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ORDINARY MEETING, MARCH 21, 1881.

H. CADMAN JONES, ESQ., IN THE CHAIR.

The minutes of the last meeting were read and confirmed, and the following elections were announced :—

ASSOCIATES :—Colonel H. Hume, C.B., London ; Rev. T. Robinson, D.D., Morpeth.

Also the presentation of the following Works for the Library :—

"Glacial Moraines." By J. F. Frisbie, M.D. *From the same.*
"The Cliff Dwellers of Ancient America." Professor J. K. Richardson. *Ditto.*

The following paper was then read by the Author :—

METEOROLOGY: RAINFALL. By JOHN FREDERICK BATEMAN, Esq., F.R.S. L.&E.

METEOROLOGY is a subject in which every dweller in Great Britain must feel an interest, and though it will probably never be subject to such laws as will make it an exact science, yet a great deal of valuable information has been collected by patient observers which is useful to many classes of the community. All are interested in the crops of the land and the fruits of the garden, the productions of which greatly depend on rain, cold, heat, and sunshine.

Without rain our rivers would become dry beds, and our springs would be exhausted. Those only who have lived in rainless countries know the privations that are suffered, and

the annoyances that are felt, by reason of the absence of rain.

It is not uncommon to hear the climate of this country inveighed against as if it were one of the worst upon earth; but I will venture to say that, notwithstanding all its drawbacks, there is none which admits of so many days in the year in which out-door exercise or enjoyment can be indulged in. Surrounded by water as our islands are, the cold is seldom excessive, or of very long continuance, nor are the heats of summer so over-powering as they are in many parts of the world.

The sea not only supplies us with perpetual moisture, but moderates all extremes of temperature.

The position of our country in the temperate zone and surrounded by water is not the least of the blessings which God has showered upon this favoured land. We do not suffer from the heats of the tropics, nor the cold of the Arctic regions.

The south-westerly winds, which are the prevalent winds during a large portion of the year, come to our shores charged with the moisture they have acquired in their passage across a broad stretch of ocean. Impinging against the mountain sides which they meet with on the south and west coasts of Ireland and of England, they part with their watery contents in copious showers. For the hills are huge natural condensers. The air at the level of the sea is charged with aqueous vapour, which is kept in a state of suspension by the warmth of the atmosphere. On meeting with high land, it is compelled to rise into colder strata, condensation takes place, and rain is the result. Thus the verdant green of our country is maintained, and our springs and rivers are kept supplied with water. Throughout the Holy Scriptures there are constant references to the blessings of water, and the horrors attendant upon a thirsty and dry land where no water is.

The want, or the deficiency of rain, produces the arid deserts of many parts of the world, and districts which in former times abounded in fertility are now destitute of vegetation and deserted by the inhabitants.

These districts were principally maintained in fertility by artificial means, and to obviate the evils which accompanied want of moisture much has been done, both in former and modern times, by irrigation. The remains of tanks for storing flood waters are evidences of the value which in former days was attached to an abundant supply of water for fertilising the soil. Egypt has been created by the judicious application of the periodical overflowings of the river Nile.

In that very interesting work on Ceylon, by the late Sir Emerson Tennent, are accounts of the stupendous works which were constructed in that island by former kings and chiefs, for the purpose of irrigating that country.

Similar tanks, and for the same purpose, were constructed in various parts of India, and in the present day, under the benign government of this country, irrigation canals are constructed with a view to producing food for the inhabitants of districts liable, in consequence of the want of water, to frequent famine and to great consequent misery. The rain which falls in India is confined to a few months in the year, during which period several hundred inches are frequently registered. The remainder of the year is almost rainless, and it is especially at such periods that the inhabitants suffer. We, in this country, can scarcely comprehend the calamity of 25 inches of rain falling in forty hours, which is stated to have been the case at the recent accident and land-slip at Naina Tal.

We have no such fluctuations in our more favoured country. The rain, though not equally distributed, is generally sufficient for all our wants, and enables us to produce most of the fruits of the earth in moderate abundance.

In Sir Emerson Tennent's work on Ceylon, he states (page 27, vol. ii.) that in the north of that island, where the influence of the monsoon is felt with unequal force and regularity, the uncertainty of rain has been counteracted by prodigious artificial works for irrigation. Many of the tanks constructed for this purpose, though partially in ruins, cover an area of from ten to fifteen miles in circumference.

Kings and petty princes attested the interest they felt in the promotion of agriculture by giving personal attention to the formation of tanks and to the labours of cultivation.

On page 422, vol. i., he states:—"The labour necessary to construct one of these gigantic works for irrigation is in itself an evidence of local density of population; but their multiplication by successive kings, and the constantly-recurring record of district after district brought under cultivation in each successive reign, demonstrate the steady increase of inhabitants and the multitude of husbandmen whose combined and sustained toil was indispensable to keep these prodigious structures in productive activity."

On page 423 he states:—"Cultivation was almost entirely dependent on the store of water preserved in each village tank."

He further writes as follows:—

"The desolation which now reigns over the plains which

the Singhalese formerly tilled was precipitated by the reckless domination of the Malabars, in the fourteenth and following centuries. The destruction of reservoirs and tanks has been ascribed to defective construction, and to the absence of spill-waters and other facilities for discharging the surplus-water during the prevalence of excessive rains; but, independently of the fact that vast numbers of these tanks, though utterly deserted, remain, in this respect, almost uninjured to the present day, we have the evidence of their own native historians, that for upwards of fifteen centuries the reservoirs, when duly attended to, successfully defied all the dangers to be apprehended from inundation. Their destruction and abandonment are ascribable, not so much to any engineering defect, as to the disruption of the village communities by whom they were so long maintained. The ruin of a reservoir, when neglected and permitted to fall into decay, was speedy and inevitable; and as the destruction of the village tank involved the flight of all dependent upon it, the water, once permitted to escape, carried pestilence and miasma over the plains they had previously covered with plenty. After such a calamity any partial return of the villagers, even where it was not prevented by the dread of malaria, would have been impracticable, for the obvious reason that, where the whole combined labour of the community was not more than sufficient to carry on the work of conservancy and cultivation, the diminished force of a few would have been utterly unavailing, either to effect the reparation of the water-courses, or to restore the system on which the culture of rice depends. Thus, the process of decay, instead of a gradual decline, as in other countries, became sudden and utter desolation in Ceylon."

The same account might be given of similar works in India and other parts of the world; for, like fire, water is an excellent servant, but a bad master. Held under proper control and made to contribute to the service of man, it may be attended with very great advantages and benefits; but if allowed to have its own way, it is frequently destructive of much that would otherwise contribute to the pleasure or welfare of mankind.

