IV.—MISCELLANEOUS.

ART. XLVIII.—*On the recent Sun-glows and the Theories that have been advanced to account for them.* By JOHN MEESON, B.A.

[*Read before the Nelson Philosophical Society, 1st September*, 1884.]

SELDOM in modern times has a natural manifestation in the physical world attracted such universal attention or excited so much admiration and wonder as the recent so-called sun-glows. The uneducated have everywhere gazed at them in mute astonishment; the learned, on all sides, have cudgelled their brains to assign for them a plausible and sufficient cause. The interest has not been merely local, for the phenomena have appeared, as far as we know, everywhere, and to appear was to excite curiosity. Scientific magazines and the ordinary public journals, during a period of more than six months, have devoted long articles to the subject; and even now, when the display is almost or quite over, public interest therein still finds frequent expression, and *savants* and scientific societies in various parts of the world are still engaged in researches which have for their object the elucidation of that which has excited the astonishment of mankind. The selection of such a subject for our consideration this evening can scarcely be thought inappropriate, the wonder rather should be that it has not been made before.

It will be well to state at the commencement what I propose to do to-night and what I do not propose to do; and, to begin with the latter, I do not presume to offer any original theory of my own. There are many branches of science connected with the subject of which my own knowledge is scanty and superficial. Others have made of these branches a life-long study. *Credendum est cuique in suâ arte.* Yet I hope to do something this evening which I would fain think will prove to some of us at least interesting and instructive. I have carefully examined such scientific magazines and public journals as are within my reach and have appeared during the past twelve months, with the view of gathering together the various facts and theories bearing on my subject. I have arranged these methodically under their different heads, and have pointed out, where I could, what appeared to me weak and fallacious arguments, what needed fuller testimony or consideration, and what seemed to satisfy the requirements of common sense and probability. The outcome is a *résumé* of the most salient facts, together with a *précis* of very much that has been written on the subject in such journals as "Nature," "Knowledge," Hardwick's Science Gossip,"

"The American Journal of Science," "The Scientific American," Dr. Taylor's Notes in the *Australasian*, and one or two other less important periodicals. In a word, I have summed up in a somewhat judicial—perhaps presumptuous—way, the whole evidence that is before us, and have not hesitated to give expression to my own opinion from time to time, nor to add arguments or objections of my own, nor to make original comments and criticisms in a way that, if not equally judicial, may be thought at least equally presumptuous.

Perhaps the present time may be considered specially suitable for a discussion on the subject, inasmuch as the phenomena have, if not totally disappeared, become comparatively insignificant; and the most distinguished men in the scientific world have, with the salient facts before them, given expression to their opinions as to the circumstances which have acted as operative causes.

The Phenomena.

It will not be necessary to describe much in detail the most widespread of the phenomena to which I am about to address myself, *i.e.*, the sun-glows, for they must be well within the remembrance of every one of us. Indeed it would require the pen of a poet or the brush of a Turner or a Canaletto to do anything like justice to the display. Our almost uniformly clear skies have enabled us in this Nelson province to witness the splendour, perhaps, at its best; but even in the murky climate of England it has excited admiration. London Bridge, nightly during the months of December and January, witnessed a concourse of people larger than usual; for the clear and open view of the western sky, which the broad bosom of the Thames permitted, revealed a picture in which imagination revelled and admiration delighted. When crowds of people are drawn nightly from "the little village" to the open country on every side to see the glows of the setting sun, we may be sure the display was not much inferior to our own, especially in Italy where the climatic conditions would assimilate the spectacle to that which we saw here. The character of the picture is shown by the fact that many persons at first said the colouring was due to an aurora. These people soon reflected, of course, that that explanation would not do, as auroras do not appear in the west, and are not necessarily connected with the setting sun, moreover the glow did not scintillate, and there were no contemporaneous magnetic disturbances. In one case, indeed, in the colony of Victoria (month of December), the display did merge into a veritable auroia—silver streamers appearing before all the red ones were gone—but that was an exceptional circumstance, and no one has asserted that there was any connection whatever between the two (Ellery, "Nature"). We have descriptions of similar appearances in various parts of

Asia (*e.g.*, India, Ceylon, China, Japan); Africa (Cape of Good Hope, Gold Coast); America (the United States, Barbadoes); the Sandwich Isles and Australia; so that we may conclude pretty safely that skies similar to those with which we have been familiar have been seen in all parts of the world. At the observatories on Mounts Washington and Pike, in the United States, it is stated that nothing remarkable was observed except a sun-glow on the first-mentioned peak on the 2nd December; the *absence* of the appearance there is in itself phenomenal when they have been seen so persistently elsewhere.

Most of the accounts agree as to the gorgeousness of the display made by masses of yellow-orange clouds, silhouetted in a clear sky of magnificent colour varying in tint from pink to primrose. The sun on many nights set somewhat hazy, but of a brilliant golden or light yellow colour. Even before he disappeared there were signs of the coming glory. But a few minutes after he sank behind the summit of Mount Arthur, we in Nelson here saw the western sky suffused, as it were, with a blush. When, as frequently happened, a few light streaked or parallel clouds attended the orb on his departure, these would first catch the colour. But it quickly passed towards the zenith, and every second became more intensely red. When there were any clouds about the face of the western sky, cumulus, cirrus, or cirro-cumulus, these at once were bathed in glorious hues. For ten minutes or more after sunset one half of the heavenly canopy was a blaze of orange, red, and green colours of every shade and tint. Then this brightness gradually waned. But meanwhile a glow as from infinite fires mounted from the western horizon, and behind the golden masses of clouds far and away transcended them in brilliance. The sky had the appearance of burnished metal under the influence of this second, and more remote, and more lasting glow. Every colour of the rainbow could be seen therein (primrose, orange, violet, rose, and pale green could be distinguished—all blending into one another), from the horizon to the zenith was a perfect blaze, forming where it touched the horizon a vein of brilliant silver white, and the opposite half of the sky, even though cloudless, appeared by contrast to be in Cimmerian darkness. To compare great things with small ones, the contrast in light and brightness between the two sides of the sky was suggestive of the effect of a splendid theatrical transformation scene. It was difficult at times to believe that the western glow was not produced by terrestrial fires of colossal proportions. Gradually, but imperceptibly, the colour would disappear. In some places it lasted even so long as a couple of hours, and frequently here it lingered, as if loath to leave the scene of its glory, till the observer grew tired of watching, and dreaming, and wondering what it might mean, and reluctantly passed indoors.

Elsewhere the colour of the sun when setting has been almost white (F.A.R.R., "Nature," 12th June), and occasionally the whole display has been, to use the language of one observer (Ellery, "Nature," April), almost frightful. This observation was made by Mr. Ellery in January last in the morning from the summit of a peak 3,000 feet high, and subsequent to the date of that gentleman's remark that there was nothing astonishing about the sunsets except that above the yellow there came a purple colour. The whole landscape on that occasion was crimson blood red. Sometimes we have had the second glow only, the *striæ* and cirrus clouds having been either absent or invisible. I find to my surprise that the sunrises have been as glorious as the sunsets. No doubt every one here but myself is well aware of the fact from personal observation. It is astonishing, nevertheless, that so little has been said about the morning glows, when so much has been said about those in the evening. Is it the retiring modesty of early risers that accounts for this? The phenomena in the morning have, of course, been reversed as to the order of their appearance. But Dr. Taylor says they have been even *more* brilliant than those in the evening (*Australasian*, 22nd March). Sometimes there has been the pre-glow alone; at other times, when the *striæ* have been visible and confused by clouds, there has been a display corresponding to the earlier one at night. The occurrence of two glows—one, the earlier, on the under surface of clouds; the other well behind them, somewhat later and apparently very high, in fact altogether above the region of clouds—may have escaped general observation; but close observers are unanimous about it (Hazen, "Am. J. Science;" Matthieu Williams; F.A.R.R., "Nature"), and I have myself distinctly and repeatedly seen it. Some correspondents of "Nature" affirm, indeed, that a second after-glow has occasionally been observed.

