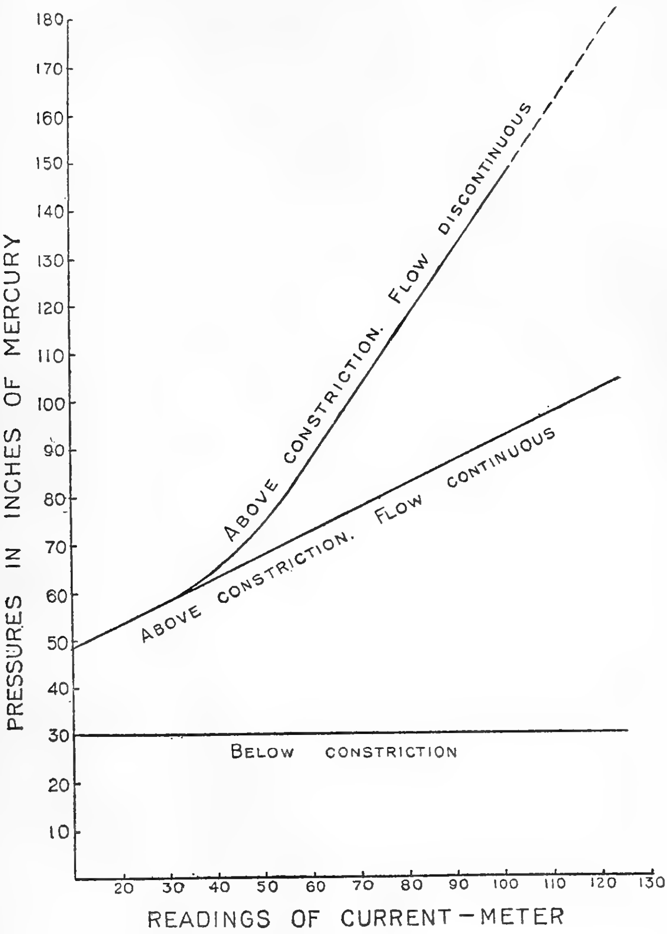

FIG. 3.

the vapour-pressure is small, the difference practically represents the tension produced. This evidently follows from the relation $p_1 - p_2 = F_{12}$ (C), as we have both the pressure p_1 for discontinuous flow *minus* the vapour pressure p_2, and the pressure p_1 for continuous flow *minus* the (negative) pressure p_2 equal to the same quantity F_{12} (C).

Scaling the largest ordinate difference off the diagram it is found to correspond to the negative pressure of 77 in. of mercury, which is equivalent to 87 ft. 6 in. of water, or to 37·8 lbs. per sq. in.

A simple and apparently possible explanation that at first occurs is that turbulent motion in the portion of the tube above the constriction is suddenly set up, and that the observed rise of pressure, coupled with diminution of flow, is due to this cause and not to rupture of a liquid column in tension. But the observations made do not lend support to this theory; for—

1st. The velocity at which rupture occurred was always more than nine times the velocity at which turbulent motion should commence in a tube of $\frac{1}{20}$ in. diameter.

2nd. The pressure corresponding to rupture was not definite.

3rd. Freshly-wetted dust-particles in the water rendered the pressure for rupture low and definite. (See obs. 7, p. 108.)

4th. Unsteadiness of the manometers indicated that turbulent motion already exists before rupture.

The way in which discontinuous flow merges into continuous is interesting. As will be seen from the diagram (fig. 3), the curve of discontinuous flow ceases to be approximately a straight line as it approaches the curve of continuous flow, and bending round meets the latter curve tangentially. The space of discontinuity in the water current, while this bent portion of the curve represents the relation between pressure and flow, does not extend over the whole cross-section of the tube, but is situated on the axis, and noticeably below the point of minimum cross-section. That the point of lowest pressure must be below the smallest cross-section is evident, as it must be where the rate of fall of pressure due to friction is equal to the rate of rise of pressure due to retardation.

A peculiar phenomenon, though quite a side issue, is the behaviour of small bubbles of air separated from the water in the space of discontinuity, and carried into the low-pressure manometer. As long as the flow in the tube remains discontinuous these bubbles do not rise to the surface of the water in the manometer tube, but remain submerged, and evidently in a state of rapid vibration. This appears to be due to eddies produced by the violent and rapid vibration of the water column in the manometer.

It is probable that liquid tension plays a much more important part in nature than is usually thought. Indeed, the fact that liquids are capable of exerting a pull is often regarded as a mere laboratory experience, interesting but inapplicable in everyday life. But it may be that certain phenomena, which have hitherto received other explanations, are really evidences of liquid tension. For instance, large stones are known to have been dislodged from the facework of sea-walls, and this has been put down to pressure of compressed air and of water behind the stone, but may it not have been due rather to pull of the receding water on the face of the stone?

IX.

A TRANSPIRATION MODEL. By HENRY H. DIXON, Sc.D.,

Assistant to the Professor of Botany, University of Dublin.

[Read, June 16; Received for Publication, June 23; Published, October 15, 1903.]

It is a matter of common observation that the leaves of tall trees remain turgid during active transpiration. This turgidity is due to the osmotic pressures of the solutions distending the protoplasmic membranes of the cells of the mesophyll of the leaves. Pressures ranging from 6 to 16 atmospheres have been measured in these cells.[1] The cells distended by these pressures adjoin directly the upper extremities of the water-conducting tracts of the plant, in which it has been shown elsewhere that the water of the transpiration current is in a state of tension.[2] During transpiration the turgid cells lose water on their outer side by evaporation.

The intervention of osmotic pressure between the evaporating surfaces and the stressed water makes the process somewhat more difficult to conceive than if the evaporation from the mesophyll-cells directly stressed the liquid in the trachëidal elements of the vascular bundles of the leaves.

In order to make clear the part played by osmotic pressures in raising the transpiration current, according to the view advocated by Dr. Joly and myself, I have elsewhere compared[3] the actions taking place in the cells of the leaf with those which would proceed in an osmotic cell formed of a semi-permeable membrane containing a solution, and placed in contact with the upper end of a vertical tube filled with water, the lower end of which dips into a reservoir of water. The arrangement was supposed to function as follows:—The

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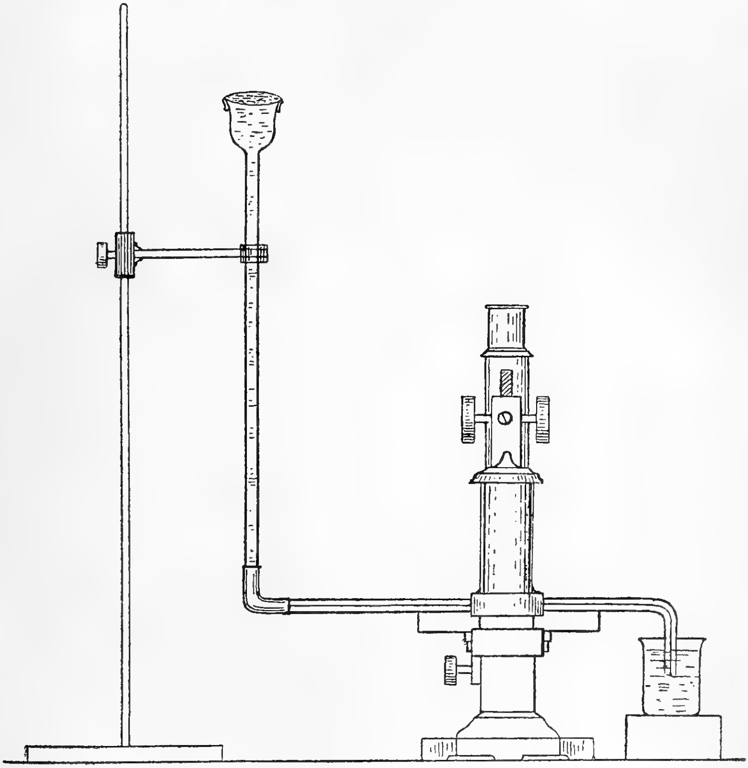
[1] Maquenne: Compt. rend. 1896, p. 898. On the Osmotic Pressure in the Cells of Leaves. Henry H. Dixon: Proc. Roy. Irish Acad., 1897.—Sutherst, Chemical News, 1901, p. 234, Heald: Bot. Gazette, 1902, p. 81.

[2] On the Ascent of Sap. H. H. Dixon and J. Joly: Proc. Roy. Soc., 1894.

[3] Note on the Rôle of Osmosis Transpiration, Proc. Roy. Irish Acad., 1896, p. 774.

osmotic solution within the membrane draws water from the upper end of the tube, and, at the same time, distends the membrane, while evaporation takes place from the upper side of the cell into the space above. The membrane will become and remain distended when the difference of vapour-tension between the water at the top of the tube and in the osmotic cell is greater than the difference between that of the solution in the cell and of the space above the cell. For then the amount of water evaporated will be less than the amount entering into the cell, and the surplus will act in distending the walls. Evaporation will continue to take place as long as the vapour-tension of the solution is greater than that of the water-vapour in the space above the upper side of the cell.



I have since found that the conditions supposed in this explanation may be easily realized in a simple model. Two similar semipermeable membranes are deposited in two pieces of vegetable parchment. This may be conveniently done by soaking the two pieces of parchment, first in gelatine and afterwards, when the gelatine has set, in a solution of tannin. One of the parchments is now spread loosely over the top of an ordinary thistle-head funnel, and its overlapping edge is bound tightly round the rim of the funnel. In order to make this junction water-tight, the outside of the rim is coated with strong glue before putting on the parchment. The second membrane is similarly bound down and glued on the rim, in such a manner as to enclose a space between it and the first. Before closing this space some dry sugar is placed on the lower membrane. After setting, the glue is rendered insoluble by an application of tannin. By this arrangement the funnel is closed by a lenticular cell (with more or less semipermeable walls), containing sugar. The funnel is now filled with water, and set upright, and water is supplied to its lower end.

Thus arranged it will soon be noticed that the cell above becomes turgid; and in becoming so, it of course draws up water through the supply tube. Even after the cell has attained its maximum distension, water still continues to rise in the tube, owing to an action which will be explained later. The upward current may be made apparent by supplying water to the funnel through a fine capillary tube, and by arranging that the water so supplied will contain a fine sediment in suspension; its motion may be observed by means of a microscope (see figure, p. 115). Such a model may be kept in action for several days. It will, apparently, only stop when leakage of the sugar back through the lower membrane makes the liquid below isotonic with that of the cell.

The action of this actual model does not resemble precisely that of the ideal model with the theoretically perfect semipermeable membrane. This may be seen from the following considerations:—At the same time as water is passing into the cell from the funnel, sugar solution is leaking back into the funnel, and exuding on to the upper surface of the upper membrane, owing to the fact that the membranes are not perfectly semipermeable. This leakage may be directly observed in the streams of more highly refracting liquid, which are seen falling down from the lower membrane into the funnel, and also by testing the outer surface of the upper membrane. Taking the leakage into account the action of the model seems to be as follows:—The osmotic pressure in the cell, due to the dissolved sugar, draws water in from below. At the same time a small amount of sugar and water passes through both the lower and upper membranes by leakage. On the outer side of the upper membrane this solution is concentrated by evaporation; and when it becomes more concentrated than the solution within the cell, it will act osmotically on the liquid there, and draw more water to the surface. The solution leaking back into the funnel, on the other hand, is quickly diluted, and is powerless to act on the liquid in the cell. The upward flow is in this case also maintained, owing to the fact that the vapour-tension of water in the space above the cell is less than that of the liquid in the funnel. This tension is communicated through the liquid, on the outside of the upper membrane, and through the liquid in the cell. The former has a higher vapour-pressure than the space above, but lower than the solution in the cell, while the solution in the cell has a higher vapour-pressure than the liquid above, and a lower vapour-pressure than the liquid in the funnel. Furthermore, as the cell remains turgid, these vapour-pressures must be so related to each other that the inflow of water into the cell at least balances the loss of water by evaporation and of solution by leakage.

In the case of the model, the water-column which is raised in the tube is only a few centimetres in height, and consequently is urged up under atmospheric pressure into the space left for it by the evaporative and osmotic actions taking place above. But in the case of high trees, the water in the trachëidal tubes of the leaves is drawn into the osmotic cells in a state of tension, and consequently the water in these turgid cells must be in a tensile state. To render the working of the model in this respect comparable to the transpiratory process taking place in high trees, it would be necessary to remove the atmospheric pressure below, and allow the water to be drawn up in a tensile state into the cell distended by osmotic pressure.

The simultaneous presence of pressure and tension within the cell, at first sight, appears paradoxical; but a little consideration will show that it is quite possible for the solvent, water, to be in a state of tension, *i.e.* at a negative pressure, while the dissolved substances may be at a positive pressure and be active as a distending force in the cell.

Although, by thus distinguishing the pressure conditions of the solvent and of the dissolved substances, it is easy to conceive how the water in a turgid cell may be in a state of tension, it appeared of interest to show experimentally in the following way that this peculiar state of affairs is possible.

It is well known that when a small piece is cut from the young stem of an herbaceous plant, and immersed in water, its curvature will show if its cells are distended by osmotic pressure or not; its outer surface, being less extensible, will become concave, if the cells of its tissues are distended by osmotic pressure. It will remain straight, or become convex, in the absence of these pressures. If, then, such a piece of tissue assumes and retains this concavity when immersed in a tensile water, we may be assured that an osmotic pressure is exercised by the solute, while at the same time the solvent is in a state of tension.

The experiment may be carried out as follows: A long piece of glass-tubing bent into a J-form is carefully cleaned by washing with caustic potash solution, followed by methylated spirit. Its upper end is then sealed, and it is nearly filled with water which has been boiled for some time. A piece of tissue cut from the stem of some suitable plant (I use the peduncle of *Doronicum austriacum*), after soaking for several hours in well-boiled water, is introduced into the J-tube, and passed up to the upper end, where there is a small bend made to receive it. The J-tube is now set in a vertical position, and its short limb is connected with an air-pump. By the action of the pump the atmospheric pressure is removed from the lower end of the column of water in the tube, and the weight of the lower parts of this column, hanging from the upper parts, puts them in tension. As the piece of tissue occupies the top of the tube, the water in it and around it is in a tensile state. It will be noticed that, although exposed to this tension for a considerable time, the tissue will retain its curvature, indicating, as we have seen, an osmotic pressure in its cells. I have exposed a piece of the peduncle of *Doronicum austriacum* to a tension of 50 cm. of water for two hours, without being able to detect any diminution of curvature.

In order to expose the water surrounding the piece of tissue to a greater tension, the lower part of the water column may be replaced by mercury. Working in this way I have submitted the osmotic cells of the peduncle of *Doronicum* to a tension of 75 cm. of mercury for one hour. During this time the turgor of the cells remained unaltered.

These experiments show the possibility of realizing experimentally the conditions we have assumed of pressure and tension in the transpiring cells of the leaves.

In another place it has been shown[1] that the leaves of plants continue to draw up water, even when surrounded with a saturated space. Contrary to my anticipations, our Transpiration Model may be made to imitate this phenomenon. The experiment may be fitted up by enclosing the thistle-head funnel (furnished with the double membrane, containing sugar solution as described above) in a small, wide-necked bottle, which contains a little water. When the funnel is set up in position, this water lies round its stem, and the space over the membranes becomes saturated with water-vapour. With this arrangement the rise of water may be observed, as before, by the motion of the suspended particles in the capillary supply-tube.

The rise of water in this form of the experiment is made possible by the distension of the cell and by the leakage of sugar solution through the membranes. Water is drawn up into the cell by osmosis, while sugar solution passes through both the upper and lower membranes. It is evident that, as long as the solution above the lower membrane is more concentrated than that in the funnel, water will pass up the supply tube. This equalization of the concentrations will require a long time, as the rate of leakage and that of diffusion through the lower membrane are very slow. In one experiment the motion of particles in the supply tube was observed for seven consecutive days, and even then the rate of motion showed no appreciable falling off. During the experiment sugar solution accumulated on the outside of the upper membrane.

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[1] Transpiration into a Saturated Atmosphere. Proc. Roy. Irish Acad., 1898, p. 627.

It may be supposed that the leaf-cells function just in the same manner as this osmotic cell continues to draw up water after it is surrounded with a saturated atmosphere. When the leaves of a plant are placed in a saturated space, the cells of the mesophyll tissues, if not completely distended, will be capable of taking in more water. Some of this water may be derived from the surrounding water-vapour; but the greater part will undoubtedly be drawn from the wood of the vascular bundles, and so will cause a rise of water in the conducting tracts of the plant. If the osmotic membranes of the mesophyll cells are not strictly semipermeable, this rise will continue, and dilution of the solutions in the cells will proceed until the fluid in the adjoining conducting-tubes is isotonic with the solution in them. The fact that the fluid exuded into a moist atmosphere contains an appreciable quantity of dissolved substances, indicates that the cells of the leaves which are active in raising water into a saturated atmosphere do not possess strictly semipermeable membranes. Hence we may, with great probability, assume that the processes occurring in leaf-cells in a saturated space, so far as the elevation of water is concerned, are extremely similar to those taking place in our model. Of course in leaves containing starch, or in those which are in a condition to carry on photosynthesis, the equalization of the concentration of the solutions in the cells and in the conduits may be long or indefinitely postponed. This is quite in agreement with the fact that submerged leaves are able to draw up water from below when exposed to light, and hardly at all, when kept in darkness.[1]

If the membranes of the model were strictly semipermeable, and the space above them completely saturated, its action would be different from what has just been described. Water would then rise in the supply-tube only as long as the cell was not distended to its maximum. As soon as it had attained its maximum distension, and if its membranes were capable of resisting the osmotic pressures, a state of equilibrium would ensue, and the number of water molecules leaving the cell through the upper membrane would be balanced by the number of those entering through it from the saturated space. And, in the same way,

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[1] *Loc. cit.*, p. 633.

there would be a balance of loss and gain through the lower membrane. Hence the upward motion in the tube would come to a standstill.

These considerations, on the actions of perfect semipermeable membranes, taken in conjunction with the observed facts of transpiration into saturated spaces, led me previously to believe that it was necessary to assume that there was, in transpiration, an expenditure of stored energy, and that vital phenomena entered into the process. But our model shows that with imperfectly semipermeable membranes, such as the leaf-cells in all probability possess, transpiration into saturated spaces is possible over long periods, and that, if photosynthesis is permitted, such transpiration might be indefinitely prolonged.

CONCLUSIONS.

A consideration of the action of the model described in this note leads to the following conclusions:—

(1) A state of tension may exist in the water (solvent) of the leaf-cells, while simultaneously the dissolved substances may be exerting an osmotic pressure. This latter is apparent from the fact that these cells remain in a turgid state.

(2) The tension set up by evaporation at the surfaces of the leaf-cells during transpiration is transmitted, through the solvent in these cells, to the water in the conducting vessels and trachëids of the leaf.

(3) The simultaneous presence of pressure and tension in these cells, coupled with a slight leakage of the solute through the membrane, is adequate to account for the observed facts of transpiration into a saturated atmosphere.

(4) There appears no need to invoke the intervention of special vital actions, *i.e.* the utilization of stored energy in transpiration.

X.

THE LEVINGE HERBARIUM.

By T. JOHNSON, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, and Keeper of the Botanical Collections, National Museum, Dublin, and MISS M. C. KNOWLES.

[Read, June 16; Received for Publication, June 26; Published, October 29, 1903.]

The late Mr. H. C. Levinge, D.L., of Knock Drin Castle, Westmeath, left by will his herbarium of ferns to the Royal Dublin Society in 1896. As is well known, the Society now possesses no collections of its own; and in consequence, Mr. R. J. Moss, F.C.S., the Registrar, offered the herbarium to the Botanical Collections of the National Museum, which the Society had done so much, up to 1877, to create. The collection is a most valuable one, and consists of more than 4000 sheets of specimens of ferns from British India, Ceylon, and nearly all parts of the world. Mr. Levinge also left a herbarium of British Flowering Plants which remained in the possession of his daughter, Mrs. Constance Smyth, whose name, as Miss Levinge, appears often in the records of finds of Irish plants. In 1902, this lady offered the collection to the National Museum. It contains some 2000 sheets of specimens from various parts of Great Britain, and in addition more than 1000 sheets from Ireland, chiefly from County Westmeath. Following the Irish Topographical Botany of Mr. R. Lloyd Praeger, the total flora of Ireland (flowering plants and vascular cryptogams) numbers 1138 species and subspecies. The value of the Levinge Irish herbarium will be appreciated when it is mentioned that it contains specimens of 1066 of these species, 619 being from County Westmeath. In the years 1894, 1895, and 1896, Mr. Levinge himself gave an account in the *Irish Naturalist*, accompanied by a list, of the most interesting species then known in County Westmeath. In the present paper the object is to record the species of which specimens are found in the collection, either from County Westmeath (collected after the publication of his paper mostly), or from other parts of Ireland, and not yet recorded. This list would have been much longer but for the excellent work done in the last few years by Miss E. Reynell. (See *Irish Naturalist*, January, 1903.)

RANUNCULACEÆ.

[1] **Clematis Vitalba*, Linn. Knock Drin, Westmeath, Oct. 4, 1884.

Ranunculus trichophyllus, Chaix. Water-hole, Portmarnock, April 30, 1890, *fide* A. G. More and E. F. Linton. On mud at edge of River Gaine, Knock Drin, July 8, 1891. River Gaine, Knock Drin; June 9, 1894, in running-water, *fide* E. F. Linton. W. P. Hiern says of this plant, "*R. trichophyllus*, or at least *R. capillaceus*." Groves, "*R. heterophyllus* without floating leaves." Top. Bot. has "Westmeath, Ballaghkeeran, 1898—P. Rare. The distribution of none of the Batrachian *Ranunculi* is as yet fully known. The present species probably occurs in all divisions."

×*Ranunculus floribundus*, Bab. Water-course from Brittas Lake, Knock Drin, June 7, 1894. E. F. Linton, W. P. Hiern, and A. G. More call this *R. floribundus*. Messrs. Groves think it a hybrid with *R. peltatus*. Not previously recorded from Westmeath.

Ranunculus penicillatus, Hiern. River Suck, Mount Talbot, Roscommon, July 26, 1891, *fide* W. P. Hiern. Inagh River at Ennistymon, June 26, 1891, *fide* W. P. Hiern. Aughrim River, Wooden Bridge, Wicklow, J. S. Gamble. E. F. Linton says of the plant from Wooden Bridge, "This plant has all the appearance of var. *penicillatus*, but maturer plants necessary for positive certainty." Top. Bot., "Westmeath, Lough Iron, 1899—P. Lough Owel —Levinge." "Probably occurs in all the divisions."

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[1] *, ‡, or †, before a name, means "introduced," "probably introduced," or "possibly introduced," respectively.

× means "new to county."

Cyb. 2 = "Cybele Hibernica," second edition.

Top. Bot. = Praeger, "Irish Topographical Botany."

×*Ranunculus Baudotii*, Godr., var. *confusus* (Godr.). Near New Quay, County Clare, May 18, 1892, *fide* W. P. Hiern. Top. Bot., "The var. *confusus* inland in Armagh"; Cyb. 2, "Pools near Cork, Carroll, 1854. Brackish pools near Sutton, County Dublin, 1882, R. P. Vowell." Not previously recorded from Co. Clare.

Ranunculus sceleratus, Linn. At edge of lake at Killua, June 6, 1894. Top. Bot., "Lough Iron, 1899—P. Rare." "Though occurring chiefly by the coast, this plant is widely distributed in the interior. Probably it occurs in all the divisions." Cyb. 2, "Rare in many parts of the west and north-west. The curious deep-water form with long-stalked floating leaves is uncommon."

BERBERIDEÆ.

**Berberis vulgaris*, Linn. Knock Drin (introduced), May, 1890, Miss Levinge.

PAPAVERACEÆ.

Papaver Rhœas, Linn. Drinmore, Sept. 26, 1888. Knock Drin, October 6, 1884. Top. Bot., "Mullingar, 1897—Carr. Frequent in the west—P." Cyb. 2, "Locally abundant. Common in the east; rare in the west and north, but rapidly spreading."

SARRACENIACEÆ.

[**Sarracenia purpurea*, Linn. Bog at Lisduff, Queen's County, Godfrey Levinge, August, 1892. (No note to say if introduced by him or how it got there).]

FUMARIACEÆ.

Fumaria confusa, Jord. W. Corofin, County Clare, August 7, 1893. Top. Bot., "Ballyvaughan, 1895—Colgan." "No doubt common." Cyb. 2, "Throughout Ireland, probably." "Seems to be less rare than *F. pallidiflora*; but the two plants have not been sufficiently distinguished by many observers."

×*Fumaria officinalis*, Linn. Drinmore, Sept. 26, 1888. Top. Bot. has no record for Westmeath. "Distribution still imperfectly known." Cyb. 2, "Throughout Ireland."

**Hesperis matronalis*, Linn. Limerick, P. B. O'Kelly, Sept. 14, 1894. Top. Bot., "I include this species out of deference to the views of the editors of the second edition of Cybele. I have never seen it except as an obvious escape or casual, and not worth noting." Cyb. 2, "Apparently semi-naturalised in some parts of Ireland, and almost deserving of a place in the Irish Flora."

***Erysimum orientale*, R. Br. Rathmines, County Dublin, July 8, 1892. Cyb. 2, "A casual, nowhere established."

‡*Brassica Rapa*, Linn., var. *Briggsii*, H. C. Wats. Shore of Lake Derevaragh at Lake House, July 18, 1895. Top. Bot., "Westmeath, Knock Drin, 1895, Levinge—W.B.E.C., 1895-1896." "This, the *Brassica campestris* of Irish records, is distributed in more or less abundance over the whole country, and in many districts appears thoroughly naturalised, growing profusely on rough banks and waste ground, and on bare limestone "crags" in the west."

†*Thlaspi arvense*, Linn. Harold's Cross, Dublin, June 13, 1891. Top. Bot., "Baldoyle, 1900, rare—Colgan. A plant of uncertain appearance and seldom permanent. Chiefly in the east, like many weeds of cultivation." Cyb. 2, "In County Dublin, sparingly at Bohernabreena, 1893, and abundant in a sandy field at Rush, 1894."

VIOLACEÆ.

**Viola tricolor*, Linn. Aran Isles, Galway Bay, P. B. O'K., July 8, 1892, *fide* E. F. Linton. Cyb. 2, "No doubt occurs throughout Ireland, but is often confounded with the following sub-species" [*V. arvensis*]. Top. Bot., "Probably in all divisions, but appears to be common in the north only. Not always separated from *V. arvensis*, and in consequence some recorded stations cannot be used. Apparently rare on the limestone."

POLYGALEÆ.

Polygala vulgaris, Linn. Bogbanks, N.-W. end of Lake Derevaragh, May 17, 1890, *fide* W. H. Purchas. Cyb. 2, "Throughout Ireland." Top. Bot., "Westmeath, Mullingar, 1897—Carr. Coosan Lough, 1898—P."

×*Polygala oxyptera*, Reichb. Knock Drin, July, 1885, *fide* W. H. Purchas. Cyb. 2, "Probably occurs on sandhills all round the coast." Top. Bot. has no record for Westmeath.

CARYOPHYLLEÆ.

Arenaria serpyllifolia, Linn., var. *leptoclados* (Guss). Ballinasloe, County Galway, June 16, 1891, Miss Levinge. Portmarnock sandhills, Sept. 8, 1888. Cyb. 2, "Castle Taylor, Galway; More."

PORTULACEÆ.

Montia fontana, Linn. End of Lough Drin, Westmeath, April, 1893, C. Levinge.

HYPERICINEÆ.

Hypericum humifusum, Linn. Knock Drin, Aug., 1888. Cyb. 2, "Throughout Ireland." Top. Bot., "A rare plant in most divisions."

MALVACEÆ.

‡*Althæa officinalis*, Linn. Lough Murray, near New Quay, County Clare. P. B. O'Kelly, 21 Aug., 1891. Top. Bot., "Clare, Lahinch—More." "Established occasionally along the west coast." Cyb. 2, "In most, if not all of its stations, an escape from cultivation."

LINACEÆ.

Linum angustifolium, Huds. Fassaroe, County Wicklow, July 11, 1890. Cyb. 2, "South side of Bray Head, N.C." Top. Bot., "Wicklow, Greystones, 1897—P. Very rare." "This plant has a continuous range over the south and east, from Kerry to the Boyne."

GERANIACEÆ.

Geranium columbinum, Linn. Kilronan, Aran Isles, June 14, 1894. P. B. O'Kelly. Cyb. 2, "South and Middle Ireland." Top. Bot., "Ballyvaughan! 1895—P. B. O'Kelly."

LEGUMINOSÆ.

×*Vicia angustifolia*, Linn. Near the sea, north of Kilronan, Isle of Aran, P. B. O'Kelly, June 14, 1894. Top. Bot., "The accepted idea that this plant is almost confined to the coast is misleading. It is tolerably evenly distributed over the country, rather commoner in the east, and becoming rare and local on the west coast."

ROSACEÆ.

‡*Poterium muricatum*, Spach. Railway bridge wall, Maynooth station, July 31, 1889, *fide* A. G. More. No record in Cyb. 2, or Top. Bot. Distinguishable by the fruiting calyx-tube.

×*Rosa mollis*, Sm. Knock Ross, County Westmeath, July 4, 1892, *fide* E. F. Linton. Terryland, Galway, Sept. 5, 1888. Top. Bot., "Probably frequent; the Irish roses are as yet very little known." Cyb. 2, "Bushy and rocky places, rare."

‡*Rosa rubiginosa*, Linn. Plantations at Clonave, near Lake Derevaragh, July 24, 1895. Cyb. 2, "Hedges in Loughlanstown, Westmeath. Top. Bot., "Westmeath, Loughlanstown (Groves)—Levinge, 1894." "Standing rather uncertain, but in the north has all the appearance of a native."

CRASSULACEÆ.

Sedum acre, Linn. Knock Drin, July, 1885. Cyb. 2, "Throughout Ireland." "Rare inland." Top. Bot., "Much commoner inland than was previously supposed."

HALORAGEÆ.

×*Callitriche verna*, Linn., var. *vernalis* (Koch). Knock Drin, Westmeath, Aug., 1888. Top. Bot., "Possibly common." Seven county records, not including Westmeath, given.

×*Callitriche stagnalis*, Scop. Knock Drin Hill, in woods, July 21, 1893. Cyb. 2, "Throughout Ireland, probably." "The commonest of the Irish *Callitriches*." Top. Bot., "Probably common everywhere."

Callitriche obtusangula, Le Gall. Watercourse, Lough Drin, Aug. 6, 1894. Cyb. 2, "Lough Derevaragh, Westmeath (H. and J. Groves); Levinge, 1894." "South and middle Ireland." "Apparently rare."

ONAGRARIEÆ.

Epilobium montanum, Linn. × *roseum*. Knock Drin, E. S. Marshall, July, 1895.

UMBELLIFERÆ.

Sium erectum, Huds. (*S. angustifolium*, Linn.). Kilmaglish, Westmeath, Aug., 1888. Cyb. 2, "Throughout Ireland." Top. Bot., "Westmeath, Lough Owel, 1899—P. Frequent in centre, and common on L. Ree." "A rare plant in many divisions, and thins out rapidly in the north."

Scandix Pecten-Veneris, Linn. Near Corofin, County Clare, Aug. 7, 1893, H. C. Levinge. Kilmacdough, County Clare, June 20, 1894. Top. Bot., "Clare, Gleninagh, 1895, J. A. Audley! Kilrush—Stewart." "Probably in all divisions, but not common in any."

Œnanthe fistulosa, Linn. Maynooth canal, R. Bayley, July 30, 1889. Cyb. 2, "Throughout Ireland, almost."

Œnanthe crocata, Linn. Lisdoonvarna, County Clare, June 22, 1891. Top. Bot., "Inchiquin Lough, 1899, Miss Knowles." "A local plant, and in a broad sense calcifuge."

Caucalis nodosa, Scop. Near Railway Station, Baldoyle, County Dublin, July 12, 1890. Top. Bot., "Old Bawn, rare, 1900—Colgan." Cyb. 2, "Frequent in County Dublin." "From south to north." "Less frequent inland than near the coast."

CAPRIFOLIACEÆ.

‡*Sambucus nigra*, Linn., var. *laciniata*, Linn. St. Bridget's Well, near Cliffs of Moher, County Clare, June 23, 1891.

COMPOSITÆ.

Gnaphalium uliginosum, Linn. Knock Drin, Aug. 1888. Top. Bot. "Calcifuge and generally rare in the Central Plain."

Anthemis nobilis, Linn. Cromlyn, Connemara, Sept. 5, 1884. Top. Bot., "Oughterard, 1899—P. Inveran—Colgan. Renvyle." Cyb. 2, "From south to north."

×*Matricaria inodora*, Linn., var. *maritima*, Linn. Cliffs of Moher, County Clare, June 23, 1891; also at Portmarnock, County Dublin, September 13, 1888. Cyb. 2, "Throughout Ireland." "*M. maritima*, Linn., as understood by British botanists, has not yet been ascertained to occur in Ireland." Top. Bot., "*M. inodora*, divisions all, common." [Of the two sheets of specimens in the Levinge collection, the one from Portmarnock, County Dublin, shows ripe heads. The fruits are not those of typical *M. inodora*, Linn., but agree with those of true *maritima* according to Coste's description (Flore de la France). The specimens from County Clare have not heads ripe enough to allow one to use the characters of the fruits, but the plants agree in habit with the Portmarnock specimens. Comparison with specimens of *M. inodora*, Linn., var. *salina*, Bab., both in fruit and habit, suggests fusion of the varieties *maritima* and *salina* under one name.—T. J.]

Senecio sylvaticus, Linn. Lisclogher Bog, Aug. 19, 1888. Top. Bot., "Strongly calcifuge, and in the Central Plain chiefly on dry bog-banks. Not a common species in any of the divisions."

Arctium minus, Bernh. Knock Drin, Westmeath, Aug., 1888. Top. Bot., "Westmeath, Moate, 1899—P." "Probably common over the greater portion of Ireland, but undoubtedly rare in the north."

×*Tragopogon pratense*, Linn., var. *minor* (Fries). Knock Drin, County Westmeath, May 8, 1895. Cyb. 2, "Southern half of Ireland. Both the type and the var. *minor* are perhaps equally frequent in Ireland, but have not been sufficiently discriminated." The specimen shows the fungus *Cystopus Tragopogonis*, Pers.

VACCINIACEÆ.

Schollera Occycoccus, Roth, shows *Exobasidium vacciniæ*, Woron. (as recorded in *Irish Naturalist*, 1894, page 100), a fungus causing a gall-like disease. According to Tubeuf (Pflanzenkrankheiten), Rostrup calls the fungus *Exobasidium occycocci*.

ERICACEÆ.

Erica Mackaii, Hook, var. *Stuartii.* Craigmore, Roundstone, Connemara, August 11, 1890. (See *Irish Naturalist*, August, 1902.)

BORAGINEÆ.

×**Anchusa sempervirens*, Linn. Killynon, May 14, 1890. Top. Bot., no record for Westmeath. "Naturalised in the north-east, but clearly of garden origin everywhere."

SCROPHULARINEÆ.

Veronica polita, Fr. Knock Drin, July 21, 1895, legit E. S. Marshall. Top. Bot., "Frequent in most parts of Ireland: apparently less so in the north."

Veronica agrestis, Linn. Knock Drin, Westmeath, July 19, 1890. Cyb. 2, "Though widespread in Ireland, this plant is apparently much rarer than *V. polita.*" Top. Bot., "Westmeath, Moate, 1899—P."

LABIATÆ.

×*Mentha sativa*, Linn. Knock Drin, Aug. 23, 1888. Ennis, County Clare, Aug. 8, 1893. Cyb. 2, "Throughout Ireland probably." Top. Bot. has no record for Clare.

×*Galeopsis versicolor*, Curt. Miltown Malbay, County Clare—P. B. O'K., Sept., 1894. Not recorded for Clare. Cyb. 2, "North Ireland chiefly."

×**Leonurus Cardiaca*, Linn. Ballyvaughan, County Clare, P. B. O'K., Aug. 7, 1891. Cyb. 2, "An escape not seen recently." Three localities given.

CHENOPODIACEÆ.

×*Chenopodium rubrum*, Linn., var. *pseudo-botryoides*—H. C. Watson. Turlough, near Newtown Gort, County Galway—P. B. O'K., Aug. 1893. Cyb. 2, Counties Kerry, Cork, and Wexford.

POLYGONACEÆ.

×*Oxyria digyna*, Hill. Near Lisdoonvarna, May, 1895, P. B. O'K. Not recorded for Clare. Cyb. 2, "Confined to West Ireland."

URTICACEÆ.

†*Ulmus montana*, With. Knock Drin, April and May, 1886. Not recorded for Westmeath in Top. Bot.

CUPULIFERÆ.

Betula pubescens, Ehrh., var. *denudata*, Gren. Cottage Walk, Knock Drin, May 5, 1895.

SALICINEÆ.

Salix lutescens, A. Kern. (*S. aurita* × *S. cinerea*). "Front dam," Brittas Lake, Knock Drin, April and June, 1890. Also Quarry Bog, July 28, 1892, *fide* E. F. Linton.

CONIFERÆ.

×*Taxus baccata*, Linn., Knock Drin, March, 1886. Top. Bot., not recorded for Westmeath. "Now almost confined to the west: formerly more abundant."

ORCHIDACEÆ.

Spiranthes autumnalis, Rich. Miltown Malbay, County Clare, Aug., 1892—P. B. O'K. Cyb. 2, "Southern half of Ireland." Top. Bot., "Clare, Ballyallia, 1900—R. D. O'Brien. Widespread but local."

LILIACEÆ.

Allium vineale, Linn., var. *compactum* (Thuill). Kilbarrack, Co. Dublin, July 8, 1890.

JUNCACEÆ.

Juncus compressus, Jacq. Murrough of Wicklow, July, 1890. Cyb. 2 says, "True *Juncus compressus* (Jacq.), has not yet been ascertained to occur in Ireland." The specimen of *Juncus compressus*, Jacq., has no ripe fruits; but the upper part of the stem is so clearly compressed—elliptic in outline in a cross-section of the restored stem, and not trigonous as in *J. Gerardi*, Loisel—that I think Mr. Levinge's identification should be accepted, and *J. compressus* admitted to the Irish flora (T. J.).

×*Juncus lamprocarpus*, Ehrh., var. *nigritellus* (D. Don). Near Cashel Hotel, Connemara, Sept. 13, 1891 *fide* A. G. More. The type is common throughout Ireland, but the variety not mentioned in Cyb. 2, or in Top. Bot.

NAIADACEÆ.

Zannichellia palustris, Linn. Cahir river, Clare—P. B. O'Kelly, Oct., 1894. Top. Bot., "Inishmore, 1890." Cyb. 2, "Throughout Ireland probably."

Zannichellia brachystemon, J. Gay. Cahira river, near sandhills of Murrough, Clare—P. B. O'K., Sept. 8, 1891. Cyb. 2, "Pool on Slieve Elva, Clare, 1895." "Probably occurs in all districts."

GRAMINEÆ.

×*Sesleria cœrulea*, Scop., var. *flavescens*, Moore. Castle Taylor, County Galway, May 16, 1892. *Vide* Report of Watson Exchange Club, 1894. Top. Bot. says of type: "Widely spread over the western limestone tracts, often occurring in great abundance."

×*Kœleria cristata*, Pers., var. *gracilis*, Boreau. The coast, Baldoyle, County Dublin, July 8, 1890, *fide* W. R .Linton.

Lepturus filiformis, Trin. Kilrush, Clare—P. B. O'K., Oct. 2, 1894. Only recorded definitely from Limerick and Clare on the west coast.

Lepturus filiformis, Trin., var. *incurvatus* (Trin.). Kilrush, Clare, July 13, 1893—P. B. O'K. Babington (Manual, ed. 8) says, "Apparently only found as a ballast plant."

FILICES.

Asplenium Ruta-muraria, Linn., var. *pseudo-germanicum* (Milde). Knock Drin, Aug., 1876. Type common on walls. Var. not recorded.

Polystichum Lonchitis, Roth. Knock Drin, 1845, "Not found now, 1891." Top. Bot., "On western mountains only."

THE
SCIENTIFIC PROCEEDINGS
OF THE
ROYAL DUBLIN SOCIETY.

Vol. X. (N. S.) NOVEMBER, 1904. Part 2.

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DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.
WILLIAMS AND NORGATE,
14, HENRIETTA-STREET, COVENT GARDEN, LONDON;
20, SOUTH FREDERICK-STREET, EDINBURGH;
AND 7, BROAD-STREET, OXFORD.
1904.

Price Eight Shillings and Sixpence.

XI.

FLOATING REFRACTING TELESCOPE.

By SIR HOWARD GRUBB, F.R.S., Vice-President, Royal Dublin Society.

(Plates VII.–IX.)

[Read, November 17; Received for Publication, November 20, 1903; Published, February 10, 1904.]

On the 21st February, 1894, I read a short paper before the Royal Dublin Society (Scient. Proc. viii., pt. 3, p. 252), describing a suggested form of equatorial suitable for reflecting telescopes of the Newtonian type, in which the principle of flotation was carried further than had hitherto been attempted.

The object of proposing the flotation principle for these large equatorials was to surmount the difficulty which is encountered when the dimensions and weights of the moving parts become excessive. The weights of the moving parts of such an instrument increase about as the cube of the diameter of the object-glass or mirror, whereas the bearing surfaces cannot be conveniently increased in a larger proportion than the square; the consequence is, that the weights on the bearings become excessive, and great difficulties arise in reducing the friction sufficiently to enable the ponderous masses of metal contained in the mounting to be driven by the clock-work with that amount of steadiness and uniformity which is absolutely necessary for modern astronomical observations.

Having lately been requested to submit designs for a refracting telescope of 48 inches aperture, I was led to consider how far the same flotation principle could be utilised in the case of refractors. In order to effect this, I propose to adopt a very practical and ingenious modification of the ordinary form of refracting telescope suggested to me a few years ago by Professor Hale, Director of the Yerkes Observatory in Chicago, where the largest existing refractor is installed. He desired to have a refracting telescope of unusually long focus mounted as an equatorial, but the long focus necessitated a very large equatorial if constructed in the ordinary manner. He therefore suggested that the tube should be made one-half the length of the focus of the telescope, and that a plane mirror should be inserted at the lower end of the tube nearly at right angles to the axis, which would reflect the rays, but without altering their convergence, to an eye-piece or photo-plate at the upper end of the tube situated beside the object-glass.

This renders the outward form of the refracting telescope very similar to that of the Newtonian reflector, and enables us to apply the same principle of mounting as I suggested before in the case of the reflecting telescope.

In the present case I had to design an instrument for a low latitude, 25°; and I found that the flotation principle could be even more perfectly carried out in low latitudes than in higher latitudes, such as ours.

In the design before submitted for the reflecting telescope, the flotation system, though it allowed of the bearings being relieved of a very large percentage of the weight of the moving parts, was not quite perfect, because, as will be seen by reference to the drawings which accompany that paper, the polar axis (which consists of a double-steel framework, embracing a sphere, which sphere forms the declination axis) is more or less immersed in the water according to the hour-angle of the object under observation.

In constructing such an equatorial for low latitudes, however, as in the present design, this flotation principle can be carried further; in fact, it can be made theoretically perfect, so that, if desired, the whole weight of the instrument can be relieved from the bearings, and the balance made equally perfect in all possible positions. It is desirable, of course, to leave a certain percentage of the weight on the bearings in order to ensure perfect steadiness; but any percentage, up to, say, 95 per cent., can be relieved by the water-pressure; and this is equally true of both declination and polar axes.

In the present design (see Plates VII. and VIII.), which is for a refracting telescope of 48 inches aperture, the moving parts of which would weigh about sixty tons, the tube is enlarged near its lower end into a sphere; the construction and distribution of the weights being such that the centre of gravity of those portions of the instrument carried on the declination axis, that is to say, the tube, object-glass, mirror, and inner sphere, shall precisely coincide with the centre of the sphere.

If this be correctly carried out, such a body will, of course, float in water in a state of perfect equilibrium at any angle and in any position.

The polar axis consists of a slightly larger sphere, supplied with bearings placed or mounted at the proper angle, in which the telescope with its inner sphere is placed; and sufficient water is supplied to the space between the two spheres to almost float the telescope with its inner sphere in the outer sphere.

The outer sphere, in which the distribution of parts is likewise such that the centre of gravity corresponds with the centre of the sphere, is itself floated in a third outer sphere or portion of a sphere, which is supplied with sufficient water to float the whole moving parts, including the telescope, with its inner sphere and polar-axis sphere. The result of the whole is that all parts are in perfect equilibrium no matter what positions they are placed in, so that the flotation principle in this case is carried out in the most effective manner; and any portion of the weight of the instrument that is desired, from none up to the whole weight, can be relieved off the bearings either of the polar axis or the declination axis, and still leave all parts in a perfect state of equilibrium.

It will be noted in the design I propose, that the driving arrangements consist of practically an independent equatorial instrument, the polar axis of which is placed in line with the polar axis of the equatorial proper, which carries the telescope, and only connected thereto by a simple driving arrangement, so that any strains of flexure which may possibly occur in the ponderous masses of the equatorial can in no way affect the smaller equatorial, which might be called the driving equatorial.

The advantages to be derived by the adoption of this flotation principle for such an equatorial are:—

1. That no matter what the weights of the moving parts are, there should be no difficulty in dealing with them, as any percentage of the weight can be retained by water-pressure if all details be well designed, and such an instrument should work

with the ease and accuracy of an instrument of one-tenth the weight.

2. The dimensions of the whole instrument, the building to accommodate it, and dome to cover it, are all reduced in a very large proportion, and the cost decreased accordingly.

3. On account of the short radius which the eye-piece describes as compared with other forms of telescope, the difficulties connected with the *status* of the observer—that is, the means for the observer conveniently to reach the eye-piece—are very much reduced.

As regards this last point, it will be seen that a pair of convenient staircases are arranged, one on each side of the tube, carried upon rails laid on the upper floor. This upper floor forms a part of the dome, and revolves with it.

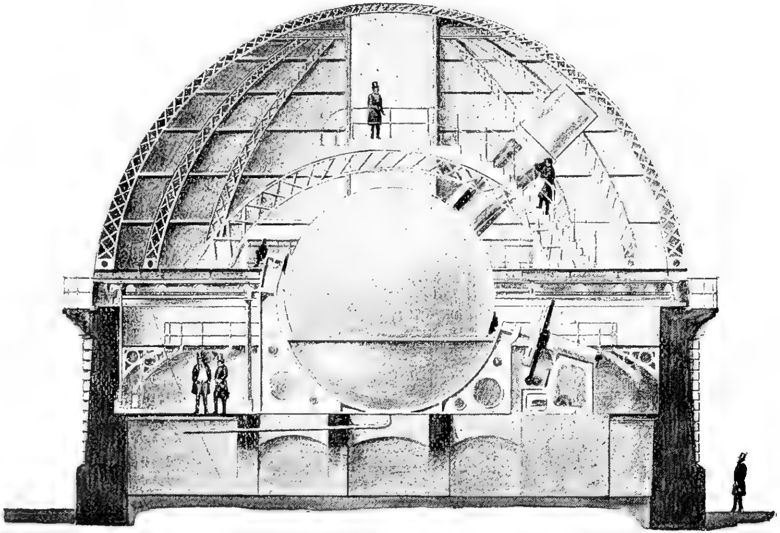
The telescope tube is supplied with attachments for eye-pieces in four places; and convenient access to one or other of these eye-pieces can always be had from some part of these travelling stair-cases.

For comparison's sake, a design of the same-sized telescope, drawn to a smaller scale (Plate IX., fig. 3), is given of the ordinary or German form, complete with hydraulic floor, &c., which would be almost indispensable in this case; and Plate IX., figs. 1 & 2, gives an outline of the buildings and dome required for the ordinary and the flotation instruments side by side, and to the same scale.

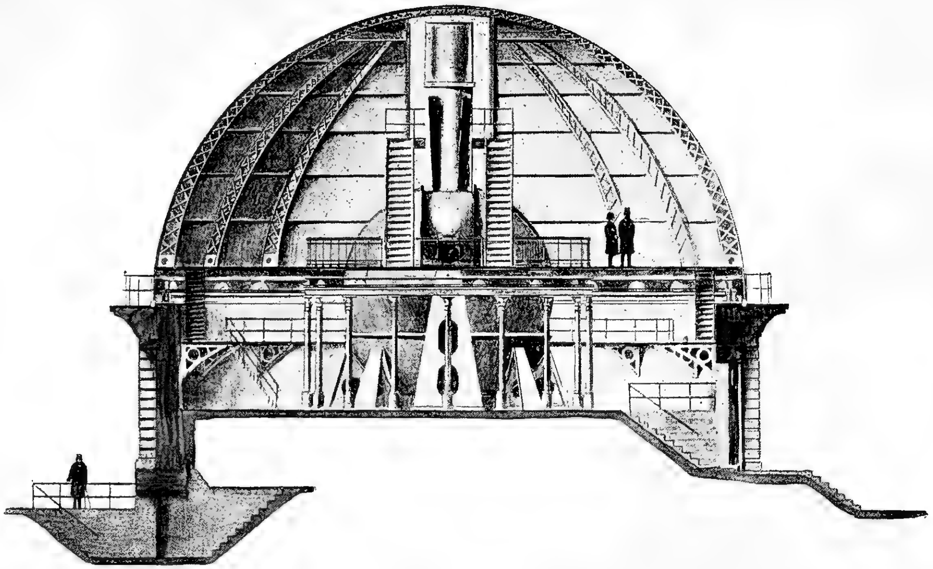
No hydraulic floor is necessary in the case of the flotation telescope, as the difference in the height of the eye-piece for various altitudes of stars never exceeds 18 feet, while in the ordinary form it amounts to about 40 feet.

For convenience of painting, oiling, &c., arrangements are provided by which an additional quantity of water can, if desired, be added either to the outside trough or between the two spheres, thus lifting, in the one case, the whole instrument, including the polar axis, out of its bearings; and in the second case lifting the declination axis and telescope out of its bearings, thus completely avoiding any necessity for employing cranes or other tackle for such purposes.

It should be borne in mind that this instrument has been designed for a latitude where frost is never likely to occur to an



48-inch Refracting Telescope, equatorially mounted on the flotation principle. Building shown in section as viewed from west
Scale 20 feet to one inch.



48-inch Repeating Telescope, equatorially mounted on the flotation principle. Building shown in section as viewed from north.
Scale 20 feet to one inch.

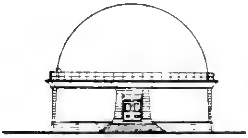


Fig. I

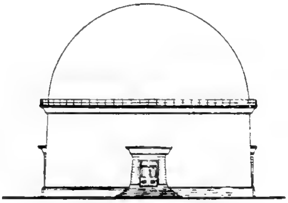


Fig. II

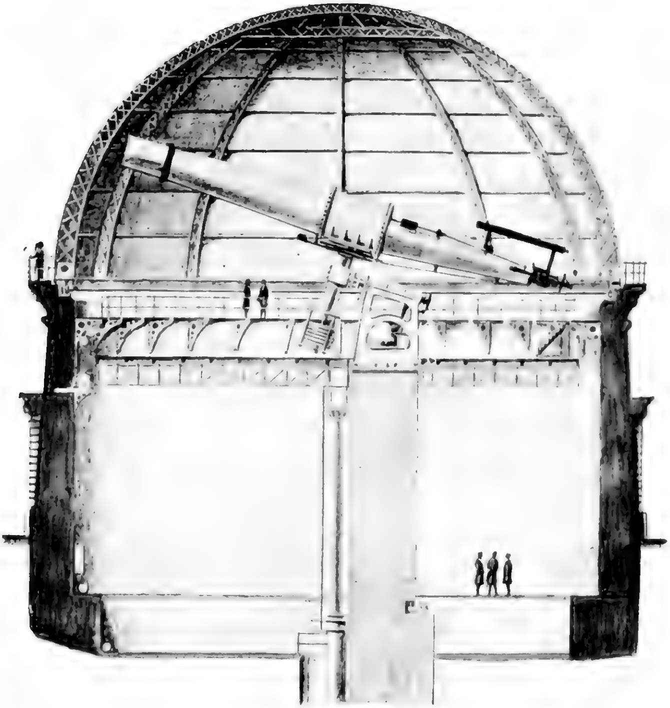


Fig. iii.

Figs. i., ii.—Design illustrating the relative sizes of building and dome required for the accommodation of fig. i., a 48-inch Equatorial mounted on flotation principle, and fig. ii., a 48-inch Equatorial of the ordinary form of mounting.

Fig. iii.—48-inch Refracting Telescope, equatorially mounted. Lifting-floor worked by hydraulic ram. Scale about 26 feet to one inch. Viewed from west

extent sufficient to freeze the water; but if required for higher latitudes, there should be no difficulty in adding some chemical to the water that would prevent this inconvenience.

All the various motions of the instrument, setting in right ascension and declination, &c., also movement of dome, are arranged to be driven by motors.

The declination readings would be taken from an arc of about 10 feet radius, attached to the outer sphere, alongside the opening through which the telescope protrudes; and this is quite close to the eye-piece and observer.

Arrangements for reading the right-ascension circle can also, if desired, be made to enable the observer to take his readings while at the eye-piece of the telescope.

An obvious objection may be raised to this form of instrument on the ground that with sudden changes the upper end of the tube will probably be of a different temperature from the lower, where it is immersed in the water; but I have already provided for this in my design for the reflecting instrument by making the tube double, and keeping a constant circulation of air of the same temperature as that surrounding the upper part of the tube passing between the double envelopes and round the sphere at the lower end. Similar arrangements are provided in this case.

I may mention that, since I proposed this last arrangement for the reflecting telescope, a very similar plan has been actually put into practice at an American observatory with very satisfactory results.

XII.

REGISTRATION OF STAR-TRANSITS BY PHOTOGRAPHY.

By SIR HOWARD GRUBB, F.R.S., Vice-President of the Royal Dublin Society.

[Read, November 17; Received for Publication, November 20, 1903;
Published, February 10, 1904.]

Notwithstanding the great assistance that photography has proved in many branches of astronomical work, very few serious attempts have been made to register transits by its means, though at first sight it would seem to be eminently fitted for this particular work.

It seems comparatively an easy problem to cause the star-image passing across a photographic plate to form its own register by some such means as instantaneously obscuring the image at stated intervals, thus forming a broken instead of a continuous line, the breaks corresponding to certain seconds of the standard clock.

Such an arrangement has been tried with fair success by Mr. W. E. Wilson, F.R.S., amongst others; but at or near the Equator, where the apparent movement of the star is greatest, and when observations are of the most importance, it is only the larger stars that can be thus treated. Smaller stars are not sufficiently brilliant to impress their trail even on the most sensitive plates, and photographers will understand that it is not desirable to use highly sensitive plates for this purpose, as the higher the sensitiveness, the coarser the granulation of the film; and when delicate microscopical measures have afterwards to be taken of the positions of the star-images, these highly sensitive but coarsely-grained plates are unsuitable.

In order, therefore, to provide an efficient photographic transit instrument, it is necessary to cause the plate to travel with the star-image, and register the seconds by some other means; but here a difficulty arises, for the star-images pass across the plate at speeds varying with the angle of declination north or south of the Equator.

They pass fastest at the Equator, and would be absolutely stationary at the exact Pole if there happened to be a star there. The clockwork arrangements, therefore, for carrying the plates would have to be regulated according to the declination of the star under observation—a difficult problem.

I suggest the following as a possible convenient solution of the question:—

The transit instrument itself would be of the ordinary form, and mounted as usual on a pair of piers or columns, the only difference necessary being that the object-glass, instead of being as usual at the upper end of the tube, must be in the centre, where the horizontal axis intersects the tube.