It is not, however, so much with the rain of the world as with that of our own country that I wish now to treat. We have, in some parts of our islands, rain almost as great as that which falls in the tropical climates of the world, and we have in other parts not more than a sixth or eighth of the quantity of rain which falls in such districts; but we have nowhere to suffer the annoyance and inconvenience which attend a rainless land, and excessive falls of rain are commonly confined to

mountain regions where, generally, the floods are moderated by large natural sheets of water and by short runs to the sea.

There have recently been introduced into the Houses of Parliament two Bills for the conservancy of rivers and for the prevention of floods,—one in the House of Lords, and another in the House of Commons.

These Bills testify to the public anxiety felt in these matters. They are now under consideration, and there is, perhaps, no question which better deserves the careful consideration of the community at large. It is, however, essential that every district should be considered with reference to its peculiar circumstances; for, great as have been the achievements of science and the knowledge which has resulted from the application of those mental gifts with which God has blessed us, no scientific research has been able to reduce the various alterations to which our climate is subject to any fixed law.

We have seasons of comparative drought and of heavy rain, and though our sufferings from these causes are not so great as they are in many countries, we very much depend upon the state of the weather; and the native energy of our people is constantly called into requisition to counteract the evil influences of either too much rain or too little.

Cultivation in this country is carried on by the application of labour which contributes to the hardihood and perseverance of our people, the necessity for which is one of the many benefits which we enjoy.

Our population is constantly increasing, and is perhaps more numerous upon the ground on which they live than that of any other country.

In the first fifty years of this century, the population of England and Wales increased from less than nine millions to nearly eighteen millions: so that in those fifty years the increase in population was equal to the whole increase which had taken place since these islands were inhabited.

The ordinary decennial census will be made this year; but in 1871 the population of the district which, in 1851, was not 18 millions, had increased to about 22¾ millions.

While the increase has been general all over the kingdom, the aggregation of people in large towns has been most remarkable, and the produce of the land has not kept pace with the products of manufacturing industry. Food has, therefore, to be imported from foreign lands, but water for the supply of the towns and for the general purposes of agriculture cannot be imported. It is fortunate, therefore, that the rain which falls is sufficient, if properly utilised, for all the wants of the inhabitants. When this fails to meet such wants,

we may expect that the period has arrived at which further increase of population will be absolutely impossible; but I trust we are as yet far from that position.

The increase of towns, and the sanitary improvements which have taken place, particularly those which have been carried out with reference to sewerage, and various manufacturing operations, have so polluted the rivers that many of them are no longer fit for the domestic wants of the inhabitants. Still, there is upon the hills and in the bowels of the earth sufficient pure water to be collected for all these wants.

It may be of some interest to take a general survey of the means which may be adopted for obtaining such supplies. Water may be collected in reservoirs or tanks as it used to be and still is in Ceylon and India and elsewhere; it may be obtained from rivers which are yet unpolluted, or from natural lakes; it may be collected, as it is in some instances, from springs; and it may be extracted from some geological formations from the bowels of the earth; but all water, whether that in rivers or in lakes, or in springs, or in the earth below the surface, depends upon the quantity of rain which falls, and it is, therefore, matter of interest to ascertain what it is that we have to depend upon.

The rain varies, as I have said, to a very considerable extent. Apart from those mountain regions in which the rain may be said to be excessive, that which falls upon the western coast of England and in Ireland measures between 30 and 40 inches in a year, while that which falls on the east coast of England will not much exceed 20 inches, being little more than half of that which falls in Ireland or upon the western coast of England.

The agricultural produce of the districts varies in great measure, in consequence of this different deposition of rain. Ireland and the western coast of England are essentially grazing-countries, while, generally speaking, the eastern coast of England is devoted to the production of grain.

The reason why Ireland and the western coast receive more rain than the eastern coast is because the prevalent rain-bearing winds are from the Atlantic ocean. The mountains and the high lands, which are generally colder than the low lands, condense the vapour contained in the rain clouds, and cause an early precipitation upon the land. As the clouds are driven on by the wind, they gradually lose their watery character, and the rain which is precipitated is consequently constantly decreasing as the clouds pass from west and south-west to the east or north-east.

Thus the rain which falls upon low hills not exceeding

2,000 feet in height, or on the first or second trough or valley behind such hills and to the eastward of them, is greater than in similar hills or troughs to the east.

Dr. Miller, of Whitehaven, who was a great observer of the fall of rain, and to whose researches we are indebted for much of what we know of the heavy rainfalls in the Lake District of England, concludes from observations that the maximum density of the rain cloud is at about 2,000 feet above the sea level. That up to this height the rain increases as a general rule, and then rapidly decreases as you ascend to a greater height. For instance, in twenty-one months the rain, which at the coast was between 60 and 70 inches, amounted at 1,900 feet above the sea to 208 inches, at 2,925 feet it had diminished to 137 inches, and at 3,166 feet it had further diminished to 128 inches.

From the observations which he made, it may be inferred, as a general conclusion, that the rain will increase as you ascend, to about 2,000 feet, and will then decrease; but, although this may be a general conclusion, local circumstances exercise a very important influence upon the quantity falling. It may, therefore, be expected that under ordinary circumstances, apart from local influences, the greatest fall of rain will be on the westerly slopes of mountains which exceed 2,000 feet in height, and that where the hills do not rise so high as 2,000 feet the rain clouds will be driven over, and will discharge their watery contents in the first trough, or on the easterly sides of the mountains, where they will be protected from the winds. Again, such observations would lead to the conclusion that in a succession of ridges and valleys running from north-west to south-east, and therefore opposing themselves abruptly to the prevalent winds which are from the south-west, but where the summits are not high enough to arrest the progress of the rain cloud, the rain will constantly diminish as you proceed to the east. Thus, a ridge exceeding 2,000 feet high, and so rising above the rain cloud, will have comparatively little rain on the east side, while those of a lesser height will show that the greatest fall of rain is upon the easterly slope.

Many instances of the truth of these conclusions may be adduced. The Liverpool Waterworks are formed upon the western slopes of the Rivington Hills, which do not exceed some 1,600 or 1,700 feet in height. The Bolton Waterworks are in the first trough over these hills. The westerly winds impinging upon the hills deposit upon the westerly slopes of the hills 48½ inches of rain upon ten years' average, while in the same time the rain at the Bolton Waterworks, which are

situated at the back of the hills, and in the first trough, the rain is 53 inches per annum. Between the Bolton Waterworks and the Blackburn Waterworks, which have been constructed in the next valley, there is a ridge of high land, but under 2,000 feet, and the mean rain at the Blackburn Waterworks in the second trough, with two ridges of hills intervening between them and the sea to the west, is only 42 inches.

Further on to the east, the rain diminishes to 30 inches per annum.