Now, in addition to the general phenomena just described, there have been locally seen others of even more astonishing character. I refer to unusual colours of the sun and moon. It does not, of course, follow, because these happen at about the same time as the brilliant glows in the sky, that they therefore owe their origin to the same general cause; but those best competent to form an opinion on the subject think they do. Blue and green suns were seen in India and Ceylon for five weeks after 27th August (A. C. Ranyard, "Knowledge"), particularly about 9th and 24th September (Langley, "Sci. Am."), also in the West Indies at Paramamibo, and on the Gold Coast, and on 24th September at London (F.A.R.R., "Nature"). A blue moon was seen in England early in December (Taylor), and during the same month it was at times of metallic-green colour. At Soporo (Japan) both sun and moon for some days in the middle of October were blood red in colour. A green sun was also seen at

Fanning's Island in the North Pacific, and at Honolulu on 5th September (S. E. Bishop, "Nature"); and the *Riverina Star*, 8th March, says that "recently the sun has been surrounded by a halo, the outer rim being black, the inner like a cloud of smoke." In Europe, in December, the moon and stars at various times were observed to be green, and the sun white towards setting. From 9th to 12th September the sun was green at Trincomalee, in Ceylon, till it ascended to the height of 10 degrees above the horizon; later it was blue; at noon, a bright blue; and during its declining similar changes took place, only reversed in order. The moon on or about the same dates was similarly tinged (Langley, "Journal Am. Sci."). It will be well to bear this observation in mind when we examine into the cause or causes of the various phenomena.

There are one or two other points that have been noticed in connection with the displays. In the neighbourhood of Timaru and elsewhere a great luminosity, almost like a continuation or a revival of the evening glow, has been observed in the depth of the night all across the face of the sky round about the place of the sun's setting. This was observed here frequently in the months of November, December, and January, at one, two, and even so late as three o'clock in the morning. The glow sometimes in these midnight displays extended from horizon to zenith over not the western but the *southern* heavens, and was so brilliant that an observer (Mr. Marsden, of Stoke) says he could by means of it easily have read ordinary clear type. During the day the sun, even when the sky was cloudless, has been frequently observed to be surrounded with a whitish glare (Conte. California, "Nature," 28th February), coronæ, or coloured halos. Often it has been very hazy. This was noticed by Mr. Hazen, who read a paper on the whole subject recently before the Philosophical Society in Washington. Occasionally also, as at Freiburg on the 11th January, and here in Nelson on the 24th of last month, even with a clear sky there has been no glow at all, though on the previous day there was a very distinct one; again, through the glow the stars have been distinctly seen, and on the 4th and 5th of January there was a ring of 30 degrees in diameter round the moon, and that satellite seemed to be gleaming through watery vapour. Again, on the 1st December it was observed that the glow did not become bright till a full hour after sunset (Hard. Sci. Gos.). Some observers, too, have noticed a large and striking coloured arc, pink or crimson, opposite the sun at the time of the glow. Furthermore, it is recorded that the cirrus-like wisps of cloud on which the sunset phenomena appeared in November and December disappeared altogether or became very faint and large towards the commencement of the current year.

Dates of Phenomena.

And now for a word or two as to the dates of the first appearance of the phenomena in the different places where observations have been made and recorded. This enquiry is decidedly important, whether we associate the phenomena with the eruption of Krakatoa or otherwise account for them by a cause or causes terrestrial rather than cosmic. The following table gives the dates of recorded observations in chronological order :—

27th August. Sun obscured during day and set gorgeously at Seychelles, and Rodriguez, and Diego Garcia.

28th August. Sun-glows at Mauritius, 3,000 miles from Krakatoa.

29th August. Sun dull and like the moon at Seychelles.

30th August. Sun very hazy at Tokio in Japan, and in Brazil.

1st, 2nd September. Sun blue at Cape Coast Castle (7,000 miles away), then rose colour, then white.

1st, 2nd September. Sun green at Barinas in Venezuela (12,000 miles away), previously like burnished silver.

1st, 2nd September. Sun-glows at New Ireland.

4th September. Sun green at Fanning's Isle.

5th September. Sun-glows at Honolulu.

8th September. Sun-glows in Ceylon.

9th September. Sun green and blue in India, Ceylon (Trincomalee).

15th September. Sun-glows in South Australia, and Nelson, New Zealand.

18th September. Sun-glows in Wellington, New Zealand.

20th September. Sun-glows at Cape of Good Hope.

2nd October. Sun-glows in Victoria.

5th October. Sun-glows at Honolulu and Valparaiso.

8th October. Sun-glows in Florida.

19th October. Sun-glows at Yuma (California).

30th October. Sun-glows in United States.

8th November. Sun-glows in England and California.

20th November. Sun-glows in Turkey.

23rd November. Sun-glows in Iceland.

27th September. Sun-glows nearly everywhere, and on this evening the grandest display of all in the Old World.

— December. Sun-glows in North China.

I regret exceedingly that I cannot supplement this list by giving the precise dates of the first appearance of the sun-glows in Nelson. I made certain notes in my diary, but they are not sufficiently conclusive. Perhaps some one present can and will kindly help me in this respect. I neither

made exact memoranda myself of the earliest displays nor can I find anyone who did. In these, as well as in other matters, one does not recognize the importance of recording observations till the opportunity of doing so has slipped by. Then we see what useful work in any locality an observatory can do, and how desirable it was for us to get our local meteorological instruments into actual work. We may now congratulate ourselves that in the future the dates of the more remarkable and patent meteorological facts will be found at Bishopdale without difficulty.

On turning over the file of our local evening paper I find the first sunset that was thought worthy of a paragraph to itself—or, indeed, of any notice at all—was on the 29th December. The issue of the 31st—the last day of the year—mentions the glow of the 29th as "the most gorgeous of the many that have excited admiration of late." This display was at its best at 9 o'clock, and half an hour afterwards had almost entirely disappeared. But certainly for three months before this date we had become familiar with the spectacle. I have a distinct impression that we had witnessed it several times before the middle of October. Our vice-president, Mr. Atkinson, whose astronomical studies would make him likely to record or remember with accuracy the dates of the earliest appearances, states his conviction that it was as early as the 1st October or the last days of September. But our secretary, Dr. Hudson, assures me that he can fix the date of one very early display as Monday, 17th September, and he thinks this was not the first. I find what notes I did make confirm this record, and so am able approximately to give the date as Saturday, 15th September.

Dr. Hector, on the 14th November, before the Wellington Philosophical Society, states "that the extraordinary coloured glow in the sky had been visible every clear night and morning since the first* week in September, proving the existence at an enormous altitude of some vapourous matter capable of refracting the sun's light into its prismatic components. He had observed, to his surprise, on several evenings that through rifts in the vapour masses crimsoned in the ordinary way by the sun after it had set, a back-ground of intense greenish blue was visible. After all the ordinary sun-tints had faded, this blue changed to orange-pink, and graduated off through the various prismatic tints to a magnificent crimson spanning over what appeared to be cloudless sky considerably to the eastward of the meridian. This spectacle gradually faded with the advance of nightfall, but lasted 1 hour and 20 minutes after the ordinary twilight tints had faded." I have quoted this at length, to embody in my paper an accurate and graphic description of phenomena, which we all well remember, but more especially because of the date given for their first appearance. In the table

* Misprint for "third." The exact date was the 18th September.—[ED.]

that I have given it will be seen that at Adelaide (South Australia), which is in 35°, the first marked appearance of the sun-glow was on the 15th September. In Victoria, which is only situated a few degrees nearer the tropics than Nelson, the glows did not appear, it seems, till the 2nd October.

To supplement the information given by the above table, I must proceed to say that the displays have continued since their first appearance intermittently up to the present time. The last ones in the old world of which I find any record in "Nature," were, one observed by Professor Reilley, I presume in Dublin, on the 11th June, another on the 22nd June in Dalston, and a third on the 7th July noted by B. J. Hopkins. The displays continued in Nelson without any intermission during the first few months of the present year. I have made memoranda of very striking ones on the 13th March, 14th April, and 5th May. Since the last-mentioned date, I cannot positively say that there have been no sun-glows here in Nelson, for I noticed something very like one even so recently as the 22nd of last month, and again on the 23rd when a faint after-glow was clearly visible for an hour after sunset; but I have not seen anything at all extraordinary in the sunsets since the 5th May. Concerning the latest appearances in distant parts of the world, there has scarcely yet been time to collect particulars and records of observations. To judge from a letter in "Nature," there appears to have been in England in June and July a return of the phenomenon. Be it observed, in no place do the glows seem to have been continuous. Everywhere there were days, even weeks, when none were observed at all. Cloudy weather and other meteorological conditions would account for this in part, but not entirely. In the month of November, there seems to have been a curious intermission, lasting three weeks, even in places so distant from one another as England, Honolulu, and the United States. Two or three days prior to the Sunda eruptions, Moncure Conway reports that he saw the sun steel-blue during the daytime, and green towards setting. This observation, reported by Mr. Ellery to the Royal Society of Melbourne on the 13th December, seems to be somewhat singular.