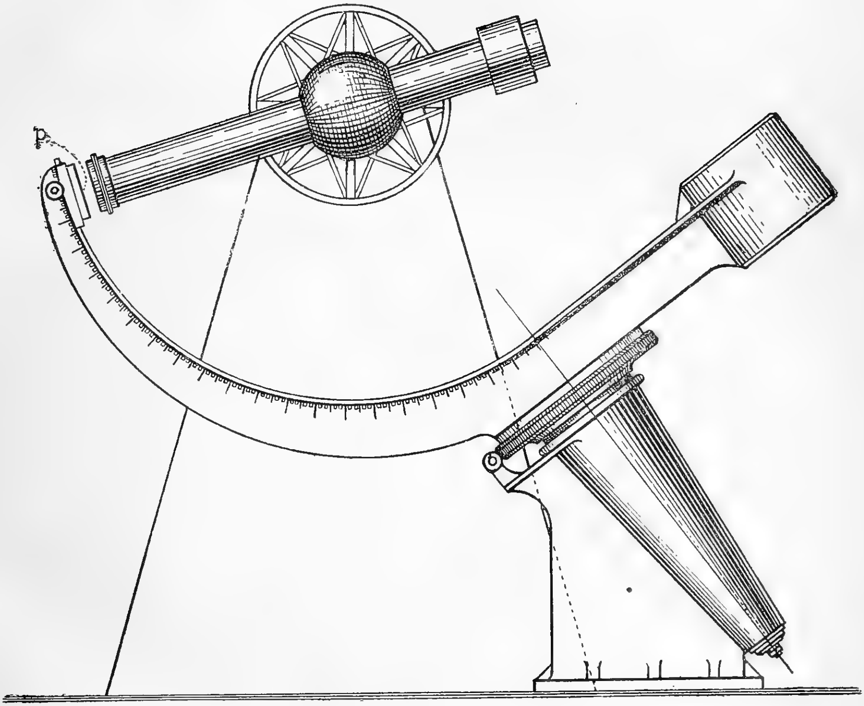


FIG. 1.

The lower end of the tube would be quite open. The photo-plate, *p*, would be carried, not on the tube, but on a metal arc attached to the upper end of a polar axis, which is mounted in a casting quite independent of the transit instrument, but so placed that a prolongation of that polar axis would pass through the horizontal axis of the transit and the optical centre of the object-glass, and the metal arc would be so constructed that its centre also coincides with the same centre of the transit instrument.

With this construction, the photo-plate, whose carrier can be slid up and down the arc, will always be at the focal distance of the object-glass from the optical centre of that glass; and therefore any star-image falling on it will be in correct focus; and if the polar axis be driven uniformly by clockwork as in the ordinary equatorial, the plate will always travel at the correct rate for images of any declination formed upon it; consequently a plate exposed in this apparatus should, when developed, show a round image of a star.

For registering the seconds on the same plate, a diaphragm would be mounted at one end of the axis of the transit instrument with optical means by which an image of that diaphragm will be formed on the same plane as the star-images. This diaphragm would be strongly illuminated by a small electric lamp, and supplied with some kind of instantaneous shutter so arranged that every second, or every alternate second, an image of this diaphragm would be flashed on the plate.

Preferably the design cut on the diaphragm would be as in fig. 2, so that the plate when developed would be as in fig. 3.

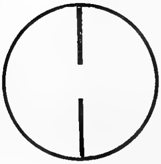


Fig. 2.

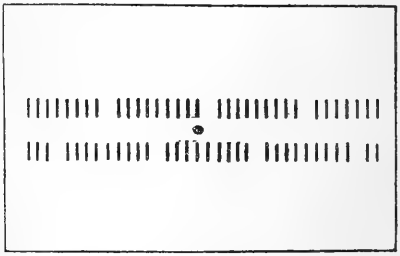
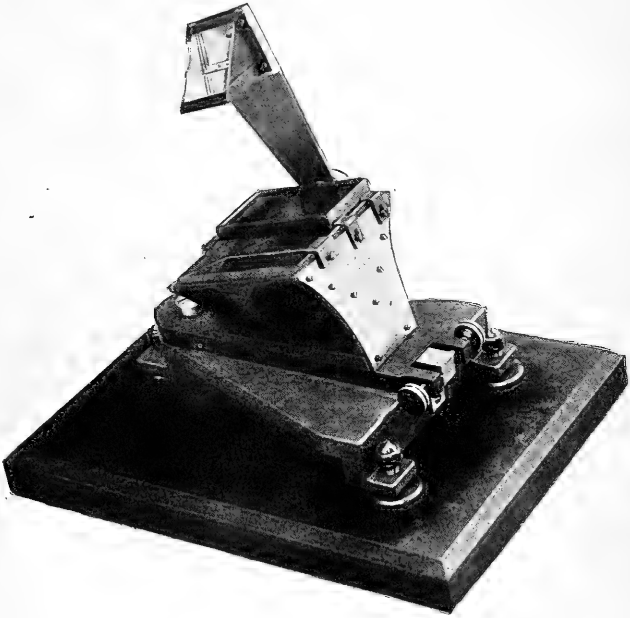


Fig. 3.

It will be observed that every fifth second is "dropped"—that is to say, every fifth flash is omitted on one side, while every tenth second is dropped on the other side. This is to facilitate the identification of the seconds.



IMPROVED DIPLEIDOSCOPE.
Scale about half actual size.

XIII.

A NEW FORM OF DIPLEIDOSCOPE.

By SIR HOWARD GRUBB, F.R.S., Vice-President, Royal Dublin Society.

(Plate X.)

[Read, November 17; Received for Publication, November 20, 1903; Published, February 10, 1904.]

Even in these days of rapid travelling and telegraphic communication there sometimes exists a difficulty in ascertaining true time in country-places.

The very causes which operate to render the distribution of time more easy also necessitate a greater accuracy than was necessary in the old coaching days.

The sun-dial, therefore, is now valued more for its old-time picturesque appearance than for its utility. We have practically nothing available between this and the astronomical transit-circle, which instrument is altogether too delicate to entrust to any but highly-skilled hands.

Many years ago I found a description of an ingenious instrument called a "Dipleidoscope,"[1] which consisted of a right-angled prism fixed in such a position that the Sun when near the meridian could be viewed in it obliquely. Two images were seen—a faint one, due to the partial reflection from the first surface of prism, and another very brilliant, being doubly reflected from the two inner surfaces.

As one of these images was due to single reflection, and the other to double reflection, they appeared to move in opposite directions; and if the prism was properly set, the two images overlapped at the moment the Sun passed the meridian.

The instrument was not very effective, because, firstly, it was necessary to view the images through a very densely-coloured glass to render bearable the intensely brilliant image formed by

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[1] "A Description of the Dipleidoscope." By E. J. Dent, 1843.

the two internal total reflections, rendering the other image hardly visible; and, secondly, as there was no magnifying power, it was not easy to form a correct judgment within some seconds of the time at which the images overlapped.

Some improvements have occurred to me, which I effect in the following way:—

1. By covering one-half of the prism with a film of sulphide of lead, such as we use in the new gun-sights, I am able to make the two images equal in intensity.

2. Instead of viewing the images directly, I add a lens by which images of any desired size are thrown on to a wall or screen.

In the instrument exhibited, the lens is about 20 feet in focus, and forms solar images of about 2 inches in diameter. These images move relatively to one another at the rate of about one-thirtieth of an inch per second, so that it is quite possible for even an unskilled observer to register the time within a second, which is sufficient for all ordinary purposes.

A table of "Equations of Time" could be arranged conveniently to the instrument, so that the true mean time could always be deduced from the solar time, as given by the instrument.

With these modifications, the little instrument becomes a really practical tool, which will be found of considerable use in districts where it is not otherwise possible to obtain correct time.

Circumferentor, or instrument for the rapid measuring of vertical and horizontal angles.
Scale about half actual size.

XIV.

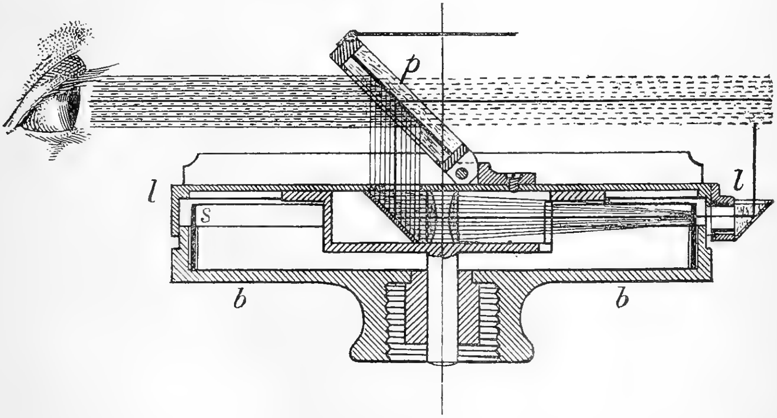
A CIRCUMFERENTOR.

By SIR HOWARD GRUBB, F.R.S., Vice-President, Royal Dublin Society.

(Plate XI.)

[Read, November 17; Received for Publication, November 20, 1903; Published, February 10, 1904.]

The instrument of which the accompanying figure shows a vertical section is primarily intended for rapidly observing horizontal and vertical angles for military purposes; but it is expected that it will also prove of use for many other purposes, notably for underground survey work, mines, &c.



Its construction is exceedingly simple. A circular box, *b*, *b*, is provided on the inside of its rim with a transparent circular scale, *s*, divided into tenths of degrees.

The lid, *l*, *l*, or upper portion of the box, is so constructed that when in use it revolves freely upon the lower.

This lid carries on its under side a pair of plano-convex lenses, with the convex faces towards one another, the combined focus of this pair of lenses being exactly equal to the radius of the circular scale; and they are so placed in the box that the optical centre of the pair is in exact coincidence with the centre of the box. Behind this is placed a right-angled prism which reflects the rays in a vertical direction on to a piece of parallel glass, *p*, hinged to the outside of the lid, and by which the rays are reflected in a horizontal direction into the eye of the observer.

This piece of parallel glass, which folds down on the lid for convenience of packing, is, in its working position, placed at an angle of about forty-five degrees to the lid, and is coated with the same film of sulphide of lead that I use for gun-sights. This film has the property of reflecting nearly half the light which falls upon it, and of transmitting the other half.

The result is that the eye, placed as shown in the figure, sees the opposite landscape through the glass, and also a part of the scale projected upon the landscape.

The pencils of light entering the eye from the scale being parallelized by the pair of convex lenses, the scale appears to be in the plane of the object; therefore, there is no parallax, and whether the eye be moved, or the lid of the box turned for the purpose of taking the bearings of various objects, the scale always appears immovable as respects the object, so long as the lower box is not moved. Again, as the focus of the pair of lenses is equal to the radius of the scale, every space between the divisions of the scale represents its true angular value on the horizon. Consequently no index is required, every object having its bearing projected upon it.

The instrument is mounted on a tripod stand, with parallel plates for levelling, and a rather stiff vertical joint.

To take bearings of various objects as regards each other, the observer turns the lid round until he sees the object through the leaded glass; but he need not set this with exactitude; if he can see the subject anywhere in the field, it suffices. He then, holding the lid with one hand, turns the lower part of the box with the other hand, till the 0 of the scale corresponds with his object. Then he turns the upper box or lid round, so as to see each object *seriatim*; and he will find the bearing of each object, as respects the first, projected upon it. He can then read off these bearings as fast as an assistant can write them down.

If desired, a magnetic compass can be fixed to the lower box; and then all his bearings can be taken with reference to the magnetic meridian.

A striking advantage of this form of instrument is that there is not the same necessity for accuracy of mechanical fitting as in the case of the ordinary forms of measuring instruments; for instance, a slight looseness in the vertical spindle, which is purposely left very free in order that it may be set without the slightest danger of moving the lower box, will not produce any error in the readings, because a shake or loss in this part affects equally the object observed and the scale projected upon it, but does not affect the accuracy of the superposition of one upon the other.

Plate XI. represents the instrument in its complete form, mounted upon a tripod stand. It will be seen that the whole instrument can be turned with its central axis into a vertical or horizontal position, so that vertical angles can be taken as well as horizontal.

XV.

A NEW FORM OF POSITION-FINDER FOR ADAPTATION TO SHIPS' COMPASSES.

BY SIR HOWARD GRUBB, F.R.S., Vice-President, Royal Dublin Society.

(Plate XII.)

[Read, November 17; Received for Publication, November 20, 1903; Published, February 10, 1904.]

This instrument possesses some advantages over the ordinary form. The figure (p. 148) is a section showing the construction. Plate XII. is reproduced from a photograph of the instrument itself.

The purpose of the instrument is to obtain from a ship's deck, with a moderate amount of accuracy, the magnetic bearing of some landmark or vessel which is in sight. It is not an operation that can be effected with great exactitude, as it is generally taken on a vessel in motion, and can only be correct for the precise moment at which it is taken. It is usually a somewhat difficult observation, more particularly if the vessel be rolling in a heavy sea.

The ordinary construction consists of a framework which is laid upon the covering-glass of the binnacle, and centred upon it by means of a little pin which fits in a hollow ground in the centre of the glass cover. This frame supports a piece of tube mounted at a convenient angle, on looking through which a portion of the divided compass-card, which is opposite the tube, is seen through a lens, as well as a pointer, mounted across the tube, to form an index. At the upper end of the tube, on a swivel, a prism is mounted; and by turning a button this prism can be brought into such a position that a portion of the landscape or horizon can be seen by reflection in it. If now the eye be so placed that one-half the pupil be used to view the landscape through this prism, and the other half to view the card and pointer, a coincidence can be made between the three objects.

IMPROVED POSITION-FINDER.

The whole instrument is then turned till the image of the particular landmark, whose bearing it is desired to take, coincides with the pointer; and then the division on the card which is seen to correspond with the pointer is noted as the bearing of that landmark.

If the vessel were absolutely steady, and the eye of the observer quite constant in position, such an observation could be made with sufficient accuracy; but the construction of the instrument is such that it is very difficult to obtain even moderately correct results, except when the above conditions exist.

The pointer, the compass-card, and the image of the landscape, all of which have to be superposed, are, of course, at different distances; and no two can be seen distinctly at the same time; while if the eye be not kept absolutely fixed (a difficult thing in a choppy sea), there will be a considerable amount of parallax and consequent error.

By employing the same principle of construction as used in my gun-sights and geodetical instruments, the following advantages are obtained:—

1. The object on landscape or on horizon is seen erect, and not, as in the old form, inverted, which constantly leads to mistakes.

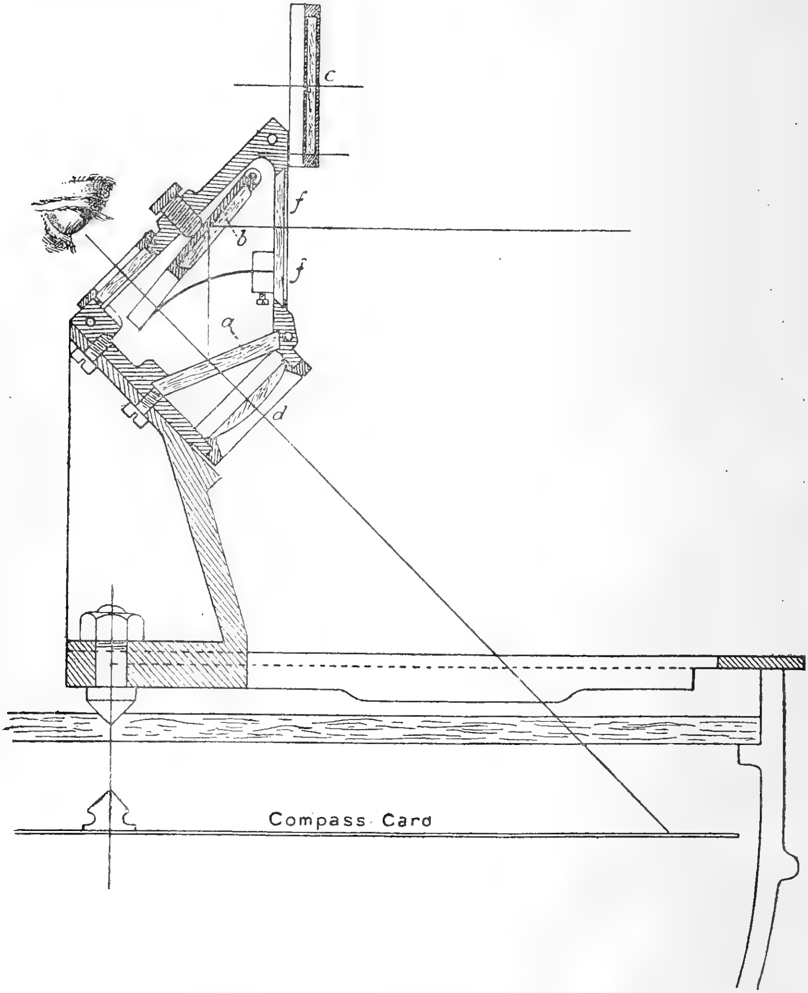
2. The image of the divided arc is formed (by the action of the collimating lens) in the same plane as that of the landscape; and therefore there is no parallax, nor any possibility of error arising from the same, nor necessity to keep the eye steady in one fixed place.

3. In the old instrument two coincidences had to be made: the first between the object and the pointer; the second between the pointer and the division on the compass-card. In the new instrument there is no pointer or index; but the divisions on the card itself are seen projected on the landscape, and the particular division which falls upon the object is the bearing of that object.

4. As the collimating lens is made of a focus equal to the semi-diameter of the compass-card, the degree-divisions on the card correspond to degrees on the horizon; consequently it is not necessary (as in the old form) to set the instrument on the binnacle with the pointer exactly coinciding with the object (another difficult operation in a rough sea). If the object be anywhere in

the field of view—say, even two or three degrees out of the centre—the particular division on the card which is seen imprinted on the object still gives its correct bearing.

Plate XII. shows the appearance of the instrument in its complete form.



a, Piece of parallel glass coated on its upper side with sulphide of lead. *b*, Silvered glass mirror. *c*, Frame carrying tinted glass to reduce brilliancy of image of landscape if desired. *d*, A lens whose focus is equal to the radius of the compass-card *f*, *f*, Plain glass window.

XVI.

AN IMPROVED SIMPLE FORM OF POTOMETER.

By G. H. PETHYBRIDGE, Ph.D., B.Sc.

[Read, November 17; Received for Publication, December 18, 1903;
Published, February 13, 1904.]

In view of the demand which exists for simple forms of apparatus for use in the study of plant-physiology, the following account of a form of potometer suitable for studying the action of various external circumstances on the rate of transpiration may be of service to those interested in this subject.

Most of the forms of potometer described in the text-books are complicated to arrange, and inconvenient to remove quickly from place to place. This applies, for instance, to the form described and figured by Darwin and Acton,[1] where it will be seen that, in addition to the potometer proper (for which a special form of U tube has to be made), a retort-stand with two clamps as well as two blocks of wood are required to complete the apparatus. Moreover, I have found this form of potometer especially disadvantageous, from the fact that, owing to there being a constant pull of some twelve to eighteen inches of water on the cut surface of the leafy shoot, unless the pull exerted by the transpiring shoot is considerable, air is drawn into the limb of the potometer from the intercellular spaces in the shoot, so that its cut surface soon comes to be standing not in water, but in air.

A very simple form of potometer has been described and recommended, consisting merely of a wide-mouthed bottle, provided with a double-holed rubber cork. Into one of these holes the leafy shoot is inserted, and into the other an L-shaped piece of glass tubing of narrow bore, the long limb of the L being horizontal. On filling the bottle with water to the brim, and inserting the cork, the surplus water is forced out through the glass tube. On the leafy shoot commencing to absorb water, and

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[1] "Practical Physiology of Plants." Exp. 92, fig. 15, p. 80. 2nd Edit. 1895.

transpire, the water in this horizontal tube is withdrawn into the bottle; and the rate of its withdrawal can easily be determined by noting the time occupied by the water in receding from the open end of the tube to a given mark on it. On reaching this mark, by gently pushing the cork somewhat more firmly into the neck of the bottle, the water can be again made to reach the open end of the tube, and thus a second determination can be made, and so on. The objections to this form of apparatus are (1) the comparatively few readings that can be taken, owing to the fact that, to ensure water- and air-tightness, the rubber cork has to be pushed in nearly as far as it will go at the outset; and (2), if left for even a comparatively short time, the supply of water in the tube becomes exhausted, air enters the bottle, and hence, before starting fresh readings, it is necessary to remove the cork, fill the bottle with water, and re-adjust.[1]

It occurred to me that both of these objections could be done away with by introducing a tapped thistle-funnel into the bottle, by which water could be let in to take the place of that removed by the shoot, and which could, at the same time, serve as a temporary reservoir during the time in which no observations were being made, so that no air should enter the bottle.[2]

In its final form, my potometer worked itself out into that shown in the accompanying figure (fig. 1). A calcium chloride tower is provided at the top with a double-

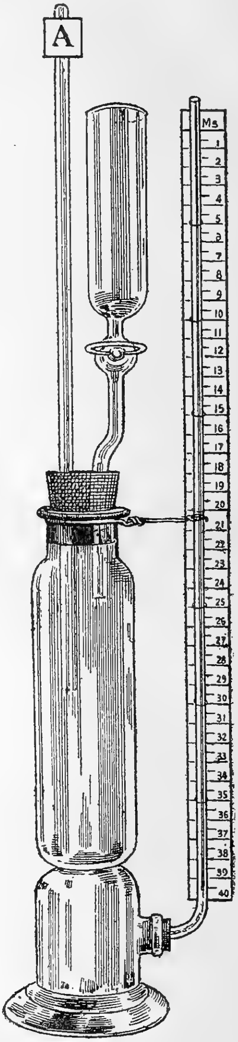

Fig. 1.

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[1] Hall, Annals of Botany, 1901, p. 558, describes and figures a somewhat similar form of apparatus, but with a three-holed cork, the third hole being provided with a wooden rod which can be gradually pushed into the bottle so as to force the water back into the capillary tube.

[2] Since this paper was read I find that Farmer has also recently made use of the tapped thistle-funnel for this purpose. Ref. in Bot. Centralblatt, Dec. 1st, 1903, p. 535.

bored rubber cork. Into one of the holes of this (that in which a glass rod bearing the letter *A* is shown in the figure), the leafy shoot is inserted; the other carries the tapped funnel. The lower outlet is also furnished with a rubber cork, through which passes an L-shaped glass tube of narrow bore, with the longer limb of the L vertical, and suitably supported about half-way up by means of a wire fastened to the neck of the tower. Fastened to this tube is a paper scale, which is a convenience in reading; but which may be dispensed with, and file or other marks on the tube substituted in its place. It will be noted that the narrow-bore tube is of the same height as the funnel, so that when filled with water (as the apparatus is at the start of an experiment), and the tap turned on, it forms one limb of a U tube. As transpiration proceeds, water is absorbed by the cut end of the shoot, and its place is supplied by water from the funnel and from the narrow-bore tube, so that the level of the water in these *slowly* sinks.

On turning off the tap, however, water can only be withdrawn from the narrow-bore tube, the level in which consequently sinks more or less rapidly according as to whether transpiration is rapid or otherwise. By means of this apparatus then, the chief features of which are its compactness, the ease with which it can be moved about, and the fact that no specially constructed tube is required, the broad effects of various external conditions, such as heat and cold, light and shade, draughts and still air, dry and moist air, &c., can be very conveniently studied and recorded by noting the time taken by the column of water in falling through a given distance in the tube in each case. It should be noted that, before each fresh experiment, the level of the water should be adjusted to the original starting-point in the narrow-bore tube by means of the tapped funnel, since, owing to differences in water-pressure, a fall of, say, 1 cm. in the upper part of the tube is not strictly comparable with a fall of 1 cm. near the bottom of the tube.

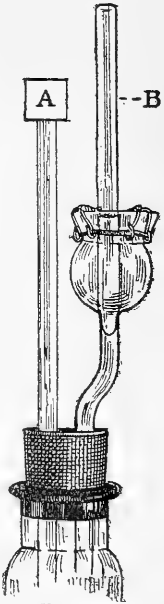

FIG. 2.

Expense may be saved by substituting for the tapped thistle-funnel, which costs about half-a-crown, an ordinary thistle-funnel costing three halfpence. A piece of glass rod is pulled out in the Bunsen flame so that its end tapers somewhat. By means of a little emery powder and turpentine, this can be quite easily ground, so as to form a kind of long-handled stopper to the bottom of the thistle-funnel, thus forming a convenient substitute for the stopcock, although the adjustment of the level of the water in the narrow-bore tube to a given mark is not quite so easily carried out with this arrangement (as shown in fig. 2, p. 151, the stopper *B* being held in its place by means of wires fastened across the top of the funnel) as with the tapped funnel.

XVII.

WILLOW CANKER: *PHYSALOSPORA (BOTRYOSPHÆRIA) GREGARIA*, Sacc.

By T. JOHNSON, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, and Keeper of the Botanical Collections, National Museum, Dublin.

(Plates XIII.–XV.)

[Read, December 15; Received for Publication, December 18, 1903;
Published, March 26, 1904.]

As long ago as the autumn of 1899, I received through the Congested Districts Board, from the osier-beds at Letterfrack in Connemara, specimens of rods called "black mauls," a commercial variety of *Salix triandra*, L., which had been rendered useless for basket-making. The rods broke in two owing to the presence, at one or more spots on the rod, of canker-spots. These spots are easily recognisable externally (Plate XIII., fig. 1), and may reach inwards to the pith (Plate XIII., fig. 2). They are weak spots, and cause the rod to snap in two at the least attempt to bend it. The skin of the rod at the spot looks as if it had been scorched; it is dried up, turns brown, and becomes cracked by the protrusion of very small black specks (Plate XIV., fig. 4); later the cracked skin peels off, more or less; the inner part of the stem becomes exposed, the "cortex" broken up, and the hard bast appears as loose, thread-like strips, sometimes accompanied by a fissure in the disorganised wood reaching to the pith.

Microscopic examination shows that the canker-spots are the external signs of the permeation, through and through, of the rod by the branching threads of a fungus of which the black specks just mentioned are the fruits. It was not until the autumn of this year that an opportunity was afforded me of seeing to what extent the disease was prevalent in the osier holts, and of obtaining, on the spot, some idea as to the cause of the trouble. I was the more interested in the question as the pest was a source of loss to the well-known basket industry at Letterfrack which Miss S. Sturge had started for philanthropic reasons, and to which she had given some seven years in teaching the boys the trade, and in making the industry a commercial success. There are some twelve acres of osiers planted, some at Letterfrack, but the greater part at Rockfield, a mile nearer Clifden. I found cankered rods at both centres, though much more common at Letterfrack, and saw much to support the impression I had formed that the disease was actually in the sets first planted, and imported from England five or six years ago. This impression was strongly supported by the microscopic examination of cankered rods from the original source of supply in England, which I found to be suffering from the same disease. It is possible to trace the disease from the set to the canker on the rod. The tissue of both set and rod is discoloured and disorganised. The cambium on the canker side of the rod is killed, and the pith also shows the effects of the fungus both above and below the canker-spot. Microscopic examination also shows the fungal hyphæ present. A canker in the willow, due to *Melampsora allii-fragilis*, Klebahn, a fungus indicated by orange-yellow spots on leaf and stem, has been recently described in England. I satisfied myself, by examination of some of this English "Melampsora" material, that the canker I am describing in the Irish and the connected English rods had nothing in common with this *Melampsora* canker, though *Melampsora* does occur in the Irish willows, chiefly in their leaves, and occasionally causes a rod-canker.

In estimating the loss to a crop by the attacks of a disease, it is necessary to take into account, not only the damaged plants before one's eyes, but the missing plants which might have been present but for the ravages of the disease.

This feature in a disease is very strikingly illustrated in the beds: many of the sets have died completely; others have a few feebly developed rods; others have some healthy rods with cankered ones on the same set. One field of osiers at Rockfield was almost a complete failure. The impression I formed was that, while the sets planted were diseased when put into the ground, the conditions of cultivation of the rods increased the trouble, and gave the fungus an opportunity of asserting itself more fully. One cause of failure is illustrated by Plate XV., fig. 2. The willow is a surface-rooting plant, and in planting, the sets, 12–13 inches long, should be put into the ground in a sloping direction, not upright, as was done in most of the planting at Letterfrack. Roots do not form on the lowest part of the rod if too far into the ground; the rod then remains much thinner than the rooting, more vigorous upper part.

The land used for planting at Letterfrack was raw bog. This needs thorough draining and suitable manure. The effects of insufficient attention to these two important points are clearly observable in the beds. Again, the best osier-cultivators insist on the necessity of cleanliness of the ground. Weeds, they say, are fatal to the growth of the sets, and should be rigorously kept under. At Letterfrack the weeds have got the upper hand; and some of the plots are full of rank grasses and other weeds. At Rockfield I also saw hundreds of bundles of rods stored green for several years past, full of disease, and now, no doubt, spreading contagion. They should have been burnt when first found useless.

A too wet, poor, peaty soil would distinctly favour the canker disease once in possession of the rods, or would render otherwise healthy ones liable to fall a prey to the attacks of the fungus. The black specks in the canker-spots prove to be of three kinds, distinguishable partly by their contents, partly by their size and shape. The specks are confined to the blisters, and are often found aggregated together, so that three or four of them form one compound common speck, divided into compartments by their cellular walls, raising the host epidermis as they form, and bursting through it as one body (Plate XIV., fig. 1). All the black specks are minute, dark-walled bladders, each with a small opening or pore through which the contents, when ripe, escape into the outer air.

In one kind the bladder, ·76 × ·3 mm., is lined throughout its whole inner surface with a layer of short cellular rods, or conidiophores, each carrying at its end a single, oblong, fusiform, septate conidium, 8·7 × 2·3 μ (Plate XIII., fig. 3). The bladder is a pycnidium, and serves, no doubt, by the production of the conidia, for the vegetative propagation of the parent fungus. By means of these conidia, judging from analogy, the fungus reproduces itself throughout the growing season on other parts of the host, or on other willow plants in the neighbourhood. The pycnidia are, from the practical point of view, sources of infection. On searching mycological literature for anything comparable, I was struck by the great similarity between these pycnidia and the ones described and figured by Prillieux and Delacroix in the canker disease of the sweet or Spanish chestnut in France. Some 300 acres of sweet chestnut grown as coppice for the supply of rods for laths and for barrel-hoops were attacked almost throughout the wood, and the value of the rods reduced quite 50 per cent. in consequence. The account these authors give agrees remarkably with that which I have given in the case of the willow—the same reduction in the yield of rods, loss of splitting and bending properties in those gathered.

The authors called their fungus *Diplodina castaneæ*, Prill. et Delac.; and a name which naturally suggested itself for the Irish willow canker was *Diplodina salicis*. This name I found, on consulting Saccardo's "Sylloge Fungorum," had been given by Westendorp to a fungus found and described by him growing on the weeping willow in Courtrai, the centre of the flax-retting industry in Belgium. Unable to see either Westendorp's description or his specimen, I wrote to Professor C. van Bambeke, of Ghent, who, with the greatest kindness, sent me a small piece of the type specimen as collected by Westendorp, a copy of the only figure given, and of the detailed description published by the author under the title "Cinquième notice sur quelques Hypoxylées, inédites ou nouvelles pour la Flore de la Belgique." Comparison between Westendorp's specimen and the Irish one shows that the two are distinct. In the Belgian specimen the pycnidia are scattered over the surface of the willow-stem, not collected on definite canker-spots, as in the Irish one. The pycnidia are also differently shaped, and contain much larger conidia.

Kickx[1] places Westendorp's species in the genus Diplodia, and gives a description, for a copy of which I am indebted to Professor Bambeke. I quote only the last few words :—"Spores (conidia) ellipsoïdes, étroites, obtuses, hyalines, offrant au milieu, d'après l'auteur, une cloison transversale que nous n'avons pu apercevoir." I have been able to satisfy myself, from the material sent,

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[1] "Flore Cryptogamique des Flandres" (Gand, 1867), tome 1, p. 394.

that Westendorp was right in placing the fungus in the genus Diplodina, in which the conidia are uniseptate, or bisporous and colourless, and not, as Kickx does, in Diplodia, in which the conidia are brown. Possibly, as Kickx himself suggests may be the case, he was examining unripe material, before the cross-wall had had time to form.

In the case of the Irish canker, in the unripe pycnidium the conidia are bisporous or uniseptate; and, had they remained so when ripe, the name *Diplodina salicicola* might have been used; but when quite ripe, the conidia are, as shown in Plate XIII., fig. 4, triseptate or tetrasporous. Hence the name Diplodina cannot be used in its original sense to indicate Diplodia-like fungi with colourless conidia. The name Septoria would seem at first sight more appropriate.

Septoria is a name given to an enormous number of fungi of the group "Fungi Imperfecti," and characterised by pycnidia containing colourless conidia, with several cross-walls. The species of Septoria are confined for the most part to the leaves of their hosts, causing leaf-spot diseases. Where the conidia are bisporous, and occur in pycnidia, as in *Diplodina castaneæ*, it seems desirable to use the name Diplodina rather than Septoria; as the name Septoria is given to leaf-parasites chiefly, and to such as have conidia with several cross-walls, I propose to call the fungus here found in the stem-canker, and provided with colourless rod-like conidia having, when ripe, three cross-walls, *Tetradia salicicola.* The cankers show a second kind of swelling, which is a true perithecium (0·130 × 0·1 mm.) differing entirely in its contents from the pycnidium just described. In this perithecium (Plate XIV., fig. 2) there rises, from the floor only, a hymenium consisting of clavate asci and filiform paraphyses. Each ascus (Plate XIV., fig. 3) contains eight ascospores, more or less in two rows, *i.e.* distichously or sub-distichously arranged.

The ascospores are hyaline, continuous, and oblong, with usually an oil-drop, and often a vacuole at each end, as well as a central nucleus. Often the ascospores look as if bisporous, though staining shows they are really continuous or simple.

Fortunately I have been able to get the opinion of Saccardo on the fungus, and can thus refer this perithecial stage of the fungus to *Physalospora gregaria*, Sacc., of which the following is a description in "Sylloge Fungorum" (i., p. 435), and of which a figure appears in Saccardo's "Fungi Italici," t. 432 :—

"Peritheciis dense gregariis peridermio tectis, globosis, brevissime papillatis atris, intus candidis, ascis clavatis, rotundatis, crasse tunicatis, breve stipitatis, paraphysatis, octosporis; sporidiis, distichis, ovoideo-oblongis, 30–40 × 6–8 μ, granulosis, guttalatisve hyalinis.

"*Hab.*—In ramis corticatis *Pruni*, *Salicis*, *Alni*, *Corni* . . . *Rosse*, &c., in Italia bor., Gallia, Sibirica Asiatica, Amer. Austr."

Physalospora is a member of the Sphæriaceæ, a group of Pyrenomycete *Ascomycetes*, and characterised, amongst other features, by the clustered or aggregate character of its perithecia, as its name indicates. While the *Tetradia* conidia probably serve for the propagation of the canker-pest during the growing season, the perithecia of *Physalospora gregaria* represent the resting stage.

In the following spring the ascospores, escaping from the asci and perithecia, germinate, no doubt, and attack the shoots of the willow as they sprout. I have, as yet, no evidence to enable me to say whether the ascospores or conidia can bore into the host through uninjured skin, or if they have their way prepared by a wound caused by insects, by rubbing together of rods in wind, &c.

The third form of fruiting-body occurring in the same canker as the *Physalospora* perithecia is shown in Plate XIII., fig. 5, and contains bodies of peculiar character. The hyphæ in the pycnidium arise at any point on its inner wall, branch and produce colourless, bisporous, fusiform conidia, in size (12 × 4·5 μ) and in structure comparable to the bisporous conidia of *Diplodina salicis*, Westendorp. Very often these bodies are intercalary, occurring in the course of the branching hyphæ (Plate XIII., fig. 6). At first sight they suggest the genus *Dendrophoma*, one of the Fungi Imperfecti, in which the conidia are simple colourless spores, as in *Phoma*, but differing from it in that they are formed on branching, not simple conidiophores. In *Dendrophoma* the conidiophore branches are also in whorls and the conidia terminal. To include the pycnidium (0·16 × 0·14 mm.) I have just described in *Dendrophoma* would need an extension of the characters of the genus; and as the conidia are larger than the *Tetradia* ones, I propose for this kind of pycnidium the provisional name *Macrodendrophoma salicicola*.

One peculiar feature which appeared in several different cankers is worthy of note. After a pycnidium has emptied its contents, its floor rises up into its cavity, and forms a second pycnidium with contents, replacing the one the cavity of which it has obliterated (Plate XV., fig. 1). Invagination is common in marine Algæ, and in some fungi, where a sporangium, emptied of its contents, becomes invaded by the turgid cell below, which becomes, in its turn, a sporangium. I have not before seen invagination of a pycnidium.

INFECTION EXPERIMENTS.

I have seen the canker-spots on so many different rods, all showing the same kind of bodies as those described, that I am fully satisfied as to the cause of the local rottenness of the rod. On July 6th, 1903, I infected, under sterilization conditions, several perfectly healthy young plants of several species of *Salix*, supplied by Mr. F. W. Moore, M.R.I.A., the Keeper of the Royal Botanic Gardens, Glasnevin. On the 29th of September, while the control plants were quite healthy and normal, the infected ones at the points of infection showed signs of canker-formation, with mycelial hyphæ and pycnidia, which were too young for complete identification. As far as the experiments went, they tended to show the reappearance of the disease.

PREVENTION OF THE DISEASE.

To carry out experiments in the prevention of the disease by fungicides requires ground such as is provided in the Government Pathological Stations I have seen in France and Germany. In the absence, as yet, of such facilities here, I have been confined to laboratory experiments. Mr. J. Adams, B.A., the demonstrator of Botany in the Royal College of Science, has made a number of experiments on the ascospores and conidia, treated with Bordeaux mixture, 2 per cent.; sulphide of potash, 0·25 per cent.; or with formalin, 0·5 per cent. solution. In each case the spores were soaked for an hour in the solution, and then cultivated in a boiled extract of willows. The formalin proved most fungicidal. Neither ascospores, conidia, nor the mycelium in the willow stem, germinated after treatment with it.

Field experiments are needed before one can make a definite recommendation for practical purposes.

Within the last month I have received specimens of cankered rods from Co. Kilkenny, through the Department of Agriculture and Technical Instruction. Microscopic examination shows that the cause of the canker is here also a species of *Physalospora.*

SUMMARY.

1. The osier-canker, which renders the diseased rods worthless for basket-work, is caused by the ascospore-forming fungus *Physalospora gregaria*, Sacc., which has associated with it two other stages, here distinguished as *Tetradia salicicola* and *Macrodendrophoma salicicola.* The former may be the microstylospore and the latter the macrostylospore stage of *Physalospora gregaria*, Sacc. Were they not septate, the conidia in the *Tetradia* stage might be the spermatia of the spermogonium of *Physalospora.*

2. Judging from analogy, all three fruiting stages are capable of infecting healthy willows.

3. The sets when planted were diseased.

4. The new habitat—poor, undrained, raw bog—and prevalence of weeds have favoured the fungus.

5. The fungus has, under the circumstances, killed off some of the sets; in some cases has caused the rods formed to be few in number and small in size; and in other cases, by forming the cankers, has spoilt them for basket-manufacture purposes.

6. The cankers are the external sign of the general permeation of the set and its shoots by the fungus mycelium or hyphæ.

7. *Every care should be taken not to plant diseased sets from an infected holt.*

8. The land chosen for osier growth should be well-drained, to avoid stagnant water or sour soil, and should be well-manured. Bog-land is especially poor in lime, potash, and phosphatic mineral food-materials.

9. As soon as disease shows itself, the attacked sets should be uprooted, burnt, and replaced, or the diseased rods cut to prevent the disease spreading. The "Black Mauls" seem to be the chief sufferers from the disease in the West.

10. A weak solution of formalin, 0·5 per cent., may be used for spraying, to kill the contents of the various kinds of fruits. This is, at the best, a surface-cure for a deep-seated disease, and has not, as yet, been tried in the holt.

EXPLANATION OF PLATE XIII.

PLATE XIII.

[Note.—*All the figures except fig. 1 were drawn by Miss R. Hensman.*]

Fig.

1. General view of canker-spot on one-year-old rods of "black mauls" (*Salix triandra*, L.) Drawn by Miss J. Hensman.

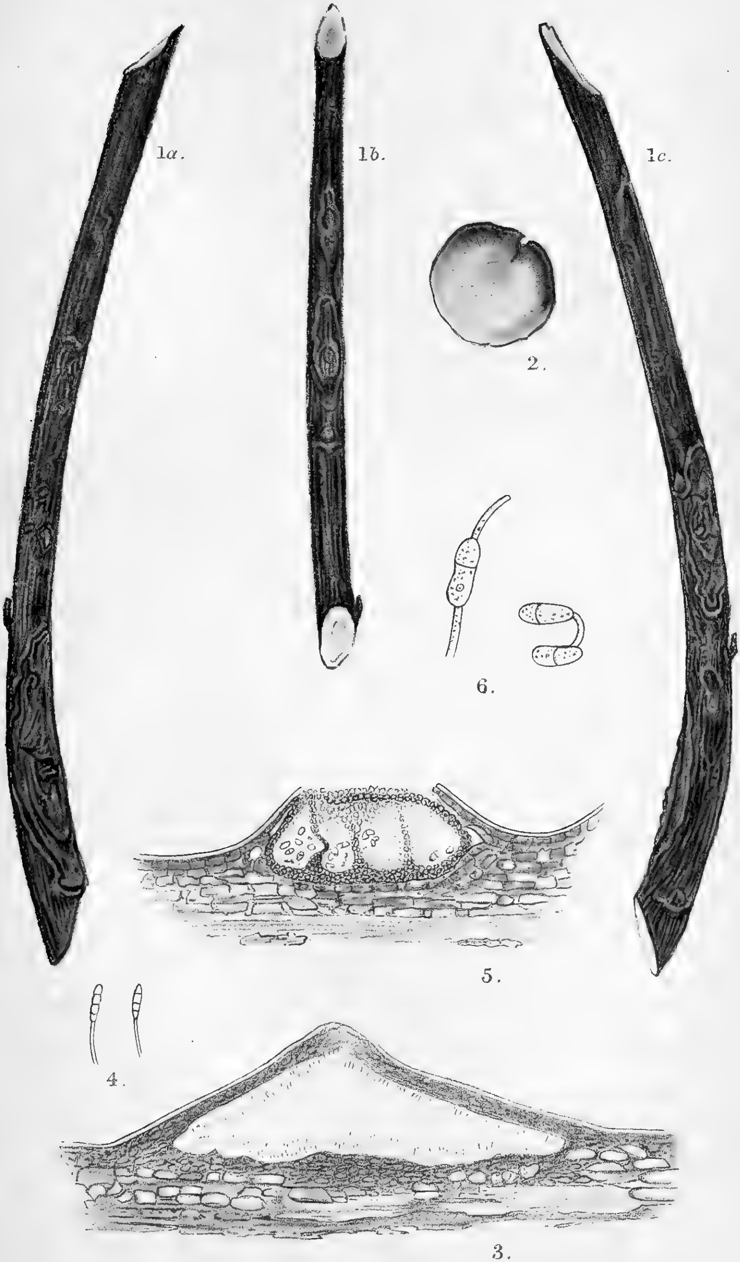
2. Cross-section of one-year-old rod, showing extent of canker destruction of tissues. Slightly magnified.

3. Section of pycnidium of *Tetradia salicicola*. × 100.

4. Triseptate conidia of Tetradia, with uniseptate conidiophore. × 440.

5. Section through a group of pycnidia of *Macrodendrophoma* in a canker. × 100.

6. Isolated bisporous conidia of same. × 440.



M'Farlane & Erskine, Lith Edinr.

EXPLANATION OF PLATE XIV.

PLATE XIV.

[NOTE.—*All the figures were drawn by Miss R. Hensman.*]

FIG.

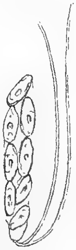
1. Section of canker showing perithecia of *Physalospora gregaria*, Sacc. × 100.

2. Section through ripe perithecium of *Physalospora gregaria*, Sacc. × 440.

3. Isolated ascus, with paraphyses of same. × 500.

4. Canker-spot, surface-view, showing skin of rod splitting and peeling away. × 10.

1.



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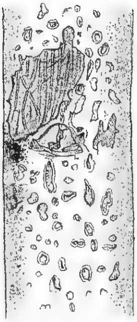

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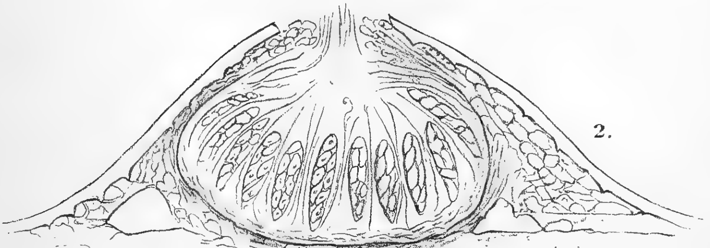

2.

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EXPLANATION OF PLATE XV.

PLATE XV.

Fig.

1. Invagination of pycnidium. Microphotograph. × 80.

2. Photographic illustration of set and rods. See text, p. 154.

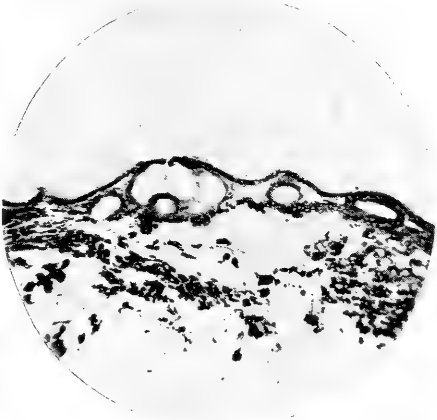

FIG. 1.

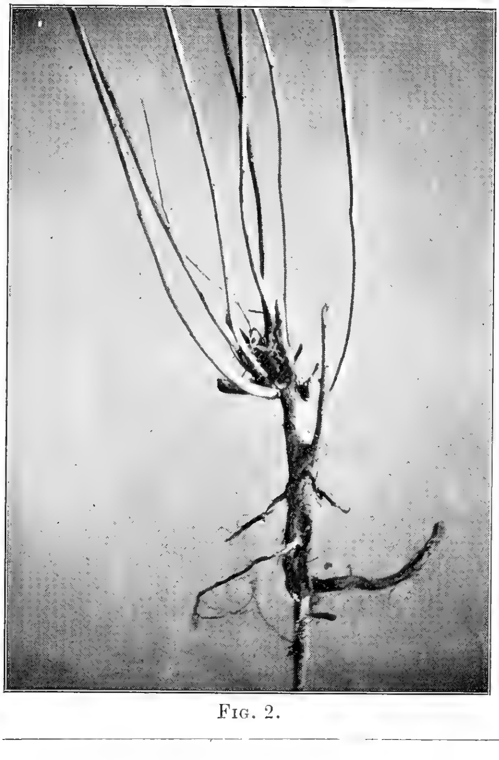

FIG. 2.

XVIII.

THE COMPARISON OF CAPACITIES IN ELECTRICAL WORK: AN APPLICATION OF RADIO-ACTIVE SUBSTANCES.

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[Read, January 19; Received for Publication, January 22;
Published, February 26, 1904.]

There are many methods by which two capacities may be compared, and which are fully described in text-books of Physics.

When only approximate results are required, we have several methods to choose from, any of which will give a fair result; but the problem is by no means so simple when an accurate determination is required, especially if we are dealing with a very small capacity. That better methods of dealing with the determination of capacities, especially small capacities, are still required may be judged from the fact that two papers have recently appeared on the subject, one by Professor Fleming and Mr. Clinton in the Phil. Mag., May, 1903, and the other by Professor Stroud and Mr. Oates in the Phil. Mag., December, 1903.

Those two papers may be taken as affording examples of the difficulty of obtaining accurate results in this work, both methods necessitating somewhat elaborate apparatus, and involving considerable experimental difficulties.

My object in this paper is to describe a method at once simple and accurate, and suitable for the determination of capacities of any magnitude down to a few micro-microfarads, or even less. The method is based on the fact that the ionisation current that can be obtained by the use of a radio-active substance like uranium is *extremely constant*, and can be made so small that the time taken to charge a condenser by it can be accurately measured. This small constant current is used first to charge one condenser to a given potential; and then a second condenser is charged to the same potential, and the time taken in the two cases observed, so that we get the ratio of two capacities by simply observing two intervals of time.

The method will probably have occurred to anyone who has been using radio-active substances; but as many workers have occasion to compare capacities accurately who are not using radio-active substances, I have thought it advisable to make a few experiments showing the accuracy of the method, and showing also how small a capacity can be detected and measured by it.

To use the method it is not necessary to have a supply of radium, as the title of the paper might suggest; uranium is even better in some respects, and uranium is to be found in every laboratory.

Description of Apparatus and Method of Working.

A and *B* are two insulated metal plates, one of which, *B*, can be joined to one terminal of a battery of small storage-cells, the other terminal of which is to earth. The battery may consist of 100 or more small test-tube cells, so that *B* can be kept at 200 volts or higher.

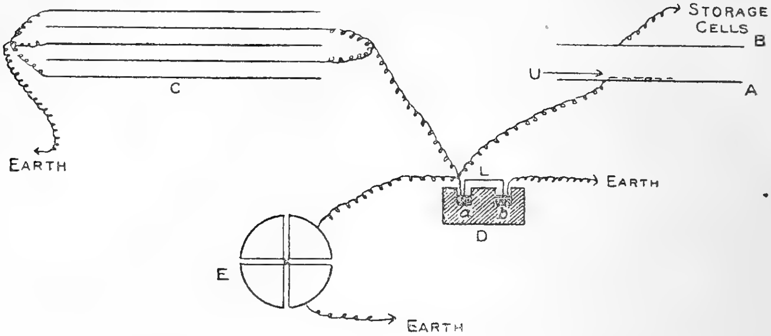

Fig. 1.

A few grammes of, say, uranium nitrate are spread on a sheet of paper, and placed on the plate *A*. The radiation from the uranium ionises the air between *A* and *B*; and so *A* gradually rises in potential if insulated, supposing *B* to be positive. As is well known, the ionisation current thus obtained between two plates increases at first as the potential difference between the plates increases; but when this potential difference is made sufficiently great, the current attains a maximum, and does not further increase for further increase of potential difference between the plates. If then B is kept at a sufficiently high potential, small changes in this potential, due to the potential of the battery falling, will produce no effect; and, again, in making an observation, the potential of A need never change by more than one volt, so that there is no trouble in keeping a constant current to the plate A. The constancy of the current in the above arrangement only depends on the constancy of the radiation from the uranium; and numbers will be given to show how very constant this radiation is. The potential difference required to produce the maximum current to A will depend on the distance between A and B; but it is well to have 200 volts available.

C represents one of the condensers being compared; and E is a quadrant electrometer. D is an insulating block of paraffin, containing two mercury cups, a and b, one of which is connected to earth. A connecting piece L is shown, joining the mercury cups, and, by means of a string arrangement, L can be lifted out of the mercury cups and lowered again as desired, from a distance, so as to avoid induction effects produced by movements of the observer.

As soon as L is lifted out of the mercury cups, the plate A, the condenser C, and the electrometer begin to charge up; and the time is observed during which the spot of light moves over, say, 100 scale-divisions. An exactly similar experiment is done with a second condenser C' in the place of C. If the intervals of time are respectively t and t', we have

$$\frac{C + c}{C' + c} = \frac{t}{t'},$$

where c is the capacity of the electrometer, the condenser AB and the connecting wires. The capacity c can be determined in terms of, say, C, by taking an observation with C joined up as shown, and then an observation with C disconnected, so that only c is charged; or the capacity c may be determined once for all by comparing it in this way with a known capacity. We thus get the ratio C/C'.

ACCURACY OF THE METHOD.

The accuracy of the method obviously depends simply on the constancy of the ionisation current, and on the accuracy with which the time-intervals are measured. Numbers are given below to show how very constant the ionisation current is. In practice it is well to screen the space between the plates *A* and *B* from air currents, as such currents, if strong, may blow away the ionised air, and diminish the ionisation current. As regards the radio-active substance used, uranium is preferable to thorium or radium, as it gives off no emanation. If radium or thorium is used, it should be in a closed vessel to prevent the emanation from escaping, otherwise the ionisation current will not be steady.

The method involves the use of a quadrant electrometer, which to some may appear an objection to the method. The writer's experience, however, is that no sensitive scientific instrument gives less trouble in working than a quadrant electrometer, when it has once been put in good order. When the capacities being compared are small, no great sensitiveness of the electrometer will be required — say 60 millimetre scale-divisions for one volt with scale one metre from electrometer. When large capacities are being compared, greater sensitiveness will be necessary, unless a very large quantity of uranium is used; but there is no trouble in having an instrument one hundred times as sensitive as above.

SOME EXPERIMENTS WITH THIS METHOD.

(*a*) We shall first give some numbers to show the constancy of the ionisation current in the above arrangement, and the accuracy with which the time required to charge any system through a given range of potential can be measured. The system charged consisted of the electrometer, a capacity marked ·001 microfarads, and the condenser formed of the plates between which the uranium is placed.

The time taken for the spot of light to move over fifty scale-divisions was taken with a stop-watch reading to fifths of a second. A series of seven observations was made, giving the following numbers, no observation being rejected.

Time taken to move over 50 scale-divisions :—

99·2 seconds.
99·5 „
99·0 „
99·4 „
99·2 „
99·2 „
99·1 „

Mean, 99·23 seconds.

The agreement between these numbers is no better than that usually observed in other experiments; in fact, not as good as in many other cases.

(*b*) We shall now give the numbers observed in a comparison of a condenser with a standard condenser, marked ·001 microforad. We shall denote the capacity of the condenser to be measured by C, and the capacity of the electrometer and other parts of the system, by c.

The electrometer in this experiment gave a deflection of about 60 scale-divisions for 1 volt, and about 30 grams of uranium nitrate were placed on the central part of the plate A; observations were taken alternately with the capacity C joined up to c, and with the capacity ·001 microfarad joined up to c, giving results as follows :—

$\cdot 001 + c$	$C + c$
50 divisions in 52·6″	
	50 divisions in 89·5″
50 divisions in 52·5″	
	50 divisions in 88·7″
50 divisions in 52·2″	
Mean, 52·43″	Mean, 89·1″

Therefore,

$$\frac{C + c}{\cdot 001 + c} = \frac{8910}{5243}.$$

A smaller quantity of uranium was then used to determine the ratio between c and ·001 microfarad, as with the quantity used above the movement of the spot of light would have been too rapid when only the capacity c is in use. The following are the numbers in this determination:—

$c + \cdot 001$	c
50 divisions in 75·8″	100 divisions in 21·9″
50 divisions in 75·7″	100 divisions in 21·8″
	100 divisions in 22·2″
Mean, 75·75″	Mean, 21·97″

Therefore, $$\frac{c + \cdot 001}{c} = \frac{15150}{2197}.$$

These equations give

$$c = \cdot 000169 \text{ microfarad};$$
$$C = \cdot 001817 \text{ microfarad}.$$

To give somewhat of a test of the reliability of the method, the same capacity was determined on another occasion, taking no care to use the same quantity of uranium, and, in fact, having very different ionisation currents from those used in the first case. The following numbers were obtained, only one observation being taken in each case:—

$C + c$	$\cdot 001 + c$
50 divisions in 48·2″	50 divisions in 28·6″
$c + \cdot 001$	
50 divisions in 56·5″	100 divisions in 16·5″

Calculating as before, we get

$$c = \cdot 000170 \text{ microfarad};$$
$$C = \cdot 001802 \text{ microfarad}.$$

The agreement with the preceding numbers is very good, especially when we consider that only one observation was taken in each case.