The Manchester Waterworks are formed in the long valley called Longdendale, running from west to east, being landlocked to a great extent at each end. The hills on each side of this valley rise to nearly 2,000 feet at their highest summits.

The rain at Manchester in 1859 was 38 inches. At the foot of the hills on the westerly side it was $46\frac{1}{3}$ inches. At the head of the valley, nearly 1,000 feet above the sea on the west side, it was $53\frac{1}{3}$ inches, and on the east side, just over the summit, it was $58\frac{1}{2}$ inches. The land which there intervenes between Longdendale and the valley of the Dun rises to a height of 1,300 or 1,400 feet. At Penistone, a few miles to the east of the hills, the rain was 39 inches. At Sheffield, still further to the east, 25 inches, showing that there is a constant decrease from west to east.

Across another portion of the Pennine chain of hills, commonly called the backbone of England, the rain at Rochdale in 1848 at the westerly foot of the hills was about $39\frac{1}{10}$ inches. At Whiteholme and at Blackstone Edge toll-bar at the top of the hills, about 1,200 feet above the sea, the rain varied from $66\frac{6}{10}$ inches to $67\frac{1}{2}$ inches. At the easterly foot the rain had diminished to $32\frac{1}{4}$ inches, and at York, in the same year, it was little more than 20 inches.

The same results are observed in the mountain ranges which surround the Scotch lakes. The mountains here run across the line of the prevailing wet winds, and every successive ridge and trough or valley to the east shows a diminishing quantity of rain.

Loch Katrine, from which the city of Glasgow is supplied with water, is hemmed in by mountains varying from 2,000 to 3,000 feet in height.

In 1854, at a rain-gauge at 1,800 feet in height, on the slope of Ben Lomond, which rises to 3,192 feet above the mean level of the sea, the rain was 109 inches. This rain-gauge was placed on a ridge on the westerly side of Loch Ard, which intervenes between the gauge and Loch Katrine. On the hills between Loch Ard and Loch Katrine the rain was 67 inches.

On the hills near Glenfinlas, which form the eastern summit of the land draining to Loch Katrine, and further to the east, at an elevation of 1,800 feet, the rain was reduced to 62 inches. In 1857, the rain on the first ridge was $84\frac{1}{2}$ inches, on the second $74\frac{2}{10}$ inches, and on the third $48\frac{3}{10}$ inches. In 1859, two years subsequently, it was 92 inches, $85\frac{1}{3}$ inches, and 48 inches respectively, and so for every year.

This shows the importance of bearing in mind that it does not do simply to calculate on increased elevation giving an increased quantity of rain, but the whole question is affected by the geographical disposition of mountains and valleys.

The heads of all valleys, too, in mountainous districts, give larger quantities of rain than the mouths of valleys. Thus at Loch Venechar, at the mouth of the great valley in which this Loch and Loch Katrine lie, the rain in 1872 was 78 in. at an elevation of 275 feet above the sea, while at Glengyle, 380 feet only above the sea, at the head of Loch Katrine, the rain was $127\frac{8}{10}$ inches, and in the same year, on the flanks of Ben Lomond, 1,800 feet above the sea, it was $96\frac{1}{2}$ inches. In the year 1866, the rain at Loch Venachar was 64 inches. At the head of Loch Katrine 101 inches, and on Ben Lomond 100 inches.

From these observations it will be seen that the rain varies very much in the same district irrespective of elevation, the variations depending upon the physical and geographical features of the country.

Much of the rain which falls, however, is lost by absorption, evaporation, and other causes. Part of it runs away in floods; some enters the bowels of the earth, to be reproduced in springs; and some supplies the wants of vegetation. The result greatly depends upon the quantity of rain which falls, and upon the greater or less declivity of the ground on which it falls, as well as upon the character of the vegetation. Where the hill-sides are steep and the rain is considerable, the loss is least; where the declivities are gentle, the growth of herbage heavy, and the quantity of rainfall small, the loss is greatest. It varies, according to these qualifying circumstances, from about 8 inches to 20 inches per annum. It therefore follows that in regions of small rainfall nearly the whole is evaporated, leaving barely sufficient for purposes of vegetation. Where the rainfall is great, much of that which falls runs away in floods; but all water, no matter how found, is the produce of the rain which falls upon the surface, and we are therefore happy in this country in being so surrounded by water that we have always an abundant rainfall for all purposes of life and enjoyment.

The constant evaporation from the seas which surround us, and the precipitation which takes place when the rain clouds are driven over the land, produce sufficient for all purposes.

My observations have been confined almost exclusively to rainfall; but there are many other questions connected with meteorology which are more or less interesting to the inquirer into natural phenomena and the causes to which must be assigned the fertility of lands, and the perseverance, activity, and hardihood of the people who inhabit them. We are specially favoured in this part of the world by the combination of causes which contributes largely to the energy of the people and the enjoyment of life.

The CHAIRMAN.—I am sure that the meeting authorises me to return our thanks to Mr. Bateman for his interesting paper. If there are any present whose studies have lain in the direction of the subject dealt with by the author, all will be much gratified to hear any remarks they may have to make.

Sir JOSEPH FAYRER, K.C.S.I., M.D., F.R.S.—I wish, first of all, to say how much pleased I have been with the paper we have just heard. The only thing I should demur to is that the author said he thought the paper hardly a fitting one for this Society. I regard it as a most fitting one, and can hardly conceive of a better way of dealing with so important a subject. One can only hope that Mr. Bateman will, in furtherance of what he has so well begun, give the Society another paper on some of the other meteorological questions that have not been touched upon in this. He has told us that the question of rainfall is one of great importance. He has reminded us that the welfare of our crops and fruits depends upon it; indeed, our very existence is dependent on it, for without it we could not exist. Where there is no moisture there can be no life; the tree cannot bear, and the seed cannot germinate. Were there no rainfall, our planet would, in fact, be reduced to the condition of an effete and worn-out globe resembling, probably, the present state of our satellite, the moon. Happily, however, this is not the case. The author of the paper has selected what is, of course, the most interesting portion of the subject to us,—the meteorology, or, at all events, the rainfall of our own islands, which are peculiarly situated, being so far distant from the equatorial regions that the supply of water is more varied, more inconstant and subject apparently to greater modifications of the great laws which govern the formation and distribution of rain, than is the case in other climates. But, as Mr. Bateman has pointed out to you, it is one of the main sources of the present greatness of our nation,—one of the reasons why our people are strong, hardy, and energetic,—why, indeed, they have become what they are, is owing to the climate they enjoy; that climate is owing to the rain and the way in which it is distributed over our islands. (Hear, hear.) Of course, it is attributable to other things; but the rainfall is the subject with which we are now dealing. This is a very comprehensive subject,—one