In leaving this part of my subject, I would point out:—

1. That the earliest places to get the sun-glows and the coloured sun and moon were within the tropics, and as a rule, near to the Straits of Sunda.

2. That the appearances commenced on the very day following the Krakatoa catastrophe, with the exception of the one reported by Moncure Conway, about the date of which there may be some slight mistake.

3. That all the places which witnessed the phenomena before the 8th September, are situated within 15 degrees of the equator.

4. That the glows have differed from ordinary brilliant sunrises and sunsets in respect of intensity, duration, area, and time of appearance. Moreover, the colours of the after-glows have been in themselves very exceptional, and they have succeeded one another with more regularity than ordinarily occurs.

5. That the period of their greatest intensity seems to have been from the middle of November to the middle of January—the display on the 27th November having been the most gorgeous of all.

6. That the phenomena are very gradually disappearing, and becoming less and less remarkable as the weeks roll on. At the present time they are very intermittent, and, when visible at all, are exceedingly faint.

Having described the phenomena, it remains for us now to consider

The various Theories

that have been advanced to account for the same, and we shall find that they are numerous and in some cases sufficiently ridiculous. As Tyndall says, "Man longs for causes, and the weaker minds, unable to restrain their longing, often barter for the most theoretic pottage the truth which patient enquiry would make their own." In the first place there is the "*Supernatural Theory.*" The world is in its death-throes. It has always been foretold that portents in the sky and convulsions of nature should precede the coming dissolution. Scientific men cannot account satisfactorily for the heavenly splendours. It is only in their pride of intellect that they attempt to do so. The sun-glows must be classed with the fearful earthquakes, the terrific volcanic eruptions, the weird colours of the sun and moon;—the spread of the destructive blights, the invention and employment of dynamite for dastardly purposes, the growth of human wickedness, etc., etc., are signs that the end of all things is near! We all know the form this argument takes and how many good people there are who honestly advance it. But it need not detain us here to-night.

Then, there are those who thought that *Biela's Comet*, which was rushing towards us in January last, might have exercized sufficient influence in some mysterious way to produce the sun-glows; and some New South Welshman who probably had been sun-struck during the fervid days of December last in his colony, attributed the world-wide appearances to the *sandy deserts* in the interior of Australia. Another theory, scarcely more respectable perhaps, is that the light is such as has been travelling to us *from distant suns* for thousands of years, and has only just succeeded in penetrating to our dark continents. In connection with which, what explanation is given of the disappearance of the abnormal light does not appear. Then, although the glows were repeatedly seen when there was not the slightest magnetic disturbance, we have, of course, the *electrical* theory.

This is a convenient one in many difficulties. Here is something we cannot understand. It must, therefore, be caused in some way by that mysterious force, electricity—which in the near future is to produce for us, even artificially, light, heat, motion, and every form of energy. As is the supernatural to one class of people, so is electricity to another, wiser in its own eyes—a key to unlock every dark and mysterious chamber in the universe. And when we consider what electricity has enabled us to do in recent times, we cannot wonder that it should be credited with effects for which it is not at all responsible.

I.—The Cosmic Dust Theory.

But now we must pass to theories which are more plausible; and the first of these is that the earth has been recently passing, particularly in its intertropical parts, through some *meteoric region* or a cloud of *cosmic dust.* But those who advance this, forget to tell us how it is that there has been even less than the usual number of shooting stars during the period of the glows. The dust in the upper air was once thought to come from outside space and to be the residuum of burnt-out meteors. Some of these erratic bodies rushing aimlessly through space are, from to time, caught by the gravitation of the earth, and then in their rapid passage towards its centre, striking the air, acquire such intense heat that they burst after a very brief moment of incandescence into vapour and are burnt out 60 miles above the level of the sea (Ranyard, "Knowledge"). Now, if we had been passing lately through such a meteoric belt as is supposed, during the numerous clear nights that we have had, meteors or shooting stars such as I have described must have been seen in considerable numbers. As a matter of fact none, or next to none, have been visible. Lockyer, Ranyard, and Williams, nevertheless, were at first inclined to this theory—the latter gentleman more especially—in consequence of the results obtained through examination and analysis of the dust gathered from melted snow; and Mr. Ellery stated, in an address to the Royal Society of Melbourne on 15th November, that there were only two admissible theories to account for the sun-glows, and one was that the earth was passing through a meteoric region resulting in refraction of the sun's rays. Mr. Ranyard says ("Knowledge," 14th March) that at first he could not resist the impression that the glows were caused by meteoric dust, though he knew well enough that in 1861 the earth passed directly through a comet's tail without any such glows appearing. But all these gentlemen abandoned this theory subsequently. A Mr. Biggs, of Launceston (Tasmania), says that if we *had* been running through a meteoric belt such as is supposed, the meteoric bodies would have been falling upon us at the rate of 200,000 miles a day—that celestial fireworks would have been astonishing, and that everything sublunary would have

been burnt up—unless, indeed, the meteoric dust was in our own orbit and moving with our velocity, in which case the phenomena would have been an old acquaintance. Other objections to the cosmic dust theory are the almost instantaneous appearance and the intermittent character of the phenomena. Every re-appearance would imply another cosmic cloud moreover; and the amount of meteoric dust requisite to produce the effect, would have to be enormous and very exceptional. The number of meteorites that enter our air daily is computed to be about 10,000,000, weighing not less than 100, nor more than 1,000 tons altogether (Langley, "Scientific American"). This amount of matter falling into the air, it is considered, would be far too small to produce the result for which we are seeking the cause. A further argument lies in the fact that particles of dust brought down by rain and snow-water recently, when subjected to microscopic and chemical analysis, are found to resemble volcanic matter rather than meteoric (Professor Rees, New York Academy of Sciences). So that, on the whole, it may be concluded that, if it is dust in the upper air that causes the sun-glows, that dust is not meteoric but terrestrial.

II.—THE AQUEOUS VAPOUR THEORY.

The precise cause of the brilliant colouring which so frequently beautifies the heavens and accompanies the setting and rising of the sun is not positively known. It is, however, generally supposed to be owing to an extraordinary amount of aqueous vapour (Lockyer, *Times*, 18th December, 1883), or dust (Hazen, "American Journal of Science") in the higher atmosphere absorbing the blue rays which go to the composition of white light, and diffusing the red. The connection between red skies and rainy weather is recognized in the oldest folk lore.

> "Red sky at night is the shepherd's delight,
> Red sky in morning is the sailor's warning."

"When it is evening ye say it will be fine weather, for the sky is red. And in the morning, it will be foul weather to-day, for the sky is red and lowering."—Matt., xvi., 2, 3. I presume red in the sky in the evening does not imply wet weather, but rather the reverse, because it shows us that the aqueous vapour in the air is following and passing away with the setting sun. Just as the colouring of the deep sea is owing to the refraction and decomposition of light passing from one medium into another of different density—shallow water appearing, as a rule, colourless—so aqueous vapour in the atmosphere causes the absorption of certain component rays of white light, and the others being dispersed in the air, impart their colour. The ordinary phenomena of *twilight* and *dawn* are partly owing to the same cause; and it is said that when the sun is seen through the funnel of a steam engine it appears green. It was natural, therefore, that

the aqueous vapour theory should be advanced to account for the sun-glows; as it was brought forward under somewhat similar circumstances, hereinafter referred to, in the year 1783, by the philosopher Lalande, so it first occurred to many eminent astronomers and meteorologists (Mr. Ellery amongst the number) of the present day; and although in most cases the theory was subsequently abandoned, yet at first it was maintained vehemently, and most other theories treated with contempt. With Mr. Ellery of Melbourne the *aqueous* was one of his two admissible theories, and that which he strongly advocated. He said—there is unusual moisture in the upper air—our exceptionally wet season proves it. The average rainfall for January is 1·60 inches. This year it has been 4·75 inches. Such exceptional moisture in the air will account for the sun-glows (Royal Society, Melbourne, 15th November). But, unfortunately for this theory, as it happened, the season in New South Wales, the neighbouring colony, was exceptionally *dry*, as the squatters there know to their cost. The drought was so severe indeed that it brought about a loss to the colony in one way or another of £10,000,000, and again in North China (from the testimony of a Mr. Sowerby in "Nature") the winter was remarkably fine. Yet in both New South Wales and China the sun-glows were brilliant—those in China, in the month of December, being described as gorgeous with magnificent rose-pink after-glows. Mr. Ellery, furthermore, says that an assistant of his at Port Darwin, in March, 1883, saw several such sunsets as we have had with similar after-glows, and that they always came before or after rain. Herein the Government Astronomer of Victoria strangely loses sight of the fact that *before* or *after* rain, as it appears to me, makes all the difference in the world, for if the sun-glows continue to appear after a rainy season, and during a succeeding dry one, as they have done in Victoria, it is clear that they must be produced independently of aqueous vapour in the air. As far as our experience here in Nelson is concerned, I do not think there can be any doubt whatever that our finest sun-glows occurred during a spell of dry, keen, and exceptionally cold weather. Moreover, the air of England is wet enough in all conscience, yet fine sunsets are comparatively rare there, and green suns almost an unheard-of phenomenon. Dr. Hector,* again, as I have already quoted, spoke on the 14th November, 1883, of the extraordinary coloured glow in the sky, as *proving* the existence at an enormous altitude of vapourous matter capable of refracting the sun's light into its prismatic components. Except that the expression employed here is "vapourous matter"—in the place of "aqueous vapour"—the language is not at all doubtful. The context, however, states that the *vapour* must have an unusual altitude, that