(*c*) To show that this method is suitable for much larger capacities than those used in the preceding examples, we shall give an example in which a capacity known to be about ·5 microfarad was determined by comparing it with a standard capacity of ·1 microfarad. For this purpose, an electrometer of the

Dolezalek type was used, giving a deflection equal to 5300 scale-divisions for 1 volt.

Observations were taken as before, first with the unknown capacity C joined up to the electrometer and the plate A, and then with the capacity ·1 microfarad joined up.

About 100 grams of uranium nitrate were placed on A (fig. 1), and the following numbers noted; c denotes the capacity of the Dolezalek electrometer, and some apparatus that was in connexion with it:—

$C + c$	$\cdot 1 + c$
50 divisions in 104·5″	100 divisions in 41·8″
50 divisions in 104·4″	100 divisions in 41·8″
Mean, 104·45″	Mean, 41·8″

Therefore,
$$\frac{C + c}{\cdot 1 + c} = \frac{208{\cdot}9}{41{\cdot}8}.$$

Less than 1 gram of uranium nitrate was now used to determine the ratio of c to a known capacity of ·001 microfarad, giving as follows:—

c	$c + \cdot 001$
100 divisions in 21·0″	100 divisions in 30·5″
100 divisions in 21·2″	100 divisions in 30·0″

Therefore,
$$\frac{c + \cdot 001}{c} = \frac{605}{422}.$$

These equations give

$$c = \cdot 0023 \text{ microfarad};$$
$$C = \cdot 5089 \text{ microfarad}.$$

A repetition of this determination gave as before, with smaller capacities, an equally consistent result.

(*d*) A careful experiment was now made to find how small a capacity could be detected and measured by this method.

To do this a condenser of the following type (fig. 2) was arranged:—

AB is a long wide tube, 7·90 cms. internal diameter; ab is another tube fixed, as shown, to be coaxial with AB. In ab a third cylinder cd slides, fitting closely into ab, the external diameter of cd being 1·94 cms. AB is joined to earth, and ab (and cd)

connected to the Kelvin electrometer. The capacity of the electrometer, the condenser as arranged (fig. 2), and joining wires is determined by comparing it with a standard capacity of ·001 microfarad.

A careful series of observations is then taken, with *cd* in its above position, using a suitable quantity of uranium nitrate.

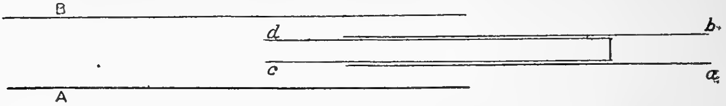

Fig. 2.

Then the tube *cd* is moved 8·01 cms. further into *AB*, care being taken not to displace *AB* or *ab*. A vernier was attached to *cd* working in a slot in *ab*, so that the distance through which *cd* was displaced could be accurately measured. A second series of observations was then made with *cd* in the new position, keeping the same uranium as before. We have thus the data for deducing from the experiments the increase of capacity produced by the movement of *cd*. This increase of capacity can also be accurately calculated from the formula

$$\frac{l}{2 \log \frac{r_1}{r_2}},$$

since the effects of the ends are eliminated by the arrangement used, l being the distance *cd* is moved, and r_1 and r_2 the radii of *AB* and *cd* respectively. We can thus estimate the value of the method for measuring very small capacities.

The numbers observed were as follows :—

(1) Finding the capacity C made up of the condenser described (fig. 2), the electrometer, and connections,

C	$\cdot001 + C$
100 divisions in 39·7″	50 divisions in 117·8″
100 divisions in 39·6″	50 divisions in 118·1″
100 divisions in 39·5″	50 divisions in 117·8″
Mean, 39·6″	Mean, 117·9″

Therefore, $$\frac{C + \cdot001}{C} = \frac{235\cdot8}{39\cdot6};$$

or, $C = \cdot000201$ microfarad;

or, $C = 201$ micro-microfarads.

(2) To find the small change in capacity a when cd has been moved into its second position.

In first position :—

100 divisions in $59{\cdot}0''$
100 divisions in $59{\cdot}5''$
100 divisions in $59{\cdot}1''$
Mean, $59{\cdot}20''$

In second position :—

100 divisions in $60{\cdot}5''$
100 divisions in $59{\cdot}8''$
100 divisions in $60{\cdot}0''$
Mean, $60{\cdot}10''$

Therefore,

$$\frac{C+a}{C} = \frac{60{\cdot}1}{59{\cdot}2},$$

and

$$C = 201 \text{ micro-microfarads};$$

$$\therefore \quad a = 3{\cdot}05 \text{ micro-microfarads}.$$

Calculating a from the formula

$$a = \frac{l}{2 \log \frac{r_1}{r_2}},$$

where

$l = 8{\cdot}01$ cms.,
$r_1 = 3{\cdot}95$ cms.,
$r_2 = {\cdot}97$ cm.,

we get

$$a = 2{\cdot}85 \text{ electrostatic units}$$
$$= 3{\cdot}16 \text{ micro-microfarads}.$$

We get, therefore, 3·16 by calculation,
and 3·05 by experiment.

The method is therefore quite capable of detecting and measuring with considerable accuracy a capacity of 1 micro-microfarad or even less.

DISCUSSION OF THE ADVANTAGES OF THE METHOD.

It is not necessary to compare this method in detail with the many other methods used in comparing capacities; it will be sufficient to point out a few leading facts.

Capacities may, of course, be compared by the electrometer without any use of radio-active substances by charging the unknown capacity to a potential which is measured by the electrometer, and then sharing the charge with a known capacity, and again measuring the potential. The method of working is not, however, as accurate as that described above, especially when the capacities are small.

Capacities are often compared by charging them to the same potential, and discharging them through a ballistic galvanometer. The galvanometer deflection must be accurately read, and a correction applied for damping—observations which cannot be made with the accuracy with which we can compare two intervals of time. Again, when the capacities are small, they must be charged or discharged through the galvanometer a great number of times per second, which requires carefully constructed apparatus to enable the number of charges to be accurately known. In addition, it is somewhat difficult to be certain that the apparatus is working properly; for example, an error might arise through faulty insulation, and escape detection.

The method of De Sauty is free from many of the objections mentioned above; but others might be urged against it, and especially that it can be of little use when the capacities are very small.

One of the chief advantages of the method described in this paper is that, from the nature of the apparatus used, it is scarcely possible for any serious source of error to come in without detection; a faulty insulation, for example, can easily be guarded against. The only quantity requiring to be measured is an interval of time, which can be done with great accuracy. The ionisation produced by the uranium keeps very constant throughout the time required to make a determination; and there is no other quantity that requires to be kept very constant. The potential of the battery joined to one of the plates between which the uranium is placed may vary considerably between the observations, and produce no effect, provided the potential is sufficiently great.

The only objection that seems likely to be made to the method is the fact that it employs a quadrant electrometer, the use of which in ordinary laboratory work has hitherto been discouraged. As stated above, the writer sees no reason for the reluctance to use electrometers when their use can be avoided by means of galvanometers and other, sometimes complicated, apparatus. Some of the lines of research in recent years have necessitated an extensive use of quadrant electrometers, with the natural result that they have been greatly improved; and whatever reasons there may formerly have been for avoiding the use of electrometers, these reasons have now entirely disappeared.

XIX.

PRELIMINARY NOTE ON THE ACTION OF THE RADIATIONS FROM RADIUM BROMIDE ON SOME ORGANISMS.

By HENRY H. DIXON, Sc.D., Assistant to the Professor of Botany, University of Dublin; and J. T. WIGHAM, M.D., Assistant to the Lecturer in Pathology in Trinity College, Dublin.

(Plates XVI.-XVIII.)

[Read, December 15; Received for Publication, December 18, 1903; Published, March 12, 1904.]

Last autumn one of us began experimenting on the effect of these radiations on plants. The experiments were made on seedlings of *Lepidium sativum* and on *Volvox globator*. They were planned so as to find out if the radiations would act as a stimulus to evoke growth-curvatures, or if they would exert a directive action on the motion of a motile organism. At the same time, abnormal and pathological effects were looked for.

The experiments carried out on the seedlings were as follows:—

Experiment I.—100 seeds of *Lepidium sativum* were uniformly distributed over an even surface of moist quartz sand. After germination had taken place and the radicles were just visible, a sealed glass tube containing 5 mgrs. of radium bromide was set over the central seed at a distance of 1 cm. from it. In order to remove the disturbing effects of uneven illumination, and to render the seedlings as sensitive as possible to the radiations, they were kept in the dark, except for the feeble light emitted by the radium bromide itself.

Thus arranged, if the seedlings were positively *radiotropic—i.e.* tended to turn to the source of the radiations—the central plants would grow vertically upwards, while those nearer the periphery of the sand would incline towards the centre. If, on the other hand, they were negatively radiotropic, they would all be deflected from the radium-tube to a greater or less degree, according to the vigour of the response.

At the end of a few days the seedlings had grown up round the tube, but no curvatures were apparent. The seedlings, however, within about 1 cm. radius, were slightly less grown than their fellows; but this difference was by no means marked, nor did they appear unhealthy or in any way abnormal. At the end of ten days, the difference in height of the seedlings close to the radium, and of those further removed, was more noticeable; and while the average height of the peripheral plants was 51 mm., that of those within the 1 cm. radius was 44 mm.

The radium-tube was then removed, and the seedlings exposed to daylight. The central plants still remained behind the others in point of growth for the few days during which their development was watched.

Experiment II.—Seeds similarly treated and similarly exposed to the radiations showed, three days after germination, the same slight retardation of growth. In this case it was noticed that the number and development of the root-hairs of the retarded seedlings were considerably inferior to those of the others. But otherwise the retarded individuals seemed healthy. Microscopic examination of their cells did not reveal any perceptible difference from those of the unretarded plants.

Experiment III.—In order that the radiations might act on the seeds throughout germination, dry seeds were distributed over moist sand. The radium-tube was supported so that only the thickness of the glass (about 0·5 mm.) intervened between it and the test of the central seed. Notwithstanding this close proximity, the central seed and its fellows had protruded their radicles on the second day after sowing. As before, a slight retardation of growth was observed in the subsequent development of the central seedlings, but no injuries could be made out. Further, there were no curvatures induced by the radiations.

In order to test a motile organism for radiotropic response, *Volvox globator* was selected as suitable material. Several hundreds of this colonial protococcoid were used in the experiment. A test by illumination with feeble daylight showed that the material was positively photoscopic. The colonies were then enclosed along with the radium-tube in a test-tube quite filled with richly oxygenated water, taking care to include no visible air-bubbles with it. By this precaution the chemiotropic influence of air-bubbles was avoided, while the organisms were not rendered insensitive through a lack of oxygen. As in the case of the seedlings, the *Volvox* colonies were screened from the action of light other than that emanating from the radium-tube. The test-tube containing the colonies was supported horizontally during the experiment.

After twenty-four hours the distribution of the *Volvox* colonies was observed; but no special arrangement due to the action of the radiations was perceptible. Most of the colonies had sunk on to the lower side of the test-tube, but were neither aggregated under the radium-tube nor repelled from it; while the numerous colonies which still remained swimming freely about showed complete indifference as to their proximity to or their remoteness from the radium-tube. These free-swimming colonies were evenly distributed throughout the body of the liquid and over the walls of the test-tube, and some even were in contact with the glass of the radium-tube.

These experiments apparently indicate that the radiations from the radium bromide were not able markedly to interfere with the metabolism of the cells experimented with; nor did they evoke any perceptible response by acting as a stimulus on the protoplasm of light-sensitive cells. It is, of course, possible that by using larger quantities of radium bromide more marked results might be obtained.

Our joint experiments have up to the present been carried out on four species of bacteria, viz., *Bacillus pyocyaneus*, *B. prodigiosus*, *B. typhosus*, and *B. anthracis*. They confirm, on the whole, the observations of other investigators.

In our experiments the bacteria were grown in agar culture-medium, supported on glass or mica plates. The bacteria were either smeared on its surface or diffused through it as an emulsion.

We found in each case that bacteria exposed to the radiations, and at no great distance from the tube, were inhibited in their development, and in some cases were perhaps killed.

A few preliminary experiments showed that inhibition of growth only occurred when the bacteria were within about 15 mm. of the radium bromide, and that the inhibitory radiations were stopped by a film of agar spread on a glass plate. We subsequently arranged our experiments so that the cultures to be exposed to the radium bromide were, at one point at least, less than this distance from the radium, and only separated from it by the glass of the containing tube and a small thickness of air.

The figures in the accompanying Plates are reproductions of contact photographs of agar-plate-cultures which had been exposed in this manner.

Fig. 1, Plate XVI., is a photograph of an emulsion of *B. pyocyaneus* spread on a glass plate. This culture was exposed to the radiations from the radium bromide at a distance of 10 mm. from the tube for four days, the tube being supported on a tiny wire stand over the central region of the plate. During these days the bacteria did not develop, as the temperature was low. On the fifth day the culture, still exposed to the radium-tube, was transferred to an oven at 22° C., and incubated for three days, when the photograph was taken. The central region, which was closest to the radium, may be seen bare of colonies; while the bacteria in those parts which were more than 15 mm. removed from it have developed normally.

Fig. 2, Plate XVI., is from a similar but denser emulsion of *B. pyocyaneus.* This culture was exposed for four days in the cold to the radiations at a distance of 7 mm. from the radium bromide. After incubation for two days at 22° C. the photograph was taken. The sterile region is here also very well marked. The line of denser growth seen below the clear patch in the figure is due to the screening action of a platinum rod 3 mm. in diameter, which was supported between the radium-tube and the culture. In a photograph taken the day before (not reproduced here), the sterile patch was of greater extent than appears in this figure, and the line of dense growth stood out prominently across the greater part of the plate. The delay in development of the colonies on the margin of the sterile patch is of interest in showing that the radiations may act as a retarding influence on growth, even where they cannot inhibit it altogether.

After the photograph which is reproduced in fig. 2 was taken, the radium was removed from the culture, and the culture-plate was transferred to an oven at 37° C. Figs. 1 and 2, Plate XVII., reproduce photographs which were taken after incubation at this temperature for two and six days respectively. It may be noted that the bacteria did not further encroach on the sterile patch during this and subsequent incubation, although the radium was no longer exercising any direct action on the culture.

Fig. 1, Plate XVIII., shows a smear-culture of *B. prodigiosus.* It was exposed to the radiations for one day at a distance of 4·5 mm. from the radium bromide, and was subsequently incubated in the absence of the radium for two days at 22° C. This culture, even during the day of exposure, had perceptibly developed. The margin of the sterile patch is peculiarly sharply defined. The colonies on the margin developed but little pigment; while those some few millimetres removed from the patch produced colouring matter very abundantly, as though the more feeble action of the radiations acting at a greater distance stimulated the development of the pigment.

These experiments amply illustrate the inhibitory action of the radiations from radium bromide; and it is needless to quote others, many of which were made on similar lines on these same bacteria and also on *B. anthracis* and on *B. typhosus.* They all gave similar results.

It next became of interest to know whether the organisms were actually killed in the sterile patches caused by the radiations, or if their development was arrested only. The fact that, even after the removal of the radium, colonies did not develop in the sterile patch, would seem to indicate either that the action of the radiations on the bacteria had rendered them incapable of development—*i.e.* killed them—or that some change had taken place in the medium, rendering it unfit for their development.

To test this point, inoculations were made from each of the sterile patches, either into broth-tubes or on to agar-plates. In almost every case the development of the inoculation showed that all the organisms at least in the patch were not killed, and that the action of the radiations was, in some cases at least, only inhibitory, while a change in the medium was probably responsible for the subsequent failure of development.

The latter deduction—viz., that the medium had undergone some change which had rendered it unfit for the development of the bacteria—is borne out by the fact that fresh bacteria inoculated into the sterile patch also failed to develop. Fig. 2, Plate XVII., illustrates this point. In the centre of the sterile patch may be seen a faint cross. It is the mechanical trace of an unsuccessful inoculation by means of a platinum needle. The photograph was taken two days after inoculation, during which time the culture was incubated at 37° C. The inoculation, however, failed to develop. This, and similar experiments, showed that the medium had become unsuited to the development of bacteria.

We have made some observations to determine whether this unsuitability is brought about by the action of the radiations, or by the diffusion of substances from or into the culture outside.

There are evidently two ways in which this question may be approached. (1) Will a plate devoid of bacteria become unsuitable for bacterial development where exposed to the radiations? (2) Will diffusion from or into a culture surrounding a sterile patch (not sterilized by the radiations) render it unsuited for the growth of bacteria?

Our results obtained while endeavouring to solve the question in the former of these two ways indicate that the unsuitability of the medium in the sterile patch is not directly due to the radiations. In these experiments plates were exposed to the radiations for from three to four days, and then inoculated by smearing their surface with an emulsion of bacteria. In each case the culture developed all over the plate, and showed no sterile patch comparable to that produced when the culture itself is exposed. But these experiments were rendered somewhat inconclusive from the fact that some unexposed medium was introduced with the inoculation, and consequently must be repeated without this possible source of error.

In order to test if diffusion from or into the surrounding culture would render the sterile area unfit for growth, we carried out several experiments in the following manner:—Emulsions of bacteria were poured out on glass plates. When the agar had set, circular patches, 15 mm. in diameter, were removed by pressing the rim of a sterilized test-tube into the agar. The patch thus removed was replaced by melted agar containing no bacteria, and so an uninoculated patch was obtained, surrounded by a culture containing developing bacteria. After incubation for three or four days the sterile patch was inoculated. Development of the inoculation did not take place when time was given for diffusion to take place between the patch and the surrounding culture. Fig. 2, Plate XVIII., is a reproduction of a photograph of a plate obtained in the way just described. The photograph was taken three days after the inoculation of the patch.

In several of the thicker cultures it was noticed that, while the growth of the culture was inhibited at the surface next to the radium-tube, colonies more deeply embedded in the medium ultimately developed. In order to obtain more precise information, as to whether this immunity towards the radiations was due to the screening action of the medium, or to the anaerobic conditions obtaining in the deeper parts of the cultures, we exposed other cultures to the radiations under completely anaerobic conditions.

The arrest of growth also takes place in cultures exposed anaerobically. We have found this to be the case with *B. anthracis*, *B. pyocyaneus* and *B. typhosus*. It consequently follows that the inhibition is neither due to the ionisation of the air nor to the production of ozone by the radium. Unfortunately in making this experiment our radium bromide met with a mishap. To fit it conveniently into the hydrogen chamber, it had to be transferred from its tube into a cell, formed by a perforated micro-slip covered above and below by a thin plate of mica sealed on by Canada balsam. For some reason, probably owing to the absorption of the remnants of oxygen in the anaerobic chamber by the alkaline pyrogallol, the pressure inside the little cell burst open its covers, and moisture got in. However, when the culture-plates were examined, after three days' growth in the anaerobic chamber, sterile patches were found in each of the cultures mentioned above. The cultures of *B. pyocyaneus* and *B. typhosus* were within 3 mm. of the radium-tube, while the anthrax culture was at a distance of 6 mm. The culture of the *B. pyocyaneus* and the mica plate which supported it also intervened between the radium-tube and the anthrax. In spite of this, its culture showed perceptible inhibition in its central region. A culture of *B. prodigiosus*, also at 6 mm distance, and with the typhoid culture and its mica plate intervening, showed no sterilization effects due to the radiations. It is uncertain in this experiment how long the radiations were allowed to act before the radium salt became moist.

In considering which of the radiations emitted by the radium bromide were responsible for the inhibitory effects observed in these experiments, it is evident that we may leave out of account the α radiations. It has been shown that they are stopped by the glass of the containing tube, and consequently do not act on either the organisms or on the matter. Neither is the feeble phosphorescent light emitted by the radium bromide responsible for the inhibition ; for we found that the radiations from the tube were effective in arresting growth after passing through a screen of platinum foil 0·04 mm. thick.

It follows that in our experiments it must have been the β or γ radiations, or both, which produced the effects observed. It does not seem probable that the γ radiations by themselves were very effective, since, being very penetrating, they can scarcely be supposed to have been absorbed by a thickness of 30 mm. of air; beyond this distance from the radium, the radiations were apparently ineffective.

Physicists have shown that the β radiations are electric charges of negative sign moving at an immense velocity. It appears undecided whether they are associated with matter or not. If they are, the mass of each corpuscle carrying the negative charge cannot be greater than the one-thousandth part of an atom of hydrogen. The charge carried by the electrons, or corpuscles, as they are called, is equal to the available charge on a monad ion. The γ radiations are not themselves negative electrons, but may cause bodies exposed to them to give off electrons.

In our experiments the negative electrons emitted directly from, or produced indirectly by, the radium bromide were in part absorbed by the bacterial cultures. In this process it seems natural to assume that they attach themselves to the positive ions of the cultures, and amongst others to the $H^{\cdot}$ of the water within the bacteria. In this way OH' ions would be set free. In other words, the water in the protoplasm would become alkaline. The alkalinity would check the action of the enzymes, on which the metabolism of the cells depends; for it is known that the action of all enzymes, with the exception of trypsin, is inhibited in an alkaline solution. This working hypothesis seems to fall in with the observations we have been able to make up to the present. While exposed to the vigorous bombardment of the electrons, it would be impossible for the cells to secure suitable conditions for the efficiency of their enzymes; whereas, when transferred outside their range, the alkalinity might be neutralized and metabolism recommenced. Where the intensity of the bombardment was feeble, diminution of the activity of the enzymes would ensue, causing retardation of growth, as has been observed on the margin of the sterile patches.

If, as this speculation demands, there is a production of OH' ions in the media exposed to the action of the radiations coming from the radium-tube, we ought to be able, by the use of indicators, to detect their presence. It might be thought that, the mass of the electrons being so hopelessly small, it would be impossible to detect their presence by chemical means. But it must be remembered that, according to theory, each electron is capable of neutralizing a positive ion, and at the same time of setting free a negative one.

As might be expected, all indicators are not equally suitable for this detection. Thus no indication of the presence of OH' ions could be detected when litmus or methyl orange was exposed to the radiations. This is probably owing to the fact that these indicators are themselves strongly ionized in aqueous solution. With phenolphthalein, which is scarcely ionized at all, the case is different; and we might expect the colour change when the OH' ions were liberated by the neutralization of the $H^{\cdot}$ ions by the negative electrons.

With this indicator our expectations appear to have been realized; and in several instances we have found, after exposure to the radiations for one or two days, the development of a feeble pink colour in an agar medium, through which previously colourless phenolphthalein was diffused. This is the more satisfactory as the amount of radium bromide available for these experiments was very small, much of the original quantity being lost in the accident before alluded to. The agar in these experiments was spread on mica plates, which were enclosed in a space deprived of CO_2 by the presence of a strong solution of caustic potash. Control experiments on the same plates, in the same chamber, but not exposed to the radium radiations, did not give any coloration.

We must remember, however, that the coloration may be due to the direct ionization of the indicator, as well as that of the water.

It is possible that with a feeble basic indicator more marked results would be obtained.[1]

In connexion with the hypothesis just described, it will be interesting to compare the action of diastase on starch, and that of trypsin on gelatin when exposed to the influence of the radiations.

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[1] [NOTE ADDED IN PRESS.—The experiment was carried out as follows:—On a mica plate, supported over a surface of caustic potash in solution, some neutral agar containing phenolphthalein was spread. The radium was supported over the agar, and at a distance of 1 mm. above it; and the whole was shut in from the surrounding atmosphere in a receiver. At the end of twenty-four hours the phenolphthalein had become pink. The receiver was then opened, and the indicator decolorized by contact with the air. When it had become colourless, it was again shut up. On the following day, it had become pink a second time. The receiver was again opened, and the phenolphthalein decolorised. Before closing for the third time, the radium was removed. The pink coloration now failed to re-appear.

Although the experiment seemed at the time quite conclusive, on repeating it subsequently with variations, it has been found that a neutral solution of phenolphthalein, either in pure water or in agar, though not exposed to radium, becomes pink when supported over a solution of caustic potash in a closed chamber. The indicator in this case, too, may be decolorised and coloured again three or four times; but it finally loses its power of regaining colour, although under the same conditions which previously caused it to become pink. This unexpected behaviour of the indicator renders the detection of the electrons by its means very uncertain.]

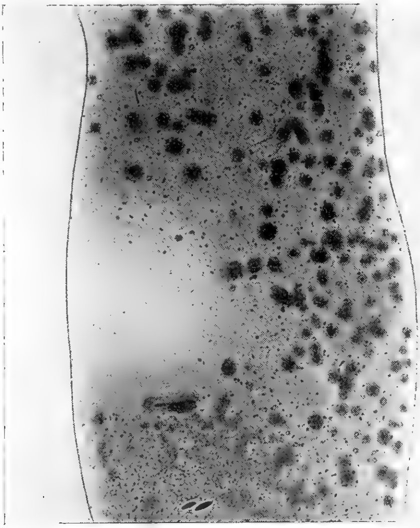
EXPLANATION OF PLATE XVI.

PLATE XVI.

Fig.

1. Plate culture of *Bacillus pyocyaneus*, exposed in the cold for four days to the tube containing 5 mgrs. of radium bromide, distant 10 mm., and incubated in presence of the radium for three days at 22° C.

2. Plate culture of *B. pyocyaneus*, exposed four days in cold to the same sample of radium, distant 7 mm., and incubated two days at 22° C. The dark horizontal line, just below the clear central patch, is the expression of the denser growth of the colonies in the shadow of a platinum rod which intervened between the culture and the radium.



1.

2.

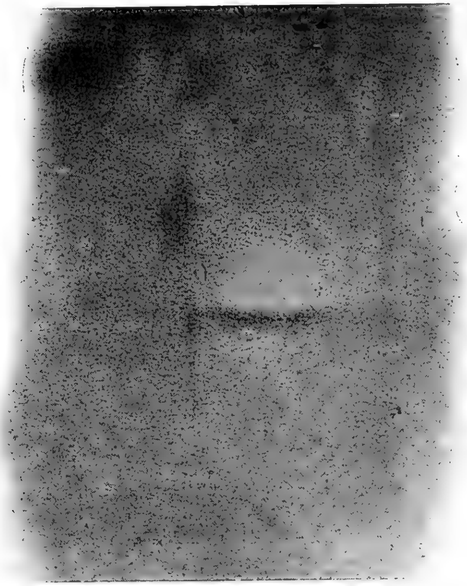
EXPLANATION OF PLATE XVII.

PLATE XVII.

Fig.

1. Photograph of the same plate culture after two days further incubation at 37° C., in absence of the radium.

2. Same plate four days later. During the interval the culture was incubated at 37° C. It may be noticed that the sterile patch has not diminished in size, nor has the inoculation in its centre developed.



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2.

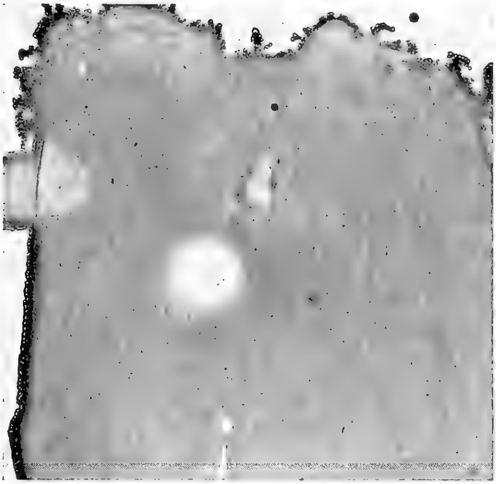
EXPLANATION OF PLATE XVIII.

PLATE XVIII.

Fig.

1. Plate culture of *Bacillus prodigiosus.* The organism was smeared on the surface of the nutrient agar and exposed to the radium at a distance of 4·5 mm. for one day in the cold. The photograph was taken after two days' incubation at 22° C., during which the radium was absent.

2. Plate culture of *Bacillus pyocyaneus.* Before incubation a circular patch was removed from the agar emulsion, and replaced by sterile agar. After incubation for two days at 37° C. the circular patch was inoculated. The inoculation failed to grow, as is shown by this photograph, which was taken three days after inoculation, during which the plate was incubated at 37° C. In the figure the scratch made by the inoculating rod is more evident than on the plate itself. The bacilli did not develop along this scratch.



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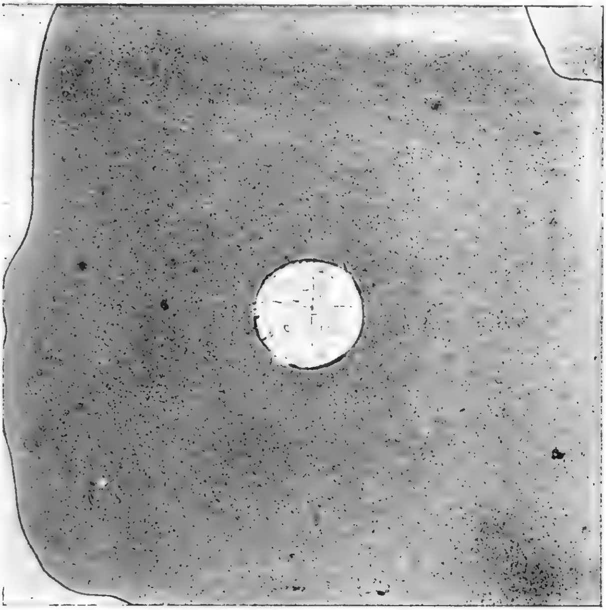


2.

XX.

AN EXPERIMENT ON THE POSSIBLE EFFECT OF HIGH PRESSURE ON THE RADIO-ACTIVITY OF RADIUM.

By W. E. WILSON, D.Sc., F.R.S.

[Read, February 16; Received for Publication, February 19; Published, March 9, 1904.]

If the phenomenon of radio-activity is due to chemical changes in such substances as radium, it seems to me to be worth trying if high pressure would in any way reduce the rate of change which is supposed to be taking place in them. We know that pressure modifies, and in some cases arrests, chemical change of the nature of dissociation; and if we found that the changes taking place in the salts of radium were affected by this means, it would go a long way to explain why radium, as now obtained from pitchblende, is radio-active at all. Rutherford estimates the life of radium as about one million years; but pitchblende, from which it is extracted, is found in some of the older geological rocks which must be of far greater antiquity than this, and therefore the question arises, Why is the radio-activity not over long ago? One possible explanation seems to be that the pitchblende when bound up with the pressure of the superincumbent rocks was not radio-active, and that it was only when the pitchblende was quarried and relieved from its rocky prison that it became radio-active.

A small annular brass cell was made to hold five millegrams of radium bromide. The radium salt was embedded in a drop of Canada balsam, along with a small piece of paper coated with barium platino-cyanide. The cell was then covered on both sides with mica attached to the brass by Canada balsam. The balsam was in a thick viscous condition, capable of transmitting the pressure to the enclosed radium salt, while at the same time protecting the salt from the action of water. The cell was then fixed inside against a strong window of quartz in a gun-metal chamber, which was attached by a pipe to a powerful hydraulic pump, which was capable of exerting a pressure of 300 atmospheres. The small screen of barium platino-cyanide could be seen through the quartz window phosphorescing brilliantly. The pressure was then suddenly raised to 300 atmospheres, but not the slightest diminution in the brilliancy of the screen could be detected. The experiment was repeated several times with the same result.

Taking the specific gravity of rock at 2·5, the pressure exerted was equal to that of 3600 feet of rock, which was probably greater than any pressure to which the pitchblende had been subjected since the rocks of Bohemia assumed their present conformation.

From this experiment it seems most probable that the radium has been giving off its energy for untold ages, and the mystery still remains as to the source of the energy. Is it from atomic change, or is it from surrounding space?

I am indebted to Mr. R. J. Moss for assistance in carrying out this experiment.

XXI.

ON THE REACTIVITY OF THE ALKYL IODIDES.

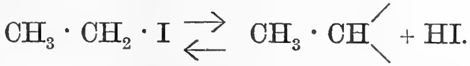
By F. G. DONNAN, M.A., Ph.D.

[Read, February 16; Received for Publication, February 19;
Published, March 30, 1904.]

Where an alkyl iodide and silver nitrate react in the absence of a dissociating solvent such as alcohol or water, the normal formation of an ester occurs: i.e.,

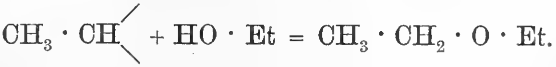
$$RI + AgNO_3 = R \cdot NO_3 + AgI.$$

Thus, as is well known, this reaction can be carried out by allowing solid silver nitrate to act on the alkyl iodide either alone or dissolved in dry ether. When, however, a dissociating solvent such as alcohol is present, the main reaction may take quite another course, the quantity of alkyl nitrate formed becoming in many cases relatively unimportant. As shown by Nef,[1] there is usually a large production of free nitric acid and an ether, some olefine being also found in certain cases. These results are explained by Nef by means of a dissociation-hypothesis, in which intermediate dissociation-products of the alkyl iodide, containing either free carbon valencies or divalent carbon, are supposed to be formed. Nef's hypothesis may be illustrated by a reference to the case of ethyl iodide. The following reactions are supposed to occur:—

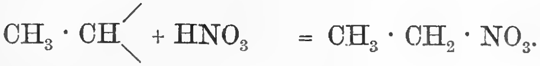
(a) 

$$CH_3 \cdot CH_2 \cdot I \rightleftarrows CH_3 \cdot CH{<} + HI.$$

(b) $$HI + AgNO_3 = AgI + HNO_3.$$

(c) 

$$CH_3 \cdot CH{<} + HO \cdot Et = CH_3 \cdot CH_2 \cdot O \cdot Et.$$

(d) 

$$CH_3 \cdot CH{<} + HNO_3 = CH_3 \cdot CH_2 \cdot NO_3.$$

(e) $$CH_3 \cdot CH_2 \cdot I \rightleftarrows CH_2 = CH_2 + HI.$$

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[1] Lieb. Ann., vol. 309, p. 126.

The production of all the actual products of the reaction, namely, silver iodide, diethyl ether, nitric acid, ethyl nitrate, and ethylene, can be plausibly explained by Nef's dissociation-hypothesis. According to this view, the reactivity of the alkyl iodides in alcoholic solution must be intimately associated with the velocity and extent of this dissociation.

In order to get exact data bearing on this interesting subject, an extended kinetic investigation of the velocity of the above reaction has been carried out by Miss K. A. Burke and the author.[1] The method of experimenting was briefly as follows:—Solutions of silver nitrate and of the alkyl iodide in dry alcohol were made up of the desired concentration and separately warmed in a thermostat. At a given moment the two solutions were mixed, and the resulting solution distributed over a number of small Erlenmeyer flasks contained in the same thermostat. At a given moment, the reaction was stopped in the flasks[2] by running in a measured excess of a solution of ammonium thiocyanate of known strength. It was an easy matter then to determine the amount of dissolved silver nitrate present in any flask at the moment the reaction was stopped, by titrating back the excess of thiocyanate with a standardised silver nitrate solution.

Working with equivalent solutions of alkyl iodide and silver nitrate, and denoting the common equivalent (in this case molecular) concentration by c, the reaction was found to be bimolecular, *i.e.*, it was found in any given case to obey the velocity-equation:—

$$-\frac{dc}{dt} = kc^2.$$

The following example exhibits the constancy of k, the "velocity-coefficient," as calculated from the integral formula,

$$k = \frac{1}{t}\left(\frac{1}{c} - \frac{1}{c_0}\right).$$

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[1] The technical details of this work will be published elsewhere.

[2] The flasks were covered with black paper during the course of the reaction between the alkyl iodide and silver nitrate.

TABLE 1.—CONSTANCY OF BIMOLECULAR VELOCITY-COEFFICIENT.

$\frac{N}{40}$ CH_3I; $\frac{N}{40}$ $AgNO_3$; Solvent, Ethyl Alcohol; Temp. 24·5°.

Time (in minutes).	Concentration of $AgNO_3$.	Value of k.
0	12·90	—
16·24	10·75	95×10^{-5}
35·49	9·05	92×10^{-5}
62·22	7·35	94×10^{-5}
100·62	5·70	97×10^{-5}
129·97	5·05	92×10^{-5}
179·80	4·10	92×10^{-5}

These velocity-coefficients provide us with exact numbers wherewith to compare the relative reactivities of the different alkyl iodides, as measured in alcoholic solution by silver nitrate. The following table gives the values of these coefficients as determined in $\frac{N}{40}$ equivalent molecular solution at 24·5° for the iodides of methyl, ethyl, *n*-propyl, *n*-butyl, isobutyl, and isoamyl in both ethyl and methyl alcohol as solvent.

TABLE 2.—REACTIVITIES OF ALKYL IODIDES, AS MEASURED BY $AgNO_3$ IN ALCOHOLIC SOLUTION.

Iodide.	$k_{EtOH} \times 10^5$	$k_{MeOH} \times 10^5$	k_{MeOH} / k_{EtOH}
Methyl, . .	93·5	180	1·92
Ethyl, . .	220·0	442	2·00
n-Propyl, . .	98·4	226	2·29
n-Butyl, . .	68·6	145	2·11
Isobutyl, . .	13·8	—	—
Isoamyl, . .	56·5	—	—

We see that the reactivity is uniformly about *twice* as great in methyl as in ethyl alcohol. This higher velocity in methyl as compared with ethyl alcohol has been previously observed by Menschutkin, Carrara, and others, and may be connected with the superior dissociating power of the former.

On examining the results obtained in ethyl alcohol, they appear to present a very extraordinary irregularity. If we plot velocity-coefficient against mass of alkyl radical, the nature of this apparent irregularity is at once brought out. Methyl and isobutyl iodides are seen to lie off the "curve," *i.e.*, their reactivities appear to be abnormally low. This result is particularly remarkable in the case of methyl iodide, for in nearly all previous kinetic investigations of the reactivity of the alkyl iodides, methyl iodide has been characterised by a pre-eminently great reactivity; and this behaviour may indeed be said to characterise the lowest member of a homologous series, just as the lowest homologue of a natural family of elements stands out from the others.

The low reactivity in the case of isobutyl iodide need not surprise us, for most of the iodides compared above possess a normal chain. The intimate relation between the structure of the alkyl radical and the reactivity of the iodide is strikingly shown in the case of isopropyl iodide. This substance is not included in the above list, because, owing to its enormous reactivity, it was not possible to determine the velocity-coefficient in $\frac{N}{40}$ solution at 24·5°. By employing $\frac{N}{200}$ - equivalent solutions of isopropyl iodide and silver nitrate, the velocity of the reaction was sufficiently slowed down to permit of accurate measurement. Thus at 17°, the value of k was found to be about 2000×10^{-5}. Considering that the velocity of a chemical reaction is increased two or three times by a rise of temperature of 10°, we may say that isopropyl iodide is at least seventeen times more reactive than ethyl iodide, as measured by silver nitrate.

Unlike the cases of acids and bases (and, to a less degree, salts), it is not in general possible, however, to construct tables of the relative reactivities of neutral organic substances—even of substances of such a simple type as the alkyl iodides—which shall be independent of the reagent and of the particular reaction employed. This is well shown by comparing the above results with those obtained in previous investigations.

In the following table are given the relative reactivities of some alkyl iodides as measured by the velocity of their reaction with sodio-aceto-acetic ester in ethyl alcoholic solution.[1]

TABLE 3.—WISLICENUS' EXPERIMENTS.

Iodide.	Relative Reactivity.
Methyl, ...	196
Ethyl, ...	21
n-Propyl, . . .	5
Isopropyl, . . .	1·9
Isobutyl, . . .	1
Tertiary Butyl, . .	Very small.
Allyl, ...	> 784

These figures show the eminent reactivity of methyl iodide as compared with other saturated aliphatic iodides. Isopropyl iodide is not distinguished by any special reactivity, and falls more or less into line in the curve connecting reactivity with mass of the alkyl group. The enormous reactivity of the unsaturated allyl iodide forms a striking feature of Wislicenus' results.

In 1890 Menschutkin[2] investigated the velocity of combination of the saturated aliphatic iodides with triethylamine in acetone solution at 100°. The reaction

$$RI + N(Et)_3 = NR(Et)_3 I$$

was found to obey the bimolecular velocity-equation. The relative reactivities, as measured by the velocity-coefficient, are given in the subjoined table.

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[1] Wislicenus, Lieb. Ann., 1882, vol. **212**, p. 239.

[2] Zeitschrift für Phys. Chem., vol. **6**, 1890, p. 41.

TABLE 4.—MENSCHUTKIN'S EXPERIMENTS.

Iodide.	Relative Reactivity.
Methyl, ...	1140·00
Ethyl, ...	10·10
n-Propyl, . . .	1·93
n-Butyl, . . .	1·38
n-Heptyl, . . .	1·08
n-Octyl, . . .	1·00

Here, again, we see the great reactivity of methyl iodide and the rapid fall of reactivity with increase of mass of the alkyl group in the three lower homologues.

Substantially the same results were obtained by Hecht, Conrad, and Brückner[1] in their study of ether-formation from the alkyl iodides and sodium alcoholate in dry ethyl alcohol at 30°. Williamson's reaction

$$\mathrm{RI + Na \cdot OEt = R \cdot O \cdot Et + NaI}$$

was also found to obey the bimolecular velocity-equation; and the following table gives the relative reactivities as determined by the velocity-coefficients (also referred to the reactivity of *n*-octyl iodide as unity).

TABLE 5.—EXPERIMENTS OF HECHT, CONRAD, AND BRÜCKNER.

Iodide.	Relative Reactivity.
Methyl, ...	61·72
Ethyl, ...	4·87
n-Propyl, . . .	1·71
Isopropyl, . . .	0·92
n-Heptyl, . . .	1·04
n-Octyl, . . .	1·00

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[1] Zeit. für Phys. Chem., vol. **4**, p. 273.

So far as the general order of reactivities is concerned, these results are in very good agreement with those obtained by Menschutkin. It may be noted that isopropyl iodide is characterised by a relatively low reactivity.

If relative reactivity be plotted against mass of alkyl radical, the general resemblance between the results of Menschutkin, and of Hecht, Conrad, and Brückner, is found to be very striking.

Considering the similarity of the results obtained in these three totally different reactions (*i.e.* with sodio-aceto-acetic ester, triethylamine, and sodium alcoholate) and the—in two main respects at all events—widely divergent order of reactivities as measured by silver nitrate, there is good ground for the belief that, in the latter case, the reaction is intimately associated with some special function or state of the alkyl iodide molecule. The number and comparative complexity of the products of the reaction afford further confirmation of this. Whether these results can be explained by Nef's dissociation-hypothesis, or indeed by any dissociation-hypothesis, can only be decided by further detailed investigation, a portion of which has been already carried out without, however, yielding any perfectly decisive results so far as the intimate mechanism of the reaction is concerned.

As is well known, the alkyl iodides turn yellow or brown when exposed to light, the coloration of the solution being due to free iodine. Possibly this reaction is connected with the dissociation-equilibrium:—

$$R \cdot CH_2I \rightleftarrows R - CH + HI,$$

the hydriodic acid being oxidized by the oxygen of the air usually present. The latter reaction is known to be catalytically accelerated by the presence of light. However that may be, an interesting relation between the rate (and extent) of this production of free iodine and the corresponding velocity-coefficients (as measured by silver nitrate) has been established. $\frac{N}{20}$ – solutions of the alkyl iodides in dry alcohol were put into tightly-corked test-tubes and exposed to uniform diffused daylight. On the following day, the solution of isopropyl iodide showed a faint yellow coloration. The other solutions became coloured in due course in the relative order of their reactivities as measured by silver nitrate, with the single exception of methyl iodide, which appeared to possess a rate of decomposition intermediate between isopropyl and ethyl iodides. After six months the colorations, as roughly judged by eye, were as follows :—

Isopropyl iodide Methyl iodide	Deep brown.
Ethyl iodide *n*-Propyl iodide	Intense yellow.
n-Butyl iodide Isoamyl iodide	Pale yellow.
Isobutyl iodide,	Colourless.

If this list be compared with the table of reactivities, as given on page 197, the general parallelism is unmistakable. The exceptional position occupied by methyl iodide is very peculiar, considering its relatively low reactivity.

ROYAL COLLEGE OF SCIENCE, DUBLIN.

February, 1904.

XXII.

ON THE STRUCTURE OF WATER-JETS, AND THE EFFECT OF SOUND THEREON.

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[COMMUNICATED BY PROFESSOR W. F. BARRETT, F.R.S.]

(PLATES XIX.-XXII.)

[Read, MARCH 15; Received for Publication, MARCH 18; Published, MAY 12, 1904.]

THE circumstances under which the disintegration of a liquid jet takes place have attracted the attention of many philosophers.

Early in the last century Savart, in a series of classical researches, investigated the subject; and, following him, Plateau, Magnus, Lord Rayleigh, and others have, in their turn, discovered and explained many beautiful and complicated phenomena.

During the course of my work, as a third-year student of physics, I had occasion to repeat some of these experiments; and I here propose to give a brief account of them, together with some additional observations of my own, the whole illustrated, as far as possible, by means of instantaneous photographs.

The observations were made, and the photographs taken, in the Physical Laboratory of the Royal College of Science, by kind permission of Professor W. F. Barrett, F.R.S., to whom I take this opportunity of expressing my thanks for the suggestions and facilities he afforded me in the work.

If we observe a jet of water flowing from a narrow orifice, we see that it may be divided into two parts—(1) a clear and unbroken column; (2) a turbid portion. The latter owes its troubled appearance to its being in reality a rapid succession of drops, which move too rapidly for the eye to distinguish them so long as they are viewed by continuous light.

On viewing the jet by intermittent light, such as that given by a rotating disc with slots in it, when interposed between the eye and the jet, or by the sparks from a Leyden jar charged from an induction coil, we can see the true shape of the drops, and discern their mode of formation.

The device I adopted was to put the spark-gap behind a condensing lens, in front of which the stream of water flowed. By means of a second lens an image of the stream was formed on a ground-glass screen, which was very brilliant when viewed from behind. If the screen were replaced by a sensitive plate (cutting off extraneous light), a photograph could be obtained of the jet at any instant by allowing a single spark to pass; this can easily be done by moving the hammer of the coil by hand. These photographs afford a very convenient way of studying the jet.

Towards the lower part of the clear column alternate swellings and contractions may be seen, while at the extremity a drop forms which extends itself horizontally and leaves the column with its major axis *horizontal*; not, as is generally thought, vertical. There is then left a slender neck of liquid, which next detaches itself, and, gathering together by surface-tension, forms a smaller drop. (Plate XIX., fig. 1.)

The larger drops as they fall do not at once assume the spherical form, but execute vibrations, being alternately elongated and compressed in the direction of their axis of symmetry. The time of vibration τ, of course, depends upon the nature of the fluid and the size of the drop.

Lord Rayleigh gives this formula[1]:—

$$\tau = \sqrt{\frac{3\pi\rho V}{8T}},$$

where V = volume of the vibrating mass, ρ the density of the liquid, and T the surface-tension. The time of vibration of a drop of water 2·5 cms. in radius is very nearly 1 second.

There is nothing very regular in the appearance of such a jet; the drops are moving with different velocities; frequent collisions occur, giving rise to the fine spray that may be seen in the lower part of the stream. If a sudden blow be given to the stand

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[1] See Lord Rayleigh's "Scientific Papers," vol. i., p. 392.

supporting the nozzle, a long portion of the stream may be detached. (Plate XIX., fig. 2.)

If now, instead of allowing the column to break up arbitrarily, we impress upon it vibrations of a regular character, a marked change takes place in its appearance. Placing a sounding tuning-fork on the stand, the first thing to be noticed is that the jet begins to separate into drops a good deal nearer the orifice, while lower down (if the conditions be favourable) it assumes a beautiful wavy outline, consisting of perfectly regular swellings and contractions. On removing the fork from the stand, the jet regains its former appearance, though the fork may be vibrating strongly, showing that the vibrations transmitted through the air have little or no effect.

Let us now consider the cause of these swellings.

If swellings are to be found in a jet, the regularity in the separation of the drops must not only take place in such a manner that (1) all the drops are equally great, but (2) the time that elapses between the formation of any two of them must remain constant. For it is only under these conditions that all drops on arriving at the same part of the stream are in the same phase. At the middle of a swelling they are drawn out to the greatest extent in a horizontal direction; and in the space between two swellings, they are most elongated vertically. It is therefore on account of their assuming these different diameters that they produce the appearance referred to.[1]

On examining the photographs, we can see clearly what has taken place. A large drop is cast off elongated horizontally; next follows a small one, formed by the narrow neck of liquid; then a large one; but, by the time the second large drop is cast off, the first has swung through half a vibration, and is now elongated in a vertical direction. (Plate XX.)

This regular alternation of drops is confined chiefly to the upper portion of the stream. Lower down, collisions occur between the large and small drops, while at the lowest part the small drops have disappeared, and the large ones have all become more or less spherical, the vibrations having died out. (Plate XXI.)

In a jet possessing no swellings, the detached masses are not

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[1] Magnus, "Hydraulic Researches," Phil. Mag., 1859, vol. xviii., p. 175.

uniform in size, nor do they separate at equal intervals. Hence all drops arriving at the same part of the stream are not in the same phase, and consequently they do not produce the appearance of swellings. The interval between one swelling and the next is the space described by the drop during one complete vibration, and is proportional, as Plateau has shown, to the square root of the head.

The disturbances by which equilibrium is upset are impressed upon the fluid as it leaves the aperture. What really happens is, according to Prof. Magnus, that the rim of the orifice vibrates up and down, and the issuing stream receives alternate retardations and accelerations which lower down effect its resolution into drops.

The continuous portion of the jet represents the distance travelled by any one of its elements before disintegration takes place; and its length depends upon the amplitude and wave-length of the disturbance.

Now, if we have a jet of water which is influenced by a tuning-fork in the manner described, and another tuning-fork of slightly different pitch be sounded, and placed beside the first, producing beats with it, the continuous part of the stream will lengthen and contract in a remarkable manner, keeping time with the audible beats.

This seems to be due to the fact just mentioned, namely, that the point of disintegration of the jet is determined, *ceteris paribus*, by the amplitude of the vibration affecting it. When the vibrations of the two forks coincide in phase, the resultant vibration has a maximum amplitude equal to the sum of the amplitudes of the two components, and the jet breaks high up. When the phases are opposite, the resultant amplitude is a minimum, and so the clear portion is lengthened. The stream is extraordinarily sensitive to these beats, and will indicate them when the forks have become inaudible.

If the stream be allowed to flow on to a stretched membrane of parchment or thin rubber, placed below the point where drops are formed, the impact of the drops will, in general, be heard as a series of taps—a mere noise.[1]

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[1] See "Sympathetic Vibration of Jets," by C. A. Bell, M.B., Phil. Trans. Royal Society, Part 2, 1886, p. 399.

Now, if we break up the jet in a regular manner by a fork, a drop will be thrown off with each complete vibration, and hence, instead of a confused noise, a musical note will be heard—the note that the fork is yielding. The sound can be made very loud and penetrating, its quality depending on the nature and tension of the diaphragm and the pressure of the water.

If the latter be suitably adjusted, a note will be emitted by the membrane without any fork being used; for the impacts of the drops will set up vibrations in the membrane which communicate themselves to the jet, and effect its regular resolution; and the note, when once established, will be maintained. If the pressure be increased, several notes may be obtained in succession, the pitch rising with the pressure.

An interesting example of the Döppler effect may here be noticed. If the membrane be rapidly moved nearer the orifice, the pitch of the note will be raised during the motion; and on lowering the membrane, the pitch will be lowered.

There is an experiment that can be performed in connection with this singing membrane that is very striking, and of some theoretical interest. Suppose the fork Ut_4, making 512 complete vibrations per second, be placed on the stand. The membrane will respond to that note. Let it now be removed, and Sol_3, giving 384 vibrations, substituted. The membrane again responds, this time to Sol_3. Place the two together on the stand, and a deep, powerful note of Ut_2, or 128 vibrations, will be heard. It is, in fact, the difference-tone, or grave harmonic of the two forks.

There has been for some years a controversy amongst physicists as to whether these difference-tones had an objective existence or not, that is whether there do really exist in the air vibrations of that period. Some held that they were purely subjective, and produced within the ear, owing largely to a peculiarity of construction of that organ, while others held that they existed in the external air. It would take too long to enter into the details upon which the respective arguments were based; but Helmholtz showed, from mathematical considerations, that when a mass of air is set in motion by two simple sources of sound, in certain cases vibrations will arise with a frequency equal to the difference of frequencies of the generating tones. If such vibrations exist objectively (he argued), they should be detected by means of suitably-tuned resonators—and, in a few cases, they can be—but more often than not, they are largely subjective.

I hope to perform some further experiments in connection with this subject shortly.

So far we have been considering the effects of sound upon jets of moderate diameter. Let us now see what happens when the jet is narrower.

If a jet of water about one millimetre in diameter is projected almost vertically, it breaks up, and scatters into fine spray soon after leaving the orifice. When a rather high-pitched tuning-fork is sounded and placed on the supporting stand, the scattering is prevented; and the stream, which now presents a beautifully wavy appearance, remains entire, until almost its highest point is reached.

If we photograph such a jet falling normally, we can see, as in the former cases, that it consists of small and large drops alternating, irregularly spaced, and of various shapes. The appearance of the same jet when influenced by a tuning-fork is quite different. (Plate XXII., fig. 1.) The drops formed are all about the same size, very regular in their outline, and practically equidistant. Fine streams may often be seen shooting out at the sides, particularly if the note be impure.

The effect of a tuning-fork of high pitch on a very fine jet, projected upwards at a moderate angle, is very curious. The stream frequently divides into two, three, or more streams, quite distinct from each other. These streams revolve round one another, making it difficult to secure a satisfactory photograph. Plate XXII., fig. 3, shows the phenomenon well. There is a central stream of drops larger than those constituting the others; but all are arranged in perfect order, the drops in each stream being equidistant from their fellows. Plate XXII., fig. 2, shows the same jet uninfluenced by sound.

From the foregoing experiments, therefore, we see that the general effect of musical sound upon liquid jets is to make them regular and uniform; and this is rendered evident to the eye by their symmetry of form, and to the ear by the notes they produce.

A musical note differs from a noise in having its vibrations periodic, and the smoother the curve that represents the wave-motion, the fuller and purer is the note. So it is with these jets of water. The more troubled and ruffled they appear to the eye, the more confused and irregular are the streams of drops that compose them ; while their symmetry and elegance of outline are but outward indications of order and regularity of formation.

[Explanation of Plates.

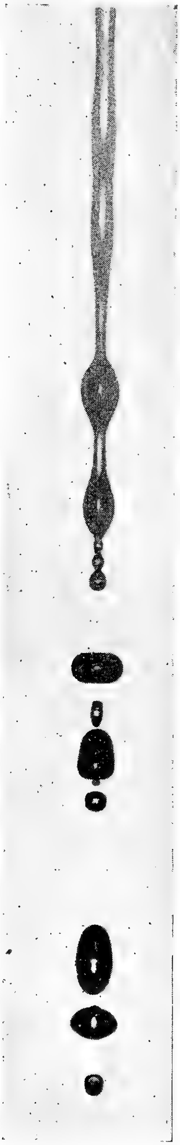
EXPLANATION OF PLATE XIX.

PLATE XIX.

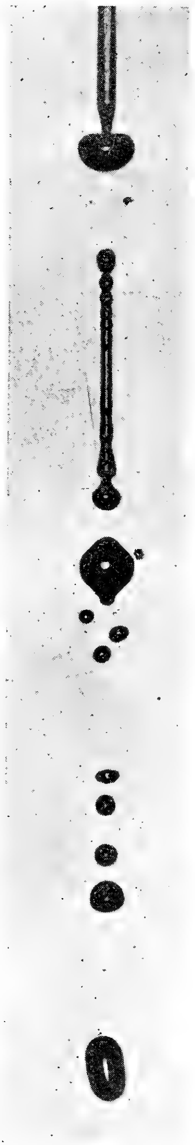
Fig.