on which one might speak for hours; but I shall not venture to trespass on your patience so long as that. I should, however, like to allude to one or two points in connexion with the rainfall with which I have been most familiar,—that of the great portion of Asia known as British India. In that part of the world, very much what has been described by Mr. Bateman, only on a much more extensive scale, takes place. You have there a country which is entirely dependent on the rainfall for its crops, its animal life, and the existence of its people. You have probably heard of late years a good deal about the famines which devastate India at recurring periods. These famines have been mainly due to an imperfect rainfall which in some seasons is experienced there. In that great country, which is not visited by uncertain rains at every season of the year, or on any day, such as may be the case in this country, but where there are three distinct seasons of cold, heat, and rain, the climate is under the influence of laws that are much more certain than in this northern country. The monsoons,—those great trade or seasonal winds,—the word "monsoon" being a corruption or alteration of the Arabic word "maussim," a "season," come laden with moisture from the equatorial regions, and which they carry over the great continent of India. The moisture is brought up by the south-west monsoon,—that is to say, a great current of hot air rushing upwards from the heated regions at the equator, takes with it a quantity of moisture abstracted from the heated ocean; meeting with mountain ridges something like, only infinitely higher than, those described by Mr. Bateman, a vast change then takes place in the condition of this south-westerly wind. For example, the monsoon from the south-western extremity of India, on the Malabar Coast, at Cape Comorin, begins to set in in May, when a great deposit takes place. This is what is called the "bursting" of the monsoon. The clouds come up suddenly, the air is intensely electrical, and very heavy rain falls. In passing over the hills that run along the western coast of India, those known as the Western Ghauts,—hills of from 3,000 to 5,000 feet in height,—a great part of the moisture is squeezed out, and in so doing the winds part with so much rain that on the Coromandel Coast there is at that time literally no rain at all. The air being thoroughly desiccated, and deprived of its moisture by the mountains over which it passes, the result is as I have said, that there is, at that period, no rainy season at all on the Coromandel coast. Travelling in a north-easterly direction it reaches the Himalayas and those great mountains which separate India from China and Siam, when, striking against the hills, it is deflected to the north-west. Here a most marvellous phenomenon takes place; for we then have the most extraordinary rainfall in the world, to which anything ever seen in Europe is a mere bagatelle. There is a station there,—or, at least, there was; for it is now no longer a station, its physical conditions being such that it was obliged to be abandoned,—situated at an elevation of about 4,500 feet. Now Mr. Bateman has stated that an elevation of 4,500 feet was that at which the deposit of rain in India most readily took place, and that in that country this elevation corresponded with 2,000 feet in England,

and he is right. At the place I have referred to, which rests on the very edge of the chain of mountains south-east of the Brahmapootra, at an altitude of 4,500 feet above the level of the sea, at a station called Cherra Poonjee, which is, as nearly as I can recollect, from 200 to 250 miles north of the Bay of Bengal, the rainfall is enormous. The intervening land between this mountain-chain and the sea is a level plain traversed by rivers, and over this comes the south-west monsoon, which has been gathering vapour from the Bay of Bengal,—not that portion of the monsoon which has passed over the Western Ghauts, but that which has escaped them, and which takes up the moisture evaporated from the Bay of Bengal. Passing over this level land it impinges at once on the mountain at a height of about 4,500 feet, and the result is that within a period of from five to six months the rainfall at the station I have mentioned is rarely ever less than 600 inches in amount. It happened that I spent my first year in India at that station, and I kept a rain-gauge, which recorded 610 inches. I somewhat doubted the result, as I had not then had any great experience with regard to rainfall, and I was inclined to mistrust my own reckoning; but the figures were entirely confirmed by the observations of the late Professor Oldham, director of the geological survey, who, about a quarter of a mile from me, made the rainfall within only a few inches of the total I had recorded; I have no doubt that 600 inches is about the average rainfall at that particular station; which I should say is, beyond all doubt, the greatest recorded. I believe there is no other part of the world that has ever been known to be nearly or even half so wet. Well, when you get further inland, only fifteen or twenty miles, or even less, and ascend some 300, 400, or 500 feet, the rainfall drops at once from 600 to 200 inches, showing that the difference is due to local conditions and circumstances. In the West of India, among the Western Ghauts, at a station called Mahabuleshwar, there is an average of from 250 to 300 inches deposited by the south-west monsoon. Beyond these Ghauts there are great tracts of country that are not altogether rainless, but which are so dry that I dare say my friend General Maclagan will tell you that the rainfall is so small that, were it not supplemented by irrigation, of which, I know, he could tell you a great deal, there would be no crops and no cultivation, and, as a matter of course, not much animal life. Mr. Bateman has spoken of the works constructed in Ceylon and other parts of India for irrigation purposes. No doubt the Mahommedan Government of India under the Great Moguls carried out great works of irrigation; and happily we have taken up the same subject, and are working out a great system that will be far more effective even than the older works that were referred to. It was about 1822 or 1823 that the British Government began to repair and re-establish the old works, and to construct a new system of irrigation; and having made this commencement, the project has gone on, and is proceeding still, to the great advantage of enormous areas of country now under cultivation, which would otherwise have been a desert. There are many other points to which I might allude in

reference to this subject of rainfall in India, and there is, perhaps, no other country in the world where its importance is more felt; but I am afraid I should weary you. There is, however, one that is of peculiar interest to me, and that is the question of health. There is no doubt that the rainfall has a most marked effect on health. Those who have had to do, as I have, with the sanitary returns of India, and who have seen how immensely the fluctuations of disease, the spread of epidemics, the increase and decrease of such diseases as cholera, are influenced by the rainfall, will recognise that in India this matter of rainfall is of the greatest importance. I do not say that the disease I have mentioned is due to the quantity of rainfall; but that the rain has a material and appreciable influence in originating, increasing, or diminishing the amount of epidemic disease, is, I say, beyond a doubt. Epidemic cholera is almost certain to diminish, if not altogether to die out, when the rains become heavy; and it is equally certain that where the heat and evaporation are great, and the air dry, epidemic cholera, being present, it will spread and increase. I would not say that the increase or decrease of epidemics is due to rain alone; but I would say that this is one cause which, combined with others, exercises potential influence, especially in the case of fevers. You will hardly believe me when I tell you of the amount of death from fevers in India. They destroy more than any other disease, and, compared with them, cholera is a mere cypher; many other forms of disease may be immensely influenced by climate. When the season is dry and the evaporation is great, fevers diminish, that is to say, for a time; but the effects of climate, whether the weather be dry or rainy, are not immediate, and the result of an accumulated or heavy and continuous rainfall is always to increase and intensify the amount of deaths from fever. Only the other day I was looking at some returns on this very subject, sent to me from the Army Sanitary Commission, and I found that the increase in a number of diseases during the dry season was great. In fact, it is known to everybody living in India that the time of danger from climatic fevers is not when the rain is on the ground, but when the drying-up takes place: it is then that fevers abound. Then, as to the question of vegetation. Not only is the botanical part of this question, one having reference to the plants themselves, of interest, but that which materially concerns the climate is of great importance: not only is vegetation regulated by the rain, but the rain is regulated by vegetation. Many parts of Europe have become dry and arid and desiccated and depopulated, or very nearly so, by the destruction of the vegetation. This is because the vegetation being destroyed and the trees gone, the rain ceases to come; it is no longer attracted there, and the consequence is that the face of the country is entirely altered. In Scinde and the Punjab, where vegetation is defective, though we have not found the districts rainless, yet the fall is defective, whilst at Mooltan there is but 10 inches of rainfall in the year, which is not sufficient to supply the wants of the people. It is a well-known fact, that wherever vegetation is increased it brings moisture: not very long ago, in passing through the Suez Canal, I observed that, in that dry and rainless country,