* Trans. N.Z. Inst., vol. xvi., p. 556.

it was gradually drawing towards the pole, and that it was connected with the Sunda eruption. But that the exceptional matter in the upper air *is vapourous at all* seems to me very doubtful. I would remark here parenthetically that it is very easy for us to be wise when a great many facts and opinions have been given and collected; but very difficult when the phenomena are quite new and few accurate observations have been made, and we have had no opportunity of comparing notes with other observers. To say this much is due to those who, from their position, are expected at all times and at a moment's notice to give a correct opinion as to the cause of whatever baffles ordinary comprehension in natural phenomena. That they should occasionally make a mistake is to be expected, but that they *have* done so as far as this aqueous theory is concerned, I conceive, as yet, is certainly "not proven." That they have, in some cases, changed their opinion, shows the difficulty and uncertainty with which the whole subject is surrounded.

However, there is another test of the "aqueous vapour" theory—the *spectroscope*. When the glow is examined by means of this tell-tale instrument, if there were aqueous vapour in any quantity in the upper air, you would have the solar spectrum with its Fraunhofer lines and certain black bands—wet weather or rain bands as they are called —intervening, even as when a ray of light is seen through straum (M. Jansen). Now, as a matter of fact, during the period of the sun-glows, whenever the spectroscope was employed, it was found that the rain bands instead of being at a maximum were at a minimum. On the other hand, the dry-air band was well defined—in fact, to use the words of Lockyer, it was at a tremendous maximum. Notwithstanding some evidence to the contrary furnished by Mr. Michie Smith, of Madras, and Dr. Assman, of Maddebûrg, this seems at first sight pretty conclusive. But it is not so, for there arises this question, *Would the spectroscopic effect be altered according to the condition of aqueous vapour in the upper air?* If the vapour were turned by the intense cold of the upper currents into icy particles, *Would the rain band then appear?* I do not think it would, and we shall see subsequently direct testimony that it would not. So that, after all, the aqueous vapour theory does not completely break down—it only becomes modified. We have *ice crystals* instead of watery vapour. I read that green and blue suns are frequently seen in polar regions; and icy particles in the air refracting the sun's light into its prismatic components are very favourable for the display of sunset colours ("Hard. Sci. Goss.") The question is, what other independent proof have we that the upper air has been full of ice crystals? The general view of the world's weather recently does not seem to provide any evidence in this direction. Some

places have been certainly unseasonably cold. I think New Zealand has for example. The summer of Christmas last was both late and cold. A frost was experienced at Ashburton on 5th December, and for the past few months we have had more than the usual amount of biting weather. But, *per contra*, last winter in England, when the sunsets were most brilliant, was very exceptionally mild. So I believe it will be found to have been elsewhere. Nevertheless, the *ice crystal* theory still finds advocates, notably Dr. Verbeek, who connects the appearances notwithstanding with Krakatoa. He says that the vapoury discharge on 26th and 27th August at Straits of Sunda was immense; that it was condensed to water as it ascended into the colder air, and eventually in the coldest, was frozen. The refraction through the innumerable ice crystals, he thinks, was quite a sufficient cause for the abnormal sun glows.

Now this carries us through all the theories which attempt to account for the sun-glows independently of Krakatoa and its memorable eruption, and it is evident that although there is very much to be said in favour of the aqueous vapour theory—or rather its modification, the ice crystal theory,—yet not one of these attempts to account for the displays is perfectly satisfactory. Moreover, when we are regarding exceptional events, we must look for their origin in events which are in themselves both exceptional and adequate.

III.—The Volcanic Theory

therefore next claims our attention. It is impossible, I think, to consider the dates of the earliest occurrence of sun-glows, coming as they do immediately after the Krakotoa eruption, which, you must remember, culminated on the 27th August at 10 in the morning,—without arriving at the conclusion that the two things are in some way associated—the fallacy in "*post hoc, propter hoc*" notwithstanding, but historical records help us also in this direction. It has been pointed out on the authority of that accurate and painstaking naturalist Gilbert White, that strangely enough exactly 100 years ago, *i.e.*, in the summer of 1783, similar phenomena were observed ("Nat. Hist. of Selborne," Letter LXV.).

"The summer of the year 1783 was an amazing and portentous one, and full of terrible phenomena; for, besides the alarming meteors and tremendous thunder storms that affrighted and distressed the different counties of this kingdom, the peculiar haze, or smoky fog, that prevailed for many weeks in this island and every part of Europe, and even beyond its limits, was a most extraordinary appearance, unlike anything known within the memory of man. By my journal I find that I had noticed this strange occurrence from 23rd June to 20th July inclusive, during which period the wind varied to every quarter without making any alteration to the air. The

sun, at noon, looked as blank as a clouded moon, and shed a rust-coloured ferruginous light on the ground, and floors of rooms; but was particularly lurid and blood-coloured at rising and setting. All the time the heat was so intense that butchers' meat could hardly be eaten on the day after it was killed; and the flies swarmed so in the lanes and hedges that they rendered the horses half frantic, and riding irksome. The country people began to look with a superstitious awe at the red lowering aspect of the sun; and indeed there was reason for the most enlightened person to be apprehensive, for, all the while, Calabria and part of the Isle of Sicily were torn and convulsed with earthquakes, and about that juncture a volcano sprang out of the sea on the coast of Norway."

And Cowper in the "Task" describes the same appearances (Task, Book ii.).

> "Sure there is need of social intercourse,
> Benevolence, and peace, and mutual aid,
> Between the nations in a world, that seems
> To toll the death-bell of its own decease,
> And by the voice of all its elements
> To preach the gen'ral doom. When were the winds
> Let slip with such a warrant to destroy?
> When did the waves so haughtily o'erleap
> Their ancient barriers, deluging the dry?
> Fires from beneath, and meteors from above,
> Portentous, unexampled, unexplain'd,
> Have kindled beacons in the skies, and th' old
> And crazy Earth has had her shaking fits
> More frequent, and forgone her usual rest."

From another source ("Nature," 17th July) I hear that extraordinary sunrises and sunsets in that year lasted for eleven months, and have been attributed by Arago to volcanic dust, for besides the volcanic activity to which the Vicar of Selborne refers in the letter mentioned, there were, it appears, in 1783 tremendous eruptions of Asama Yama, in Japan, and Skaptar Jokul, in Iceland. Mrs. Somerville, Sir C. Lyell, and Sir J. Herschell all refer to the latter event, and the last named says that on that occasion 21 cubic miles of lava were ejected from the crater. Again, similar phenomena were observed in Europe and America in 1831, and at first when this fact was disinterred from historical archives or recalled by human memory, it was stated that that year was memorable for no particular eruption. But a quotation from Nile's Register, 31st October, 1831, given in "Nature" of May last, puts a different aspect on the case. It says that on 7th August preceding, there occurred a violent eruption off the coast of Sicily, during which Graham's Isle was formed: two days later the sunsets began to be very lurid and remarkable, the glow extending to the

zenith, and lasting beyond twilight. After the 11th August a blue sun was seen at the Bermudas, and on the 15th at Mobile. In October at Washington, and at Alexandria in Virginia, there was a red sun-glow, and at midday the sun was silver white. Again, Dr. Taylor (in his *Australasian* notes) quotes Col. Stuart-Wortley to the effect that he has seen similar skies in the Pacific, caused by the volcanic eruptions of South America: and Ed. Whymper, on the slope of Chimborazo. 3rd July, 1880, saw an eruption of Cotopaxi, 65 miles away, which produced not only a blood-red sky, changing to verdigris green and the colours of brick dust, copper, and shining brass, but also a veritable green sun.

