up with sandstones, conglomerates, and breccias. The red stain of these deposits, occasional pseudomorphs of rock-salt and layers of gypsum, combined with ripple-marks and sun-cracks seem, as Prof. Ramsay has suggested, to indicate the concentration of the saline waters which filled these basins; while further evidence of the unwholesome nature of the water may be indicated by the general paucity of fossils in the strata, and by the immense numbers of well-preserved fishes which are sometimes met with crowded into a small space, as if they had come from fresher water elsewhere, and had been inclosed and killed in scattered pools. The peculiar breccias and brecciated conglomerates of the Upper Old Red Sandstone have been compared to some recent Glacial deposits, and the resemblance has been pointed out between the form of the stones in these deposits, and those in common boulder-clay. It should be noted also that in many cases these breccias occur in old valleys, and bear many of the characters of valley-moraines. Such are those to the east of Ullswater, and those which flank, and in some places penetrate the Lammermuir Hills. In the latter district worn dome-shaped bosses of rock underlying the breccias recall the aspect of true *roches moutonnées*. Another glacial feature is suggested by the basin-shaped hollows (apparently sometimes true rock-basins) in which the deposits lie. Further indications of ice are given by the remarkable patches of angular and rounded stones scattered through the red sandstones of Arran, the occurrence and position of which may be accounted for on the supposition that they are portions of shore-gravel, which have been frozen and transported in cakes of floating-ice.

Indications of terrestrial disturbance during the accumulation of the Upper Old Red Sandstone in Scotland are furnished by the Lammermuir Hills. Towards the close of the period, and thence through the deposition of the Lower Carboniferous rocks, volcanic action which seems to have been quiescent for a long interval, broke out again over the south of Scotland. To this period belongs the chain of old lavas and tuffs which may be traced from the mouth of the Nith eastwards by Langholm and the Tarras Water, to the head of the Slitrig Valley, and through the plain of the Tweed as far northwards as the Whiteadder. The Garlton Hills, Campsie Fells, and the ranges of hills which run down Renfrewshire and the north-east of Ayrshire, and are prolonged into Bute, the Cumbrays and Arran mark a prolonged series of volcanic eruptions during this same period. Probably the terraced hills of Lorne are of similar age. Traces of contemporaneous volcanic action occur likewise in the Upper Old Red Sandstone of the north of Scotland, and form a remarkable feature in the cliffs of Hoy, one of the Orkney Islands.

The author brought forward evidence to show that while the Upper Old Red Sandstone was being deposited in the British area, there existed outside that area a sea in which some of the characteristic corals, brachiopods, and other organisms of the time of the Carboniferous Limestone already existed. He pointed out the intercalation of limestone bands in the Red Sandstone series in Arran and elsewhere, a long way below the base of the Cementstone group which underlies the Carboniferous Limestone. These calcareous bands, full of species of fossils which are familiar in the Carboniferous Limestone, seem to indicate that while, on the whole, the Upper Old Red Sandstone, and the red strata at the base of the Carboniferous system were deposited under conditions unfavourable to the presence of at least corals, crinoids, and molluscs, their formation was interrupted by intervals during which clearer and less saline water prevailed, perhaps owing to the removal of barriers which allowed the access of the main ocean with its animal forms into the closed lagoons and inland seas of the Upper Old Red Sandstone.

ON REPULSION RESULTING FROM RADIATION[1]

THIS paper contains an account of experiments on the action of radiation on bodies the surfaces of which have their radiating and absorbing powers modified by various coatings. The difference between a white and a lamp-blacked surface in this respect was at first not very decided, and experiments have been instituted with the object of clearing up some anomalies in the actions observed. Two pith discs, one white and the other black, are suspended on a light arm in a glass bulb by means of a fine silk fibre; after perfect exhaustion the white and black discs are found to be equally repelled by heat of low intensity, such as from the fingers, warm water, &c. A copper ball is then tried at gradually increasing temperatures. Up to 250° C. it repels both equally, above that the black is more repelled than the white, and at a full red heat the repulsion of the black disc is very energetic. A lighted candle acts with more energy than the red-hot copper.