1. A jet of water falling vertically from a glass nozzle, with an orifice 2 mm. in diameter.

2. The same jet broken up by a blow on its support.



1.



2.

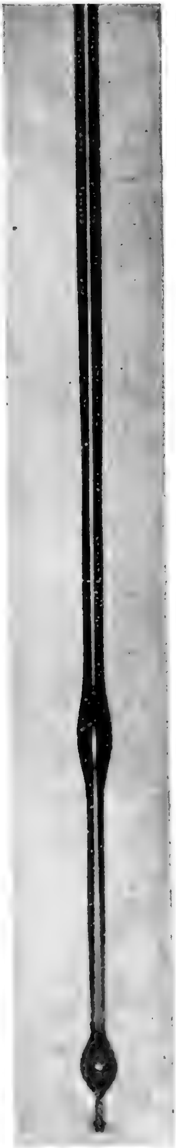
EXPLANATION OF PLATE XX.

PLATE XX.

FIG.

2, 3, 4. A jet of water under the influence of a vibrating tuning-fork (384 vibrations per sec.), showing successive stages in the formation of drops, and their phases of vibration.

The point of disintegration has been considerably raised by the action of the tuning-fork, as may be seen by comparison with fig. 1, which represents the jet before the application of the tuning-fork.



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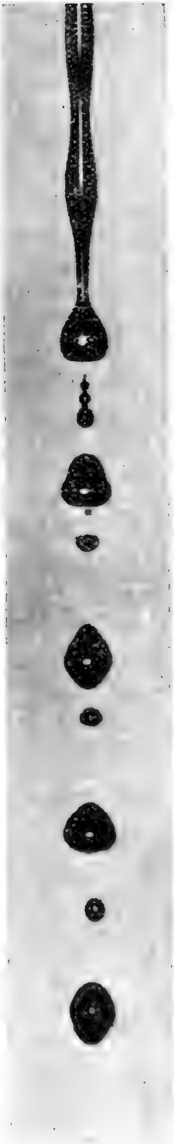
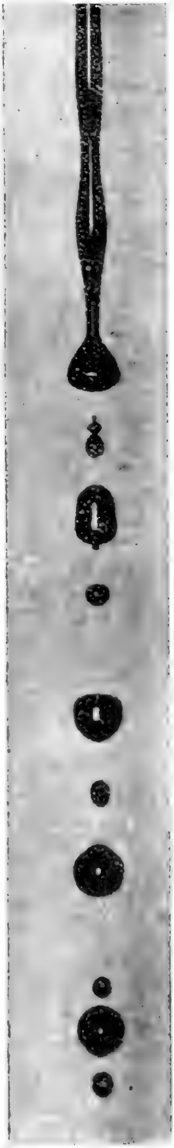
2



3.



4.

EXPLANATION OF PLATE XXI.

PLATE XXI.

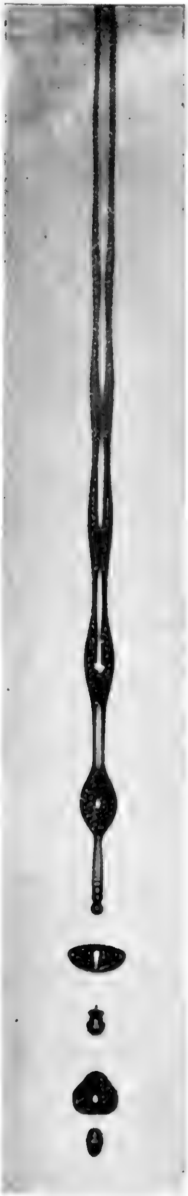
Successive portions of the same jet when influenced by a vibrating tuning-fork.

Fig.

1. Lower part of the clear column, showing the disturbance travelling down with increasing amplitude, until disintegration takes place.

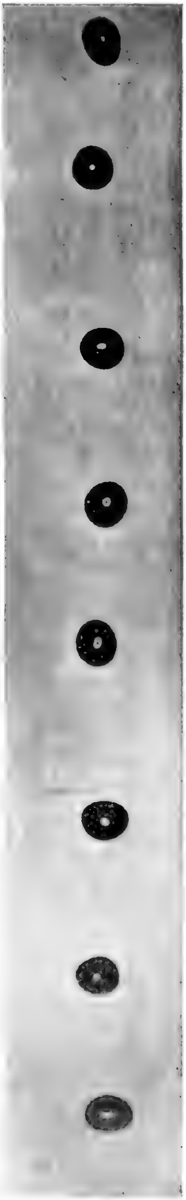
2. Middle of the jet. Collisions occurring between large and small drops.

3. Lowest part of the jet.



1.

2



3.

EXPLANATION OF PLATE XXII.

PLATE XXII.

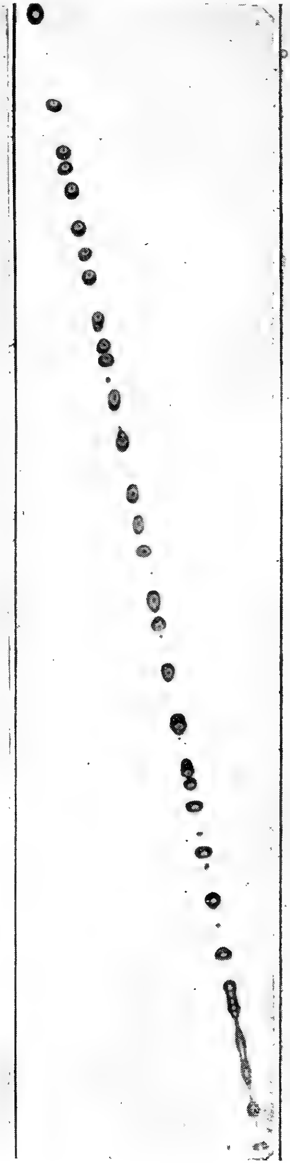
FIG.

1. A jet of water about 1 mm. diam., falling vertically, influenced by a vibrating tuning-fork.

2. A jet of water about ·75 mm. diam., projected upwards.

3. Resolution of the same upward jet into three distinct streams, by a tuning-fork making 512 vibrations per second.

1.



2.

3.

XXIII.

REMARKS ON THE CASES OF CARBON MONOXIDE ASPHYXIATION THAT HAVE OCCURRED IN DUBLIN SINCE THE ADDITION OF CARBURETTED WATER-GAS TO THE ORDINARY COAL-GAS.

By E. J. McWEENEY, M.A., M.D., D.P.H., M.R.I.A.,

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[Read, April 19; Received for Publication, May 20; Published, October 27, 1904.]

In a paper read before the Royal Dublin Society in 1900, and entitled "Recent Analyses of the Dublin Gas-supply and Observations thereon,"[1] Professor James Emerson Reynolds, F.R.S., drew attention to the increased proportion of carbon monoxide in the Dublin illuminating-gas. The mean result of twelve analyses made between November 25th, 1899, and February 16th, 1900, was a CO percentage of 6·2, which may be taken as the amount normally present. An analysis of ordinary coal-gas, published in Sutton's "Volumetric Analysis," gives the CO as 5·68 per cent.; and a sample of house coal (probably Orrell), which Mr. Holms Pollok, of the Royal College of Science, was good enough to test for me, yielded a gas containing 6·6 per cent. of carbon monoxide. Towards the end of February, 1900, Professor Reynolds noted a sudden and marked increase in the proportion of CO present, which on March 9th amounted to no less than 17·9 per cent., or nearly threefold what it had previously averaged. Furthermore, this increase in the carbon monoxide was, with certain fluctuations, persistent; and, so far as I am aware, it has lasted uninterruptedly up to the present time. The mean of five analyses made in January, 1901, by Mr. Holms Pollok, was 10·3 per cent. of CO. Of late the tendency seems to be towards an increase; for the average of three analyses, very

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[1] Scientific Proceedings, R.D.S., vol. ix. (N.S.), Part III., No. 21.

kindly carried out by the same authority at my request this week, was 16·2 per cent. of carbon monoxide. From the health point of view, carbon monoxide is the most objectionable of all constituents of coal-gas. Its presence in increased quantity is to be ascribed to the addition of what is known as "carburetted water-gas" to the coal-gas during the process of manufacture. Carburetted water-gas is made by passing steam over red-hot coke, whereupon the carbon of the coke combines with the oxygen of the water-vapour, and forms carbon monoxide, whilst hydrogen is liberated, according to the equation $H_2O + C = CO + H_2$. The mixture of carbon monoxide and hydrogen burns with an almost non-luminous flame, and is nearly inodorous. A subsequent addition of vapourised petroleum or other oils confers upon it illuminating power, and a powerful odour, which is, to most people, very objectionable, but which has the important advantage of betraying its presence. Manufactured as it is to a large extent from the by-products of the ordinary industry, carburetted water-gas is cheap; and its addition in considerable volume to the ordinary gas is therefore profitable to the producing company. It contains about 30 per cent. of carbon monoxide, and its introduction into dwellings is therefore by no means a matter of indifference to the public. Carbon monoxide is an extremely dangerous substance, which owes its deleterious effect on the animal economy to the intense affinity which it has for the hæmoglobin of the blood—an affinity which has been calculated to be almost exactly 300 times as great as that between hæmoglobin and oxygen. For it has been found[1] that if blood be shaken up with a sample of air containing 0·07 per cent. of CO—in other words, 10,000 volumes of which contain 2,100 volumes of oxygen and 7 of CO—one-half of the hæmoglobin will be found saturated with O, and the other half with CO, which amounts to saying that air containing only one-three-hundredth of its volume of carbon monoxide will half saturate the blood with that gas. The result is that at each inspiration of such air a certain proportion of the hæmoglobin is deprived of its oxygen-carrying function, and after a longer or shorter time, according to the proportion of CO present, the amount of functional hæmoglobin

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[1] See Lorrain Smith: British Medical Journal, April 1st, 1899.

becomes insufficient for tissue metabolism, the cardiac and respiratory functions fail, and the patient dies asphyxiated. Experiments have shown that when the atmosphere of a room comes to contain two volumes of carbon monoxide per thousand of air, it becomes dangerous, and when the proportion reaches four per thousand, life is speedily extinguished.

The Departmental Committee appointed some years ago by the Home office to inquire into the manufacture and use of water-gas and other gases containing large proportions of carbon monoxide, referred in their Report, published in 1899, to American statistics, as showing the danger of this substance. A table prepared by Dr. Haldane, F.R.S., in the Appendix to that Report, shows that with ordinary coal-gas the annual deaths in England by gas-poisoning, calculated on a gas-distribution equal to that of London in 1896, were three in number; whereas the deaths that occurred in Boston, U.S.A., during the same year, would have amounted to 620, calculated on the same gas-consumption, and in Brooklyn the number would have been 400. In Boston the gas supplied consists of 90 per cent. water-gas, whilst in Brooklyn the proportion is 97 per cent. Dr. Haldane goes on to say: "From the table it is evident that by no possibility can the conclusion be avoided that the distribution of carburetted water-gas without any special precaution is enormously more dangerous, or, to speak more correctly, less safe, than the distribution of coal-gas. Roughly speaking, the loss of life arising in one way or another—accident, suicide, or homicide—appears to be fully a hundred times greater with water-gas in America than with coal-gas in this country." It would appear that in 1886 there were in Boston 29,554 consumers of ordinary coal-gas *without accident.* In 1890, amongst 46,848 consumers of a gas-supply containing 8 per cent. of added water-gas, there were six deaths from gas-poisoning. In 1895 the consumers were 68,214, 90 per cent. of the gas was water-gas, and the deaths were twenty-four. In 1897, with 79,893 consumers, and a gas containing 93 per cent. of water-gas, the deaths were forty-five in number. Dr. Haldane, on whose researches the Report of the Committee is mainly based, further points out that the number of accidents referable to the use of mixed gas would appear to increase approximately as the *cube of the gain in percentage of carbon monoxide.* Thus, if the percentage of CO be increased from six to twelve, the chance of being poisoned is not twice, or even four times, but eight times as great as before the increase; and if the CO becomes three times as abundant as heretofore, the chances of being poisoned become increased no less than twenty-sevenfold. I was recently asked the very pertinent question, what number of the Dublin fatalities would have been averted had the supply consisted of ordinary coal-gas. The nearest approach to a correct answer is to be expected from a survey of the statistics of deaths from this cause certified in Dublin during the twenty years previous to the commencement of the introduction of water-gas. To the kindness of the Registrar-General (R. E. Matheson, Esq., LL.D.), who was good enough to have the Dublin death tabulation sheets, for the years 1880–1900, examined, I owe the important information that during that period no death was tabulated as having resulted from coal-gas poisoning.[1] During the four years that have elapsed since the addition of carburetted water-gas has begun to be practised, there have been in Dublin ten cases, with seven deaths due to that cause. It would therefore seem impossible to escape from the conclusion that coal-gas with this addition constitutes a new source of danger to the community—one which is readily avoidable, no doubt, but which ought not to be completely overlooked. The cases that have occurred since the publication of Dr. Reynolds's paper afford a full justification for the words of warning which he thought it his duty to utter, and in the course of which, whilst deprecating "undue alarm" and "exaggerated fears," he emphasized the need for "increased caution in dealing with the new gas."

Group I. (comprising Cases 1, 2, 3 and 4).

These occurred in November, 1901, in a small house, No. 9, Eccles-place, *to which gas was not laid on.* It contained only two rooms, one over the other. In the upper room slept an elderly man of the working class (J. C., aged seventy, coal-labourer), and

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[1] In 1895 a death occurred which, according to the finding of the coroner's jury, was caused by "coma from congestion of brain and lungs, due to inhalation (accidental) of poisonous gases *at Gas Company's premises.*"

his son (A. C., aged twenty-one). In the lower room slept the old man's daughter and her husband. On the 15th November all four persons were feeling unwell, and the son-in-law sent for a doctor, who, on arrival, perceived a strong, unpleasant odour, suggestive of a mixture of coal- with sewer-gas, pervading the house.

He cautioned the inmates on no account to sleep in the house that night. To this warning they paid no heed, and slept there as usual, retiring at 10 p.m. Next morning, between 6 and 7, the son-in-law felt so unwell that he left his bed and went to the Mater Hospital, where the resident pupil treated him. He had vomited, and complained of headache and prostration. After a time he felt better, and returned home. Nothing more was heard of the family till noon on the following day (Nov. 17), when another married daughter of old C. knocked, and, after some delay, was admitted by the son-in-law (the man who had called in the doctor on the 15th, and had been to the hospital in the early morning of the 16th). After opening the door he staggered, and appeared to be giddy and stupefied. His wife's condition was similar. The police were sent for; and, on going upstairs, they found the old man lying dead. The body was unclothed, and lay beside the bed. The son was found sitting in a dazed condition at the top of the stairs.

Condition of survivors.—The son (who slept in the same room as the deceased) was, on admission to Dr. Redmond's ward in the Mater Misericordiæ Hospital, found to be pale, semi-collapsed, almost unable to walk; temp. normal; pulse 120. He complained of feeling cold, but not of headache. Unfortunately the blood was not examined till next day (Monday), when it no longer showed any trace of carbon monoxide. A blood-count yielded reds 4,800,000, whites 10,000, about 60 per cent. of which were polynuclear, and the remainder lymphocytes, small and large.

The son-in-law, who with his wife occupied the lower room, was found, on admission, to have a very slow pulse, about 48. He complained of severe headache. In these respects his condition was the reverse of that of his brother-in-law. He was almost unable to walk. His reds were 6,000,000, his whites 8,700, with 30 per cent. of mononuclears. Carboxy-hæmoglobin not demonstrable.

The young woman's symptoms soon passed off, and she refused admission to hospital. The *post-mortem* examination of the body of the old man revealed the usual signs of poisoning by carbon monoxide, as well as other points, which it would be out of place here to detail. The blood was mostly uncoagulated, bright cherry-red. Suitably diluted, it gave an absorption-spectrum hardly distinguishable from that of normal blood, but differing from the latter in the persistence of the bands after treatment with ammonium sulphide sol., and warming. The dilute solution had a characteristically pink colour; and, on being tested by Haldane's quantitative method, it yielded a result corresponding to 73 per cent. saturation of the hæmoglobin with carbon monoxide.

Inspection of the premises.—Gas not laid on, and no fittings. Lower room, 19 ft. 4 in. by 16 ft. wide, and 9 ft. high; small window and fireplace. Upper room (where the fatal case occurred), 18 ft. by 15 ft., with a sloping roof, rising from about 5 ft. to 7½ ft. above floor. The three windows, nearly on floor-level, measured 3 ft. 2 in. by 2 ft. 10 in. each. There was also a skylight, 2 ft. 1 in. by 1 ft. 5 in. *There was no fireplace.* All the windows were found shut when the room was entered by the police. The skylight was open when I visited the place, and there was some doubt as to whether it had not been found partly open at the time of the fatality. It was situated nearly over the head of the stair, and far away from the bed.

Explanation of the occurrence.—The premises, on being entered, smelt strongly of coal-gas, as did also the next house, occupied by a man, his wife, and six children, who do not appear, however, to have suffered any ill-effects. Examination by the officials of the Gas Company showed that the *main-pipe in the street was broken about* 18 *inches below the surface.* The fracture was recent, and was ascribed to the weight of some passing vehicle. The surrounding earth smelt strongly of gas, which must have found its way through the soil into the house where the fatality occurred. The sewers were examined, and found staunch. It is interesting to note that though the gas entered below, its effects were most severely felt in the upper room. This is accounted for by the existence of an additional means of ventilation in the shape of a fire in the lower apartment.

Group II. (Cases 5, 6, and 7.)

These cases were those of a family, consisting of a man, aged thirty-eight (mechanical engineer), his wife, aged twenty-six, and their child, aged five years, who were found dead in their cottage on the evening of the 7th April, 1902. Having been absent on the Continent when this case occurred, I owe my knowledge of it to the courtesy of the City Coroner (L. A. Byrne, Esq., F.R.C.S.), who placed the depositions at my disposal.

The family were about as usual on the previous day. Several persons having called at the house during the morning and early afternoon of the 7th, and, having failed to elicit any response from the inmates, the door was forced towards 8 p.m. by the police, who were at once driven back by an overpowering odour of coal-gas. After the lapse of fifteen minutes an entrance was effected, when the man was found lying dead on the floor of the front room, attired only in a shirt, as though he had risen from bed, and attempted to reach the door. The dead bodies of the woman and child were found in bed in the same room. Death had occurred some hours previously.

Inspection of the premises.—The "penny-in-the-slot" meter, which stood on a shelf in the living-room, had been disconnected and removed, and, by means of two pieces of brass-pipe and flexible rubber-tube, a direct connexion effected between the gas-main and the house-supply. The brass tubes used were of smaller bore than the gas-pipes, into which they were inserted, the joints being made staunch with red-lead. Over the free ends of the brass-pipes, so fixed, the length of rubber-tubing had been slipped, and the gas thus "short-circuited" into the house. Unfortunately for the inmates, the rubber-tube had in some way become detached during the night, with the result that all three were asphyxiated.

Necropsy.—This was carried out next day, in all three cases, by Dr. H. C. Earl, at the Coroner's request. The notes describe the peculiar pink colour of the *post-mortem* staining, the bright cherry-red colour of the uncoagulated blood, and its characteristic behaviour to the usual chemical and spectroscopic tests. The cause of death in each case was poisoning with carbon monoxide gas.

Explanation of the Occurrence.—This man was a mechanical engineer; and it is only too evident that his life, and those of his wife and child, were sacrificed in a clumsy attempt to defraud the Gas Company.

Group III.

Cases 8 and 9 were those of a married couple, J. and G. M., who were asphyxiated in their bedroom at a Dublin hotel on January 15th, 1903. They had arrived on the previous evening, and engaged the room, to which they subsequently retired. Next day nothing was seen of them, though it would appear that sounds of stertorous breathing were heard in the narrow corridor into which the room opened. Towards evening the hotel people became alarmed, and directed the porter to effect an entrance, which he did, through the window. Dr. Martin Dempsey was sent for. He pronounced the woman dead, and ordered that the man, who was lying unconscious beside her in bed, should be removed to hospital. He was taken to Jervis-street, and admitted into Dr. Thompson's ward, but never recovered consciousness, and died on the third day. Next day, at the Coroner's request, I performed the autopsy of the female; and from the notes taken at the time, which are of a purely technical character, I will merely give the fact that the blood was found between 60 and 70 per cent. saturated with carbon monoxide. The man, J. M., lived three days in Jervis-street Hospital. He continued to breathe stertorously, and was absolutely unconscious, incapable of any voluntary movement, and irresponsive to stimulation. He was treated by inhalations of oxygen. On the day after his admission the blood looked very dark and tarry: carbon monoxide could not be demonstrated in it. The red corpuscles were 7,640,000, and the white 10,000, per cubic millimetre. The differential leucocyte-count worked out approximately normal. The temperature rose from 101° on admission, to 103° on the following day. It was 106° on the morning of the third day, and towards evening it was over 108°, when he died.

Necropsy.—This was fully and carefully done by myself, with the assistance of the house surgeons, Drs. Ryan and Mason, but elicited no special abnormality. The blood in the cavities of the heart was for the most part coagulated; it did not yield a pink solution, nor could any trace of carboxy-hæmoglobin be detected in it by the spectroscope.

In view of the evidence of the clinical symptoms, and of the results of the autopsy of the female, I concluded that death was due to poisoning with carbon monoxide, and the jury so found.

Explanation of the occurrence.—When the room was entered at 6.30 p.m., it was in darkness, and smelt strongly of gas, which was found to be escaping from a wall-bracket, the stop-cock of which was about half open. How this had come about was not fully cleared up at the inquest. Possibly the luckless couple, who had dwelt in the country, far from a gas-supply, may have blown out the flame. There is another possibility which deserves explicit mention. The corridor into which this room opened is a dark one and lighted by gas. The supply to it and the rooms opening off it was governed by a special stop-cock, which would appear, from the evidence, to have been, at any rate occasionally, turned off at night, and turned on next morning. If this had occurred on the night in question, and the couple had retired to rest, leaving the gas in their room lighted, the state of things found would be most probably accounted for.

Inspection of room.—I personally inspected the bedroom, and noted the following points. The dimensions were 11 ft. 1 in. by 10 ft. 6 in., by 9 ft. 6 in. high, giving a cubic space of 1,105 ft., from which the space occupied by a large wardrobe 6 ft. 7 in. high, 44 in. wide, and 19 in. deep had to be deducted; a large double bed, 6 ft. 5 in. long, 44½ in. wide, and 14 in. thick. There were also a large dressing-table, a toilet-table, a large basket-chair, and two ordinary ones—in fact, the little room may be said to have been crowded up with furniture. The cubic space thus occupied I estimated at 71 cubic feet, thus leaving only 1,034 cubic feet available for respiration. *There was no fireplace.* On the side opposite the door was a large window, which was closed, but not fastened. The only ventilation at the time of the occurrence was into a dark and close-smelling corridor, and was effected through two sets of apertures, one being a series of slits in a pane of muffed glass over the door. These were eighteen in number, and arranged in three horizontal rows of six. Each slit was $1\frac{3}{4}$ in. long, by about $\frac{1}{6}$ in. wide, and their conjoint area I estimated at rather less than 6 square inches. There was also a perforated zinc plate, pierced with holes, and let into the wall close to the floor under the head of the bed. The conjoint area of the holes might have been about 20 square inches on a liberal estimate. Their ventilating value must have been seriously diminished by their position close to the floor; they opened into the corridor. Assuming the admitted air to be cooler than that already in the room, the effect would be to form on the floor a stratum of purer air, which could only slowly affect the composition of the general atmosphere of the room. The wall-bracket was furnished with a No. 5 brased fish-tail burner, consuming about 5 feet of gas per hour.

The fatal result was in this case due to several circumstances, of which the leading one was undoubtedly the escape of gas; whilst the defective ventilation of the apartment, in which the unfortunate couple were allowed to remain shut up without food or attendance throughout the entire day, was a contributory factor. On comparing the ventilation with the recognised standards, we find that the cubic space was 517 feet per head (instead of 1,000). The functional "fresh" air inlet was only 8 square inches; but allowing the same value for any advantage that might have accrued from the perforated zinc plate beneath the bed, let us say 16 square inches (instead of 48). Of course, air can enter through any crevice. Dr. Haldane has shown that the air of such a room is changed, even in the absence of a fire-place, about once every 2¼ hours. It would, therefore, be quite a mistake to suppose that the ventilation of a room, with, at any rate, one of its walls an outer one (that is, forming part of the outside of the house), is solely dependent on the ventilation apertures made *ad hoc.* Pettenkofer experimented many years ago with a room of about 3,000 cubic feet capacity, and found that without definite ventilation, the air was changed once every 3 or 4 hours. Dr. Haldane, in his Appendix to the Gas Commission Report, concludes that the air of a closed room of 1,000 cubic feet capacity is changed once in from 2 to 3 hours. It may be interesting to inquire what was the condition of the air of this particular bedroom, assuming that the air was completely changed once every 2¼ hours by diffusion through the walls, and, for the sake of ease in calculation, that its cubic content was 1,000 (instead of 1,034) cubic feet. We shall also assume that the gas continued burning for 2 hours after the couple retired to the room (that is, till 12 o'clock), and then became extinguished.

The problem may, therefore, be stated thus:—

A room has a capacity of 1,000 cubic feet, and the atmosphere is changed once every 2·25 hours. Its original composition may be assumed normal (790 vols. of N, 209·6 of O, and 0·4 of CO_2). CO_2 is introduced (*a*) by combustion of coal-gas, (*b*) by respiration: (*a*) goes on for only 2 hours (at the rate of 5 feet per hour), and delivers 2·5 cubic feet of CO_2 per hour (being at the rate of half a foot of CO_2 per foot of gas burnt; (*b*) continues all through the experiment, which lasts from 10 p.m. till 6 p.m. next day (20 hours), and delivers 1·2 cubic feet CO_2 per hour (0·6 per individual).

Coal-gas is delivered into the room during the last 18 hours of the experiment at the rate of 5 feet per hour. It contains 16 per cent. of carbon monoxide.

Required—(1) The maximum percentage of CO_2 that will be reached in the atmosphere.

(2) How long it will be before it will be reached.

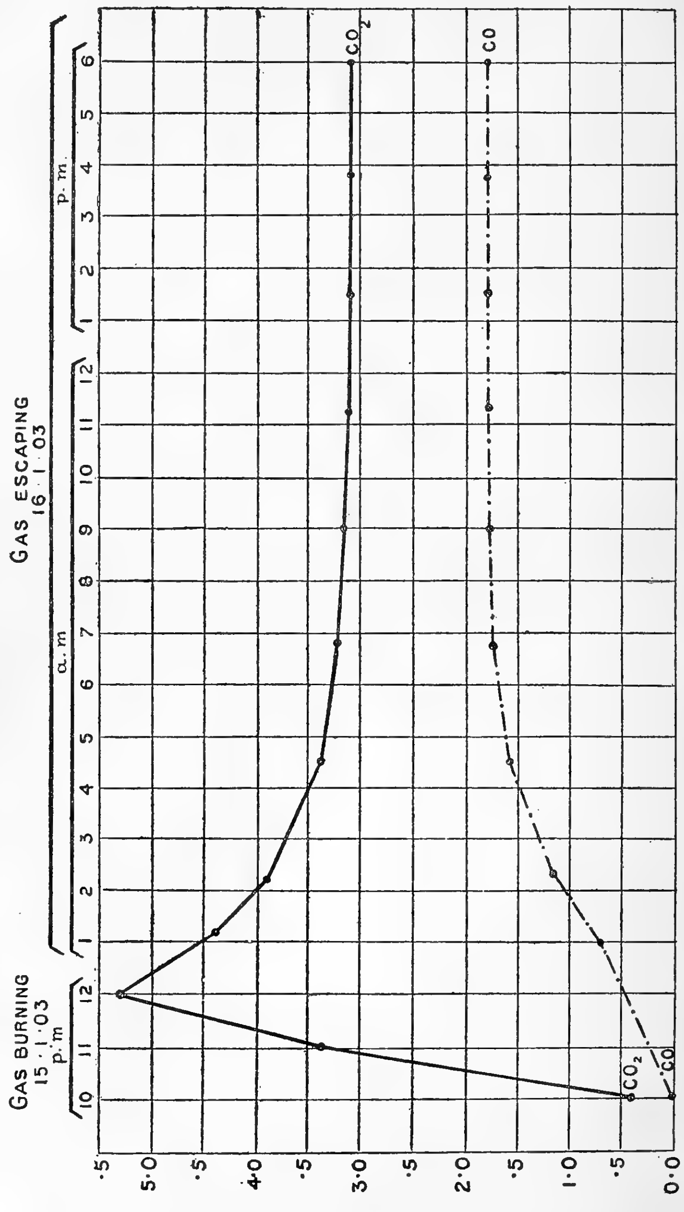
(3) The maximum percentage of CO which will be reached during the experimental period.

(4) How long it will be before the maximum percentage is reached.

It is assumed that the entering air is normal in composition, and that it at once and completely mingles with the air already in the room.

I have submitted this problem to a competent mathematical authority, who reports as follows:—The CO_2 introduced attains its maximum at the end of the first 2 hours, when it is 4·9 cubic feet. It then decreases during the 18 hours to practically 2·7 cubic feet. The change is more rapid at the beginning and very gradual towards the end. It is 3·51 cubic feet at the end of 2·25 hours, and 3 cubic feet at the end of 4·5 hours, so from this it changes very little.

As regards the coal-gas, the percentage goes on increasing all the time, tending towards the theoretical maximum which would be 11·25 cubic feet, containing 1·8 cubic feet of CO. That 11·25 cubic feet is the maximum is shown by the fact that the wastage



Graphic representation of content of room in cubic feet of CO_2 and CO during period of occupancy, and on the assumptions mentioned in the text.

per hour would be $\frac{11{\cdot}25}{2{\cdot}25}$ or 5 cubic feet, which is balanced by what is delivered per hour. The maximum is never actually reached; but at the end of 18 hours the quantity of coal-gas present is 11·246, containing 1,799 of CO, which is for all practical purposes the same. The curves show the percentage of CO and CO_2 present at the stated intervals, on the assumptions already stated.

Inasmuch, however, as the tap was not fully open, and therefore delivered less than 5 feet of gas per hour, they represent an over-estimate of the amount of carbon mon- and di-oxide contained in the room. Their value lies in a fact which they bring out, viz., that asphyxiation may be induced in a room where the proportion of carbon monoxide, *in the atmosphere as a whole,* falls short of 2 per cent. The fatal result was, no doubt, due to the carbon monoxide having been unequally distributed through the room, so that the two persons may, at times, have been breathing an atmosphere much more highly charged with the poisonous gas.

GROUP IV. (Case 10.)

The last case is of interest as illustrating the danger of badly-constructed arrangements for the rapid heating of bath-water—what are known as "Geysers." On the night of March 30, 1904, at about 9 o'clock, J. J. K., aged 29, pharmaceutical chemist, went to take a bath at his residence. About three-quarters of an hour afterwards, the female servant, who had been out on an errand, returned, and, on passing the bath-room on her way upstairs, noticed nothing particular.

Shortly afterwards, on her way down, she remarked a powerful odour of gas in the lobby. She saw the light in the bath-room shining through the muffed-glass door, knocked, could hear no sound, and becoming alarmed, sent for the caretaker, who burst open the door, when the body of the unfortunate young man was found lying just inside, in the narrow space intervening between the bath and the door. He was completely undressed, and the hair was wet. He had evidently been in the bath. So overpowering was the odour of gas that the caretaker was partially overcome, and with much difficulty dragged the body out into the lobby, where he applied artificial respiration, sending meanwhile for medical assistance. Dr. Herbert Byrne, the medical officer of the district, speedily arrived, and could only pronounce life extinct.

The necropsy, done by myself next day at the Coroner's request, revealed no trace of any disease in the body, which was that of a finely-developed young man. Rigor mortis extreme: the blood was still perfectly fluid, and bright cherry-red in hue. I may add that it was still uncoagulated a fortnight after collection. I was unable to detect much difference between a dilute solution of this blood and a similar one of normal blood (my own) after shaking with coal-gas to complete saturation. An accurate titration by Haldane's colorimetric method revealed the fact that the sample which I took from the right auricle was 87·3 per cent., and the sample from the left auricle 87·7 per cent., saturated with carbon monoxide.

I learn from Prof. Lorrain Smith, of Belfast, who kindly did the titration for me, that this is the highest percentage of saturation as yet seen in the human subject. There remained only one-eighth of the subject's hæmoglobin available for oxygen-carriage. The deceased would appear to have sat reclining in the bath until deprived of seven-eighths of his hæmoglobin, and on arising and attempting to step out, had fallen unconscious on the floor, where death must have speedily supervened.

Inspection of the premises.—A bath-room about 7 feet by 7, with a sloping roof varying from 6 to 7½ feet high. Most of the available floor-space was taken up by a full-sized metal bath and a pedestal w. c. which stood beside it, at the head end. At the other end was a chair, and there was just space to stand comfortably between the door and the side of the bath. The upper half of the wide double doors was glazed with muffed glass. They fitted tightly. On the other side of the bath was a large "French" window, which was closed at the time of the occurrence. On the same side of the room was an ordinary "Sheringham" valve, near the roof. Its flap was properly counterbalanced by a weight, and was described at the inquest as "slightly open" at the time of the occurrence. The "Geyser" was placed over the foot end of the bath. It consisted of a metal heater of about two gallons capacity, into which water was led through a pipe connected with the supply to the bath. From this receptacle a brass pipe opened over the bath. Underneath, in a space partly surrounded by a japanned metal jacket, but open in front, stood what might be described as a "battery" of six powerful Bunsen burners, which were supplied by a half-inch-bore gas-pipe, from which an ordinary wall-bracket was also taken off. The heated air and products of combustion were carried up round the sides of the boiler within an outer metal casing, which was contracted over the top of the boiler into a sort of funnel discharging them into the room. *There was no ventilation pipe.*

The ceiling was guarded by a metal disc from being blackened by the products of combustion discharged from the funnel. There was no safeguard whatever for the life of the luckless person who might shut himself up in this nearly air-tight space of 350 cubic feet, with six Bunsens capable of burning about 60 feet of gas, and, therefore, of consuming some 300 feet of air in a single hour! The poisonous condition of the air may be accounted for in various ways:—

1. One or more of the burners may have remained unlighted. All were on the same tap.
2. They may have "struck back."
3. The flames, by impinging on a cold metallic surface, may have had their temperature so much lowered that combustion became imperfect, and CO was consequently liberated.
4. The air in the bath-room may have become charged to such an extent with the products of combustion that the gas was only partly consumed, with consequent liberation of carbon monoxide.

Whatever may have been the immediate cause, the fact remains that had the Geyser been ventilated into the outer air, this young man's life would have been saved. Several similar mishaps have been recorded from the use of badly-ventilated apparatus for the heating of water. Two are referred to in the Appendix to the Report of the Water-gas Committee; and I have since come across a third, reported in the *Deutsche Medicinische Wochenschrift* for February 4th, 1904, by Dr. Scheven, throat-surgeon of Frankfurt-am-Main. The patient was taken unconscious from his bath, and, after some hours of active treatment (which comprised hypodermics of camphor, intra-venous injection of 1,500 ccm. of warm saline solution, artificial respiration, and inhalations of oxygen), he recovered. The bath was heated by a Geyser, which, on examination by an expert, was pronounced to be in good working order, but *which was not ventilated.* The bath-room was relatively large, 10 feet high, and with a capacity of 660 cubic feet. Dr. Scheven's theory is, that so large a consumption of gas as is needed for the rapid heating of the bath-water must necessarily diminish the oxygen content of a small enclosed space to such an extent as to lead to imperfect combustion and formation of carbon monoxide. In order to test this, he fixed a number of candles at varying heights in the bath-room, and set the Geyser going. *In ten minutes all the candles were extinguished.* His second experiment consisted in hanging up a cage, containing a large white rat, 19 inches from the roof. A second cage, containing two smaller rats, was put on the floor. The Geyser was then set going; and on entering the room in twenty minutes—the time necessary to prepare a full bath—the rat in the upper cage was already dead, whilst the two animals in the cage on the floor were lying on their side quite unconscious, but still breathing. They recovered in three-quarters of an hour. The large rat in the upper cage was examined, and *found to present the typical signs of carbon monoxide poisoning.* I am unable to say whether the gas supply of Frankfurt contains an admixture of carburetted water-gas; but, in any case, the fact remains that unventilated Geysers are distinctly dangerous, and should not be allowed.[1]

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[1] On this day (19th May, 1904), in the act of preparing the MS. of this paper for the press, I see in the English daily papers the account of a similar accident from the use of a Geyser at Birmingham. A nurse-maid was engaged in bathing two children, when all three became unconscious, and the younger child slipped into the bath and was drowned. The medical evidence showed the presence of carbon monoxide in the blood, and attributed the sudden unconsciousness of the other two persons to the same cause. *The Geyser was unventilated.*

Concluding Remarks.

Carburetted water-gas is convenient, cheap, and can be more readily and quickly produced in large quantities, to meet sudden emergencies, such as might be caused by fog or by the breakdown of an electric system of lighting, than coal-gas. For these reasons I believe that *it has come to stay*; and I should be the last person to reproach a Gas Company for availing itself of so important an improvement in their procedure. My reason for writing this paper is to warn the public that in dealing with this gas greater precaution is required than in dealing with ordinary coal-gas. The experience of the great American cities shows that where the illuminating-gas consists nearly altogether of water-gas, accidents have increased between fifty- and one hundred-fold from its use. The delivery into houses of so poisonous a gas likewise affords undesirable possibilities for suicide, and even for homicide—facilities which, it would seem, are being increasingly availed of in the United States.

In view of the fact that whilst little or no danger results from the leakage of ordinary gas, considerable danger does result from leakage of gas containing a considerable proportion of water-gas, the rational and proper course of procedure would, I think, be for the sanitary authorities to take action in the matter. The action which I suggest they should take comprises the following steps:—

1. To require of companies or persons selling gas to make notification beforehand of their intention to increase the proportion of the poisonous constituent (carbon monoxide) in such gas.

2. To require of such companies or persons that the said poisonous constituent shall not at any time exceed a certain proportion, say 15 or at the utmost 20 per cent. of the total volume of the gas supplied.

3. To require that when gas containing the full admissible proportion of the said constituent is being supplied, this shall only be *during the day*: the proportion supplied at night (when people are asleep, and the danger therefore greater) not to exceed 10 per cent.

4. To require of gas-producing companies that a daily statement be made of the proportion of carburetted water-gas supplied.

5. To introduce in their gas-testing stations apparatus for testing the coal-gas as regards its content in carbon monoxide, and employ expert chemists to apply the test at stated intervals.

6. To require of gas-producers an account of the percentage of gas unaccounted for, the consumption of which cannot be traced. This would afford some measure of the leakage through broken or defective mains. (See the first group of cases in this paper.)

7. To direct constables on duty to take special note of any odour of gas arising from excavations in the streets, and report thereon.

8. To institute an inspection of gas-fittings, especially with regard (*a*) to taps unprovided with a stop, and therefore capable of being turned right round, so as to turn on the gas again in the act of cutting it off, and (*b*) to stoves and Geysers not provided with proper ventilating pipes or flues carried out to the open air.

So far as I am aware, the existing law does not enable sanitary authorities to take such steps, and special legislation would therefore be required, except in regard to recommendation No. 8, which refers to defective fittings, as stoves, Geysers, gas-cookers, &c. These might be brought under the provisions of the Public Health Act (Ireland), 1878, section 107, and dealt with as nuisances.

In conclusion, I may say that I do not desire in any way to excite public alarm on this subject, or to interfere with the legitimate prosecution and development of the gas-making industry. Having had the dangers of inhaling the gas, as recently manufactured, so forcibly brought under my notice, I have thought it well to bring the results of my observations under the notice of members of the Royal Dublin Society. I am convinced that should the question come to be looked upon as one of public inquiry, legislation will not fail to follow.

I wish finally to express my sense of very special indebtedness to Professor Lorrain Smith, M.D., of Belfast, who kindly checked my results in determining the percentage saturation with carbon monoxide of the several samples of blood. I have also to thank the City Coroner and the Registrar-General for information courteously placed at my disposal.

XXIV.

PHOTOGRAPHS OF SPARK-SPECTRA FROM THE LARGE ROWLAND SPECTROMETER IN THE ROYAL UNIVERSITY OF IRELAND. PART III.[1]: THE ULTRA-VIOLET SPARK-SPECTRA OF PLATINUM AND CHROMIUM.

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[Read, March 19; Received for Publication, March 22; Published, Sept. 17, 1904.]

The wave-lengths of the lines in the ultra-violet spark-spectra of the metals platinum and chromium, which form the subject of this communication, have been calculated from measurements made from photographs of the first order of spectra, reproductions of which have been published in Part I. of this work.

The measurements have been made by means of a light microscope, mounted on a stage which can be moved through a space of about one inch long by a short micrometer screw. Each line has been measured at least twice, and many of them three and four times.

Kayser's measurements[2] of well-defined lines in the arc-spectrum of platinum have been employed for standards. The conditions under which the photographs were obtained are described in Part I., and it is only necessary to state that the spectrum of platinum was derived from a pure specimen kindly presented to the author by Messrs. Matthey and Johnson. The chromium spectrum was obtained by sparking a saturated solution of pure potassium chromate between platinum electrodes.

In the cases where the calculated wave-lengths of the intermediate platinum lines have shown a close agreement with those by

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[1] For Part I. see Trans. Roy. Dublin Soc., Vol. vii. (Ser. ii.), 1901, p. 331, and for Part II., see Sci. Proc. Roy. Dublin Soc., Vol. x. (N.S.), Part I., No. 3, 1903.

[2] Kayser, Konigl. Preuss. Akad. d. Wissench. Berlin, 1897.

Kayser, the latter observer's numbers have been adopted. In those cases in which they have not agreed, they have been confirmed, or corrected, by re-measuring the lines with a microscope and eye-piece micrometer, by Zeiss, the photographic plate being mounted on a carriage actuated by a micrometer screw. The lines were measured in reference to a standard scale formed by the lines of a photograph of a *réseau* belonging to the Observatory of Cambridge University.

In the author's photographs of the platinum and chromium spectra 443 lines have been measured between the two extreme limits of wave-length 2229·45 and 4560·21 in the former, and 1283 in the latter. Kayser gives between the same limits the wave-lengths of 497 lines. Exner and Haschek[1] have given in their list of the chromium lines, between the above limits of wave-length, measurements of 2027 lines.

The author again has to acknowledge his indebtedness to Miss M. Hall for the very valuable assistance she has given in the work of making the micrometer measurements, and of calculating from them the wave-lengths recorded in this communication.

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[1] Kais. Akad. d. Wissensch., Wien, Sitzungsb. Math.-Naturw. Cl., Vol. cvi., 1897, p. 1133.

PLATINUM.

KAYSER.	ADENEY.	KAYSER.	ADENEY.
	2229·45		2381·95
	35·46	2383·73	83·73
	45·65		84·47
	50·76		86·52
	51·63	86·89	
	53·33	87·45	87·44
	56·20	89·62	89·61
	62·73		90·14
	63·37		90·92
	64·08	91·86	
	66·63	96·24	96·24
	67·55	96·76	96·77
	74·53	2401·09	
	81·53	01·96	2401·96
	87·63	03·18	03·18
	88·38		05·84
	92·55		10·39
	96·03	13·14	
2305·72			17·82
08·12	2308·12		18·14
	10·97	18·15	
	13·04	20·91	20·91
15·58	15·58	24·96	24·96
18·37	18·37	26·52	
	19·96	28·21	28·21
26·19	26·30	29·19	
	28·60		29·42
31·05		34·55	34·55
	39·58	36·77	36·77
40·26	40·26	39·53	
	42·87	40·16	40·16
43·47	43·36		42·72
46·82			45·60
47·24		50·53	50·53
	48·62	51·05	
53·12			55·22
56·42		60·16	
57·18	57·18	61·47	
57·66		67·50	67·50
	63·93	69·54	
	65·37	71·09	71·06
	66·55	73·25	
68·36	68·36		75·94
	71·68	77·37	
	77·28	81·27	
	78·04		82·05
	78·77	83·31	83·33
80·04		83·45	
	81·45	87·26	87·26

KAYSER.	ADENEY.	KAYSER.	ADENEY.
2488·82		2608·33	
	2489·01		2612·94
90·22	90·23	13·20	
	92·64	13·34	
	93·30	14·70	
95·91	95·91	16·84	16·84
97·20		19·67	19·67
	97·98	19·98	
98·59	98·59		
2500·90			21·12
03·08			21·63
04·13		25·42	25·42
	2505·95	27·48	
06·01		28·12	28·11
08·59	08·53		35·03
10·60		35·37	
14·00	14·00	39·43	39·43
14·17		45·45	
15·12	15·12	46·97	46·97
15·67	15·66	50·94	50·91
17·27		53·87	
20·36		56·91	
22·62		58·27	58·28
23·11		58·79	58·79
	24·42	59·54	59·54
	26·10	64·72	
29·50	29·50	68·75	
36·07		73·71	
36·58	36·60	74·65	74·65
38·36			76·95
39·29	39·29	77·23	77·23
41·43			79·22
44·04		86·99	
44·81		88·35	88·35
46·56			89·52
46·99			92·32
48·19		94·31	
49·55		96·07	
	51·36	98·50	98·50
52·33		2701·21	
60·44		02·48	2702·48
64·26		05·99	05·99
	68·62		11·03
72·72	72·72	13·22	13·20
74·58		14·61	
	78·51	15·87	
	81·30	17·71	17·71
82·42		19·13	19·13
	83·38		21·97
87·89		25·43	
96·08	96·08		26·52
99·15		30·00	30·00
99·99			30·86
2602·18		33·73	
03·22	2603·22	34·06	34·06
06·13		34·58	34·57

KAYSER.	ADENEY.	KAYSER.	ADENEY.
	2735·81	2814·12	2814·12
2736·89			17·21
37·66		18·35	
38·57	38·54	18·74	
	43·54		18·95
44·93		21·18	
47·70	47·70	22·27	
	49·32	22·60	22·58
53·85			23·34
53·96	53·96		24·44
54·33		25·19	
55·00	55·00	30·40	30·42
	57·58		31·64
57·80		31·98	
58·16			33·60
58·33		34·82	34·78
59·42		37·34	
63·30	63·38	37·64	
66·76		39·35	
	69·10		42·08
69·94	69·94		44·35
71·75	71·72		45·32
72·93			47·97
	73·35	48·41	
73·70		49·24	
74·10	74·10	53·21	53·20
74·31		53·48	
74·88	74·88	54·78	
76·11		55·87	
76·86			58·46
77·56			60·73
	82·30		65·07
	82·80		66·12
88·73	88·71		66·92
90·59		68·79	
90·99			70·31
93·37	93·37	70·57	
93·74			75·11
	93·84		75·80
94·30	94·30		77·46
	95·62	78·82	
96·17		84·58	
	97·88	85·45	
	98·29		85·56
	2800·10	88·31	88·31
2800·56		90·50	90·51
	02·77	91·03	
03·34	03·34	91·17	
06·15		91·87	
07·40		93·34	93·34
08·60		93·98	93·98
	08·93	96·25	
	09·72	97·99	97·97
10·92		99·76	99·78
13·08		2900·90	
	13·45	01·28	

KAYSER.	ADENEY.	KAYSER.	ADENEY.
2901·80			2987·00
03·13		2988·18	
04·26		88·91	
06·00	2906·03	89·92	89·92
08·01	08·05	94·92	
08·93		98·09	98·09
10·57			99·18
11·89		3001·30	3001·30
	12·30	02·39	02·39
12·88		03·40	
13·36		04·27	
13·66	13·64	05·91	
	14·22		07·87
14·44		10·05	
15·28		12·50	
16·51			12·70
19·45	19·45	14·64	
21·34		15·01	
21·50	21·50		15·32
22·38			17·40
	23·45	17·45	
	25·32	18·00	18·00
27·04			19·12
	27·81	19·96	
28·23	28·23	22·96	22·96
29·90	29·90	24·41	24·41
30·90	30·90	25·18	
	31·70		25·34
33·84		25·67	
38·94	38·94	26·45	26·45
41·22			31·36
41·91		36·55	36·55
42·88	42·88	39·61	
44·88	44·88		41·25
	46·38	41·32	
48·84		42·75	42·75
49·90			47·31
50·93		48·60	
51·34		54·40	
	55·93	54·80	
58·65	58·65	55·40	55·40
59·22	59·22		56·13
59·83		56·72	
60·86	60·84	59·75	59·75
	62·10	61·91	
67·60		62·30	
69·97		62·85	
	73·84	64·83	64·83
74·25		69·21	
78·18		70·37	
	79·26	72·04	72·04
	79·86		74·25
82·41		74·94	
83·88	83·88	75·12	
84·57			76·12
	85·46		76·80

KAYSER.	ADENEY.	KAYSER.	ADENEY.
3078·95			3194·44
79·67	3079·67		98·09
81·17	81·17	3199·08	
	82·55	99·22	
82·78		3200·85	3200·89
84·22	84·20	04·17	04·20
84·98		07·35	
87·32		08·97	
88·68		12·50	
89·78			12·60
	97·16	18·60	
98·89		18·97	
3100·15	3100·10	20·90	
01·08	01·08	21·42	
02·71		22·68	
03·23		22·93	
03·70			24·16
	03·80	27·31	27·35
04·17		30·40	30·42
	04·70	33·55	33·53
	09·40		39·43
12·72		40·32	40·31
	16·85	41·65	
	18·14	43·22	
18·55		43·53	
19·91			43·82
22·19		47·39	
23·07			47·67
	27·04	48·62	
32·19		48·84	
33·44		50·48	50·48
33·79		52·12	52·12
34·41		52·79	
	35·45	53·32	
36·38		55·36	
39·50	39·50	56·05	56·05
41·77	41·77	56·63	
	44·13	58·55	
	45·09	59·28	
54·86		59·87	59·86
56·69	56·69	61·20	61·13
	59·20	61·82	61·84
59·84		63·74	
60·31			65·40
	67·55		67·25
69·01		68·56	68·56
74·96	74·85		73·29
76·08			74·17
77·71		82·10	82·10
	79·11	83·34	
	79·52	83·44	83·44
79·65			84·99
	88·24	85·37	
	91·23		85·97
91·60		87·25	
92·64	92·64		88·20

KAYSER.	ADENEY.	KAYSER.	ADENEY.
3290·36	3290·36	3491·16	3491·15
93·62			92·20
93·82		98·32	
98·69			3501·70
3300·07			03·83
	3300·29	3505·85	05·85
02·02	02·00	14·87	14·87
11·50			21·57
11·96			23·80
12·61	12·65		26·92
13·19		28·70	28·70
15·19	15·18		32·90
23·91	23·94		34·48
	25·68		36·14
25·86			48·69
27·23			51·57
	29·60		60·60
	32·24		61·97
38·21			65·10
	38·34		72·18
	40·22		77·43
42·43			87·55
44·03	44·03		3605·12
	54·22		08·02
	55·77	3611·06	11·06
	57·05	15·44	
67·14	67·14	21·84	21·84
68·63			25·30
	71·00	28·28	28·28
72·96		29·03	29·03
	74·09		37·32
	77·38	38·96	38·96
	83·91	43·33	43·32
3406·73		52·41	52·41
08·29	3408·29	54·13	54·19
14·61			54·89
17·23	17·23	59·57	59·57
18·31		63·24	63·24
20·49			64·32
26·89	26·89		68·20
28·08	28·08	68·56	
31·50		72·17	72·15
32·00	32·00	74·21	74·19
	47·92	75·11	75·09
48·52			75·96
	53·98	81·23	81·25
54·29		83·17	83·16
	55·96	87·58	87·58
	57·22	3700·07	3700·05
64·10		06·69	06·66
72·08			30·42
	76·80		66·55
	77·70		68·56
83·59	83·59		3801·20
85·43	85·43		08·18
88·88			12·58

KAYSER.	ADENEY.	KAYSER.	ADENEY.
	3813·48	4247·84	
	15·22	51·28	
	16·04	63·66	4263·66
3818·83	18·83	69·41	
	68·59	74·04	
	75·87	81·91	
98·88	98·90	88·22	88·22
3900·87	3900·87		88·45
03·86		91·07	
04·53	04·53		4302·60
	06·22	4327·24	27·24
06·43		34·83	34·83
11·05	11·04		37·00
23·11	23·12	43·85	
25·48	25·48	58·52	58·52
	33·83 Ca	64·62	64·62
48·55	48·55		72·10
53·78		92·00	92·00
66·51	66·51	4411·58	
	68·59	14·42	
	70·28	37·47	
76·46		42·73	4442·73
80·75		45·71	
96·72		73·63	
4002·65		81·81	
	4046·55	84·88	84·88
54·93		93·35	
	61·68	98·93	98·93
	65·95	4511·42	
66·09			4514·33
81·63	81·63	21·10	21·10
92·43		23·19	23·19
4118·85	4118·85	48·06	48·06
	48·50	52·12	
64·71	64·71	52·59	52·59
92·58	92·55	54·76	54·76
4201·37		60·21	60·21
	4226·85		

CHROMIUM.

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XXV.

THE PRE-GLACIAL RAISED BEACH OF THE SOUTH COAST OF IRELAND.[1]

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(Plates XXIII.–XXXI.)

[Read, February 16 ; Received for Publication, March 18 ;
Published, September 12, 1904.]

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Part I.

Part II.

PART I.

1. Introduction.

The attention of workers on the Pleistocene Geology of Ireland has up to the present been mainly concentrated on the glacial and post-glacial deposits of the country. With regard to its condition immediately before the advent of the ice, little, however, is known. Indeed, it is only in that part of Ireland which has been most neglected by glacial geologists that there existed a condition of glaciation sufficiently feeble for the ample preservation of unconsolidated deposits laid down prior to the boulder-clay. Such an area was not likely to attract those who, as pioneers in the study of the glaciation of the country, naturally preferred to work in districts where the phenomena were more marked and striking.

During the examination of the drifts of Cork by the Geological Survey in the year 1903, some raised-beach deposits, obviously older than any boulder-clay of the district, were found fringing

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[1] The observations relating to the neighbourhood of Cork Harbour are communicated with the permission of the Director of H. M. Geological Survey.

the shores of the Harbour. It was at once recognised that a wider investigation was desirable, and we employed our leisure in visiting various points on the south coast at which the conditions seemed promising for the preservation of the beach.

The action of the land-ice on the coast from Clonakilty to Carnsore Point has been comparatively feeble; and where recent marine erosion has not proceeded too far, the beach is in consequence well preserved. West of Clonakilty, however, we get too near the Kerry and West Cork centre of dispersion of the land-ice for such preservation to be possible. The rock-shelf of the beach can, however, be traced as far as Baltimore, this being the most westerly point at which search was made for it.

Although never properly investigated, the deposits in question did not remain entirely unnoticed by former geologists. In the Geological Survey Memoir, on Sheets 185 and 186, published in 1861, Jukes has a brief but accurate account of the head and raised-beach gravels. On the 6-inch working sheet, No. 99, County Cork, he has a sketch of the section at Ringabella, shown in Pl. XXVII., and the note, "Small raised sea beach about 8 or 10 feet above ordinary high-water mark." The sections at Ballymadder Point, County Wexford have already been described by Mr. G. H. Kinahan in the Geological Survey Memoir on Sheet 181.