there were little grooves in the banks of the cutting. I asked, "What they were?" and was told, "They were produced by rain." I then asked, "What about that vegetation?" and the reply was, "That has all come since the cutting of the canal." Even the small accession of moisture caused by the canal has brought some rain into the desert; and so it would be in India if, instead of destroying the vegetation, they were to preserve it; if, instead of cutting down the trees and burning them as they do for fuel for the railway-engines, they preserved them, and increased the growth and development of the forests, the tendency would be to cool down the climate and temper it. A most remarkable example of this is seen in the case of the Terai, which runs along the outer range of the Himalaya chain. There is a dense belt of forest there, which varies from fifteen to twenty and even thirty miles in breadth, though sometimes it is very much less; but the ground is always moist, and produces a rank and luxurious vegetation. I believe they could do nothing worse than take away that belt of forest, because, although elsewhere the air is so dry and hot that it is like a furnace, and everything is dried up, as you approach this district of vegetation the air is tempered and becomes cool and moist. But it is not for this reason alone that I would preserve it. Its importance is very great from another point of view. I feel that here I am perhaps trenching on a subject that has to do with engineering, and on which my friend General Maclagan could give better information than I could offer; but I would say, with reference to this dense vegetation which grows on the very margin of this chain of mountains, that not only does it temper the air and bring a vast quantity of moisture which would not otherwise be there, but it also regulates the moisture that trickles down the hills; and, were it not for the trees and vegetation which clothe the lower sides of the mountains, the water would rush down in torrents that would overwhelm the country, bridges would be swept away, and the district would be desolated, instead of which there is now an equal distribution. The result is that the water finds its way gradually to the level ground below, rising up in springs and producing the wide belt of vegetation of which I have spoken as in the Terai, which is a term meaning moisture, or damp ground. There are other points connected with the rainfall on which I might speak the whole evening. I will not now trespass further on your patience except to say that I have had very great pleasure in listening to Mr. Bateman's paper.

General R. MACLAGAN, R.E.—I may say that my own experience enables me to confirm some of the remarks made by Sir Joseph Fayrer, and of the statements contained in the very interesting paper of Mr. Bateman. In some parts of India there is even a smaller amount of rainfall than has been mentioned. At Mooltan there is an average of 8 or 9 inches, but in the province of Scinde the average rainfall is little over 4 inches, a remarkable contrast to the enormous rainfall that has been spoken of as taking place at Chirra Poonjee. A brother officer of mine, who wrote an article in one of the journals on the rainfall in that part of India, took the opportunity of saying it was scarcely worth while to talk of the inches of rain there, the

better way was to speak of it by the number of feet. With regard to the different effects of the rain falling on the bare and treeless hill sides, and that which fell on slopes covered with wood and undergrowth, we have in India illustrations of both. Where there is this vegetation the water is checked and well distributed, and the rivulets flow in an ordinary and more equable way, but in places where the undergrowth has been cut down, the water-courses fill with rapidity, and the flooded rivers do much damage. At several places where valuable buildings have been threatened, protective works have been constructed to preserve them. In one part of the paper reference is made to the manner in which the rainfall is affected by the ranges of high hills. In a tour I made some years ago across the hills during the rainy season, for the first nine days we were exposed to exceedingly heavy rains, and the hill sides were covered with rank vegetation. On crossing the hills we entered a rainless country, and for the next six weeks had not a drop of rain. On our return, immediately on crossing to the south side of the hills we again came upon abundant vegetation, and were immediately enveloped in clouds and rain. I think that this Society is greatly indebted to Mr. Bateman for the most interesting paper he has given us upon this important subject.

Mr. W. Griffith.—The science of meteorology, though less comprehensive now than in Aristotle's time, includes all physical causes affecting or affected by the atmosphere. Etymologically, it signifies an account of the sublime. It deserves the name, for we cannot reason thereon without raising our thoughts from earth to heaven. When we consider the atmosphere as the medium which transmits light and heat, and retains or disperses moisture, and that without its aid in the dispersion of the rays of light the whole of the heavens above our heads would be one black canopy, we can understand the benefits we derive from it; and Mr. Bateman's paper is of value, inasmuch as it leads us to consider some of those benefits, one of them being that the atmosphere is a large reservoir of moisture, which produces the effects which we witness on the cultivation of the earth. If we were to go back to an early period in the earth's history, we should find how this moisture in times past has not only been productive of crops, but has positively produced the earth which has grown the crops. Some of the most fertile parts of England are formed of the new red sandstone, which is not generally supposed to be capable of growing crops; but we know that owing to the way in which the moisture of the atmosphere has worn it away, it has become one of the most fruitful of our soils. The facts that have been brought before us with regard to India are calculated to arouse the interest of all who have heard them. A few years since, when I had occasion to devote my attention to matters connected with Indian law, I extended my reading, and was much struck by the part played by the monsoons in the watering of that country during six months in the year. I noted that during half the year the melting snows of the Himalayas replenished the rivers, and during the other half the monsoons brought from the ocean the heavy rain-clouds, so that in each period the

supply of water was abundant, but that the idleness of man neglected to store it up for use, and that in consequence of that idleness famines were ever recurring. There is no doubt that Calcutta is well watered; but, with due deference to those gentlemen who have already spoken, I have always understood that the English Government have allowed great works of irrigation formerly established in other parts of India to go to ruin, and that we have been rather behind our predecessors in carrying out those public works which should be established and maintained for the benefit of the country at large. Sir A. Alison's "History of Europe" contains one or two interesting chapters on India, and he brings a strong indictment against those in authority for allowing the splendid reservoirs that were formerly constructed in India to fall into ruin, and for not rebuilding them.