The fact which I wish to bring out by all this evidence is that somehow or other by the discharge of smoke, dust vapour, or gas—*i.e.*, matter in one of its three leading forms—from volcanic rents, the colours in the sky and of the heavenly bodies have been and can be for a period of time, short or long, very considerably changed. Here, therefore, we have an additional reason besides that of sequence in point of time, for associating the late manifestations with the outbreak at Krakatoa, and the very exceptional violence and extent of the operation of that eruption enables us to see why the sun-glows recently have been so remarkable and brilliant, and of such long continuance.

But that is not all. The year 1883 was as a whole wonderful in its volcanic activity. The old fiery life is still throbbing in the earth's veins, and as the *Times* recently remarked in a leading article, the lava catastrophe clearly shows that our little world is not near its latter end yet. I find that from March of last year almost up to the present time there has been a series of earthquakes and eruptions such as mankind has probably never before experienced in historic times, within a similarly brief period. By the microseismometer, earth-tremors of the faintest character are duly recorded; and this delicate instrument reveals the fact that for some time, particularly in certain parts of the world, earth-tremors have been more than usually continuous. I would ask you to carefully note the following list of the eruptions and earthquakes during the period indicated. I have compiled it up to Christmas last from a journalistic summary of the events of the year:—

22nd March. Earthquakes in Sicily, eruption of Etna.
26th March. Eruption of Hecla.
12th April. Earthquakes in Tasmania begin, and last through year.
20th May. First eruption of Krakatoa.
22nd July. Earthquake in Ischia (6,000 killed; felt even so far as Wiesbaden).
25th August. Great eruption of Krakatoa.

28th August. Earthquakes in West Australia and Tasmania.
29th August. Earthquakes in New South Wales and Tasmania.
30th August. Earthquakes in New South Wales and Queensland.
20th September. Earthquakes in New South Wales.
8th October. Eruptions in Iceland.
10th October. Last eruption of Krakatoa.
11th October. Earthquakes in California. Eruptions in Alaska.
15th October. Earthquakes in the Levant and Asia Minor, 200 perished.
22nd October. Earthquake in Lisbon.

It is indeed, though very incomplete doubtless, a formidable list, and since Christmas almost up to date, the volcanic activity has been continued. Ischia and Alaska have again suffered, and even steady Old England has felt the effect of internal fire, or shrinking, or whatever may cause earthquakes—having experienced a severe shock in the neighbourhood of Colchester.

But of all these outbreaks that at Krakatoa was by far the most formidable and gigantic. Professor Verbeek, who was at the head of the Committee of Enquiry appointed by the Dutch Government at Batavia to investigate on the spot the causes, features, and effects of the eruption, has already sent in a long report, a translation of which appeared in "Nature" of 1st May; it is a most complete and interesting account. Even a synopsis of it, however, would be too long for me to give to-night. I must content myself with mentioning a few of the particulars and estimates given, mainly with the view of showing the magnitude of the operations.

It appears that there is a rent in the earth across the Straits of Sunda, and that a slight pressure on the molten matter beneath the crust, or the entrance of salt water causing the generation of steam, produced the explosion. The Professor naturally thinks that the simultaneous occurrence of earthquakes in Australia indicates a very large area of operations. The activity of Krakatoa really began in May, 1883, but culminated on Monday, 27th August, at 5 minutes past 10 a.m., in an explosion so terrific that the noise of it was heard in Ceylon, at Perth in Western Australia (1,800 miles away), and even at Diego Garcia, near Mauritius, 3,000 miles away; in fact over nearly one-fourth of the earth's circumference. Seven or eight air-waves were also formed in all directions—violent throbbings of the entire atmosphere of the world—producing effects like those of earthquakes. Even at Pasoeroean 830 kilometres (say 520 miles) distant, walls were rent by these jerks in the air, which were very quickly communicated and—being registered at places so wide apart as Batavia, Wellington, Dunedin, Melbourne, St. Petersburg, and London—they form, as it were, a register of the

successive explosions, and are exceedingly interesting. The air-wave following the 10.5 eruption seems to have travelled three and a quarter times round the world before it allowed the atmosphere to regain its normal condition; journeying at the rate of 674 or 706 miles an hour according as it passed to the east or to the west, *i.e.*, according as it was assisted or retarded by the upper currents of wind (Col. Strachey, Royal Society). Besides this "atmospheric shudder," as Ellery graphically calls it, there were enormous sea-waves—tidal-waves as they are improperly called—formed by the tumbling-in of the burnt-out mountain, or the falling into the sea of vast bodies of ashes, or by submarine explosions or otherwise. These waves were, as you know, awfully destructive to human life—perhaps carried off 100,000 people. To show their force and rapidity, I may state that they reached Geraldton in Western Australia so early as the 27th, Mongonui and Timaru, New Zealand, on the 29th, and Nelson on the 30th. Shortly afterwards they reached places more distant still, even the coast of France. Verbeek computes that 18 cubic kilometres—nearly twenty-five thousand million cubic yards—of solids, and more of gas, were ejected. The steam cloud rose to the height of 11,000 metres (nearly seven miles) even on 20th May, when the eruption was trifling, and probably to the height of 20,000 (over thirteen miles) on the 27th. But naturally enough, nobody in the vicinity on that exciting day was sufficiently calm to note with accuracy such phenomena. Before the eruption the Island of Krakatoa contained 33½ square kilometres (nearly thirteen square miles), now it contains only 10½ square kilometres, that is, less than one-third of the old area. It consisted of three large peaks, one of which was 2,500 feet high; the two smaller of these and a cleanly-cut half of the largest one have disappeared entirely, and the sea over the place where they were is now over 1,000 feet deep. The whole neighbourhood is changed. One island, Poelsche Hoedje, has vanished entirely. Others are trebled in size. Within a radius of 15 kilometres (say nine miles) the ashes are 20 to 40 inches deep, and an area as large as Germany, Holland, and Belgium put together is covered to a less extent. A locality subject to visitations of this kind, with sixteen active volcanoes, some of them 12,000 feet high, and many more only quiet for a time, is well called "The Lid of Hell," and after such a visitation to any one part of the world, we need not wonder at all to see curious meteorological phenomena as a consequence, even in very distant places.

But, as I have already pointed out, this eruption of Krakatoa was by no means the only outbreak through the earth's crust during last year. That of Hecla on 26th March, and that of Alaska, were anything but insignificant. The latter especially must have resulted in the throwing up of a vast quantity of matter. The whole Alaskan peninsula was in volcanic activity.

One mountain, St. Augustine, was split into two parts; another 12,000 feet high was *very* violent—threw the whole district into darkness for some time and covered every foot of the ground to a long distance with a layer of ashes five or six feet deep. An island a mile and a half long and 75 feet high was suddenly formed, and tidal-waves 30 feet high broke on all the surrounding coasts. Still even this was vastly inferior to the Krakatoa catastrophe, and almost all the prominent scientific men of the day concur in connecting our sun-glows with the latter event, although they allow that the smaller eruptions of the year may have contributed to the intensity and duration of the displays.

But it remains to be shown how that connection is established. Something unusual was evidently carried into the higher air in immense quantities in the last days of August, 1883. *What was that something?* Dust, vapour subsequently to be frozen into ice-crystals by the cold aerial upper currents, or some gas such as hydrogen or chlorine. Each of these has its advocates—perhaps the truth is that each has contributed to the result. Let us see more closely what is or can be advanced in favour of each supposition.

Firstly, as to the *hydrogen gas* there really is little to say. Several authorities (Ellery and Hazen, *e.g.*) incidentally mention it as a possible product of the eruption, resulting from the decomposition of the ejected water through electric action, I suppose. When once released the hydrogen would readily and naturally ascend to a great height, for its specific gravity is less than that of any other gas, and we can conceive it as suspended at a great altitude in great quantities, and for a long time. But granting all this, would it produce the sun-glows? Mr. Ellery thinks not, and nobody of scientific standing contradicts him. Again the heavy yellow gas—chlorine—would probably be liberated in large quantities by the pouring of sea-water into the fiery craters of Krakatoa, and in combination with other causes may have contributed to the exceptional colouring.