The presence of even a small quantity of aqueous vapour in the exhausted apparatus almost, if not quite, neutralises the more energetic action which luminous rays appear to exert on a blackened surface.

After describing several different modifications and some new forms of apparatus devised to facilitate experiment, the author gives a drawing of an instrument which enables him to get quantitative measurements of the amount of incident light falling on it. It consists of a flat bar of pith, half black and half white, suspended horizontally in a bulb by means of a long silk fibre. A small magnet and reflecting mirror are fastened to the pith, and a controlling magnet is fastened outside so that it can slide up and down the tube, and thus increase or diminish sensitiveness. The whole is completely exhausted and then inclosed in a box lined with black velvet, with apertures for the rays of light to pass in and out. A ray of light reflected from the mirror to a graduated scale, shows the movements of the pith bar. The degrees of deflection produced by the light of a candle at distances from 6 feet to 35 feet are given.

The experimental observations and the numbers which are required by the theoretical diminution of light with the square of the distance, are sufficiently close, as the following figures show:—

Candle	6 feet	off gives	a deflection of	218°
„	12	„	„	54
„	18	„	„	24·5
„	24	„	„	13
„	10	„	„	77
„	20	„	„	19
„	30	„	„	8·5

The effect of two candles side by side is practically double, and of three candles three times that of one candle.

The action of various solid and liquid screens is next given.

A candle three feet off, giving a deflection of 180°, has its action reduced to the following amounts by

Yellow glass	... ...	161°
Blue „	... ...	102
Green „	... ...	101
Red „	... ...	128
Water „	... ...	47
Alum „	... ...	27

A candle on each side of the apparatus, and equidistant from it, keeps the index ray of light at zero; by shading off either one or the other the light flies off to either extremity of the scale. This gives a ready means of balancing two sources of light one against the other. Thus,

[1] Paper read at the Royal Society, Feb. 10, by William Crookes, F.R.S., &c. Part III.

retaining the standard candle 48 inches off, on the left of the bar, the index is brought to zero by placing on the right

2 candles	67 in. off.
1 candle behind solution of sulphate of copper	6 „
„ „ alum plate	14 „
A small gas burner	113 „

These experiments show how conveniently and accurately this instrument can be used as a photometer. By balancing a standard candle on one side against any source of light on the other, the value of the latter in terms of a candle is readily shown; thus in the last experiment the standard candle 48 inches off is balanced by a gas-flame 113 inches off. The lights are therefore in the proportion of 48^2 to 113^2, or as 1 to $5\frac{1}{2}$. The gas-burner is therefore equal to $5\frac{1}{2}$ candles.

By interposing screens of water or plates of alum, and so cutting off the dark heat, the actual luminosity is measured. In addition to this, by interposing coloured glasses or solutions, any desired colours can be measured either against the total radiation from a candle, its luminous rays, or any desired colour. One coloured ray can be balanced against another coloured ray, by having differently coloured screens on either side.

The variations in the luminosity of a "standard" candle will cease to be of importance. Any candle may be taken; and if it be placed at such a distance from the apparatus that it will give a uniform deflection, say of 100 divisions, the standard can be reproduced at any subsequent time; and the burning of the candle may be tested during the photometric experiments by taking the deflection it causes from time to time, and altering its distance, if needed, to keep the deflection at 100 divisions.

If the pith bar in this instrument be blacked on alternate halves, an impetus given by a ray of light always acts in the same direction of movement. A candle causes it to spin round very rapidly until the suspending fibre is twisted up, and the rotation is stopped by the accumulated torsion.