2. GLACIATION.

It is now widely recognised that a large portion of Ireland was, during the Glacial Period, covered by an ice-cap, which had its centre of dispersion somewhere in the neighbourhood of Fermanagh. The ice moved from this centre in a south-easterly direction over Cavan, Meath, Dublin, and Kildare to the east coast. This stream seems to have divided into two on the north-westerly flank of the Wicklow Mountains. The westerly branch went south through Kildare and Queen's County, and merged with the stream which passed over Kilkenny into Waterford, where the striæ indicate ice-motion from north to south out to sea. The easterly branch was deflected south near Kingstown, and helped to swell the ice which moved in a southerly direction along the coast of Wicklow and Wexford. The cause of this deflection was the existence, in the basin of the Irish Sea, of a more or less independent ice-sheet, which overflowed through St. George's Channel, and passing across the south-east corner of Wexford, spread along the south coast of Ireland at least as far as Power Head in County Cork. The evidence in the neighbourhood of Dublin tends to show that this 'Irish Sea Ice' attained its maximum development shortly before that of the centre of Ireland.[1] This is borne out by the sections on the south coast at Dungarvan and Ballycroneen (County Cork). In the former place, the marly boulder-clay of the Irish Sea Ice is overlain by that which came from the north; and in the latter, by a boulder-clay similar to that seen around Cork, and which the striæ show to have been laid down by ice moving from west to east across the Harbour. This ice apparently had its centre of dispersion in Kerry or West Cork, as striæ in a similar direction have been observed in the valley of the Lee at Macroom and Gougane Barra, and there is a gradual swinging round from an easterly to a southerly direction as we proceed along the coast from Cork to Baltimore.

It will be seen from these considerations, and on consulting the map (Pl. XXXI.), that the direction of the ice-motion on the south coast was generally off-shore. The deposits, owing to their position in the lee of the cliff, were thus protected from erosion by the ice, the action of which, as pointed out above, was comparatively feeble over the greater portion of the area.

In order to give an idea of the mode of occurrence of the preglacial[2] deposits thus preserved, we shall, before proceeding to a general account, describe a few characteristic sections. The first, that in Courtmacsherry Bay, is typical of those areas which the inland ice alone appears to have invaded. The second, in Ballycroneen Bay, is of interest as being within the debatable ground which appears to have been first occupied by ice from the Irish Sea Basin. The third furnishes a proof of the pre-glacial age of the old rock-platform, independent of the mere superposition of the boulder-clay.

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[1] This result is in accordance with Mr. Lamplugh's conclusion that the centre of greatest accumulation over the British Isles shifted westward and south-westward during the period of glaciation. See "Geology of the Isle of Man"—Mem. Geol. Surv. U.K., 1903.

[2] The term 'pre-glacial' is used throughout the paper to signify 'prior to the deposition of the boulder-clay of the area in question.'

3. TYPICAL SECTIONS.

Section in Courtmacsherry Bay.—Along the greater portion of the northern shore of Courtmacsherry Bay stretches a remarkably smooth platform of rock about 5 feet above high-water mark. At a varying distance from its seaward edge it disappears beneath a mass of drift. The drift deposits lie on the water-worn platform, and are banked against a cliff or slope of rock which rises from behind them to a height of 150 feet above O. D. They are packed into the angle between the platform and the cliff, and form a terrace of varying width. About 350 yards east of the Coastguard Station at Howe's Strand, the drift-cliffs present the following section :—

	Feet.
Upper head (rubble and soil), ...	2
Boulder-clay, ...	10
Lower head or rubble-drift, ...	5
Stratified pebbly raised-beach sand, lying among sub-angular blocks of rock, ..	1½

Water-worn rock-platform.

The succession and relation of the deposits to one another are shown in the following diagram :—

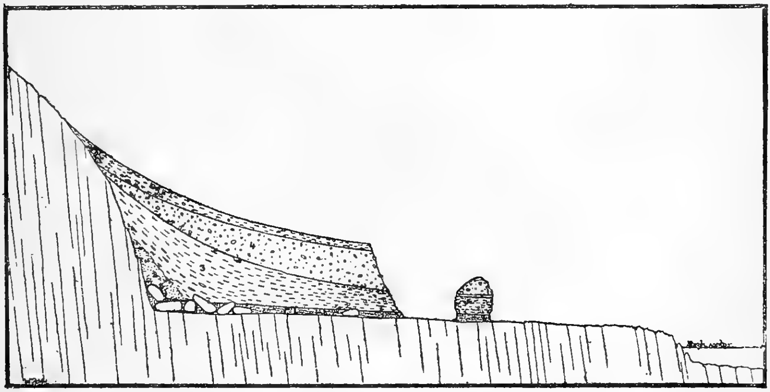

FIG. 1.—Diagram of Section in Courtmacsherry Bay.

1. Raised-beach gravel and blocks.
2. Blown sand.
3. Lower head.
4. Boulder-clay.
5. Upper head.

The rock-platform is cut across the edges of the highly inclined black slates and sandstones of the Carboniferous Slate series. It has a smooth, water-worn surface, sloping gently seaward, and at its outer margin drops more or less steeply on to the modern shore. It is raised about 5 feet above high-water mark of ordinary spring-tides.

The blocks which lie on the platform embedded in the beach-sand sometimes attain a length of 10 feet. They are sub-angular, and even rounded in form, and have obviously been subjected to a certain amount of erosion by wave action. They are of similar nature to the rocks in the pre-glacial cliff above, having fallen from it during the formation of the beach. They probably mark a period when undercutting of the cliff was still in progress.

The raised-beach sand rests on the wave-worn platform, and consists chiefly of small oval flakey bits of the local black slate, lying flat, and cemented by oxides of iron ('ferricrete'). The pebbles occur in rows in the sand; all are well rounded, and most of them consist of vein quartz. The whole deposit is well stratified, and obviously water-sorted.

The blown sand overlies the beach-gravel and blocks, and is banked against the old rock-cliff, behind the head, which has obviously slipped down little by little over it. The sand is tolerably free from admixture of rubble.

The lower head consists of fragments of black slate and angular lumps of vein quartz. The slate fragments are all perfectly angular, and are bounded by cleavage and joint planes. Consequently the common shape is that of slabs or plates which lie flat in the deposit, and impart a sort of rude stratification to it when seen from a distance.

The boulder-clay is a stiff, grey, unstratified clay, containing a variety of stones which lie in all positions in it, and have been derived from the Carboniferous Slate and Old Red Sandstone. The boulders exhibit different degrees of rounding, and the harder ones are often striated.

The upper head is, like the lower, composed of angular slate fragments, but also contains a small number of sub-angular and rounded stones.

A short distance from the section described above, a stack about 10 feet high stands on the raised-shore platform, and exhibits the following section:—

	Feet.
Boulder-clay, ...	4
Lower head, ...	5
Black sand and pebbles (of slate and quartz) in lines, ...	1–2
Platform.	

It now stands about 5 yards from the cliff, and shows that at one time the drifts covered a considerably larger extent of platform than at present (see Plate XXIII.).

It is worth noting in this connexion how seldom any erosion of the drifts is effected by the waves. Vegetation often obscures the cliff to its very base, and even spreads out on the platform, which is always overgrown by lichens (see Plate XXVI.). It seems to be swept by waves only at high tide during storms with an on-shore wind.

The superposition of the boulder-clay proves the pre-glacial age of the lower head and raised beach. The lower head, in its turn, marks a period before the oncoming of the ice, when *débris* from the old sea-cliff accumulated on the beach, after it had been raised above the reach of the waves. The occurrence of blown sand close down to the rock-platform indicates that elevation commenced before the head began to accumulate.

Three-quarters of a mile to the east of the section just described, where a road descends on to the shore, the section in the cliffs is as under:—

	Feet.
Boulder-clay, ...	26
Sand and gravel, ...	7½
Rock-platform.	

At the base, and resting on the platform, there is a thickness of 3 feet of coarse gravel, which is succeeded by beds of fine and coarse sand, with layers of well-rolled pebbles. Not only is the sand sifted into beds of different degrees of coarseness, but the pebbles are fairly well sorted into sizes. A few pebbles of distant origin were picked out of the gravel (see p. 261).

The boulder-clay is of a greyish colour, and contains numerous small pieces of slate as well as larger striated stones, all of which seem to be derived from the Carboniferous Slate and Old Red Sandstone.

Although the section at this point is incomplete, it is, perhaps, the finest exposure of the beach-deposits on the coast (see Plate XXIV.).

Section in Ballycroneen Bay.—East of the Coast-guard Station in Ballycroneen Bay, the following section can be made out:—

	Feet.
Reddish clay and stones, ...	7
Fine loamy sand with stones, ...	8
Marly boulder-clay, ...	20
Head, ...	6–12
Rolled gravel and sand, ...	1–2

Platform.

The marly boulder-clay is a tough, greenish-grey clay containing shell fragments, and small stones of local and distant origin. It is overlaid by a very fine loamy sand with numerous angular and sub-angular local stones and a few rounded erratics. Above this, and graduating into it, is a red, sandy boulder-clay, similar to that of Cork, which, as pointed out above, has been deposited by ice coming from the west. The marly boulder-clay, on the other hand, can be traced eastward into County Wexford, and thence northwards to the neighbourhood of Dublin, being undoubtedly the boulder-clay of the 'Irish Sea Ice.' The 'West Cork Ice' seems to have advanced over ground once occupied by the 'Irish Sea Ice'; this overlapping of the characteristic boulder-clays of these sheets taking place along a limited area near their junction.

The section shows clearly that the beach-deposits and head were formed prior to the occupation of the ground by the 'Irish Sea Ice.'

Section in Ringabella Bay.—An extreme modification of the cliff-sections arises when all the deposits are eliminated but the boulder-clay. It thus comes in contact with the platform which is glaciated beneath it. On the north side of Ringabella Bay the platform attains a width of 40 to 60 yards, and has a remarkably level surface. The boulder-clay, which is banked against the cliff behind, thins gradually seaward for a distance of 20 or 30 yards, where it ends abruptly in a small cliff 3 or 4 feet high, leaving the rest of the platform uncovered. The surface of the rock is beautifully polished and striated, and forms a remarkable contrast to the water-worn appearance it usually presents. The striæ run in an approximately eastern and western direction, nearly parallel to the shore, so that they could not have been formed by soil-slip, even if their nature were such as to render this explanation possible. Thus, the proof of the pre-glacial age of the platform does not depend merely on the superposition of the boulder-clay (see Plate XXV.).

4. GENERAL ACCOUNT OF THE RAISED-SHORE PLATFORM AND OVERLYING DEPOSITS.

The most persistent relic of the raised-beach period is the *buried rock-cliff and shore platform.* The platform, as already described, presents a smoothed, slightly undulating surface, which slopes seawards from the foot of the buried cliff, usually at angles varying from 3° to 10°. Where the inner margin of the platform is exposed, it is rounded off into the cliff, and the wave-worn surface of the platform is prolonged 3 or 4 feet up the face of the cliff. This feature, it need hardly be pointed out, is to be seen everywhere on a modern shore where the sea washes the foot of the cliff at high tide.

In Courtmacsherry Bay, about 500 yards east of Howe's Strand Coast-guard Station, the surface of the platform is channelled from north to south by furrows which pass under the ferricrete sand of the raised beach. The furrows run down the slope of the platform across the strike of the rocks, and seldom seem to coincide with a joint or other line of weakness. They appear to have been produced by the washing of gravel and sand backwards and forwards across the shore; but, whatever their origin, it is to be noted that similar furrows are to be seen in many places on the present shore, where the rocks have been cut down to a nearly level surface (see Plates XXIII. and XXVI.).

In comparing and contrasting the pre-glacial with the modern shore, it became very evident that on the former the rocks were reduced to a much more uniform level. Hard beds do not stand out so conspicuously; and stacks and knobs of rocks, so often found on the modern shore, are seldom seen projecting above the general level of the pre-glacial one. In two general cases only does the modern shore exhibit as plane a surface as the pre-glacial one; first, when the rocks are very soft and easily eroded; and secondly, when the seaward portion of the pre-glacial platform forms the modern shore.

The cause of this is to be found in the much slower advance of the sea during the raised-beach period. It had then, in extending the upper margin of the platform, to undermine a cliff, in most places over 100 feet high. At the present day it has only to remove the 12 feet, more or less, which represents the difference in level between the recent and pre-glacial shores. The former is, as a consequence, much less mature than the latter; or, in other words, it is reduced somewhat less below high-water mark at the present day than the pre-glacial platform was below high-water mark at the time of its completion.

In measuring the height of the raised-beach it was found impossible to obtain a datum which could be used everywhere and at any state of the tide. In some places the high water of mean or ordinary spring-tides was available; in others, the upper growth limit of *Balanus* and *Fucus* was used; or again, where the rocks have been sufficiently eroded, the inner edge of the present shore-platform was employed. Measurements made from this last line to the corresponding margin of the pre-glacial platform are particularly useful, as they serve to indicate the amount of elevation of the beach. Owing, however, to the want of maturity of the present shore, they are likely to give an under-estimate of the elevation.

Near Ballinglanna Cove in Clonakilty Bay the pre-glacial platform was found to be about 10 feet above the present shore (see Pl. XXIX.). In a small bay, five furlongs east of Howe's Strand Coastguard Station (Courtmacsherry Bay), the inner edge of the pre-glacial platform is 10 feet above the corresponding part of the shore-platform; and a similar difference of level was found a quarter of a mile east of Ballycroneen Coastguard Station.

A number of observations, taken with reference to high-water at ordinary spring-tides, showed that the exposed part of the pre-glacial platform was generally about 5 feet above this line. Details are given in the sequel.

Occasionally a water-worn surface is found at rather higher levels. This may be due to hard beds of sandstone or grit forming the platform, or to a buttress of rock at the foot of a point which projects forward from the pre-glacial cliff. In Powerhead Bay, where the platform is cut in grits with thin slates, it rises at one point to a height of 15 feet above the modern beach-shingle. At the north end of White Bay (Cork Harbour entrance) the pre-glacial beach attains the unusual height of 15 feet above high-water mark of ordinary spring-tides. The beach may be traced eastwards round Carlisle Fort, and southwards towards Roche's Point, in both of which directions it gradually regains its ordinary level. It, therefore, cannot be regarded as a beach of different age, marking a period of greater submergence.

The extraordinary height to which the beach rises in the north-east corner of this bay seems to be connected with the fact that a valley, which reaches the coast here, has on one side of it a broad, terrace-like feature which slopes towards the sea. The beach-gravel, which seems to have been driven up by the waves on to this terrace, might be considered as a storm-beach.

Sections near Camden Fort, and again in Courtmacsherry Bay, are noted in the sequel in which the beach seems to have been thrown up above the level at which it is commonly found.

In many of the bays the buried cliff recedes inland; and the platform, owing to its seaward slope, sinks to a low level where it is exposed on the coast. West of Simon's Cove, in Clonakilty Bay, where the platform is about 50 yards broad, the lower half of it is covered at high tide. At Donaghmore, in the same bay, the buried cliff is nearly 50 yards behind the present cliff of boulder-clay and raised-beach shingle. Here the pre-glacial platform forms the modern shore, and high spring-tides reach up to the foot of the drift-cliffs. In Ballycroneen Bay the pre-glacial cliff retreats as much as 200 yards inland. In this case the base of the lower head is below high-water mark, and the cliffs are being worn away at a comparatively rapid rate.

When due allowance is made for the formation of storm-beaches and for the recession of the pre-glacial cliff into the drift-filled bays, it is found that the beach maintains a remarkably uniform level. In all the sections visited on the Wexford coast, the beach-gravel appeared to be rather lower than in the western sections. As, however, so little was seen of the inner margin of the shore-platform, and as the amplitude of the tide is somewhat greater here than on the Cork coast, it is difficult to be certain on this point. The difference in level between the pre-glacial beach and the modern one appears to be about 12 feet.

The *beach-deposits* consist of stratified gravel and sand commonly cemented into a hard conglomerate or sandstone by oxides of iron (see Pl. XXX.). They vary in thickness from a few inches to 12 feet. Shingle is usually found near the buried cliff, whilst further seawards there is generally a bed of gravel overlain by fine sand or sand with pebbly layers. The pebbles have smooth worn surfaces, and, especially in sections on the open coast, take the form of flattened ellipsoids—a shape characteristic of pebbles subject to continued wave-action on a beach. The sand varies from coarse to fine; but the grains forming any particular bed are of about equal size. The sorting of the material into sizes is also noticeable in the gravel. In sections at right angles to the trend of the coast-line, the bedding is often seen to dip seawards at angles slightly greater than the slope of the platform. This structure is particularly well seen in a section 80 yards south of Myrtleville Cottage, Crosshaven (see Plate XXVII.). The section is also of interest on account of Jukes having sketched it on the 6-inch map deposited in the Geological Survey Office, and noted that it was a "small raised sea-beach about 8 or 10 feet above ordinary high-water mark."

The shingle and sand are almost entirely composed of the local rocks. In some places, indeed, the sections were searched over long stretches of coast without bringing to light any foreign pebbles. In others, however, a small proportion of flints and igneous rocks occurred. The search made was by no means exhaustive, owing to the very limited time available at each section, nor can the list given below be taken as indicating the relative proportion in different places. It can be definitely stated, however, that at Ballymadder, on the coast of Wexford, which is nearer the outcrop of some of the igneous rocks, pebbles of them are much more abundant.

LIST OF ERRATICS FOUND IN THE RAISED-BEACH GRAVEL.

Clonakilty Bay.—In beach-gravel, beneath boulder-clay, in Donaghmore.

Several well-rounded flints from ½ inch to 1 inch long.

Courtmacsherry Bay.—In beach-gravel, beneath boulder-clay, where a road descends to the shore about one mile east of Howe's Strand.

Grey flint (two specimens).
White chert (with crinoids).—Carboniferous Limestone.
Red granite.
Porphyry.—Probably from Silurian area of County Waterford and County Wexford.
Pink microgranite or aplite (two specimens).—Similar to veins in Carnsore granite.

Ballycroneen Bay.—In beach-gravel, beneath head and marly boulder-clay, 150 yards east of the Coastguard Station.

Quartziferous porphyry.—Probably from Silurian area of County Waterford and County Wexford.
Pink microgranite or aplite.—Similar to veins in Carnsore granite.

Youghal Bay.—In beach-gravel, beneath head and boulder-clay, at the south end of the bay near Greenland.

Grey flint.
Felsite.—Probably from Silurian area of County Waterford and County Wexford.
Quartz porphyry.—A rock very like this occurs on road east of Ballyvoyle Bridge, and in Boat Harbour Cove, Stradbally, County Waterford.
Andesite, or basalt, with small porphyritic felspars.—A rock similar to this occurs at extreme south-east of Ballydowan Bay, County Waterford.
Epidiorite (two specimens).—Probably from schists of County Wexford.
Gneiss.—Similar to foliated granite, south of St. Helen's, County Wexford.

Ballymadder, County Wexford.

Several pebbles of pink microgranite or aplite.—Similar to veins in Carnsore granite.

Granite.—Similar to a specimen of granite from Great Saltee Island.

Porphyritic andesite or felsite (two specimens).—Probably from Silurian area of County Waterford and County Wexford.

Flint.

The method of transport of these pebbles forms an interesting problem. Dried seaweed floated off the beach has been known to bear stones for long distances; but as a cause for such an extensive distribution it seems rather inadequate. It is not improbable that glacial conditions may have existed further north at the time of formation of the beach, and the temperature may have been sufficiently low for the presence of floating ice, which would form a much more effective carrier.[1] It must be noted in this connexion, however, that no disturbance of the beach-deposits such as might be attributed to the grounding of floating ice was noticed in any of the sections. The striations on the rock-platform at Ringabella Bay and elsewhere are immediately overlaid by boulder-clay.

Although search was made in the beach-deposits for fossils, none were obtained. Springs commonly issue along the platform through the beach-deposits, and the frequent conversion of the latter into ferricrete, even where no springs issue, testifies to the percolation of much water. This water, escaping as it does from the non-calcareous Carboniferous Slate and Old Red Sandstone, would readily dissolve any calcareous matter in the beach.[2]

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[1] It may be remarked that most, if not all, of the erratics found in the raised beach of the Cork coast have travelled from E.N.E. to W.S.W., *i.e.*, against both the tidal drift (such as there is) and the prevailing winds of the recent period. It is interesting to note that if an ice-cap, accompanied by more or less permanent anticyclonic conditions, had already established itself in Scandinavia, the prevalent winds on the south coast of Ireland would blow from the east and north-east, owing to the shifting southwards of the track of the cyclones. (See F. W. Harmer, Q. J. G. S., vol. lvii., p. 405, 1901.)

[2] It was implied, in the abstract of a paper printed in the Geological Magazine (Dec. 4, vol. x., p. 501, 1903), that shells had been found in the pre-glacial beach. These proved, on further investigation, to be recent, and not to be included in the beach-deposits.

Attempts to find the beach-deposits at the foot of cliffs of limestone in Cork Harbour and on the Waterford coast were unsuccessful. Not far from the limestone outcrop on the west side of Whiting Bay, limestone pebbles, often bored by *Saxicava* and *Cliona*, are common in the modern shingle. The pre-glacial beach is exposed in the cliffs, but not a single limestone pebble could be found in it. This seems to point to the complete decalcification of the beach-deposits.

The pre-glacial *blown sand* occurs buried beneath the head (see Plate XXVIII.) and banked against the rock-cliff. Where not cemented by iron-oxides, it is a fine, yellowish, even-grained sand. It often shows bedding dipping gently away from the cliff. Concretionary layers are not uncommon. Generally there are a few thin slivers of slate lying along the bedding planes in the upper layers. The matrix of the lower portion of the head is often formed of it; but the line of separation of the sandy head and the blown sand is fairly distinct. As it often lies on the beach-deposits, not more than a foot or so above the platform, it furnishes clear proof that the elevation of the beach commenced before the head began to accumulate. It occurs in places lodged against the cliff at a height of 35 feet above the platform.

At the entrance to Cork Harbour, blown sands were most frequently met with in the sections lying between Ringabella Bay and Camden Fort. They also occur near Roche's Point, but are not as abundant on the eastern side of the Harbour entrance as on the western—a point worth consideration in connexion with the travel of erratics in the beach (see foot-note, p. 262).

The *lower head*, or rubble-drift, is found overlying the raised-beach shingle and blown sand. When the latter are not present, it rests directly on the platform. It consists of angular rock-fragments of strictly local origin identical with the rocks forming the cliff or slope against which it is banked. The cleaved slates and sandstones of the Old Red give rise to a head composed of small slabs, which lie parallel to one another, and constantly dip at low angles away from the cliff. Grit bands naturally afford more or less cubical blocks. The soft, grey slates of the Carboniferous Slate series produce by their decomposition a yellow loam mixed with small slivers of slate. The deposit thus varies in composition according to the locality, but there are also variations noticeable according to the distance from its source. Close to the cliff are the larger fragments piled up on one another, and lacking the decided parallel arrangement found in other portions of the deposit. Sometimes a loam or sand fills the spaces between the fragments; sometimes the spaces are open. This first-formed part of the head is quite comparable with ordinary screes. In the upper parts, and those further from the cliff, the fragments are generally smaller. They are packed closely together, and always dip away from the cliff at low angles. The interstices between the fragments are invariably filled in by loam. Lenticular bands of loam, lying parallel to the fragments, occasionally occur in all parts of the head, but are frequent in the most seaward sections. They often have small slivers of slate imbedded in them. The loam represents the finer material derived from the waste of the cliffs. The bands or streaks in which it occurs, together with the parallelism of the fragments, give an appearance of rude stratification to the deposit (see Plates XXVII. and XXVIII.).

The accumulation of the head all along the coast is due to the pre-glacial shore platform subtending the base of the cliff, and catching all the material brought down on to it. It probably never accumulated inland to the same extent, owing to the absence of these conditions.

The pre-glacial cliff is always rounded off at the top—a feature due to its waste at the time the head was formed.[1] The pre-glacial coast-line can be traced by this feature even where the platform and overlying drifts have been entirely removed by recent erosion, as on the greater part of the Waterford coast (see fig. 3).

Since there is no head accumulating along the south coast of Ireland at the present day, its formation must indicate a change of climatic conditions. The angularity of the fragments, and their origin from the adjacent heights, point to the action of frequent frosts or rapid alterations of temperature. As already pointed out, the inner portion of the head near the old cliff is quite comparable with modern screes. With respect to the greater portion of the head, however, the distance to which it extends

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[1] For the form assumed by cliffs in consequence of disintegration, see "On the Disintegration of a Chalk Cliff," by the Rev. O. Fisher, *Geol. Mag.*, vol. III., 1866, p. 354.

from the cliffs and its low angle of slope preclude the idea of its being ordinary screes. The materials seem to have been carried out from the cliff; and, on the whole, the finer materials have been moved furthest. Periodical heavy rains washing down the slopes might have effected this.

Owing to the superposition of the boulder-clay, it is not easy to perceive the form of the upper surface of the head. Though it generally seems to rise towards hollows in the hills, there is hardly sufficient evidence for stating that it accumulated as a series of cones of dejection. It is, however, to be noticed that a large cone of head, with its apex pointing up a valley, lies on the pre-glacial shore-platform, just over two miles east of Ballycroneen. The upper head also forms a small cone, resting on the boulder-clay in the middle of Ballycroneen Bay. Its apex is directed up a small valley in the pre-glacial cliff.

In order that the head might accumulate, it is necessary for the platform to have been raised beyond the reach of the waves. An elevation of 10 or 20 feet above its present level would have been sufficient to allow of this accumulation.

There is difficulty in the way of making any definite deductions from the nature of the head as to what were the climatic conditions at the time it was formed. It is fairly clear that it indicates the action of frost, or of rapid alterations of temperature, in shattering the rocks and forming screes, and of periodic heavy rains in washing the material further from the cliff. It is hard to say, however, whether the shattering action is that due to the expansive force of water in a wet climate, or that due merely to rapid and unequal expansion and contraction in an arid climate. The first state, and indeed a condition equivalent to the second, might arise as the result of a great elevation of which the 10 or 20 feet mentioned above may have been only the beginning. There were, however, changes of climate in progress before the uplift began, so that, although it must always be kept in mind as a possible cause of the conditions, it is not at all a necessary nor even a probable one.

Other ways in which the required climatic conditions might be brought about can be adduced. A general lowering of mean temperature during part or the whole of the year might cause more frequent frost-action without any other change in the climate.

It is possible that the cold conditions indicated by the erratics in the beach may have been continued into the head period, and perhaps intensified. A still further intensification may have resulted in the invasion of the area by land-ice. Again, rapid diurnal alterations of temperature might be produced merely by a change of meteorological conditions without any lowering of mean temperature. This would happen if the supply of moisture were diminished during a portion of the year, and a climate thus established with arid seasons, in which sun-heat by day and radiation by night would be very intense.

The *marly boulder-clay* is a greenish or bluish-grey clay, which effervesces freely with acid. Some parts, particularly those of a greenish tinge, exhibit on a surface exposed to the weather, a fine lamination which is frequently contorted. This is well seen in Whiting Bay, east of Youghal. Other parts are compact and sometimes well-jointed. The jointing is very perfectly developed in the coast sections in the middle of Ballycottin Bay. The marl weathers at the top to a brownish clay, with blue-faced joints. It contains fragments and numerous smaller particles of the shells of marine mollusca, including several northern and Arctic species.

List of Shells found in the Marly Boulder-clay.[1]

Ballycroneen Bay.

Pecten opercularis, *Linn.*
Astarte sulcata, *Da Costa.*
Mytilus, sp.
Buccinum undatum (young).

Ballycottin Bay.

Nuculana (Leda) pernula, *O. F. Müller.*
Cyprina Islandica, *Linn.*
Mytilus, sp.
Astarte borealis, *Chem.*
Astarte sulcata, *Da Costa.*
Mactra solida, *Sow.*
Tapes, sp.
Nucula nucleus, *Linn.*

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[1] We are indebted to Mr. J. de W. Hinch for the identification of the shells.

Youghal Bay.

Astarte sulcata, *Da Costa.*
Mactra solida, *Sow.*
Tapes decussatus, *Linn.*
Mytilus, sp.
Tellina balthica, *Linn.*
Turritella terebra, *Linn.*

The marl also contains subangular and rounded stones, some of which are striated. They are scattered sparingly throughout it, but are occasionally seen to be more abundant in its upper portion. In this connexion it may be noted that a striated surface has not yet been found beneath the marl along the south coast. The stones are of various sizes; and, in addition to local rocks, include a number of distant origin, amongst which chalk-flints are the most abundant. A series of fine-grained porphyritic rocks, which seem to include quartz-porphyry, felsite, andesite, porphyrite, and dolerite, form the largest class of igneous rock. Some of them are identical with—and others closely approach—specimens of the igneous rocks associated with the Silurian sediments of Waterford, Wexford, and Wicklow. Some gneisses and altered basic igneous rocks (epidiorites) are similar to rocks cropping out on the shore between Greenore Point and Carnsore, County Wexford. A white granite, with dark quartzes and drusy cavities, is exactly like the Mourne Mountain granite; and one or two basic rocks correspond with some occurring on Slieve Foy, County Louth.

LIST OF BOULDERS FROM THE MARLY BOULDER-CLAY.

Ballycroneen Bay.

Hard chalk.—Antrim, or possibly bed of Irish Sea.
Glanconitic chalk.—Antrim, or possibly bed of Irish Sea.
Grey and black flints.—Antrim, or possibly bed of Irish Sea.
Hornblende micro-granite.—Similar granites occur at Crosspatrick, five miles east of Shillelagh; Croghan Kinshela; and on Great Saltee Island.
White granite, with druses.—Mourne Mountains.

Ballycottin Bay.

Grey flint.—Antrim, or possibly bed of Irish Sea.

Hornblende granite, with conspicuous sphene.—Like granite from Camlough Mountains, County Armagh.

Gabbro.—Like 'eucrite' of Slieve Trasna, County Louth.

Andesite (?).—Silurian area of Waterford and Wexford.

Whiting Bay.

Flint.—Antrim, or possibly bed of Irish Sea.

Bored limestone.—Bed of the sea.

Felsite (?).—Similar to 'felsites' from County Waterford.

In addition to the boulders from the marl, a number were also collected from the modern shore beneath the cliffs of marl. The same kinds of rock occur in about the same proportions, and there can be no doubt that most, if not all, of these have been washed out of the marl or raised-beach gravel. The riebeckite-eurite of Ailsa Craig, the occurrence of which so far south is of interest, has not been found in the marl up to the present. Beyond the most westerly limits of the marly boulder-clay in Ballycroneen Bay, pebbles of flint and igneous rock were here and there picked up on the beach. These pebbles may have come from the pre-glacial beach, or may have been brought by floating weed or ice after the land-ice had melted away.[1]

List of Boulders from the Modern Beach.[2]

Ballycroneen Bay.

Riebeckite-eurite.—Ailsa Craig.

Biotite granite.—Like that of Glenmalure, County Wicklow.

Granite, with yellowish felspars (two specimens).—Like that of Great Saltee Island.

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[1] Mr. G. H. Kinahan informs us that a quantity of flints were brought to Valentia Island as ballast by ships which took away slates, and that the flints found on parts of the shore of Sherkin Island, off Baltimore, were probably brought there in a similar manner when the slates in that island were worked. Pebbles and blocks (sometimes dressed) of the Dalkey granite are found on the shore near the lighthouses. This rock has been used in their construction.

[2] This list includes only those rocks whose probable place of origin and parent rock have been recognised.

Quartz porphyry (three specimens).—Similar to rocks from County Waterford.

Spherulitic felsite.—Rocks like this occur one-eighth of a mile east of Knockmahon ore yard (County Waterford), near Geneva Barracks, Arthurstown (County Waterford), and near Arklow Head.

White granite, with drusy cavities.—Mourne Mountains.

Ballycottin Bay.

Granite, with yellow felspars.—Like specimens from Great Saltee Island.

Coarse red granite.—Carnsore, County Wexford.

Banded gneiss.—Wexford metamorphic rocks.

Youghal Bay.

Riebeckite-eurite (three specimens).—Ailsa Craig.

Gneiss.—Wexford metamorphic area.

Augite-granophyre.—Slieve Foy, County Louth.

Whiting Bay.

Riebeckite-eurite.—Ailsa Craig.

Felsite, with inclusions.—Like a rock from Stradbally, County Waterford.

Agglomerates and ashes (several large boulders).—Silurian area of County Waterford and Wexford, or Croghan Hill, Philipstown, King's County.

Ballymadder.

Spherulitic and nodular felsites (several large boulders).—Possibly Arklow Head.

Associated with the marly boulder-clay are fine yellow sands, which are best exposed in Youghal and Ballycottin Bays.

The distribution of the marly boulder-clay from Ballycroneen Bay, County Cork, into County Wexford, and thence to the neighbourhood of Dublin, has already been mentioned.

The *boulder-clay of the inland ice*, which overlies the head west of Ballycroneen Bay, and the marly boulder-clay east of the bay, is a stiff clay full of Old Red Sandstone and Carboniferous Rocks, and does not show any sign of lamination. The stones lie in all positions in the clay, and exhibit varying degrees of rounding.

The sub-angular and rounded boulders of the harder rocks are generally striated. In many sections it has the structure of a typical till; in others it is rubbly on account of the working up of the head into it.

Around Baltimore it is a greenish-grey clay, containing numerous boulders of green and purple slate and grit. The striæ and the aspect of the crags show that the ice travelled from N.N.W. to S.S.E. In Clonakilty and Courtmacsherry Bays, it is a grey or yellowish-grey clay, containing abundant Carboniferous slate and sandstone with a small admixture of Old Red Sandstone pebbles. The boulder-clay is in fact made up almost entirely from the Carboniferous Slate series, and it is significant that these rocks occupy a large area to the north and west of the bays, whilst the Old Red Sandstone outcrops are of comparatively small extent. In the neighbourhood of Cork Harbour, where the hills are formed largely of Old Red Sandstone, the boulder-clay is more sandy and of a reddish colour.

It has been mentioned previously that in Ballycroneen Bay and along the coast to the east, a red boulder-clay overlies the marly boulder-clay. As might be expected, the former contains a few erratics derived from the latter. One or two pebbles of flint and igneous rock have been found in the boulder-clay between Ballycroneen Bay and Cork Harbour. At one place in White Bay the boulder-clay rests on the raised-shore platform, and contains a number of rolled ellipsoidal pebbles such as are common in the raised-beach gravels. Two of these were of igneous rocks, and were doubtless derived from the pre-glacial beach.

The boulder-clay of the inland-ice in the gorge of the Blackwater above Youghal overlies striæ running N. 50° W. to S. 50° E. In Whiting Bay it overlies the marl, and contains some limestone in addition to Old Red Sandstone, which is the predominant constituent as far as Dungarvan. Here we begin to get an admixture of Silurian rocks; and from Stradbally westwards, the stones in the boulder-clay are chiefly 'felstones' and other local rocks. At Ballymadder Point the boulder-clay is composed chiefly of the local rocks, but also contains large blocks of the Leinster granite. At Carnsore Point there is a local granitic boulder-clay with flints and pebbles of schist overlying a glaciated surface of granite with striæ running N. 10° E. to S. 10° W.

The *upper head* rests on the terrace of drifts where the pre-glacial cliff rises behind it. In some sections the upper head differs from the lower head only in that it contains a few pebbles derived from the boulder-clay; in others it becomes very loamy, and the rounded pebbles rather abundant. In the latter case it is not easy to separate from the weathered top of the red boulder-clay. The fact that it forms small flat cones at the mouths of valleys has already been noticed.

The recurrence above the boulder-clay of a head similar to the lower head is of interest, as showing that the conditions, under which the lower head was formed, returned for a period after the ice had melted away. The preponderance of the lower over the upper head is no doubt due to the greater steepness in pre-glacial times of the dominating cliff or slope from which the head was derived. It is, as a consequence, not to be taken as any indication of a longer lapse of time between the elevation of the beach and the period of glaciation than between that period and the present day.

5. GENERAL CONCLUSIONS.

In his classic paper, "On the Mode of Origin of some of the River-valleys of the South of Ireland,"[1] Jukes proved that the river-system is superposed on an old plain, which he believed to be one of marine erosion. This plain slopes from north-north-west to south-south-east, and is truncated by the pre-glacial coast-line. Expressing Jukes' results in the terms of a later nomenclature, the rivers occupying the deep and narrow gorge-like valleys, which trench the plain from north-north-west to south-south-east, are consequent on the plain, whilst the more open west and east valleys which conform to the strike of the rocks are eroded by subsequent streams. Cork Harbour, and the estuaries of the Blackwater, Suir, and other rivers, are parts of this river-system now submerged beneath the sea. The occurrence of the pre-glacial beach fringing their shores is therefore a point of considerable interest, since it proves that their submergence took place in pre-glacial times.

Whether the old plain be one of marine erosion or the result

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[1] Quart. Jour. Geol. Soc., vol. xviii, p. 378, 1862.

of a previous cycle of subaërial denudation ("peneplain"), the deep trenching of the rivers indicates an uplift of the plain above its former level.

The next movement it is possible to record is a depression of the land to the level at which the raised beach was formed; *i.e.*, about 12 feet below its present level. This small discrepancy between recent and pre-glacial sea-levels cannot but be regarded as remarkable, when one considers the long and varied succession of events which are known to have taken place in the interval.

An uplift of the land again occurred when the blown sand and lower head were accumulated. It has been pointed out that this uplift need not have been more than 10 or 20 feet above *present level*, though it may have been greater.

The lower head is overlaid by boulder-clay deposited by land-ice, which originated in more than one centre, as already explained.

The succession of events subsequent to the formation of the old plain may thus be summarised[1]:—

1. Land higher than at present—erosion of valleys now submerged.
2. Land depressed to about 12 feet below present level—formation of raised beach.
3. Land again elevated to an unknown extent above its present level—accumulation of blown sand and lower head.
4. Advance of Irish Sea ice-sheet from the north-east and east, and deposition of marly boulder-clay. Advance of ice from the West Cork Mountains and from the Central Plain contemporaneous with the above, and also at a later stage, advancing over ground formerly occupied by the Irish Sea ice-sheet.
5. Accumulation of the upper head.

The outline of the pre-glacial coast-line of the south of Ireland at the period of the raised beach was, as a whole and in many of its details, similar to that of the present coast-line. Even where the platform and its overlying deposits have been removed by the recent encroachments of the sea, the peculiar rounding off at the

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[1] For possible dates of these events, see Croll, R. Ball, and others.

top of the pre-glacial cliff may often be detected. This feature serves to show that the pre-glacial shore was in these places not far seawards of the modern one.

The pre-glacial coast-line can also be seen to coincide with the present one in one or two places in the neighbourhood of County Dublin. On the south and east sides of Howth the glacial deposits are banked against an old cliff-slope. Near the Lion's Head a coarse, angular quartzite rubble underlies the glacial drifts. On the south side of Bray Head a rubble-drift, composed of angular slate fragments similar in structure to the head on the south coast, is banked against a degraded cliff, and overlaid by boulder-clay. At the foot of the cliff there are traces of rock-platform at about the same level above the sea as on the south coast. These two localities are situated on the lee-side, with reference to the direction of ice-flow, of two high headlands—a position in which pre-glacial deposits are more likely to be preserved than elsewhere in the same district.

Of the Isle of Man, Mr. Lamplugh says[1] :—"The recession of the rocky part of the coast since glacial times has not been sufficient to affect materially the outline of the old massif, and there are many indications that cliffs of the slate rocks were in existence in pre-glacial times in approximately the same position as those of the present day. The rocky tidal shelf on the more exposed parts of the coast appears usually to represent the extent of post-glacial erosion, while in some of the larger bays, *e.g.*, those of Douglas, Port St. Mary, and Port Erin, where the foreshore is broad and smooth, there are patches of drift upon the rocky platform, apparently indicating that even this feature may sometimes be pre-glacial; and in a few sheltered recesses, the ancient cliff-slope is still unbroken."

A raised beach, fringing the shores of the Bristol and English Channels,[2] is buried beneath blown-sand and head or coombe-rock. Mr. Tiddemann proved,[3] in 1900, that along the coast of

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[1] "Geology of the Isle of Man," p. 14.—Mem. Geol. Surv. U.K., 1903.

[2] *See* Ussher, "The Post-Tertiary Geology of Cornwall." Printed for private circulation. Hertford, 1879. Prestwich, "The Raised Beaches and 'Head' or Rubble-drift of the South of England." Quart. Jour. Geol. Soc., vol. xlviii., p. 263, 1892. And others.

[3] Rep. Brit. Assoc., 1900, p. 760.

Gower, in South Wales, the boulder-clay overlies the raised beach and head. As far back as 1887, Mr. Lamplugh described a pre-glacial beach, little raised above the modern beach, and overlaid by blown sand, a land-wash, and boulder-clay, near Bridlington, Yorkshire.[1]

It would appear, therefore, that a considerable portion of the coast-line of Southern Britain is of pre-glacial age. The approximation over so wide an area of the sea-level in pre-glacial times to that of the present day renders it very probable that Ireland was already insulated before the Glacial Period.

PART II.

Detailed Description of Coast Sections visited between Baltimore and Carnsore Point.

Baltimore.—The glaciation in the neighbourhood of Baltimore is more severe than in the districts to the east, and neither lower head nor beach-deposits were found; but from a point on the shore near the church to the small bay at the southern end of the village, boulder-clay rests in several places on a striated platform of rock, and is banked against a rock-cliff behind. The platform is 3 or 4 feet above high-water mark, and presents the same features as the platform beneath the boulder-clay at Ringabella Bay. There is little doubt that it is the pre-glacial platform of marine erosion, from which all beach-gravel and lower head were removed during the glaciation of the district.

Lough Hyne.—At the south side of the small bay opposite Bullock Island, on the western side of the entrance to Lough Hyne, a narrow but distinct platform was found at about 6 feet above high-water mark. The boulder-clay overlies it, and is plastered against an old cliff at the back of the platform. Between

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[1] "Report on the Buried Cliff at Sewerby," Proc. Yorks. Geol. and Polytec. Soc., vol. ix. (1889), pp. 382–392; and Rep. Brit. Assoc. for 1888. See also "Drifts of Flamborough Head," Quart. Jour. Geol. Soc., vol. xlvii., p. 394; and Proc. Yorks. Geol. and Polytec. Soc., vol. xv. (1903), pp. 91–95.

the boulder-clay and the rock-ledge there is generally a thickness of 1 to 2 feet of angular slaty rubble (head).

Clonakilty.—The rock-platform, overlaid by the terrace of drifts, is seen on the east side of Clonakilty estuary.

Excellent sections of the raised beach are to be seen in Clonakilty Bay from near Simon's Cove to Donaghmore. For the whole of this distance there is a smooth platform cut across the edges of the highly inclined strata, and sloping gently seaward at angles varying from 3° to 10°. It is sometimes as much as 50 yards broad from the foot of the drift-cliff to its seaward margin. The lower, 25 to 30 yards, is covered by high tides, and this portion of the platform is being broken up by the action of the sea. The higher portion of the platform at the foot of the drift-cliff presents an undulating wave-worn surface.

West of Simon's Cove, the base of the cliff is occupied by 2 to 3 feet of ferricrete gravel resting on the platform. The gravel is well bedded, and composed of well rolled stones. Above this, and not sharply marked off from it, there is a thick bed of uncemented gravel. The stones are sub-angular or rounded; and though the material is bedded, it is not so well sorted as in the cemented gravel below. The gravel becomes rather clayey, and contains angular local *débris* near the top, and in some places looks rather like stony boulder-clay, though no scratched stones were found in it so far as it was accessible. It thus resembles a glacial gravel; and it is easy to understand that when it was deposited upon the beach-gravel, the upper part of the latter might be re-arranged and more or less incorporated in the former. Another distinction to be noticed is that, although the materials forming the pebbles are the same in both, the lower gravel contains a larger proportion of vein-quartz and hard grit pebbles. The greater wear to which the beach-gravel has been subjected has resulted in the survival of a higher proportion of the harder rocks.

The upper gravel is overlaid by 2 to 6 feet of angular, slaty rubble (upper head).

Immediately east of Simon's Cove the platform is hummocky, and overlaid by a variable thickness of head. A short distance eastwards, gravel, and then boulder-clay, come in beneath the upper head.

The following section was obtained here :—

	Feet.
Upper head, with clayey matrix, ..	6
Yellowish-grey boulder-clay, with scratched stones, ...	3–5
Rolled gravel, ...	3–4

Platform.

The gravel contains large sub-angular blocks of local rock up to 8 feet long ; and also near its base, a few slabs of slate usually less than 2 feet long.

Further eastwards, a hard grit band in the slates runs obliquely from the cliff across the platform, above the general level of which it projects in a series of rounded hummocks. The pre-glacial cliff is exposed for a short distance ; and for about 4 feet up from its base it presents the same smoothed, wave-worn surface that is seen on the platform. The inner angle of the platform, where it is rounded off into the cliff, is only 3 to 4 feet above the upper limit of growth of *Balanus* and *Fucus*, which is here close to high-water mark. The gravel is banked against the cliff to a height of 12 feet above the platform, and is covered by head. One or two large blocks were observed in the gravel at the base of the cliff.

From this point the platform, with the gravel resting on it, may be traced almost continuously for half a mile to the east.

About 300 yards east of Simon's Cove a striking effect is produced by the ferricrete sands of the beach bridging over a gully which has been cut in recent times into the pre-glacial platform. The following section is visible at this point :—

	Feet.
Head, with sand and angular blocks towards base, ...	6–7
Gravel and sand, with blocks of rock, ..	15
Ferricrete gravel, ...	3–4

Smoothed rock-platform.

The base of the ferricrete gravel is 5 to 6 feet above the upper growth limit of *Fucus* and *Balanus*, and is estimated to be 18 to 19 feet above ordinary low tide, which occurred at the time the section was visited. The uncemented gravel-and-sand contains many large blocks of rock, especially near the base.

Towards the top of this deposit there is a well-marked horizontal shingle-bed extending for a long distance. Small remnants of boulder-clay can be detected here and there above the head.

A similar gully lies a short distance to the east (see Pl. XXX.). The upper portion of the platform at this second gully is 10 to 12 feet above the line of sea-growth (*Balanus*). On the landward side of this gully is the following rather complicated section :—

	Feet.
7. Upper head, ...	5
6. Boulder-clay, ...	4–8
5. Ferricrete sand, with irregular base, ..	4–6
4. Clay, with angular bits of slate, ..	4–6
3. Yellow laminated clay, ...	0–1
2. Coarse breccia, ...	1–2
1. Coarse ferricrete gravel, ...	2–3

Platform.

The deposits numbered 2, 3, and 4 in the above section together form a peculiar local deposit. The breccia consists of rough, angular blocks, up to 2 feet long, of the local slate mixed up with a few well-rounded beach-pebbles, and cemented by iron-oxides. The top of the breccia is uneven, and is overlain in part of the section by an irregular lenticle of yellow laminated clay. The next deposit consists of smaller angular pieces of slate lying in all positions in a clayey matrix. It is not cemented by iron-oxides, and thus weathers more readily than the breccia below it. The hollows in its irregular upper surface are occupied by laminated clay. Together with the coarse breccia beneath, the stony clay thins out when traced laterally, so that the ferricrete sand comes to rest on the basal gravel. The tumbled character of the deposit suggests that it might have been produced by a slip from the pre-glacial cliff.

The ferricrete sand is coarse, and includes one or two rows of pebbles. It is stratified, but not distinctly false-bedded; and does not seem to be a blown sand.

The boulder-clay is of a greyish colour, and contains pieces of the local grits and slates, as well as of Old Red Sandstone in all stages of rounding. The harder rocks are often striated.

The cliffs to the eastward of the above section afford good exposures of the beach-gravel and sand overlain by head. Sometimes the junction between the two deposits is sharp, but the upper part of the gravel frequently contains angular fragments of slate, either scattered through it, or more or less arranged in layers, so that the line of separation is difficult to draw.

East of Ballinglanna Cove, yellowish boulder-clay, 10 to 12 feet thick, overlies the rocks, and is covered by a varying thickness of upper head. The shore-platform of the small bay, one-third of a mile to the south-east, is cut in a series of vertical black slates to a very smooth surface, which slopes gently upwards from low-tide mark to the foot of the cliffs. The slates extend up into the cliffs for 10 feet, at which height they are abruptly truncated by a similar seaward-sloping surface, and are overlaid by about 12 feet of gravel. The gravel is cemented by iron-oxides, and consists of well-rolled pebbles with a good proportion of vein-quartz and hard grits. Yellowish-grey boulder-clay, from 12 to 15 feet thick, caps the cliffs. The pre-glacial cliff is close behind the present cliff at the centre of the bay; but when traced eastward, it gradually recedes inland from the modern cliff. Consequently, at the eastern end of the bay, the truncated edge of the pre-glacial platform, being further from the pre-glacial cliff, is a few feet lower, and the base of the drift almost reaches high-water mark. At this point there are several stacks on the shore which are planed off at the top, and continue the slope of the old platform seawards (see Plate XXIX.).

For some distance to the east, the seaward portion of the pre-glacial platform forms the modern shore, and the cliffs consist of boulder-clay overlying the cemented gravel. Two or three outlying patches of gravel remain cemented on to the rock-platform several yards from the cliffs. The pebbles in the gravel are composed chiefly of the local green grits and of vein quartz, but several well-rolled pebbles of flint, about half an inch long, were also found in it. The boulder-clay is a stiff yellowish-grey clay, containing numerous local grits and slates, and some pebbles of Old Red Sandstone. Most of the stones are sub-angular, but they vary from angular to rounded. Probably some of the rounded ones have been derived from the underlying gravel. The stones are seldom more than 8 inches long, and many of them are well striated.

Courtmacsherry Bay.—The following notes, in the handwriting of Jukes, are taken from the 6-inch maps deposited in the Geological Survey Office :—

About the middle of Seven Heads Bay (on the west side of Courtmacsherry Bay) there is noted :—"Thick deposit of red sandstone, and conglomerate (Recent) with beds of sea-sand dipping 10° south."

A short distance to the north: "Red conglomerate and sandstone, 10 to 15 feet. Recent."

And again, a little further on: "10 feet, on top of slates and grits, and filling up all hollows in them, of coarse sandstones and conglomerate, small pebbles [of] quartz, well-rounded."

In the small bay north of Broadstrand Bay: "Sand and gravel, stained bright red and brown," is recorded; and again, half a mile south of Land Point, "6 feet and upwards of pure sand and pebbly gravel stratified horizontally."

250 yards north of the last are: "Hard layers of Recent sandstone, dark brownish-black colour, 4 feet."

Though the localities have not been visited, there can be little doubt that these observations refer to the cemented gravel and sand of the raised beach.

Extending for about one-third of a mile along the south side of Broadstrand Bay, there is a remarkably level platform cut in the Carboniferous Slate, and overlaid by a thick deposit of boulder-clay. The rock surface beneath the boulder-clay is striated. (See 37, Appendix.)

Very fine sections of the raised beach are exposed along the north side of Courtmacsherry Bay, eastwards from Howe's Strand. Immediately after passing the Coastguard Station, the broad wave-worn platform, with the cliff of drifts behind, is seen. A section, 350 yards east of the Coastguard Station, has already been described (see p. 253).

Nearly 500 yards from the Coastguard Station, the cliffs showed a section as follows :—

	Feet.
Upper head, ...	0–2
Yellowish-grey boulder-clay, ...	3–4
Lower head, ...	6
Brown and black ferricrete sand, well bedded with occasional pebbles, ..	5

The sandstone of the beach rests on a deeply furrowed rock-platform, which has been described previously (see p. 257, and Plate XXVI.).

A little beyond this point, more than 3 feet of loose sand, with lenticular ferricrete layers, is seen in the cliffs. It is a blown sand resting on the beach-deposits, and lying beneath the head. A few yards further east, near a small cove, the ferricrete sand resting on the platform is over 7 feet thick, and contains bands of pebbles. The platform is here also channelled by deep north and south furrows, and was estimated to be 10 feet above high-water mark of ordinary tide.

In the small cove, the platform is seen further back nearer the old cliff; it is 2 to 3 feet higher.

From this cove to the headland, where the stream reaches the sea, the platform is overlaid by head and boulder-clay.

In the bay, east of the headland, the slates have been planed to a low level on the shore. Their surface slopes very gently upwards from low-water mark, and is furrowed from north to south in the same manner as the raised-shore platform is. Near the east end of the bay, a relic of the pre-glacial platform is preserved at the foot of the cliff. The cliff-face above the platform is water-worn at its base. The inner angle of the platform is 10 feet above the corresponding angle on the modern shore.

About half a mile to the eastwards, where a road leads down the cliff, there is a very fine exposure of the boulder-clay resting on the beach-deposits. A description of this section has already been given (see p. 255, and Plate XXIV.).

Old Head of Kinsale.—In the bay, behind the lighthouse at the extreme end of the Old Head, the following section is seen:—

	Feet.
Boulder-clay, ...	20–30
Head, ...	10
Gravelly layer, with larger blocks, ..	0–1

The gravel is composed of the local sandy green slates, and the pebbles are not well rounded, but the modern beach shows that the green slate does not form well-rounded, smooth pebbles. The degree of rounding shown in the two cases is the same.

The boulder-clay is of a greenish colour, and contains numerous angular and sub-angular pieces of the local rock, and one or two rounded grits not found *in situ* in the immediate vicinity.

At the head of the inlet Coosnaclasha, about half a mile north-west of Black Head, a similar section is to be seen. The boulder-clay is not so thick, and contains fragments of Old Red Sandstone. The gravel at the base is thicker, and rests on a water-worn surface. This surface can be traced as a steeply-shelving platform, from which the drifts have been denuded, for a short distance along the north side of the inlet.

In Bullen's Bay the boulder-clay rests directly on the Carboniferous Slates, and the raised-beach gravel is not seen.

The rock-platform, covered by head, is seen in Kinsale Harbour above the town.

Around Nohaval and Robert's Cove, the cliffs are bare and precipitous; and only slight traces of the platform, a few feet above high-water mark, were found in the most sheltered situations.

Ringabella.[1]—The raised-beach platform on the northern shore of Ringabella Bay is from 40 to 60 yards wide. At its western end it is overlain by boulder-clay only, and its surface is beautifully glaciated by ice moving in the direction E.S.E., almost parallel to the shore (see p. 256, and Plate XXV.). Its outer edge at this point is from 8 to 10 feet above the line of sea-growth.

As the drift-cliff is traced eastward from this point, the platform beneath is less glaciated, while the boulder-clay becomes mixed with angular material, and passes gradually into head. At the same time, the pockets of raised-beach material lying on the platform become more and more common. The following typical section is 30 to 40 yards from the pre-glacial cliff:—

		Feet.
Head, with a few rounded stones,	..	10
Well-rounded gravel and sand,	..	2 ±

Platform—well smoothed.

The platform is well developed from here to Myrtleville, and the cliffs of head are sometimes very striking. At one point the head is sufficiently removed to reveal blown sand banked behind it against the rock-face at a height of 20 to 25 feet above the platform. It has a decided stratification dipping seawards, with a few

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[1] For localities in neighbourhood of Cork Harbour, see fig. 2, p. 285.

delicate slate fragments similar to those of the head lying along the bedding planes.

Myrtleville.—About 80 yards south of Myrtleville Cottage the beach is well seen in section normal to the coast-line:—

	Feet
Head, very slaty and gravelly in places, ..	10
Sand, with some gravel and stones, ..	2–3
Sandy gravel, with large blocks at end near old cliff	½–2

Rock-platform.

The sand and sandy gravel are dovetailed into one another, and much cemented with oxides of iron. The stratification dips seaward on to the rock-platform at a low angle (see p. 260, and Pl. XXVII.). The highest portion of the platform here seen is 5 to 10 yards from the old cliff. It is 10 feet above the line of sea-growth, and 8 feet above the modern shingle at the head of the gully in which the section is exposed. The platform slopes gently seaward, and at its outer edge is 5½ feet above the same line of sea-growth. On the south side of Myrtleville Bay blown sand can be seen beneath the head in several places (see Plate XXVIII.).