Secondly, there is the aqueous vapour, or rather ice-crystal theory. There is more to be said here. But, on the threshold, there is a great difficulty. Aqueous vapour in the air is no unusual thing. Often the atmosphere is heavily charged with it. But the sun-glows are phenomenal. Is it not curious that the vapour has never before assumed the condition requisite for producing such an effect? Hazen argues in favour of this theory thus: there are three conditions necessary to produce the best results in the way of sun-glows: (1) clear sky; (2) abundant refracting material; and (3) great force to carry the same high up into the air; all these conditions have been fulfilled. The universality of water secures the fulfilment of the second condition even independently of the Krakatoa

eruption; and for the fulfilment of the third condition we have electricity, which during the past year has been in great force as shown by electrometers—incessant volcanic eruptions, a maximum development of sun-spots (Secchi and others offer testimony to this also), and the striæ gathering about the setting sun. One of the three conditions (clear sky) being occasionally absent, the glows would naturally be intermittent. The frost particles in the upper air would produce the colouring by diffraction, and being transparent, would not hide the stars from view. The persistence of the phenomena through many consecutive months is certainly against this theory; and the absence of the rain band is a very strong objection, but not so strong as it looks; *because frozen water does not produce the rain band like aqueous vapour: e.g.*, before a light rain a rain band of 70 degrees has been observed, but before a heavy snow storm only one of 10 degrees (F. W. Cory).

All this is very plausible it must be allowed, but against it one may ask, Where has the upper-air moisture gone to—whether liquid or ice? It certainly has not been precipitated, and the glows have ceased or are ceasing. Russia (*Times*, 11th July) has been excessively wet, but *per contra* an English writer says, about July last—"we are passing through a droughty summer, the driest we have had since the famous one of 1868;" and the *Times* summarizes the great defects of the English climate from 1st January to 26th May as—(1) prevalence of cold searching dry air causing frequent frosts at night and (2) absence of rainfall. Nevertheless, there are many little facts which may be gathered all along the line telling in the same direction as Mr. Hazen goes. Lockyer, for example, mentions that he has seen a green sun through the mist on the Simplon Pass, and every one who has travelled in an alpine land knows the beautiful effect, which I think the Germans call Alpenglühen, produced by the rays of the setting sun falling aslant through the keen icy air upon glaciers and masses of névé snow. The most gorgeous as well as the softest colours play about the mountain peaks. Every icy crystal coruscates and flashes like a diamond, and the sky all around is flushed with the golden glow beneath it. I once saw this to perfection, standing in the valley of Lauterbrunnen and gazing towards the glaciers of Breithom and the Tschingel Alp. Never will the picture leave my memory! Again there is the strong argument drawn from the accounts given by those who have voyaged in polar regions. There, glows and coloured suns seem to be of frequent occurrence.

Thirdly and lastly we have the *volcanic dust* theory of which Dr. Taylor says, or rather said, a few months ago—that "there is a general consensus of opinion, now that the microscope and polariscope have been brought into the discussion of the question, that it is the true theory." It is stated in

"Knowledge" to have been first advanced by G. T. Symons in a letter to the *Times* of 1st December. But in these colonies the theory was advanced, I feel pretty sure, long before that date. It was repudiated in fact by Mr. Ellery on the 15th November, before the Royal Society of Melbourne, and had been advocated both here and in Victoria some time before that.

It will be well perhaps if we consider in the first place the various points that are in favour of this view.

1. We have already by anticipation considered the certainty that there was something unusual projected into the upper air, and that it was thrown there by the Krakatoa eruption, which, as says Professor Rees, was the greatest eruption on record.

2. The immense quantity of dust ejected from Krakatoa suggests that dust was the thing thrown into the higher atmosphere. As Langley says—"Krakatoa ejected millions of tons which would not soon sink." Thirty miles away from Sunda the ashes fell in such quantities as to make pitch darkness at noon-day. Java was like Holland in its garb of snow. White dust fell on the decks of vessels from 300 to 400 miles away.

3. Dust in the upper air is not an inherent improbability, because the air at all heights is always more or less charged with quantities of dusty particles, as is easily seen when an isolated ray of light is admitted into a dark room. The motes are always in the sunbeam. The smoke of Chicago was seen, again, on the Pacific Coast, so that dust in the air travels far; and Nordensfeld found the fissures in Greenland ice full of fine dust. Where *did* this come from if not from the air? In Italy from time to time also there occur veritable showers of sand brought over by the sirocco from Africa. Piazzi Smyth, in 1872, noted such an occurrence in Palermo Bay and, if I mistake not, I have read somewhere that the red sand of the Sahara, carried by the Harmattan and other desert winds, finds its way to immense distances across the Atlantic. Dr. Taylor says that the air on the very summit of Monte Mazo, 9,000 feet high, is full of Bacteria, mould, spores, etc. In fact, though ordinary dust is not carried very high and is always denser in the lower strata of the atmosphere, which was demonstrated by Tyndall's experiments on the Bel-Alp, there is always dust in the air in greater or less quantities. This is clearly shown by the phenomena of radial polarization of light (*i.e.* the reflection or refraction of light so that it has new properties—sides as they are called of different intensities), and to some extent it is also shown by the beautiful effects which we call twilight and dawn, though the principal cause of these is the reflection of light from the air itself and the clouds and vapour suspended in it. Professor Langley says that there is a zone of dust to the height of three miles all round the earth. In 1878 he wintered on Mount Etna and he

found the air full of dust not local in origin. So Piazzi Smyth also found on Teneriffe at the height of a mile; and on Mount Whitney, in South California, 15,000 feet high, Langley found a sea of dust 6,000 feet deep. Tyndall says, "What mainly holds the light in our atmosphere after the sun has retired behind the earth is, I imagine, the suspended matter which produces the blue of the sky, and the morning and evening red. Through the reverberation of the rays from particle to particle, there may be at the very noon of night a certain amount of illumination. Twilight must continue with varying degrees of intensity all night long, and the visibility of the nocturnal firmanent itself may be due, not as my excellent friend Dove seems to assume to the light of the stars, but in great part to the light of the sun scattered in all directions through the atmosphere by the almost infinitely attenuated matter held there in suspense" ("Hours of Exercise in the Alps"). Incidentally, I must remark that this probably gives us the true cause of the remarkable light that has been observed at midnight in different places during the period of the most intense glows. Given exceptionally large quantities of dust in the air, and assuming the correctness of Tyndall's theory, exceptional luminosity at night-time is just what we should expect.

4. In the next place, notice particularly Mr. Lockyer's argument that the order of the first appearance of the sun-glows in different parts of the earth is, upon the whole, in proportion to the distance of those places from Krakatoa, and therefore such as we should expect if dust were the reflecting or refracting medium of which we are in search. Generally speaking the tropics first witnessed the displays, and first of all those parts of the tropics nearest to Krakatoa. The temperate zones were reached at a later time, and more irregularly—the irregularity of winds in the temperate zones accounting for this naturally enough. I believe, if observations had been carefully made at all the different centres of population, the steady onward progress of the upper-air dust, as it radiated outwards from Krakatoa, would be even more apparent and convincing than it is now,—but to understand that progress thoroughly we ought to know more than we do as to the upper currents of wind in the earth's atmosphere.

5. Dust in the upper air is *sufficient* to account for sun-glows, coloured suns, and all the other phenomena. In the Loes district of China, where the air is often laden with yellow dust, blue suns are constantly seen. F.A.R.R., a writer in "Nature," 12th June, says that the weather in the upper air must have been unusual, for ordinarily whatever matter may be there assists the blue rays of light and scatters them, whereas lately the blue rays have been absorbed. Now, a stratum of larger particles than ordinary, 20 to 40 miles high and descending at the rate of 1,000 feet a day,

would produce the effects with which we have been familiar. Such dust would cause a green reflection to be seen, followed by a yellow one. Then there would be competition between the red-arresting upper dust and the blue-dispersing lower air. Lower still the yellow would pass to orange, pink, and crimson—more striking as darkness increased. Perhaps there is some analogy to this decomposition of white light and reflection of certain component rays, in the green colouring of the ocean, which Tyndall regards as resulting from the interruption of the usual green rays by impurities suspended in the water. If this matter be absent and the sea be deep as well as pure, it is of a blue colour. On Mount Whitney, Langley found the dust itself bright red, but the sky, as seen through it, violet; but near the sun quite white. He says red rays are transmitted with the greatest ease through our air, the variation of colour depending on the size of the particles of dust therein contained. Krakatoa may have charged the air, or a belt of it, with dust large enough to scatter the red rays and partly absorb the others. G. F. Chambers, at a January meeting of the Astronomical Society, mentioned the case of the crushing of seaweed by steam machinery at Eastbourne. The engineer of the works there says that he frequently sees the sun blue and green through the fine dust in the air. Dr. Buddle, in "Nature," on the 20th December, refers to the Frenchman in Algeria, who said one day when looking at the sun, *C'est la première fois que j'ai vu le soleil bleu*, and was informed that the dust from the Sahara was the cause of the novel colour. Ranyard's explanation is this: the particles of dust, when small compared with the wave-length of light or of invisible spectrum, disperse different proportions of red and blue—the larger the wave-length the less the intensity of dispersed light. Usually the colour of the sun is not affected by dust in the atmosphere. But when that dust is much increased in amount, the intensity of the dispersed light is much increased also, and the blue colour of the light between us and the sun affects the colour of the sun itself. Lockyer at first thought that the particles floating in the air were themselves blue and red, and thus that the colours we have witnessed were simply the result of reflection, and Hardwick's "Science Gossip" recently spoke of the blue and red particles remaining suspended in mid or upper air. But no such coloured particles have fallen, and so this hypothesis has been, I believe, generally abandoned.