Sir J. FAYRER.—Since 1822 or 1823 the Government have undertaken to resuscitate the old works.

Mr. GRIFFITH.—It is, of course, highly interesting to consider the benefits our own country has derived from its rainfall. The atmosphere not only collects the deleterious products of life, but it is also a reservoir of health-giving moisture, which, flowing down upon the soil, cleanses everything, and makes the country habitable and productive. I may add one other fact to those adduced by Mr. Bateman, namely, that the great quantity of moisture suspended over our heads, and descending in fruitful showers, is largely increased by the Gulf Stream, which flows into the Gulf of Mexico, whence it proceeds in an easterly direction, and surrounds the whole of the British Islands. That stream is heated in its passage across the tropics, and contributes not only to the quantity of moisture in the atmosphere which produces our rainfall, but also warms the air, and, so to speak, renders England a kind of hothouse in the midst of what would otherwise be an almost Arctic region, cold as Kamschatka. We are, therefore, very much indebted to the Gulf Stream for the exceptional position we enjoy. The subject of meteorology is, however, one which presents so many points of interest that it would be too great a tax on your time to attempt to discuss them all.

General MACLAGAN.—With regard to the irrigation works constructed in India by the Mahommedan emperors; Sir Joseph Fayrer is right in saying that it was about the year 1823 that attention began to be directed to them, after we came into possession of that part of the country, and their restoration was taken in hand. Originally those works were not altogether for purposes of irrigation; they were intended for supplying the pleasure-grounds of the rulers. To a place at the west of Delhi, which was a favourite resort of theirs, the water was carried a long distance from the Jumna. In 1826 the restoration of those works commenced. With regard to the effect of such works upon famines, it is quite true that irrigation by itself would not sufficiently supply what is wanted. We know that in times of great distress from deficiency of food, there has been, in other parts of India, which the famines have not visited, abundance of food, and what was

necessary was not so much more food itself, as the means of its distribution. India is now deriving great benefit in this way from the railways that have been constructed over the country, which convey the food wanted to those parts where famine exists. This combined use of camels and railways may be expected to do much for the prosperity of India.

Mr. D. Howard, F.C.S.—Mr. Bateman's interesting paper has brought before us the great problem of the rainfall—the tendency to diminution from West to East. Sir Joseph Fayrer has interestingly supplemented Mr. Bateman's paper by explaining how the monsoons charged with wet, as they are on reaching the coasts of India, completely part with their moisture, so as actually to leave some parts of the country almost arid for want of the rain which has been extracted from them in their passage over the Ghauts. This occurs in India only at one period of the year; but, of course, it is exactly the same sort of process that goes on constantly in Switzerland. There you find two kinds of south wind. There is an intensely wet south wind, which in a small way imitates what we have heard of the Indian rainfall; and you also get what is called the *Föhn* wind, which is so hot in certain parts of the country that it has occasionally led to the destruction of villages, which have been burnt down in the Swiss valleys. The wind is so unaccountably dry and parching, that when the *Föhn* begins, the houses being built of wood, a fire will quickly spread from one to another. It was a puzzle to the Swiss meteorologists how it could be that this south wind, which is usually a wet wind, could, in certain places, be so intensely dry. The idea was that it was a sirocco, though how a sirocco could pass over some valleys and confine its work to those parts which suffered from the *Föhn* wind was not explained; but it was found that, after all, it was the same wind which was first so wet and then so dry. The south wind blows up the southern side of the Alps, and deposits all its moisture before it passes the top of the Alps, in an exceedingly rarified condition. As it descends, and the rarification becomes condensation, the air becomes hot, but there is no moisture for it to take up, and it consequently arrives in the valleys almost absolutely dry. So that we have this state of things, that the intense dryness, which is a danger on the one side, is brought by the same wind which causes the great floods of the Rhone Valley on the other side. This is one example of what has caused such great effects, and on so vast a scale, in India. It is an effect repeated on a smaller scale in the difference that exists between the great dampness noticed on the western side of England, and the dryness of the other side. There is one point I should like to put to the author, and that is, Whether he has gone into the question of the cycles of rainfall,—whether he thinks the sun-spots, of which we have heard so much, have any connexion with our recent rainy seasons? Of course, these sun-spots are connected with certain phenomena of terrestrial magnetism, and so forth; but what I want to ask is, whether any clear connexion has been made out between the cycles of the sun-spots and the cycles of rainfall?

Mr. Bateman.—In answer to the question just put, I may say that I have already stated that we have not, up to the present time, been able to reduce

meteorology to anything like an exact science. We can tell what has been, but I question very much whether we can tell what is to be.

Mr. Baldwin Latham, M. Inst. C.E.—It makes no difference whether we collect rain from the roofs of our houses or from a large area of the earth's surface, called by engineers a "gathering-ground," or if we obtain water from springs, or take it from wells sunk into the earth; all these sources of water supply are entirely dependent, and are solely due to rainfall. The science of meteorology at the present day is making rapid progress, but there is little doubt that some centuries ago much more was known with regard to the laws of the atmosphere than is known at the present day. Hippocrates taught his disciples that they could foretell the state of the seasons, and, as a consequence, what diseases would afflict mankind at particular periods. This, he said, was due in a measure to the observations made of the motions of certain stars. What was the nature of these observations we do not now know; but Professor Balfour Stewart appears, from his investigation, to think that even the stars have some influence on the atmosphere, as they have some influence on the sun spots. Before the advent of Hippocrates, the influence of stars on the atmosphere seems to have been known. In the sacred books of the Parsees, the Khordah Avesta, the influence of a star is set forth as causing the presence or absence of rain, and the absence of rain is clearly shown as a condition of things which produces disease. In our own country the climate is, to a certain extent, uncertain, because of the smallness of the country, whereby the general laws in operation are everywhere modified and interfered with by our being surrounded by so much water; we also occupy a position in which a constant interchange takes place between currents of air moving from the direction of the tropics and the arctic regions, which cause great alternation in the climate, but the nearer to the equator and the sun's path we go, meteorological conditions are always much more defined and certain, and you can there predict with certainty, for many months beforehand, what the weather is likely to be. Rainfall is entirely due to the heat of the sun and the diurnal motion of the earth. The air travels with the motion of the earth, from west to east, and that is the reason why the storms travel in that particular direction, and why our western coasts receive the largest amount of rain. But rain falls on the sea as well as on land. Very heavy rains take place at sea, and the reason for it is that, if the rains were always following in defined lines, we should have tracts of country in which there would be a large amount of rainfall, and tracts in which there would be practically dryness. But the wind is not moving in straight lines, but gyrates in circles. When the wind gyrates in a circle in which the movement is in the opposite direction to the hands of a watch, we call it a cyclone; and when this movement takes place, the air is moving upwards from the surface of the earth. When the wind gyrates in the same direction as the hands of the watch, we call the period anti-cyclonic, and at such times the air is moving down from the higher regions towards the earth's surface. In a cyclonic movement, the air is moving from a warmer to a cold region, and this movement is usually attended with rain, for as the air