On the north side of Myrtleville Bay, cliffs of boulder-clay and head 30 to 40 feet high rest on a low-lying seaward portion of the rock-platform, which stretches out below high-water mark, and terminates in the rock known as Carrigabrochell.

Going north, however, the platform rises again as the drift-cliff approaches the pre-glacial shore, and half way between Myrtleville and Poulnacallee reaches a height of 15 feet above the line of sea-growth. At this point there is a 45-foot cliff of drift, consisting of 10 feet more or less of boulder-clay on head, which in turn rests on the water-worn rock-platform. Here, also, caves in the head show blown sand resting immediately on the rock-platform among large blocks, and also at a height of 35 to 40 feet above it, banked against the rock-face.

Just south of Poulnacallee Bay is the following section:—

	Feet.
Boulder-clay, ...	6
Head, ...	30
Blown sand, Beach-gravel, } in patches of irregular thickness.	

Uneven rock-platform.

The platform is uneven and cut up; a portion of it is water-worn, and lies about 12 feet above the line of sea-growth.

Poulnacallee (Church Bay).—Section at south end of Poulnacallee Bay, a short distance south of ladies' bathing-place:—

	Feet.
Boulder-clay, ...	10
Head, ...	15
Raised-beach gravel, with blocks, ..	1–2

Rock-platform.

A cave shows blown sand on the platform behind the beach-gravel, covered up by the head.

Close to this section, at the head of a small inlet, some sand, probably blown, is exposed at the foot of a 50-foot cliff, mainly composed of head. It contains a layer of silt 3 inches thick near the top, and several thin clayey layers below. The silt was carefully searched for organic remains, but none were found.

Close by is an outstanding stack showing—

	Feet.
Current bedded gravel (glacial), ..	8
Head, ...	10
Raised-beach shingle, ...	1–2

Uneven rock-platform.

On the north side of Church Bay, and due east of the Hotel, is a good exposure of blown sand, which at this point also can be traced to a height of 35 feet above the platform.

Weaver Point.—One hundred and fifty yards south-west of Weaver Point is a section showing 15 feet of boulder-clay resting immediately, or with very little intervening head, on blown sand, which lies behind it against the rock-face.

Twenty yards to the north of this is the following section:—

	Feet.
Upper head, ...	2
Boulder-clay, ...	5
Lower head, sandy and very coarse, ..	5
Blown sand, showing bedding dipping seaward,	—

Platform, with blocks and beach-gravel.

The blown sand lies over and among the blocks, and is banked as usual against the cliff behind the head. It passes up into the head, which is composed of rather large angular fragments embedded in a sandy matrix.

On Weaver Point, beach-gravel lies on the platform among blocks, at a height of 8 feet above the line of sea-growth. The following section is seen here at the top of a small gully:—

	Feet.
Boulder-clay, gravelly in places, ..	12
Sand, with rubbly admixture, ...	2–3
Beach-gravel and large blocks, ...	2–3

Rock-platform.

The beach-gravel is well rounded, and fills up the crevices between large blocks, which lie in a hollow of the platform.

From Ringabella to Weaver Point, the pre-glacial beach-deposits consist for the most part, like those of the present day, of shingle.

Grab-all Bay.—In Grab-all Bay the rock-platform, though low-lying, is well marked, and remarkably smooth. It is overlain for a considerable distance by 4 or 5 feet of a compact red and black horizontally-bedded fine-grained sandstone (ferricrete). This is capped by 35 feet of drift, much overgrown and obscured, the top portion probably being boulder-clay.

Camden Fort.—The platform is continued round Ram's Head to the north of Camden Fort. About 150 yards west of the Pier is 25 feet of head, resting on the rock about 8 feet above ordinary high-water mark. The crevices in the rock are filled with shingle, and the lower half of the head is gravelly, with large, angular blocks of rock and well-rounded boulders. These well-rounded stones are abundant up to about 17 feet above ordinary high-tide as shown by sea-growth, and there are round blocks at least 6 feet higher. It is not obvious that the head at this point is pre-glacial, otherwise the occurrence of these boulders in it would be of considerable interest.

About 200 yards west of this is 10 feet more or less of pre-glacial shingle, resting in a hollow of the rock a few feet above high-water mark. There is a tendency also for modern storm-beaches to accumulate along this coast.

Curraghbinny, Ringaskiddy, and Spike Island.—The pre-glacial shore-platform can be traced round Curraghbinny, Ringaskiddy, and the south side of Spike Island, being overlaid either by head or boulder-clay or by both. No beach-deposits were, however, found.

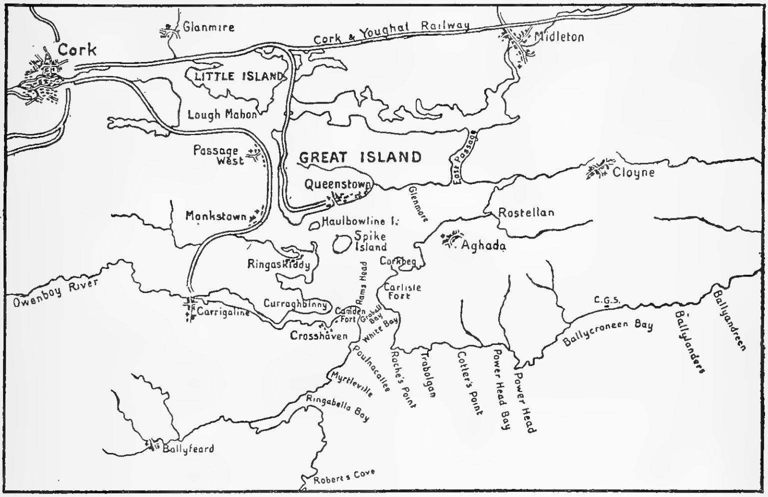

Fig. 2.—Index Map of Queenstown Harbour.

Great Island.—A narrow rock-platform extends almost continuously along the west, south, and east shores, and is found in several places on the north side of the Island. Where it passes under the drifts, its surface is usually between 2 and 4 feet above high-water mark of ordinary spring-tides, though it is sometimes higher or lower. It is overlain by head or boulder-clay, or by both deposits. Beach-gravels are found lying on the platform beneath the lower head, 500 yards east of Queenstown Lifeboat House, and 200 yards east of Glenmore. The pebbles in the gravel are not so well rolled as those in the gravels on the open coast. In this character the pre-glacial beach-gravel agrees with the modern shore-deposits. At Marino Point red boulder-clay overlies the platform, which is striated from W. 25° N. to E. 25° S.

The Eastern Shores of Cork Harbour.—On the eastern side of the East Passage the platform is narrow but well marked. Just south of the ferry it is overlain by 6 feet of slaty head. From here it may be traced round into Cork Harbour.

The pre-glacial cliff, rising behind a terrace of head or boulder-clay, stretches from Rostellan westwards to Corkbeg, but a retaining wall hides most of the drift-sections. A little over half a mile west of the gravel bar, which connects Corkbeg with the mainland, the beach-gravels are seen lying on the platform, and are overlaid by boulder-clay and head.

White Bay.—The rock-platform may be followed round Carlisle Fort a few feet above high-water mark. On the south side of the Fort, beach-gravels come in beneath the head. The following section occurs here :—

	Feet.
Upper head, ...	3
Stony red boulder-clay, ...	4
Lower head, ...	12
Well-rounded gravel, ...	7

Rock-platform.

From this point the rock-surface, on which the beach-gravel rests, rises eastwards to Glan-na-gow, and then falls again to the southwards, as already explained (p. 259).

Where a road descends to the shore, 400 yards south of Glan-na-gow, the section in the cliffs is as follows :—

	Feet.
Weathered boulder-clay and rubble, ..	2–3
Red boulder-clay, ...	4
Lower head (base hidden by talus), ..	12

Rock-platform.

The rock-platform is 6 feet above high-water mark of ordinary spring-tides; and from here to Roche's Point, it forms a well-marked feature. It is nearly always overlain by lower head, which is seen to change in composition as the rocks in the preglacial cliff vary. At one point a flint was found in the head.

Below a ruined cottage, 400 yards south of the last section, the boulder-clay cuts out the head, and comes to rest on the rock-platform, which is striated from W. 15° N. to S. 15° E.

About 80 yards to the south, the section in the cliffs is :—

	Feet.
Upper head, ...	4
Red boulder-clay, ...	6
Lower head, ...	18
Ferricrete sand	0–3 in.

Rock-platform.

A little over 100 yards further on, large blocks with some gravel rest on the platform, and blown sand is mixed with the lower part of the head. The boulder-clay again comes down to the platform 300 yards to the south. Here it contains a number of well-rolled pebbles evidently derived from the pre-glacial beach. Amongst them were two pebbles of distant origin, one being a felsite of a type found amongst the Silurian Rocks of County Waterford, and the other a micro-granite.

Nearly 400 yards to the south, and just north of the Coastguard Station, boulder-clay, 9 feet thick, overlies loose bedded blown sand, which is over 5 feet thick.

Roche's Point to Power Head.—Blown sand, covered by lower head, is banked against the pre-glacial cliff to the south of the Coastguard Station, and again, below Roche's Tower, half a mile east of the Lighthouse. A little gravel, overlain by head, is seen resting on the rock-platform close by.

The head may be followed into the bay at Trabolgan, where it is overlain by stony red boulder-clay, 20 feet thick. The head is composed of the local red sandstone and slate, but one broken piece of chert, with its edges rubbed, was found in it. The base of the head here passes below high-water mark. About a foot and a half of greenish, sandy loam was exposed on the shore below the head by the removal of the beach during a storm. Some of the beds of loam were pierced by vertical pipes filled with ferruginous matter. They might have been rootlets.

On the east side of the bay the rock-platform, 4 to 5 feet above high-water mark, is covered with large blocks of rock, more or less rounded, between which beach-gravel is packed. The gravel and blocks are overlain by head, with traces of boulder-clay above it. In one part of the section blown sand occurs above the beach-gravel and blocks, and is mixed with the base of the head.

The rock-platform, with either head or gravel lying on it, runs round the eastern horn of the bay into the next one. On the western side of this bay, and close to the pre-glacial cliff, the platform is 6 to 8 feet above high-water mark. The full succession of deposits from the beach-gravel to the upper head is seen. A flint pebble was found in the boulder-clay here.

Just east of Cotter's Point the section in the cliff is as follows:—

	Feet.
Head, with a few pebbles, ...	6
Angular slaty head, ...	12
Well-rounded gravel, ...	3
Rock-platform.	

The head with pebbles is probably upper head.

A third of a mile west of Gyleen, the head is 25 to 30 feet thick, and overlies 6 feet of gravel, which rests on the smoothed platform.

The pre-glacial cliff along this portion of the coast is from 100 to 150 feet high.

East of Gyleen the rock-platform is 5 to 6 feet above high-water mark, and is overlaid by head about 20 feet thick. In Powerhead Bay, half a mile east of Gyleen, the platform rises locally to 15 feet above the modern beach, whilst the pre-glacial cliff is only 20 to 25 feet high. On the east side of the Bay, the following section is seen about 300 yards south of the strand:—

	Feet.
Head, ...	4
Bedded gravel and sand, ...	4
Sharp sand, ...	1
Boulder-gravel, with sandy matrix, ..	3
Smoothed, but uneven, platform.	

On the more exposed parts of the coast round Power Head, the platform and the overlying drifts have been removed by recent marine erosion, but a little rubble is generally found lying on the rounded slope of the pre-glacial cliff. At one place a coating of rubble-drift, 30 feet in height, but only 5 or 6 feet thick, is left banked against the pre-glacial cliff, and resting on a narrow remnant of the rock-platform.

Ballycroneen Bay.—At the western end of Ballycroneen Bay, the platform, together with the terrace of drifts, has been almost entirely eroded away. It is, however, seen in the same bay, 1¼ miles east of Power Head, where a little gravel with large blocks, somewhat rounded, is overlain by head, and lies on the platform about 5 feet above high-water mark.

From the place where the road from Inch reaches the shore, as far as Ballycroneen Coastguard Station, the cliffs are composed of drift, forming a nearly level terrace, from 60 to 200 yards broad, from the inner side of which the pre-glacial rock-cliff slopes steeply upwards to nearly 200 feet above O.D. line.

About 75 yards east of the foot of the road mentioned above, the following section was measured :—

	Feet.
Stony loam and soil, ...	2
Red boulder-clay, with 1 ft.-bed of gravel, ..	12
Grey, marly boulder-clay	3
Lower head, ...	3½ +

The lower head consists of angular pieces of red slate and sandstone, lying flat, and having a red or yellowish loam filling up the interstices between the fragments. Its base is hidden by the gravel of the beach; but the lower part of the shore is formed of slates and sandstones, which have been planed down to level scaurs. This shore-platform is the seaward portion of the pre-glacial platform, and extends inwards beneath the terrace of drifts to the foot of the pre-glacial cliff.

The clay lying on the head is a bluish or greenish-grey marl, containing shell-fragments, foraminifera, and boulders of local and extraneous rocks. The rocks of distant origin include flint, Carboniferous Limestone (generally striated), and a variety of igneous rocks, some of which are identical with those occurring in Counties Waterford and Wexford (see list, p. 267).

The junction line of the marl with the lower head is an undulating one. The base of the marl is very compact, and almost free from stones, which are scattered through the rest of the deposit, and are locally abundant near the top. Above the marl, but not sharply marked off from it, is a reddish boulder-clay containing abundant boulders of local rock and a very few of flint and igneous rock.

The stony loam is probably weathered boulder-clay. It is sometimes mixed with angular fragments of the local rocks, when it may represent the upper head of the other sections.

Sections similar to the above are exposed in the cliffs to the east. The head beneath the marl is sometimes disturbed and the parallelism of its fragments destroyed. Tongues of marl, from a few inches to a foot broad and up to sixteen feet long, penetrate into the head from east to west. Lenticles of head are separated from the main mass of the deposit, and lie contorted and drawn out in the marl. The red upper clay does not appear to be present always, in which case the marl weathers to a brownish clay, which contains few stones, and sometimes exhibits blue joints.

In the middle of the bay, at a small break in the cliffs, upper head, 5 feet thick, caps the cliff. The material is similar to the lower head, but is, perhaps, less compacted. It forms a flat cone spread out on the terrace of drifts, and its apex points up a small valley cut into the hillside above the terrace. The tiny stream which flows down the valley has not succeeded in cutting through the cone.

Near the eastern end of the line of cliffs an irregular mass of gravel, composed almost entirely of subangular and rounded pebbles of Old Red Sandstone and Carboniferous rocks, overlies the marl.

Beyond this the cliffs are interrupted by the valley which enters the bay from the north. On the other side of the valley, below the Coastguard Station, the pre-glacial cliff is nearer the present cliff, and the platform rises towards it.

The coast east of Ballycroneen Bay.—A section just east of the Coastguard Station has been described on p. 256, and two well-rolled pebbles of igneous rock found in the beach deposits recorded on p. 261.

The beach-gravel may be traced along the platform to the eastward. At one point, about 6 inches of blown sand rests on the gravel, and is overlain by head. The gravel also contains a few large fallen blocks.

In the small bay, 400 yards to the east of the Coastguard Station, stratified gravel 5 feet thick rests on the platform, and is overlaid by a thick deposit of head. The cliff is capped by reddish clay with angular and rounded stones, probably boulder-clay. The platform can be plainly followed into every bay and round every headland, though the beach-gravel may not always be present. It is about 10 feet above the modern shore-platform. The head, when seen close to the pre-glacial cliff, often resembles screes in structure.

In the bay, three-quarters of a mile east of the Coastguard Station, the pre-glacial cliff recedes from the modern cliff, and consequently the platform scarcely rises above high-water mark of spring-tides. Just west of the small stream which enters the bay, 40 feet of head overlies 2 to 3 feet of sand and coarse gravel. The head contains loamy streaks and irregular bands of blown sand.

A few yards the other side of the stream, the following section was obtained:—

		Feet.
Yellowish marl, ...	more than	2
Head, ...	about	25
Coarse, rolled gravel, with some head,	..	2
Sand, ...	..	2–3

In the next bay to the east, the section is as under:—

	Feet.
Head, ...	100
Cemented sand and gravel, ...	1–2

Platform 6 feet above high-water mark of ordinary spring-tides.

The eastern side of the bay runs almost at right angles to the strike of the rocks, and the pre-glacial shore is cut up by several gullies eroded along the softer beds. Sand and gravel, or sand with layers of pebbles from 2 to 6 feet thick, fills up the gullies, and is overlain by 20 to 30 feet of head.

After rounding the headland, and for about half a mile to the east, the head in many places has been cleared off, and the pre-glacial cliff exposed. It slopes steeply towards the shore; and at its foot, there is generally some trace of the water-worn rock-platform.

East of the large stream in Ballylanders townland, 20 feet of red sandstone head, with some yellowish loam at its base, rests on the platform.

About fifty yards round the next point, the section seen in the cliffs is as under:—

	Feet.
Loam, with angular and some rounded stones,	3
Loamy sand, ...	1
Gravel, ...	3–4
Red boulder-clay, ...	3
Lower head, ...	12
Beach-gravel in pockets in platform, ..	—

The next headland, a quarter of a mile further east, is formed by a large cone of head, the apex of which points up a valley. The stream which occupies the valley has cut a narrow but deep channel through the head. The cone rests on the rock-platform, and has been eroded by the sea, so that it is now cut off by cliffs from 12 to 40 feet high. It is composed of angular *débris* of red sandstone with reddish loamy layers, which dip seawards at low angles.

Ballyandreen.—On the west side of the cove at Ballyandreen, the platform was seen overlain by head, and a thin deposit of boulder-clay, containing flints and small shell-fragments. On the east side there are vertical rock-cliffs, capped by a variable thickness of head; but a stack, standing a short distance from the cliff, and planed off from 5 to 6 feet above high-water mark, is surmounted by a thick deposit of head, and points to the local destruction of the platform and its overlying deposits of drift.

Ballycottin.—On the southern shore of Ballycottin Bay the beach-deposits are fairly well developed, being in some places overlain by boulder-clay of the Cork type, and in others by the shelly marl of the eastern ice. The following sections can be seen on the shore, north-east of the chapel, close to the end of a lane:—

	Feet.
Head, yellow and clayey, ...	10
Beach-gravel and sand, ...	5
Rock-platform.	

There is a pasty band, 1 foot thick, at the bottom of the head. The rock-platform is 5 to 7 feet above ordinary high-water mark. About 60 yards east of this, we have—

	Feet.
Boulder-clay, ...	8–12
Head, ...	12–8
Beach-gravel and sand, ...	2–3
Rock-platform.	

The boulder-clay is of the Cork type, but contains an occasional flint. The rock-platform is 5 feet above ordinary high-water mark. Below Bayview Hotel:—

	Feet.
Marly boulder-clay, ...	5
Head, ...	18
Gravel and rounded boulders	traces.
Rock-platform.	

The marly boulder-clay is a reddish-brown clay, with shell-fragments and a few stones.

The head has a sandy matrix, and is composed of red and green angular fragments of rock, with some broken vein-quartz. The rock-platform is 6 to 7 feet above ordinary high-water mark.

In the middle of Ballycottin Bay, the cliffs consist of brownish marly clay with shell-fragments and erratics, and of fine yellow sands which overlie the marl. (See lists, pp. 266 and 268.)

Knockadoon Head.—On the north side of Knockadoon Head there are good sections of the drifts resting on the rock-platform. The pre-glacial beach-gravel is sometimes 6 feet thick, and several erratic pebbles were picked out of it here. It is overlain by lower head, which is sometimes succeeded by red boulder-clay and upper head.

North of the Coastguard Station, reddish boulder-clay, 18 feet thick, rests on the rock-platform, which is striated from N. 37° W. to S. 37° E. The boulder-clay contains a number of pebbles of Old Red Sandstone and Carboniferous rocks, and also one or two flints and shell-fragments.

Youghal.—South of Youghal Railway Station, the cliffs consist of marly boulder-clay, with fine bedded sands, overlain by gravels composed of Old Red and Carboniferous rocks. The rock-platform is seen on both sides of the estuary at Youghal. Marly boulder-clay, apparently overlain by a reddish stony boulder-clay, occurs at the Youghal Brick Works, north of the town, but the former does not appear to extend north of Youghal Bridge. In a small quarry, east of Ardsallagh House, and a little over half a mile north-north-east of Youghal Bridge, the local stony boulder-clay rests on rock, which is striated from N. 50° W. to S. 50° E.

Whiting Bay.—At the western end of Whiting Bay the cliffs consist of head, which is composed of angular red sandstone fragments and vein-quartz, with a reddish loamy matrix. It is often over 40 feet thick, and rests on the rock-platform, which has an uneven water-worn surface. In the hollows of the platform, and under the head, there is a thickness of from 2 to 3 feet of fine and coarse bedded gravel, which sometimes has a loamy matrix, derived from the washing down of the fine material of the head. At one place a little blown sand was seen below the head. A short distance west of the road down to the shore, marly boulder-clay overlies the head, which gradually thins out eastwards until the marl comes to rest on the beach-gravel. Finally, the base of the marl passes below the level of the modern beach-shingle.

Near the eastern end of the Bay, the following section is seen in the cliffs:—

	Feet.
Stony boulder-clay, ...	15
Marly boulder-clay, ...	20

The stony boulder-clay is slightly reddish in colour, and contains sub-angular boulders of yellow grit, red sandstone, and vein-quartz. Its junction-line with the marl is an uneven one, and the upper clay was probably deposited by the inland ice coming from the north. The marly boulder-clay is of the usual type, and a list of the erratics found in it is given on p. 268.

Ardmore.—Just east of Ardmore village, the rock-platform was seen overlain by head.

Dungarvan.—On the southern side of Dungarvan Harbour, the raised-beach platform can be seen emerging from beneath thick drift deposits, consisting largely of marl and sand. The cliffs are much overgrown and obscured by slipping, and are, in consequence, difficult to decipher. When visited, the following sections were fairly clear:—

(1). Two hundred and fifty yards west of Ringville Stream.

	Feet.
Gravel, ...	8
Marly boulder-clay, ...	4
Head, ...	12

Rock-platform.

(2). Three hundred yards further west.

	Feet.
Reddish boulder-clay, with much Old Red Sandstone, ...	10–15
Fine silt, with a few stones towards top, ..	3–4
Fine loamy sand, ...	5–10
Bluish marly boulder-clay, ...	10
Head, ...	12–15 +

Rock-platform probably near.

The reddish boulder-clay at the top of the latter section has a rather clayey matrix, and contains much Old Red Sandstone. A pebble of porphyry was also found in it, and a flint was obtained from the top of the underlying silt. The marly boulder-clay throws springs out of the sand which lies above it. The bottom 4 feet of the head has its matrix composed of a white clay, which occurs also in patches through it, and can be seen beneath the shingle on the shore.

Some yards further east there is an exposure of 15 to 20 feet of the stratified series, showing alternating silts and sands very free from stones. There seem to be some obscure contortions. The sands in places show obvious current bedding.

On the northern side of Dungarvan Harbour, there can be seen in one or two places a ledge of limestone a few feet above high-water mark, which may represent the pre-glacial shore-platform. No beach-deposits or head, however, accompany it.

Ballyvoyle Head.—Just west of Ballyvoyle Bridge, the Old Red Sandstone rock-cliffs have a fringing ledge of head. This is, at first, almost uncovered by boulder-clay; but as we go west, the drift-cliff leaves the pre-glacial cliff, and the boulder-clay thickens, ultimately replacing the head. A wide terrace of drift is thus formed, which extends so far seaward that the platform on which it lies passes below high-water mark, and is entirely covered by sand. The drift-cliffs along this stretch of coast from Ballyvoyle Bridge to Clonea are very fine, there being in one place 40 feet of boulder-clay of the inland type.

Immediately east of Ballyvoyle Bridge is the following:—

	Feet.
Boulder-clay, ...	15–25
Coarse blocky head, ...	3–5
Beach-shingle, well rolled,	traces.

Water-worn rock-platform.

Of the platform, only a mere remnant of the upper edge is left. It is decidedly water-worn. The beach-shingle is mixed up with the base of the head, and lies at a height of 12 to 15 feet above ordinary high-water mark.

A little further east is a rather better section, showing:—

	Feet.
Boulder-clay, with much Old Red Sandstone,	15
Head, with large blocks at base in places, ..	20–25
Beach-gravel and shingle among blocks, ..	1–2

Water-worn rock-platform.

The higher portions of the platform seen at this point are 8 to 12 feet above ordinary high-water mark.

The platform, although much eroded, is traceable 200 yards or so further east, beyond which are the cliffs of Ballyvoyle Head.

Ballyvoyle Head is the easterly extremity of the main mass of the Old Red Sandstone rocks on the south coast; and from this to Tramore, the cliffs are composed of sedimentary and igneous rocks of Silurian age. These have yielded much more easily to the action of the sea than the Old Red Sandstone to the west, and considerable erosion has been effected since the Glacial Period. In consequence, no traces of the beach have been found, although search was made in several places, and long stretches of the coast examined. That it once existed here there can, however, be little doubt, as the perpendicular post-glacial cliffs are often seen to truncate the old rounded slope, so characteristic of the areas in which the beach is to be found. This slope can often be seen to be continued on a stack some distance out to sea, as in fig. 3.

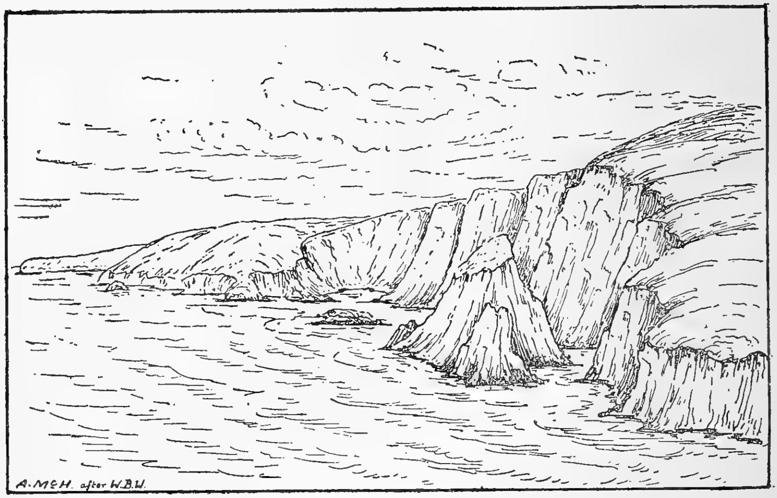

Fig. 3.—View looking west from Stradbally Cove, showing rounded feature by which the pre-glacial shore-line may be traced even where the beach has been removed by the sea.

Ballymadder Point, County Wexford.—The raised-beach platform, and its accompanying deposits, are well developed along a stretch of coast a mile and a half long at Ballymadder Point, County Wexford. The sections are best described from east to west, commencing a little over half a mile west of Bar of Lough at the point where the Cullenstown Road joins the coast. Near the remains of an old limekiln, built in the modern cliff, is the following section:—

	Feet.
Boulder-clay, with Leinster Granite, ..	9
Head, ...	4
Sandy pebbly loam, with slate fragments and quartz pebbles, ...	5
Black and red ferricrete sands and gravels (beach), ...	4–5

Rock-platform, covered by recent shingle.

The boulder-clay is a clayey drift with many small stones and large blocks of Leinster Granite.

The head is rather coarse, with angular fragments of broken rock. The pebbly loam beneath the head is a remarkable and rather unique deposit. It is a brown loam, sandy in places, containing angular fragments of green slate and rounded quartz pebbles. It has gravelly current-bedded bands at the base. The bed extends almost continuously from here to Ballymadder Point—a distance of three-quarters of a mile.

The beach-deposits are horizontally bedded, and contain well-rounded stones.

The platform is seen on the shore sixty yards out from the cliff, and thirty yards to the east at the limekiln.

Near a small point, a few hundred yards west of the limekiln, large, more or less rounded local blocks lie on the rock-platform among the beach-gravel and sand, showing that the rock-cliff is not far behind the present drift-cliff. The section is:—

	Feet.
Boulder-clay, ...	12
Coarse and local angular head, ...	6
Sandy, pebbly loam, as before, ...	5
Ferricrete sand and gravel blocks, ...	2–3

Uneven ribbed rock-platform just above high-water mark.

About thirty yards west of this point the sand having the appearance of blown sand can be seen under the head. Here, also, there is an outstanding knob of rock water-worn to a height of about 5 feet above the platform, which is a few feet above high-water mark.

At the next point:—

	Feet.
Boulder-clay, with many small stones,	5
Head, sandy and very angular,	2–3
Blown (?) sand, among rounded blocks,	4 ±

Rock-platform.

The sand is a fine, horizontally-bedded sand, very much resembling blown sand, and lying on the platform among the rounded blocks. Further seaward, there is a little pre-glacial beach-gravel lying among these blocks.

About 100 yards west of where the stream enters the sea, a water-worn knob of rock, 6 feet high, has its base (the ordinary level of the platform) 5 feet above the line of seaweed, *i.e.* 2 to 3 feet more or less above ordinary high-water mark. Section here:—

	Feet.
Boulder-clay, with small, rather angular stones,	8
Head, rubbly and very angular,	3
Pebbly loam, as before,	3
Coarse beach-shingle, with blocks,	2

Rock-platform.

Half-way between the stream and Ballymadder Point:—

	Feet.
Boulder-clay, very stony,	15
Head, coarse and angular,	4
Red sandy pebbly loam, few angular fragments,	5
Ferricrete sand,	4

Smoothed rock-platform, just above high-water mark.

Here the pebbly loam has fewer angular fragments; and a little further west, it passes downwards into a layer of yellow pasty clay, which rests immediately on the beach-gravel:—

	Feet.
Boulder-clay, very stony and full of angular fragments,	15
Angular head,	2–3
Pebbly loam, as before,	3
Yellow pasty clay,	2
Beach-gravel and sand, ferricrete	2

Rock-platform.

Still further to the west, the angular rubbly head dies out altogether, giving:—

	Feet.
Boulder-clay, ...	15
Sandy, pebbly loam, ...	6
Ferricrete sand and gravel, ...	4+

Platform covered with shingle.

The pebbly loam has bands of stratified silt and sand at its base. The platform is seen on the foreshore about 30 yards out.

Just west of Ballymadder Point is the following section:—

	Feet.
Boulder-clay, rather stony and full of angular fragments, ...	7
Angular head, ...	3–5
Beach-gravel and sand, ...	5

Rock-platform.

The beach-gravel lies in a hollow of the platform. The head forms the roof of a cave, which is excavated in the platform and beach-gravel. The top of the gravel is from 8–10 feet above ordinary high-water mark.

Thirty yards west of this, and continuing with slight variation for some distance:—

	Feet.
Boulder-clay, ...	9
Stratified sand and gravel, with blocks, ..	3–4

Rock-platform, 8 to 10 feet above ordinary high-water mark.

The boulder-clay here has a good deal of angular material and much Leinster Granite.

At the top of the cliff-sections described above, the surface of the ground rises inland at a gentle and uniform slope, there being no feature to mark the existence of a pre-glacial rock-cliff, which must consequently be very low along this coast. This low cliff (20 to 30 feet) can be seen emerging from behind the drifts a few hundred yards west of Ballymadder Point. From this on, however, the sea has removed the platform along the more prominent portions of the coast, and it is only retained in the bays, at the sides of which the rock-cliff can be seen receding behind the drifts. In these bays the boulder-clay, head, and pebbly loam seem to be developed, the sequence of the deposits being the same as before.

The only section examined was one on the shore, nearly due south of the Glebe House:—

	Feet.
Boulder-clay, ...	8
Angular head,..	3, or less.
Pebbly loam, ...	6 +

These are the sections described by Mr. Kinahan in the Memoir on Sheets 169, 170, 180, 181 of the Geological Survey, p. 29. He also gives several sections further west in the townlands of Haggard and Bannow.

Carnsore Point.—Round Carnsore Point an elevated platform can be seen, which is possibly a portion of the pre-glacial shore. There is, however, no well-marked pre-glacial cliff. Just north-west of the point, some gravel, resembling beach-gravel, was seen lying on the platform beneath the boulder-clay. The boulder-clay contains a large number of flints.

The pre-glacial shore-platform can also be seen emerging from beneath the drift-cliffs between Greenore Point and Rosslare Harbour.

APPENDIX.

APPENDIX.

LIST OF STRIÆ IN THE NEIGHBOURHOOD OF THE SOUTH COAST OF IRELAND (including new records).

District.	No.	Locality.	Direction.	Record or Observer.	Notes.
Sneem.	1	On S. side of road $\frac{1}{4}$ m. E. of Lough Fadda, nearly $4\frac{1}{2}$ m. E. of Sneem.	E. 10 N.	Geol. Survey 1" sheet 192,	
,,	2	2 m. E.N.E. of last on N. shore of Kenmare estuary, $\frac{1}{4}$ m. W. of Lacken Pt.	E.N.E.	,, ,,	
Bantry and Glengariff.	3	On shore on extreme N. point of Whiddy I., due N. of East Redoubt.	W. 15 N.	,, ,,	
,,	4	On shore of Whiddy I., due S.W. of the East Redoubt.	W. 35 N.	,, ,,	A little over $\frac{1}{4}$ m. S.S.W. of last.
,,	5	Near fork of roads $\frac{1}{2}$ m. S. of Glengariff Church, nearly $\frac{1}{2}$ m. E.N.E. of Glengariff Castle.	N. 15 W.	,, ,,	Marked as if moutonné from N. to S.
,,	6	$\frac{1}{2}$ m. S.S.E. of last on main road, due E. of Δ 356.	N.N.W.	,, ,,	
,,	7	300 yds. S.S.W. of last, and 300 yds. S.S.E. of Δ 356.	N. 30 W.	,, ,,	
,,	8	On roadside $\frac{1}{2}$ m. W.S.W. of Lough More.	N.W.	,, ,,	
,,	9	On shore at fossil locality S.W. of last	N.W.	,, ,,	
,,	10	On shore S. & W. of Dunnamack House.	W. 5 N.	H. B. Muff and W. B. Wright,	Two surfaces giving same reading.
,,	11	On shore N. of Gurteenroe House.	N. 25 W. & N.E.	,, ,,	Cross striæ.

,,	12	On shore a short distance N.E. of last.	N. 30 W.	,, ,,	Fine large surface.
,,	13	On road 500 yds. N. of cross-roads, near Ballylicky House.	N. 60 E.	,, ,,	
Coomhola Valley.	14	On road in Coomhola Valley $1\frac{1}{4}$ m. N. of Lough Atoreen, and just opposite Bailin School.	N. 20 W.	,, ,,	
,,	15	$2\frac{1}{2}$ m. N. of last, below road, and opposite mouth of Bailin Valley.	N. 5 E.	,, ,,	Motion from N. to S. indicated by moutonné surface.
,,	16	Above road round head of Cromhola Valley, 600 yds. N.W. by W. from Drumcollig Lodge.	W. 30 N. & W. 20 N.	,, ,,	Two surfaces close together.
Gougane Barra.	17	On rock barrier at east end of Gougane Barra Lake.	W. 10 S.	,, ,,	Fine ice-moulded surfaces.
,,	18	$\frac{3}{4}$ m. a little S. of E. from last.	W. 15 N.	,, ,,	
Dunmanway.	19	Close to Dunmanway workhouse on opposite side of road.	W. 10 N.		
,,	20	$\frac{1}{4}$ m. E.N.E. of R. C. Chapel.	W.N.W.		Rocks all ice-worn.
Ballyneen.	21	Near road, 1 m. N.N.E. of Ballyneen.	W. 5 N, W. 10 N.	Alex. M'Henry.	Two surfaces.
,,	22	Near road, $\frac{1}{4}$ m. N.N.E. of Killanur House, and 3 m. N.W. of Ballyneen.	W. 5 N.		
Skull.	23	On Skull Point, W. side of Skull Harbour.	N.	Geol. Survey 1" sheet 199.	
Baltimore.	24	At mouth of Roaring Water River.	N. & N. 37 W.	,, ,,	Cross striæ.
,,	25	On the N. side of the estuary of the Ilen, 2 m. due N. of Baltimore.	N. 20 W.	Alex. M'Henry, 6" 141, Cork.	
,,	26	On shore N. of Baltimore House.	N. 10 W. & N. 17 E.	H. B. Muff and W. B. Wright.	Two surfaces.
,,	27	At head of gully 750 yds. S.S.W. of Baltimore House.	N. 10 W.	,, ,,	

LIST OF STRIÆ IN THE NEIGHBOURHOOD OF THE SOUTH COAST OF IRELAND.—*continued.*

District.	No.	Locality.	Direction.	Record or Observer.	Notes.
Lough Hyne.	28	Close to Templebreedy on S. shore of Lough Hyne.	N. 30 W.	H. B. Muff and W. B. Wright.	Several surfaces.
,,	29	On shore of mainland, W. of Bullock Island.	N. 20 W.	,, ,,	
,,	30	Beside road, half-way between ∆ 271 and ∆ 310.	N. 30 W.	,, ,,	
Skibbereen.	31	On Ilen Valley Railway, $\frac{3}{4}$ m. S. of Madore, and nearly 4 m. N. of Skibbereen.	N. 30 W.	Geol. Surv. 1″ sheet 200.	
,,	32	W. shore of Castle Haven, 300 yds. N.E. of Castle Haven Rectory.	N. 30 W.		
,,	33	W. shore of Castle Haven, 300 yds. N.W. of Tracarta.	N. 15 W		
,,	34	200 yds. N.W. of last.	N. 30 W.	,, ,,	
Clonakilty.	35	On railway near Croppy's Cross Roads, 1 m. S. of Ballynascarthy.	W. 15 N.	H. B. Muff and W. B. Wright.	A little drift on top.
,,	36	W. side of Dunworly Bay.	N. 10 W.	Geol. Surv. 1″ sheet 201.	
,,	37	On S. side of Broadstrand Bay, S.E. of Courtmacsherry.	N. 10 W.	H. B. Muff and W. B. Wright.	Three surfaces near one another on raised beach platform.
			W. 40 N. & N. 20 W.	,, ,,	Cross striæ, N. 50 W. predominant.
			N. 10 E. & N. 20 W.	,, ,,	Cross striæ.

Macroom.	38	350 yds. W. of Carrigaphooca Bridge in valley of Sullane River, 2½ m. W. of Macroom, on S. side of road.	W. 20 S.	,, ,,	Crags all remarkably ice-moulded from west to east.
,,	39	700 yds. W. of Carrigaphooca Bridge.	W. 10 S.	,, ,,	
,,	40	On N. side of road, 1⅛ m. W. of Carrigaphooca Bridge.	W. 20 S.	,, ,,	
Cork.	41	On road, ½ m. due E. of Blarney Railway Station (G. S. & W. R.).	W. 10 N.	Geol. Surv. 1″ sheet 186.	
,,	42	Templemichael Bridge on the Glashaboy River.	W. 20 N. & W. 30 N.	W. B. Wright. Geol. Surv. 1903.	Large area of splendidly glaciated surfaces.
,,	43	On S. side of stream opposite Kilcully "Old Mill."	W. 17 N.	,, ,,	
,,	44	400 yds. W.N.W. of Δ 436, Ballynoe.	W. 18 N.	,, ,,	
,,	45	575 yds. N.E. of Δ 436, Ballynoe.	W. 10 N.	,, ,,	
,,	46	620 yds. due S. of Ashton Grove, and ⅞ m. W.S.W. of Knockraha.	W. 15 N.	,, ,,	Good horizontal surface.
,,	47	In bottom of gorge, 1000 yds. a little N. of W. from last.	W. 30 S.	,, ,,	Parallel to gorge.
,,	48	In quarry at bend in valley, 1 m. N.E. of Queenstown Junction Station.	W. 35 N.	H. B. Muff. Geol. Surv. 1903.	Striated surface on side of valley overlain by 2–3′ sandy drift.
,,	49	On side of a lane, a little over a furlong W.S.W. of last.	W. 20 N.	,, ,,	
,,	50	In Ballinphelin Brick Works, 2¼ m. E.S.E. of Ballinhassig.	W. 10 S.	A. M'Henry. ,,	On l. st. under b. cl. of O.R.S.
,,	51	In Little Island limestone quarries.	W. 3 N.	W. B. Wright. ,,	
,,	52	On Great Island, 150 yds. W. of Marino House.	W. 35 N.	H. B. Muff. ,,	On raised beach platform.
,,	53	Ringaskiddy—on shore 250 yds. S. of Lough More.	W. 5 S. & W. 10 S.	W. B. Wright. ,,	Fine surface on limestones under O.R.S. b. cl.

List of Striæ in the Neighbourhood of the South Coast of Ireland.—*continued.*

District.	No.	Locality.	Direction.	Record or Observer.	Notes.
Cork.	54	Valley of the Owenboy. In railway cutting due N. of Aghamasta Castle.	W. 10 S.	W. B. Wright. Geol. Surv. 1903.	
,,	55	On Weaver Point, Crosshaven.	W. 20 N & W. 10 S.	,, ,,	On back of anticline.
,,	56	On N. side of Ringabella Bay, close to farmhouse.	W. 5 N. & W. 10 N.	W. B. Wright.	On raised-beach platform under 3′ boulder-clay. See Plate XXV.
,,	57	N.E. corner of Corkbeg Island.	W. 10 S. & W.	H. B. Muff. Geol. Surv. 1903.	On limestone under 10′ boulder clay.
,,	58	White Bay, $\frac{1}{2}$ m. N. of Roche's Point C.G.S.	W. 15 N.	,, ,,	On raised-beach platform under 12′ boulder clay.
,,	59	Roche's Point — within lighthouse grounds.	W. 5 N.	,, ,,	
,,	60	At top of an old quarry behind the most northerly cottage in Barrykilla, 2 m. E. of Aghada Pier.	W.	,, ,,	
Youghal.	61	On shore N. of Greenland, on S. side of Youghal Bay.	N. 37 W	H. B. Muff and W. B. Wright.	On raised-beach platform under 18′ of red b. clay with flints and shell-fragments.
,,	62	On another surface close by.	N. 15 W.	,, ,,	
,,	63	In a small quarry E. of Ardsallagh House, a little over $\frac{1}{2}$ m. N.N.E. of Youghal Bridge.	N. 50 W.	,, ,,	Under local b. clay in valley of the Blackwater, and going parallel to river.
,,	64	$1\frac{1}{4}$ m. S.S.W. of Clashmore, and 400 yds. N.W. of Δ 289.	N. 15 E.	Geol. Surv. 1″ sheet 188.	
,,	65	On E. shore of Blackwater, 600 yds. E.N.E. of Strancully House, and opposite ruined castle.	N. & N. 30 E.	,, ,,	Cross striæ.

Dungarvan.	66	On shore opposite Bayview, $1\frac{3}{4}$ m. E. of Dungarvan Bridge.	N. 20 E.	W. B. Wright.	On limestone under 15′ O.R.S. b. clay.
Ballylaneen.	67	Close to Δ 293, $\frac{1}{2}$ m. S.S.W. of Ballylaneen, about 50 yds. from road.	N. 8 E.	,, ,,	Good striæ on nearly horizontal vein-quartz.
Tramore.	68	1 m. slightly E. of S. from Fennor Bridge, and 3 m. S.E. of Tramore.	N. 10 W. & N. 15 W.	,, ,,	Surface remarkably ice-moulded from N. to S., grooves almost weathered off.
,,	69	At S.E. corner of Ballyscanlan Lake, on top of trap ridge.	N. 2 W.	,, ,,	On vein-quartz, moulding shows motion from N.
,,	70	1 m. due S. of Cullen Castle, and $1\frac{1}{2}$ m. N.W. of Tramore.	N. 5 W.	,, ,,	On vein-quartz, going uphill, moulding shows motion from N.
Waterford.	71	On N. side of by-road, $\frac{1}{2}$ m. a little E. of N. from Ballinamona Ho.	N. 12 W.	,, ,,	On vein-quartz.
,,	72	On hill close to Δ 210, 700 yds. E. of Waterford Lunatic Asylum.	N. 10 W.	,, ,,	Good striæ on recently exposed surface.
,,	73	On N. side of road, a little E. of N. from Milepost Village.	W. 40 N. & W. 45 N.	,, ,,	On quartz pebbles in O.R. Conglomerate.
Wexford.	74	On the Mountains of Forth, exactly 3 m. W. 52 S. from Ferrycurrig Bridge, Wexford.	N. 15 E.	Geol. Surv. 1″ sheet 169.	
,,	75	300 yds. E.N.E. of Walsh Bridge, Ballyconnick.	W. 27 N.	,, ,,	
,,	76	300 yds. E.S.E. of Ballyconnick Bridge.	N. 20 W. & N. 20 E.	,, ,,	Cross striæ.
Carnsore.	77	On shore N.E. of Netherton, Carnsore.	N. 10 E.	H. B. Muff and W. B. Wright.	Good striæ on granite under $2\frac{1}{2}'$ of boulder-clay with reddish matrix, much granite, and several flints.

EXPLANATION OF PLATE XXIII.

PLATE XXIII.

Platform and overlying deposits 350 yards east of Howe Strand Coastguard Station, Courtmacsherry Bay. Water-worn and channelled platform in foreground. Stack showing beach-sand under head and boulder-clay. To right, large wave-worn blocks and cliff showing similar deposits to stack. See p. 253.

Bemrose Ltd Derby

EXPLANATION OF PLATE XXIII.

PLATE XXIII.

Plate [illegible] deposit 850 yards east of Howe Strand [illegible] Bay [illegible] channelled [illegible] and [illegible] deposit [illegible]

Bemrose Ltd, Derby

EXPLANATION OF PLATE XXIV.

PLATE XXIV.

Section in Courtmacsherry Bay three-quarters of a mile east of last, showing beach-gravel and sand resting on shore platform, and overlain by boulder-clay. See p. 255.

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PLATE XXIV.

Section in Courtmacsherry Bay three-quarters of a mile east of last, showing beach-gravel and sand resting on slate platform and overlain by boulder-clay. See p. 255.

Bemrose Ltd., Derby.

EXPLANATION OF PLATE XXV.

PLATE XXV.

Striated raised-beach platform, overlain by boulder-clay, in Ringabella Bay. Looking W.S.W. See p. 256.

Bemrose Ltd, Derby.

PLATE XXV.

Striated raised beach platform, overlain by boulder-clay, in Ringabella Bay. Looking W.S.W. See p. 256.

Plate XXV

Bemrose Ltd, Derby.

EXPLANATION OF PLATE XXVI.

PLATE XXVI.

Section nearly 500 yards east of Howe's Strand Coastguard Station, Courtmacsherry Bay. Channelled platform covered by lichens, and overlain by ferricrete beach-sand, lower head, boulder-clay and upper head. See p. 257.


UPPER HEAD
Boulder clay
Lower Head
Raised beach sand
Pool
Channelled platform
with lichens and grass

PLATE XXVI.

Section nearly 500 yards east of Howe's Strand Coastguard Stati
Courtmacsherry Bay. Channelled platform covered by lichens, a
overlain by ferricrete beach-sand, lower head, boulder-clay and up
head. See p. 257.

Bemrose Ltd, Derby.

EXPLANATION OF PLATE XXVII.

PLATE XXVII.

Section normal to coast-line, about 80 yards south of Myrtleville Cottage, and about a mile and a half due S. of Crosshaven. Beach deposits, with stratification dipping seawards, and overlain by lower head. Fallen blocks on left. Springs issuing along platform. Modern beach-shingle at bottom. See p. 260.

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PLATE XXVII.

Section normal to coast-line, about 80 yards south of Myrtleville Cottage, and about a mile and a half due S. of Crosshaven. Beach deposits, with stratification dipping seawards, and overlain by lower head. Fallen blocks on left. Springs issuing along platform. Modern beach-shingle at bottom. See p. 260.

Bemrose Ltd, Darby.

EXPLANATION OF PLATE XXVIII.

PLATE XXVIII.

Section on south side of Myrtleville Bay, showing blown sand beneath lower head. Rock-platform on left in foreground. See p. 263.


Head
Blown sand in cave.
Modern talus.
Rock Platform.

PLATE XXVIII.

Section on south side of Myrtleville Bay, showing **blown** sa
beneath lower head. Rock-platform on left in foreground. **See p. 2**

Plate XXVIII.

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EXPLANATION OF PLATE XXIX.

PLATE XXIX.

Section in Clonakilty Bay, one-third of a mile south-east of Ballinglanna Cove. Boulder-clay overlying beach-gravel on pre-glacial rock-platform 10 or 11 feet above modern shore-platform. See p. 278.


Boulder clay
Raised beach gravel
Modern shore platform

PLATE XXIX.

Section in Clonakilty Bay, one [illegible] Ballinglanna Cove. Boulder-clay over [illegible] at rock-platform 10 or 11 feet above [illegible] [illegible]78.

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EXPLANATION OF PLATE XXX.

PLATE XXX.

Four hundred yards east of Simon's Cove, Clonakilty Bay. Ferricrete beach-gravel bridging over recent gully in raised platform. For section in overlying drifts, see p. 277.

Plate XXX

Bemrose Ltd. Derby

Fifty [illegible] Terri-

[illegible] For

Plate XXX

Bemrose L^{d}, Derby

EXPLANATION OF PLATE XXXI.

PLATE XXXI.

Sketch Map of the South Coast of Ireland, showing Raised Beach and Glaciation.


CLON
Kn
T
ulti
WATERFORD
DUNGARVAN
Ri
more
Ardr
MOREo
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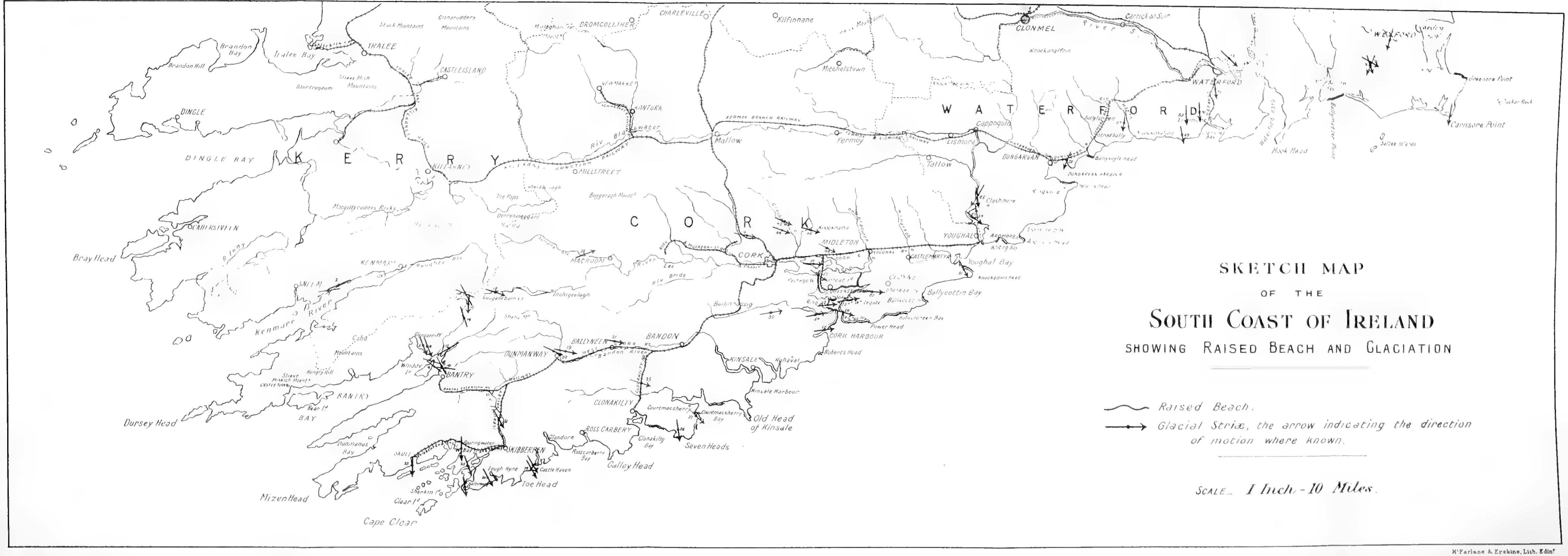
ting Bay
Bay
oon Head



SKETCH MAP
OF THE
SOUTH COAST OF IRELAND
SHOWING RAISED BEACH AND GLACIATION

Raised Beach.

Glacial Striæ, the arrow indicating the direction of motion where known.

SCALE _ 1 Inch - 10 Miles.

M'Farlane & Erskine, Lith. Edinr

XXVI.

VAPOUR-PRESSURE APPARATUS.

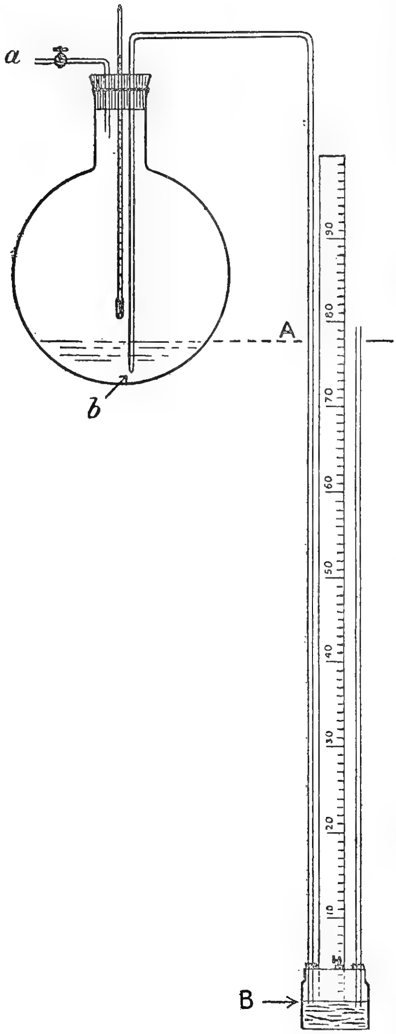
By JAMES J. HUTCHINSON.

[COMMUNICATED BY PROF. W. F. BARRETT, F.R.S.]

[Read, March 15; Received for Publication, April 22;
Published, Sept. 17, 1904.]

The simple method usually employed in determining the vapour-pressure of a liquid at various temperatures below its boiling-point, consists of the following :—

A round-bottomed flask is fitted with a cork, through which pass a thermometer and long tube, the latter bent twice at right angles; the shorter arm of the tube passes just through the cork, the other arm dipping into a mercury-tank. On boiling the liquid in the flask, vapour is forced out through this tube, and escapes through the mercury-valve into the atmosphere. The pressure of the vapour is thus transmitted to the mercury through the vapour itself. On removing the source of heat, the pressure within the flask falls below that of the atmosphere; and the mercury rises in the tube, and serves to indicate the pressure at various temperatures as recorded by the thermometer. The method has serious defects: one is, that, as the vapour condenses in the tube, a head of liquid is formed on the mercury-column; and, as condensation continues, this head of water is constantly changing, so that exact correction for this error is impossible. The following method, in part due to suggestions received from Professor Barrett, gets over this difficulty. The flask is now provided with a cork, through which three holes are bored, as shown in the figure, p. 326. Through one hole passes a short piece of tubing, bent at right angles, and provided with a tap or press-clip. The second hole allows a thermometer to pass into the vapour, while through the third hole passes the long pressure-tube. This tube is similar to the older one; but the pressure-tube, in this case, passes almost to the bottom of the flask, and below the surface of the liquid. It is essential that the end of this tube, *b*, dipping below the surface of the water in the flask, be contracted, in order to prevent the rapid siphoning over of the liquid in the flask.