Ranyard in "Knowledge" refers to the blue sun in the tropics becoming green as it neared the horizon, and sinking red. At Trincomalee, in Ceylon, from the 9th to the 12th September the sun rose green, and continued to be of that colour till it reached the height of 10 degrees above the horizon, then it became blue, and at noon bright blue. During its declining, similar changes were noted, but in the reverse order. The moon was

similarly tinged. According to the size of the particles suspended in the air, would be their effect by refraction upon the rays of light falling on them. Gravitation would naturally bring the heavier particles down first, and so it is conceivable that for some months perhaps the air was filled with strata of dust, whereof the lower were composed of heavier, and the upper of lighter particles. Hence, as it seems to us, the change in the colour of the sun as it mounted in the heavens, and again in reverse order as it descended, was just what it was natural to expect. But if you ask me why the abnormal colours of the sun were not seen daily like the sun-glows, I can only suggest that the dust varied in density and character from day to day according to winds, or that for the most part some counteracting influence, moisture *e.g.*, was at work, so that the coloured sun and moon were rare phenomena. Even the after-glow is a result which dust in the air might be expected to produce; for this species of second twilight is not by any means unusual in the Nubian Desert, and Sir T. Herschell referred it to a second reflection of solar light in the atmosphere (Chambers' Encyclopædia, "Twilight"). I do not know that this circumstance has hitherto attracted any notice in this discussion, but it seems to me that it deserves to do so.

6. Chemists and microscopists have been busy in many different places in collecting from rain- and snow-water the dust brought down from the atmosphere, and have, generally speaking, from the analysis subsequently made, come to the conclusion that the matter so collected is volcanic in its origin; further, that it corresponds to the dust ejected from Krakatoa. M. W. Beyerinck, of Wageningen, says that *this is beyond doubt*. That rain- and snow-water have for some time back left considerable deposits in the rain-gauge and otherwise seems pretty certain. Whether such sediment has been collected and examined here in Nelson, our local microscopists can tell us. The deposits have been collected at places very wide apart, *e.g.*, Queenstown (Cape Colony), Launceston (Tasmania), Harrow (England), Sandhurst (Victoria), Unaluska (Alaska), and in parts of Norway. But as there is always more or less dust in the atmosphere, and as in some places from local causes, such as iron and other manufactories, dust storms, strong desert winds, etc., it occasionally becomes abnormally charged with additional matter, accurate and careful analysis alone will help us here. Such analysis would need to be made by most skilful experts, or it would not be trustworthy as the basis of argument. But when we find such men as M. Daubrèe, of Paris, and M. Renard, of Brussels, agreeing with Macpherson, Murray, and Diller, as to the analysis and identification of the dust, scepticism becomes less justifiable. The Royal Society of England has recognized the great importance of the investigation, and specially

appointed a Commission to collect all observations and documents bearing thereupon. It appears that the Krakatoa ashes contain abundance of vitreous matter and elongated gas-bubbles enclosed in pumice, volcanic sand, and ashes. The two first-mentioned are almost characteristic, and, if so, make the Krakatoa dust less difficult of identification than one might suppose. Diller says he has found glass always most abundant in Krakatoa dust collected on the Java coast; Macpherson, in dust collected from Madrid, found crystals of hypersthene, pyroxene, magnetic iron, and volcanic glass, all of which Daubrèe found in the Javan volcanic ashes. Verbeek, by microscopic examination of Krakatoa dust on the spot, found therein glass with oval vacuoles, felspar, pyroxene, and magnetite in grains, and octahedra. He also gives the chemical analysis, which I need not repeat. Unfortunately the enquiry is complicated by the circumstance that the vitreous and mineral fragments found near Krakatoa are similar to those found in deep-sea deposits, *i.e.*, such as have fallen from time to time through countless ages from the air into the sea, and which may be either of meteoric or cosmic origin or both. Further, Mattieu Williams on the 5th December last got a black sediment from 75 ounces of snow which fell at Harrow. In this he found much black oxide of iron readily attacked by the magnet and containing nickel. This, he says, is a characteristic of meteoric iron, and cannot possibly have come from Krakatoa, being too heavy. But too much weight must not be attached to this either, for it is evident that the recent fall of Krakatoa dust in different parts of the world would not be likely to stop the supply of meteoric or cosmic dust that the earth is continually receiving. Altogether, this sixth argument at the present date, in the absence of fuller information, is very difficult to work out, and I do not ask you to lay much stress upon it.

7. The occurrence, as we have already said, of similar phenomena after the volcanic eruptions of 1783 and 1831, furnishes a *strong* argument for associating our sun-glows with the Krakatoa eruption, and, of the various materials cast out by Krakatoa, *dust* seems more likely than water or gas to be the operative cause of the colouring.

8. The very gradual disappearance of the sun-glows is what we should expect if the volcanic dust theory were a correct one, for the dust would fall from the atmosphere very slowly—the heavier particles first, then those of medium weight, and last of all, and after perhaps a long period of time, the most minute and insignificant.

9. Where, as in this case, a proposition does not admit of positive demonstration, the occurrence of a number of arguments all tending to show its probability must be allowed to have preponderating weight—particularly if the objections thereto can be satisfactorily answered.

Let us, therefore, in the last place examine the *objections* that either are or can be, in my humble opinion, urged against the dust theory.

1. The *amount* of dust that would be requisite to form even a thin belt over so large an area of the earth's surface as is comprised, say, between the 52nd parallel of north latitude (that of London), and the 44th parallel of south latitude (that of Dunedin),—that is to say, roughly speaking, about 150 millions of square miles,—would be so enormous that it is difficult to believe that it could all have been thrown up by Krakatoa. We must allow this to be a forcible objection; but reflect at the same time on what has been said as to the gigantic scale of the operations at Krakatoa, and furthermore consider two points:—(1) That the dusty cover need not have been, as far as I know, very thick, and the third dimension, the thickness of the cover, would materially affect the total amount of its solid contents; (2) That the dust was probably not distributed equally thickly or densely over the whole of the vast area; indeed one can well understand that it hung suspended only in particles, for there were undoubtedly periods of intermission in the displays, and these intermissions may have been occasioned by the temporary absence of the causal medium as well as by other counteracting atmospheric conditions. What do we really know for certain about either the exact amount of dust ejected from Krakatoa or that requisite for producing the phenomena? Very little I imagine.

2. It is said, even if dust had been shot up to an enormous height by the Krakatoa eruption, from its inherent weight it would soon have *settled down* on the earth again (Professor Rees). Undoubtedly the heavier particles would have done so, and actually did so; but in proportion to the minuteness of the particles in all probability would be the distance and time they would travel. The heavier dust fell at Krakatoa, but we have read of thick dust falling on a vessel at sea many hundred miles away. One writer suggests that the air may possess some *viscosity* which would check the tendency of the dust to settle. Moreover, Professors Preece and Crooke say that minute particles ejected into the upper air would be negatively electrified, and therefore repelled by the earth and by one another (which, by the way, would account perhaps in part for their rapid diffusion) and so would probably remain at a high level for a long time. Besides the lower strata of the atmosphere itself might be denser than the foreign matter of the upper strata—even though not composed of exceptional gases ejected from Krakatoa. Rollo-Russel points out, too, the vesicular nature of pumice, each particle really consisting of a bubble of glass—which, when shot high and removed from the action of vapour and weather, would be easily carried to the most distant parts of the globe ("Hard. Sci. Gos."). Very fine dust

of any kind settles from the air on a surface warmer than itself very reluctantly. Once in the higher air, therefore, dust would be perhaps able for a long time to resist gravitation. Professor Trowbridge believes that the upper currents of air would tend—by their motion, I presume—to keep the dust in suspense. Of these said upper currents our knowledge, as Lockyer remarks, is really very limited; but the investigation of these sun-glows and a careful comparison of the dates of their appearance in different places may perhaps extend our knowledge in this respect as well as in others. And this brings up

3. The actual *dispersion* or *diffusion* of the dust as a great difficulty. As Hazen says, the currents of the upper air, if they caused the diffusion, must have acted in opposite directions, whereas we have always understood that the upper air moves steadily in one current from west to east. In answer to this I can only repeat what has been said. Nothing is certainly known about the higher aerial currents. And as I have just now ventured to suggest incidentally, the electrical repugnance of the particles of dust to one another may have had something to do with their diffusion.