moves upward, the vapours are condensed and fall as rain. As the wind gyrates either in one direction or another, the air moves from warm to cold quarters, or *vice-versâ*, and rain or dryness occurs in consequence. In a cyclone there is a movement of air upwards from the surface of the earth, and this movement causes a diminution of atmospheric pressure which is indicated by the fall of the barometer, but when an anti-cyclone affects us, as the current of air is directed downward on to the surface of the earth, a rise of the barometer is observed, and so the barometer becomes a weather-glass. As air moves downward in an anti-cyclone, or from a cold to a warmer region, its capacity for vapour increases, and so a rise of the barometer is, under such conditions, likely to be accompanied with fine weather, but in a cyclonic period, which produces a fall of the barometer, as the movements of the air are from a warm to a cold region, so rain is likely to occur, and as the wind may be moving from the same quarter both in a cyclone and anti-cyclone, it is quite possible for a south wind in some districts to be a dry wind, and in another to be a wet wind. It is a natural law at work that causes the rain to descend and to be equally distributed all over the country. The rain in our own districts increases with the elevation of the ground on an average at the rate of two and a half per cent. for every 100 feet of elevation. But during the last three or four years the rate of increase has been very much more than that; we have passed through three or four of the wettest consecutive seasons ever known. As a natural consequence of all this, the country has enjoyed good health latterly. In the lake districts they have had less rainfall than their due, while in the southern counties of our country we have had more than belongs to us. With regard to the periodicity of the rainfall, there have been many guesses made. We have a suspicion that the climate of the country is regulated by the metonic period. With regard to my own observations, I find that, taking underground water as a guide, the number of observations collected from the year 1835 down to the present time give every ten years as a period of low water. For instance, the years 1844, 1854, 1864, and 1874, or 1844–5, 1854–5, 1864–5, and 1874–5, are the low periods, which run from the latter part of one year into the beginning of the next. These are periods of marked lowness, but whether they have relevancy to the sun-spot periods I do not know. During the last two years there have been very few sun-spots observed; but whether or not there is any connexion between them and the weather, just as there has been shown to have been an increase in the magnetic influence of the earth during the presence of sun spots, is at present doubtful. Nothing is known for certain on the subject; but I have little doubt that as time goes on we shall be able to place meteorological science on a firmer foundation than it now holds. As far as we know, the laws are extremely simple. Since Dr. Ballot discovered the law which governs the wind, the prediction of the state of the weather for a given number of hours is tolerably certain. With reference to the predictions which come to us from America, it may be taken for granted that so long as our country is under the influence of a cyclone, the tendency

is to draw the atmospheric current towards us, and at such times the predictions are likely to be correct, but when our country is under the influence of an anti-cyclone, as the movement is outwards, it repels the advance of the storm towards us, and at such periods the predictions are not likely to be fulfilled. The storms that were predicted for the 16th to the 18th of this month we did not feel, that effect being due to an anti-cyclone passing over the country at the same time. Again, the diminution of temperature also affects rain. The air, when warmed, holds a larger amount of vapour. When it cools, rain is the result. Our temperature diminishes about one degree of latitude as we pass northwards. It diminishes also one degree for every 300 feet of elevation, so that, if 2,000 feet is the elevation at which the maximum of rain occurs in the neighbourhood of Whitehaven, the same condition of temperature would produce the same effect in the neighbourhood of London, at an elevation of about 3,000 feet, if we had hills of sufficient height in this neighbourhood to receive it. There is one point with reference to the influence of elevation on rainfall which ought not to be lost sight of, and that is, that although rain increases with the elevation of the ground, yet, if you go upwards from a particular spot, it is found to diminish. This would seem to be paradoxical, but in 1766 Dr. Herberden placed a rain-gauge on the roof of Westminster Abbey, and he found it collected less rain than on the ground, and since that period numerous observations have been made which confirm the results. This diminution of rain with altitude above the ground has been ascribed to a variety of causes, but the real cause is that shown by Professor John Phillips, of Oxford, who pointed out that it is due to the difference of angle at which the rain falls, or in an elevated gauge the rain forms a small angle with the plane of the mouth of the gauge, and consequently does not present so large an area for collection of rain as is the case with a gauge on or near the ground, in which the angle is found to be larger than in the elevated gauges. With regard to the influence of rain on health, some persons attribute disease to an excess of rainfall; but in reality the intensity of disease in this country is always in proportion to the degree of dryness that has prevailed, and I may point to the fact that during the last four years we have had four remarkably wet seasons, and these years have all been remarkably good as far as the public health is concerned.

Dr. A. Longhurst.—There can be no doubt whatever that we are all most materially influenced by atmospheric phenomena. The vegetable world shows the effects of this influence in all its features, especially the electrical conditions and all sudden and extreme changes of heat and cold, dryness and moisture, both of degree and duration; and doubtless the animal kingdom is equally sensitive to them, though the outward evidence of such change or influence may be less sensibly recognised by us. I think we ought to be grateful to the writer of the paper we have heard read for having brought the subject to our notice, and I feel sure that the more it is studied the more the human race will be benefited. With regard to the influence of the rainfall on health, I feel sure that great advantage will result from what has been said, and that there are many

places which have been loudly spoken of on the score of health that have gained their repute from insufficient observation. The observations that ought to be taken, in order to give any reliable degree of authenticity as to the healthiness of a locality, should be extended over a long period of years.

Mr. T. K. Callard, F.G.S.—I should like to ask the author of the paper if his observations have led him to notice whether, after long-continued frosts, we usually have a very large rainfall? The reason I put this question is that geologists generally accept the evidence of a pluvial period having followed the glacial period. It is estimated that at this pluvial period the rainfall was 125 times what it now is. I want to know, therefore, whether it has fallen within the range of Mr. Bateman's observation that there is any relation between a period of long-continued frost and a large rainfall,—whether he thinks the one is really the cause of the other? There is more in this question than may appear at the first glance, for one of the results of this pluvial period would be the rapidity with which the river valleys would be eroded; and upon this question arises another and a very important one on the antiquity of man; one of the arguments relied upon in support of that theory being the many flint implements found in certain spots where the river valleys have been eroded,—a process that would have taken a certain length of time under existing circumstances, which time would have been altogether altered if there had been a rainfall amounting to 125 times that of the present day.