When the liquid in the flask is heated to boiling-point, air and vapour are allowed to escape through the short tube *a*; and when all air is expelled from the flask, the tap is closed. The pressure developed inside the flask will now force the liquid up the pressure-tube *b* and into the mercury-tank, driving out all the air in the tube. Quickly removing the flame, and allowing the pressure to fall, hastening it if necessary by chilling the vapour in the flask, the mercury is forced back into the tube. A column of water now completely fills the part of the tube above the mercury, so that the vapour-pressure of the liquid is found from the mercury-column, less this column of water from the level in the flask to the surface of the mercury in the tube. The level of the liquid in the flask A may be regarded as constant, so that this column of water is accurately measured by the reading of the mercury surface.

The method has been adapted to determining pressures greater than atmospheric, by fitting another tube into the mercury-tank. Here, in the case of high pressures, the liquid forced over from the flask cannot escape, and forces the mercury up the second tube. The apparatus is thus capable of giving, from one experiment, pressures above and below that of the atmosphere, and thus takes the place of the two methods, distinct and apart, which are usually employed.

The method is in daily use in the Physical Laboratory of the Royal College of Science, and yields results, even in the hands of inexperienced workers, which are accurate and concordant. The following figures have been taken from the work of students using the apparatus for the first time:—

Temp. C.	Vapour-pressure in mms. of Mercury.	Regnault's Figures.
104°	875·3	875·7
101	787·3	787·6
90	525·1	525·4
80	354·1	354·6
20	173·7	173·9

XXVII.

FORMATION OF SAND-RIPPLES.

By J. JOLY, B.A.I., D.Sc., F.R.S., F.G.S.,

Professor of Geology and Mineralogy in the University of Dublin.

[Received for Publication, August 15; Published, September 23, 1904.]

Observations made on the sandy shore of Ballinskelligs Bay, Co. Kerry, appeared to show that sand-ripples were formed on the sand by the wind in the following manner.

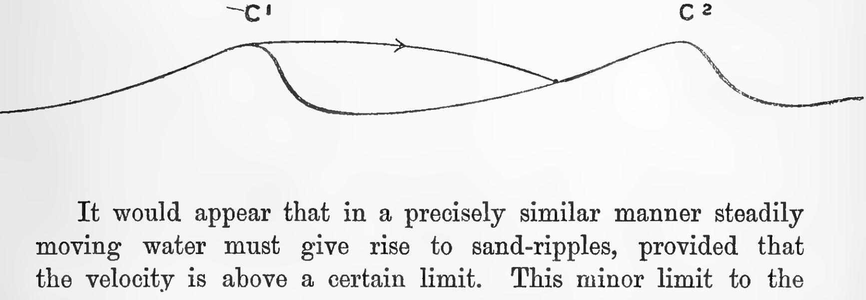
The particles of sand rolled by the wind up to the crest C_1 [see figure] were projected from it by the force of the wind; described a trajectory under wind-impulse and gravitational force, reaching the next slope at some point near a second crest C_2. Up this they were again transported until projected from the crest C_2. In addition to these movements, grains were rolled over the crests (apparently the larger and heavier grains, on the whole), and so gave rise to a gradual forward travel of the ripples.

It is evident, if this be the mode of formation of the ripples, that the spacing of the ripples (wave-length) and their height are inter-dependent.

To test this theory, I raised a temporary ripple of almost three times the normal height. It rapidly blew away at the crest, and at the same time an elevation, several normal wave-lengths removed from it, began to form in its lee; while the hollow between, being insufficiently fed from the raised crest, began to deepen by wind-scour till the damp and firm sand beneath was exposed to view.

Observation of the spacing of the ripples on inclined surfaces also supported the foregoing explanation. Thus I found that on inclines facing the wind the wave-length was shortened, and on inclines away from the wind, the wave-length was lengthened beyond the normal as observed upon the flat. Obviously in the first case the trajectory of the sand particle is shortened, in the second lengthened, owing to the inclination of the ground.

Of course, it will be seen that ripples can only form—according to this explanation—when the wind is moving above a certain velocity. When this velocity is attained (and what this must be will depend upon the density and coarseness of the sand), there is necessarily instability, as any roughness then initiates the flight and convection of grains, and thus the beginnings of ripples, which will increase in height till the transport is a maximum for the wind-force, and they are removed from the crests just as fast as they accumulate there by projection and rolling.



It would appear that in a precisely similar manner steadily moving water must give rise to sand-ripples, provided that the velocity is above a certain limit. This minor limit to the velocity will, of course, be less than that required for sand-ripples due to wind, owing to the greater "transporting power" of water.

In both cases there would seem to be reasons to expect that under very various rates of movement of the fluid medium (above the minor limit) the height and wave-length of the ripple would approximate to a certain average. In fact, if the velocity is great, the crest is pushed over and levelled; and the trajectory is diminished in throw by its origination at a lower level, while it is increased in throw due to the greater transporting power. Hence there are conditions which would appear to confer upon the path of the particle a certain average length, from which it will not very much diverge. This, I think, agrees with observation. There was nothing in my observation to negative the view that a rotary motion of the wind occurs in the lee of each ripple, thus affecting the nature of the curve described by the particles. It is rather to be expected that such a motion would arise.

XXVIII.

ON A METHOD IN QUALITATIVE ANALYSIS FOR DETERMINING THE PRESENCE OF CERTAIN METALLIC OXIDES.

By CHAS. R. C. TICHBORNE, F.I.C., Dip. P.H., F.C.S., etc.

[Read, June 21; Received for Publication, Sept. 14; Published, October 31, 1904.]

The determination of the presence of an oxide either in a mixture or by itself is not always easy; in fact, it is largely indicated by the negation of special reactions, and by the analyst's knowledge of the special properties of the well-known oxides.

A recent text-book by an authority on analysis speaks of this question in the following manner[1]:—

"If no acidulous radical can be detected in a substance under analytical examination, or if the amount found is obviously insufficient to saturate the quantity of basylous radical present, the occurrence of oxides or hydroxides, or both, may be suspected. . . . Hydroxides and oxides insoluble in water not only neutralize much nitric acid, or acetic acid, but are thereby converted into salts soluble in water. Most oxides and hydroxides have a characteristic appearance. In short, some one or more properties of an oxide or hydroxide will generally betray its presence to the student who not only has knowledge respecting chemical substances, but has cultivated the faculties of observation and perception."

If the above quotation fairly represents the method now in use, it is certainly not very definite.

To the experienced analyst the ordinary reactions of well-known oxides rarely present a difficulty; but it is not so with most students, who, lacking a general experience, are often sorely puzzled how to make up their minds on such questions.

Under these circumstances an easily applied test of a general character is desirable.

The test I propose is based upon a very simple reaction between the indicator, phenol-phthalein, and the carbonates of sodium. This indicator, phenol-phthalein, as is well known, whilst colourless in

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[1] Attfield's *Chemistry*, 17th edition, p. 453.

neutral solutions, is crimson in solutions of alkalies and alkaline carbonates, but it is also colourless in solutions of acid-carbonates.

The test solution I use is made by dissolving 10 per cent. of pure sodium acid-carbonate in distilled water. If this solution is tested with phenol-phthalein, it will probably give a faint pinkish coloration, although the sodium acid-carbonate may be perfectly pure. The act of dissolving it produces a slight dissociation. This coloration is indeed so slight that in practice it might be ignored. I prefer, however, to gradually add a few drops of a normal solution of nitric acid. After this treatment we get a solution which is quite colourless when tested with phenol-phthalein. If the sodium acid-carbonate solution has been laid by for some time, it must be again brought to the neutral stage.

Most metallic oxides, acting on this solution, will reduce a certain proportion of the acid carbonate to the normal carbonate, according to the following equation :—

$$MO + 2NaHCO_3 = Na_2CO_3 + MCO_3 + H_2O.$$

I find that most of the hydroxides, and oxides formed in the moist way, will bring about this decomposition. Those that have been ignited do not, as a rule, act so well.

The test may be applied in two ways—

(1.) A little of the suspected substance is rubbed in a mortar with two or three c.cs of the sodium acid-carbonate solution. It is then thrown upon a filter; and if it contains any of the specified oxides, the filtrate will immediately give a deep crimson coloration with the phenol-phthalein solution. The object of rubbing in a mortar is, that as we are dealing with insoluble oxides and insoluble carbonates, the reaction is rather slow unless this device is adopted.

(2.) If time is no object, it is not necessary to do this. The suspected substance is shaken occasionally for about an hour in a test-tube, when the decomposition will be sufficiently advanced to give a marked reaction. On testing the filtrate from such an experiment, heat should not be applied. Dissociation of carbonic acid takes place, resulting in permanent decomposition when operating in an open tube.

LIST OF THE OXIDES EXAMINED AS REGARDS THEIR REACTION WITH SODIUM ACID-CARBONATE AND PHENOL-PHTHALEIN.

NAME.	VARIETY.	OBSERVATIONS.
Lead, PbO, . . .	Litharge.	Gives the reaction very readily.
Lead, Pb_3O_4, . . .	Minium, or red lead.	No reaction.
Silver, Ag_2O, . . .	Pharmacopœia.	Gives the reaction readily.
Mercury, Hg_2O, . .	Precipitated oxide, well washed.	No reaction.
Mercury, HgO, . .	Yellow, precipitated.	Marked reaction best obtained by trituration process.
Mercury, HgO, . .	Red crystalline.	Reactions obtained, but in a less marked manner than with the yellow variety; test-tube process.
Copper, Cu_2O, . .	Cuprous oxide by reduction.	Gives the reaction badly. The most satisfactory results obtained by digesting for some time in the test-tube.
Copper, CuO, . . .	By precipitation and ignition of carbonate.	No effect.
Bismuth, Bi_2O_3, . .	Pharmacopœia.	Marked reaction by the trituration process.
Tin, SnO_2, . . .	Putty powder.	Marked reaction by either process.
Antimony, Sb_4O_6, .	Pharmacopœia.	Marked reaction by trituration process
Aluminium, Al_2O_3, .	—	No reaction.
Iron, FeO, . . .	Moist.	Marked reaction by trituration process.
Iron, Fe_3O_4, . . .	Magnetic oxide by precipitation.	Marked reaction by trituration process.
Iron, Fe_2O_3, . . .	By precipitation.	No reaction.
Manganese, MnO, .	By precipitation.	Marked reaction by trituration process.
Manganese, MnO_2, .	—	No reaction.
Zinc, ZnO, . . .	Flowers of zinc.	Well-marked reaction.
—	Oxide by ignition of the carbonate.	Well-marked reaction by trituration process.

The oxides of the alkaline earths and the alkalies give the reaction; but, of course, their own alkaline reaction is sufficiently marked to render an experiment with the sodium acid-carbonate superfluous.

Magnesium carbonate $3\,MgCO_3, Mg(HO)_2\,4\,H_2O$, and Bismuth carbonate $2(Bi_2O_2CO_3)\,H_2O$, being basic carbonates, give a slight pink tinge, but present no diagnostic difficulty owing to the evolution of CO_2 on acidulation.

The ferric oxide and alumina, as might naturally be expected, give no reactions, as the carbonates are not known to exist. We thus see that this reaction is of very general application; but it is right that we should bear in mind that some of the ignited oxides lose more or less the power of decomposing the acid-carbonate. The same remark applies to most of the mineral oxides as found in nature.

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THE

SCIENTIFIC PROCEEDINGS

OF THE

ROYAL DUBLIN SOCIETY.

Vol. X. (N. S.) JULY, 1905. Part 3, and last.

CONTENTS.

DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.
WILLIAMS AND NORGATE,
14, HENRIETTA-STREET, COVENT GARDEN, LONDON;
20, SOUTH FREDERICK-STREET, EDINBURGH;
AND 7, BROAD-STREET, OXFORD.
1905.

Price Two Shillings and Sixpence.

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XXIX.

THE TEMPERATURE OF HEALTHY DAIRY CATTLE.

By G. H. WOOLDRIDGE, M.R.C.V.S.,
Professor of Medicine, Royal Veterinary College of Ireland.

[Read, March 21; Received for Publication, March 24; Published, April 20, 1905.]

I have been impressed on many occasions when referring to the works of various observers, by the considerable differences in the average temperatures of apparently healthy cattle quoted by them, and also by the variations one might expect to meet with during health. Consequently I determined to make observations with a view to ascertaining, as far as possible, the mean temperatures of healthy cattle taken per rectum, and the extremes between which they might be expected to fluctuate under normal conditions.

Robertson[1] made observations on 352 cows and oxen, and gave 101·9° F. (38·85° C.) as an average, with extremes of 100° and 104·5° F.

Singleton[1] gives an average of 101·5° F. (38·6° C.), with extremes of 100° and 103·3° F. His observations number 100.

Hobday[1] made observations on eighty-seven cows, and agreed with Singleton in the case of the mean temperature, viz. 101·5° F.; but his range is a little lower, 99·5° F. to 103° F.

Fred. Smith[2] gives 101·8° F. to 102° F. (38·7° C. to 38·8° C.). Colin,[3] Meade Smith,[4] and Thanhoffer,[5] all give identical figures, viz. 100·4° F. to 101·3° F. (38° C. to 38·5° C.).

Friedberger and Fröhner[6] give 101·8° F. (38·8° C.) as the average, and quote Hadschopulo, who took 50,000 temperatures at Moscow, and gave an average falling between 101·1° F. and 101·8° (38·4° C. to 38·8° C.).

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[1] Quoted by Schäfer, "Text-book of Physiology," p. 790.

[2] "Veterinary Physiology," p. 306.

[3] "Traité de Physiologie Comparée des Animaux, vol. 1, p. 1046.

[4] "Physiology of the Domesticated Animals," p. 696.

[5] "Vergleichenden Physiologie und Histologie," pp. 476, 477.

[6] "Lehrbuch der Klinischen Untersuchungsmethoden," p. 166.

Thanhoffer[1] also quotes Gavarret-Rosenthal, who states the very low average of 99·5° F. (37·5° C.).

On comparing these figures it will be seen that Robertson and Fred. Smith give a *mean* temperature of 101·9° F., which is ·6° F. higher than Colin and others give as the *higher extreme.* Again, comparing the averages of Robertson and Gavarret-Rosenthal, we find a difference of almost 2·5° F., the former giving 101·9° F., and the latter 99·5° F.

The observations I have recorded were all made on apparently healthy dairy cattle. They number 1395, and were made on 174 animals. I shall presently draw attention to the fact that a large proportion of these animals were subsequently submitted to the tuberculin test, and that many of them reacted. But it is advisable first to see what their average temperature is, in order to compare it with those quoted by previous observers who omit to state whether the subjects of their observations were proved free from tuberculosis, in which case I think it is fair to conclude that they come under the same heading of "apparently healthy" animals. I find, then, that the average temperature of these 1395 observations is 101·6° F. (38·66° C.), which is ·1° F. higher than Hobday and Singleton give, and ·3° higher than Colin and others give as the higher extreme.

Much greater importance, however, must be attached to the statistics based on observations made on animals proved to be free from tuberculosis, which is often responsible for considerable fluctuations. I know of no such observations previously recorded. In fact, nearly all the statistics we have were compiled before tuberculin was introduced into regular practice; and its use is the only definite method we have of detecting most of the early cases of the disease.

Of the previously mentioned animals, 63 of those tested failed to react to the tuberculin, and were consequently considered to be free. On those 63 animals I have 520 observations; and the average temperature I find to be 101·4° F. (38·5° C.). The lowest recorded temperature of the 520 was 100·4° F. (38° C.), and the highest observed was 102·8° F. (39·3° C.); but these extremes were very rarely indeed met with. The lowest average of any individual was 100·8° F., and the highest average was 102·2° F.

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[1] *Op. cit.*, pp. 476, 477.

Of the 63 healthy animals, only 7 had an average temperature below 101° F.; and the same number had an average temperature of 102° F. or over.

Thus my conclusion is:—that in healthy dairy cattle the temperature may vary between 100·4° F. and 102·8° F., with an average mean temperature of 101·4° F.

SOME CAUSES OF VARIATIONS.

Time of Day.—Some of the causes and the extent of the variations of temperature in health are well worthy of note; and therefore I made 370 observations on a dairy of 37 apparently healthy cows, some in calf, and others not in calf. The temperatures were taken twice daily for five consecutive days: in the mornings, about 8 o'clock, and in the afternoons, between 4 and 5 o'clock, before feeding. The average morning temperature of 185 observations was 101·5° F., and the average evening temperature was 102° F. Thus we see an average rise of ·5° F. from morning to evening.

Feeding is usually credited with some slight influence in raising the temperature. In order to see to what extent this occurred, I took the temperatures of the same 37 cows during feeding between 4.30 and 5 p. m. The average temperature at that time was found to be 102·3° F. As the average temperature of rest of the same animals at the same hour on other days was found to be 102° F., it is permissible to assume that feeding was responsible for an average rise of temperature of ·3° F.

Drinking, immediately before taking the temperature, is usually responsible for a slight reduction; but I have no records at hand to show to what extent.

Pregnancy.—To see the extent of the rise caused by this condition, I made 60 observations on 6 apparently healthy, in-calf cows. Their average was 102° F. On comparing that with 310 observations made on 31 non-pregnant cows kept in the same cowshed at the same time, the average of the latter being 101·7° F., a rise of ·3° F. is shown, presumably due to their pregnant condition.

Various other conditions are said to cause variations of temperature in health, such as œstrum, rumination, active lactation, housing, and the time of year. Hadschopulo states that, in cold weather, the temperature per rectum is raised from ·2° to ·4° F. (Quoted by Friedberger and Fröhner.)

All these observations were made on housed dairy cattle. I hope at some future date to be able to record the results of observations made on store cattle kept outside.

THE TEMPERATURE OF TUBERCULOUS DAIRY CATTLE NOT CLINICALLY AFFECTED.

It has long been an accepted fact that the temperature is of little assistance to the clinical observer in making his diagnosis in cases of tuberculosis in cattle by ordinary means; and one is not infrequently astonished on examining the viscera of cattle in prime condition slaughtered for food, to find tuberculous lesions when least expected. Friedberger and Fröhner[1] say, "The temperature of the body in tuberculosis may be normal, although we far more frequently find an irregular remittent or even intermittent fever up to 41° C. (105·8° F.) . . . Clinical diagnosis is very uncertain. No diagnostic sign may be present, especially during the first few months of the disease."

Since the introduction of tuberculin as a diagnostic agent, however, tuberculosis may be detected in the very earliest stages, and where there has been no reason to suspect the presence of the disease. Tuberculin has now been in use for nearly fifteen years, and during that period has had a very extensive trial and proved itself to be almost infallible.

The observations here recorded were made on dairy cows that were not suspected of tuberculosis, which disease was only revealed by submitting the animals to the tuberculin test.

My observations number 505, and were made on 74 reacting dairy cows out of 137 tested. The temperature of each of the cows was taken on several consecutive days, and at various times of the day, and they were tested immediately afterwards. Obviously the temperature of these animals during the test period must not be included, since the reaction consists of a rise of temperature. The average temperature shown by the 505 observations is 101·7° F. (38·7° C.), which is ·3° F. higher than the

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[1] "Veterinary Pathology": translated by Hayes.

average temperature of health. The lowest observed temperature was 100·4° F., and the highest was 104·3° F. The lowest average temperature of an individual was 100·6° F., and the highest average was 103·3° F. The greatest range of any individual observed was from 100·7° F. to 104·3° F.; while the average of fifteen observations on that same cow was found to be 102·2° F. Of the 74 cows in question, 50 per cent. had an average temperature falling between 101° F. and 102° F., while 10 averaged below 101° F., and 27 averaged 102° F. or over.

Thus I am justified in concluding that tuberculosis in early cases causes only a slight rise in the average temperature, viz., ·3° F., but that affected animals are subjected to greater variations from day to day than non-tuberculous cows kept under similar conditions.

A rather startling side-issue is revealed by the testing of these 137 cows, and that is, the enormously large proportion of apparently healthy animals that reacted, viz., 74 out of 137, or 54 per cent.

XXX.

ON THE PETROLOGICAL EXAMINATION OF ROAD-METAL.

By J. JOLY, D.Sc., F.R.S.,
Professor of Geology and Mineralogy in the University of Dublin.

[Plate XXXII.]

[Read, March 21 ; received for Publication, March 24 ; published, May 13, 1905.]

In a Paper on the application of petrological methods to the examination of paving-sets (these Proceedings, vol. x., N.S., p. 63, *et seq.*), I arrived at results sufficiently promising to suggest that microscopical study might also prove of use in the selection of road-metal. I postponed the question until I should have acquired some practical data bearing on material in use. In November, 1903, Mr. T. Aitken, M.INST.C.E., of Cupar-Fife,[1] was so good as to send me a collection of sixteen various metals in use on the roads in his district. Along with these he forwarded information as to his experience of their qualities. Pressure of other work has hindered me from publishing the petrological notes I then immediately made upon the microscopic character of these rocks.

General Considerations.

A road-metal may fail from (*a*) being deficient in hardness and coherence, (*b*) feeble weathering qualities, and (*c*) being deficient in cementitious or binding quality.

Failure under (*a*) results in a rapid development of mud in wet weather, or of dust and sand in fine weather—in short, what may be described as bad *wearing properties.* A hard stone is not necessarily a good wearing stone. Something more than hardness is required. Thus a hard rock may possess cleavage in

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[1] Author of "Road-Making and Maintenance" : a Practical Treatise for Engineers, Surveyors, and others, 1900.

EXPLANATION OF PLATE.

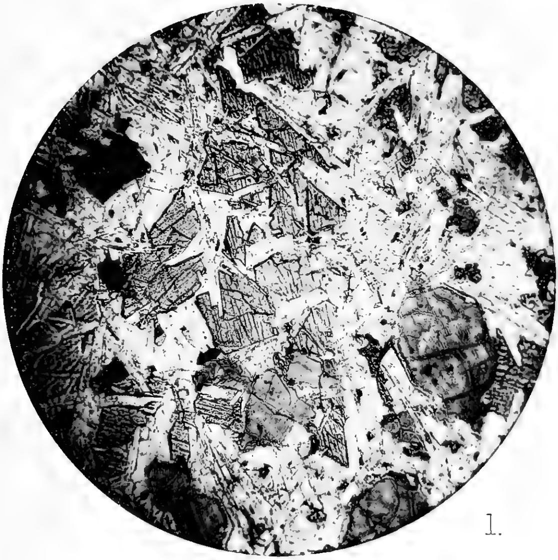
PLATE XXXII.

Fig. 1.

Ophitic Dolerite, No. X.—The felspar is the lightest in colour, the iron ores are the darkest. The fresh Augite, in which the felspars are imbedded, is intermediate in shade. A couple of crystals of altered Olivine appear in the lower right-hand quadrant. Magnification, 28 diam.

Fig. 2.

Ophitic Dolerite, No. XIII.—In this the Augite is so much darkened by decomposition-products as to be hardly distinguishable in many places from the opaque iron ores. Magnification, 28 diam.



1.

2.

Bemrose Ltd Derby.

a degree which will render it useless, or hard grains may be insufficiently bonded or mutually attached to preserve the macadam from crumbling under traffic. In short, coherence or toughness is an essential quality.

Bad wearing quality is expensive in an accelerative manner, if the term may be used. For hollows in a road-surface collect damp; and this promotes further destruction in many cases.

On the question of *resistance to chemical agents*, it must be admitted that not much is known beyond the broad fact that in any but calcareous rocks, or fragmentary rocks cemented by calcareous material, physical defects generally determine the destruction of the rock long before it is softened by chemical changes due to surface-waters. Doubtless the impure surface-water of a road appreciably accelerates the destruction of limestone metal. It must be borne in mind that the weathering of a limestone in a building or wall is not an indication of its resistance in the road. This, indeed, applies to any stone. The reason is twofold. The waters of the road are charged with salts and organic acids; and again, friction and crushing greatly assist the solvent power of water.

The *cementitious qualities* of a rock depend apparently on its toughness or resistance to spalling and fracture, and on the roughness of the surface of fracture and persistence of this roughness under wear. Displacement upwards is due mainly to the working of grit and dust into positions beneath the stone. The stone must loosen, in the first instance, for this effect to come about. In most cases this must be attendant on the crushing or spalling of the stone upon the angles which are concerned in keying it to its neighbours. It may happen that in moist places, the formation of the finest dust is hindered, or remains adherent to the surface of the stone, and fails to work downwards. Dust and mud lodged between the stones will behave in very different ways under the small movements of the stones in their beds. The first will work downwards on the whole; the second will be squeezed upwards on the whole. The causes of loose working are worthy of more careful study than they have as yet received.

It will be evident that retention of a rough surface under wear is not of primary importance in the same sense as it is in the case of the paving-set. The surface-structure of the road is itself sufficient to afford the requisite bite to the horse-shoe. In a secondary way, however, a rough-fracturing stone appears to be best for road-metal. The cementitious quality is undoubtedly in part dependent on the frictional hold of one stone on another, and on the packing.

It appears then that, in a road-metal, we should look for coherence and toughness along with a rough surface of fracture. There is some mechanical advantage in a heavy stone, but a disadvantage on the score of expense. A stone giving a white road is doubtless, other things being equal, the best. First cost has, of course, to be considered in every case.

Of the sedimentary rocks, quartzite makes an excellent macadam if it is really coherent. Limestone makes a metal which rapidly crushes and turns to a very slippery mud. Among the igneous rocks are many of great value. Granites are often badly coherent, and soon wear into freestone. They, in many cases, lack toughness. The group of felspar-augite rocks, perhaps, make the best macadam of any. Of these the dolerites have roughness of grain and great toughness. This toughness is often dependent on the "ophitic structure" of these rocks. In this type of structure, the augite acts as a matrix in which the felspar is imbedded. It is, however, of primary importance to make sure that the augite is not weakened or softened by decomposition. The veining of this mineral with decomposition-products on a very minute scale is apparently sufficient to determine the weakness of the stone. The augite is often completely altered to serpentine or to chloritic substances. Such rocks are greatly inferior to dolerites, having a fresh augite. This point is very clearly shown in the practical and analytic notes which follow.

A basalt of the coarser sort also may be a capital road-metal. And there is a long category of andesites, both the more acid and more basic, which make more or less good macadam. The andesites, however, suffer apparently from their too smooth fracture-surfaces. Samples of andesites after some years of wear, which Mr. Aitken kindly forwarded to me, show a smoothness which might almost rival the frictional-solution surface of a water-worn stone.

In what follows the practical notes are in italics. In the case of the first sixteen specimens, these notes are by Mr. T. Aitken, and are given *verbatim* and lettered (T. A.).

I. *Felsite.*[1] *Geological formation,*[2] Po^{c_1}.

Very hard, deficient in cementitious property, wears best in damp or shady places. (T. A.)

A rock of a terra-cotta colour and dull lustre: very fine-grained. Only with difficulty scratched by penknife. Broken under hand-lever without difficulty, suggesting that it is deficient in toughness.

The rock is vesicular on a very minute scale, the pores being hardly discernible without a strong lens. A polished surface reveals to the eye a few minute but visible white felspars. After five years' wear, not much rounded, but smoothed on flat surfaces. The micro-section is reddish-brown in colour.

Under microscope.—The *ground-mass* consists of irregularly double-refracting granules, polarising in greyish colours like a thoroughly devitrified glass. In this are *vesicles* of various sizes, none large, and filled with or lined by a dirty isotropic *glass*, containing minute indeterminate inclusions. Frequent *felspars* occur, mostly short and stout, but some elongated; no lamellar twinning. These felspars are idiomorphic, and often show turbid cavities. They polarise in grey tints: many are probably orthoclase. In some cases the felspars show a structure resembling hour-glass form. Without polarised light the felspars are only distinguishable by their slightly more brownish colour. There is occasionally some indication of flow in their arrangement.

Biotite in small flakes; pale yellowish to greenish-brown; often bent; hypidiomorphic, and associated often with ragged masses of *red-brown oxide of iron.* These masses range from dimensions similar to the felspars to minutest particles, and confer upon the rock its red colour.

Remarks.—The rock is wanting in tough minerals. It will crush readily, in spite of its hardness, to a fine dust. Again, the fracture is too smooth to lead us to expect good binding properties. Doubtless it will work less in its own dust if laid in a damp place where its powder will cohere around it.

II., III., IV., V., *Acid andesites.*

Very hard, but slightly deficient in cementitious properties, but wear well, especially on level stretches; become loose on hilly roads, especially in dry weather. (T. A.)

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[1] Dyke 40 feet wide, running north to south. Conglomerate on either side. (T. A.)

[2] The nomenclature is that given on the Geological Survey sheets, 40, 41, 48, and 49.

II. *Geological formation*, Pc_1 Ts^{c_1}.

Very fine-grained, brownish-grey, almost black. Cleavage faces of largest constituents visible in reflected light.

Breaks under hammer with sharp conchoidal fracture, and yields only with difficulty to the hand-lever. After two and a half years' wear, rounded and smoothed.

Under Microscope.—Ground-mass is holocrystalline, and contains some lath-shaped and some square felspars with fluxion structure (trachytic); in this occur large isolated areas of devitrified spherulitic glass, which, when examined by polarised light, show a black cross; probably *opal.* Also crystalline outlines with black resorption borders; contents quite altered, or fallen out wholly or in part. In places suggesting an altered augite by traces of cleavage, and light golden-yellow polarisation tint.

Phenocrysts of *felspar*; apparently Carlsbad twins: fresh and clear.

Hematite and magnetite common—especially the latter—in grains, dust, and crystals.

III. *Geological formation*, Pc_1 Ts^{c_1}.

Grain about same as II. Same appearance as II., rather browner in colour. Under hammer appears to be less tough than II. After eleven years' wear much rounded and smoothed.

Microscope.—Ground-mass of microliths, lath-shaped felspars, and a few square forms: fluxion marked: trachytic. No glass or very little. In this are *felspar* phenocrysts, which show some zoning, and little or no lamellar twinning: fresh. *Magnetite* in less quantity than in II., and in small grains, dust, and crystals. The dust apparently replaces some decomposed mineral, and shows crystalline outlines to aggregates of particles. Spots of cloudy *red oxide of iron.*

IV. *Geological Formation*, Po^{c_1}.

Very fine grained, nearly black. Very tough under hammer: breaks away with difficulty in small conchoidal flakes. After four years' wear, smooth and rounded.

Microscope: Ground-mass.—Very uniformly composed of lath-shaped felspars, rather larger than those entering into the ground-mass of I., II., and III. Marked fluxional structure. No lamellar twinning in lath-shaped felspars. Phenocrysts absent. Some chloritic areas occur. No glass. The structure might be described as pilotaxitic. In this ground-mass occur (*a*) a greenish, fibrous mineral, same size as felspars, idiomorphic; polarises golden yellow; extinction not quite straight; pleochroic green to colourless: *ægerine* ?, (*b*) *magnetite* in grains, dust, and crystals, and a little *hematite*.

V. *Geological formation, Po*^{c_1}.

Very fine-grained, black rock. Fracture conchoidal. Hard, but possesses some cleavage.

Microscope.—Same generally as IV. An interstitial substance appears, however, between felspars making up the ground-mass. This is occasionally spherulitic, and is associated with a strongly refracting colourless substance, not clearly outlined, but occasionally showing traces of prismatic form, and then cracked transversely. Felspars in ground-mass are very distinct, clean, and sharp.

Remarks.—Of these acid andesites, II., III., V. are not conspicuously tough rocks. They are also fine-grained, and not rough on fracture. IV. is very tough, but is of fine grain. The last should not fail by crumbling; but its comparatively smooth fracture is doubtless the cause of its faults. The report of their qualities is, on the whole, favourable. They are examples of fine-grained, fairly tough rocks, wearing well, but failing in some degree, owing probably to possessing too smooth a surface of fracture.

VI., VII., VIII., and IX. Andesites. VI. is an acid variety, the others basic.

Hard and fairly tough, good-wearing stones. No. VI. best. (T. A.)

VI. *Geological formation, Po*^{c_1}.

This is a nearly black, fine-grained rock. In it the phenocrysts are easily seen by eye by reflected light. Some of these crystals are up to 2 or 3 mms. in length. The greater part of the rock is fine, and not resolvable even with a lens. Specimens taken up after six years' wear are much rounded and surfaces smoothed. Under the hammer it breaks fairly easily, showing no cleavage.

Microscope: Ground-mass.—Holocrystalline, composed of lath-shaped felspars, very heterogeneous in size and appearance; some fluxional structure. Large, fairly idiomorphic crystals of *felspar*, with lamellar twinning up to 3 mms. in length; clear and fresh. Also a greenish, fibrous mineral extinguishing longitudinally when in long prisms, sometimes in irregular grains. Prisms up to 2 mms. Not much of this substance, which appears to be *bastite* or *hypersthene*. It is feebly dichroic, pale green to yellowish-green. *Augite* is scarce, clear to colourless. A fair amount of *magnetite* in dust and small crystals, as well as a little *red oxide of iron*.

VII. *Geological formation*, Po^{c_1}.

A black, very fine-grained rock. Fracture only feebly glistening, nearly dull. Under hammer, breaks fairly easily with conchoidal fracture more or less, but shows also some cleavage. Tough. After four years' wear, fairly rounded and smooth.

Microscope: Ground-mass.—Holocrystalline, of lath-shaped and irregular-sized felspars. Grain about same as IV. Phenocrysts are *felspars*, lamellar and simple twins; not plentiful. A faintly pleochroic *enstatite* or *hypersthene*, colourless to pale pinkish. *Biotite*, pleochroic, associated with *red oxide of iron* and *epidote*; not abundant. *Augite*, small grains associated with an olive-green, brightly polarising alteration product.

VIII. *Geological formation*, Pc^1 TS^{c_1}.

Like VI. in appearance, but coarser-grained on the whole, as a larger part of the constituent minerals is visible to eye-examination. Some cleavage apparent under hammer. It breaks fairly easily, giving a fine smooth surface of fracture. After two and a half years' wear, is fairly rounded and smooth.

Microscope.—*Ground-mass* of lath felspars, triclinic and closely interfitted; no glass. The general appearance is of a rock with more phenocrysts than any so far examined. These are a triclinic *felspar* for the most part. *Augite*, twinned, colourless, and in minute grains. *Hypersthene*, fibrous, pleochroic green to yellow. *Bastite*: possibly some of the fibrous forms are bastite. *Olivine* doubtful; associated with much *hematite*, which also veins it in a fashion often seen in serpentine. *Magnetite* in small grains. *Epidote* and *calcite*: rock is evidently considerably altered.

IX. *Geological formation,* Po^{c_1}.

A fine dark-grey, nearly black rock. Spotted with inconspicuous reddish-brown spots. Some cleavage. Under hammer, breaks easily. After four and three-quarter years' wear, considerably rounded and smoothed.

Microscope: Ground-mass.—a mixture of augite (?) and very small lath-felspars, apparently triclinic. Very few phenocrysts: a few idiomorphic *felspars* with zonal structure, and with simple twinning or not twinned; rarely lamellar. A decomposed mineral which appears to be *olivine*; it is veined with *hematite.* A little *magnetite.* Also fairly abundant spicules, green-brown to opaque; no pleochroism nor optical activity visible in these.

In some experiments (unpublished) upon the effect on rocks of prolonged heating, alterations were obtained very similar in character to the changes which appear to affect this rock.

Remarks.—The foregoing four andesites are found to be good wearing-stones. None of them are coarse-grained, and none show a rough fracture. The best in wearing quality is the most acid. Stone of these physical and petrological characters evidently makes fairly good metal. The longest down (six years) shows no visible sign of softening or decay.

X. *Olivine Dolerite*, and XI. *Basalt.*

Very hard and tough, splendid-wearing stones under all conditions of weather and traffic. (T. A.)

X. *Dolerite* (*olivine*). *Geological formation,* d^2G^nB.

A black stone with a rough fracture, showing its crystallized constituents glistening like broken sugar. No cleavage whatever. Is tough under hammer. After four years' wear is considerably rounded, but still with fairly rough surfaces, showing that removal of angles leaves the surface rough. There is no visible sign of chemical change.

Microscope.—The rock is a typical ophitic olivine dolerite. The *olivine* is mostly altered to *serpentine.* *Augite* abundant, ophitic with lath-shaped felspars, and very fresh. This is the coarsest rock yet examined. (See fig. 1, Plate XXXII.)

XI. *Basalt. Geological formation,* d^2B.

This is a finer rock than the last. It is black in colour; with easily visible constituents. The fracture is fairly rough, with no trace of cleavage. It is hard, and spalls rather conchoidally under hammer.

After ten years' wear is very little rounded, but shows a fairly smooth surface. No chemical change visible.

Microscope.—Ground-mass is typically intersertal. A dark, dusty-looking *glass* is present along with fine lath-shaped felspars. Phenocrysts of *augite* abundant, fairly idiomorphic. *Olivine* in lesser quantity; often idiomorphic, and veined with serpentine. *Ilmenite* (?) in branching needles through the glass. Doubtful felspar phenocrysts.

Remarks.—Numbers X. and XI. are the most successful stones. The first has roughness, toughness, and durability in its favour. It is also a heavy rock (some advantage perhaps). The second is less tough, but harder, and not so rough. It also is a heavy rock. The results on these rocks are very valuable, as they are typical stones of their kind, and ought to afford a safe criterion in selecting among igneous rocks where these varieties are available. But the rocks to be now described show that all dolerites are not equally valuable.

XII., XIII., XIV., XV., XVI., *Dolerites. Tough, but deficient in hardness: go quickly to mud on level stretches under traffic in wet weather, fairly good material on steep hills. No. XII. makes excellent kerbs, channels, and, in a lesser degree, paving-sets.* (T. A.)

XII.[1] *Geological formation,* Ts^{c_1}. *G.B.*

A dark-grey rock with glistening fracture, finer than X. in texture, but shows a fairly rough fracture. After nine years' wear is not very much rounded, and surface still rough. A fresh surface on the used stone shows no visible change within.

Microscope.—This is a dolerite, without olivine, or very little. The rock is made up of *felspars* of the usual type, imbedded ophitically in a very much decomposed *augite.* The felspar is fresh. The augite is changed for the greater part to a cloudy grey substance, among which is much *chlorite.* The augite

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[1] Dyke extending from Glenfaig (Perthshire), through Fife, to near Cupar: 40 feet to 60 feet wide. (T. A.)

amounts to about one-fifth of the rock. There is a little *magnetite* or *ilmenite* present. The texture is a little finer than X; the structure not quite so ophitic.

XIII. *Geological formation,* $d^1 G^r B$.

Like X. in appearance, but a little coarser in grain. It is tough under hammer, giving a rough fracture. After five years' wear is much rounded and smoothed on surfaces.

Microscope.—A coarser grain than X. *Felspars* fresh and in places ophitic towards an abundant *augite.* The latter much altered to *serpentine,* and in every case veined with this alteration-product. A good deal of *ilmenite* or *magnetite.* (See fig. 2, Plate XXXII.)

XIV. *Geological formation,* $d^1 G^r B$.

Like X. in colour, but coarser. The coarsest in texture so far examined. Tough under hammer, and very rough in fracture. After six years' wear not very much rounded, and surfaces still rough.

Microscope.—Practically same as XIII. Varying amount of alteration-products in *augite*; but in no case is this free from veins of *serpentine,* etc.

XV. *Geological formation,* Po^{c_1}.

A fairly coarse dolerite, but finer in grain than the last. Very tough, and giving a rough surface of fracture; after ten years' wear is fairly rounded. Practically the same as XIII. and XIV. *Augite* as before, much decomposed; and *felspar* fresh and ophitic towards the augite. The latter is sometimes granular, and then encroaches on the felspar.

XVI. *Geological formation,* d^1 "*B.*"

A very rough, black dolerite, possessing, however, basaltic characters. The coarsest in grain of the entire series. Under hammer, very tough and rough. After five years' wear is fairly round, but surface shows some of its original roughness.

Microscope.—A very coarse rock with large fresh *felspars* sometimes ophitic in an *augite* considerably altered. Along with these, large grains of *olivine* more or less serpentinized. A *variolitic glass* often extends in radiating fibres from angles of felspar crystals. There are a few well-shaped prismatic forms filled with alteration-products of spherulitic appearance. *Magnetite* in large irregular pieces. *Quartz* is present as a secondary mineral, sometimes in well-formed limpid crystals. The rock is much altered and decomposed.

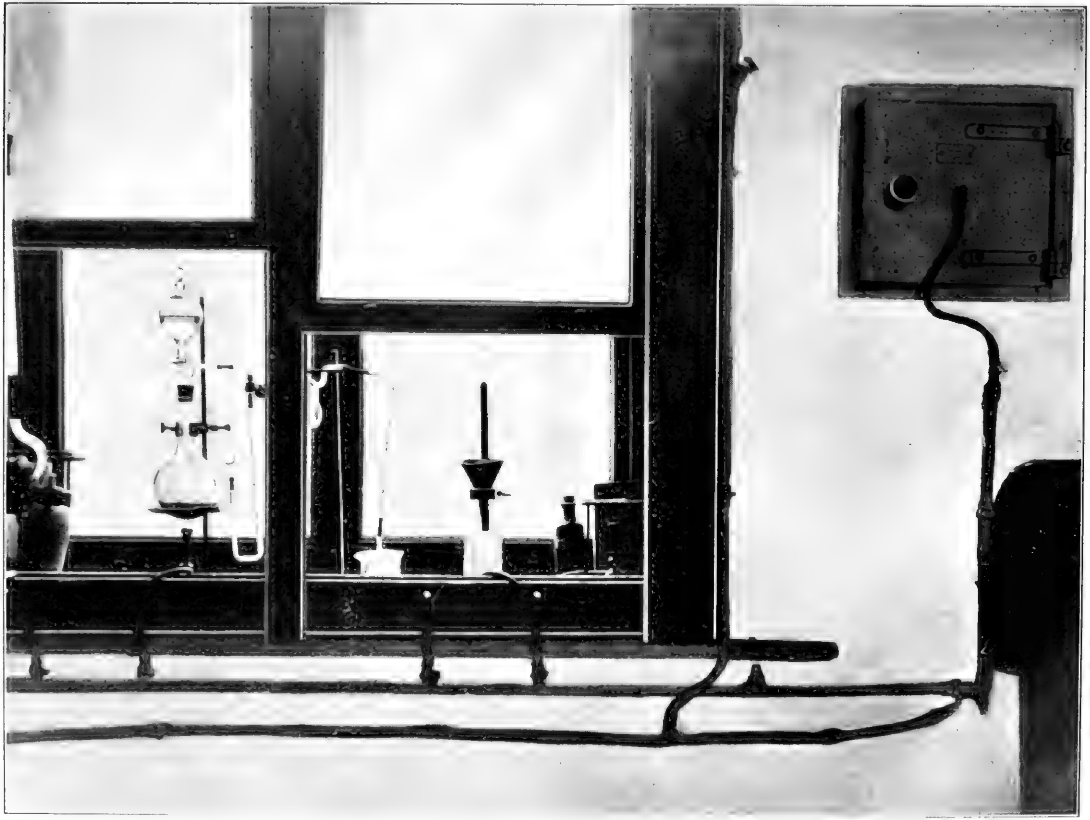
Remarks.—This closes the list of rocks submitted to me by Mr. Aitken. The result of comparing the properties of the dolerite No. X. with the last five dolerites is of considerable importance, and strongly emphasises the legitimacy of referring to petrological examination in such cases. The rapid destruction of the last five dolerites is at once ascertained to be due to the decomposed state of the rocks, especially of the augite. On this mineral the coherence of an ophitic rock depends. If it is turned to soft minerals or veined by such, the coherence of the stone is lost; and it must inevitably soon break up to mud. Number X. is a rock of characters practically identical with the defective rocks, but possesses a perfectly fresh and unaltered augite. Thus the whole mass of felspars and augite is held together as one coherent substance. Hence its resistant properties.

It is apparent, from Mr. Aitken's observations, that an ophitic dolerite having a fresh augite is an excellent metal in every way, whereas one with softened augite should be rejected.

Quartzite.—Geological formation, Cambrian. From Howth, County Dublin. This is a yellowish rock, almost pure quartz, and very hard and tough under hammer, breaking with a rough fracture. It has no appreciable cleavage.

It is very durable, and makes excellent roads of white colour.

Microscope.—Is practically quartz throughout, consisting of quartz granules cemented together by a cement of quartz.



One of the fume-chambers, showing the door giving entrance to the bottom of the flue, on the right, in the wall.

XXXI.

ON THE CONSTRUCTION OF FUME-CHAMBERS WITH EFFECTIVE VENTILATION.

By WALTER NOEL HARTLEY, D.Sc., F.R.S.

[Plate XXXIII.]

[Read, March 21; Received for Publication, March 24; Published, May 11, 1905.]

The ventilation of a laboratory is as necessary for the preservation of health as the ventilation of workshops for unhealthy trades. Both should be provided with an enormous fresh air-supply, and a continuous extraction of foul gases. The latter provision necessitates very highly efficient fume-chamber ventilation, so that, in fact, the fume-chambers should act as ventilating shafts to the laboratory. By this it should be understood that in no circumstances whatever should there be a down-draught even of a momentary or temporary nature, and no escape of foul air from the chamber into the laboratory even when the doors are opened. A very common defect in the ventilation of a fume-chamber is a flue of dimensions which are too small, the entrance to which is wrongly placed at the top of the chamber. A second defect is that the direction of the flue is not vertical. A flue constructed of pipes 6 inches in diameter placed against an outside wall gives rise to cooling, so that there is condensation of steam and acid vapours within, which causes the dripping of condensed moisture containing acid. It must be borne in mind that every bend at right angles diminishes the speed of the draught by one-half; and a flue so constructed has been known to have the speed reduced to $\frac{1}{64}$th of that intended, solely by the introduction of six bends. The net result was—

(1) An insufficient draught, at a speed which was ineffective.

(2) Condensation of steam and acid vapours in the flue.

(3) Drip of condensed water and acid, with consequent corrosion and destruction of the gas-fittings.

A further necessary provision is that the external opening of the flue should be carried above the pitch of the roof; for otherwise sudden and powerful blasts of wind descend, the effects of which are fraught with danger to those using the chambers, both from poisonous gases and from explosions. Explosions are liable to occur when the reversed draught extinguishes the gas-jet under the flue, and fills the chamber with an explosive mixture of gas and air which may be easily ignited by the flame of a burner on the floor of the chamber. A serious explosion of this kind has been known to occur.

I propose to give a description of the most efficient and simple mode of ventilating draught-chamber I have yet seen, with a series of measurements made daily during a period of five weeks, both of the air extracted and the gas burned. Observations were actually conducted over a period of six months. The actual successful working of these chambers has continued uninterruptedly for fourteen years. (See Plate XXXIII.)

Each fume-chamber inside is 4 ft. 10 in. broad, 2 ft. 6 in. deep from front to back, and 4 ft. 3 in. high; the slope of the roof is 6 inches. The floor of the chamber is sunk 3 in. below the framework, and is covered with lead overlying a slate bed. Outside the chamber, and at the right-hand side, is the tap for water-supply, the spout of which is 27 in. above the floor of the chamber and inside it; the service being at high pressure, and the delivery a half-inch pipe, the chamber can be flooded almost instantly; for all that, when not otherwise required, the water-supply can be used for cooling condensers, filling water-baths, &c. At the left-hand corner is the out-flow for waste water. The acid from a large Kipp's sulphuretted-hydrogen apparatus can be discharged into this without any trace of the gas escaping into the laboratory. At the right-hand side, the flue of 9 in. square section is built into the wall, and terminates above the pitch of the roof. At 12 in. above the floor of the chamber, an opening 9 in. square passes horizontally to the bottom of the flue. The bottom of the flue is a small chamber 13 in. wide, and 16 in. from front to back, larger, therefore, than the flue itself; and the floor of this rises from the horizontal opening, the slope being about 30°. In the wall of the room, about 3 ft. above the bottom of the chamber, is an iron door about 18 in. square, 17 in. broad, by 16 in. high.

Into this is fitted a gas-delivery tube which projects about 3 in. into the interior. It is connected on the outside with the gas-supply by means of flexible tubing; and on the inside it is connected in a similar manner with a large ring-burner of Fletcher's make (about 9 in. diameter), supported on a ledge of brickwork which on the right-hand side is 5 in. wide, and on the frontal wall of the flue is 6 in. wide. In some cases the ring-burner is dispensed with, and the flue is warmed by a flaring gas-flame burning from the end of the tube which is screwed into the door. It should be remarked, however, that the ring-burner is twice as effective as the flaring gas-flame for the same quantity of gas burnt. The entrance to the flue being horizontal, no drip or dirt can drop into the vessels standing in the chamber; moreover, as it is about 12 inches above the floor, it is at the height which experience has shown that in the majority of operations the noxious fumes and gases are evolved. They do not rise through the air of the chamber, but pass directly into the flue, along with the supply of air which is necessary for the combustion of the gas. This latter quantity is very large, and as the velocity of the upward current of heated air and the products of combustion is very great, owing to the flue being vertical, and freely discharging vertically into the open air, there is nothing deposited on the walls of the flue, nor upon the ring-burner, which therefore remains quite free from moisture or acid, and consequently from corrosion. In fact, the ring-burner is not corroded by such substances as oil of vitriol and hydrofluoric acid evaporated in large quantities. Above all considerations, we have the security of the upward current being constant under all conditions. On no occasion has any interruption of the draught or any downward current been observed, even in the most tempestuous weather. The air from every possible inlet, whether above or below, travels through the chamber directly to the entrance to the flue. So strong is the draught that when the sash is raised only an inch or two a Bunsen flame is made to bend over horizontally; and it is best to work with the sash raised for at least a foot.

Should any inflammable liquid within the chamber take fire, the flames roar up the flue without causing any damage, since it is built of fire-brick. Each of the three fume-chambers has a cubic capacity of 51·30 cubic feet; and the rate of extraction is, on an average from the three together, about 1060 cubic feet per minute, or 63,000 cubic feet per hour.

The measurements of the air-currents were made with an anemometer of Cassella's construction, which had been properly tested and corrected for measurements at different speeds, and where necessary the corrections were applied to the readings on the dial of the instrument. Fixed to the end of a wooden rod, the anemometer was held in position at the top and bottom, at each side, and also within the centre of the opening of the flue. The mean of the five measurements in these positions was taken in each case, and they were each repeated and verified. The height of the barometer, the temperature inside and outside the building, whether the air was calm or the wind strong, and also the direction of the wind, were noted. Lastly, the daily consumption of gas was recorded, and the number of hours during which it was burning in the flues. The observations were continued daily on two of the three flues during a period of six months. On several occasions no gas was burnt, the draught being strong enough without. This was caused by the velocity of the wind blowing across the mouths of the chimneys. Eventually it was thought desirable to note the direction and force of the wind; and this was done daily during a period of two months.

As the details are valuable for reference, I submit a tabulated statement of them to the Society; they are of general application, and clearly show what amount of ventilation may be expected and should be obtained under almost any atmospheric conditions.

I have always regarded it as important in the construction of laboratories that the fume-chamber space should be large and evenly distributed, so that the general ventilation of the laboratory should, to a large extent, be effected through these chambers. This means, of course, that there should be an adequate supply of fresh air evenly distributed so as not to create draughts. Unless there is such a supply, the same chambers will not act with full efficiency. To indicate the amount of ventilation effected through the fume-chambers, the general result of some measurements is here recorded. It should be mentioned that the only entrance to the laboratory was by a door leading on to a wide staircase, on the landing of which was a large window. When the laboratory windows were not open, the chief supply of air came through this door as a powerful draught. Measurements were made of the air which thus passed into the building; and it was found to be 63,000 cubic feet per hour, or, more precisely, 1054 cubic feet per minute. This is nearly identical in quantity with that which went up the flues.

The following are particulars of an average set of measurements taken at the door:—

Over 5 feet 1 inch from the floor there was no steady inward current, but occasional gusts of wind rushed in.

Rate of Flow of Air-currents.

At the left-hand side of doorway.		Midway on a horizontal line 5 ft. 1 in. above the floor.		At the right-hand side of doorway.
100 ft. per minute	...	123 ft. per minute	...	44 ft. per minute.
At 4 feet above the floor.		At 4 feet above the floor.		At 4 feet above the floor.
126 ft. per minute	...	157 ft. per minute	...	63 ft. per minute.
At bottom.		At bottom over floor-level.		At bottom.
127 ft. per minute	...	144 ft. per minute	...	170 ft. per minute.

At a height of 5 feet from the floor, on the right-hand side, the flow was irregular; sometimes there was no inward current.

So far the description applies to vertical flues; but the same arrangement of a vertical flue connected with a down-draught has been applied to a lecture-room table, and at the same time to an adjacent draught-chamber; the current of air in these cases flows first downwards, and then is discharged vertically upwards. It is essential for efficiency that this discharge be vertical; and, for securing this condition, an old flue in the wall of the room was slightly diverted at its lower end from its original direction, which was crooked.

One point of importance to be attended to in lecture-room ventilation is, that the two flues which pass downwards, one from the lecture-table and the other from the draught-chamber, should not differ greatly in vertical height from the floor; otherwise the draught in one will be greater than that in the other. On this account they should be made to open at or about the same level. This makes the position of the opening in the fume-chamber unusually low down; but nevertheless, in the construction of which I have had experience, the draught, both on the lecture-table and in the chamber, is excellent. The downward flues are earthenware pipes 6 inches in diameter, with curved bends.

To illustrate the efficiency of the mode of ventilating the fume-chambers in the laboratory, it may be mentioned that in one of them very large quantities of hydrofluoric acid were disengaged at intervals during a period of nearly ten years; and though the glass of the sashes and windows was never at any time seen to be attacked, the effect of it is seen at the entrance, and just within the flue, by the corrosion of the slate and of the fire-bricks, more particularly at the edges. The loose incrustation caused by the corrosion can easily be swept away. There is an advantage in sloping the bottom of the flue, as any dirt or incrustation falling can be easily removed with a hand-brush. The inside of the iron door to the flue should be well coated with tar, or be thickly galvanized. There is at present a loose layer of rust, a quarter of an inch thick, on the iron; but this is an accumulation of fourteen years. In the second of the chambers there is a considerable crust of ammonium chloride on the upper surface within the horizontal entrance to the flue, which, of course, is easily removable. A third chamber has been used more particularly for manipulations with sulphuretted hydrogen; and in the flue of it there is no deposit. A fourth flue is provided with an iron hood simply instead of a window, under which the combustion furnace for organic analysis is placed; but there is no need to refer to this.

With regard to the different measurements which were made, it may be remarked that the minimum amount of air which passed through any one of the chambers at any season of the year and under any conditions, such as dead calm or a gale of wind, high or low barometer, great or little difference between inside and outside temperature, was 194·7 cubic feet per minute when there was practically no gas burning; the maximum was 421·8 cubic feet per minute. The minimum was found once only out of not fewer than eighty-four recorded observations; the maximum once, also out of eighty-four measurements; but the gas consumed was at the rate of $76\frac{6}{7}$ cubic feet per hour. The average quantity of air exhausted all through was, in round numbers, 354 cubic feet per minute per chamber. Sixty measurements which were made between April 10th and May 15th also give this quantity. As the cubic contents of the chambers are 51·3 cubic feet, it means that on an average the air of each chamber is completely changed every nine seconds. It is important that the rate per minute, and not the rate per hour, be stated; because this indicates that the exhaustion was practically continuous; on the other hand, the rate per hour might admit of intervals when there was no exhaustion at all.

The rate of flow of the heated gases within the flue being influenced by so many different conditions, the majority of which are not under control, and which may interfere with each other, it was found useless to attempt to draw any conclusions by plotting curves; but it was, however, clearly shown that the manner in which the gas is burnt is of importance, the ring-burner being much the more economical, as it causes twice the amount of exhaustion that is provided by the flaring-jet, for the same volume of gas burnt. Notwithstanding this, it will be seen that the flaring-jet is much the more efficient on the whole in creating a draught. Lastly, I may draw attention to the small height of the flues—about 25 feet—which have proved effective. This renders such a means of ventilation readily adaptable to small out-buildings, such as school laboratories, or to rooms at the top of a building. Of course the longer the flues, the better the exhaust.