By arranging the apparatus so that the black and white surfaces are suspended on a pivot instead of by a silk fibre, the interfering action of torsion is removed, and the instrument will rotate continuously under the influence of radiation. To this instrument the author has given the name of the "Radiometer." It consists of four arms of very fine glass, supported in the centre by a needle-point, and having at the extremities thin discs of pith lamp-blacked on one side, the black surfaces all facing the same way. The needle stands in a glass cup, and the arms and discs are delicately balanced so as to revolve with the slighest impetus.

In the "Proceedings of the Royal Society" last year, the author gave a brief account of some of the earlier experiments with these instruments. In the present paper he enters very fully into the various phenomena presented by them, and gives Tables showing the number of revolutions made by the radiometer when exposed to a constant source of light removed different distances from the instrument. The law is that the rapidity of revolution is inversely as the square of the difference between the light and the instrument.

When exposed to different numbers of candles at the same distance off, the number of revolutions in a given time are in proportion to the number of candles, two candles giving twice the rapidity of one candle, and three, three times, &c.

The position of the light in the horizontal plane of the instrument is of no consequence, provided the distance is not altered; thus two candles, one foot off, give the same number of revolutions per second, whether they are side by side or opposite to each other. From this it follows that if the radiometer is brought into a uniformly lighted space it will continue to revolve. This is proved to be the case by experiment.

The speed with which a sensitive radiometer will revolve in full sunshine is almost incredible. Nothing is visible but an undefined nebulous ring, which becomes at times almost invisible. The number of revolutions per second cannot be counted, but it must be several hundreds, for one candle will make it spin round forty times a second.

The action of dark heat (*i.e.*, from boiling water) is to repel each surface equally, and the movement of the radiometer is therefore arrested if a flask of boiling water is brought near it. The same effect is produced by ice.

From some observations made by the author, it appears probable that heat of a still lower refrangibility repels the white more than it does the black surface. Many instances are given of the radiometer revolving the reverse way. Thus, breathing gently on the instrument will generally cause this effect to be produced.

An experiment is described with a radiometer, the moving parts of which are of aluminium, blacked on one side. When exposed to the radiation from a candle, the arms revolve the normal way. On removing the candle they revolve the reverse way. Heated with a Bunsen burner the arms revolve the normal way as they are getting hot, but as soon as the source of heat is removed and cooling commences, rotation sets up in the reverse way, and continues with great energy till the whole is cold. It appears as if the reverse movement during the cooling is equal in energy to the normal movement as it is being heated.

It is easy to get rotation in a radiometer without having the surfaces of the discs differently coloured. An experiment is described with one having the pith discs blacked on both sides. On bringing a candle near it, and shading the light from one side, rapid rotation is produced, which is at once altered in direction by moving the shade to the other side.

The author describes many forms of radiometer, by means of which the movements can be exhibited to a large audience, or can be made to record themselves telegraphically on a self-recording instrument.

THE WATER SUPPLY OF THE METROPOLIS

IN the concluding portion of his anniversary address printed in the last number of NATURE (p. 376), the late president of the Geological Society severely criticises the proposal of the Rivers Commissioners to supply London with pure spring water. The Commissioners advise that the drinking water of London should continue to be derived from its present sources, but that it should be led away to its destination before it is mixed with the sewage of Oxford, Reading, Windsor, and other towns, and before it is fouled by the filthy discharges of paper mills and by other disgusting refuse.

Mr. John Evans thinks that it can hardly be believed that such a proposal as this should have been brought forward, involving, as he believes it would, if carried out, the conversion of the "fertile meadows" of the Thames Valley into "arid wastes," and the utter destruction of "watercress beds, now of fabulous value;" he adds that "even the canals and navigable rivers will become liable to sink and be lost in their beds." In predicting these dire results, he doubts whether his "judgment is *seriously* distorted," although he admits being deeply interested in the water power of one of the threatened valleys, and protests that no one can submit silently to an insidious (?) attack upon his property.

Having carefully studied for many years the hydrographical features of the Thames and other valleys, I have no hesitation in saying that Mr. Evans's fears are, for the most part, entirely unsupported by experience. Sterility