4. Hazen regards the *rapidity* of the dust dispersion as a stumbling block. The upper currents or something else must have carried the dust 12,000 miles (to Barinas, Venezuela) in 150 hours, *i.e.*, at the rate of 80 miles an hour; whereas *observations* on Pike's Peak, 14,134 feet high, show the current there to be running at the uniform rate of 20 miles an hour. To this the reply at once occurs: an observation at the height of, say three miles, is not conclusive as to the rate of the wind throughout the upper regions, and we do not know at what height the line of dust was spread out. Moreover, Symonds thinks that the rapidity of the westerly dispersion may perhaps be accounted for by the rotation of the earth from west to east, so that the dust was as it were left behind by a process analogous to that which causes the trade winds in the tropics. But this would, it appears, only account for a progress of 440 miles a day, whereas that to Barinas was at the rate of 1,700 miles a day. Then, again, Symonds suggests that perhaps the dust got quite out of the earth's atmosphere, and so was left a whole hemisphere behind, which idea Cowper Ranyard will not entertain at all, and I confess that I do not understand it. That the dispersion of the unusual material in the upper air (for the difficulty is the same whether dust was the material or not) was exceedingly rapid in some directions, particularly to the west, is certain. But, perhaps, the earth's rotation, the upper-air currents, and the electrical repulsion combined, were sufficient propelling causes. It is, you will notice, in connection with this branch of the subject that accurate observations of the dates of the first appearances

of the sun-glows in different places are so important; *e.g.*, we could tell the rate of progress of the dust to us in Nelson pretty well if we knew for certain when the glows first appeared in Port Darwin, Brisbane, Sydney, and Nelson. Unluckily people did not attach much scientific importance to the phenomena when they first appeared, and so made no notes.

5. The *intermittent* nature of the phenomena, also, Hazen thinks, is against the supposition that dust is the cause; but I see no force in this. It is only natural that the appearances should vary in intensity with varying meteorological and atmospherical conditions, and, as I have already said, the dust may not have been very evenly distributed.

6. Hazen's last objection is that ashes are *opaque*, and the appearances indicate a transparent something. Another writer (in the "Sci. Amer.") puts this objection in this way:—He says, earthly or lunar volcanic dust cannot be the cause of the glows at the rising and the setting of the sun, or the ordinary light from sun, moon, Mars, Jupiter, etc., would be affected. But there is no diminution of this light. Therefore the cause of the glows lies far beyond the sun's orbit.

But are the premises in this argument true? Have we not already stated that a haziness of the sun has been observed at several places—*e.g.*, at Seychelles and Tokio? And is not a change in the colour of the sun and moon virtually a change in the intensity of their light? Moreover, although individually the particles may be opaque (which their intense character leaves open to doubt), collectively they do not constitute an opaque mass, being exceedingly minute and widely scattered. Also, before we can attach much importance to this objection we must know accurately what the photometer has to say on the subject. As the writers quoted do not tell us this, we may presume they speak from conjecture only.

7. Some may say that the volcanic force of Krakatoa, however great it might be, would scarcely be great enough to force up such a vast amount of ashes *to so great a height*. It is generally considered that the dust cloud, or whatever it was, lay very high indeed; but what gigantic forces were at work at Krakatoa! An electrical force was in violent action also, for simultaneously with the outbreak all the telephones in Singapore were unworkable, and on one line reports like pistol shots and a mighty roar were continually heard; and again the heated air, emanating from the crater of Krakatoa, would carry with it to unknown heights vast volumes of dust, etc.; and incidentally I may mention that the heated air of the tropics ascending as it always does, to be replaced by cooler air from the north and south temperate and polar zones, would account to some extent for the dispersal of the dust.

8. Again it may be asked, if dust were the cause of the sun-glows, why were they not seen *in the daytime*? Whatever foreign material in the upper air caused the glows, this difficulty would remain the same. Probably the greater perpendicularity of the sun and therefore the greater intensity of his light during the daytime account for the glows then being absent. Towards night and morning, also, his rays would traverse a greater length of the dust-laden upper air.

9. Lastly, if dust caused the green and blue suns and the air is always dust-laden, why do we not have such phenomena *more frequently*? Ordinarily the dust in the air is not very high, and the particles near the earth are large, and aqueous and gaseous vapour counteract the effect of dust by absorbing more light at the blue end of the visible spectrum than at the red.

In conclusion, there is no reason, as far as I know, why we should confine ourselves to any one theory. Perhaps many causes have co-operated accidentally to produce one phenomenal result. If we *must* have only one theory, I incline to the Krakatoa dust theory, because I think the balance of evidence is in its favour. In any case, whatever the upper-air medium may have been, it certainly seems to have emanated from the Straits of Sunda during the memorable eruption of 27th August. However, when we come to speculate upon the nature of the substance thrown into the upper currents, difficulties and objections and doubts meet every suggestion or supposition. We shall, therefore, if we are wise, guard ourselves against all dogmatism on the subject, particularly as fresh facts and fresh theories are coming forward daily.

Even as I write there appears, in the notes on popular science by Dr. Taylor in the pages of the *Australasian*, a modification of the aqueous vapour theory which is well deserving attention. It appears that Dr. Prince, a well-known meteorologist, thinks the phenomenal sunsets are due to the crystallization of saline particles from masses of sea-water ejected in the form of vapour into the upper air by the Krakatoa eruption, and he argues that the greatest displays having occurred in the coldest weather, can only be accounted for on the theory that the crystallization of saline products is a great factor in their production. So long ago as last January, M. Beyerinck, of Wageningen, collected from rain which fell during a storm succeeding a fine after-glow a remarkable quantity of common salt. Again, I find in "Nature" of 3rd July, that M. Gay, in a paper read before the Paris Academy of Sciences on the 23rd June, not only connects the recent sun-glows with the Krakatoa eruption, but thinks that the persistent rains of this year are owing to the same cause, directing attention to the fact that after the volcanic eruptions of 1783, 1831, 1856, and 1862,

there came not only the sun-glows to which we have several times made reference, but also abundant rains. And in "Knowledge" of 6th June, Mr. Neison, Director of the Government Observatory at Natal, is quoted as saying that in his colony they had the sun-glows so early as February, 1883, but that they became most vivid on the 28th and 29th of August, and from 31st August to 5th September, after which they vanished for four months,—whereas in Transvaal, 250 miles distant, they were first noticed on the 2nd September, and continued very vivid till January of this year.

Evidently, we have not either heard or said the last word on this subject yet, and we must retain that philosophic attitude so absolutely necessary in many matters—suspension of the judgment. During the next few months the problem may become easier of solution. Some one of our members may then take it up again and give us the benefit of the later lights. I trust we may then be the better able to see our way, for the long consideration you have kindly allowed me to give to the matter to-night. I must indeed apologize for the length of my paper, "*Dum brevis esse laboro, obscurus fio.*" Brevity may be bought at the expense of perspicacity. And much as I have said on this subject, there is far more that can be said. It is astonishing with how many departments of natural science and natural philosophy the enquiry is connected. But, as says a great thinker, "From every natural fact invisible relations radiate, the apprehension of which imparts a measure of delight; and there is a store of pleasure of this kind ever at hand for those who have the capacity to turn natural appearances to account." I must apologize also for treating this subject so much in the Dr. Dryasdust fashion. So beautiful, and weird, and heavenly a display as the recent evening glows should have been treated poetically,—but man is like some long-winged sea-birds, which rise from sand-hills with great difficulty. And after all, the imagination had to be kept well in hand, for, as it is, have we not been led by our enquiry into the volcano's crater, and down to the depths of the sea, and up to the blue ether, and to the furthest parts of the earth.

Art. XLIX.—*Red Sunsets.* By Wm. Ringwood.

[*Read before the Philosophical Institute of Canterbury, 1st May,* 1884.]

Plate XIX.

The equatorial diameter of the earth is 7,901 miles, and the circumference is 24,825 miles, and, as she revolves once on her axis in 24 hours, a place on the equator moves through 1,034 miles per hour, but at any depth