Sir J. Fayrer.—I should like to ask a question which, probably, Mr. Bateman can answer. It is one that is germane to the subject under discussion. The west coast of Scotland is very wet; the reason for this being the Gulf Stream and the warm currents of air which that stream brings with it. I should like Mr. Bateman to tell me why it is that the northern part of the east coast of Scotland is mild and temperate, and displays an equable extreme, which is higher even than that of many parts of central England? Is it owing to the warm air blowing across from the west, or is the water warmed in coming round John O'Groat's House? I confess that this has always been more or less of a puzzle to me.

Mr. Bateman.—I am afraid I cannot answer Sir Joseph Fayrer's question, except by supposing that it is in some way owing to the effect of the Gulf Stream. There is no doubt that the temperature depends very much indeed on the rainfall. Rain is the consequence of the condensation and precipitation of the moist atmosphere, and therefore, properly speaking, when rain falls it is in consequence of aqueous vapour arising from the surface of land or ocean meeting with a colder stratum of air, when condensation takes place, and the moisture is precipitated in the form of rain, whereby the plain on which it falls ought to be cooled. But I remember a gentleman named Hopkins, who contended that whenever it rained it was warmer than at other times. This ought not to be, because, if we suppose the rain to be the consequence of condensation and precipitation in a cold

atmosphere, it ought properly to render the temperature colder, and, in my opinion, it must be so. Therefore, wherever there is a large amount of rain, it is reasonable to expect that inasmuch as aqueous vapour has been held in suspension by the warmth of the atmosphere and is condensed as it rises into higher elevations, there will be a cooler temperature where the air is dry, and probably cold on account of its dryness. Where you have a large stratum of air holding a large amount of aqueous vapour not precipitated on the earth near the hills, it is precipitated on the plains by reason of its rising into a higher elevation, where it is condensed. Therefore I can understand the fact that the valleys of the English lakes, where the quantity of rainfall is excessive, are warmer and more equable than in the Midland counties, and, in the same way, the rocky coasts of Norway and the West of Ireland, as well as the west and north-west of Scotland, must be a good deal warmer than the eastern coasts. I think the experience of every Englishman who has lived on the east coast, and who knows the circumstances best, will coincide with the opinion, that though more rain falls in the west than in the east, the warmth is greater in the west than in the east. I can only account for it in this way, that there can be little doubt, philosophically, that the vapour of the atmosphere is generated in the ocean and maintained by the warmth of the air on the surface of the ocean, or of land only a little elevated above the surface of the ocean ; that it becomes condensed on the high lands, and as it travels towards the east the clouds are emptied of their contents, and the atmosphere desiccated and emptied of its watery contents, so that in the eastern part of the country there is less rain. I am glad to hear that the Indian experience corresponds with that of the British islands, and that as the wind goes east under certain circumstances there is less rain, the bulk of the rainfall being delivered on the western slopes of very high mountains, so that there is less to deliver in the east, and that, on the contrary, where the land is low, the clouds are driven over the summits and rain falls in the valleys beyond. I cannot help disagreeing with Mr. Baldwin Latham in the idea that the rain is due entirely to cyclonic action.

Mr. Baldwin Latham.—I did not say entirely.

Mr. Bateman.—Because, as I have endeavoured to show, a very different quantity of rain falls on the tops of the hills and in the valleys. If the rain were due to cyclonic action the quantity ought to be the same whether in a valley or on the top of a hill. In my view it is owing to the formation of the hills and valleys. The clouds become hemmed in by the head of the valley, and they cannot escape except by rising to a higher elevation. Rising to that higher elevation, they get into a colder atmosphere, where condensation and precipitation take place, and consequently you have a large quantity of rain. In making these observations I have not indulged in anything like speculation. I have merely given dry results, on a wet subject, from observations I have had occasion to make in the course of my professional career. I have for a long time held the opinion that all water, no matter where it is found, whether in springs or whether it runs down the brooks and rivers, is due to the rain which falls on the surface, and there is no other source what-

ever except vapour which falls on the surface from the ocean. Chalk, sand, and some other of our geological strata are very absorbent, and to a great extent, though not entirely, they absorb the water which falls upon them. There are other measures, such as the primitive measures, including the granite, some of the slates and the millstone grit, where the country is very rugged, and where the great bulk of the water runs away and comparatively very little of it enters the surface of the ground. The consequence is, that in these districts there is very little spring water, while in the chalk and sand you have much spring water. In considering the quantity of the rainfall, and the useful purposes to which it may be applied, all these circumstances have to be taken into account. With regard to the reference made to the spots on the sun as bearing upon the rainfall, I believe that that is only a coincidence. There have been spots on the sun at all times, and I do not believe that these phenomena can have sufficient influence to affect materially the power of evaporation which acts upon the surface of the ocean, or the quantity of rain that falls. We have heard it stated that the felling of the timber in India has considerable influence on the climate, and that the droughts which have been suffered in that country are due to the destruction of the forests. We have had four or five uncommonly wet summers which may have been accompanied by spots on the sun, and the interference thus made with the sun's usual surface may have affected its action ; but I can scarcely believe that the result is at all appreciable, and that if the sun has been thus affected, we can measure the extent of the interference. We are not yet in a condition to be able to determine any law as to the succession of droughts and wet weather. There are some districts which are rainless ; there are, as we have heard, others where there are 610 inches of rain, so that the rainfall in the latter is not 125 times the ordinary amount, but between 500 and 600 times the average fall. Therefore I think that any calculations of the kind we have heard are as unstable and uncertain as the wind that blows, and which has so great an effect on meteorology. It may be that in some parts of the country the figures of the rainfall may be multiplied by themselves to produce the results met with in other parts. If you take 10 inches on the east coast as against the 200 inches found on the west coast the one figure can be multiplied by twenty to produce the other ; and you cannot draw any conclusion from this beyond knowing that the figures have been taken for the purpose of multiplication. I do not believe we have any sufficient information at the present time to enable us to say that a period of frost or cold,—hardly a glacial period,—is followed by a period of wet. It may be, and it may in past times have been, that we have suffered from a glacial period at one time, and at another from a period of excessive rain and denudation, but we can only reason to a certain extent as to the past by what we see at the present time, by that of which we have some certain knowledge. I have not in this paper endeavoured to speculate on the circumstances I have adduced, but have merely narrated the facts, and I believe that the best way of promoting scientific investigation is to collect a number of absolute facts, and present them in their bearing on each other. A friend

of mine calls them positive facts, but I say facts are facts. If we collect facts, and not speculations,—undoubted facts,—we may perhaps in time be able to draw certain positive conclusions, but as long as we are merely pains-taking observers of facts we are not in a position to draw conclusions. I am very much obliged to you for the way in which my paper has been received.

The meeting was then adjourned.