[TABLE.

EXPERIMENTS ON VENTILATION.

Date of Observation.	EAST CHAMBER.*		WEST CHAMBER *		CLIMATIC CONDITIONS.			
	Gas burnt per hour.[1] Tube-burner.	Air extracted per minute.[2]	Gas burnt per hour.[3] Ring-burner.	Air extracted per minute.[4]	Differences in temperature inside and outside the building.	Barometer: daily readings.	Direction of the wind.	State of the weather.
	Cubic feet.	Cubic feet.	Cubic feet.	Cubic feet.	° F.	Inches.		
April 10, . .	$74\frac{6}{7}$	382·5	$28\frac{4}{7}$	274·5	16·2	30·13	N.	Calm.
,, 11, . .	$79\frac{5}{8}$	388·0	30	261·9	14·2	30·13	S.E.	,,
,, 13, . .	$69\frac{1}{7}$	378·5	$32\frac{1}{7}$	299·0	13·5	30·05	E.S.E.	,,
,, 14, . .	$72\frac{4}{7}$	365·6	$29\frac{4}{7}$	273·9	17·1	30·19	W.	,,
,, 15, . .	$67\frac{1}{7}$	365·6	$27\frac{1}{7}$	267·7	13·5	30·33	W.	Slight breeze.
,, 16, . .	$71\frac{5}{7}$	374·6	$26\frac{3}{7}$	305·4	11·7	30·20	W.	,, ,,
,, 17, . .	$71\frac{3}{7}$	367·3	$28\frac{4}{7}$	290·8	17·1	30·22	N.W.	Calm.
,, 18, . .	$64\frac{1}{2}$	382·5	$31\frac{3}{7}$	281·2	15·2	30·18	N.E.	,,
,, 20, . .	72	378·5	$29\frac{2}{7}$	296·4	16·2	30·32	E.	Slight breeze.
,, 21, . .	$71\frac{1}{7}$	376·8	$24\frac{3}{7}$	315·0	15·2	30·24	N.E.	,, ,,
,, 22, . .	79	392·0	$23\frac{4}{7}$	277·3	17·1	30·12	E.	,, ,,
,, 23, . .	65	374·6	$24\frac{2}{7}$	298·0	18·0	30·18	N.	High wind.
,, 24, . .	69	371·2	$22\frac{6}{7}$	**241·8**[5]	18·0	30·27	E.N.E.	Slight breeze.
,, 25, . .	72	380·8	$24\frac{4}{7}$	279·5	18·9	30·16	S.E.	,, ,,
,, 27, . .	$70\frac{6}{7}$	389·8	$23\frac{2}{7}$	262·1	16·2	29·68	E.S.E.	,, ,,

,, 28, . .	72	372·9	$18\frac{1}{7}$	258·7	14·2	29·69	N.N.W.	,, ,,
,, 29, . .	$59\frac{1}{7}$	378·5	$17\frac{3}{7}$	270·0	13·5	29·44	S.W.	Very stormy at intervals.
,, 30, . .	$57\frac{3}{7}$	**333·5**[5]	$17\frac{4}{7}$	247·5	13·5	29·49	S.W.	Slight breeze.
May 1, . .	66	365·6	$28\frac{4}{7}$	299·8	15·0	29·33	S.S.W.	High wind.
,, 2, . .	$76\frac{6}{7}$	**421·8**[6]	$32\frac{6}{7}$	268·3	14·0	29·75	N.N.W.	Slight breeze.
,, 4, . .	68	371·2	$26\frac{3}{7}$	288·5	10·8	30·01	W.S.W.	Calm.
,, 7, . .	$65\frac{5}{7}$	369·5	$27\frac{4}{7}$	253·1	7·2	29·73	E.	Slight breeze.
,, 8, . .	$63\frac{5}{7}$	391·5	$28\frac{4}{7}$	277·3	10·8	29·61	W.S.W.	,, ,,
,, 9, . .	$75\frac{4}{7}$	405·0	$32\frac{3}{7}$	**316·6**[6]	7·2	29·97	N.E.	,, ,,
,, 11, . .	$69\frac{5}{7}$	365·6	$22\frac{1}{7}$	279·5	3·6	30·21	N.E.	Breezy.
,, 12, . .	$60\frac{4}{7}$	356·0	$22\frac{1}{7}$	270·0	4·5	30·27	E.N.E.	Slight breeze.
,, 13, . .	$66\frac{1}{7}$	374·6	$25\frac{4}{7}$	271·6	6·3	30·27	W.	Calm.
,, 14, . .	$67\frac{1}{7}$	388·1	$25\frac{5}{7}$	277·3	8·1	30·10	W.	Breezy.
,, 15, . .	$67\frac{6}{7}$	386·4	$29\frac{1}{7}$	296·4	10·8	29·84	N.W.	Stormy.

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[1] Average gas consumption, 69·8 c. ft. per hour.

[2] Average volume of air extracted, 380·9 c. ft. per minute.

[3] Average gas consumption, 28·0 c. ft. per hour.

[4] Average volume of air extracted, 281·0 c. ft. per minute.

[5] Minima of air exhausted.

[6] Maxima of air exhausted.

* It is difficult to ascertain the precise conditions which determine the volume of air extracted from these two chambers, because neither the minima nor maxima fall upon the same day. From an examination of all the measurements there can be little doubt but that the direction of the wind and currents of air from open windows can affect the east and west chambers differently.

XXXII.

ON THE STRUCTURE OF WATER-JETS, AND THE EFFECT OF SOUND THEREON. PART II. By PHILIP E. BELAS, A.R.C.Sc.I. WITH NOTE ON COMBINATION-TONES BY PROFESSOR W. F. BARRETT, F.R.S.

[Plate XXXIV.]

(communicated by professor w. f. barrett, f.r.s.)

[Read, March 21; Received for Publication, March 24; Published, June 9, 1905.]

In a former Paper[1] I described some experiments, showing the effect of periodic vibrations upon a jet of water flowing from a glass tube, and amongst others, one in which a difference-tone was produced by the vibration of a parchment membrane, on which the jet of water impinged when it was influenced by two tuning-forks of different pitches sounded together.

My attention was first drawn to this combinational tone in the following way:—Shortly after his discovery of sensitive flames, Professor Barrett noticed that a flame occasionally and audibly *reproduces* the note by which it was affected. While I was assisting him to prepare some experiments for a lecture on the subject before this Society, we noticed that when such a flame was excited by two tuning-forks bowed simultaneously, the note it emitted was the difference-tone. On trying the experiment upon a jet of water, I obtained a similar result. The tuning-forks used were ones making, respectively, 384 and 512 vibrations per second, and the pitch of the difference-tone was therefore 128.

The object of this Paper is to describe some further observations upon this phenomenon, and to suggest an explanation of it.

It first occurred to me that, as a membrane was used, the difference-tone produced in this way might be caused by the

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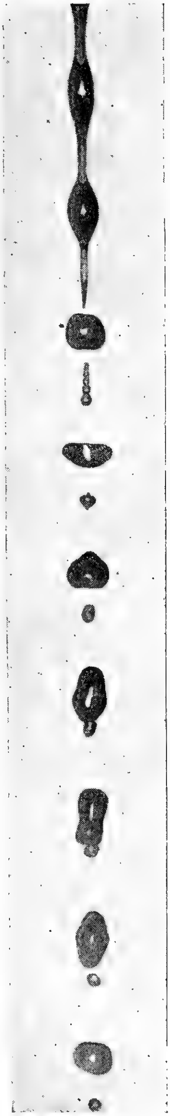
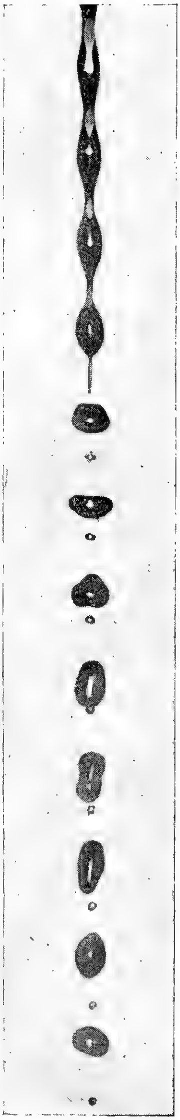
[1] Scientific Proceedings, Royal Dublin Society, vol. x. (N.S.), Part ii., No. 22.

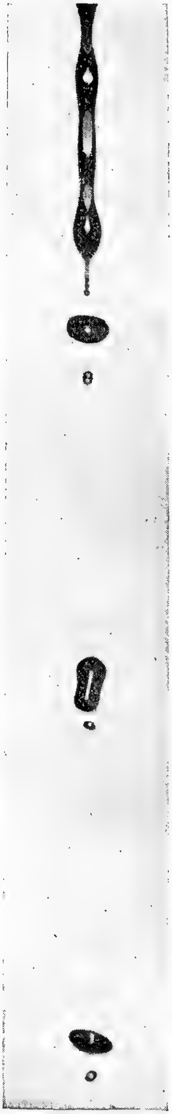


I.



II.

III.



IV.

membrane itself, vibrating in one of its natural periods, and perhaps assisted by the resonance of the hollow glass cylinder over which it was stretched.

To test this I made an experiment as follows:—The jet—other arrangements remaining the same—was allowed to flow on to the diaphragm of a Bell's telephone-receiver, the coil and magnet of which were protected from the water by paraffin wax. This was connected in series with a couple of dry cells, and a similar receiver. On applying the tuning-forks separately to the support of the jet, the notes were heard very distinctly by an observer listening in the telephone outside the room; and when the two tuning-forks were used together, the change to the difference-tone was most marked. I have frequently heard this tone myself, by mounting the two tuning-forks on their respective sounding-boxes and bowing them strongly, but others to whom I referred seemed unable to distinguish it. In the telephone, however, the note was unmistakable, as the generating tones disappeared entirely. This result seemed to me to exclude any possibility of the note being due to resonance, or to the particular membrane used. I tried membranes of various sizes, some of thin rubber. The result obtained was the same in all cases, but the quality of tone varied, that given by the parchment being more sonorous, while the rubber emitted penetrating and "brassy" notes.

Later on, by listening carefully to the impacts of the drops upon the bottom of the sink or a wooden board, I was able to hear the difference-tone.

I next photographed the jet when falling under the influence of the lower tuning-fork (384), and found the distances between the centres of successive large drops in the photograph to be very uniform, and equal to 2 cms. (See fig. I.)

In a similar way, I found the distances between the drops when the higher tuning-fork was used to be 1·5 cms. (See fig. II.)

The ratio of these distances is 4:3—inversely as the corresponding periods of the tuning-forks. I next took photographs of the jet when sounding the difference-tone. The results were at first most disappointing. The jet did not seem to possess any regularity. The drops were large, of irregular outline, and collisions seemed to occur anywhere, showing a want of regularity in the separation of the drops. While endeavouring to rectify matters by varying the conditions slightly, I noticed that the difference-tone, though pronounced enough, was not quite steady, but had a quiver in it. On loading one of the tuning-forks very slightly, this was improved, and ultimately the note became quite steady. When the jet was photographed again, the result shown in fig. III. was obtained. To produce this difference-tone, the jet of water must be sensitive to both tuning-forks separately, and exhibit the characteristic shape of a jet when thus affected. But a jet, if sensitive to vibrations of such frequencies as 384 and 512, is not affected by one of 128. A single tuning-fork making 128 vibrations per second will not cause the membrane to emit that note unless the pressure of water and the size of the orifice be changed. How, then, is the effect produced? I think, by reason of the amplitude of the periodic disturbance produced when the two forks act together.

To quote a passage from one of Lord Rayleigh's Papers,[1] "If the initial disturbances are small enough, that one is ultimately preponderant for which the measure of instability is greatest . . . But a disturbance of less favourable wave-length may gain the preponderance in case its magnitude be sufficient to produce disintegration in a less time than that required by the other disturbances present."

Now, the periods of the tuning-forks used are in the ratio of 3:4, and by the time that one fork has completed three whole vibrations, the other will have completed four; and if the time was reckoned from the instant that the two tuning-forks were in the same phase, they will be so again at the expiration of this time and of multiples of it. Now, their being in the same phase means a maximum amplitude of the resultant vibration; and this takes place, then, at intervals corresponding to three complete vibrations of the lower fork—*i.e.*, 128 times per second. We might expect, then, as this disturbance is mainly instrumental in resolving the jet, that drops would appear in the figure, separated by a distance corresponding to this period—*i.e.*, 6 cms.

This would likely be the case if the jet could be resolved by

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[1] Collected Papers, Lord Rayleigh, vol. i., p. 390.

a simple vibration having a frequency of 128. In order to explain the real state of affairs more easily, let me refer once more to Part i. of this subject.

Plate XIX., No. 2, shows a jet of water broken up by a single blow on the support. There is a long bar of liquid separated, having indentations upon it, which cause it to break into separate drops lower down, on account of its instability. The resolution of a water-jet falling freely is determined by accidental tremors and friction in the pipe, but is rendered rhythmical to a large extent by the vibrations due to the impacts of the drops on the sides of the sink or other vessel reacting on the orifice. The effect of a blow is to cause a single disturbance of large amplitude to travel down the jet, and to break it up considerably nearer the orifice, and so the bar of liquid is formed. But the undulations impressed upon that part of the fluid column still persist, and effect its resolution into smaller drops, after it has been cast off from the main column.

This is, I believe, similar to what takes place in the jet when the difference-tone is produced. The disturbance of large amplitude caused by the periodic agreement of the phases of the separate forks breaks up the column into long bars, which have the smaller undulations impressed upon them, and these bars are again resolved as they fall. If we remove the two intermediate groups of three drops from fig. iii., as has been done in fig. iv., we have left three drops separated from each other by a space of 6 cms.

Furthermore, the first and third are oblate spheroids, while that in the centre is prolate, showing that a space corresponding to at least a complete period of oscillation of the drop has been included.

The accepted theory of combinational tones is that due to Helmholtz; and it depends upon the fact that when the amplitudes of the generating tones are large, the restoring force can no longer be considered proportional simply to the displacement, but also to its square. Now such combinational tones (produced by the double siren, or harmonium reed, or two singing-flames) are only heard when the generating tones are very strong, and then as present along with them.

But in this instance, the generating tones disappear, and the difference-tone may be distinguished when the forks are almost inaudible themselves.

The theory advanced by Dr. Thomas Young, to explain the difference-tone—at that time called, after its discoverer, "Tartini's beats"—was, that beats, when sufficiently rapid, merged into a musical note, which was heard as an accompaniment of the two beating-tones. This explanation was rejected subsequently, on the ground that mere rapidity of beats would never produce a musical note.

Perhaps the production of the difference-tone I have described may be an exception to this; for any note arising from a membrane, played upon by a water-jet, is produced by the impacts of drops. Now, if (in consequence of their being cast off nearer the orifice) any drops or groups of drops strike the membrane with greater momentum than others, at equal intervals, and with sufficient rapidity, the result should be a musical note.

The quality of this note is rough, and different from the pure clear notes that issue from the membrane when a single fork is used.

On experimenting with a resonator of the same pitch as the difference-tone, I failed to detect any resonance, and am therefore doubtful as to its existence external to the ear.

I have so far tried to account for this difference-tone by the periodic impacts of certain drops, but there are other drops between these.

May it not be that with respect to the general disturbance emitted by the membrane, the ear exercises a selective function, and gives a general impression of a note, roughened perhaps by the presence of the other drops as a disturbing element?

These difference-tones may be obtained otherwise than by using two tuning-forks, but not so certainly. If one tuning-fork be used and the jet sung to, they can be produced. A jet of water at suitable pressure will produce a pure clear note from a membrane alone. On now singing to the jet, or sounding an organ-pipe of proper pitch, a difference-tone may be heard.

In experimenting thus, one is limited in the production of difference-tones, for the jet must be sensitive to both components separately, and thus the interval between them cannot be great.

I hope soon, if time allows, to examine these differential tones by means of manometric capsules, and if possible to photograph the effects observed in a rotating mirror.

In conclusion, I tender my best thanks to Professor Barrett for communicating this Paper, and for much kind advice and assistance in the preparation of it.

EXPLANATION OF PLATE XXXIV.

FIG. I.

Instantaneous photograph of a jet of water falling on a stretched membrane, and influenced by a tuning-fork making 384 vibrations per second. The spaces between successive large drops are equal to 2 cms.

FIG. II.

The same jet influenced by a tuning-fork making 512 vibrations per second. The spaces between the corresponding drops are equal to 1·5 cms. These numbers are in the ratio 4 : 3, inversely as the periods of the tuning-forks.

FIGS. III. AND IV.

The same jet influenced by both tuning-forks simultaneously, and emitting a difference-tone of 128 vibrations per second. The drops should then be separated by a distance of 6 cms., and this is the case when the two intermediate groups of 3 drops each are eliminated, as in fig. IV. These groups are formed by the breaking up of the long bar of liquid *after* it has separated from the main column.

NOTE.

As the photographs for this plate have been reduced from the original negative, the distances between the drops in it are not those cited in the text, but are, however, strictly in proportion. The distances referred to in the text are those measured on the negative, and are themselves proportional to the *actual distances between the drops.*

NOTE ON COMBINATION-TONES

IN CONNEXION WITH THE FOREGOING PAPER.

By Professor W. F. Barrett, F.R.S.

In an afternoon discourse that I was invited to deliver before the Royal Dublin Society so long ago as 1869, I showed that a sensitive flame, when responding to a note of definite pitch, entered into a state of synchronous vibration; in fact, the flame itself sometimes yielded an audible musical note of the same pitch as that which excited it.[1] It so happened that this occurred when preparing for a lecture on "Sensitive Jets" which I recently delivered before the Society in February, 1903. The gas issued at low pressure from a V-shaped orifice (about one-sixteenth inch diameter) in a glass tube, similar to that which I originally described in 1867; and the flame was sensitive through a considerable range, responding to notes of comparatively low pitch. When tuning-forks giving 512 and 384 vibrations per second were *successively* sounded, the flame vigorously responded; and the variation in its rate of vibration was clearly seen in a moving mirror. But when both forks were sounded *simultaneously*, the flame uttered a note much lower than either fork, and the moving mirror showed its lower rate of vibration. My friend and former student, Mr. Belas, who was assisting me at the time, and who has a remarkably fine musical ear, at

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[1] See also my Papers on Sensitive Flames and Jets of Air in the "Phil. Mag." for March and April, 1867. A plate showing the appearance of a sensitive flame when viewed in a moving mirror, and its state of vibration thus revealed when responding to notes of different pitch, is given in an article I published in the "Popular Science Review" for April, 1867. In that article I remark: "Hence a sensitive flame is the analogue of a resonant column of air; both are caused to vibrate by a given note, and when the pitch of the note accords with the normal rate of vibration of the flame or air, each responds with energy to that note, so that bringing the flame to the point at which it is sensitive to a particular note is like adjusting the length of a column of air till it responds to a certain tuning-fork." A sensitive jet, however, differs from a resonant air-column inasmuch as it is in a state of unstable equilibrium when sensitive—the air or gas or water then issuing at a certain critical velocity.

once remarked that the note given by the flame was exactly two octaves below that given by the higher fork, *i.e.*, a note corresponding to 128 vibrations per second. This is what might have been expected, as the difference-tone of the two forks is 512 – 384 = 128. Selecting a König resonator corresponding to this low note, the difference-tone arising from the flame could be distinctly heard throughout the room.[1] Having briefly referred to this experiment in my public lecture, I intended to pursue the matter further, hoping that by this means some further light might be thrown on the vexed question of the objective reality of combination-tones arising from distinct and independent primaries.

Mr. Belas having, at my suggestion, taken up the photographic study of water-jets under the influence of sound, succeeded in obtaining photographic evidence of a sensitive water-jet responding first to the same respective primaries, viz., the 512 and 384 tuning-forks, and then to the difference-tone of these primaries when both forks were sounded simultaneously. Moreover, the jet showed the difference-tone even when the primaries were extremely feeble. A similar result, Mr. Belas found, could be heard when the water-jet impinged on a stretched membrane. In the foregoing Paper Mr. Belas describes these experiments, accompanied with admirable instantaneous photographs.

The interest of these experiments consists in the fact that they appear to indicate that the difference-tone has an objective existence outside the ear. As this has long been a disputed point, the matter is worth further consideration. In 1740 Sorge first noticed these difference-tones, subsequently called Tartini's tones. In

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[1] Since writing the foregoing, I have found that, in March, 1900, a German physicist, N. Schmidt, had already made a very similar observation, a brief abstract of which, taken from a German scientific periodical, is published in "Science Abstracts" (vol. iii., p. 700). In this case, however, the primaries were much higher in pitch and more intense, arising from two Galton's whistles, and, as in my observation, the sensitive flame itself gave forth the difference-tone. Audible difference-tones may arise from primaries whose pitch is so high as to be separately inaudible: this has been shown by König and Mayer. On this Lord Rayleigh remarks ("Theory of Sound," vol. ii., p. 462), "The passage of an inaudible beat into an audible difference-tone seems to be more easily explicable upon the basis of Helmholtz's theory"—that is, supposing the inaudible sounds were due to very vigorous disturbances of the air. Whether this is so or not, it could be tested by the sensitive flame. For my own part, I think the result and its cause are similar to that above described in the text.

1807 Dr. Thomas Young explained their origin as due to the coalescence of rapid beats into a single resultant tone.[1]

This explanation was rejected by von Helmholtz, who suggested a wholly different origin of the Tartini's tones; and though it has been subjected to criticism, Helmholtz's view is now generally accepted by physicists. This explanation depends on the fact that in the case of any violent vibration of an elastic medium the restoring force is not proportional to the displacement. This notably occurs in a limited air-cavity, or in an unsymmetrical membrane like that of the drum-skin of the ear. Hence a "simple harmonic force acting on the membrane, or on the cavity, will produce not merely a simple harmonic vibration of its own frequency, but a series of harmonic vibrations giving rise to overtones, which we may term *self-combination tones.* When two harmonic forces of different frequencies act on the membrane, or cavity, they produce vibrations having frequencies equal to the differences of frequencies of the original vibrations, or their harmonics. These give rise to *difference combination-tones.* There are also vibrations equal to the sum of the frequencies of the original vibrations, or their harmonics. These give rise to *summation combination-tones.* Hence two pure tones of frequencies m and n, entering the ear, may give rise to the following notes:—

$m \quad n$	primaries.
$2m \quad 2n$	self-combination tones.
$m-n$	first difference tone.
$m+n$	first summation tone."[2]

And various other combinations of less importance.

In most cases these combination-tones arise within the ear, and have no existence external to the auditory apparatus. But Helmholtz showed that when the primaries were powerful, and issued from a common and confined air-space, as in the case of the double siren and harmonium he used, the combination-tones do have an existence in the external air. To prove this Helmholtz

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[1] Young says: "When the beats of two sounds are too frequent to be heard as distinct augmentations of their force, they have the same effect as any other impulses which recur in regular succession, and produce a musical note which has been called the grave harmonic."—Young's Lectures, 1845 edition, p. 306.

[2] Poynting and Thomson, "Sound," new edition, p. 156.

showed they were reinforced by resonators; now, resonators are only able to reinforce a tone when pendular vibrations actually exist in the air; they have no effect on tones which exist only in the auditory apparatus. Several distinguished acousticians have, however, criticised and dissented from Helmholtz's proofs; the matter is fully discussed in Ellis's translation of Helmholtz's "Tonempfindungen,"[1] and the general conclusion arrived at by Ellis was that Helmholtz's views need reconsideration. In 1886 Prof. Lummer confirmed Helmholtz's experiments with resonators by using instead a microphone transmitter and distant telephone receiver; and in 1895 Professor (now Sir A.) Rücker and E. Edser proved that both difference and summation-tones did exist outside the ear. For this purpose they employed tuning-fork resonators, their vibration being revealed not to the ear, but to the eye by means of a delicate optical method; thus the principal objection raised to Helmholtz's experiments was removed. But they could only detect the objective existence of combination-tones when the primaries issued from a double siren, and were peculiarly powerful. They could obtain no evidence of their existence outside the ear when the primaries were two tuning-forks or other sources of sound.[2] Nor could Helmholtz obtain any independent proof of the external existence of combination-tones when the primaries were two tuning-forks, or two violins, or two singers, or two separate wind-instruments. The combination-tones were heard in all these cases, but they doubtless arose within the mechanism of the ear; their origin was physiological and not physical. Even in this case Helmholtz's explanation, as Lord Rayleigh remarks, "is admissible only when the generating sounds are loud—*i.e.*, powerful as they reach the ear."

The foregoing facts render the experiments with the sensitive flames and water-jets of peculiar interest, inasmuch as both flame and water-jet responded to the difference-tone when the primaries were not only distinct but feeble—in fact, hardly audible sources of sound. Obviously Helmholtz's theory cannot here account for the difference-tone; for if the combination-tone were an effect of

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[1] See Appendix xx., sect. L, of Helmholtz's "Sensations of Tone." Second English edition, 1885.

[2] Proc. Physical Society, vol. xiii., p. 412.

the second order, as this theory requires, then by withdrawing the two primaries from the sensitive jet—or allowing them to die down as was done—the combination-tone should fall off more quickly than the generating tones; but this was not the case. Is, then, the view of the critics of Helmholtz correct? Do "the beats of the generators, with their alternations of swellings and pauses, pass into the differential-tone of like frequency, without any such failure of superposition as is invoked by Helmholtz"? Employing a sensitive jet as a delicate phonoscope, it certainly would appear that the greater amplitude of the disturbance produced at the beats gives a definite and disintegrating shock to an unstable jet of flame or water. This disturbance being periodic and recurring with sufficient rapidity, the successive shocks in some way became audible as the difference-tone, or what König called the beat-tone.

In the case of the sensitive water-jet falling on a membrane, this is the explanation suggested by Mr. Belas. The sound actually heard is due to the impact of the drops of water on the membrane, and those drops which break off high up on the jet, and have therefore a greater distance to travel, must strike the membrane with greater momentum than the others. Now the photographs clearly show that the jet *does* disintegrate higher up. When, therefore, the phases of the two primary tones coincide, the difference-tone should be heard more loudly than the primaries, as is the case.[1]

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[1] Professor Poynting, D.SC., F.R.S., was good enough to read the proof of the foregoing paper, and writes to me as follows:—"It appears as if Mr. Belas had got a good mechanical explanation of this particular difference-tone. Another similar case occurs to me. Suppose a reservoir is at the sea-shore, just below the level of the highest spring-tide, and with some contrivance for emptying it slowly. Then it will fill once a fortnight, and its rise and fall will have a frequency equal to the difference in frequencies of the solar and lunar tides. Its oscillations will, of course, not be harmonic, but its chief vibration will be fortnightly. This appears to me to be very like the water-jet experiment as explained by Mr. Belas. We have a mechanical explanation then of the beat-tones. And now I remember a case where summation-tones appear to occur; perhaps worth troubling you with, but not bearing on the case in point. I used to live near a railway incline where an engine was used at the rear to help to push the train. The puffing of the two engines, front and rear, could be heard, sometimes coinciding, sometimes alternating. Suppose they each gave two puffs per second; when they alternated, it sounded as if an engine was giving four puffs per second, and the frequency was the summation-tone. I suppose—but perhaps there is some

As regards the difference-tone emitted by the sensitive flame, we have here an audible vibration set up *in the flame itself*, the greater amplitude of the waves recurring at the beats exciting a more vigorous disturbance of the flame.[1] The fact of the flame speaking, *i.e.*, giving out a note of its own corresponding to the impressed disturbance, indicates that the issue of the stream of gas through the orifice is rendered periodically variable.

Now, a jet of air or a flame can act as a resonant jar; "a tuning-fork vibrating feebly, and presented to the jet, is loudly heard," or the ticking of a watch is reproduced by a sensitive flame so loudly as to be heard all over a large lecture-room.

How the disintegration of the flame occurs under the influence of sound is not yet clearly ascertained. The disturbances by which the equilibrium of a sensitive jet is upset are certainly impressed on the stream of gas or liquid as it leaves the orifice; hence the root of the flame is the seat of its sensitiveness. Lord Rayleigh's experiments show that a sensitive flame is affected at the *loops* of a sound-wave, where the variation in *motion* of the air-particles is greatest, and not at the nodes, where the variation in *pressure* is greatest; and somewhat doubtfully he was led to the conclusion that the disintegration of a sensitive flame was due to an increased sinuosity given to the issuing stream of gas by the sonorous disturbance; "the necessity, as remarked by Barrett, for an unsymmetrical orifice points strongly in this direction."[2] For my own part, I am disposed to think we have not yet arrived at any adequate explanation of the phenomenon. Some experiments indicate that the effect is due to symmetrical swellings about an axis on the issuing stream—*varicosity*, as Lord Rayleigh

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doubt here—that if there had been two 256 puffs per second, they might have been arranged to give equally-spaced puffs 512 per second, and so the summation-tone would have been heard. Just as with the water-jet difference-tone, where the difference-tone alone is heard, and not the primaries, here also, I imagine, the summation-tone alone would be heard, and not the primaries."

[1] So far as regards notes nearly in unison, this was pointed out in my papers, and shown in my lecture to this Society thirty-six years ago—a sensitive flame visibly throbbing to the beats of two tuning-forks nearly in unison, even when the sound of the forks was barely audible. This is of course due to the fact that the energy of the sonorous vibrations which affect the flame is proportional to the *square* of their amplitudes.

[2] "Theory of Sound," vol. ii., p. 402.

calls it—and not to sinuosity. But with this question we cannot here deal.[1]

On the general question of the cause of difference-tones, Lord Rayleigh, though supporting the Helmholtz theory, remarks that "it presupposes a more ready departure from the superposition of vibrations within the ear than would have been expected."[2] The experiments with sensitive jets certainly indicate that a more complete theory is required; and it is to be hoped that Lord Rayleigh will be able to give it to us.

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[1] The difference between a high-pressure sensitive flame issuing from a pin-hole orifice, and a low-pressure sensitive flame issuing from a nicked orifice, is very marked, a definite fish-tail flame being produced by a musical note in the latter case. Possibly the cause of the speaking of the sensitive flame may be analogous to that suggested by Lord Rayleigh as the source of sound in a "bird-call," or small pair of parallel plates, perforated with a central hole through which a current of air is driven.

[2] "Theory of Sound," vol. ii., p. 462.

XXXIII.

NOTES ON THE CONSTITUTION OF NITRIC ACID AND ITS HYDRATES.

By WALTER NOEL HARTLEY, D.Sc., F.R.S.

[Read, April 18; Received for Publication, April 20; Published, June 19, 1905.]

It has already been shown that the spectra photographed through definite thicknesses of nitric acid of different strengths afford direct evidence of the existence of a compound with the formula $H_3NO_4 \cdot H_2O$ termed orthonitric acid from analogy with orthophosphoric acid, and, in addition, of several hydrates formed in solution until the molecular proportions were $HNO_3 : 14H_2O$. (Chem. Soc. Trans., 1903, **83**, 658.) When studying the reactions of some of the acids, the spectra of which had been photographed, a paper by H. Erdmann of remarkable interest came under my notice, to which I beg leave to draw attention (Ueber Orthosaltpetersäure $N(OH)_5$ und die durch Wasserabspaltung daraus entstehenden Verbindungen. Zeit. f. Anorg. Chem., 1902, **32**, pp. 431–36). It is stated therein that Mitscherlich believed he had prepared an acid of the composition required by the formula $N(OH)_5$, and Wislicenus was of opinion that this acid was a stable compound at low temperatures. Further important evidence of its existence was obtained by Pictet and Genequand (Ber. Deutsch. Chem. Gesellsch., 1902, **35**, p. 2526) by preparing a diacetyl derivative by the interaction of equal volumes of acetic anhydride, and nitric acid, of sp. gr. 1·4. The action is more under control if glacial acetic acid and fuming nitric acid of sp. gr. 1·52 are employed.

The new compound is not decomposed on distillation, it boils at 127·7 at 730 mm., and its formula is $(CH_3 \cdot COO)_2N(OH)_3$; thus the existence of the acid $N(OH)_5$ is satisfactorily established by a definite chemical reaction. Erdmann obtained this acid crystallized in long needles which melt at $-35°$; it boils under a pressure of 13 mm. at from 40° to 40·5°, undergoing dissociation, but it is a stable substance at $-15°$. My observations showed its existence in solution, but the formula assigned to it was $H_3NO_4 \cdot H_2O$. Other four acids were isolated by Erdmann, one of the most interesting being octobasic nitric acid $(HO)_4N \cdot O \cdot N(OH)_4$ corresponding to crystallized arsenic acid $(HO)_4 \cdot As \cdot O \cdot As(OH)_4$, and to the tetracalcic phosphate obtained from "basic slag." As Erdmann points out, Graham discovered this and two other acids by observing their viscosity or transpiration time through a capillary tube, the flow of the octobasic acid showing a characteristic maximum. ("Chemical and Physical Researches," by Thomas Graham. Edinburgh, 1876, p. 602.) Graham gives the formulæ of some copper and bismuth salts derived from the octobasic nitric acid. (*Ibid.*, p. 378.)

The transpiration time, in seconds, of water is **348**; of HNO_3, **344·5**; of H_3NO_4, **705**; of $H_8N_2O_9$, **732**; and of H_5NO_5, **712**; these figures are very remarkable. Pickering obtained two acids (Chem. Soc. Trans., 1893, **63**, p. 436) crystallized, namely, H_3NO_4, melting at $-36^{\circ}\cdot 8$, and $H_5NO_5 \cdot H_2O$, melting point $-18^{\circ}\cdot 0$. These acids were shown to exist at a considerable range of temperature above their freezing or melting points, the first H_3NO_4 at 52°, and the second $H_5NO_5 \cdot H_2O$ at 36°.

Erdmann determined the melting point of the acid HNO_3, which is not well crystallized, to be -42°; and with a special apparatus the boiling point, which was $21^{\circ}\cdot 5$ under a pressure of 24 mm. of mercury. His results are summarised as follows:—

Erdmann's Acids.

Formulæ.	Composition HNO_3 per cent.		Constitution.
	Calculated.	Found.	
Metanitric acid, HNO_3	100·00		$\begin{matrix}O\\O\end{matrix}\!\!>N-OH$ (Graham.)
Tetrabasic nitric acid, $H_4N_2O_7$	85·52	87·65	$O<\begin{matrix}NO(OH)_2\\NO(OH)_2\end{matrix}$
Tribasic nitric acid, H_3NO_4	77·78	77·78	$O=N(OH)_3$ (Pickering, m. p. $-36^{\circ}\cdot 8$.)
Octobasic nitric acid, $H_8N_2O_9$	68·87	69·10	$(HO)_4N \cdot O \cdot N(OH)_4$ (Graham.)
Orthonitric acid, H_5NO_5	63·63	63·63	$N(OH)_5$ (Graham.)

The above acids were isolated as crystalline solids with low melting points, capable of being distilled unchanged under diminished pressures, and under these conditions maintaining the character of definite stable compounds.

At – 15° orthonitric acid, $N(OH)_5$ is produced from either stronger or weaker acid by passing a current of dry air through it. The solutions of nitric acid in which several hydrates were recognised by their absorption spectra are shown in the following table :—

Hydrates of Nitric Acid.

Sp. Gr.	Composition, per cent. HNO_3.	Constitution.
1·490	89·60	A mixture of $(HO)_2ON \cdot O \cdot NO(OH)_2$ with HNO_3.
	78·78	Pure $O : N(OH)_3$, Pickering, found 77·9 per cent., calculated 78·02 per cent.
1·432	72·57	A mixture of $(HO)_4N \cdot O \cdot N(OH)_4$ with H_3NO_4.
1·420	69·80	Pure $(HO)_4N \cdot O \cdot N(OH)_4$.
1·397	63·63	Pure $N(OH)_5$.
1·339	53·93	Hydrate, pure, $N(OH)_5 \cdot H_2O$, Pickering, m.p. – 18°. Berthelot, Thomsen.
1·263	41·18	Hydrate, pure, $N(OH)_5 \cdot 3H_2O$.
1·207	33·33	Hydrate, pure, $N(OH)_5 \cdot 5H_2O$, Graham.
1·127	20·31	Hydrate, pure, $N(OH)_5 \cdot 12H_2O$, Berthelot, 18 per cent. HNO_3, Pickering, crystallised at – 17°.

The important work of Veley and Manley (Proc. Roy. Soc., 1901–2, **69**, pp. 86–119) by curves of densities and curves of contractions shows the existence of compounds formed in solutions when the ratios are $HNO_3 : 14, 7, 4, 3, 1·5$, and 1 H_2O, and by refraction indices with ratios HNO_3 : 14, 7, and 1·5 H_2O. From these measurements we get the following hydrates and acids:—
$N(OH)_5 \cdot 12H_2O$, $N(OH)_5 \cdot 5H_2O$, $(HO)_4N \cdot O \cdot N(OH)_4$,
$N(OH)_5 \cdot 2H_2O$, $N(OH)_5 \cdot H_2O$, $ON(OH)_3$.

Both Pickering's curves and those of Veley and Manley indicate in a remarkable degree the existence of the octobasic acid isolated by Erdmann. This is the acid with maximum viscosity in Graham's transpiration experiments.

The transpiration times recorded by Graham are larger with weak acids down to a dilution of 200 parts of water to 1 of HNO_3, the limit of his observations, than for pure water, or for pure HNO_3. This corresponds to an acid of 33·33 per cent. HNO_3. But Graham's times of transpiration become gradually diminishing quantities with large dilutions, and a similar change may be seen in the density curve drawn by Pickering from Kolb's Specific Gravity Tables, and with the curve of heat evolution taken from Berthelot's results; nevertheless Pickering notices a break in his freezing point curve corresponding to acid of the strength of 18 per cent. HNO_3 or $HNO_3 \cdot 18H_2O$, which agrees with a break in the density curve and in that drawn from Berthelot's heat of dilution. With the absorption spectra, the transmission of rays is perfectly definite to oscillation-frequency 3079 with all acids from 69 · 80 per cent. down to 20 · 31 per cent. strength, there being a feeble extension to $1/\lambda$ 3083 in the spectrum of the latter. This marks the commencement of a change in the constitution of the acid, and at this point we have the ratio $HNO_3 : 14H_2O$. The acid corresponding to this is $N(OH)_5 \cdot 12H_2O$, and the hydrate indicated by Pickering's curves is $N(OH)_5 \cdot 16H_2O$. Examined through the same thickness, namely, 3 mm., the acid $HNO_3 : 21H_2O$ or $N(OH)_5 \cdot 19H_2O$ exhibits a profound change; the spectrum is continuous to $1/\lambda$ 3079 (λ 3247), and extends weakly to $1/\lambda$ 3157 (λ 3167), from which point there is an absorption band $1/\lambda$ **3157** to **3662** (λ **3167** to **2730**); beyond this the rays extend to $1/\lambda$ 3947 (λ 2533).

The interest attached to the spectrum observations lies in the recognition of four hydrates of the orthonitric acid. It remained to be seen what compound would be formed by the absorption of water vapour from the air under ordinary conditions of temperature and pressure. The first experiment was made with an acid of 1·420 sp. gr., containing 69·80 per cent. of HNO_3, and consisting almost entirely of the octobasic acid. There were 30 grs. of this placed in a beaker under a bell-jar containing a dish with distilled water in it. The acid remained without disturbance from December 16th, 1904, till January 18th, 1905; the gain in weight was 8·30 grs., making the total quantity of acid 38·30 grs. The composition of this had become 54·68 per cent. HNO_3 and 45·32 per cent. H_2O, which corresponds to a monohydrated orthonitric acid $N(OH)_5 \cdot H_2O$, the same as that isolated by Pickering, m. p. – 18°·0. It continues, however, to absorb water.

NOTE.—On May 26th, 1905, after an interval of more than five months from December 16th, during which the temperature never exceeded 17°·5 C., the acid was found to have become reduced in specific gravity to 1·187 at 15° C., and it contained 29·56 per cent. of HNO_3. It is improbable that this acid will undergo any further change in composition under normal atmospheric conditions.

XXXIV.

ON FLOATING BREAKWATERS.

By J. JOLY, Sc.D., F.R.S.;
Professor of Geology and Mineralogy in the University of Dublin;
Hon. Sec., R.D.S.

(Plates XXXV. and XXXVI.)

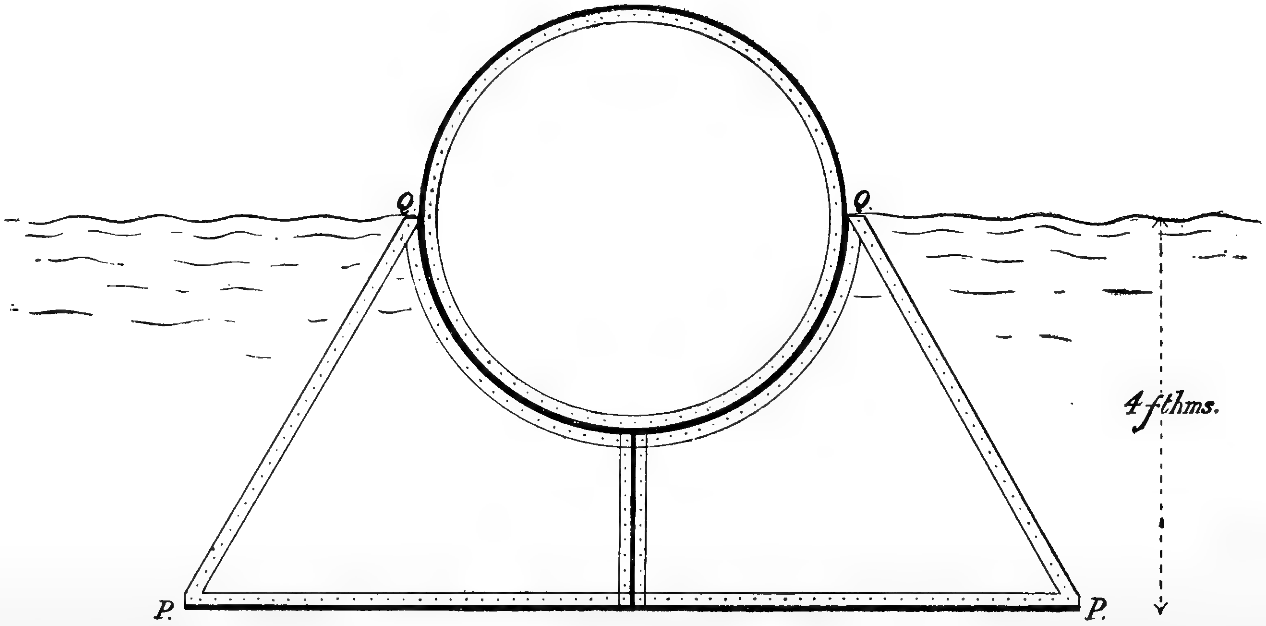
[Read, May 16; Received for Publication, May 19; Published, July 5, 1905.]

The subject of floating breakwaters has engaged the attention of engineers from time to time, and references to experiments and suggestions (mainly the latter) will be found in treatises on harbour engineering, in the Report of the Commissioners of Harbours of Refuge, which dates back to the middle of the last century, as well as in the Transactions of the Institution of Civil Engineers.

In none of these sources of information have I been able to find any reference to the principle involved in the suggestion described in the following note. It formed the subject of an informal communication to a Trinity College Society some years ago. Recent references in the daily papers to the proposed improvements of harbours on the east coast of Ireland, induce me to publish it. The conditions, both in the case of Arklow and Wicklow, seem precisely those which would justify its use.

It is evident that if a floating body is to check the transmission of undulating motion in water, its own oscillations in the water must be damped to such a degree that only vibrations, as a whole, of long period are open to it. Thus a very large ship will give rise to still water under its lee, provided the sea is not so great as to carry the vessel up and down upon its undulations.

Let us now imagine a vessel riding in a sea sufficiently big to raise her upon each wave. Such a sea is not materially obstructed by its passage across the vessel (which we will suppose broadside on to the waves), although broken water will not exist under her lee. Let us now assume a horizontal platform to be attached beneath the vessel sufficiently far down to be in still water. If the platform and its attachments are strong enough to


Q.
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constitute, along with the ship, a rigid system, and if the platform is of sufficient area, the upward and downward motion of the vessel will be completely checked. She will no longer allow the wave-motion to be so freely transmitted. A wave rising against the side of the vessel, in order to lift the vessel has to set in motion the mass of water surrounding the platform. The vessel, therefore, instead of facilitating the transmission of the wave-motion by rising with the wave, obstructs the passage of the latter to the full extent of her draught. The wave will accordingly be scattered and reflected in a greater degree, its energy being expended partly in turbulent motion, partly in vibrations communicated to the vessel, and in part sent back in the reflected wave.

Such a breakwater is a floating body towards the tidal rise and fall of water-level, but not to the more rapid rise and fall of waves. In a sense, therefore, it is as fixed in position as a stone breakwater rising from the bottom. There is no doubt it can be made to be so by conferring sufficient dimensions upon it. These dimensions need not be extravagant where the conditions are not such as to require protection from deep-water waves. The principle is embodied in its most generalized form in Plate XXXV., showing in cross-section a cylindrical float supporting a submerged platform *PP* at a depth of about four fathoms. The float and platform are braced together by vertical webs at frequent intervals. A submerged web, transverse to these, further connects the float and platform, and stops the transmission of undulatory motion between float and platform. Assuming a diameter of 30 feet for the float, and taking into account the lateral horizontal rigidity conferred upon it by its attachment to the platform (which is about 60 feet wide), a length of ten diameters would probably be admissible. Such a breakwater, moored in some six fathoms of water off a bight or small indentation of a coast, would give shelter within, allow entrance at either extremity, in no way obstruct tidal currents or tidal scour, and, lastly, be removable at pleasure if circumstances so warranted. Obviously, a construction involving less or more draught might be conferred upon it according to requirements.

A modification of this breakwater, presenting different features of construction, and doubtless having advantageous qualities, is shown in Plate XXXVI.

Here the breakwater has assumed somewhat the character of a very deeply water-logged vessel, which, however, for purposes of transport, can be brought to the surface at any time.[1] Almost the whole of her iron work is then open to easy inspection. As shown in the figure, the water-chamber is full, and the inertia is a maximum. The air-pump tube C enables the water to be expelled from the hold through the valve V. This valve is commanded from the upper deck, and may then be closed. The interior is accessible by means of a hatch. When thus raised, the breakwater is easily towed from place to place. The chemical influence of sea-water on iron being mainly confined to the zone between wind and water, this part of the structure is of double thickness, so that renewal may be effected by removing the outer plates. This also secures a specially strong construction at the part most tried by wave action and possibly even exposed to impact of floating bodies.

The floating part is stiffened by frequent bulk-heads. I would suggest for these a spacing of 20 feet, and that similar bulk-heads divide the water-chamber, spaced every 40 feet. The float is, in fact, a strong box-girder, and this character, indeed, prevails throughout. The amount of lateral and vertical rigidity will, of course, depend upon the dimensions conferred upon the structure, and the thickness of steel or iron used in its construction. I assume a beam of about 36 feet on the upper deck, and a maximum beam (submerged) of nearly 50 feet. The draught would, on the proportions shown, then come out at about two and a-half fathoms. For shallow-water coast protection this should be sufficient. In this case also a length of 300 feet would be admissible: perhaps rather more.

It will be seen that the principle here involved is much the same as that of the first design. The inertia is increased by a large mass of water which has to rise and fall with the vessel. I have made a rough computation of the masses involved. Assuming the dimensions as above, and that 1-inch steel plate is used throughout, and allowing twenty per cent. additional metal for girders, rivets, etc., the mass of the hull, if 300 feet in length, comes out at

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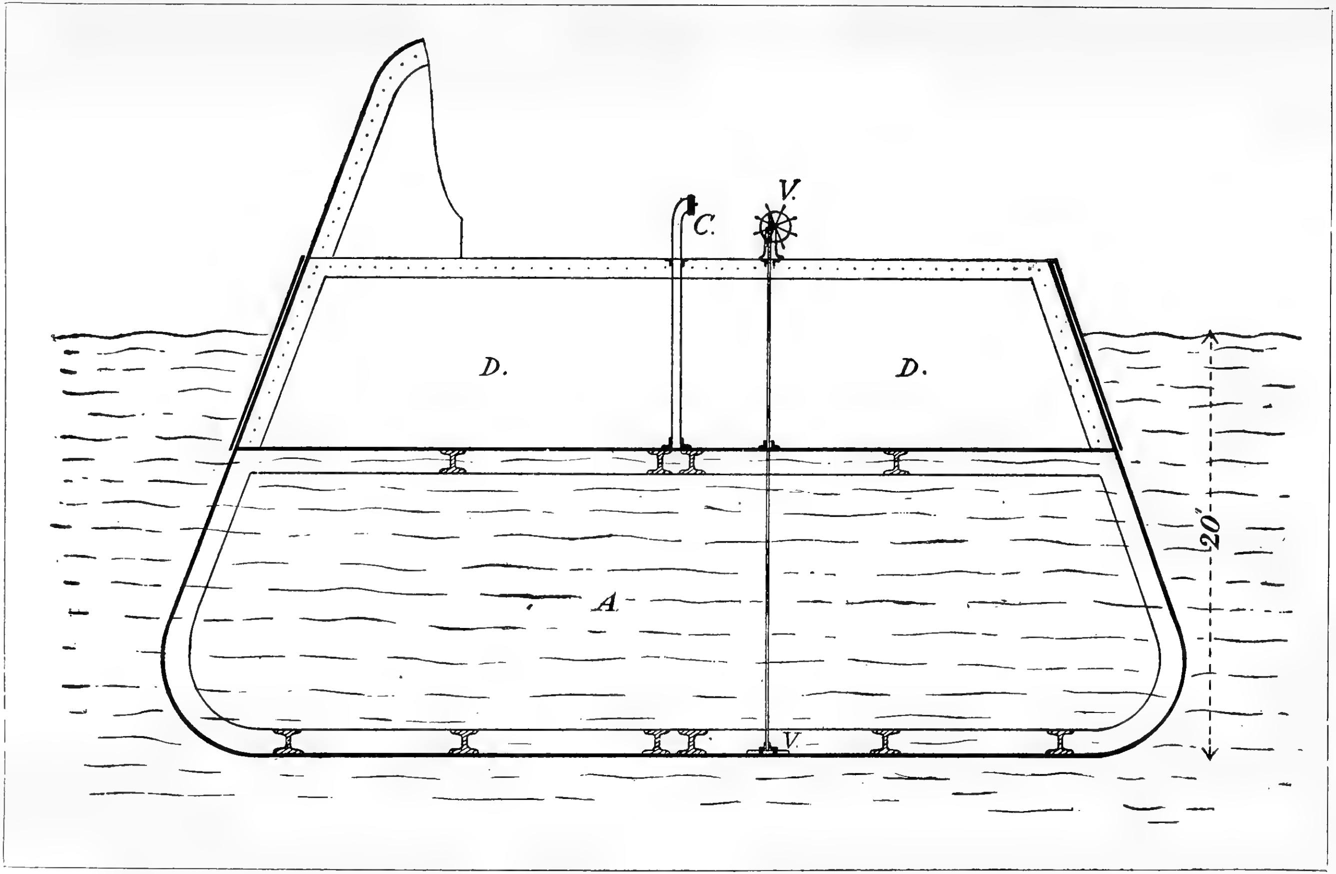
[1] A similar advantage can be conferred on the first design by covering in the sloping edges QP by continuous plates.


V.
C.
D.
D.
A.
V.
20'

about 1700 tons. The water enclosed in the hull adds to this about 5,300 tons, so that the breakwater possesses the inertia of 7000 tons. In such seas as reach inside the banks on the east coast of Ireland, as at Wicklow and Arklow, such a mass might, I think, be assumed as unaffected by the wave-motion.

The free-board, if it was found desirable to entirely fill the hold, would be about 4 feet only. Some further screen from waves and wind would be desirable. On the sea-ward side I propose a shield of about 10 feet in height above the upper deck. This is strongly supported by webs at frequent intervals. A total shelter-height of 14 feet would afford considerable shelter to small vessels. As this breakwater rises with the tide, its effectiveness is never less than this.

Difficulties attending the mooring of floating breakwaters have often been urged against the use of such structures. The objection is justified if the breakwater rises on the seas. The difficulty of mooring against the steady stress of tide or wind is, however, of a lesser degree. Assuming that the dimensions of the structure are suitable to the conditions of wave-motion to which it will be subjected, the question of mooring becomes a very different one from that of mooring a vessel rising and falling on the waves—a light-ship, for instance.

In a tidal stream of four knots, the force will be less than one pound on the square foot. This is, relatively to wind-pressure, negligible. A wind-pressure of fifty pounds to the square foot would be very exceptional. This would give a total of about sixty tons over the exposed part of the structure (Plate XXXVI.). To this must be added an allowance for wind-drift of the water against the hull. If we assume that a force of one hundred tons may act at *each* end, there would be a considerable margin of safety. Moorings to resist this stress from on-shore winds should be provided, and a lesser stress reckoned on from off-shore winds. There would not appear to be any practical difficulty in meeting these conditions, using two mooring chains at each extremity. In certain cases the landward moorings might be made fast ashore.

Further suggested details are out of place here; it only remains to point out some advantages attending the use of floating breakwaters. The failure of piers and breakwaters by silting, after every care and great outlay, is so frequent, that trial should be given to a means of obtaining shelter which would suit many localities, and which would be free from the risk of failure on this score. The presence of the breakwater would in all probability increase the scour by deflecting the tidal current to the bottom, while, at the same time, surface-currents would be checked. These are just the conditions often so unattainable in harbour construction, and yet so desirable.

The stone breakwater once built has to remain. If a larger area of shelter has to be subsequently provided, or if found to be improperly placed, it is an additional difficulty in bettering the conditions. The floating breakwater, on the other hand, is removable, and may be experimentally placed so as to make the best harbour. It can be added to at any time. Finally, if, as often happens, the maritime development of the place disappoints expectations, or a fishery dies out, the harbour can be removed altogether and used elsewhere.

With regard to the consideration of cost, it is necessary to take into account not only first cost, but cost of maintenance, and set these against the corresponding cost in the case of fixed structures. The running expense of dredging would probably be absent. Repairs, again, would be more easily effected, as, in fact, the breakwater may be removed and dry-docked. If this consists of several units, these may be separately dealt with. It would be quite possible to secure a very permanent surface against corrosion by the sea-water by the use of concrete. I have not referred to this in the foregoing remarks; but surfacing with cement concrete, supported by projecting T-irons, might readily be applied to interior work exposed to water, or to the wind and water zone.

As regards prime cost, it must be borne in mind what very large sums are sunk in quite small harbours around our coasts; and, as already observed, it must be set down on the side of the removable breakwater that the lamentable failures so often attending the best efforts of the harbour engineer would be impossible. In the case of Arklow, now before the public, the proposed extension of the piers seaward would very probably merely result in carrying the accumulation of sand further out. There is an unlimited supply of sand around the coast. The true solution of the Arklow problem is, in my opinion, to trust to sand-pumping for preserving a clear entrance in fair weather, and to a floating shelter, moored about a quarter of a mile off the piers, as harbour of refuge. There is a depth of four fathoms at this distance. The shelter should consist of two separate breakwaters, moored so as to afford shelter from north round by east to south, and having an entrance between them opening east. The breakwater should be lit, and be guarded by a bell-buoy. Behind these breakwaters there would be perfect security for the small vessels of Arklow, which might be prevented from returning to harbour owing to sudden silting of the bar. The short and dangerous sea which rapidly gets up in the bay in rough weather would be excluded from the space enclosed between the breakwaters, and here also there would be considerable shelter from on-shore winds.

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